Curtin School of Allied Health

Word learning and memory in children with developmental language disorder

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Declaration

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.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007), updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (HRE2017-0836 and HRE2017-0836-01), Catholic Education Office of Western Australia (RP2017-59), and the Department of Education of Western Australia (D18/0156186).

Signature:

Date: 31st January 2021

Acknowledgement of Country

I acknowledge that Curtin University works across hundreds of traditional lands and custodial groups in Australia, and with First Nations people around the globe. I wish to pay my deepest respects to their ancestors and to members of their communities, past and present, and to their emerging leaders. My passion and commitment to work with all Australians and peoples from across the world, including our First Nations peoples, is at the core of the work I do. This work is reflective of my institutions' values, where we are committed to our role as leaders in the Reconciliation space in Australia.

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Abstract

Children with developmental language disorder (DLD) experience significant difficulty with language development. One key area of difficulty shown by both younger and older children with DLD is in word learning, which can lead to vocabulary deficits that considerably impact comprehension and expression of language in spoken and written contexts. Despite this, little is known about the encoding and retention of word forms and meanings in children with DLD. Additionally, while a body of literature has explored the cognitive underpinnings of language impairment in these children, there is equivocal evidence regarding the function and interactions between the working, declarative, and procedural memory systems. Furthermore, although word learning is theoretically associated with impairments within the working memory system, there is a paucity of empirical evidence regarding this relationship in children with DLD. Finally, little is known about the application of word learning evaluation methods by speech-language pathologists in clinical practice. In response to these identified gaps, this doctoral research aimed to: (a) explore assessment practices of vocabulary and word learning in the research and clinical domains, (b) profile the systems of working, declarative, and procedural memory in children with DLD and their typically developing peers, and (c) comprehensively explore word learning, and its association with memory, among these children.

Five studies were conducted to address these aims. The first study – a systematic scoping review of the research literature – aimed to investigate methods used to evaluate word learning in people with DLD. Seventy articles were identified, and descriptive analyses revealed a wide variety of methodologies in the literature that were developed according to several key parameters (e.g., learning context, types of words being learned, and use of cues to support learning). The findings from this scoping review highlighted the need for further multifactorial evaluation of how children with and without DLD learn different aspects of new word knowledge over time. In response, a novel word learning protocol was developed, and used in a subsequent study (Study 5). Furthermore, the scoping review highlighted the need for further research to explore memory skills, and their associations with word learning, in children with and without DLD (addressed in Studies 3, 4, and 5).

Another query that arose from the scoping review was whether speech-language pathologists apply word learning evaluation methods in clinical practice. This lead to the second study, which was clinically-focused, and involved an international survey of 135 clinicians. Current practices in the assessment of vocabulary and word learning were explored in order to build understanding of the clinical application of research-driven assessment methods. The findings indicated that while norm-referenced, standardised assessments of vocabulary are frequently used in clinical practice, speech-language pathologists less frequently evaluate word learning with their clients. This highlights the need to promote the translation of research to practice, and to further develop clinically-applicable, culturally-appropriate word learning assessment tasks.

In order to explore the nature of word learning and memory (and the relationships between these skills) in children with and without DLD, Studies 3, 4, and 5 were conducted. Driven by existing theoretical and empirical evidence, Study 3 involved an analysis of previously-collected data in order to preliminarily explore the relationship between word learning and verbal short-term memory in five-year-old children with DLD (n = 23) and typical language (n = 26). The results revealed a significant relationship between verbal short-term memory and the learning of new word forms, which substantiated the need for comprehensive investigation of memory and word learning skills in children with DLD.

Subsequently, a cohort of 50 children with DLD and 54 typically developing children, all aged five to eight years, participated in a comprehensive battery of assessments for memory and word learning. Study 4 involved analysis of the memory performance of these children to build a profile of working, declarative, and procedural memory. The findings highlighted a core deficit within the working memory system, which affected processing of verbal and visual–spatial information. Furthermore, working memory deficits accounted for the poor performance of children with DLD on the declarative and procedural memory tasks. Finally, Study 5 involved exploration of word learning skills in this cohort of children. The children with DLD were significantly less accurate than their typically developing counterparts at learning the forms and meanings of new words. These impairments were evident early in learning (*encoding*), which had a subsequent impact on learning over time (*re-encoding* and *retention*). Given the findings of Study 4, the final study also involved testing whether verbal working memory amplified DLD-related differences in word learning. The results showed that word learning was considerably more difficult for children who had DLD and impaired verbal working memory.

This doctoral research makes a valuable theoretical contribution to the understanding of memory and word learning in children with developmental language disorder. While this research adds to the clinical evidence base, future efforts should be made to translate research to practice in order to support speech-language pathologists in their application of empirically-driven assessment and intervention methods.

List of Peer-Reviewed Publications Arising from this Thesis

Published

1. **Jackson, E.**, Leitão, S., Claessen, M., & Boyes, M. E. (2019). The evaluation of word-learning abilities in people with developmental language disorder: A scoping review. *International Journal of Language and Communication Disorders, 54*(5), 742-755. https://doi.org/10.1111/1460-6984.12490

Authorship attribution statement:

As lead author, I was responsible for the conceptualisation and design of the study, including formulation of the research question and the strategy for systematic literature searching. I also directed the article screening process, extracted data from the included articles, and led discussions regarding interpretation of the data. I was responsible for writing the manuscript, as well as final approval and submission. One co-author (SL) participated in title, abstract, and full-text screening. All co-authors assisted with the conceptualisation and design of the study, and were involved in discussions regarding data interpretation. All co-authors were also involved in editing the manuscript and providing final approval before submission.

2. **Jackson, E.**, Leitão, S., Claessen, M., & Boyes, M. E. (2019). Fast mapping short and long words: Examining the influence of phonological short-term memory and receptive vocabulary in children with developmental language disorder. *Journal of Communication Disorders, 79*, 11-23. https://doi.org/10.1016/j.jcomdis.2019.02.001

Authorship attribution statement:

As first author, I was responsible for running the investigation, writing the original drafts of the manuscripts, and submitting the paper. I led discussions with MC and SL regarding the conceptualisation of the study and formulation of the methodology. MC and SL were also responsible for providing resources for the project, as well as reviewing and editing draft versions of the manuscript. The final co-author (MB) was involved in data curation and analysis, as well as in the review and editing processes.

3. **Jackson, E.**, Leitão, S., Claessen, M., & Boyes, M. E. (2020). Working, declarative, and procedural memory in children with developmental language disorder. *Journal of Speech, Language, and Hearing Research, 63*(12), 4162-4178. https://doi.org/10.1044/2020_JSLHR-20-00135

Authorship attribution statement:

As lead author, I led the conceptualisation of the study, and was solely responsible for participant recruitment and the acquisition of data. I was also responsible for data preparation and analysis, with guidance from MB. I led discussions regarding the interpretation of results, and was primarily responsible for writing the manuscript and providing final approval for submission. All co-authors contributed to the conceptualisation and design of the study, including the selection of data collection assessment tasks, and were responsible for reviewing and editing the manuscript prior to submission.

4. **Jackson, E.**, Leitão, S., Claessen, M., & Boyes, M. E. (2021). Word learning and verbal working memory in children with developmental language disorder. *Autism and Developmental Language Impairments, 6,* 1-20. https://doi.org/10.1177/23969415211004109

Authorship attribution statement:

As first author, I was primarily responsible for leading the conceptualisation and design of the study, with guidance from all co-authors. I developed the methods for data collection (including the design of a novel assessment task for data collection), recruited participants, and collected data. Whilst I was responsible for data analysis, MB provided close guidance with data conditioning, statistical methods, and interpretation of data. I led discussions regarding the interpretation of the findings, and was predominantly responsible for writing the manuscript. All co-authors were involved in the conceptualisation of the study, editing the manuscript, and providing final approval prior to submission.

Currently Under Review

1. **Jackson, E**., Leitão, S., Claessen, M., & Boyes, M. E. (2020). Listening to SLPs: An international survey of assessment practices for vocabulary and word learning. *International Journal of Speech-Language Pathology,* under review.

Authorship attribution statement:

I led discussions with all co-authors regarding the conceptualisation and design of the study. All co-authors provided significant contributions regarding the development of the survey, and assisted in the distribution of the survey to assist with data collection. MB provided support with data extraction, and I was predominantly responsible for analysis and interpretation of quantitative and qualitative data. I led discussions regarding the interpretation of results and was primarily responsible for writing the manuscript, with guidance from SL and MC. All co-authors were responsible for editing the paper and providing final approval for submission.

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Dr Mark Boyes

Date: 31st January 2021

Signature:

List of Peer-Reviewed Presentations Arising from this Thesis

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Jackson, E., Leitão, S., Claessen, M., & Boyes, M. E. (2019). *A scoping review and clinical protocol for evaluating word learning in people with developmental language disorder*. Poster presented at the Speech Pathology Australia National Conference; Brisbane, Australia.

Jackson, E., Leitão, S., Claessen, M., & Boyes, M. E. (2019). *Fast mapping short and long words: Examining the influence of phonological short-term memory and receptive vocabulary in children with developmental language disorder*. Poster presented at the Speech Pathology Australia National Conference; Brisbane, Australia.

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Glossary of Abbreviations

ADHD	Attention deficit-hyperactivity disorder
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ASHA	American Speech-Language-Hearing Association
CALD	Culturally and linguistically diverse
CATALISE	Criteria and Terminology Applied to Language Impairments: Synthesising the Evidence
CELF	Clinical Evaluation of Language Fundamentals
CPM	Coloured Progressive Matrices
DLD	Developmental language disorder
EALD	English as an additional language or dialect
fMRI	Functional magnetic resonance imaging
GLMM	Generalised linear mixed model
IQ	Intelligence quotient
LSD	Least significant difference
MANCOVA	Multivariate analysis of covariance
MANOVA	Multivariate analysis of variance
MGR	Mental graphemic representations
PDH	Procedural Deficit Hypothesis
PPC	Percentage of phonemes correct
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QUIL	Quick incidental learning
RCSLT	Royal College of Speech and Language Therapists
SLI	Specific language impairment
SLP	Speech-language pathologist

SLT	Speech and language therapist
SPA	Speech Pathology Australia
SRT	Serial reaction time
STM	Short-term memory
TD	Typically developing
WM	Working memory

Copyright Statement

PART ONE: An Introduction to this Thesis

Chapter 1: Thesis Overview

The overarching aim of this doctoral research was to investigate memory and word learning in children with developmental language disorder (DLD), as well as the relationship between the two. This thesis is organised into four parts.

Part One comprises this thesis overview (Chapter 1), the purpose of which is to direct the reader and provide a context for each of the studies and linking chapters within this thesis. A comprehensive background to the programme of research is presented in Chapter 2, which includes an overview of key theoretical frameworks and terminology, as well as a comprehensive review of the empirical literature that preceded this research program. Chapter 2 concludes with the aims of this doctoral research.

Part Two consists of Chapters 3 and 4, which focus on building understanding of how word learning is currently evaluated in research and clinical practice. Chapter 3 (Study 1) presents a published scoping review of the literature. This review paper focused on exploring and describing the previously-used methods for evaluating word learning in people with DLD. The findings were used to inform the specific aims of the current investigation into word learning, and supported the development of a novel assessment protocol that was used to evaluate word learning at a later stage in this research programme (Study 5). Chapter 4 (Study 2) presents a prepared manuscript (under review) that reports the findings of an international survey of speech-language pathologists. In response to the findings of Study 1, this survey was conducted to identify and describe assessment methods that are being used to evaluate vocabulary and word learning skills in clinical settings worldwide. Part Two concludes with a general summary that provides a link between the separate papers, and highlights implications for the subsequent parts of the thesis.

Part Three of this thesis, which comprises Chapters 5, 6, and 7, involved the investigation of word learning and memory skills in children with DLD. Chapter 5 (Study 3) presents the findings of a published empirical study that preliminarily explored the relationship between verbal short-term memory and word learning in these children. This involved the re-analysis of existing data, and the findings informed the direction for a more comprehensive investigation into memory, word learning, and the relationship between the two, which is presented in the two subsequent studies. Chapters 6 (Study 4) and 7 (Study 5) present research involving a large cohort (N = 104) of children with DLD and their age-matched, typically developing peers. Chapter 6 (Study 4) is a published paper investigating the relationships between the working, declarative, and procedural memory systems in this cohort of children. Chapter 7 (Study 5) consists of a published paper that presents the findings from an investigation into the word learning skills of these children with and without DLD. Additionally, extending the findings of Study 4, Study 5 assessed the contribution of verbal working memory to the word learning process. A general summary of Part Three is provided, where the links between the separate papers are described and significant contributions are highlighted.

Part Four includes Chapter 8: a General Discussion integrating the findings from the five separate studies. These findings are related back to past literature, as well as theoretical frameworks regarding word learning and memory. The theoretical and clinical implications are highlighted, along with strengths, limitations, and future directions arising from this research.

This doctoral research is presented as a *thesis-by-compilation*: The five studies were written as standalone manuscripts, which have been accepted, or are in the final stages of the review process, in peer-reviewed journals. As such, there may be some unavoidable repetition of theory and literature throughout each of these five chapters; however, effort has been made to minimise additional repetition in the Introduction and General Discussion chapters. Each chapter throughout this thesis begins with a brief Chapter Overview, to provide context and develop cohesion throughout the document. The formatting of the accepted or submitted manuscripts (including headings, tables, and figures), has been altered to ensure consistency within the larger thesis document. Reference lists have been removed from all manuscripts, and are instead presented within an integrated bibliography at the end of this thesis.

Chapter 2: Background, Literature Review, and Research Aims

Chapter Overview

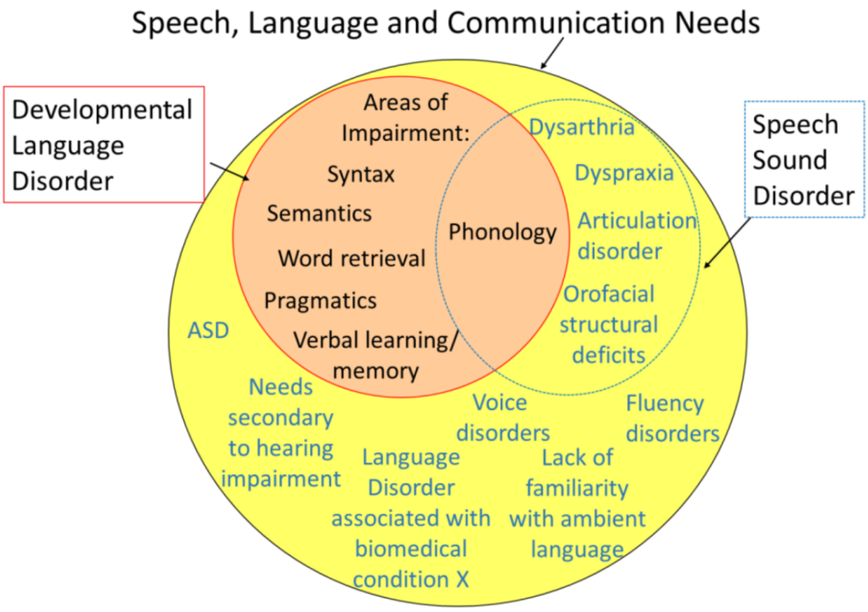
This chapter begins with an introduction to the epidemiology of the population of interest in this doctoral research: children with developmental language disorder (DLD). This is followed by a theoretical description of word learning – a skill that is particularly difficult for many children with DLD – with a focus on *mapping theory* and the *encoding–retention* framework. A discussion of three key memory systems of interest is also provided, framed by Baddeley's model of working memory (Baddeley, 2000) and the Procedural Deficit Hypothesis (Ullman & Pierpont, 2005). This chapter also reviews the current literature on the function of memory and word learning skills, and the relationship between these mechanisms, in children with DLD. The literature review aimed to identify gaps in current knowledge, thus guiding the formulation of research questions and variables of interest for this research programme. This chapter concludes with a statement of the overarching research aims that are subsequently addressed in the five individual studies presented within this thesis.

Developmental Language Disorder (DLD)

DLD is a neurodevelopmental condition that affects approximately 7% of the population (Norbury et al., 2016; Tomblin et al., 1997). This disorder is nested within the broader category of *speech, language, and communication needs*, along with other disorders such as speech sound disorder (see Figure 2.1). DLD describes the presence of language problems that are persistent and significant, and that have a functional impact on areas such as educational progress and/or social–emotional wellbeing (Bishop et al., 2017). DLD is diagnosed when there are no known differentiating biomedical conditions that could account for the language problems, such as sensorineural hearing loss or autism spectrum disorder (Bishop et al., 2017). In these instances, the term *language disorder associated with X* (e.g., autism spectrum disorder) is applied. The diagnosis of DLD is, however, inclusive of children who have co-occurring developmental conditions, such as developmental coordination disorder, attention deficit-hyperactive disorder, and specific learning disorders (Bishop et al., 2017).

Figure 2.1

Model of Speech, Language and Communication Needs



Note. A schema for developmental disorders impacting speech, language, and communication, as outlined by Bishop et al. (2017). No permissions required.

The term *developmental language disorder* is relatively new to the field, having been recommended by the CATALISE panel in 2016 to replace the many alternatives; in particular, specific language impairment (SLI; Bishop et al., 2017; Leonard, 2014; Rice, 2013). This term became increasingly disfavoured given its implications that the difficulties experienced by these children were limited to language, which was inconsistent with the body of literature indicating that language impairments often co-occur with non-linguistic cognitive, motor, and perceptual deficits (Hill, 2001; Tallal et al., 1993; Ullman, 2013). The term "SLI" was also used to describe children with a clear discrepancy between verbal and nonverbal ability; however, this assumption was criticised in light of evidence that children with average-range versus low-average nonverbal skills are not meaningfully different in areas such as severity of language impairment, social–emotional development, or educational progression (Norbury et al., 2016). Instead, DLD is inclusive of children who present with below-average nonverbal intelligence but do not meet criteria for an intellectual disability, and who may also have concomitant non-linguistic difficulties (Bishop et al., 2017). While "SLI" is still used in some parts of the world (e.g., Rice et al., 2020), “DLD” and its associated diagnostic criteria have largely replaced SLI as a more inclusive diagnostic category, and its consistent use in clinical and research contexts is recommended as a way of aiding common understanding, and facilitating effective communication about the disorder (McGregor et al., 2020b).

The term “DLD” was adopted for use throughout this doctoral research programme. It must be noted that many previous studies that are discussed throughout this thesis involved groups of children who were described using alternative terms (primarily SLI, but other terms included *primary language impairment*, *language disorder*, and *language learning impairment*). For simplicity, throughout this thesis these groups of children with poor language are referred to as having DLD.

Across childhood, DLD is characterised by heterogeneous impairments in language (Lancaster & Camarata, 2019). This is the result of DLD having a complex neurodevelopmental basis, involving the interaction between several genetic and environmental factors (Bishop, 2006; Pennington, 2006). Individuals with DLD may experience deficits that range from mild to severe in their expressive and/or receptive language across various domains, including syntax, morphology, semantics, phonology, and pragmatics (Paul et al., 2017). Deficits may also be apparent at varying language levels, including in single words, sentences, and discourse (Bishop et al., 2017). In DLD, the impact of these deficits is significant, resulting in problems with effective functional communication across contexts (Snowling et al., 2016). Notably, DLD is often associated with hallmark deficits in grammatical development, with difficulties in tense marking and finiteness considered to be sensitive indicators of the disorder (Ash & Redmond, 2014; Conti-Ramsden et al., 2001). Additionally, some researchers have noted the utility of nonword and sentence repetition tasks in identifying DLD (Archibald & Joanisse, 2009). Deficits in the ability to learn new words (i.e., vocabulary development), have also been highlighted in children with DLD, resulting in vocabulary knowledge that is limited in depth (i.e., fewer words are known) and breadth (i.e., representations of the words are less rich than those of their peers; McGregor et al., 2012; McGregor et al., 2013b). This domain of language is the focus of this doctoral research.

Beyond language, DLD is also associated with deficits in a range of cognitive and motor skills (Hill, 2001; Leonard, 2014). Of particular interest to this programme of research are the memory skills of children with DLD. A substantial body of research has investigated memory in these children, driven by the notion that these non-language problems might cause (or at least exacerbate) impairments with the acquisition of oral language (Lum et al., 2014; Montgomery et al., 2010; Ullman & Pierpont, 2005). Specifically, three key memory systems have been identified as critical in understanding the nature of language deficits in children with DLD: working memory, procedural memory, and declarative memory. The function of these memory systems in children with DLD forms another key aim of this doctoral research.

Word Learning and Memory in Children with DLD

Theories of Word Learning

Vocabulary knowledge is critical for academic development, and has been linked with performance in literacy (Dockrell et al., 2007; Ehri et al., 2001) and mathematics (Spencer et al., 2017). Furthermore, weaker vocabulary skills are a strong predictive factor for adverse psychosocial outcomes in adolescence and adulthood (Armstrong et al., 2017). Throughout this thesis, the term *vocabulary* is used to refer to the body of words that are stored within long-term memory. In contrast, *word learning* is used to refer to the active, dynamic processes that are involved in developing new word knowledge and storing that knowledge in the lexicon (Gray et al., 2020). While assessments of vocabulary provide information about a child’s existing (i.e., crystallised) word knowledge, they allow only a limited insight into the mechanisms involved in establishing that information. On the other hand, assessing word learning allows investigation of the dynamic processes and variables that affect learning (Gray et al., 2020). It is important to gather information about the word learning skills of children with DLD; this informs our understanding of their profile of lexical knowledge (McGregor et al., 2013b; Rice & Hoffman, 2015). Furthermore, an understanding of the points of breakdown within the word learning process is important to inform the development of targeted interventions (Alt & Suddarth, 2012).

In early research, word learning was conceptualised as a process of *mapping* (Brown, 1958; Carey, 1978). When a child first encounters a word, they form a representation of the way a novel word sounds, and link this with elements of meaning derived from the context in which the word was encountered. This process – termed *fast mapping* – has been the subject of a large body of research concerning typically developing and language-disordered populations (e.g., see Carey, 1978; Kan & Windsor, 2010; Ricketts et al., 2015; Swingley, 2010). While this process may occur rapidly, leading to the establishment of a new word in the lexicon, subsequent encounters are required to further develop and refine the phonological and semantic representations, as well as information about the word's syntactic, orthographic, and pragmatic properties (Carey, 2010; Stackhouse & Wells, 1997). This process is referred to as *slow mapping*, or *extended mapping*, and may take years before word knowledge becomes highly nuanced and adult-like (Bion et al., 2013).

Building on this seminal theory of word learning, various other frameworks have been proposed. For instance, Leach and Samuel (2007) conceptualised word learning as a process of *triggering, configuration*, and *engagement*. The triggering stage is proposed to occur as the child hears the word and recognises it as new, "thus triggering attention to and storage of the word" (Gray et al., 2020, p. 1447). The subsequent stages of configuration and engagement are overlapping. During configuration, representations of the word's form (i.e., phonological or orthographic representations) and meaning, and its syntactic roles, are developed and linked. Engagement describes the process by which the novel word integrates with existing words in vocabulary (Leach & Samuel, 2007).

Word learning has also been conceptualised using a neurological theory that describes a two-stage process of initial learning in the hippocampus, followed by a gradual process of transferring newly-learned words into long-term memory (Davis & Gaskell, 2009; McClelland et al., 1995; Shtyrov, 2012). This theory has been supported through various neurological investigations involving typically developing adults and children (see Gray et al., 2020, for a review). These neurological investigations of word learning have focused on the inherent involvement of memory in the process of learning new words, and formed the basis of the *encoding–retention* framework for word learning. Encoding is described as the brain's initial response to a new word: When a novel word is perceived, an initial memory trace is created based on details encountered in the environment, such as the word form and meaning

(McGregor et al., 2013a). Theoretically, this largely aligns with the *fast mapping* stage within mapping theory. Subsequently, the encoded memory trace may be forgotten if insufficient details were learned, or may be retained in long-term memory (Wilhelm et al., 2012). Retention is supported by consolidation processes, which may occur during periods of sleep or wakefulness, and involve a series of neurological changes that result in the conversion of the initially-encoded memory trace into long-lasting, integrated memory (Stickgold, 2005).

Earlier studies that investigated word learning in children with DLD tended to be framed by mapping theory, while more recently, the body of work has moved towards investigations that are underpinned by the encoding–retention model (Bishop & Hsu, 2015; Kan & Windsor, 2010; Leonard et al., 2019; McGregor et al., 2017a). It is important to note that the evolution of these theoretical frameworks is also reflected throughout this course of this doctoral research. The first empirical investigation into word learning that is presented in this thesis (Study 3) was framed by mapping theory, which was viewed as the working model of word learning at the time the study was conducted. Subsequently, as theoretical understandings of word learning shifted throughout the broader literature, the “newer” framework of encoding–retention was adopted, on the basis that it more closely aligned with the theoretically-driven aim of this thesis: to explore memory and word learning (and the relationship between the two) in children with and without DLD. This framework is therefore used in the later study of word learning (presented in Study 5).

Current evidence indicates that word learning deficits in people with DLD may be attributed to impairments at the encoding stage, with retention itself remaining unimpaired. This pattern has been demonstrated in adolescents and adults with DLD in a series of studies by McGregor and colleagues (2013a, 2017a, 2017b, 2020a). In these studies, college students with typically developing language and those with DLD were taught sets of novel words during computer-based tasks. All students were provided with the same number of exposures to the novel stimuli. To evaluate encoding, learning was tested immediately after training, and to measure retention, knowledge was re-tested after a delay. Across these studies, the students with DLD showed an initial deficit in learning word forms and meanings, indicating impaired encoding (McGregor et al., 2013a, 2017a, 2017b, 2020a). Once the deficit in encoding was accounted for, however, these students tended to demonstrate intact retention of word knowledge. This pattern of impaired encoding has also been demonstrated in a small number of recent studies involving children with DLD. For instance, Haebig et al. (2019) and Leonard et al. (2019) taught pre-school children new words via retrieval training. An encoding deficit was demonstrated for the children with DLD, with naming accuracy being significantly worse after a five-minute interval. Retention, however, appeared intact, with a similar rate of learning observed in both groups observed following a one-week interval (Haebig et al., 2019; Leonard et al., 2019).

The encoding–retention model is a useful theoretical framework when considering the longitudinal process of learning new words. It is also important to examine the multifactorial aspects of knowledge that must be developed throughout the course of word learning. At its foundation, learning a new word rests on the ability to establish knowledge of the word form (i.e., phonological representation), and link the form with elements of meaning (e.g., physical attributes of the new object; Nation, 2014). Other aspects of knowledge are required for functional use of the word across contexts. This includes knowledge of the word's grammatical and pragmatic uses, and an orthographic representation so that the word may be used in reading and writing (Gray et al., 2020; Stackhouse & Wells, 1997).

Across the literature, a broad variety of experimental paradigms have been employed to evaluate the multifaceted process of learning words and developing the lexical store. In general, these involve introducing a novel word (e.g., an unfamiliar or nonsense word linked with an unknown object or action) in a learning context, such as during book reading, or within a play-based activity. Learning is then tested through tasks requiring the child to recall newly-learned information, such as the item name or elements of meaning (Gray et al., 2020). However, word learning has also been evaluated in many different ways. Given the complexity of word learning and the subsequent variety of paradigms that have been used to evaluate word learning in people with DLD, a scoping review was conducted to identify and describe the varied methods and approaches (presented in Chapter 3; Study 1). In order to explore the use of such methods in clinical practice, a survey of speech-language pathologists was also conducted (presented in Chapter 4; Study 2).

The Working, Procedural, and Declarative Memory Systems

Working Memory in Children with DLD. Since the 1940s, research findings have supported a distinction between long-term memory (a "durable" system for retaining information) and short-term memory, which stores and temporarily processes information as it is received from the environment (Brown, 1958; Hebb, 1949). In 1968, Atkinson and Shriffin proposed a two-component model of these two broad systems, in which short-term memory was described as an antechamber to long-term memory. In subsequent research, the concept of *working memory* was introduced, which extended the idea of short-term memory to incorporate the notion that information could be temporarily held, and concurrently manipulated, in order to perform more complex tasks (Baddeley & Hitch, 1974). Since this early work, the concept of working memory has become influential in the literature, especially in guiding investigations into developmental disorders, such as developmental language disorder (Alloway, 2018). While the terms *short-term memory* and *working memory* have been used somewhat interchangeably in the literature, there is evidence of their distinction, and it is generally accepted that *short-term memory* should be used to describe the simple storage of information, with *working memory* applying to the more complex concurrent storage and manipulation (Baddeley, 2012).

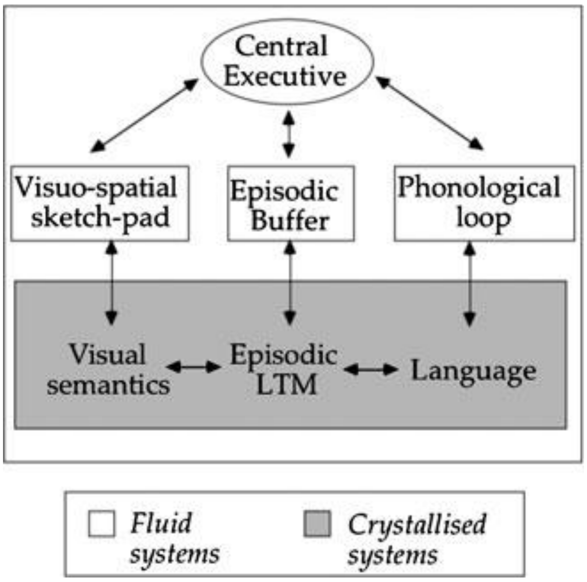
Throughout the literature, different conceptualisations of working memory have been offered, such as Cowan's (2005) account that working memory is not a distinct system in itself, but instead works as an activated subset of long-term memories. Another model was proposed by Barrouillet et al. (2004), who described working memory as a "time-based resource-sharing model" (p. 83), which assumes that attention is regularly and automatically switched between the task being performed and the rapid reactivation of decaying memory traces during complex working memory span tasks. Arguably the most prominent and empirically-tested conceptualisation of working memory is that offered by Baddeley and Hitch (Baddeley & Hitch, 1974; Montgomery, 2002). According to this model, the working memory system serves as a capacity-limited workspace that temporarily stores incoming sensory information, holds information active to support additional processing or manipulation, and supports the transference of information into long-term memory (Baddeley & Hitch, 1974).

Since the first iteration of the Baddeley and Hitch model, there have been various updates. The most current version, described in Baddeley (2000), outlines a working memory system that comprises four subcomponents, with links to long-term memory (see Figure 2.2). Two of the subcomponents are domain-specific slave systems responsible for temporary storage of visual–spatial information (*visuospatial sketchpad*) and verbal information (*phonological loop*). Maintenance of information within the phonological loop is thought to be supported by a mechanism of subvocal rehearsal (Baddeley, 2003). The *central executive* component is responsible for attentional control of the system. It is considered to be domain-general, working to monitor and coordinate the function of the domain-specific visuospatial sketchpad and phonological loop (Baddeley, 2000). The fourth component (the *episodic buffer*) is a limited-capacity system that binds together information from different sources into chunks, or episodes. As such, this buffer links information between the two slave systems, monitors information, and provides a link between the working memory system, sensory perception, and long-term memory (Baddeley, 2000, 2012). A key feature of the working memory system is that it is capacity limited, and the imposition of excess processing or storage demands results in the loss of information (Alloway, 2018).

The working memory system is strongly associated with performance in a range of complex tasks, such as reading and mathematics (Peng et al., 2018; Swanson, 2004). Working memory is also strongly linked with language development (Archibald, 2016; Gathercole & Baddeley, 1989), and as such has been the subject of a substantial body of research involving children with DLD (e.g., see Archibald & Gathercole, 2006a; Estes et al., 2007; Montgomery & Evans, 2009; Vugs et al., 2013). Much of this research has involved exploration of how these children process *verbal* information within the working memory system. Often, digit span tasks are used in these evaluations (Archibald & Gathercole, 2006a). Simple digit span tasks involve hearing, temporarily storing, and verbally repeating strings of digits that increase in length (i.e., digit recall; Gathercole & Pickering, 2001). Given that digit recall requires only simple, temporary storage with no additional manipulation of information, this task is used as a measure of phonological loop capacity (Archibald & Gathercole, 2006a). Throughout the literature, and this thesis, phonological loop capacity is also referred to as *verbal short-term memory* (Alloway et al., 2009). Nonword repetition tasks have also been commonly used to assess verbal short-term memory in children with DLD (Coady & Evans, 2008; Estes et al., 2007). These tasks require the child to repeat pseudowords that increase in length, and therefore are designed to tax the capacity of verbal short-term memory (Gathercole et al., 2005). Compared to digit span tasks, nonword repetition involves a range of additional phonological processes that may impact performance, including speech perception, phonological segmentation and assembly, and articulation (Coady & Evans, 2008). Finally, backwards digit recall tasks are also used to evaluate the processing of verbal information within the working memory system. These tasks require the repetition of strings of digits in reverse order, thus engaging both the phonological loop and central executive (Gathercole & Pickering, 2001). Backwards digit recall tasks are therefore used as a measure of *verbal working memory*, which is distinguished from tasks measuring only verbal short-term memory through the added requirement of simultaneous processing for verbal information (Archibald & Gathercole, 2006a).

Figure 2.2

Baddeley's Multicomponent Working Memory System



Note. A depiction of the multicomponent model of the working memory system, as described by Baddeley (2000). This model shows four components of working memory and their links to long-term memory. Used with permission (see Appendix B).

There is strong evidence for a verbal short-term memory deficit in children with DLD (for reviews, see Estes et al., 2007; Henry & Botting, 2016; Montgomery et al., 2010). On tasks such as digit recall and nonword repetition, these children tend to have poorer repetition accuracy than their typically developing peers, and have particular difficulty as the stimuli become longer, indicating a deficit in the capacity of their verbal short-term memory (Archibald, 2016; Estes et al., 2007; Jackson et al., 2016; Jones et al., 2010). Notably, children with DLD tend to exhibit a relatively greater deficit on nonword repetition tasks in comparison to digit recall, thought to occur as a result of the additional demands that nonword repetition places on the linguistic system (Archibald & Gathercole, 2006a).

Additionally, there is evidence to suggest that children with DLD have impaired verbal working memory, as indicated by poor performance on tasks such as backwards digit recall and listening span (Alloway et al., 2009; Baird et al., 2010; Hutchinson et al., 2012; Montgomery & Evans, 2009). Yet, there is some inconsistency in this finding, with some studies highlighting a deficit in verbal short-term, but not verbal working memory, in children with DLD (Archibald & Griebeling, 2016; Bavin et al., 2005). Archibald and Griebeling (2016) proposed that children with DLD do not experience impairments in the central executive component of working memory, and instead have deficits in their capacity for phonological storage that may be related to broader phonological deficits. Inconsistent findings across the literature may also reflect issues with statistical power (due to small sample sizes) and the inherent variability in cognitive skills within this disorder (Pennington, 2006). That is, Archibald and Joanisse (2009) suggested that deficits in verbal short-term and working memory impact most, but not all, children with DLD, with their findings indicating that approximately 25% of these children may have intact skills.

The visual–spatial domain of working memory has received less attention than the verbal domain for children with DLD. Tasks such as block recall are typically used, whereby the child watches the examiner tap a pattern of blocks, and then repeats that pattern (Gathercole & Pickering, 2001). This type of task requires the temporary processing of visual–spatial information within the visuospatial sketchpad, and as such is considered a measure of *visual–spatial short-term memory* (Henry & Botting, 2016). Other tasks (e.g., mazes) have been used to measure *visual–spatial working memory*, as they require both simple storage and manipulation, hence engaging the central executive. The findings of research exploring the visual–spatial domain in children with DLD have been mixed. While a number of studies found evidence of unimpaired skills in the DLD group (Archibald & Gathercole, 2006b; Ellis Weismer et al., 2017; Henry et al., 2012; Hutchinson et al., 2012; Lum et al., 2012; Petruccelli et al., 2012), results from a meta-analysis highlighted a significant impairment in children with DLD for both visual–spatial short-term and working memory (with effect sizes of $d = 0.49$ and 0.63, respectively; Vugs et al., 2013). Vugs et al. (2013) noted that inconsistent findings may stem from issues with study power (i.e., small sample sizes), as well as inclusion criteria used for the DLD group. For instance, the effect size for a visual–spatial deficit was greater in studies that involved children with a more severe oral language deficit (i.e., a pervasive deficit affecting receptive and expressive language). Additionally, it is noted that the previous studies examined within the meta-analysis included children meeting criteria for SLI, meaning that children with a fuller range of non-verbal difficulties may have been excluded (Bishop et al., 2017; Vugs et al., 2013). As such, it is important to further explore both verbal and visual–spatial processing within the working memory system in children who meet the broader criteria for DLD, in order to develop understanding of the cognitive mechanisms underpinning this disorder (Norbury et al., 2016).

Procedural and Declarative Memory in Children with DLD. Not all research on memory skills in children with DLD has focused on the working memory system. A body of research has also explored the function of the procedural and declarative memory systems, which, unlike working memory, are capable of storing information over a period of minutes to years (Lum et al., 2010). These long-term memory systems have been explored in children with DLD within Ullman and colleagues' *declarative/procedural model*, which outlines the roles of the procedural and declarative memory systems in the acquisition of normal and disordered language (Ullman, 2001a).

Procedural memory is involved in the implicit learning, storage, and use of sequentially or probabilistically structured information (Lum et al., 2012). Learning within this system proceeds gradually, requiring multiple opportunities for skills and sequences to be practiced and consolidated (Kuppuraj et al., 2016). Once acquired, however, these can be executed rapidly and usually without conscious awareness. Procedural memory is thought to underpin learning for a range of cognitive, verbal, visual, and linguistic skills (Alexander, 1990; Packard, 2009). Specific to language, procedural memory is proposed to subserve the learning and use of rule-governed grammatical skills, including syntax and morphology (Ullman, 2001b). While there are currently no standardised assessments available for procedural memory, a number of experimental paradigms have been developed. These include tasks that measure learning and retrieval of skills across auditory-verbal, visual, and motor domains (Obeid et al., 2016). A commonly-used measure is the serial reaction time (SRT) task, which emphasises visuo-motor sequence learning. Typically, this task involves repeated exposure to images in one of four predefined locations on a computer screen (Lum et al., 2014). Participants are required to press a corresponding button that matches the location of the image on the screen, and reaction times are measured to determine how quickly the participant makes their selection (Nissen & Bullemer, 1987). This task is considered to be a measure of implicit, procedural learning, as the participant is not informed that the stimuli follow a predefined sequence. Participants with intact procedural memory should therefore improve their reaction times across trials as they implicitly learn the sequences (Gabriel et al., 2011).

Declarative memory is involved in learning, storing, consolidating, and retrieving general knowledge about the world (semantic knowledge) and personal experiences (episodic knowledge; Eichenbaum, 2004). Declarative memories are developed mostly through explicit learning (Daselaar et al., 2006), and while information may be encoded and stored within declarative memory after a single exposure, knowledge is strengthened and refined through additional exposures (Squire, 2004). Information stored within declarative memory is retrieved through recall and recognition processes (Knowlton & Squire, 1995). In relation to language development, declarative memory is thought to be particularly important for vocabulary, and has been specifically linked with the development of word knowledge (i.e., semantic details; Ullman, 2004). Neurological evidence also suggests that declarative memory may underlie the storage of phonological word forms (i.e., in the posterior superior temporal cortex; Indefrey & Cutler, 2004). A variety of tasks (including a range of standardised, norm-referenced measures) have been developed to evaluate declarative memory for verbal and nonverbal information (Cohen, 1997; Lum & Conti-Ramsden, 2013). Declarative memory for verbal information (hereafter referred to as *verbal declarative memory*) is often measured using tasks such as word pair learning, where the child receives multiple auditory exposures to pairs of unrelated words, and is required to recall the items after each presentation, and then again after a short and long delay (Lum et al., 2015). Declarative memory for nonverbal, or visual–spatial information (*visual–spatial declarative memory*) is evaluated using tasks such as dot locations learning, where the child is required to remember a set of randomly-positioned dots (Lum & Conti-Ramsden, 2013). Learning on these tasks is also evaluated by requiring the child to recall the position after short and long delays (Lezak, 2004).

While the working, declarative, and procedural memory systems are considered to be distinct, they interact in various ways (Ullman, 2004). In particular, there is evidence of a close link between the working and declarative memory systems. Working memory is suggested to support encoding of information in declarative memory by temporarily storing stimuli encountered in the environment, and re-organising or chunking information prior to encoding (Blumenfeld & Ranganath, 2006). This has been supported by evidence from neurological studies whereby the dorsolateral prefrontal cortex is active while information is manipulated during working memory tasks (D'Esposito et al., 1995), and while novel items are encoded into declarative memory (Blumenfeld & Ranganath, 2006). Working memory may also support the retrieval of information from declarative memory by monitoring information as it is retrieved and holding it active in the focus of consciousness (Cabeza et al., 2002). Evidence has also been derived from behavioural studies which show significant associations between performance on measures of working memory and declarative memory (Cohen, 1997; Millis et al., 1999). In contrast, the relationship between the working memory and procedural memory systems is less well understood. Neurological data does support a link between these systems, with evidence that the basal ganglia and its associated circuitry are involved in the function of both systems (Menon et al., 2000; Ullman et al., 2019). However, there is a paucity of behavioural research exploring the interactions between these systems.

Extending the *declarative/procedural model*, Ullman and Pierpont (2005) proposed the *Procedural Deficit Hypothesis* as a potential account for the disordered language patterns observed in children with DLD. According to this hypothesis, language problems in DLD may be largely explained by abnormalities in brain structures underlying the procedural memory system (Ullman & Pierpont, 2005). This leads to impairments in implicit learning of probabilistic and sequential skills, and as such may explain why deficits in the comprehension and production of syntax and morphology are a hallmark feature of children with DLD (Hendricks et al., 2019; Leonard, 2014). Data from a number of empirical studies supports the prediction that procedural memory is impaired in children with DLD. For instance, research involving neuroimaging methods with these children indicates abnormalities in brain regions subserving procedural memory, such as the basal ganglia and frontal cortex (Krishnan et al., 2016; Ullman, 2013). Evidence of impaired procedural memory is also drawn from poor performance among children with DLD on behavioural tasks. Evidence of poor learning emerges from tasks that tap learning in the verbal domain (Evans et al., 2009; Hsu et al., 2014; Plante et al., 2002) and visuo-motor domain (Lum et al., 2010; Lum et al., 2012; Mayor-Dubois et al., 2015). However, these findings have not always been replicated (e.g., see Gabriel et al., 2011; Gabriel et al., 2013; Gabriel et al., 2012; Lum & Bleses, 2012; Tomblin et al., 2007). As noted by Lum et al. (2014), different findings may arise due to factors such as the age of participants, the modality of the task, and the number of learning trials provided. Given the small sample sizes of individual studies exploring procedural memory in children with DLD, further research is required.

The Procedural Deficit Hypothesis also posits that the working memory system may be impaired because it depends, at least in part, on impaired neurological structures that also underlie procedural memory (Ullman & Pierpont, 2005). Deficits in the working memory system in children with DLD are well-established, as reviewed previously in this chapter. In contrast, the Procedural Deficit Hypothesis outlines that declarative memory is intact in children with DLD, and may play a compensatory role in the development of grammar in the face of impaired procedural memory (Ullman & Pullman, 2015). There is strong evidence for intact declarative memory with respect to the visual–spatial domain, with groups of children with DLD showing largely normal performance in comparison to their typically developing peers (Baird et al., 2010; Bavin et al., 2005; Lum & Conti-Ramsden, 2013; Lum et al., 2012; Lum et al., 2010; Riccio et al., 2007). However, the evidence regarding verbal declarative memory is mixed, with some studies demonstrating deficits (e.g., see Lum & Conti-Ramsden, 2013 for a review) and others finding comparable skills among children with DLD and typically developing children (Baird et al., 2010; Records et al., 1995; Shear et al., 1992). Some evidence suggests that children with DLD have particular difficulty with the encoding of verbal information into declarative memory, with deficits observed on tasks such as list-learning, even when multiple exposures are provided (Lum et al., 2015). Past research findings also indicate that children with DLD may experience difficulty with retrieving information from declarative memory, both immediately after learning, and after a delay (Lum & Bleses, 2012; Lum et al., 2012; Lum et al., 2015; Nichols et al., 2004). However, these findings have not been consistently replicated (Baird et al., 2010; Records et al., 1995), and the findings from Bishop and Hsu (2015) suggest that deficits with retention and retrieval of verbal declarative memory may be accounted for by problems in initial encoding.

While past research indicates that DLD may be associated with a verbal declarative memory deficit, a handful of studies have explored the possibility that poor performance may be accounted for by deficits in the working memory system. For instance, Lum et al. (2015) demonstrated that deficits in verbal declarative memory were related to verbal working memory impairments in children with DLD. In contrast, Lum et al. (2012) and Lum and Bleses (2012) found that verbal declarative memory performance remained significantly worse in the DLD group, even after controlling for verbal working memory. This contrasting research (described in more detail in Chapter 6; Study 4) necessitated the investigation of these memory systems with a larger sample of children with and without DLD. Relatedly, it is notable that there are very few studies that have explored procedural memory alongside working and declarative memory, and this is also explored further in Study 4.

The Relationship Between Word Learning and Memory

Understanding the source of word learning deficits in DLD has been the subject of a small body of research. The most frequently-explored explanation rests on the well-established working memory deficit in children with DLD. According to

Archibald (2016), there is a dynamic relationship between the working memory system and word learning. Specifically, verbal short-term memory is suggested to be critical in facilitating the establishment of novel phonological forms in the lexicon. In relation to Baddeley's model of the working memory system, it is the phonological loop that acts as a "language learning device" (Baddeley et al., 1998, p. 158). This component is suggested to temporarily store incoming verbal information, thus holding the new word form active while additional information about the word is processed. As such, children who have deficits in verbal short-term memory are theorised to experience an impaired ability to learn novel word forms, especially as these forms become longer, or when learning occurs in environments with competing processing demands (Archibald, 2016; Archibald & Griebeling, 2016). In turn, verbal short-term memory may be supported by existing vocabulary knowledge, highlighting the idea of a reciprocal relationship between verbal short-term memory and word learning (Majerus et al., 2006). That is, sequences of phonemes stored within existing vocabulary (i.e., in long-term memory) may be retrieved and held active in the working memory system during novel word learning, which may allow for more efficient establishment of novel phonological representations (Gathercole et al., 1992; Munson et al., 2005b). Thus, children with better verbal short-term memory capacities likely find the task of encoding novel phonological representations easier, and in turn, those with broader vocabularies are more effective at establishing novel word forms (Archibald & Griebeling, 2016).

There is evidence to support the role of verbal short-term memory at the stage of initial encoding of new words (i.e., fast mapping), especially with regards to learning the word form (phonological representation). In typically developing children between the ages of five and eight, robust associations between verbal short-term memory and the ability to encode novel phonological forms have been reported (Bowey, 2001; Gathercole & Baddeley, 1989, 1990; Gathercole et al., 1997; Jarrold et al., 2004; Jarrold et al., 2009). This link continues to be significant, albeit weaker, after the age of eight and into adulthood (Atkins & Baddeley, 1998; Gathercole et al., 2005; Gupta, 2003). Relatively few studies have directly explored this relationship in children with DLD, and the findings are conflicting. While Alt and Plante (2006), Gray (2006), and Jackson et al. (2016) found that verbal short-term memory (as measured by nonword repetition) was a significant predictor of how well the children learned the novel word forms, Gray (2004) and Hansson et al. (2004) reported no significant correlation between encoding (fast mapping) skills with nonword repetition and digit span. The source of these equivocal findings is not clear, as there were similarities among participant characteristics, sample sizes, and the experimental tasks across these studies. It is possible that the heterogeneous nature of memory impairment in children with DLD contributes to the varied findings (Archibald & Joanisse, 2009); therefore, the nature of the relationship between memory and word learning in children with DLD requires detailed exploration.

Gathercole (2006) posited that a verbal short-term memory deficit alone may be insufficient in explaining word learning problems in DLD, instead suggesting that a more general working memory system deficit may be more influential than a verbal short-term memory weakness in defining the relationship between word learning and memory. However, this is yet to be investigated; previous research that has explored the relationship between the working memory system and word learning has focused on the single component of verbal short-term memory. This highlights the importance of exploring the association between word learning and other components of working memory, such as verbal working memory, in order to build understanding of the precise factors that contribute to breakdown in this aspect of language development (Henry & Botting, 2016; Ullman, 2004).

Furthermore, most previous research has been concerned with the factors underlying breakdown in the initial encoding (or fast mapping) stage of word learning. Generally, this past research supports the notion that the word learning deficit experienced by children with DLD originates at these early stages of word learning, which results from (or is at least significantly related to) deficits in verbal short-term memory (Archibald, 2018; McGregor et al., 2020a; Ullman, 2004). The subsequent retention of new words is likely to remain intact, presumably as a result of an unimpaired declarative memory system (Bishop & Hsu, 2015). In light of evidence for the interactions between the working memory and declarative memory systems, it is possible that the working memory system may be called upon again when additional learning opportunities are presented, thus triggering retrieval of word knowledge from declarative memory (Cabeza et al., 2002; Simons & Spiers, 2003). Importantly, however, these theoretical notions require empirical investigation. Little research has explored the interaction between the working memory system and word learning longitudinally – that is, across the processes of encoding and retention – making this a priority for further research. This issue is discussed in further detail in Chapter 7 (Study 5).

Aims of the Current Research Program

While language problems, such as word learning impairments, usually emerge in the early developmental period in children with DLD, these problems are enduring, and can persist throughout adulthood (Conti-Ramsden et al., 2012; McGregor et al., 2020a). Research evidence highlights that without the provision of targeted, evidence-based support, the functional impact of word learning impairments on academic, social, and vocational outcomes can be significant (Wright et al., 2018). In light of these significant implications, the nature of word learning impairments in children with DLD is a priority for further research. Word learning deficits in these children may be related to impairments in the working, declarative, and/or procedural memory systems (Baddeley et al., 1998; Bishop & Hsu, 2015; McGregor et al., 2017b); however, the function and interrelationships of these systems also requires investigation in children with DLD so that their association with the word learning process may be understood.

Thus, the overarching aim of this doctoral research is to develop a more comprehensive understanding of the function of memory and word learning, and how these processes relate, in children with DLD. This research program focuses on children who are in their second and third years of formal schooling within the Western Australian school system (i.e., Year 1 and 2; aged five to eight years). DLD is reported to be reliably diagnosed from the age of five (Dockrell & Hurry, 2018; Tomblin et al., 2003), and the period of early schooling is a critical time for children to be developing their vocabulary knowledge (Beck & McKeown, 2007; Joshi, 2005). Furthermore, the working, declarative, and procedural memory systems may be reliably assessed during this time (Cohen, 1997; Gathercole & Pickering, 2001). Thus, it is crucial to investigate word learning, memory, and the interrelations between these skills in order to build understanding of the factors impacting language development in DLD at this critical stage of development. This knowledge has important clinical applications for the provision of thorough and accurate assessment and intervention for these children.

PART TWO: The Evaluation of Word Learning Skills

The broad aim of Part Two was to compile important knowledge regarding the evaluation of word learning, in order to guide the formulation of specific research questions and the methodology of subsequent studies. First, I present a systematic scoping review of the literature involving word learning evaluation in people with DLD. Subsequently, a clinician survey is presented, which explores the clinical use of assessments for word learning (and more broadly, vocabulary). The two studies reported here sought to identify current gaps in knowledge, with the aims of guiding the formulation of research questions, and grounding the theoretical approach to subsequent explorations of the relationships between memory and word learning.

Chapter 3: The Evaluation of Word Learning Abilities in People with Developmental Language Disorder: A Scoping Review

Chapter Overview

This chapter (Study 1) presents the accepted manuscript of a published scoping review of the literature. As discussed in the background literature review (Chapter 2), the word learning process is multifaceted, and has been explored from a variety of theoretical perspectives. The extent of the research base on this topic is not well-known, and the breadth of assessment methods have not been the subject of any previous review. Therefore, the current study systematically explores and describes the varied methods that have been used in the research to evaluate word learning in people with DLD. Studies involving children, adolescents, and adults with DLD are included in order to build context for how word learning is evaluated broadly within this population. In this paper, word learning methodologies are described according to several key methodological parameters that researchers have taken into account when designing their word learning tasks. The findings are also discussed in light of various theoretical perspectives that have been used to frame investigations of word learning in the DLD population.

In the next section, I present the accepted manuscript version of an article entitled, '*The evaluation of word learning abilities in people with developmental language disorder: A scoping review'*, published on 5th July 2019 by John Wiley & Sons Publications in the International Journal of Language and Communication Disorders[1]. This article is available online: https://onlinelibrary.wiley.com/doi/full/10.1111/1460-6984.12490.

[1] Copyright permission letters of approval for each manuscript are provided in Appendix A.

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Abstract

Background: The ability to learn new words is critical in the development of oral and written language, and significantly impacts engagement in social, academic, and vocational situations. Many studies have evaluated the word learning process in people with developmental language disorder (DLD). However, methodologies for assessment are heterogeneous, creating difficulties in synthesising findings and identifying gaps in the knowledge base.

Aims: To (1) systematically scope the literature and identify key methodological parameters considered in evaluations of word learning in people with DLD; and (2) identify gaps in the literature to guide further research in this area.

Methods: Twelve databases were searched and a total of 70 studies that met eligibility criteria were identified. The studies were evaluated according to key parameters that researchers varied in their word learning methodologies.

Main contribution: Most research has focused on word learning in the oral modality, and specifically in children with DLD. Fewer studies have explored word learning in adults and adolescents with DLD, and in the written modality. Depending on the research question and theoretical perspective driving the investigation, methodologies for assessing word learning considered a range of parameters, including words being learned, learning context, and cues to support learning in the tasks.

Conclusions: This review aggregates a variety of methods used previously to assess word learning. Findings highlight the need for further research to explore areas such as: the learning of varied word types (e.g., adjectives and adverbs); learning in the written modality; and word learning (both oral and written) in adolescents and adults with DLD.

What This Paper Adds

What is Already Known on the Subject? The ability to acquire new vocabulary is a complex process, and the findings of numerous studies document this as an area of weakness for children with DLD. The range of methods for evaluating word learning reflect the multifaceted nature of this skill. Yet, these varied methodologies used in the literature to evaluate word learning in people with DLD have not been the focus of a previous review.

What this Paper Adds. This review involved systematic scoping of the literature to summarise previous methodologies used to evaluate word learning in people (of all ages) with DLD. Despite the complex nature of the word learning process, the review identified that approaches to evaluate word learning are guided by several methodological parameters. These findings are discussed in light of varied theoretical perspectives, and gaps in the knowledge base are identified to guide future research efforts.

Clinical Implications. While an abundance of word learning assessment tasks has been used in research, to our knowledge these types of measures are seldom used in clinical practice by speech-language therapists (SLTs). Future research may focus on translating research to practice so that SLTs are equipped with resources to evaluate the word learning process in clients with DLD.

Introduction

The skill of acquiring new words is fundamental to language development (Leonard 2014). Word learning commences in early infancy and involves a multifaceted and incremental process (Carey, 2010; Nation, 2014), which has been conceptualised to involve the gradual mapping of information about the word's form and meaning (Carey, 2010). The term *fast mapping* is often used to describe the initial process of word learning in which a tentative map of the phonological and semantic representations is developed after minimal (e.g., one to four) exposures (Chiat, 2001; Rice et al., 1992). Further encounters with the novel word prompt gradual refinement in long-term memory (i.e., *slow mapping*, Carey 2010), during which form-meaning representations are specified further across contexts.

While children with typically developing (TD) language appear to learn new words with relative ease, this process is problematic for many children, including those with developmental language disorder (DLD). DLD is marked by varied oral language deficits (e.g., in semantic, grammatical, and discourse skills; Bishop et al., 2017), and a large body of research indicates that many children with DLD experience poor performance when their word learning skills are compared to those of TD children (Alt & Spaulding, 2011; Gray, 2004; Jackson et al., 2016; Rice et al., 1994; Storkel et al., 2017b; van der Lely, 1994). Children with DLD struggle with learning both the phonological form of new words and semantic attributes such as colour, shape, and pattern (e.g., Alt & Plante, 2006), and are also less sensitive to syntactic cues, resulting in difficulty ascertaining novel word information from spoken sentences (Johnson & de Villiers, 2009). A meta-analysis by Kan and Windsor (2010) confirmed that children with DLD (termed "primary language impairment" in the paper) showed significantly poorer word learning performance than age-matched TD children, but performed equivalently to younger TD children matched for language skills. Recent research also indicates that word learning deficits may persist into adulthood for people with DLD (McGregor et al., 2017b).

While there is a general consensus that this is an area of deficit for most children with DLD, methods for evaluating the word learning process vary considerably across studies. Word learning assessment tasks generally involve assigning a nonword (or unusual real word) label to an unfamiliar object (if teaching nouns) or action (if teaching verbs), to control for previous language knowledge (Kan & Windsor, 2010). Children are presented with the novel word embedded in spoken sentences in either an interactive activity with the researcher, or on a computer (Alt, 2011; Jackson et al., 2016). The ability to produce and/or comprehend the target word is then evaluated. For instance, naming tasks are used to evaluate the child's production of the target word (e.g., Dollaghan, 1987). Comprehension is tested through tasks requiring the child to select the target item when they hear the novel word (e.g., Rice et al., 1994), or to select the correct label of the novel word when presented with a range of choices (including the target and phonologically-similar distractors; Alt, 2011). If a study also explores how well children learn the semantic features of novel words, knowledge may be tested using a describing or definition task (e.g., Nash & Donaldson, 2005; Vogt & Kauschke, 2017a). This general task design has been adapted widely to allow examination of different aspects of word learning.

In earlier studies, Rice and colleagues introduced novel object-word pairs using a quick incidental learning (QUIL) paradigm in which new words were embedded in sentences and presented in animated stories, without explicit instruction to attend to the novel words (Oetting et al., 1995; Rice et al., 1990; Rice et al., 1992; Rice et al., 1994). This design was intended to replicate the incidental nature of everyday word learning situations, and comprehension of the novel words was tested using a picture identification task. While the QUIL approach has also been used in more recent studies (e.g., Rohlfing et al., 2018), other researchers have adopted an instructional paradigm in which the researcher makes explicit the intention of the task and draws attention to novel words in an interactive approach (Nash & Donaldson, 2005). For instance, Jackson et al. (2016) presented novel objects with nonword labels in simple sentences within an interactive play activity, and measured learning using a naming task.

Word learning has also been evaluated over a series of days. For instance, Gray and colleagues utilised an extended word learning paradigm in which novel nouns were taught to preschool children over four days using an interactive play context, with learning evaluated using comprehension and naming tasks (Gray, 2003, 2004, 2005; Kiernan & Gray, 1998). A similar model was used by Storkel et al. (2017b) using a book sharing task to identify the optimal intensity of exposures to novel words required by preschool children with DLD so that they may perform comparably to TD children.

Different methods have also been employed to explore how well children with DLD learn the form and meaning of novel words when they are presented in a reading task (e.g., Steele & Watkins, 2010; Wolter & Apel, 2010). Learning the meaning of novel words through reading involves several processes like learning in the oral modality, such as using syntactic cues to build new word knowledge from context (Steele & Watkins, 2010). However, learning the novel word form differs, because an orthographic representation, or mental graphemic representation (MGR), must be formed (rather than a phonological representation; Ricketts et al., 2015). Yet, MGR development may also involve phonological processes, such as the translation of graphemes in novel words to phonemes, and then blending of the phonemes to pronounce the written word (Wolter & Apel, 2010).

Purpose and Research Question

As a wide range of tasks has been used to evaluate word learning in children and adults with DLD, a review of these methodologies was warranted. The nature of this investigation was not amenable to a systematic review, which is suited to answering precise questions, usually on the effectiveness of an intervention (Peters et al., 2015). Instead, a scoping review was conducted, as this type of review allows for a broader approach to map the available literature on a topic (Arksey & O'Malley, 2005; Peters et al., 2015). This review therefore aimed to systematically scope the literature to identify the range of methodologies used to evaluate word learning in people (of any age) with DLD, and to identify gaps in previous literature to guide further research (e.g., to identify whether there are aspects of word learning that have not been well-investigated). The central question guiding this review was: *What methods have been used to evaluate word learning in the first language of people who have developmental language disorder?*

Method

This scoping review was guided by the five-stage methodological approach outlined by Levac et al. (2010) and the Joanna Briggs Institute and Collaborating Centres (Peters et al., 2015): 1) identify the research question (stated above); 2) identify relevant studies; 3) select studies; 4) chart the data; and, 5) collate, summarise, and report the results.

Identifying Relevant Studies

Where: Identification of Peer-Reviewed Literature. The search terms (listed in Appendix C.1) were identified based on the aspects of *Population* (people of all ages with DLD) and *Concept* (the evaluation of novel word learning; Peters et al., 2015), and were used to search 12 databases. First, the Cochrane Library (Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, and the Central Register of Controlled trials) was searched to identify any previous reviews. A meta-analysis by Kan and Windsor (2010) was identified, which reviewed word learning performance in children with DLD and TD children; however, no meta-analyses, systematic reviews, or scoping reviews on word learning methodology were found. A search of Ovid (AMED, PsychINFO, and MEDLINE), Web of Science (Current Contents Connect), ProQuest, Scopus, Embase, Informit, and Google Scholar electronic databases was also conducted.

Where: Other Sources. The database searches included both peer-reviewed and grey literature (e.g., unpublished theses and other non-peer reviewed work) at the same time. Only primary studies were included, and commentary papers and reviews were excluded. In addition, reference lists of review papers were hand-searched for any additional articles, and a hand search of a special issue on word learning in the Journal of Clinical Practice in Speech-Language Pathology (2007) was conducted.

Time Span and Language. Database searching included any articles published before 2018. Searches were conducted between February and March 2018. There were no articles published prior to 1987 that met eligibility criteria. All retrieved articles were available in English, except for one paper for which a translation could not be obtained (Yang et al., 2015).

Study Selection. Eligibility criteria to guide the selection of studies were established through team discussions, using the aspects of *Population, Concept*, and *Context* (Peters et al., 2015). The full criteria are listed in Appendix C.2.

Population. The focus of the review was people of all ages with DLD. Studies were included if people in the DLD group were identified according to conventional or clinical criteria, which were difficult to specify as varied terms were used in the literature (e.g., "specific language impairment", "language difficulties", and "primary language impairment"). Furthermore, varied criteria were used to identify language impairment. To capture a broad range of studies, eligibility criteria were guided by those outlined in Kan and Windsor (2010) and the Delphi consensus study (Bishop et al., 2017):

1. Reference to low receptive and/or expressive oral language skills, as indicated by performance of ≤ 1 SD below the mean on at least one standardised oral language test;
2. Reference to evidence of no intellectual disability, as indicated by achieving a standard score of >70 on a standardised measure of nonverbal cognitive ability.

In accordance with the criteria for *developmental* language disorder, studies that included children with an acquired language disorder were excluded. Adults with an acquired language disorder were also not included, and studies needed to provide evidence of adult participants' language difficulties being developmental in nature. Studies were therefore included if a self-report measure regarding a history of language difficulties was used, plus a confirmatory standardised assessment indicating current language disorder or impairment (Alt & Gutmann, 2009).

People learning novel words in their primary language was the focus. Word learning in a second language is inherently more complex than in a first language; it is impacted by degree of language exposure and may involve different mechanisms for familiar and unfamiliar languages (Thordardottir, 2011). The complex nature of bilingual word learning in DLD therefore went beyond the scope of the current review.

Concept. The aim was to broadly examine research that investigated any aspect of word learning, such as learning from an oral or written task and learning the different representations of novel words, e.g., phonological, semantic, and orthographic. Tasks needed to include some element of learning the word form, either phonological or orthographic. Studies that included only visual learning, for instance, were not included in the review as these were not considered to reflect language learning (e.g., Alt, 2013). Studies that measured existing vocabulary (e.g., using a standardised test) as an indication of word learning capabilities were not included. Instead, studies needed to teach and evaluate the learning of new words.

Context. Studies that evaluated word learning across a range of settings (e.g., research, educational, or clinical) were the focus. Only those that measured word learning behaviourally (rather than neurologically, or through cognitive modelling) were included as these investigations were deemed most relevant to practitioners and educators. These criteria were used to guide the procedure for study selection, as described below.

Results

Procedure for Study Selection

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Peters et al., 2015) outlines the search decision process for our review (see Figure 3.1). The database searches yielded a total of 1265 reports, and a further five were identified via other sources (e.g., hand-searching pages of key researchers). After the removal of duplicates, there were 369 remaining. Of these, 360 were peer-reviewed and nine were grey literature (all unpublished theses).

Thus, 369 records were reviewed. Initially, the first author of this review screened the titles and keywords according to the eligibility criteria. Then, the abstracts of articles that passed the first stage of screening were independently screened for inclusion by the first and second authors. There was high inter-rater agreement in the reviewers' classification of papers for inclusion, $\kappa = .71$ (95% CI,

.63–.78), $p < .001$. Contended articles were discussed to reach a consensus, and 101 articles met criteria at this stage.

The same authors then independently reviewed these 101 articles at the full-text level with high agreement, κ = .80, (95% CI, .67–.92), $p < .001$. After discussion of contended articles, 63 articles were included and 38 were excluded: 19 studies were excluded as they did not evaluate the process of word learning (e.g., only a static assessment of word knowledge/vocabulary was included); two were theses that were later published as peer-reviewed articles (which were included in the review); six involved teaching novel words in a language that was not the participants' primary language; five did not include a "DLD" group, and; six did not apply appropriate criteria for inclusion in the DLD group (e.g., children were *late talkers* but did not meet DLD criteria). Following full-text screening, seven additional articles were further identified (and met criteria) through hand-searching reference lists, yielding a total of 70 articles.

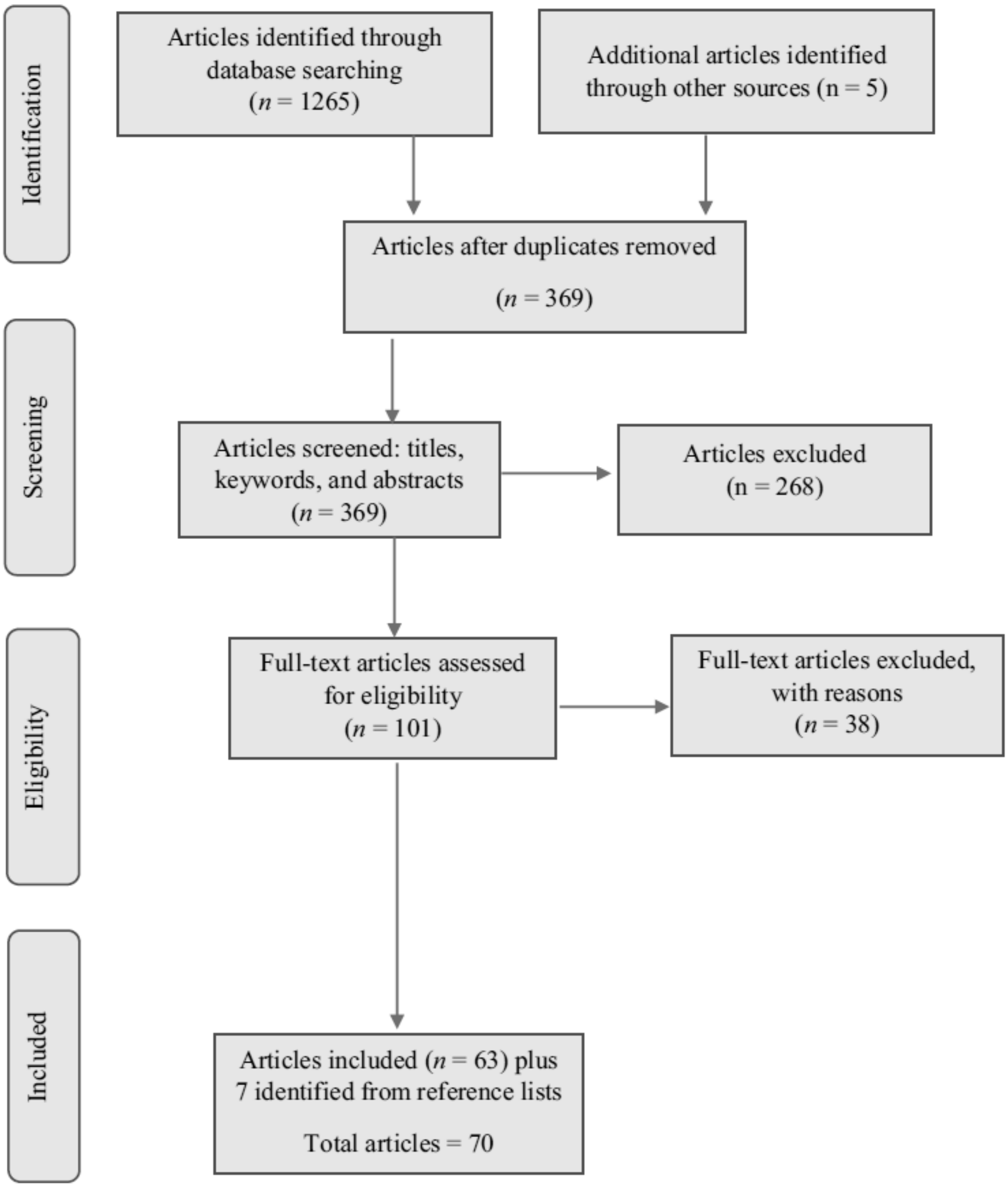
A total of 47 studies were conducted in the United States, eight in the United Kingdom, four in Germany, three in Canada, three in the Netherlands, two in Israel, and one in each of New Zealand, Taiwan, and Australia. This indicates that a substantial amount of research into word learning has been conducted with English-speaking populations.

To assist with data extraction and to facilitate the summarisation of studies, a data charting table was developed to record information about key parameters that researchers varied in the development of their word learning methodology (see Appendices C.3 and C.4; Peters et al., 2015). These parameters were:

- age of participants;
- the learning context (e.g., a play-based or computerised task);
- the modality (oral versus written) and domain (e.g., phonology, semantics, or orthographic) of word knowledge that was investigated;
- word learning stimuli, such as the selection of different word types, the use of real or nonsense words, and/or manipulation of the phonotactic probability;

Figure 3.1

PRISMA Flow Diagram for the Systematic Scoping Review Process



- task characteristics and methodological details regarding how the stimuli were taught, such as investigation into the impact of learning cues or rate of input; and subsequently;
- the outcome measures that were used to assess learning.

These parameters are further discussed below.

Age

Thirty-nine studies (56%) included only young children with DLD, defined here as children aged 3 to 6 years 11 months. Depending on the country or region of the study, children within this age bracket may have been attending *Kindergarten, Preschool*, or *Pre-primary*. Regardless of terminology, the defining feature is that this cluster of young children had not commenced formal schooling in their respective school systems. Sixteen studies included school-aged children: those who had commenced formal schooling (Grade/Year 1 and above), and whose ages ranged from seven to 13 years. Ten studies examined word learning in both young children and school-aged children (e.g., Johnson & de Villiers, 2009 included children aged four to nine). The fact that most research was conducted with children reflects the developmental nature of this disorder; the research has aimed to understand the nature of these deficits during critical periods of language and academic development (Kan & Windsor, 2010). Feasibility is also a factor, with many studies recruiting pre-school and school-aged children with DLD from specialist language schools (e.g., Gray et al., 2014).

A substantially smaller number of papers (five) investigated word learning in adults. McGregor and colleagues (2013a, 2017a, 2017b) studied young adults aged 18 to 25 years, and Alt and Gutmann (2009) included those with a mean age of 19 years. Except for Bishop et al. (2012), who included children and adolescents (mean age 15 years) and their parents (mean age 43 years), there were no studies involving 14 to 17-year-olds or adults aged above 25 years.

Learning Context

Learning context refers to the situation or task format in which the novel words were presented. Forty-six studies presented novel words within a structured task, of which 26 were delivered “live” to each child (e.g., face-to-face, interactive activities with experimenter and participant), and the other 20 using a computerised task. These tasks, whether live or computerised, involved the participant seeing the target object or image and hearing the production of the target word within short sentences or carrier phrases (e.g., “Look! It’s a X”; Alt & Spaulding, 2011, p. 645).

Nineteen studies presented the novel words within a story context. Six of these used an interactive book-sharing task, such as in Storkel et al. (2017a, 2017b), where the novel words were embedded within a story. Another four required participants to independently read the texts themselves (e.g., Steele & Watkins, 2010) in order to investigate orthographic word learning (discussed further in *Modality and Domain of Knowledge*). Conversely, nine studies used a digitised story context, such as animated pictures with the novel words embedded in spoken stories (e.g., Horohov & Oetting, 2004; Rice et al., 2000) or simulated story book reading, where static images were presented on slides alongside an audio recording of the story (e.g., Wolter & Apel, 2010). Most studies that presented the novel words within a story context aligned with the principles of a QUIL approach, where the child's attention was not directed to the novel words (to mirror everyday word learning scenarios; Rice et al., 1990).

Four studies examined word learning in more than one learning context. For instance, Nash and Donaldson (2005) explored word learning in a structured task (e.g., presenting one word at a time accompanied by a definition) compared to a QUIL story context, to determine how the learning situation influences word learning in children with DLD. Smeets et al. (2014) compared word learning in two storybook tasks: one presented statically, one via video. The static condition replicated a print version of a book (still images with an audio reading); the video version was similar but used animated pictures and additional sound effects.

One study used a learning context that differed from the others. Bishop et al. (2012) presented a modified nonword repetition task, where participants heard and repeated a novel word five times in a row; this task was then repeated an hour later.

Modality and Domain of Knowledge

Oral Modality. Sixty-six of the 70 included studies (94%) explored word learning in the oral modality. Orally learning a new word involves developing representations for multiple domains of language; however, phonology and semantics are considered the initial aspects crucial to fast mapping (Chiat, 2001). Mostly, these tasks involved verbally presenting the novel word along with a visual stimulus (e.g., the unfamiliar object to which the label referred, or a video clip of characters acting out the novel verb), to encourage the development of a form–meaning map (Alt et al., 2004). Of the 66 studies, 32 provided only phonological information: the novel word was heard by participants and they were given a visual referent (e.g., a picture representing the novel word), but no attention was directed to its semantic features. The only exception was Bishop et al. (2012), who presented the phonological label but no visual referent. Thirty-one of the 66 studies also focused on semantic learning; this involved providing instruction regarding the word's semantic features (e.g., physical attributes or functions; Alt & Plante, 2006) in addition to exposure to the phonological form.

Word learning tasks also involve inherent mapping of a grammatical representation. For example, if a nonsense word is provided with a visual referent (e.g., an object), it could be inferred from context that the word is the label (i.e., a noun) representing the object (Carr & Johnston, 2001). However, studies that specifically focused on grammatical learning (for instance, learning to attach morphemes to novel words or learning to use syntactic frames) were not included, as this did not fit with the purpose of understanding learning of whole novel words.

Written Modality. Of the 66 studies that investigated oral word learning, three studies additionally examined learning via the written modality (Diestelmeier, 2014; McGregor et al., 2017a; Ricketts et al., 2015). For instance, Diestelmeier (2014) presented the novel words in a verbal task (e.g., saying the word and explaining the meaning). Participants then read the novel words independently in a story reading task. This was intended to encourage development of comprehensive word knowledge (phonology, semantics, and orthography), which is required so that the word may be used in both spoken and written tasks (Diestelmeier, 2014; Nation, 2014).

There were only four studies that primarily investigated word learning in the written modality. For instance, Steele and colleagues presented novel word stimuli via an independent reading task and assessed how well children learned new word meanings (Steele, 2015; Steele & Watkins, 2010; Steele et al., 2013). Similarly, Wolter and Apel (2010) presented kindergarten children with a written fast mapping task, where they viewed an image and written sentences containing the target words. The purpose of this task was to investigate how these children developed initial MGRs, which are significantly related to reading and spelling abilities in later schooling (Wolter & Apel, 2010).

Word Learning Stimuli

Selection of Stimuli: Real or Nonwords. Forty-eight studies (69%) used nonwords as their word learning stimuli, to avoid potential confounds from semantic and lexical factors (Kan & Windsor, 2010). Twenty-three of these studies involved creation of the nonwords, using methods such as random generation (e.g., Alt et al., 2004 assigned numbers to phonemes and randomly selected numbers to create CVC or CVCVC nonwords), while 25 studies used stimuli that had been developed for a previous study. For instance, Alt and Gutmann (2009) and Alt and Plante (2006) used the nonwords created by Alt et al. (2004) for their word learning task. Overall, nonword stimuli were taken from 24 different sources, showing that there is no common bank of nonwords used for developing word learning tasks.

The remaining 22 studies (31%) used real instead of nonsense words as stimuli: these were words that existed in the language but were unfamiliar to participants, as confirmed by pre-testing (e.g., Vogt & Kauschke, 2017b) or words considered to be low incidence in children's vocabulary (e.g., Gray, 2003). The decision to use real words tended to be ethically motivated, wherein the participants might use those words in future contexts (Gray, 2005).

Manipulation of Word Characteristics. Various novel word lengths and syllable shapes have been explored; 20 studies used only monosyllabic novel words (e.g., CVC, CCVC, or CVCC; Steele & Watkins, 2010), and 20 studies used disyllabic stimuli (e.g., CVCVC, CVCCVC, CCVCVC; McGregor et al., 2017a). A further 13 studies used novel words ranging in length (e.g., two, three, and four syllables; Jackson et al., 2016). Of these 13 studies, Alt (2011) was the only one to manipulate the length of novel words, and compared the children's ability to learn two- and four-syllable nonwords (CVCVC and CVCVCVCVC, respectively). For 18 studies, it was not possible to determine the syllable shape due to insufficient reporting of information on the stimuli (see summary table in Appendix C.4).

When creating or selecting stimuli, the phonological properties of the nonwords have been considered for potential influence on performance. Ten studies examined the effect of manipulating phonotactic probability (the frequency with which sound segments occur in a language; Gray et al., 2014). This factor was explored to determine whether participants with DLD learned novel words with high phonotactic probability more effectively, given their resemblance to other words in the language (Plante et al., 2011). Two of these studies additionally investigated the influence of neighbourhood density (the number of words that differ from the target word by just one sound; McKean et al., 2014). One of the studies exploring phonotactic probability also explored orthotactic probability (the incidence of a word's graphemes and bigraphs occurring in other English words), which was of interest as the novel words were introduced in a reading task (Wolter & Apel, 2010).

Selection of Stimuli: Word Type. Successfully building vocabulary involves learning a range of word types, with concrete nouns considered the simplest to learn given that they can be mapped to a visual referent and are static in nature (Alt et al., 2004; Eyer et al., 2002). Forty-four studies used only concrete nouns as stimuli, usually presented as labels or proper names for unfamiliar objects, such as aliens or dinosaurs. Verbs are considered more difficult to learn as they are transient and abstract in nature (Chiat, 2001), and 10 papers taught only novel verbs. Tasks for verb learning tended to involve participants watching animated scenarios where familiar objects were made to perform unfamiliar actions, while they heard statements about the action (e.g., "See, it dacks"; Riches et al., 2005, p. 1402). It was not possible to determine the word type for the nonword stimuli used by Bishop et al. (2012), as the stimuli were presented in isolation (with no referent).

Fifteen studies compared learning of at least two different word types, to explore how word learning may differ depending on the grammatical function of words (Windfuhr et al., 2002). Of these, nine studies compared learning of nouns and verbs, two compared nouns, verbs, and adjectives (Storkel et al., 2017a, 2017b), two compared nouns, verbs, attributes, and affective states (Oetting et al., 1995; Rice et al., 2000), one compared nouns, verbs, adjectives, and adverbs (Smeets et al., 2014), and one compared nouns and attributes (Rice et al., 1992).

Task Characteristics

To explore factors contributing to word learning breakdown in people with DLD, a group of studies manipulated the task conditions.

Learning Cues. Twenty-four studies (35%) investigated the impact of providing cues during word learning. Eight of these explored the impact of semantic cues (e.g., highlighting the novel word's physical attributes, parts, or associations), phonological cues (e.g., providing the first sound, and segmenting and blending the syllables), or both (Diestelmeier, 2014; Mundrick, 2012; Steele et al., 2013).

Twelve studies presented novel words in varied syntactic frames, to explore how effectively people with DLD use syntactic bootstrapping cues to infer meanings of unfamiliar words (van der Lely, 1994). For instance, if a nonsense word is provided with a visual referent (e.g., an object), it might be inferred from context that the nonsense word is the label (i.e., a noun) representing the object. Similarly, if the novel word is provided in a sentence context, you might use syntactic bootstrapping to infer that the word functions as a common noun (e.g., "I see a gaystul"; Alt, 2011, p. 178) or a verb (e.g., "Here she's biffing"; Carr & Johnston, 2001, p. 605). Seven of these 12 studies taught novel verbs (e.g., Johnson & de Villiers, 2009; Riches et al., 2006), four taught nouns and verbs (e.g., Eyer et al., 2002; Horohov & Oetting, 2004), and one taught only nouns (Rice et al., 2000).

Five studies explored the impact of gestural cues on oral learning in children with and without DLD. Comparisons included: auditory-only input versus auditory-plus-accompanying-gestures (Ellis Weismer & Hesketh, 1993); iconic versus attention-directing gestures (Luke & Ritterfeld, 2014; Vogt & Kauschke, 2017a, 2017b); and augmentative pseudo-signs versus no gesture (van Berkel-van Hoof et al., 2016). These studies aimed to determine how children with DLD may exploit non-verbal gestural information to strengthen the encoding of, and relationship between, phonological and semantic representations (Vogt & Kauschke, 2017a).

Input Variations. Some studies explored how effectively people with DLD learned the phonological forms of novel words when the verbal presentations were manipulated (Horohov & Oetting, 2004). Three studies manipulated the rate of input, presenting the words in sentences spoken at fast (six syllables per second) or slow (two syllables per second) rates (Ellis Weismer & Hesketh, 1993; Ellis Weismer & Hesketh, 1996; Horohov & Oetting, 2004). Another three studies explored the impact of varied prosody, presenting the words in utterances that were either emphatically or neutrally stressed (Ellis Weismer & Hesketh, 1993; Ellis Weismer & Hesketh, 1998), or that contained the presence or absence of a pause before the target word was said (Rice et al., 1992).

Three studies manipulated the number of verbal exposures for each novel word within a training session to determine whether a greater number of exposures yields more accurate establishment of novel word forms (Plante et al., 2011). For instance, Rice et al. (1994) examined word learning accuracy when children were provided with three versus 10 verbal exposures to each novel word, and Plante et al. (2011) compared one versus 10 exposures. Fifteen studies explored frequency effects over a series of sessions. For instance, Kiernan and Gray (1998) and Gray (2003, 2004, 2005) presented a word learning task over four days and examined the number of exposures required to reach criterion. This involved presenting the words in a play-based task interlaced with assessment probes and feedback over the four days. Within the first session, six exposures were provided, and 24 were provided each day from days two to four. This allowed examination of learning rate in children with DLD compared to TD children, and provided insight into the number of exposures required for successful vocabulary instruction for these children (Gray, 2004).

More recently, Storkel et al. (2017b) examined the impact of exposure frequency on children with and without DLD via a book sharing task. Over four days, novel words were presented with incremental exposures (12, 24, 36, and 48) to determine an adequate number of exposures needed effectively learn the novel words (Storkel et al., 2017b). Similarly, Steele and colleagues (2010, 2013, 2015) explored frequency effects on word learning in the written modality, presenting novel words in *low rate* (two presentations in the text) and *high rate* (five presentations) conditions.

Outcome Measures

A range of outcome measures were used to assess word learning. Measures were selected to assess learning in the language domain of interest (e.g., phonology, semantics) and modality (oral and/or written), and probed receptive and/or expressive knowledge.

Oral Outcome Measures: Phonology. Sixty-two studies (89%) used a receptive (comprehension) task to measure how well participants learned to link the phonological form of novel words to a referent. Frequently (39 studies), a visual identification measure was used: if the novel stimuli were nouns, participants were required to identify the target from an array of pictures when they heard the word (Rice et al., 1994; Ricketts et al., 2015); for novel verbs, participants saw a selection of action pictures and pointed to the target (e.g., "Show me X-ing"; Oetting, 1999, p. 1267), or watched two video clips simultaneously and identified where the action was taking place (Shulman & Guberman, 2007). These tasks were scored in an all-or-nothing fashion (e.g., correct/incorrect), and therefore drew on whole-word phonological representations.

Of the 62 studies that used a receptive phonological outcome measure, 23 used a recognition task. Participants heard an array of phonological labels (usually the target label and two or three phonological foils), and judged which were correct or incorrect (e.g., Alt & Gutmann, 2009, Ellis Weismer & Hesketh, 1998). This task type reflects how effectively participants can recognise the correct phonological form of the target words (Alt, 2011).

Thirty-five studies (50%) measured phonological learning using tasks that assessed the expressive link between the referent and what was taught about that referent (e.g., "What is this picture called?" for nouns; Mundrick, 2012, p. 17; and, "What is he doing?" for verbs; Vogt & Kauschke, 2017b, p. 11). Twenty-six of these were scored as correct/incorrect, thus assessing expressive phonological learning at a whole-word level, while the remaining nine were scored using a measure of accuracy, such as percentage of phonemes that were correctly produced (Jackson et al., 2016). Similarly, McGregor et al. (2017a) assessed fine-grained phonological knowledge through a stem-completion task, where participants produced the target word after being given its onset sounds. Additional expressive phonology tasks included a sentence-completion task (e.g., "Little kangaroo has jumped into Mama's…?"; Smeets et al., 2014, p. 439), and free recall (participants recall as many of the 16 novel words as possible in two minutes; McGregor et al., 2013a), both of which were scored at a whole-word level.

Oral Outcome Measures: Semantics. Like phonological learning, semantic learning was assessed receptively or expressively. Six studies measured receptive knowledge, using tasks such as asking "Yes/No" questions about the elements of semantic meaning (e.g., physical attributes or category – "Is a gauntlet a sock?"; Nash & Donaldson, 2005, p. 446). Similarly, Alt and Plante (2006) showed isolated pictures of an attribute (e.g., eyes) and asked whether it was a property of the target object's appearance. Tasks that required participants to reflect on deeper semantic knowledge of words in a receptive way included multiple choice tasks requiring them to judge the correctness of the word's definition (e.g., from an array of four options, select the closest meaning for the target word; Steele & Watkins, 2010).

Fourteen studies assessed the ability to express semantic knowledge of the target items. They employed tasks which varied by either directly or indirectly tapping into the taught semantic information. For example, Gray (2005) used a drawing task to assess recall of physical features (scored from 1 to 7 according to the degree of accuracy and completeness). Horohov and Oetting (2004) asked participants to provide synonyms for the target items ("Tell me a real word that means the same thing as X", p. 51), which required the children to build understanding of the novel word and create links with existing vocabulary. This was scored using in-depth error analysis, looking for how well synonyms matched the target in meaning and syntax (Horohov & Oetting, 2004). Similarly, McGregor et al. (2013a) used a word association task (i.e., the participant said the first word that came to mind after hearing each target), scored according to whether the response was semantically related.

Most studies that measured semantic learning (10) used a definition measure (e.g., "Tell me what X means"; Storkel et al., 2017b, p. 21). These tasks were often scored according to the inclusion of component parts of a definition (Nash & Donaldson, 2005), and in nine studies these were delivered dynamically, with graduated prompting provided depending on the completeness of the oral definition provided (e.g., contextual cues or forced-choice prompts were given if required; Steele, 2015).

Written Outcome Measures. As outlined in the section above on *Modality and Domain of Knowledge*, three studies examined word learning in both the oral and written modalities (e.g., Diestelmeier, 2014). Of these, Diestelmeier (2014) used an oral definition task as the sole outcome measure. While the word learning task involved both oral and written input, the purpose was to explore how well participants could use the written task to develop word meaning, so no orthographic outcome measures were included. McGregor et al. (2017a) used oral measures (e.g., a stem-completion task) and an orthographic task requiring letter identification. Ricketts et al. (2015) used a visual identification task to determine oral learning of the word's phonology, and a spelling task to measure learning of the orthographic representation.

Four studies measured word learning only in the written domain. Wolter and Apel (2010) used a pseudoword generation task, requiring participants to spell all target items to dictation, and a pseudoword identification task (to find the written word from three foils), as a measure of receptive orthographic knowledge. The remaining three (Steele, 2015; Steele & Watkins, 2010; Steele et al., 2013) provided written input and only used oral definition measures. Thus, these tasks were designed to measure how children learned novel words through reading, such as their use of decoding skills, and use of contextual information to build meaning (Steele et al., 2013).

Discussion

The aim of this scoping review was to review the state of knowledge and identify gaps in the literature with regards to word learning evaluations in people with DLD. The results highlighted an impressive variety of tasks; each of the 70 reviewed studies developed a new method, or modified one used previously, to investigate specific aspects of word learning. Despite this variability, the literature was united in its aim: to build understanding of why word learning is a problem for people with DLD. This systematic scoping review summarised the research by discussing several key methodological parameters considered by researchers in developing a word learning task. Here, we discuss further how these methodological decisions are generally driven by the theoretical perspective of the research team regarding potential cause of word learning breakdown in DLD. Understanding these theoretical perspectives allows insight into theory-driven elements of word learning that have been well-investigated, as well as gaps in the knowledge base that may guide future research.

Much of the literature explored word learning in people with DLD from a *performance-based perspective*, which focuses on the cognitive constraints potentially underlying difficulties with how information about new words is processed, stored, and retrieved (Evans, 2001; Kan & Windsor, 2010). Various performance-based accounts have been considered, with some researchers considering generalised processing deficits, and others exploring deficits in specific mechanisms (such as phonological processing; Ellis Weismer & Hesketh, 1998). Other researchers adopted a *linguistic perspective* to frame their methodology, exploring the notion that deficits in the grammatical system may account for difficulties with using syntactic cues in word learning tasks to extract information about new word forms and meanings (van der Lely, 1994).

Some studies designed methods to investigate whether word learning difficulties in DLD may be due to *generalised limitations* in processing capacity (Nation, 2014). Usually, this involved manipulating the conditions of the task (i.e., learning context and/or task characteristics). Studies that presented the novel words in more structured contexts, involving exposures to the novel words in a focused, explicit manner (e.g., Nash & Donaldson, 2005), likely minimised processing demands, allowing the allocation of cognitive resources to the identification, processing, and storage of the phonological and semantic representations for novel words. However, others explored whether presenting novel words in stories with added sound effects and animations had a detrimental impact on learning novel words, potentially due to the diversion of limited cognitive resources to additional linguistic and non-linguistic cues during learning (Smeets et al., 2014).

Attentional abilities were mentioned in the literature as being a potential factor impacting general processing capacity for word learning (e.g., Alt & Spaulding, 2011), yet this was not explicitly explored in any of the included studies. Ebert and Kohnert (2011) found that children with language impairments often exhibit attention deficits; thus, the influence of attention on word learning should be further explored. A generalised capacity perspective would predict that attention would especially impact how people with DLD learn novel words in tasks that require processing and integration of multiple sources of information, or in conditions with numerous potential distractors (Alt, 2013; Alt & Gutmann, 2009).

Many studies explored word learning from a performance-based perspective and focused on whether deficits in the specific mechanisms involved in phonological processing may account for word learning difficulties (e.g., Ellis Weismer & Hesketh, 1996; Horohov & Oetting, 2004). Phonological processing theory is grounded in evidence that people with DLD experience inherent deficits for processing, storing, and retrieving sound-based information. Earlier studies that adopted this view explored factors related to input processing of the stream of speech. For instance, Rice et al. (1990, 1992) manipulated task input variables by embedding the novel word at the end of an utterance, and inserting a pause before and after. Others presented the novel word in connected utterances at either fast or slow rates, or using emphatic versus neutral stress (Ellis Weismer & Hesketh, 1993, 1996, 1998; Horohov & Oetting, 2004). These studies aimed to test the hypothesis that word learning abilities in children with DLD break down when the task demands exceed the child's available resources for processing phonological information (Horohov & Oetting, 2004). While various task factors have been explored, future research may focus on investigating word learning contexts that are linguistically facilitative for people with DLD.

Other studies, also drawing on a phonological processing perspective, explored the impact of manipulating the phonological properties of novel words. Specifically, novel words with high versus low phonotactic probability were used to determine how well people with DLD were able to draw on existing phonological forms in vocabulary to facilitate establishment of new word forms (Alt & Spaulding, 2011; Gray & Brinkley, 2011). Similarly, learning ability for novel words with high versus low neighbourhood density was explored, but only in two studies (Gray et al., 2014; McKean et al., 2014). Gray et al. (2014) argued the importance of considering both aspects when selecting stimuli for word learning tasks, as people with DLD (who tend to have restricted vocabularies) may be disadvantaged when presented with novel words that are phonologically-like those in their language. Thus, future research may investigate the impact of both phonotactic probability and neighbourhood density.

Other studies drew on a performance-based approach but focused on the involvement of memory processes in word learning (Alt, 2011). Specifically, to explore the notion that word learning difficulties may result from deficient encoding and long-term retention of novel word information, researchers explored whether a higher number of encounters would facilitate more accurate establishment of phonological and semantic forms in long-term memory (Riches et al., 2005). This was tested in some studies through manipulating the task characteristic of frequency of exposures (Gray, 2003, 2004, 2005; Kiernan & Gray, 1998; Storkel et al., 2017b). While these studies generally found that more exposures facilitated effective word learning for DLD participants, with the exception of Storkel et al. (2017b), no research explicitly explored an *optimal intensity* required to reach mastery of learning. Further research could explore optimal intensity of word learning instruction for various age groups to inform intervention strategies and instructional approaches.

Other studies grounded their methodologies in a *linguistic perspective*, exploring the notion that deficits in the grammatical system of people with DLD impact their ability to use syntactic bootstrapping abilities to infer crucial information about the form and meaning of novel words (Eyer et al., 2002). Several studies presented novel words in varied syntactic conditions to evaluate how effectively children with DLD tune into the cues provided by syntactic structures (e.g., Johnson & de Villiers, 2009; Steele & Watkins, 2010) or morphological markers (e.g., Carr & Johnston, 2001; Eyer et al., 2002) associated with the novel word. While syntactic bootstrapping was mostly explored in relation to verb learning (Carr & Johnston, 2001; Eyer et al., 2002; O'Hara & Johnston, 1997; Riches et al., 2006), its influence was also investigated in teaching different types of nouns (i.e., count and mass nouns; Rice et al., 2000), and the influence of varied syntactic cues for noun (object names) and verb (action) learning was also compared (Horohov & Oetting, 2004).

A small number of studies also explored the influence of syntactic bootstrapping on learning novel adjectives, adverbs, prepositions, and conjunctions (Oetting et al., 1995; Storkel et al., 2017a; Rice et al., 1990, 1992). However, in comparison to noun and verb investigations, the exploration of how well people with DLD learn these other word types has been limited. Research indicates that this population is likely to especially struggle to learn these types of words given their abstract nature, which results in the subsequent need to rely on sentential context and morphology to derive meaning (Chiat, 2001; Shulman & Guberman, 2007), and so this should be the focus of future research.

Regardless of the theoretical perspective driving the various methodologies, most research included in this review focused on learning novel words in the oral modality. While some studies additionally included orthography as a learning cue for the oral word learning task, only four studies focused exclusively on how people with DLD learned novel words through orthographic input. It would be expected that dual deficits for learning words through the oral and written modalities would emerge for many people with DLD given the evidence that this population may struggle with one or more of the component skills involved in reading (Catts et al., 2005). For instance, weaknesses in phonic knowledge and phonemic awareness skills could impede the ability to decode novel words, and thus establish an orthographic representation (Wolter & Apel, 2010), as could weaknesses in the use of language comprehension skills to infer the meaning of novel words (Steele & Watkins, 2010). Further research into how people with DLD learn novel words through reading is crucial to address this gap in this literature. Learning novel words through reading is an important phenomenon to explore given that "reading is a primary source of vocabulary development in the upper elementary years" (Steele & Watkins, 2010, p. 521).

Finally, a significant gap in the literature arose regarding the investigation of word learning in adolescents and adults with DLD. This may reflect issues with recruitment, such as a lack of dedicated education sites for adolescents and adults with DLD from which to recruit. Additionally, issues with retrospective reporting of developmental impairments may contribute to difficulties recruiting adult participants. For instance, adults may underreport their impairments, or confuse language difficulties with literacy problems (Alt & Gutmann, 2009). Given that adolescents and adults are required to continually learn new vocabulary, especially when entering a new workplace where new jargon is frequently used (Alt & Gutmann, 2009), further research should be conducted on their word learning capabilities in both oral and written domains.

Summary and Future Directions

In this scoping review, a total of 70 studies were examined to explore the current state of knowledge regarding evaluation of word learning in the DLD population, and to identify gaps in the literature. The review identified a paucity of research into word learning in adolescents and adults with DLD and limited investigation into learning novel words via the written modality. Other gaps in the literature include limited exploration of learning word types other than nouns and verbs. It is hoped that the findings of this review provide a foundation from which further research may be developed.

Future research efforts may be directed toward the clinical application of word learning assessments. While the purpose of this scoping review was not to compare word learning performance of people with DLD to those with typical language development, it is apparent that word learning deficits in this population are well-established. Thus, a task that dynamically assesses word learning seems a valuable addition to the assessment battery for speech-language therapists (SLTs). Future research may consider how best to translate the methods used in research contexts to clinical practice, so that SLTs are equipped with the resources to investigate the nature of word learning abilities in their clients with DLD.

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Chapter 4: Listening to Speech-Language Pathologists: An International Survey of Assessment Practices for Vocabulary and Word Learning

Chapter Overview

An additional aim of this doctoral research was to explore the manner in which speech-language pathologists (SLPs) assess vocabulary and word learning in clinical settings. As such, this chapter presents the findings of a survey of clinical assessment practices of SLPs who work in a range of countries (Study 2). While the overarching focus of this doctoral research is children with DLD, it was decided that this survey should more broadly explore the assessment methods that SLPs use when working with clients of any age, and with any population. The reasons for this were two-fold:

1) Requesting that clinicians only complete a questionnaire based on their work with children with DLD would likely yield limited responses. Clinicians may not feel the survey is relevant if they work in a region in which the term *developmental language disorder* is not in use. Alternately, if they have limited experiences working with this disorder, they may feel ill-equipped to reflect on practice;
2) While the evaluation of vocabulary and word learning is important in children with DLD, it is also important to explore assessment methods used with a broader range of client ages and clinical populations. Word learning problems are not limited to children with DLD, making it pertinent that the findings of this study are relevant to practitioners who work with clients with varying diagnoses and communication needs.

In the next section of this chapter, I present the prepared manuscript version of an article entitled, *'Listening to speech-language pathologists: An international survey of assessment practices for vocabulary and word learning'*, under review by the International Journal of Speech-Language Pathology as at 29th January 2021.

Prepared Manuscript (Under Review)

Abstract

Purpose: Past literature highlights the clinical importance of evaluating a person's word learning abilities in order to develop an accurate understanding of their language-learning capacity, and to make well-informed clinical decisions. However, there has been little previous research into the clinical use of word learning assessment practices of speech-language pathologists (SLPs). This international survey of SLPs aimed to build an understanding of clinical assessment practices regarding the domains of vocabulary and word learning.

Method: An online survey was completed by 135 clinicians from 10 countries. Questions explored SLPs' assessment of vocabulary knowledge and word learning skills in clients of all ages.

Results: Of the surveyed SLPs, 131 (97%) reported using norm-referenced measures of vocabulary, 25 of which also reported supplementary use of non-normed measures. Seventy nine SLPs (58.5%) reported that they measure word learning skills, with 20 of those respondents indicating the use of dynamic assessment to evaluate word learning. SLPs reported using vocabulary and word learning assessment data in a variety of ways, including making diagnostic decisions and planning intervention. SLPs were also asked to comment on their views regarding the use of norm-referenced vocabulary assessment methods when working with clients from culturally and linguistically diverse backgrounds. Key concerns were raised regarding lack of cultural sensitivity, and limited access to alternative assessment methods.

Conclusion: The findings highlight the importance of developing and disseminating clinically-accessible resources to support SLPs in their evaluation of word learning skills for clients from a range of backgrounds.

Introduction

Vocabulary knowledge is a crucial building block for language comprehension and expression, and there is a well-established link between vocabulary and reading comprehension, social–emotional development, and professional success (Armstrong et al., 2017; Law et al., 2009; Spencer et al., 2017).

Throughout this paper, we use the term *vocabulary* to refer to the existing store of words in a person's lexicon (i.e., the words that a person already knows). In contrast, the term *word learning* is used to describe the processes that are involved in learning new vocabulary items (Kelley, 2017). Word learning is a multifactorial process (Jackson et al., 2019b). Initially, a new word is encountered, and basic details (such as the word form and elements of word meaning) are mapped, or encoded (McGregor et al., 2020a). Through further exposures to the new word, these initial representations may be gradually refined and consolidated. The new vocabulary item may also integrate with existing vocabulary, and knowledge of how to use the word flexibly across contexts develops (McGregor et al., 2013b). Successful word learning leads to the development of broad vocabulary knowledge, which supports a person's engagement in precise, nuanced communication about a range of topics (Gray et al., 2020). However, a person who experiences difficulties with the active word learning process is likely to develop an "impaired" vocabulary – one that is limited in depth and/or breadth (McGregor et al., 2013b; Messer & Dockrell, 2006).

Speech-language pathologists (SLPs) working in a range of settings, from early intervention clinics to aged care facilities, often assist clients who present with poor vocabulary (American Speech-Language-Hearing Association, 2016; Royal College of Speech and Language Therapists, 2005; Speech Pathology Australia, 2015). Such vocabulary deficits may occur due to various aetiologies, such as having a disorder that affects the acquisition of language (e.g., developmental language disorder; Bishop et al., 2017) or an acquired condition (e.g., aphasia; Chapey, 2008). So that clinicians may provide effective intervention for their clients, it is vital to conduct thorough vocabulary assessments (Speech Pathology Australia, 2015). There are a range of methods SLPs can use to gather evidence about a client's abilities in this domain (Laing & Kamhi, 2003), and these may be used to guide clinical-decision making, such as providing a diagnosis, determining eligibility for services, aiding the selection of therapy goals, and monitoring progress (Caesar & Kohler, 2009). In line with Denman et al. (2019)'s criteria, vocabulary assessments may be described according to four components:

1) The administration procedures are either *standardised* (i.e., follow a strict, pre-determined protocol) or *non-standardised*;

2) The individual's score is interpreted with reference to a normed sample (*norm-referenced*) or to a pre-defined set of criteria (*criterion-referenced*). Alternately, assessments may focus on the collection of *descriptive* data rather than comparison to expected norms or criteria;
3) Assessment may evaluate a *discrete skill* (e.g., vocabulary knowledge tested at a single word level) or *contextualised performance* (such as the use of vocabulary during naturalistic communicative tasks);
4) Assessment methods may be *static* (where vocabulary knowledge is evaluated at a single time point) or *dynamic* (in which methods such as the test-teach-retest procedure are used to determine whether an individual may be able to improve their vocabulary knowledge if guided through the task; Haywood, 2012).

Notably, we consider the dynamic assessment of vocabulary to effectively be an evaluation of *word learning* skills. While a static vocabulary assessment evaluates the client's current, crystallised vocabulary knowledge, dynamic testing instead requires the person to engage in learning processes for new words, or words that are not well-known (Jackson et al., 2019b). The test-teach-retest procedure is a common framework for dynamic assessment, and for the evaluation of word learning this would involve: 1) testing the client's knowledge of a set of new or unfamiliar words; 2) teaching those new words using a variety of strategies; and 3) re-testing knowledge on targeted words to determine what has been learned, potentially using scaffolds such as graduated prompting (Lidz, 1991). Such dynamic assessment of word learning has the potential to provide clinicians with more detailed knowledge about an individual's lexical abilities than a static vocabulary assessment. For instance, the clinician may gather information regarding aspects of the learning process that were difficult, the types of learning strategies that proved effective, and modifiability in the client's word learning abilities (Hasson, 2017).

Dynamic assessment has long been advocated as an important adjunct to norm-referenced language assessments in order to aid clinical decision-making (Haywood, 2012); however, static and norm-referenced vocabulary assessments tend to be the primary assessment tool used by SLPs to determine the presence of impaired language across populations (Caesar & Kohler, 2009; Eickhoff et al., 2010, June). Norm-referenced, static measures of vocabulary have been criticised for their suitability, particularly with regards to working with clients from culturally and linguistically diverse (CALD) backgrounds (Pena et al., 2001). Issues arise when considering that these assessments are usually normed on a broad sample of middle-class, monolingual people, and that standardised testing procedures are a cultural phenomenon that may be inherently biased against children raised in environments that do not expose them to decontextualised situations, similar to those of testing (Burton & Wakins, 2007; Laing & Kamhi, 2003). This problem is magnified when we consider that vocabulary knowledge is so closely linked to cultural and linguistic experiences (Camilleri & Botting, 2013).

To overcome these issues, a growing body of literature has explored the use of dynamic assessment as a less-biased method for assessing children from CALD backgrounds, and the results suggest that these measures may be reliable and sensitive tools for planning intervention and for differentiating between language disorder and language difference (Camilleri & Law, 2014; Gutierrez-Clellen & Pena, 2001; Laing & Kamhi, 2003). For instance, Pena et al. (2001) and Kapantzoglou et al. (2012) trialled novel procedures for the dynamic assessment of word learning and found that in CALD children, dynamic measures (such as pre to post-test change scores and modifiability measures) were more accurate than static measures at differentiating children with typical language and a language disorder. Similarly, Camilleri and colleagues (2007, 2013, 2014) found that dynamic assessment of word learning enhanced the predictive capability of static measures for identifying language disorder. These measures captured additional information about each individual's learning processes, including "the types of cues that facilitate the child's identification of a vocabulary item, whether generalisation to other examples is occurring and whether the child has any insight into their own vocabulary learning strategies" (Camilleri & Botting, 2013, p. 578).

In addition to these studies exploring word learning dynamic assessment in children from CALD backgrounds, the evaluation of word learning is a growing area of interest in the research literature more broadly, and has been investigated across varied populations, including adults with aphasia (Tuomiranta et al., 2014) and those with developmental language disorder (McGregor et al., 2020a). These studies highlight the clinical utility of using word learning tasks as a way of gaining detailed insight into how individuals develop new vocabulary. Despite the varied use of word learning evaluations in the literature, and the well-established argument for supplementing norm-referenced assessments with dynamic assessment, our impression is that clinically, these practices are not being widely used. A number of previous surveys have been conducted regarding the broad assessment practices of SLPs (Arias & Friberg, 2015; Caesar & Kohler, 2009; Fulcher-Rood et al., 2018), and the findings suggest that norm-referenced assessments of oral language are most regularly applied in clinical settings. Non-normed measures of oral language are also used, with various results emerging from different surveys (e.g., Caesar & Kohler, 2009 found that in school settings, SLPs more frequently use informal measures, such as language sampling and informal observations when assessing oral language). To the best of our knowledge, however, no previous studies have specifically investigated SLPs' assessment practices for vocabulary and word learning.

As such, the broad aims of the current research were to identify and describe current clinical practices for the assessment of vocabulary and word learning skills, and to explore SLPs' viewpoints on vocabulary assessment practices for clients from CALD backgrounds. The intended outcomes of the research were to inform future research and the development of clinical resources, such as clinically-applicable and culturally-appropriate assessment tools that may assist SLPs in their clinical decision-making. The specific aims were to:

1) Describe how SLPs assess vocabulary and use these assessment data to make clinical decisions;
2) Explore how SLPs assess word learning, including: the types of tasks used by clinicians, how they learned these methods, and how these assessment data are used to make clinical decisions;
3) Explore SLPs' beliefs around using norm-referenced vocabulary assessments for clients from CALD backgrounds.

Method

Participants

The target population for the survey included SLPs who could respond to a survey written in English, and who lived in any country. SLPs working with clients at any age were invited to participate, so long as they currently assessed vocabulary and/or word learning with their clients. Distribution materials are provided in Appendix D.1.

The Survey

A comprehensive survey was developed to gather information from SLPs about their clinical methods for evaluating vocabulary and word learning skills. Survey questions were informed by empirical literature and available clinical guidelines regarding assessment practices in speech pathology (American Speech-Language-Hearing Association, 2016; Royal College of Speech and Language Therapists, 2005; Speech Pathology Australia, 2015). Web-based survey host *Qualtrics* (2005) was used to develop and disseminate the survey. An online method was used as it allows for the recruitment of numerous respondents worldwide (Wright, 2005). The survey comprised 13 questions: six related to demographic information, including service delivery, area of practice, age range of clients, and languages used in practice; three questions asked about vocabulary assessment practices; and three questions asked about word learning assessment. An additional question asked SLPs about the use of norm-referenced assessments for clients from CALD backgrounds. Question formats included yes/no, multiple choice, and open-ended responses. The survey is provided in Appendix D.2.

Procedure

This project was approved by the Curtin University Human Research Ethics Committee. A pilot version of the survey was trialled by five SLPs who worked in varied settings. They provided comments on overall structure and clarity of the questions, resulting in minor amendments. The final version was distributed via purposive and snowball sampling. The survey was anonymous and respondents were asked not to provide any identifying information. Potential respondents were invited to participate using several strategies. Special interest groups related to language (e.g., the Australian-based *Language and Literacy Community of Practice*) were contacted and asked to distribute information about the study to their members. Additionally, the authors posted information about the study to social media sites (Twitter and SLP-related Facebook groups) and distributed information to colleagues at the 2019 Speech Pathology Australia National Conference. Responses via Social Media accounted for 66% of respondents, and 33% were completed via anonymous email link. A reminder was sent four weeks after the initial contact. To maximise recruitment, the survey was open for two periods: April to July 2019, and September to November 2019. Eighty-nine respondents completed the survey in the first period, and 77 in the second.

Data Analysis

Responses from *Qualtrics* were downloaded into IBM SPSS Statistics version 26. The results were analysed predominantly using descriptive statistics (i.e., frequencies and proportions of responses). Content analysis procedures were applied to analyse responses to open-ended questions, which involved coding written responses into descriptive categories (Watts Pappas et al., 2008). This involved grouping responses into categories, most of which had been pre-determined through review of existing literature, and some of which were developed as they emerged from the data.

Results

Responses

A total of 166 SLPs began the survey. Thirty-one (19%) completed only the demographic information. As they did not provide further information, their data were not included in the analyses. Therefore, a total of 135 responses were analysed. It was not possible to calculate a response rate given that the exact number of SLPs worldwide could not be ascertained (e.g., in some countries, Australia included, registration in the profession is non-mandatory). However, demographic information provided suggests that participants were broadly representative of a range of English-speaking countries (see Table 4.1). It was not within the scope of this study to survey student SLPs.

Participant Demographics

Many SLPs had more than 10 years of clinical experience. The most common clinical settings were education, private practice, and early intervention. Most SLPs reported working with paediatric clients, with a small portion (16%) working with adults. Most respondents reported using only English when communicating with clients.

Table 4.1

Demographic Information of Respondents

Question	Responses	*n* of responses (*N* = 135)	% of responses
Country of residence	Australia	83	61
	United States of America	27	20
	United Kingdom	17	13
	Singapore	2	1
	Sweden	2	1
	Canada	1	<1
	New Zealand	1	<1
	The Netherlands	1	<1
	Vanuatu	1	<1
Years of experience	<1	0	0
	1 – 4	39	29
	6 – 10	34	25
	> 10	62	46
Language spoken with clients	English only	120	89
	English & additional language	13	10
	Swedish only	1	<1
	Dutch only	1	<1
Clinical setting[a]	Education	71	53
	Private practice	38	28
	Early intervention	22	16
	Community health	11	8
	Disability	11	8
	Hospital	9	7
	University	7	5
	Aged care	2	1
	Other	4	3
Main area/s of practice[a]	Speech	125	93
	Fluency	69	51
	Voice & resonance	29	21
	Language (receptive & expressive)	129	96
	Pragmatics & social skills	109	81
	Cognitive communication	31	23
	Problem solving/higher level language	58	43
	Literacy	95	70
	Sensory awareness	13	10

Table 4.1 continued.

Question	Responses	*n* of responses (*N* = 135)	% of responses
	Eating, drinking & swallowing	20	15
	AAC	64	47
Age of clients[a]	0 – 2 years	57	42
	3 – 5 years	110	81
	6 – 10 years	115	85
	Adolescents	90	67
	Adults	22	16

Note. "United Kingdom" included participants from England (*n* = 11), Northern Ireland (*n* = 3), and Scotland (*n* = 2). Additional languages spoken alongside English included American Sign Language (*n* = 6), Mandarin (*n* = 4), Auslan (*n* = 4), Russian (*n* = 1), German (*n* = 1), Bislama (*n* = 1), and Kriole (*n* = 1). "Other" responses regarding *Clinical Setting* were listed as "consultation" services. AAC = alternative and augmentative communication.

[a]For these questions, respondents were allowed to select more than one option in their response.

Assessment of Vocabulary

One hundred and thirty-five clinicians completed this section of the survey. Ninety-seven percent (*n* = 131) reported assessing vocabulary in clinical practice. Nearly all of these SLPs (*n* = 127, 97%) reported using at least one norm-referenced, standardised assessment tool, while four respondents (3%) reported *only* using a non-normed, non-standardised measure (i.e., "informal tasks", with no further details provided by participants). The most common norm-referenced assessments included vocabulary-specific subtests from the Clinical Evaluation of Language Fundamentals (CELF), 5th edition (Word Classes: *n* = 86; Word Definitions: *n* = 73; Wiig et al., 2017), CELF-4 (Expressive Vocabulary: *n* = 38; Word Classes: *n* = 36; Word Definitions: *n* =32; Semel et al., 2006b), and CELF Preschool 2nd edition (Expressive Vocabulary: *n* = 73; Semel et al., 2006a), as well as the Peabody Picture Vocabulary Test (*n* = 39; Dunn & Dunn, 2007) and the MacArthur Bates Communicative Development Inventories (*n* = 31, including the OZI version; Fenson et al., 2007). There were 25 SLPs (19%) who reported *additionally* using assessment tools that were non-normed to supplement the data from norm-referenced measures. These included language sample analysis (*n* = 12), aided by software such as Systematic

Analysis of Language Transcripts (Miller & Iglesias, 2012) and the use of criterion-referenced assessment measures such as type token ratio (Templin, 1957). Some SLPs also described their use of "informal" tasks, which involved descriptive measures of contextualised performance (e.g., "shared reading experiences", "play-based interactions", and "checklists with parent interview"). Responses to this question revealed the availability and use of a vast range of vocabulary assessments worldwide, some of which were developed to suit specific regions (e.g., the Singapore English Action Picture Test; Brebner, 2002).

SLPs were asked to identify what they do with the data obtained from these vocabulary assessments (and were able to select more than one response): make diagnostic decisions (n = 97, 41%), determine eligibility for intervention (n = 58, 44%), plan intervention (n = 110, 84%), monitor progress (n = 80, 61%), or other (n = 4, 3%). SLPs were asked to elaborate via an open-ended question regarding how they use data from vocabulary assessments (n = 71). Three main themes were identified from content analysis of these responses.

a) Diagnostic decision-making and communicating results

Several SLPs described their use of vocabulary assessment data to aid in diagnostic decision-making. Specifically, normative scores were described as "necessary" for the processes of diagnosis, and for reporting to parents and teachers. For example, "… [I] use formal assessments for formal reports and annual review of progress", and "… use scores on standardised assessments at initial diagnosis". Among the responses was the idea that norm-referenced data were "used to determine eligibility for disability support" (this response was typical from US SLPs), and for "supporting National Disability Insurance Scheme [NDIS] applications" (typical among Australian SLPs).

b) Using vocabulary assessment data to identify intervention targets

SLPs commented that they use vocabulary data to determine intervention targets according to three key aspects: 1) whether vocabulary is an area of weakness that warrants intervention; 2) identifying the types of words that need to be targeted in therapy, such as specific word classes (e.g., nouns, adjectives, verbs), language to support social communication, words relevant to the school curriculum, or words that will support reading comprehension; and, 3) whether there are specific aspects of semantic knowledge that should be targeted (e.g., attributes, categorisation).

c) Norm-referenced data are insufficient for therapy planning

While SLPs often described their use of norm-referenced assessments to plan intervention, many others voiced concerns that these assessments do not provide sufficient information to set goals and determine intervention targets. Specifically, many SLPs identified that they are required to supplement these data with a range of additional information when making clinical decisions regarding vocabulary assessment and intervention planning. The following responses from SLPs reflected this issue: "Above list of tools [norm-referenced tests] inadequate other than for identifying potential gaps in vocabulary; need to be supplemented"; "I don't really consider any of these [norm-referenced assessments] help that much with intervention planning although they do give some insight into how vocab is processed"; "I prefer to work on vocabulary that is functional for my students, rather than what tends to be assessed on standardized assessments".

Assessment of Word Learning

One hundred and twenty-eight SLPs completed this section of the survey, 79 of which (62%) reported the use of word learning evaluation with clients. To our knowledge, there are few published or manualised word learning assessments. Therefore, SLPs responded to an open-ended question asking them to detail the task(s) they used to evaluate this skill. No respondents reported using a standardised, norm-referenced form of assessment for word learning. Of the 79 SLPs who reported assessing word learning, eight (10%) referred by name to a specific task or resource that they use for assessment purposes: Dale's (1965) scale of vocabulary knowledge (n = 1), Starling's LINK-S (n = 1; Starling et al., 2012), Rice's Quick Incidental Learning task (n = 1; Rice et al., 1992), Personal Objects Representation Independence Consolidation (n = 1; Woods et al., 2010), and Word Aware screening (n = 4; Parsons & Branagan, 2017). In contrast, 49 respondents (62%) did not specify their use of a particular resource or procedure, and instead reported using "informal" or "functional" tasks to assess word learning (i.e., descriptive measures of contextualised performance; Denman et al., 2019). These SLPs described their use of observations to collect information about word learning, such as whether a client could learn new words throughout a book sharing session. Others reported their use of informal questioning, such as "asking [the] pupil what they know about taught words and can they use the word in a sentence".

A further 20 respondents (25%) specified their use of dynamic assessment to measure word learning. Two of these SLPs reported using a specific resource: the Dynamic Assessment of Word Learning (Camilleri & Botting, 2013). No other responses included mention of a specific resource or dynamic assessment task. Some responses included descriptions around the use of the *test-teach-retest* method (Haywood, 2012). Other SLPs did not explicitly refer to specific dynamic assessment processes (such as test-teach-retest, or graduated prompting), but provided details about their individual methods for teaching and evaluating learning. For example: "[I] teach new words and then evaluate learning through multiple choice, pictures of things that do and do not depict the word", and, "Provide child with the word, use the word in context several times, move onto other things, then return to the context to see if the child attempts the new word within this context, then see if child carries word over to similar/new appropriate context(s)". Finally, two SLPs (3%) stated that they use nonword repetition tasks to gain a sense of a client's word learning ability, and that these are "particularly useful for our high NESB [non-English speaking background] population."

The 79 respondents who stated that they evaluate word learning also reported where they learned about the method(s), and were able to select more than one response. Most commonly, SLPs learned to evaluate word learning while attending a professional development course (n = 47), learning from colleagues (n = 40), and reading research articles (n = 37). Some SLPs reported learning these methods for word learning assessment through reading clinical articles (n = 16) or through training provided within their SLP university course (n = 13). The clinicians were asked to outline what they do with data collected from word learning evaluations (and were able to select more than one response): make diagnostic decisions (n = 35), determine eligibility for intervention (n = 15), plan intervention (n = 51), monitor progress (n = 45), or other (n = 1). SLPs were asked to elaborate via an open-ended question regarding how they use word learning assessment data (n = 47), and three main themes were identified:

a) Setting targets for vocabulary intervention

Seven SLPs (9%) made statements related to the use of word learning assessment data to support their intervention planning; specifically, they use the data to identify the types of words that should be prioritised in therapy. For example, “I look at the types of words that the child struggles to understand or use and then plan therapy activities around those types of words”; “I use the information to determine if there are any types of words that are more easily retained than others”; and, “relative strengths and weaknesses with aspects of word knowledge.”

a. Identifying effective strategies to aid learning

Eight SLPs (10%) described their use of data to guide the selection of specific strategies and cues in intervention that may be most beneficial for individual clients. For example, “… how much and what kind of support they are likely to need during intervention sessions (i.e., multiple repetitions, lots of visual resources to reduce working memory demands and free up processing capacity, etc.)”; “if I know a child has poor word learning capacity, I create and use visual supports as much as possible in therapy”; “Informally test-teach-retest unfamiliar words, and check which prompts they respond well to”; and, “judge length of syllables and how this affects production, familiar vs less familiar/unknown words; how many practices required to learn new vocabulary”.

b. Informing diagnosis and eligibility for services

Ten respondents (13%) spoke of using word learning data to support their diagnostic decisions and supplement the data collected from standardised assessments. For example, “Monitor progress and report on outcomes (e.g., for NDIS)”; “To add to dynamic assessment of CALD clients to better differentiate difference from delay”; and, “Children who need further work on this will get an extra focused vocabulary learning each week in small groups”.

Reflections on Assessment with CALD Populations

Sixty-four SLPs (47%) responded to the open-ended question regarding their thoughts on the use of norm-referenced vocabulary assessments for purposes such as diagnosis, intervention planning, and measuring change with clients from CALD backgrounds. There were a range of responses, with three key ideas identified through content analysis:

a) *Concern around lack of cultural sensitivity and suitability*

In 52 of the responses (81%), SLPs made statements about their belief that norm-referenced assessments were "inappropriate" for clients on their current caseloads who were from CALD backgrounds. Key concerns were raised regarding the picture stimuli (e.g., "picture stimuli not applicable for contexts and cultures", "some pictures are culturally insensitive"; "I have found them to be quite inappropriate in some situations… for example, with Aboriginal children"). Another concern related to the fact that data from these assessments may not support intervention planning for individuals from "non-mainstream" backgrounds (e.g., "results on standardised assessment do not necessarily reflect a child's vocab development as the selection of vocabulary may not reflect what sort of language they have worked on").

b) *Lack of alternatives*

In 14 responses (22%), SLPs noted that they feel required to administer norm-referenced assessments with CALD clients due to a lack of available alternatives. The following responses summarised these concerns: "I am not aware of a culturally appropriate assessment. Basically I don't have a norm-referenced test for children who identify as Aboriginal or Torres Strait Islander", and "I can't use the scores anyway when the student's native language is not English, but it would be nice to have more culturally-relevant vocabulary tests. I'm not sure how that would be possible, though – vocabulary is always culturally-biased."

c) *Use caution when interpreting results*

Some SLPs (*n* = 13, 20%) also spoke about their need to administer norm-referenced assessments, despite knowing they may not be suitable for clients from CALD backgrounds, and highlighted their need to use caution when interpreting results and reporting to key stakeholders. These responses were typical: "we need to use clinical judgement to navigate", and "[norm-referenced assessments] are needed for formal reporting but are usually reported with a disclaimer". Others outlined the importance of making clinical decisions based on multiple pieces of assessment data;

for example: "use standardised assessment and supplementation with other assessments including observation and parent report."

Discussion

An international survey of SLPs was undertaken to explore and describe assessment practices for vocabulary and word learning. Overall, the findings highlighted that, in comparison to vocabulary, SLPs evaluate the word learning skills of clients less frequently. Furthermore, there were concerns raised with the suitability of using norm-referenced vocabulary assessments with clients from CALD backgrounds. In this discussion, the results are summarised and compared to the existing literature. Limitations of the study are acknowledged, and possible future directions for research are presented.

Current Practices for Assessing Vocabulary and Word Learning

While a number of previous surveys into the assessment practices of SLPs have been conducted, these relate to the assessment of broad oral language skills (i.e., across a range of domains, such as in Betz et al., 2013; Caesar & Kohler, 2009; Fulcher-Rood et al., 2018). Most surveys have concerned the assessment of children, with some focusing on practices for assessing CALD children (e.g., Arias & Friberg, 2015; Guiberson & Atkins, 2012; Williams & McLeod, 2012) and those with specific developmental conditions (such as autism spectrum disorder; Gillon et al., 2017). The current survey extended this previous research by including clinicians working with any age clients (i.e., including adolescents and adults) to gather knowledge about broad assessment practices. Additionally, we explored practices specific to vocabulary and word learning, rather than broad oral language skills, with the aim of gathering information that would guide further research and the development of resources specific to this area of language.

Nearly all of the surveyed SLPs reported using at least one norm-referenced assessment of vocabulary knowledge. The responses suggested that these SLPs have access to a range of norm-referenced assessment resources, and that data from these tests are used when making a range of clinical decisions (e.g., making diagnoses, determining eligibility for services, and planning intervention). These findings align with previous research into assessment practices of SLPs, and reflect the notion that using standardised, norm-referenced measures is a well-ingrained practice in the profession (Betz et al., 2013; Records & Tomblin, 1994). While most of this previous research has concerned assessment practices of paediatric clients (e.g., when assessing children with suspected language disorder), we found that this pattern of practice extends to SLPs working with adolescents and adults. This highlights the value placed by clinicians on evaluating vocabulary skills with clients across the lifespan.

In addition to using a norm-referenced measure, we found that a relatively small number of SLPs (19%) additionally use an *alternative* (e.g., non-normed) tool, such as language sampling analysis, to gather data on vocabulary knowledge. This is a smaller portion in comparison to previous findings, such as Kemp and Klee (1997) who found that 85% of SLPs used language samples when assessing (broad) oral language skills in children. Perhaps when it comes to the specific assessment of vocabulary, SLPs feel that they gain sufficient information from standardised, norm-referenced assessments. However, our findings do echo those of Fulcher-Rood et al. (2018) who found that while SLPs sometimes used informal measures, they regarded these as less important than standardised, norm-referenced tests in diagnostic decision-making.

In contrast to the assessment of vocabulary, few SLPs reported assessing the word learning skills of clients, although the results indicate that when word learning assessments are conducted, the data are used for similar purposes as vocabulary data. There are a number of word learning procedures (some of which followed a specific dynamic assessment method) that have been developed and used for research purposes. There are also a small number of resources that have been manualised and made clinically available. We found that very few SLPs used these sorts of resources to aid their word learning evaluations. Notably, our analysis of open-ended responses revealed that clinicians rarely access and utilise any previously-developed assessment resource. Additionally, while some responses included reference to particular dynamic assessment procedures, such as *test-teach-retest*, responses generally indicated a lack of specificity in procedures for the collection and interpretation of dynamic assessment data.

What we glean from analysis of the SLPs' responses is that a primary barrier to assessing word learning in clinical practice relates to a lack of accessible resources and clear guidance (i.e., a standardised protocol) on how to administer and interpret the results of these assessments. Thus, while there is a range of research literature that outlines procedures for word learning and dynamic assessment (e.g., Camilleri & Botting, 2013; Kelley, 2017; Pena et al., 2001), it seems that this information is not being effectively translated to clinical practice. Some potential reasons for this might be: that research papers may be inaccessible for many clinicians; that the tasks are designed for research purposes, and so are inherently complex and/or require access to specific materials in order to replicate the procedures; the procedures have only been trialled with specific populations and may not be clinically-applicable for other clients in practice. As such, we have collated a list of resources (presented in Appendix D.3) that readers may refer to as a general guide for conducting word learning evaluations in clinical practice. Resources have been drawn from responses to the current survey, and from the broader research literature and knowledge of available clinical resources.

Another potential barrier is limited access to training opportunities. This was reflected in SLPs' responses, with only a small number of clinicians reporting that they had learned to use methods for assessing word learning (using procedures such as dynamic assessment) at university. Instead, most learned these methods through professional development courses, learning from colleagues, and independent reading of research articles. A final barrier relates to institutional policies and time constraints. In their responses, SLPs highlighted the requirement to prioritise norm-referenced, standardised assessments, for the purposes of fulfilling agency requirements regarding the collection of this assessment data for diagnosis and determining eligibility for services (Fulcher-Rood et al., 2018). It is likely that administering additional assessment tasks, such as for word learning, may not be feasible to administer within allocated assessment timeframes (Caesar & Kohler, 2009).

The final component of this survey was to explore SLPs' beliefs around assessment practices for clients from CALD backgrounds. The results highlighted concerns among clinicians regarding the suitability of using norm-referenced assessments, primarily due to issues with the materials (e.g., picture stimuli), the decontextualised nature of the tasks, and issues with comparing individuals from CALD backgrounds to norms based on non-diverse populations (Burton & Wakins, 2007). These are concerns that have long been echoed in the literature, forming the basis for the body of research that has explored the use of dynamic assessment for people from CALD backgrounds (Guiberson & Atkins, 2012; Gutierrez-Clellen & Pena, 2001; Hasson et al., 2012; Kapantzoglou et al., 2012). While this literature exists, SLPs' responses indicate a lack of use of these methods, with concerns raised around the requirement to use norm-referenced assessments, given the lack of suitable alternatives.

These findings have implications for future research and clinical practice. Clinical implementation of the most recent, best-practice evidence is crucial for adhering to evidence-based practice, as is conducting thorough, unbiased assessments that incorporate a range of tools within an assessment battery (American Speech-Language-Hearing Association, 2016). While non-standardised, dynamic procedures for evaluating word learning have been explored with varying populations (e.g., Jackson et al., 2019b; McGregor et al., 2020a; Tuomiranta et al., 2014), the survey results suggest that these types of tasks are not being regularly used by SLPs. It is important that this gap between research and practice is bridged so that a broader range of clinicians feel equipped to use these types of alternative assessment methods with clients, including those from CALD backgrounds. Importantly, resources for use with adult clients are crucially needed as the use of these methods have been "almost exclusively" described in the SLP literature in relation to assessment with children (Caesar & Kohler, 2009; Camilleri & Law, 2014). These procedures are critical in the process of identifying strengths and weaknesses, making diagnoses, and planning intervention (Laing & Kamhi, 2003). An aspirational goal is for the development of an assessment protocol that could be used flexibly by clinicians to support their dynamic evaluation of word learning skills. Ideally, this could be adapted for use with clients of different ages, levels of language, background, and areas of need. To ensure the protocol may be used accurately and confidently, it must include clear guidelines for administrating, scoring, and interpretation of data (Denman et al., 2019). In addition to procedures for using the test-teach-retest process, clinicians would also likely benefit from guidelines on how to: interpret pre- to post-test change data; use graduated prompting to identify cues that are effective for improving task performance; and, how to gather data on individuals' use of learning strategies (Hasson et al., 2012).

Finally, further research should also explore the use of processing-dependent measures, such as measures of verbal working memory, as these may be of great predictive value for identifying clients at risk of ongoing problems with vocabulary development (Laing & Kamhi, 2003). Notably, only two respondents in this survey reported using a processing task to evaluate vocabulary (i.e., nonword repetition tasks). Clinically, these tasks hold promise as being non-biased, quick to administer measures of a client's word learning capabilities; however, this requires further exploration and with different populations (Laing & Kamhi, 2003).

Limitations

Although the findings from this survey provide useful information regarding the assessment practices of SLPs, generalisability of these findings may be limited given the relatively small sample size, and the fact that the data were only collected in English. Furthermore, detailed information regarding the cultural and linguistic background of clients on the SLPs' caseloads was not ascertained, making it difficult to gather a comprehensive picture of their clinical context. Future surveys could be conducted on a wider scale and be available in other languages to develop a broader understanding of international SLP practices. Further, there was a potential non-response bias, with participants opting out of the survey if they felt vocabulary and word learning were out of their scope of regular practice, or if they did not feel confident to provide responses about assessment of these domains. This study also obtained limited information regarding the barriers and facilitators involved in the use of word learning assessment tasks, which would have further informed understands of why such alternative assessment methods appear to be under-used in clinical practice (Caesar & Kohler, 2009).

Conclusion

Speech-language pathologists around the world use a range of measures to assess vocabulary, with norm-referenced, standardised measures continuing to be the most widely used methods for evaluating a client's lexical abilities (Beck, 1996; Caesar & Kohler, 2009). The dynamic process of word learning is measured less frequently, and there appears to be few clinically-accessible resources for clinicians to support their evaluation of word learning with clients. These results highlight the need for the development of clinically-accessible dynamic assessments of word learning that can be easily implemented by clinicians for a range of clients. SLPs also need access to information about this area of language development, such as information about how to interpret performance on word learning tasks and how to use these data to support clinical decision-making. Incorporating these types of measures into an assessment battery would likely alleviate some of the concerns voiced by many SLPs regarding their use of norm-referenced vocabulary assessments with clients from CALD backgrounds, and provide them with integral information required for decision-making processes. This includes whether a client presents with a language disorder or difference, what intervention targets to set, the types of learning strategies suited to the individual, and whether the client is responding as expected to intervention (Hasson et al., 2012).

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General Conclusions from Part Two and Implications for the Thesis

The scoping review (Study 1) identified a range of empirical studies that drew on a wide variety of methodologies to evaluate word learning in people with DLD. A number of areas requiring further investigation were highlighted, with the intention of guiding the direction of this doctoral research, as well as other researchers in the field more generally. Such gaps included a paucity of research investigating word learning for adolescents and adults, and learning novel words in the written modality. While investigation into these avenues is important, the overall aim of this doctoral research remained as the exploration of the nature of (oral) word learning in children with DLD. In this regard, it was noted that many previous investigations into word learning in children with DLD did not comprehensively evaluate word learning. That is, few studies explored how well these children learned multiple aspects of knowledge (e.g., phonological and semantic representations) over time (e.g., a series of days), using a range of outcome measures to comprehensively capture learning abilities. Furthermore, while the scoping review showed that some studies explored the possible contributions of processing weaknesses (e.g., in phonological processing or linguistic capabilities), few explored cognitive mechanisms – namely, memory skills – underpinning word learning in children with DLD. As such, this was highlighted as a priority for this programme of research. To support this exploration, a novel word learning assessment protocol was developed and used to assess word learning in children with and without DLD in Study 5. Furthermore, memory skills, and their relation to word learning in these children, were explored in depth in Studies 4 and 5.

An additional query arising from the scoping review related to the evaluation of word learning in clinical practice. While these assessments feature in various iterations across a body of research, it was not known how these practices were being applied in clinic by SLPs. This was subsequently explored in the clinician survey (Study 2). The findings indicated that while norm-referenced, standardised assessments of vocabulary are frequently used in clinical practice, SLPs less frequently evaluate word learning with their clients. The results highlight a lack of translation of research to practice, with research-based word learning evaluation methods being used by only a handful of SLPs in clinic. The implications of this finding are described further in the General Discussion of this thesis (Chapter 8).

PART THREE: Investigating Memory and Word Learning

The objective of Part Three of this thesis was to develop a comprehensive understanding of the nature of memory and word learning in children with DLD. The first study presented in this section (Study 3; Chapter 5) involved a re-analysis of data that I collected in a previous programme of research. These findings helped to further develop the specific aims for a more comprehensive investigation into memory and word learning. Subsequently, a large cohort of children with and without DLD were recruited, and their data contributed to Study 4 (an investigation of working, procedural, and declarative memory) and Study 5 (an investigation of word learning and verbal working memory). This cohort of children were administered a comprehensive battery of testing for hearing, speech, oral language, nonverbal cognition, and memory. The novel word learning protocol developed for this PhD research (in response to the scoping review study) was also administered. Studies 4 and 5 are presented in Chapters 6 and 7, respectively.

Chapter 5: Fast Mapping Short and Long Words: Examining the Influence of Phonological Short-Term Memory and Receptive Vocabulary in Children with Developmental Language Disorder

Chapter Overview

This chapter presents Study 3 of this programme of doctoral research, in which the relationship between fast mapping and verbal short-term memory was investigated in children with DLD and their age-matched typically developing peers. The data analysed for this study were collected as part of a previous, recent research project. Some of these data were reported in Jackson et al. (2016), and some were re-analysed in Study 3 in order to add to background understanding regarding the relationship between word learning and memory in children with DLD, and provide guidance for further investigation into these mechanisms.

In this study, the term *fast mapping* is used, as mapping theory was the prominent model of word learning at the time of the study's conceptualisation. In a later paper (Study 5), however, I refer to the initial stage of the word learning process as *encoding.* It should also be noted that at the request of the journal reviewers, the term *phonological short-term memory* (rather than *verbal short-term memory*) is used; however, these terms are interchangeable, both referring to the construct of phonological loop capacity in relation to Baddeley's model of working memory (Baddeley et al., 1998).

Participants were recruited for this study prior to the terminological shift from *specific language impairment* to *developmental language disorder* in 2016. As such, the participants with impaired language were selected for this study on the basis of meeting criteria for SLI (i.e., low language in the presence of normal development in other areas, including nonverbal cognitive skills). During the peer-review process for this paper, the reviewers recommended that the term *developmental language disorder* be applied to describe this group of children, as part of the effort toward the consistent use of terminology when describing children who have poor language of neurodevelopmental origins. It should be noted that the "DLD" group were significantly different to the typically developing group for oral language skills, but not for nonverbal cognitive skills. The implications of the use of these criteria are discussed further in the General Discussion (Chapter 8).

The next section of this chapter presents the accepted manuscript version of an article entitled, '*Fast mapping short and long words: Examining the influence of phonological short-term memory and receptive vocabulary in children with developmental language disorder'*, published on 9th February 2019 by Elsevier Linguistics in the Journal of Communication Disorders. This article is available online:

https://www.sciencedirect.com/science/article/pii/S0021992417302678?via%3Dihub

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Abstract

Purpose: To investigate factors that influence word learning in children with developmental language disorder (DLD).

Method: The participants were 23 children with DLD and 26 typically developing (TD) children, aged five. Participants completed a fast mapping task (assessed using a production measure), as well as tests of nonword repetition and receptive vocabulary. We explored the effect of word length on nonword repetition and fast mapping abilities while controlling for receptive vocabulary skills.

Results: The results indicate that children with DLD demonstrate significant difficulties accurately repeating nonwords of all lengths relative to their TD peers. Children with DLD also exhibited significant difficulties with fast mapping, especially when learning longer novel words.

Conclusions: Our findings indicate that children with DLD demonstrate an impaired capacity to encode phonological information; however, this differentially impacts their nonword repetition and fast mapping abilities. TD children may more effectively take advantage of receptive vocabulary to support performance on these tasks.

Learning outcomes: Readers will understand how phonological short-term memory and receptive vocabulary contribute to fast mapping in children with DLD and in TD children.

Introduction

Developmental Language Disorder

Developmental language disorder (DLD) – formerly known as specific language impairment – affects around 3-7% of the school-aged population and is characterised by an impaired ability to acquire language in the absence of any other areas of significant impairment (Bishop et al., 2017). DLD may manifest as impairment in the ability to comprehend and/or produce language across one or more of the following domains: morphosyntax (i.e., grammar), phonology, semantics, and pragmatics; however, children with DLD represent a heterogeneous population, with the profile of language deficits varying widely (Leonard, 2014). We were particularly interested in word learning impairments in this population, generally thought to occur as a result of deficiencies in the storage, specification, and/or use of the phonology and semantics of words (Alt et al., 2004; Kan & Windsor, 2010). Specifically, we aimed to build understanding of the relationship between phonological short-term memory (STM) and word learning by exploring how accurately preschool children with and without DLD learn and encode the phonology of novel words of varied length.

Word Learning

The ability to effectively learn new words is a fundamental skill, and usually occurs with relative ease for children with typical language development (Chiat, 2001; Ramachandra et al., 2011). Carey and Bartlett's (1978) *mapping theory* provides a framework which describes the typical process of word learning as occurring over two distinct yet overlapping phases (Chiat, 2001). First, *fast mapping* involves brief exposure to the novel word, during which representations of the phonology and semantics are stored to create a form-meaning "map" (Carey & Bartlett, 1978). Initially, this fast-mapped word may be unstable, and contain sufficient detail only to distinguish the word from others. However, as the word is encountered in subsequent contexts, the phonological and semantic representations are further enriched and more accurately established in long-term memory (Bion et al., 2013). This process is referred to as *slow mapping*, and is thought to occur repeatedly as the word is encountered across linguistic contexts (Carey & Bartlett, 1978).

It has been hypothesised that impairments in the fast mapping stage have a cascading effect on slow mapping success, because an inaccurate form-meaning map may not be recognised, and therefore refined, in future encounters (Bion et al., 2013). Additionally, the quality with which a child fast maps phonological representations is suggested to influence how effectively the representations for semantic, syntactic, motor programming, and orthographic information may be stored for use in oral and written forms (Castles et al., 2018; Stackhouse & Wells, 1997). Thus, poor storage of phonological representations may affect learning across multiple aspects of language (Constable, 2001), and as such, the manner in which children with DLD learn the phonology of new words has been a major focus of word learning research.

Nonword Repetition in Children with Developmental Language Disorder

Phonological STM plays a significant role in how the phonological form of the novel word is learned (Gathercole et al., 1997; Montgomery et al., 2010). As such, this component of working memory has been widely explored in children with DLD, often using nonword repetition tasks (Dollaghan & Campbell, 1998; Estes et al., 2007). Numerous studies indicate that children with DLD exhibit significant difficulties with nonword repetition. For instance, a meta-analysis by Estes et al. (2007) showed that, across 23 studies, children with DLD performed on average 1.27 standard deviations below TD children (indicating a significant deficit). This substantial difficulty with repeating nonwords has supported the development of the *limited capacity processing account* for DLD, which posits that the language impairments experienced by these children may be largely explained by deficits in the processing, encoding, and storage of sound-based information (Chiat, 2001). It is suggested that this underlying deficit contributes considerably to problems learning new words, as the word learning process requires the temporary storage of novel phonological strings in short-term memory, before being transferred to long-term memory (Botting & Conti-Ramsden, 2001; Ramus et al., 2013).

While the research consistently shows a deficit in nonword repetition performance in children with DLD (Archibald & Gathercole, 2007b; Dollaghan & Campbell, 1998; Jones et al., 2010) the magnitude of this deficit varies greatly, hypothesised to be a result of differing task characteristics across measures. Perhaps, most notably, the length of nonwords has been shown to considerably affect performance (Estes et al., 2007). Studies have found that children with DLD may show a similar level of accuracy to TD children when repeating short nonwords (i.e., one and two syllables; Coady & Evans, 2008; Gathercole & Baddeley, 1990); however, with longer nonwords (i.e., those with three or more syllables), an impaired phonological STM capacity in children with DLD is clearly shown (Jones et al., 2010). While Estes et al. (2007) found that children with DLD also struggled to repeat shorter nonwords in comparison to TD children (one and two-syllables), the magnitude of this deficit was considerably smaller than that seen for repetition of longer nonwords (three and four syllables). Thus, while children with DLD may struggle to repeat shorter nonwords, they generally reach their capacity limitation (and exhibit the greatest level of difficulty) for multisyllabic nonwords.

The phenomenon of declining repetition accuracy as nonword length increases is described as the *word length effect*, and what we glean from previous studies is that this effect differentially impacts children with DLD and TD children, presumably as a reflection of their differing phonological STM capacities (Baddeley, 2003). That is, children with DLD may generally reach the capacity limitation at three syllables, while TD children may reach this at four and five syllables (Dollaghan & Campbell, 1998; Estes et al., 2007). The fact that children with DLD tend to exhibit greatest difficulty with longer nonwords supports the notion that their nonword repetition deficit largely reflects impaired phonological STM capacity, rather than general deficits in phonological perception, phonological encoding, articulation, or motor programming, which would presumably impact repetition across nonwords of all lengths (Archibald & Gathercole, 2007a).

The *word length effect* has numerous practical implications for how well children (especially those with phonological STM impairments, such as children with DLD) may cope with processing lengthy phonological strings, such as encoding multisyllabic novel words (Montgomery, 1995; Riches, 2012). Therefore, this effect is also expected to extend to performance in fast mapping given the similar processing requirements of nonword repetition and word learning (Gathercole, 2006). That is, both tasks require input processing of a novel phonological string, and temporary storage in phonological STM prior to transference into long-term memory (as in fast mapping), or formulation of an output representation (as in nonword repetition; Gathercole, 2006).

The Relationship Between Phonological Short-term Memory and Fast Mapping

In light of the theoretical link between nonword repetition and fast mapping, a body of research has explored this relationship in TD children and found a robust association (Adlof & Patten, 2017; Montgomery et al., 2010). In earlier work, Gathercole et al. (1997) found that new word learning (of two- and three-syllable novel words) in five and six-year-old children was significantly associated with phonological STM abilities, as measured by both digit span and nonword repetition. A similar relationship was demonstrated in eight to ten-year-olds by Morra and Camba (2009), who introduced 24 novel words (two and four syllables in length) matched to pictures. Among other factors (e.g., phonological sensitivity and rehearsal efficiency), phonological STM significantly predicted their fast mapping production accuracy. This relationship was further reinforced in a group of TD children (aged five to 12 years), whose fast mapping of bisyllabic unfamiliar real words was strongly predicted by nonword repetition performance (Adlof & Patten, 2017). Taken together, these findings highlight the role of phonological STM in how TD children encode and store novel word forms and facilitate their transfer to long-term memory; thus reinforcing phonological STM as a core "language learning device" (Baddeley et al., 1998, p. 158). However, to our knowledge, there is a paucity of research investigating the nature of this relationship in TD children, such as whether performance differs across short versus long novel words.

A smaller body of research has investigated the relationship between phonological STM and fast mapping in children with DLD. Due largely to variations in methodology (particularly, the utilisation of different novel word lengths and different measures to assess learning in the fast mapping tasks), the findings of investigations in this population have been equivocal. Alt (2003) and Alt and Plante (2006) provided three exposures to novel words (two syllables in length) for five-year-olds in their respective studies, and found that those with DLD were significantly less accurate at fast mapping than the TD children. In this study, fast mapping was assessed with a semantic task (i.e., children had to recall semantic features of the novel items), and with a recognition task that required them to identify the correct phonological label from three foils. Performance on both tasks correlated with nonword repetition performance (Alt, 2003; Alt & Plante, 2006). This supports the suggestion that fast mapping of the phonological form is facilitated by the ability to hold verbal information in phonological STM (Baddeley, 2003), and additionally suggests that phonological STM plays a role in establishing semantic representations. The fact that the novel words used by Alt (2003) and Alt and Plante (2006) were bisyllabic aligns to a degree with the *word length effect*, which states that nonword repetition (and by extension, word learning) may be especially difficult for children with DLD as nonword length increases (Dollaghan & Campbell, 1998). To further unpack this relationship, further research is required to explore how children with DLD and TD children learn novel words across different lengths.

In contrast, Gray (2006) found no association between phonological STM and fast mapping (of bisyllabic novel words) in children with DLD. While these null findings may seem to suggest that phonological STM did not constrain fast mapping in these children, it is noteworthy that, in their groups of three, four, five, and six-year-olds, fast mapping performance in the TD and DLD groups only differed significantly at age five. Gray (2006) suggested that this may have occurred due to the increased severity of language deficits in this age group of children with DLD. Alternately, the lack of group differences might have reflected the nature of the fast mapping task and the outcome measures that were used to evaluate learning of the novel words. First, a comprehension task was used, which required children to identify the item when provided with its label from an array of all eight target items (Gray, 2006). Both groups of children performed well on this task and thus group scores were similar, reflecting the fact that comprehension tasks are less linguistically-demanding (that is, they require the storage of only enough phonological information that allows differentiation from the other items; Kan & Windsor, 2010). However, the second measure involved producing each novel word label – a task that requires storing the word's phonology in sufficient detail to support production (Stackhouse & Wells, 1997). This measure is considered to be linguistically-demanding (Kan & Windsor, 2010), and was simply scored as *correct* or *incorrect*. As such, children in both groups tended to score close to basal on the production task. This resulted in a lack of variability in the group scores for both the comprehension and production measures of fast mapping, which may have contributed to a non-significant relationship between nonword repetition and fast mapping performance (Gray, 2006). The equivocal nature of the literature highlights the need for further investigation into the relationship between phonological STM and fast mapping in children with DLD.

Despite the theoretical link between phonological STM and fast mapping, to our knowledge only one study has explored the nature of this relationship by examining fast mapping accuracy in novel words of different lengths. Alt (2011) presented seven and eight-year-old children (with and without DLD) with either short (two-syllable) or long (four-syllable) novel words as a means of exploring whether the *word length effect* – observed in nonword repetition performance – would extend to fast mapping performance. Children with DLD produced and recognised the short novel words with similar accuracy to the TD children; however, accuracy was significantly worse for the longer stimuli. Alt (2011) proposed that children with DLD experienced this pattern of difficulty because the longer novel words exceeded the bounds of their phonological STM capacity; a finding that suggests the proposed *word length effect* may similarly affect both nonword repetition and fast mapping, and provides further support for theoretical claims that deficits in phonological STM may contribute to word learning impairments experienced by children with DLD (Alt, 2011; Baddeley et al., 1998).

The Relationship Between Receptive Vocabulary, Phonological Short-term Memory, and Fast Mapping

A body of research demonstrates a strong link between nonword repetition and existing vocabulary knowledge in children with typical language (Alloway et al., 2009; Baddeley, 2003; Gathercole & Baddeley, 1990; Gathercole et al., 1999). Existing vocabulary is suggested to support nonword repetition by providing a store of phonological patterns or templates to draw from in order to form new representations required for repetition (Bowey, 2001). This relationship has also been documented in children with DLD (Munson et al., 2005b; Vugs et al., 2016). While these findings support a link between vocabulary (i.e., static measures of word knowledge) and nonword repetition (arguably a dynamic task involving processing and encoding), findings regarding the influence of existing vocabulary during the dynamic process of word learning (i.e., fast mapping) are equivocal for both DLD and TD populations.

For instance, Gray (2006) explored the relationship between receptive vocabulary and fast mapping in TD children and those with DLD, and found that it contributed to a small (non-significant) amount of variance. While it was suggested that receptive vocabulary was likely to be an important contributing factor, in this study the groups were not separated in the regression analysis, which may have resulted in the TD group scores masking a potential relationship (Gray, 2006). Similarly, Rice and colleagues (1990, 1992, 1994) found no association between receptive vocabulary and fast mapping comprehension scores. However, in these studies, children were sampled based on lower vocabulary performance, hence limiting the variability among scores. In contrast, Alt et al. (2004) and Gray (2004) explored the influence of receptive vocabulary on fast mapping in four to six-year old children with DLD and TD children, and found it correlated with fast mapping recognition, production, and comprehension performance in both groups. This aligns with theoretical expectation that the existing vocabulary store facilitates the establishment of novel phonological strings (Montgomery et al., 2010).

While previous research into the association between receptive vocabulary, nonword repetition, and fast mapping in children with DLD remains unclear, it seems that receptive vocabulary may similarly support both nonword repetition and fast mapping (Baddeley, 2003; Hick et al., 2002; Montgomery et al., 2010), and this relationship requires further investigation in this group of children.

The Current Study

In a previous study by our research team, we examined fast mapping performance in five-year-old (preschool) children with DLD and TD children using novel words of varied lengths (two, three, and four syllables; Jackson et al., 2016). The results indicated that overall, children with DLD were significantly less accurate at fast mapping the phonological label (measured by a production task that was scored according to the percentage of phonemes that were correctly produced) compared to TD children. Additionally, nonword repetition performance and receptive vocabulary were both significant predictors of fast mapping production accuracy (Jackson et al., 2016). However, in that study we did not examine nonword repetition and fast mapping performance at the different nonword lengths, which may have shed further light on the *word length effect* and how it affects accuracy on these two tasks. One previous study (Alt, 2011) found evidence of this effect on fast mapping performance in seven and eight-year-old children; however, we aimed to extend this research into younger (preschool) children. This is important given that working memory capacity is thought to considerably grow throughout the period of childhood (Gathercole & Hitch, 1993), and thus, if phonological STM capacity does in fact constrain word learning, this may impact how children of different ages learn novel words at different lengths (Gathercole & Baddeley, 1990).

Thus, the present study aimed to extend the findings of Jackson et al. (2016) by re-analysing the data to investigate the effect of word length on nonword repetition and fast mapping performance. Specifically, we aimed to compare performance of children with and without DLD on these tasks, and examine whether performance on both tasks varies as a function of nonword length, after controlling for receptive vocabulary. If the *word length effect* is indeed found to constrain fast mapping performance in children with DLD, this will have implications for the development of intervention strategies that support these children to develop strong and accurate representations of novel words that are both short and long – an important skill given the high incidence of English words that are multisyllabic (Balota et al., 2007).

Method

Participants and Measures

This research involved further analysis of data (collected within Australia) from Jackson et al. (2016). A total of 49 five-year-old children participated in the study (see Table 5.1 for participant characteristics). The project was approved by the Curtin University Human Research Ethics Committee. Following ethics approval, a specialist language development centre was approached to recruit children with DLD, and a mainstream school (matched to the language centre for socio-economic status) was approached regarding recruitment for the TD group. Following principal consent, teachers at the respective schools were informed of the general criteria for inclusion, and they then distributed information letters and consent forms to parents or caregivers of children who met these criteria. General criteria included: English as a primary or dominant language; no significant history of hearing or medical conditions, and; no significant behavioural, pragmatic, or articulatory difficulties. Parents or caregivers provided informed written consent prior to their child's participation. At the language development school, 70% of the approached sample were consented to participate, and 58% consented from the mainstream school.

Twenty-three children diagnosed with DLD were recruited and formed the DLD group. These children were enrolled at the centre on the basis of meeting the diagnostic criteria for DLD that were in effect at the time of recruitment: impaired oral language skills with unimpaired nonverbal cognitive skills (American Psychiatric Association, 2013). Their inclusion in the study was confirmed by meeting the following criteria: a Core Language Score of 85 or less (at least 1 *SD* below the mean) on the Clinical Evaluation of Language Fundamentals, Preschool Second Edition (CELF-P2; Semel et al., 2006a) and a raw score of 14 or more (average range) on the Raven's Coloured Progressive Matrices (CPM; Raven, 2003). The CELF-P2 Core Language Score was selected because its diagnostic accuracy at the standard score cut-off of 85 has .85 sensitivity and .82 specificity (Semel et al., 2006a). While standard scores are not available for the Raven's CPM, a raw score of

14 or higher indicates non-verbal cognitive functioning in the average range for this age group. This assessment has acceptable internal consistency (Cronbach's α = .80) and test-retest reliability (r = .87; Raven, 2003).

Twenty-six children with normally-developing language were recruited from a mainstream school to form the TD group. Teachers at the school were asked to flag children with apparent typical language skills for potential participation, and inclusion in the group was confirmed by achieving a Core Language Score of 86 or above on the CELF-P2 and 14 or higher on the Raven's CPM. While the Core Language criteria of ≤ 85 for DLD and ≥ 86 for TD raises questions about the similarity of oral language skills between the groups, a *t*-test confirmed that the two groups differed significantly in their performance on the CELF-P2 Core Language Score (standard scores ranged 63 to 84 in the DLD group and 100 to 134 in the TD group; see Table 5.1). In addition to having lower scores on this standardised test, the children included in the DLD group were enrolled at the language centre as they required ongoing specialist intervention and educational support for oral language difficulties, as determined by the team of specialist teachers and speech-language pathologists at the centre.

Additional descriptive measures of receptive vocabulary and phonological STM were administered for use in the analysis but had no bearing on group inclusion. To assess receptive vocabulary, the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was administered according to the assessment guidelines. This task involves pointing to a named item from an array of four pictures and has high internal consistency (α = .93 to .95) and acceptable validity (.84; Dunn & Dunn, 2007). Standard scores were obtained to be used in the analyses (see Table 5.1 for group scores).

The Nonword Repetition Test, developed by Dollaghan and Campbell (1998), was administered to assess phonological STM and has an acceptable level of internal consistency (demonstrated by a split-half reliability coefficient of .85). The stimuli are 16 nonwords – four each at four syllable lengths (one to four syllables). The syllable shapes at each length are: CVC, CVCVC, CVCVCVC, and CVCVCVCVC (Dollaghan & Campbell, 1998). Nonwords were constructed to be dissimilar to English words, and exclude any of the *late eight* consonants to minimise articulatory

Table 5.1

Participant Characteristics and Means and Standard Deviations on Standardised Assessments

	DLD (18 boys, 5 girls)		TD (10 boys, 16 girls)			
	M	*SD*	*M*	*SD*	*p*	*d*
Age in months	64.39	4.10	65.92	2.98	.148	0.43
CELF-P2 CLS[a]	80.39	5.70	108.54	8.74	<.001*	3.82
Raven's CPM[b]	17.13	2.94	20.42	3.71	.079	0.20
PPVT-4[a]	90.83	7.13	108.04	9.43	<.001*	2.06
Nonword Repetition[c]	65.59	8.91	87.46	4.55	<.001*	3.09

Note. CELF-P2 CLS = Core Language Score on the Clinical Evaluation of Language Fundamentals, Preschool Second Edition; CPM = Coloured Progressive Matrices; PPVT-4 = Peabody Picture Vocabulary Test, Fourth Edition.

[a]Standard score. [b]Raw score. [c]Percent phonemes correct score.

*$p < .01$.

difficulty (Dollaghan & Campbell, 1998). Procedures for nonword pronunciation and administration were followed, and the task was delivered live voice to participants. Responses were scored on-line using the percentage of consonants correct (PPC) method, and were audio recorded for later checking. A trained research assistant (a final-year speech-language pathology undergraduate student) later re-scored all nonword repetition tasks, and high reliability between scorers was found ($r = .96$). To ensure that performance on the task was not constrained by restrictions in participants' phonological inventories, in accordance with procedures outlined by Dollaghan and Campbell (1998), we examined each participant's nonword repetition performance and flagged any consonants that were repeated incorrectly at least once. In subsequent testing sessions, the spontaneous speech of participants was observed to look for evidence that those incorrectly repeated sounds were in the participant's phonological inventory. If so, these incorrect productions were marked as errors in scoring the nonword repetition task; if not, the sound was scored as correct (Dollaghan & Campbell, 1998).

Fast Mapping Stimuli

The fast mapping task (also described in Jackson et al., 2016) was designed to assess participants' ability to fast map the phonological label for nine unfamiliar "alien" objects. The objects were hand-constructed from coloured modelling clay and were designed to be visually dissimilar (see Appendix E.1). The nine objects were paired with nonword labels ranging in length (3 x two-syllable, 3 x three-syllable, and 3 x four-syllable nonwords). Phonotactic probability (the frequency with which sounds and sound segments occur within a word position; Munson et al., 2005b) of the nonwords was considered, as this can significantly impact word learning performance (Alt & Plante, 2006; Gray et al., 2014). First, a randomised list of 227 real words were processed using the N-Watch algorithm (Davis, 2005) and the mean and standard deviation phonotactic probabilities of real words at two, three, and four syllables were calculated. Following that, 29 nonwords were selected from previous nonword repetition and fast mapping studies (Gathercole et al., 1994; Munson et al., 2005a) and the N-Watch algorithm was used to calculate their phonotactic probabilities. All those with probabilities that were less than one standard deviation below the mean for that syllable length (calculated from the real word sample) were considered to have low phonotactic probability (Davis, 2005). Previous research shows that children with DLD may not take advantage of high phonotactic probabilities to the same extent as TD children (Gray et al., 2014); thus, nonwords with low phonotactic probabilities were selected as stimuli (see Appendix E.2).

The articulatory complexity of the nonwords was also considered: we selected nonwords if they contained phonemes that are considered to typically develop before the age of five. Some consonant clusters were included, as the use of cluster reduction phonological process generally resolves by this age (Bernthal et al., 2009). Participants' phonological errors (such as cluster reductions) were taken into account when scoring the fast mapping task (see *Scoring* section below). The selection of nonwords with low phonotactic probability and developmentally-appropriate phonemes was prioritised; thus, the nonwords varied in syllable shape. All two-syllable nonwords were CVCVC; the three-syllable stimuli were CVCVCVC, CVCVCVCC, and CVCCVCVC, and; four-syllable nonwords were CVCVCCVCV, CVCVCVCVC, and CVCVCVCVC. An additional two nonwords were selected for training purposes: one two-syllable (CVCVC) and one three-syllable nonword (CVCVCVCC). The novel names were arranged into three sets, each set consisting of a two, three, and four-syllable nonword (see Appendix E.2).

Fast Mapping Training Phase

The fast mapping task involved presenting the novel objects and their nonword labels in an interactive task using coloured blocks. To familiarise participants with the task requirements, the two training items were presented, one at a time. First, the participant was encouraged to build a farm scene using the coloured blocks (see Appendix E.1). They were then instructed that they would be learning the names of some aliens and that they had to try their best to remember the names.

Both training items (aliens) were inside a toy rocket, and the examiner pretended to land the rocket on the farm. The participant was instructed to select an item from the rocket without looking (to ensure random presentation). Over a period of approximately 60 seconds, the examiner modelled the nonword label for the alien three times within simple commenting or instructional phrases (e.g., “You picked out Poʊdɔd… Put Poʊdɔd on the horse… Poʊdɔd likes the horse”). Following this exposure phase, a production probe was administered to assess how accurately participants had fast mapped the phonological label (i.e., “What is its name?”). Participants were provided with feedback regarding their production accuracy in the training task. Training proceeded identically with the second item in the training set.

Fast Mapping Experimental Phase

The experimental phase proceeded similarly to the training phase. The three sets were presented one at a time, in randomised order. To present the first set, the farm setting was used, as in the training phase. All three items (the aliens with the two, three, and four-syllable labels) in the first set were placed inside the rocket, and the examiner landed the rocket on the farm. As in the training phase, the participant randomly selected one item, and the examiner provided three verbal exposures to the nonword label within simple sentences. The production probe was then administered, and neutral feedback was provided. This procedure was followed for the remaining two items in the set.

After all items had been administered in a set, participants were given up to three minutes to use the blocks to construct a different setting (such as a park or backyard). This was to provide a break from the task and maintain interest. The examiner placed the second set of three items into the rocket, and the items were individually presented and production was assessed. Participants then changed the blocks to create a different setting, and the third set was presented following the same procedure.

Scoring

Responses on the production task were scored on-line using the PPC method. They were also audio recorded for score checking, and all productions were double-scored by a trained research assistant (final year speech-language pathology undergraduate student). There was high inter-rater reliability (r = .93) and internal consistency (α = .84). As with the nonword repetition scoring, observations of participants' spontaneous speech were used to examine phonological inventories, and any consistent errors in their speech production were taken into account when assigning a PPC score (Dollaghan & Campbell, 1998).

General Procedures

Following approval from relevant committees, participant recruitment commenced. Each participant took part in four short sessions over two days in consecutive weeks. In their first week of participation, the CELF-P2 Core Language subtests and Raven's CPM were administered in two sessions (15-20 minutes each) on the same day. The following week, participants took part in the data collection measures in two 20-minute sessions: the first session involved administering the nonword repetition and PPVT-4 tasks, and the second was for the fast mapping task (the training and experimental task were administered in succession).

Analysis

The current study involved the use of two mixed model analyses of covariance (ANCOVA) with appropriate post-hoc tests. The first ANCOVA was a 2 (group) x 4 (word length) design, selected to explore the impact of word length on nonword repetition accuracy amongst children with DLD and TD children, while controlling for receptive vocabulary. The second ANCOVA was a 2 (group) x 3 (word length) design to examine the influence of word length on fast mapping production accuracy in the two groups (with receptive vocabulary as a covariate).

Results

Fast Mapping and Nonword Repetition

As reported in Jackson et al. (2016), the children with DLD were significantly less accurate overall at producing the fast-mapped words than the TD children, and also performed significantly worse on the nonword repetition task. Furthermore, both nonword repetition and PPVT-4 scores accounted for a significant proportion of variance in fast mapping production performance when collapsing scores across the groups.

Nonword Repetition and Word Length

Given that previous research indicates a strong relationship between receptive vocabulary and nonword repetition (Alloway et al., 2009; Gathercole et al., 1999), we explored correlations between these measures and found that PPVT-4 scores correlated significantly with nonword repetition across all nonword lengths (*r* values ranged from .49–.64, all p values < .001). Therefore, a mixed model ANCOVA with a 2 (group) x 4 (word length) design was used to investigate the impact of word length (number of syllables) on the nonword repetition accuracy of children with DLD and TD children, after controlling for receptive vocabulary. All assumptions were tested and met, and the results of the ANCOVA are summarised in Table 5.2. The main effect of nonword length was not statistically significant, $F(3, 132) = 1.04$, $p = .379$, partial $\eta^2 = 0.02$. However, there was a significant main effect of group, $F(1, 44) = 48.79$, $p < .001$, partial $\eta^2 = .53$, with nonword repetition scores in the TD group ($M = 87.34$ PPC, $SE = 1.74$ PPC) being significantly higher than in the DLD group ($M = 66.29$ PPC, $SE = 1.89$ PPC). There was also a significant interaction between nonword length and group, $F(3, 132) = 5.44$, $p < .001$, partial $\eta^2 = 0.11$. This suggests that after controlling for receptive vocabulary, nonword repetition performance does not decline as the word length increases for TD children. However, children with DLD exhibit increased difficulty as nonword length increases (see Figure 5.1A).

Table 5.2

ANCOVA Results for Nonword Repetition by Group and Word Length

Source	Sum of Squares	df	Mean Square	*F*	*p*	partial η^2
Group	9352.04	1	9352.04	48.79	< .001*	0.53
Length	289.15	3	96.38	1.04	.379	0.02
Group × length	1519.70	3	506.57	5.44	< .001*	0.11
PPVT	0.90	1	0.90	0.01	.946	< 0.01
Error	144.53	29	4.98			

Note. Reported values are percent phonemes correct.
*p < .01.

To further analyse the interaction between nonword length and group, we conducted post-hoc ANCOVA comparisons for each nonword length (controlling for receptive vocabulary). In comparison to the children with DLD, TD children were significantly more accurate at repeating nonwords at all four syllable lengths, with medium to large effect sizes (see Table 5.3). When examining performance across the nonword lengths in the DLD group, there was no significant difference in performance for repetition of two and three-syllable nonwords. However, their performance dropped significantly from three to four syllables. In contrast, in the TD group, there was no significant difference in performance at any of the nonword lengths.

Fast Mapping and Word Length

In light of research suggesting that receptive vocabulary may influence fast mapping (Alt et al., 2004; Gray, 2004), correlations were run, and PPVT-4 standard scores significantly correlated with fast mapping production performance across all novel word lengths (*r* values ranged from .47–.68, all *p* values < .001). Therefore, we conducted a mixed model ANCOVA with a 2 (group) x 3 (length) design, to investigate the influence of novel word length on fast mapping performance while controlling for receptive vocabulary. The assumptions for a mixed model ANCOVA

Table 5.3

Results of the Post-hoc ANCOVAs for Nonword Repetition and Fast Mapping

	DLD (*n* = 23)			TD (*n* = 26)					
Measure	*M*	*SE*	95% CI	*M*	*SE*	95% CI	*F*	*p*	partial η^2
Nonword repetition									
1-syllable	84.48	2.85	[78.74, 90.22]	94.66	2.61	[89.40, 99.92]	5.05	.030*	0.10
2-syllable	74.23	2.26	[69.68, 78.78]	90.91	2.07	[86.75, 95.07]	21.63	< .001**	0.33
3-syllable	62.94	2.75	[57.40, 68.94]	87.44	2.52	[82.3, 92.52]	31.27	< .001**	0.42
4-syllable	43.53	3.81	[35.86, 51.20]	76.36	3.49	[69.34, 83.39]	29.41	< .001**	0.40
Fast mapping									
2-syllable	52.91	5.72	[41.39, 64.42]	70.80	5.39	[59.93, 81.66]	3.74	0.059	0.08
3-syllable	33.64	4.61	[24.36, 42.91]	73.43	4.35	[64.68, 82.19]	28.52	< .001**	0.39
4-syllable	21.96	4.68	[12.53, 31.39]	55.80	4.42	[46.90, 64.70]	19.95	< .001**	0.31

Note. Estimated marginal means are reported; reported values are percent phonemes correct.

**p* < .05. ***p* < .01.

were tested and were not violated. The results of the ANCOVA are summarised in Table 5.4. There was no significant main effect of length on fast mapping performance after controlling for receptive vocabulary, $F(2, 90) = .14$, $p = .869$, partial $\eta^2 = 0.003$, indicating that overall fast mapping accuracy does not significantly change as the length of novel words increases. However, a significant main effect of group on fast mapping was found, $F(1, 45) = 24.73$, $p < .001$, partial $\eta^2 = 0.36$, with TD children (M = 66.68 PPC, SE = 3.58 PPC) showing significantly higher fast mapping production performance than children with DLD (M = 36.17 PPC, SE = 3.79 PPC).

Table 5.4

ANCOVA Results for Fast Mapping by Group and Word Length

Source	Sum of Squares	df	Mean Square	F	p	partial η^2
Group	14822.48	1	14822.48	24.73	< .001*	0.36
Length	64.13	2	32.06	0.14	.869	0.003
Group × length	1361.83	2	680.91	3.00	.055	0.06
PPVT	798.45	1	798.45	1.32	.254	0.01
Error	26969.43	45	599.32			

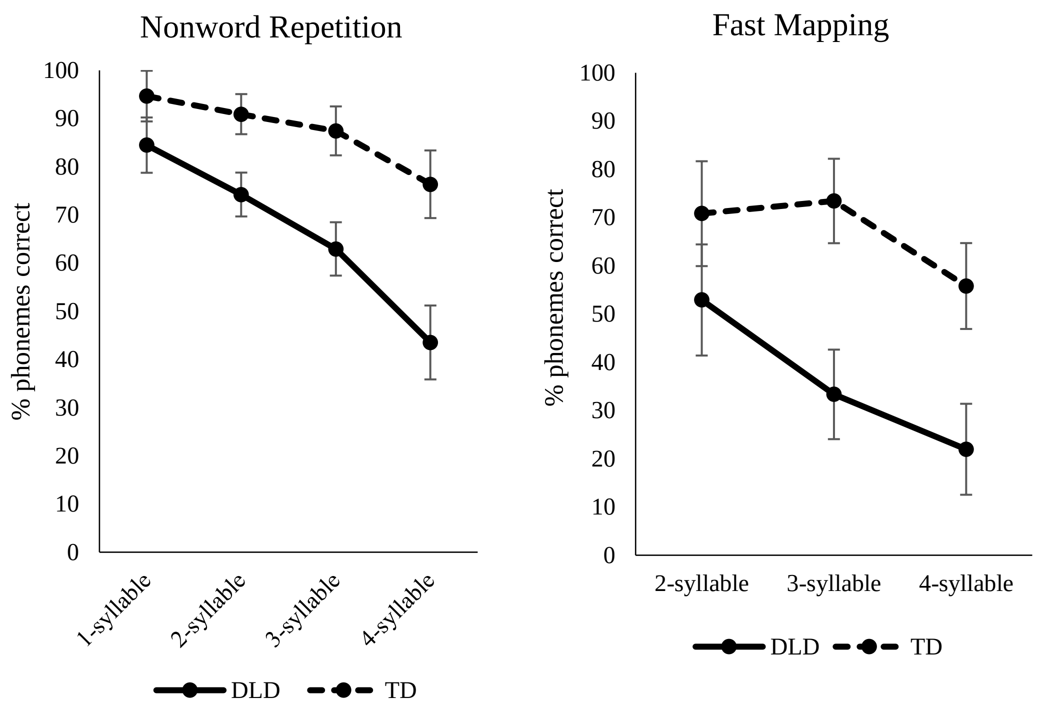
Note. Reported values are percent phonemes correct.
$^*p < .01$.

We did not find a significant interaction between word length and group in their effects on fast mapping performance, $F(2, 90) = 3.00$, $p = .055$, partial $\eta^2 = 0.06$. However, the effect size was small to medium; therefore, exploratory post-hoc ANCOVAs were conducted to explore between-group differences at each syllable length while controlling for receptive vocabulary (see Table 5.4). There was no significant between-groups difference for fast mapping two-syllable novel words, but TD children were significantly more accurate at producing fast mapped novel words of three and four syllables in comparison to children with DLD (with large effect sizes). The (non-significant) interaction between word length and group is plotted in Figure 5.1B.

Figure 5.1

Interaction Between Word Length and Group for Nonword Repetition and Fast Mapping

A B



Note. Error bars represent 95% confidence intervals. Panel A: Significant interaction between word length and group for nonword repetition. Panel B: Non-significant interaction between word length and group for fast mapping.

Discussion

The Impact of Word Length on Nonword Repetition and Fast Mapping

Extensive evidence of a phonological STM deficit in children with DLD has been provided by studies exploring their nonword repetition abilities (e.g., see Archibald & Gathercole, 2007b; Edwards & Lahey, 1998; Gathercole & Baddeley, 1990). The findings of our previous paper aligned with this research (Jackson et al., 2016), with our group of preschool children with DLD overall performing significantly worse on a nonword repetition task (Dollaghan & Campbell, 1998) relative to their TD peers. To further explore the nature of the nonword repetition deficit in children with DLD, previous research has examined performance at different nonword lengths, with the results generally indicating that shorter nonwords are produced with greater accuracy (Baddeley et al., 1998; Coady & Evans, 2008; Ellis Weismer et al., 2000); however, the deficit increases when faced with longer words. Thus, the first aim of the current paper was to further investigate the proposed *word length effect* for nonword repetition (Dollaghan & Campbell, 1998; Jones et al., 2010).

The results of our investigation diverged somewhat from those of previous studies. In line with the predictions of the *word length effect*, we were expecting that children with DLD would be comparable to TD children when repeating one and two-syllable nonwords, but would show significantly poorer performance for three and four-syllable nonwords (i.e., at the point where they reach their *capacity limit*; Dollaghan & Campbell, 1998; Jones et al., 2010). However, our group of children with DLD were significantly worse at repeating nonwords of all lengths compared to their TD peers. It is noteworthy, however, that while all effect sizes for the between-groups differences were large, the largest effect sizes were obtained at three and four syllables (partial $ŋ^2$ = 0.42 and 0.40, respectively). This aligns with the findings of Estes et al. (2007) and suggests that the magnitude of the deficit experienced by children with DLD is greater when they are faced with lengthier phonological strings that place a greater strain on their reduced phonological STM capacities.

A factor that may explain the global difficulty our children with DLD had with repeating both short and long nonwords might be that our participants were considerably younger (aged 5;0 to 5;11) than those in previous studies. For instance, Dollaghan and Campbell’s (1998) participants (in the DLD and TD groups) were aged 6;0 to 9;9, and significant between groups diffferences were not found at one and two syllables, but were found at three and four syllables. The poorer performance across all syllable lengths exhibited by our group of children with DLD may therefore be a reflection of developmental differences in phonological STM capacity size (Gathercole & Hitch, 1993). Another possible interpretation is one which challenges the suggestion that the nonword repetition deficit in children with DLD is largely a reflection of reduced phonological STM capacity (Estes et al., 2007). For instance, Ellis Weismer et al. (2000) also found that older children with DLD (mean age 7;11) struggled to repeat short nonwords, and suggested that broader issues regarding phonological processing (such as general difficulties with encoding phonological stimuli, phonological analysis, or motor programming) may affect the capacity of some children with DLD to repeat novel words above and beyond a phonological STM deficit (Bishop, 1997; Nash & Donaldson, 2005). While previous studies have specifically explored these factors, and suggested they do not significantly contribute to nonword repetition deficits in children with DLD (Edwards & Lahey, 1998), the heterogeneity of the DLD population may mean that our relatively small sample comprised children with deficits in these broader phonological processing skills (Kamhi & Catts, 1986; Metsala, 1999; Tallal et al., 1996). We attempted to exclude participants with deficits in hearing and articulation; however, specific and comprehensive assessment of areas such as hearing, phonological discrimination, and articulation were not administered. Future research should consider measuring and controlling for these factors in nonword repetition performance, with larger sample sizes.

Examination of the within-groups performance for nonword repetition showed greater consistency with the proposed *word length effect*. In relation to their own performance, children with DLD performed similarly when repeating one and two-syllable nonwords; however, their repetition accuracy dropped significantly from two to three-syllables, and then again from three to four-syllables. These findings support the predictions of the *word length effect* in that longer nonwords pose a greater challenge for processing capacity than shorter ones (Dollaghan & Campbell, 1998; Estes et al., 2007). On the other hand, in the TD group, nonword repetition performance declined non-significantly as nonword length increased. Based on previous research, it was expected that the TD children may have exhibited a considerable drop in accuracy when faced with the longest words (e.g., four-syllables; Dollaghan & Campbell, 1998). This pattern of performance suggests that our particular group of TD children may have had greater phonological STM capacities (Gathercole & Adams, 1993). Alternately, given that receptive vocabulary was used as a covariate in the analyses, these findings may indicate that for TD children, vocabulary knowledge may work to offset difficulties with nonword repetition as the task becomes more difficult and the nonwords exceed the bounds of phonological STM capacity (Alt et al., 2004; Gray, 2004, 2006; Hick et al., 2002; Vugs et al., 2016).

Given that phonological STM is thought to constrain fast mapping abilities (Baddeley et al., 1998; Gathercole & Baddeley, 1990; Kan & Windsor, 2010), we expected a similar pattern of performance in nonword repetition and fast mapping accuracy across the groups. However, our results showed that word length affected fast mapping differently to nonword repetition. Examination of the between-group differences of fast mapping accuracy at the different word lengths revealed that there was not a statistically significant difference between the groups for fast mapping of the shortest (two-syllable) novel words. However, there was a moderate effect size (partial $\eta^2 = 0.08$). Post-hoc testing also revealed that children with DLD were significantly worse at fast mapping both three and four-syllable novel words relative to the TD children (and large effect sizes were observed). These findings seem to differ from those of a previous study by Alt (2011), in which the DLD and TD groups fast mapped two-syllable novel words with comparable accuracy. These contrasting findings may be attributable to age differences in participants (children were aged seven and eight years in Alt, 2011); thus, the children with DLD may have had greater phonological STM capacities than our five-year-olds, which facilitated their successful fast mapping of the shorter novel words. While our findings provide preliminary insight into the impact of word length on fast mapping, the results need to be interpreted with caution given that the overall interaction was not significant. This may have occurred due to the relatively small sample size; we were potentially underpowered to find statistically significant effects. These findings should be replicated and extended using a larger sample.

Finally, on examination of the general accuracy of the children's nonword repetition and fast mapping (as indicated by their PPC scores on both tasks), we can see that at each nonword length these scores were higher for nonword repetition than fast mapping (see Table 5.3). These results suggest that both groups of children were more successful at working with phonological forms in a nonword repetition context. We had expected that, overall, the children may have achieved greater PPC scores in the fast mapping task compared to nonword repetition, because our fast mapping procedure involved processes that should facilitate phonological learning. For instance, the novel words were heard three times (instead of just once, as in nonword repetition). Based on previous research that indicates increased input frequency facilitates learning (e.g., Rice et al., 1994), this factor was expected to result in greater accuracy, given that the children had increased opportunities to refine the phonological representation before production was required (Kan & Windsor, 2010).

The items were also given as labels for tangible objects, which would presumably facilitate the establishment of a semantic representation (Zens et al., 2009), and were presented in simple sentence frames, which should allow the child to use implicit syntactic and semantic bootstrapping processes that generally work to strengthen representations for unfamiliar words (Horohov & Oetting, 2004).

Yet, the lower fast mapping scores may have resulted from the nature of the learning context for fast mapping, with the multiple linguistic cues placing a greater load on cognitive resources (Alloway et al., 2009). This was perhaps detrimental to learning the phonological form. It is also possible that attentional resources were directed towards engagement in the play-based aspects of the fast mapping task, whereby children could interact with the setting while hearing the novel word forms. In contrast, nonword repetition is highly specified and designed to primarily require phonological processing, with minimal demands placed on other areas of processing (such as semantics; Dollaghan & Campbell, 1998), thus supporting the processing of the phonological representations.

While the idea of teaching new words in an isolated, phonological manner does not seem particularly useful (given the need for children to develop multiple representations to be able to understand and use a new word in context; Stackhouse & Wells, 1997), this consideration raises some possibilities around how we initially introduce novel words to children. For instance, it may be the case that children are able to achieve greater success with word learning if they are first introduced to the phonology of a new word in relative isolation, before bringing in additional information regarding other components (i.e., building up a complete *map* of a new word progressively). This could be the focus of further research.

Clinical Implications

In summary, the results showed that children with DLD exhibited an impaired capacity to encode incoming phonological information, but this differentially affected their nonword repetition and fast mapping abilities. In the fast mapping task, the children with DLD achieved relatively more success laying down an accurate phonological representation if the words were shorter. This has implications for informing targeted intervention strategies for word learning for children with DLD, such as ensuring the provision of visual information to facilitate the development of a semantic representation that supports the establishment of a more stable form–meaning map (Alt & Plante, 2006). Additionally, given that children with DLD struggled most with longer novel words, strategies need to be trialled that support their success for establishing multisyllabic words that exceed the bounds of their phonological STM capacity. This could include scaffolding a child into a new concept by first teaching a shorter word to build understanding (Alt, 2011). Previous research also suggests that children with DLD benefit from a greater number of exposures to a novel word to effectively learn it (Rice et al., 1994), and investigation into whether this strategy may assist with offsetting phonological STM weaknesses would be beneficial.

Our findings also reinforce the utility of the nonword repetition task as a clinical marker of the disorder (Bishop et al., 1996; Botting & Conti-Ramsden, 2001); however, differential performance across the word lengths should be considered, and performance should be carefully interpreted in light of other areas of potential impairment that may contribute to global difficulties repeating nonwords of all lengths (Ellis Weismer et al., 2000). Given the general similarities in performance on both nonword repetition and fast mapping in the children, we suggest that nonword repetition has predictive value in understanding a child's potential word learning capabilities, and is therefore a helpful tool in devising directions for therapy (Conti-Ramsden et al., 2001).

Limitations and Future Directions

A key limitation in the study was our use of a single outcome measure to assess fast mapping (i.e., a production task). Previous research suggests that production is the most difficult task for children to complete, as it requires the establishment of an output representation, which involves a "fine-grained knowledge of the phonemic structure of words" (Alt, 2011, p. 181). However, a different pattern of performance may emerge when using tasks that assess input processing, such as comprehension or recognition (Kan & Windsor, 2010); therefore, future research should include a range of assessments to measure fast mapping success. Another methodological limitation is that we did not include a one-syllable novel word in the fast mapping task, making it difficult to make a direct and comprehensive comparison between all word lengths on the fast mapping and nonword repetition tasks. Future investigations should modify the fast mapping methodology to allow for this. An additional consideration for future use of the fast mapping task is that the four-syllable stimuli included later-acquired fricatives (e.g., /s/ and /ʃ/; Bernthal et al., 2009). While we considered each child's phonological inventory in scoring these items, future use of the task may involve replacement of these items with those that contain only earlier-developing phonemes, in order to avoid the potential confound of delayed phonological or articulatory development.

While our research focused on short-term learning of novel words, in line with mapping theory it would be expected that deficits with initial encoding of novel word forms would adversely impact slow mapping (i.e., long-term word learning; Carey & Bartlett, 1978; Nash & Donaldson, 2005). However, to verify these assumptions, the trajectory of the word learning process should be explored longitudinally, which would further add to understanding of potential points of breakdown in this process in children with DLD (Bion et al., 2013). Further, our findings highlight the specific deficit in phonological learning experienced by children with DLD; however, it is conceivable that this would extend to their difficulty in establishing detailed semantic representations (Stackhouse & Wells, 1997). Future studies should therefore investigate factors that additionally impact semantic learning, and consider broader ramifications of poor phonological fast mapping on the establishment of other aspects of lexical development (Chiat, 2001).

Conclusions

Our findings reinforce the notion that phonological STM is an area of core deficit in children with DLD, and provides evidence that this factor considerably impacts their ability to establish phonological representations in the early stages of learning new words (Baddeley et al., 1998; Gathercole, 2006). Thus, the results help to clarify the nature of word learning problems in children with DLD, and provide additional support for the *limited capacity processing account* of DLD – that these children experience an inherent deficit in the processing, encoding, and storage of verbal information, and this affects broader aspects of their language development (Gathercole, 2006; Conti-Ramsden et al., 2001). In contrast to previous findings, however, our results suggest that the deficit experienced by children with DLD in nonword repetition may not be fully ascribed to a deficit in phonological STM capacity, as they experienced breakdown at all word lengths relative to their TD peers. Thus, these findings likely reflect the heterogeneity of the DLD population, and suggest that performance on nonword repetition and fast mapping tasks in children with DLD may be adversely affected by more general deficits in phonological encoding, phonological representations and/or poor perception, which warrants further investigation (Archibald & Joanisse, 2009).

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Chapter 6: Working, Declarative, and Procedural Memory in Children with Developmental Language Disorder

Chapter Overview

The current chapter presents a published empirical study involving a between-groups comparison of various memory systems in children with DLD and their typically developing peers (Study 4). Specifically, in light of previous research and key theories such as the Procedural Deficit Hypothesis, this study explores the working, procedural, and declarative memory systems, and the interrelationships between these systems, in this cohort of children. The data regarding verbal working memory are also used in the subsequent study in this programme of research (Study 5). The participants described in Studies 4 and 5 were recruited after the publication of the CATALISE recommendations for the diagnosis of DLD (Bishop et al., 2017). As such, the children with impaired language met criteria for DLD: Critically, these children had poor language, and were permitted to exhibit low nonverbal cognition skills (so long as they did not meet criteria for intellectual disability).

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Abstract

Purpose: Previous research into the working, declarative, and procedural memory systems in children with developmental language disorder (DLD) has yielded inconsistent results. The purpose of this research was to profile these memory systems in children with DLD and their typically developing peers.

Method: One hundred and four five- to eight-year-old children participated in the study. Fifty had DLD, and 54 were typically developing. Aspects of the working memory system (verbal short-term memory, verbal working memory, and visual–spatial short-term memory) were assessed using a nonword repetition test and subtests from the Working Memory Test Battery for Children. Verbal and visual–spatial declarative memory were measured using the Children's Memory Scale, and an audio-visual serial reaction time task was used to evaluate procedural memory.

Results: The children with DLD demonstrated significant impairments in verbal short-term and working memory, visual–spatial short-term memory, verbal declarative memory, and procedural memory. However, verbal declarative memory and procedural memory were no longer impaired after controlling for working memory and nonverbal IQ. Declarative memory for visual–spatial information was unimpaired.

Conclusions: These findings indicate that children with DLD have deficits in the working memory system. While verbal declarative memory and procedural memory also appear to be impaired, these deficits could largely be accounted for by working memory skills. The results have implications for our understanding of the cognitive processes underlying language impairment in the DLD population; however, further investigation of the relationships between the memory systems is required using tasks that measure learning over long-term intervals.

Introduction

Developmental language disorder (DLD) is a neurodevelopmental condition in which language problems occur in the absence of a known biomedical condition, intellectual disability, or acquired brain injury (Bishop et al., 2017). DLD has a prevalence rate of approximately 7%, and may co-occur with motor coordination disorder and attention deficit-hyperactive disorder (Bishop et al., 2017; Norbury et al., 2016). Hallmark features of DLD include impairments in morphosyntax (e.g., use of past tense verb forms; Leonard, 2014), and a body of literature also highlights deficits in vocabulary development (e.g., see Kan & Windsor, 2010). However, it is important to note that DLD is characterised by a heterogeneous profile of linguistic and cognitive abilities due to the complex aetiological basis of the disorder, which involves interactions between various genetic and environmental risk factors (Bishop, 2006; Pennington, 2006).

A body of research has explored the idea that language problems in DLD are related to memory impairments (Montgomery et al., 2010; Ullman et al., 2019). Specifically, the working, declarative, and procedural memory systems have been the focus of research, and while individual variation must be acknowledged, the research generally supports the hypothesis that the procedural and working memory systems are impaired in children with DLD, while the declarative memory system remains intact (i.e., the Procedural Deficit Hypothesis; Lum & Conti-Ramsden, 2013; Ullman, 2013; Ullman & Pierpont, 2005). In this study we aimed to replicate and extend the findings of previous research that has examined the relationships between these three memory systems in children with DLD (Lum & Bleses, 2012; Lum et al., 2012; Lum et al., 2010) in order to contribute to the knowledge base regarding the cognitive underpinnings of language impairments in this disorder.

The Relationship between the Working, Procedural, and Declarative Memory Systems

Evidence demonstrates the existence of neural systems for working, declarative, and procedural memory that are at least partly distinct, yet interacting (Baddeley, 2003; Squire, 2004; Ullman, 2004). The working memory system supports the short-term storage and processing of information and, according to Cowan's account, involves a *focus of attention* that holds a limited number of items, which are an activated subset of long-term memories (Cowan, 2005; Lum et al., 2012). Baddeley, on the other hand, proposes a model for the working memory system that subsumes multiple components, including the central executive, which coordinates and controls information processing in the phonological loop, visuospatial sketchpad, and episodic buffer (Baddeley, 2012; Baddeley & Hitch, 1974). The phonological loop and visuospatial sketchpad are slave mechanisms responsible for temporary storage of verbal and visuo-spatial information, respectively, while the episodic buffer binds information from multiple sources to form chunks of information for further processing (such as transference to long-term memory). Similar to Cowan's *focus of attention*, the central executive in Baddeley's model underpins these processes and has a limited attentional capacity (Baddeley, 2003).

In line with research by authors such as Alloway et al. (2009), Archibald (2018), and Gray et al. (2017), in the present study we adopt the term *verbal short-term memory* to refer to the capacity for hearing and temporarily storing phonological material (i.e., in the phonological loop) with no secondary processing involvement. This component is typically measured using simple span tasks, such as serial recall of digits or nonwords that increase in length (Estes et al., 2007; Henry & Botting, 2016). *Verbal working memory* is distinguished by the involvement of concurrent processing activity in the central executive (Archibald & Gathercole, 2006a). While verbal short-term memory tasks involve minimal processing demands, verbal working memory tasks engage both storage and secondary processing (Freed et al., 2012). For instance, backward digit recall tasks involve the brief retention of verbal information plus additional processing, to complete the higher-order cognitive task of repeating digits in reverse order. Research supports the distinction between verbal short-term memory and verbal working memory abilities (e.g., Gray et al., 2019), highlighting the importance of exploring these as distinct yet related processes. Finally, we use the term *visual–spatial short-term memory* to refer to the temporary storage of visual or spatial information (i.e., in the visuospatial sketchpad; Baddeley, 2012), which is measured using simple storage tasks (e.g., pattern recognition and pattern recall; Vugs et al., 2013).

While the working memory system maintains information "… in the order of seconds, declarative and procedural memory support long-term knowledge, and can store information for years" (Lum et al., 2012, p. 1139). Procedural memory is involved in the implicit acquisition, consolidation, and automatisation of cognitive, perceptual, and motor skills (West et al., 2017). Learning in this system typically requires multiple exposures to lay down the pattern, but once complete, the processes can be carried out with relative automaticity (Lum & Conti-Ramsden, 2013). On the other hand, declarative memory involves explicit (conscious) learning, storage, and retrieval of knowledge for semantic and episodic information (Lum & Conti-Ramsden, 2013). Knowledge can be encoded quickly from a brief instance, but is strengthened through consolidation, and with repeated opportunities to re-encode from the environment (Lum et al., 2015). The *declarative/procedural model* has been proposed to describe the involvement of these systems in language development. Specifically, procedural memory is thought to underlie the acquisition and use of grammar, particularly rule-based grammatical forms (e.g., regular past tense), and may also support the learning of regularities in language, including morphological and phonological forms (Ullman, 2004). The declarative system is proposed to be responsible for aspects of learning lexical information, specifically in the binding of conceptual, phonological, and semantic representations (Lum et al., 2010). Declarative memory may also play a compensatory role in grammar development in the face of impaired procedural memory (Ullman & Pierpont, 2005).

While working, declarative, and procedural memory have been explored as distinct systems, there is also evidence of their interactions (Quam et al., 2018; Ullman, 2004). The working memory system is suggested to function as a “gateway” for storing, organising, and retrieving material from long-term memory (Lum & Bleses, 2012). Specifically, research demonstrates evidence of a close relationship between working and declarative memory, particularly for the processes of encoding and retrieving information (Lum et al., 2015). Working memory supports encoding by temporarily storing novel stimuli as they are encountered, and also works to re-organise or chunk information prior to being encoded into declarative memory (Blumenfeld & Ranganath, 2006). Furthermore, evidence from functional magnetic resonance imaging studies shows that brain regions underlying working memory are activated during declarative memory recognition tasks, supporting the notion that this system works to temporarily hold and monitor information retrieved from declarative memory (Cabeza et al., 2002; Simons & Spiers, 2003). In contrast, the relationship between the working memory and procedural memory systems is less well understood; however, there is evidence that the basal ganglia and its associated circuitry (which underlies the procedural memory system), is also involved in the function of working memory (Ullman et al., 2019). This relationship has been demonstrated through various neuroimaging studies in typically developing and language-disordered populations (e.g., see Menon et al., 2000). However, further research is required to behaviourally examine the influence of working memory on learning during procedural memory tasks (Quam et al., 2018).

Working, Procedural, and Declarative Memory in DLD

A body of research provides evidence that children with DLD have an impaired ability to process verbal information in the working memory system (Archibald, 2017; Henry & Botting, 2016; Montgomery et al., 2010). Notably, however, most findings relate to group averages in empirical studies, and there is evidence that approximately 20-25% of individuals with DLD may be unaffected (Alloway et al., 2009; Lum et al., 2015). Groups of children with DLD tend to perform poorly on verbal short-term memory tasks (i.e., those that impose storage demands only; Archibald & Gathercole, 2006a). Findings of impaired task performance on measures such as digit recall and nonword repetition have been well-replicated; however, the effect for nonword repetition in children with DLD tends to be larger than for digit recall (Archibald & Gathercole, 2006a). This nonword repetition deficit is shown to be highly heritable in DLD, and as such is considered a reliable phenotypic marker of the disorder (Bishop et al., 1996). It is likely that the nonword repetition deficit reflects impairments in verbal short-term memory, as well as in other factors related to phonological processing, such as sensitivity to the phonological structure of words (Edwards & Lahey, 1998). Additionally, the nonword repetition deficit in children with DLD highlights the interdependent relationship between the working memory system and long-term memory. On many tasks evaluating the working memory system, the stimuli are familiar (e.g., digits), and so these items may activate in long-term memory to support temporary retention (Archibald, 2018). On nonword repetition tasks, the stimuli do not exist as complete chunks in long-term memory; however, segments of the stimuli (such as strings of phonemes and syllables) may be well-established. Children with limited vocabulary knowledge, however, have reduced quality of stored phonological representations in their lexical stores to support temporary processing in short-term memory (and subsequent production of the items), and as such they are subject to facing higher working memory load and poorer nonword repetition performance (Archibald, 2018; Munson et al., 2005a). It is important that research with DLD populations includes both digit recall and nonword repetition tasks to capture the potential effects of the different processing demands underlying these tasks.

There is evidence that children with DLD also exhibit deficits on more complex processing tasks (e.g., backwards digit recall) that engage verbal working memory (Gray et al., 2019; Henry & Botting, 2016). The observed deficit across verbal short-term and working memory tasks has been named a “dual deficit” (Archibald & Gathercole, 2006a), which describes an underlying impairment in the phonological loop capacity and in the use of flexible processing resources of the central executive (Archibald & Gathercole, 2006a; Baddeley, 2003; Ellis Weismer et al., 1999). However, this dual deficit has not been consistently found: Some research has highlighted intact verbal working memory in children with DLD but impaired verbal short-term memory (Archibald & Griebeling, 2016; Freed et al., 2012; Lum et al., 2015).

The visual–spatial domain of the working memory system has been less well investigated than the verbal domain for children with DLD. A body of research points to intact visual–spatial storage in these children (e.g., see Alloway et al., 2009; Archibald & Gathercole, 2006a; Archibald & Gathercole, 2006b, 2007a; Lum et al., 2012); however, other research highlights a significant impairment (see Vugs et al., 2013, for a meta-analysis). Additionally, longitudinal research demonstrates a slower pattern of development for visual–spatial storage in children with DLD (Hick et al., 2005). These findings support the suggestions that DLD is associated with more general limitations across verbal and visual–spatial domains within the working memory system, but further investigation is required.

As an extension of the *declarative/procedural model* of language, Ullman and Pierpont (2005) proposed the Procedural Deficit Hypothesis (PDH) to provide an account for memory deficits underlying the general profile of language impairments observed in DLD. The central claims of the PDH are that children with DLD have a core deficit in procedural memory, which underlies their hallmark impairment in grammar (Conti-Ramsden et al., 2015). Within this framework, the working memory system is also posited to be impaired as a result of its reliance on similar brain structures as the procedural system (as described above). Declarative memory, however, is theorised to remain intact, which would result in generally spared lexical processing (Ullman et al., 2019). There is considerable evidence of an impaired procedural memory system in children with DLD that emerges from research using a range of tasks (Krishnan et al., 2016). Most frequently, procedural memory has been assessed in children with DLD using serial reaction time (SRT) tasks (Nissen & Bullemer, 1987). These task paradigms usually emphasise visuomotor sequence learning, and typically involve repeated exposure to a visual stimulus on a computer display. Participants are required to select a target item from the visual stimulus, and reaction times are measured. Stimulus presentations usually follow a predefined sequence, and learning is indicated by reaction times decreasing across multiple exposures to the sequenced stimuli (Krishnan et al., 2016). Other measures of procedural memory include those that tap learning in the verbal domain, such as artificial grammar learning tasks and speech-stream tasks (Obeid et al., 2016).

Lum et al. (2014) conducted a meta-analysis of eight studies that used visuomotor SRT paradigms, which revealed a significant impairment in the groups of children with DLD compared to control groups (with a small effect size of 0.33). However, there was considerable variability among study findings. Six of the eight included studies reported statistically non-significant between-group differences, likely due to issues with statistical power (i.e., resulting from small sample sizes). Age of participants moderated performance (studies with younger children yielded larger effect sizes), as did the number of exposures to the stimulus sequences (i.e., there were smaller group differences in studies that provided a higher number of training exposures; Lum et al., 2014). More recently, Obeid et al. (2016) conducted an updated meta-analysis and found similar results. Across 14 studies that used a range of visuomotor and auditory-verbal procedural learning tasks (e.g., SRT tasks, artificial grammar, and probabilistic classification), children with DLD showed significantly poorer performance in comparison to control groups (effect size of 0.47). Contradictory to Lum et al. (2014), Obeid et al. (2016) did not find a relationship between age and task performance. Obeid et al. (2016) suggested that this may have been because the original effect was relatively weak, or because performance on different types of procedural memory tasks may develop differently with age. Furthermore, task modality did not moderate the effect sizes, with similar deficits in performance observed on tasks that were verbal or non-verbal in nature. It is clear that the pattern of performance on procedural memory tasks is complex, with varied factors influencing performance, and that further research with larger sample sizes is required (Obeid et al., 2016; West et al., 2017). Across these two meta-analyses, the influence of working memory on task performance was not investigated, which is a factor that may further contribute to task performance (Ullman, 2004). If performance on procedural memory tasks can be accounted for by working memory abilities, it could call into question whether the task adequately taps procedural memory, or whether performance is confounded by a reliance on the working memory system to aid the learning of sequences across trials (Hedenius, 2013). It may also be the case that procedural memory itself is unimpaired in children with DLD, but that problems with the short-term processing of information in working memory impedes the acquisition of skills in the procedural memory system (Krishnan et al., 2016).

With regards to declarative memory, the PDH predicts that this system is spared in children with DLD (Ullman & Pierpont, 2005). This has been well-supported with respect to learning in the nonverbal or visual–spatial domain (Bavin et al., 2005; Lum et al., 2012; Lum et al., 2010; Riccio et al., 2007). For instance, children with DLD tend to perform comparably on tasks requiring them to learn and recall visual and spatial information, such as dot locations or paired picture associates (Bavin et al., 2005; Cohen, 1997). In contrast, some research indicates that children with DLD perform poorly on declarative memory tasks involving verbal information (see Lum & Conti-Ramsden, 2013, for a meta-analysis). Notably, however, after controlling for verbal short-term and working memory abilities, these deficits are usually not apparent (Lum et al., 2015). This pattern was demonstrated by Bishop and Hsu (2015), whereby children with DLD (and groups of age- and grammar-matched peers) took part in a verbal declarative learning task (learning novel vocabulary items). The children with DLD performed poorly at the initial block of learning, and performance was predicted by verbal short-term memory scores. While their vocabulary learning scores remained below their age-matched peers over subsequent sessions, both groups made similar gains across sessions (Bishop & Hsu, 2015). These findings indicate that initial encoding during verbal declarative learning is impaired for children with DLD, but that declarative memory itself may be intact (Bishop & Hsu, 2015; Cabeza et al., 2002; McGregor et al., 2013a; Records et al., 1995). It is important that research examines the impact of verbal short-term and working memory skills when examining declarative memory in children with DLD in order to unpack whether an apparent declarative memory deficit may be accounted for by impairments within the working memory system (Lum et al., 2015).

The interactions between the working, procedural, and declarative memory systems are complex, yet only a handful of studies have examined all three systems in the same cohort of children with DLD (Lum & Bleses, 2012; Lum et al., 2010, 2012). In this series of studies, groups of children with DLD (ages ranging five to 11 years), and their age-matched typically developing peers were assessed on a variety of measures of the working, declarative, and procedural memory systems. There is some inconsistency between the study findings. For instance, Lum et al. (2010) observed statistically significant group differences on the verbal declarative memory task, even after controlling for receptive vocabulary and nonword repetition scores. Similarly, Lum et al. (2012) found that the children with DLD had significantly poorer verbal declarative memory performance, and the group difference remained significant after controlling for performance on a battery of working memory tasks (but with a smaller effect size). In two of the studies (Lum et al., 2010, 2012), the groups of children with DLD performed significantly less accurately than their peers on the SRT task (i.e., procedural memory), and Lum et al. (2012) went on to demonstrate evidence of this impairment even after holding working memory constant. In contrast, Lum and Bleses (2012) found that the children with and without DLD performed comparably on the SRT task. Given the small sample size, these null findings may have resulted from individual variation in memory impairment in children with DLD, and the fact that the sampled children had impairments only in expressive language (whereas other studies sampled children with severe deficits across expressive and receptive domains; Lum et al., 2010, 2012). These findings form an important foundation for exploring the relationships between the working, declarative, and procedural memory systems, and provide a strong motivation for further research.

The Current Study

The aims of the current research were to replicate and extend findings of Lum and colleagues (Lum & Bleses, 2012; Lum et al., 2010, 2012) by exploring the working, declarative, and procedural memory systems in a large cohort of children with and without DLD. In line with the PDH and with the findings of previous literature, we predicted that children with DLD would demonstrate significant deficits on the measures of verbal short-term memory, verbal working memory, and visual–spatial short-term memory. Additionally, we expected that children with DLD would perform poorly on a measure of procedural memory (an audio-visual SRT task), even after controlling for working memory abilities, which would indicate a deficit in procedural memory that cannot be accounted for by working memory problems. Furthermore, we predicted that children with DLD would demonstrate unimpaired declarative memory skills in the visual–spatial domain. Based on extant literature, we predicted that verbal declarative memory performance would be poor in the DLD group, but that a deficit would no longer be apparent after controlling for verbal short-term memory and verbal working memory (which would indicate that the declarative memory system itself is intact).

Method

Procedure

Following ethics approval, the researcher met with head teachers at two specialist language schools and three mainstream schools to discuss the research and obtain consent. Teachers for Year 1 and 2 classrooms distributed letters and consent forms to the parent or caregiver of eligible students. General eligibility criteria included that the child spoke English as a dominant language and had no significant problems with articulation or behaviour. Additionally, children with a biomedical diagnosis such as autism spectrum disorder, Down syndrome, or sensorineural hearing loss, were not eligible to participate in the current study (Bishop et al., 2017). Informed consent was obtained from each participant's parent or caregiver prior to testing.

Participant Selection Measures

Participants were individually assessed on a range of measures to confirm inclusion in the study. A hearing screen was conducted using a Grason-Stadler GSI 39 (Version 3) Pure Tone portable audiometer with a cut-off level set at 25dB at 250, 500, 1000, 2000, 4000, and 8000Hz (Doyle, 1998). The Diagnostic Evaluation of Articulation and Phonology Diagnostic Screen (which has high test-retest reliability, $r = .94$, and strong content and concurrent validity; Dodd et al., 2002) was individually administered to participants to briefly evaluate the presence of difficulties in the areas of articulation, phonology, and oromotor ability. The task involves labelling pictures, and any errors in phoneme production were identified. The Core Language subtests from the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel et al., 2006b) were administered to evaluate overall oral language ability and to confirm inclusion in the study. The Core Language Score is derived from performance across four subtests: Concepts and Following Directions, Word Structure, Recalling Sentences, and Formulated Sentences. This composite score is used to make decisions about the presence or absence of a language disorder. It provides a measure of a range of oral language abilities, including interpreting oral directions, recalling and imitating sentences, using morphological rules, and formulating grammatically and semantically correct sentences (Semel et al., 2006b). The Primary Test of Nonverbal Intelligence (PTONI) was administered to evaluate nonverbal intelligence (IQ), and has strong reliability (e.g., internal consistency of r = .90– .95) and validity (Ehrler & McGhee, 2008). The task was designed for use with young children and requires them to examine a series of pictures and point to the item that does not belong in the series (Ehrler & McGhee, 2008).

Participants

One hundred and four children participated in the present study: 50 with DLD (36 boys, 14 girls) and 54 with typically developing (TD) language (30 boys, 24 girls). The mean age for the DLD group was 6 years 11 months, and for the TD group was 6 years 10 months. Demographic information and performances on the participant selection measures for each group are presented in Table 6.1.

DLD Group

The participants for the DLD group were recruited from two publicly-funded specialist language development schools in the metropolitan area of Perth, Western Australia. These children had already been clinically diagnosed as having DLD 6–24 months prior to participation in the current study. This clinical diagnosis process involved assessment from a speech-language pathologist, with evidence of the following criteria: scores of at least 1.25 standard deviations below the mean on the Core Language Score, Receptive Language Index, and/or Expressive Language Index on the CELF (either the Preschool or Fourth Edition, depending on the age of the child) and poor performance on norm-referenced measures of expressive grammar and narrative retell (e.g., the Bus Story; Renfrew, 2010). At the time of initial diagnosis, informal teacher and parent developmental and behavioural questionnaires were also completed to gather information about each child's functional communication and social–emotional development. A diagnosis was supported by evidence that the child's language difficulties were having a functional impact on communicative success and academic progress (Bishop et al., 2017). To confirm diagnosis, the children were also assessed by a registered psychologist and did not fall within the "intellectual disability" range, as indicated by a standard score of above 70 on the Wechsler Intelligence Scale for Children (Wechsler, 2016).

Table 6.1

Participants' Demographic Features and Means and Standard Deviations on Participant Selection Measures

Variable	TD, *n* = 54			DLD, *n* = 50			Comparison of means	
	M	*SD*	Range	*M*	*SD*	Range	*t*	*d*
Age in months	82.04	7.61	70–98	83.54	7.64	71–104	1.00	0.23
CLS[a]	101.26	11.86	86–134	64.16	11.55	40–85	-16.14*	3.16
PTONI[a]	102.93	18.96	76–140	87.40	15.20	70–141	-4.62*	0.90

Note. TD = typically developing; DLD = developmental language disorder; *t* = independent samples *t*-test statistic; *d* = Cohen's *d* effect size; CLS = Core Language Score on the Clinical Evaluation of Language Fundamentals, Fourth Edition; PTONI = Primary Test of Nonverbal Intelligence.

[a]Standard scores are provided (tests standardised to a mean of 100 and an *SD* of 15).

$^*p < .001$.

Upon their recruitment to the current study, each child was re-evaluated on a small battery of measures by the primary investigator to confirm their current suitability for inclusion in the DLD group. The criteria outlined by Bishop et al.

(2017)[2] were used: Each child was required to attain a composite standard score of 85 or less on the Core Language subtests of the CELF-4 (see Table 6.1 for descriptive statistics, aggregated by group). This criterion has high sensitivity (1.00) and specificity (0.82) for identifying the presence of a language disorder (Semel et al., 2006b). As part of their enrolment at the language school, the children with DLD were subject to routine oral language assessments. Thus, if participants had been assessed using the CELF-4 within 12 months prior to the study, their Core Language Score was obtained and this assessment was not re-administered. Additionally, participants were not excluded based on low-range nonverbal IQ scores; however, in line with Bishop et al.'s (2017) criteria for DLD classification, there were no participants who achieved a standard score of 70 or below on the PTONI (Ehrler & McGhee, 2008).

TD Group

The children participating in the TD group were recruited from three mainstream schools in the same region and with similar demographic profiles as the specialist language schools. Participation in the TD group was confirmed by demonstrating test scores consistent with typical language development, as indicated by a Core Language Score of 86 or above. TD participants were also required to score above 70 on the PTONI. The application of these selection criteria resulted in groups that were comparable in age but significantly different in oral language skills (see Table 6.1 for results of independent sample *t*-tests). Of note, the groups were also significantly different on the PTONI; therefore, these scores were controlled for in statistical analyses to ensure group effects on the memory analyses were not a result of differences in nonverbal IQ.

Experimental Measures

Aspects of the working, declarative, and procedural memory systems were assessed using well-validated measures.

The Working Memory System. Three subtests from the Working Memory Test Battery for Children (WMTB-C; Gathercole & Pickering, 2001) were

[2] At the commencement of the current study, the publication of the CATALISE research had recently become available (Bishop et al., 2017). As such, these updated criteria were followed to ensure the children selected as participants would suitably represent DLD in the context of the literature on this population.

administered. These subtests have high reliability and validity (e.g., inter-tester reliability: r = .86–.90; Gathercole & Pickering, 2001). Verbal short-term memory was assessed using the Digit Recall task, which involves hearing, temporarily storing, and repeating random strings of digits that increase in length. Verbal working memory was evaluated using Backwards Digit Recall, in which the child listens to a string of digits and repeats them in reverse order. Visual–spatial short-term memory was tested using the Block Recall subtest, which involves the child sitting in front of an array of randomly-placed blocks. The examiner taps the blocks (an increasing number of blocks are tapped as the test progresses) and then child taps the blocks in the same order (Gathercole & Pickering, 2001). Standard scores (standardised to a mean of 100 and an *SD* of 15) were used in the analyses.

In addition, verbal short-term memory was evaluated using the Nonword Repetition Test (Dollaghan & Campbell, 1998). This task involves the child hearing, encoding, temporarily storing, and then recalling nonwords that increase in length. The stimuli were pre-recorded in accordance with the guidelines for pronunciation outlined by Dollaghan and Campbell (1998) and were played to participants via noise-cancelling headphones. Participant responses were scored online using the percentage of phonemes (PPC) method, and were audio recorded for later checking and re-scoring. Scoring procedures outlined by Dollaghan and Campbell (1998) were followed. A trained research assistant (a speech-language pathologist and PhD student) independently re-scored 20% of the nonword repetition tasks, and high reliability between scorers was found (r = .96).

Procedural Memory. Procedural memory was evaluated using an audio-visual SRT task developed by Kuppuraj et al. (2018). This SRT task was designed to measure implicit sequence learning in procedural memory, and it tests learning of two types of statistical dependencies: adjacent deterministic (i.e., patterns that follow the same, fixed sequence) and adjacent probabilistic (i.e., where certain sequences of trials occur more frequently than others, but do not follow a fixed sequence; Hsu & Bishop, 2014). In the 2018 study, the task was administered to adult participants, and high reliability and validity was demonstrated (full details regarding task design and administration with adults can be viewed in Kuppuraj et al., 2018). Subsequently, the task was adapted for use with young children with and without DLD (Kuppuraj, 2018).

The task was administered individually through the MATLAB program (Higham & Higham, 2010) and took approximately 30 minutes. The participant sat in front of a Microsoft Surface Pro 4 and held the accompanying stylus pen. Drawing from a bank of 61 monosyllabic common nouns (see Appendix F.1), six triplet sequences were created to use as stimuli for the learning task. Two of the triplets were adjacent deterministic sequences, two triplets were adjacent probabilistic sequences, and two were random (i.e., control) sequences (which did not follow a sequence). Full details regarding the construction of task sequences are presented in Kuppuraj et al. (2018).

The SRT task involved eight blocks of testing. The first six blocks of testing involved presentation of the six triplet sequences in pseudorandomised order. The participant listened as the first two items in a triplet were presented singly on the screen and named (using a synthesised British English voice). Then, the third item (the target) in the triplet sequence was presented in an array of four images, with the voiceover saying the name of the target noun. The participant was required to select the target from the array as quickly as possible using the stylus pen on the screen. Learning was indexed by measuring reaction times (i.e., how quickly the target item was selected in each triplet sequence). For adjacent deterministic and probabilistic sequences, reaction times were expected to decrease across the six learning blocks in comparison to the reaction times for random triplets, indicating that the patterns had been implicitly learned. In the seventh and eighth blocks of testing, the deterministic and probabilistic patterns were interrupted: The first two nouns in a previously patterned sequence were followed by a new noun. Reaction times were expected to increase to reflect the break in anticipated sequence (Kuppuraj et al., 2018).

The top left corner of the screen displayed visual rewards (coloured pictures) for faster responses to the target stimuli. A practice set with 20 items was presented prior to the eight blocks of training to familiarise participants with the image–name pairs and the method of selecting the target image using the stylus pen. Participants were not informed that patterns would occur but were encouraged to select the stimuli as quickly as possible (see Appendix F.1 for task script). Participants were allowed a break of up to two minutes at a time between blocks.

Data extraction for the SRT task involved the following procedure (Kuppuraj, 2018). At the individual level, two slopes were extracted for both the deterministic and probabilistic sequences: (a) the reaction time slope for the initial learning phase (i.e., across the first six testing blocks) and (b) the reaction time slope for the phase when the pattern was broken (i.e., the seventh and eighth blocks). For both of these sequence types, the regression discontinuity method was used to yield a *t*-statistic[3], which indicated if there was a significant difference in the two slopes. It was expected that the slope would decrease across the initial learning phase, with a rebound in the slope for the phase when the pattern was broken. This pattern was interpreted as evidence that learning had occurred. A *t*-statistic was calculated for each child for the deterministic and probabilistic conditions to quantify evidence of learning. A higher *t*-statistic suggested that the participant's reaction time increased in the phase where the pattern was broken, relative to the initial patterned phase. Two scores (a deterministic *t*-statistic and probabilistic *t*-statistic) were yielded for use in the analyses.

There were significant technological issues that impacted the administration of the SRT; namely, the program crashed when administering the task to 25 of the participants. After the program crashed, it was not possible to resume the task from the point where testing was interrupted. To avoid practice effects and the risk of collecting invalid data, the task was not re-administered in these cases, and partial data could not be used in the analyses. As such, we report the SRT results for a subset of the sample. SRT data were available for 79 cases (38 for the DLD group and 41 for the TD group). Descriptive statistics on relevant measures for the group of children whose SRT data were analysed are presented in Appendix F.2. There were no significant differences between the group of children whose data were included versus the group of children whose SRT data were excluded in age, $t(102) = 0.30$, $p = .77$, oral language skills, $t(102) = 0.84$, $p = .41$); nonverbal IQ skills, $t(102) = -0.03$, $p = .98$; Nonword Repetition, $t(102) = 0.01$, $p = .99$; Digit Recall, $t(102) = 0.80$, $p = .43$; Backwards Digit Recall, $t(102) = 1.65$, $p = .56$; or Block Recall, $t(102) = -0.58$, $p = .49$.

Declarative Memory. Declarative memory for verbal and visual information was tested using two subtests on the Children's Memory Scale (CMS), which has high reliabilty and validity (e.g., reliabiltiy coefficients: $r_s = .76–.91$; Cohen, 1997).

[3] The *t*-statistic demonstrates the ratio of difference between the slope for the learning phase and the slope for the phase when the pattern was broken.

The Word Pairs subtest evaluates declarative memory for verbal information, and involves the child hearing a list of 14 semantically unrelated word pairs (e.g., nurse–fire). The first word in a pair is provided, and the child is required to recall the second word. This process is repeated across three trials and the total number of correctly recalled words summed across the trials provides a *Learning* score. The child then recalls as many word pairs as possible without prompting (this score is summed with the *Learning* score to create a *Short Recall* score). After approximately 30 minutes, the child is asked again to recall all word pairs (*Delayed Recall*). Finally, they are presented with the 14 word pairs alongside 14 distractor pairs and indicate whether they recognise the word pair from the initial learning session (*Delayed Recognition*).

The Dot Locations subtest was used to measure visual–spatial (nonverbal) declarative memory (Cohen, 1997). This task involves the child looking at a picture of randomly placed dots three times. After each exposure, the picture is removed and the child recreates the picture using small tokens (*Learning*). After a distractor picture, the child is asked to recreate the initial picture (that they had seen three times) from memory. This score is summed with the *Learning* score to create a *Total Score*. Approximately 30 minutes later, the child recreates the same picture using the tokens (*Long Delay*). Standard scores (standardised to a mean of 10 and an *SD* of 3) were calculated for each of the Word Pairs and Dot Locations scores and were used in the analyses (Cohen, 1997).

Results

A series of multivariate analysis of variance (MANOVA) procedures were conducted to examine between-group differences across measures of working, procedural, and declarative memory. As noted in the Method, nonverbal IQ significantly differed between the groups. Furthermore, there were significant correlations between nonverbal IQ and each of the memory constructs (correlations are reported in Appendix F.3). As such, each MANOVA was re-run as a MANCOVA (with nonverbal IQ entered as a covariate), in order to ensure group differences were due to language status and not nonverbal IQ abilities. Further exploratory MANCOVAs were run to explore the relationships between the memory systems and are detailed below. The main effects of the MANOVA and MANCOVAs are reported in Table 6.2. Summary scores (aggregated by group) for the memory measures and post-hoc tests for each analysis are included in Tables 6.3, 6.4, and 6.5. Full tables including the effects of the covariate factors are included in Appendix F.4.

Working Memory

Four measures of the working memory system were included in the MANOVA: Nonword Repetition, Digit Recall, Backwards Digit Recall, and Block Recall. A significant multivariate effect of group was obtained for working memory; Wilks' $\lambda = .42$, $F(4, 99) = 33.79$, $p < .001$, partial $\eta^2 = 0.58$. Critical α level was set at .0125 for univariate analyses. Children with DLD performed significantly worse across all four measures of working memory, all with large effect sizes (see Table 6.3; Cohen, 1988). This analysis was re-run with the inclusion of nonverbal IQ as a covariate. The MANCOVA showed a significant multivariate group effect with a large effect size, Wilks' $\lambda = .49$, $F(4, 98) = 25.40$, $p = .001$, partial $\eta^2 = 0.51$ (see Table 6.2). Post-hoc univariate tests revealed significant differences on all subtests after controlling for nonverbal IQ, with a small-to-medium effect for visual–spatial short-term memory and large effects for the verbal measures (see Table 6.3).

Finally, to further explore the presence of a "dual deficit" in both verbal short-term and working memory abilities (Archibald & Gathercole, 2006b), an ANCOVA was conducted to test whether children with DLD demonstrated significantly impaired Backwards Digit Recall performance (i.e., verbal working memory) after controlling for Nonword Repetition and Digit Recall scores (verbal short-term memory). The results showed a significant main effect for group, $F(1, 100) = 9.43$, $p = .003$, partial $\eta^2 = 0.09$.

Procedural Memory

A MANOVA was run to determine the effect of group on SRT performance. Two measures of procedural memory were included in the analysis: the deterministic pattern learning *t*-statistic and probabilistic pattern learning *t*-statistic. A significant multivariate effect of group was obtained with a large effect size; Wilks' $\lambda = .87$, $F(2, 76) = 5.59$, $p = .005$, partial $\eta^2 = 0.13$ (see Table 6.4). Follow-up univariate post-hoc tests, with a critical α level set at .025, revealed significant group differences for deterministic learning with a large effect size. No significant group difference was found for probabilistic learning. Examination of the group means indicates that both

Table 6.2

MANOVAs and MANCOVAs for Working, Declarative, and Procedural Memory

Memory system	Adjusting for	Wilks' λ	*F*	*p*	partial η^2	Observed power
Working memory	No covariates	.42	33.79	< .001	0.58	1.00
	NVIQ	.49	25.40	< .001	0.51	1.00
Procedural Memory	None	.87	5.59	.005	0.13	0.84
	NVIQ	.92	3.34	.041	0.08	0.62
	General WM	.98	0.81	.449	0.02	0.18
	NVIQ & General WM	.98	0.72	.492	0.02	0.17
Verbal declarative	None	.63	14.46	< .001	0.37	1.00
memory	NVIQ	.74	8.58	< .001	0.26	0.99
	Verbal ST/WM	.90	2.76	.032	0.10	0.74
	NVIQ & Verbal STM/WM	.97	0.87	.488	0.03	0.27
Visual–spatial	None	.96	1.46	.231	0.04	0.38
declarative memory	NVIQ	.99	0.30	.829	0.01	0.11

Note. The verbal short-term and working memory (Verbal ST/WM) factor was created using principal components analysis of three individual subtest scores (Nonword Repetition, Digit Recall, and Backward Digit Recall); the general working memory (General WM) factor was created using principal components analysis of four individual subtest scores (Nonword Repetition, Digit Recall, Backward Digit Recall, and Block Recall). NVIQ = nonverbal IQ (as measured using the Primary Test of Nonverbal Intelligence).

Table 6.3

Summary Scores for Measures of Working Memory

Dependent variable	Group means	DLD, *n* = 50			TD, *n* = 54			
		M	*SE*	95% CI	*M*	*SE*	95% CI	partial η^2
Nonword Repetition[a]	Unadjusted	72.45	1.60	[70.14, 74.76]	89.83	1.12	[87.61, 92.05]	0.53*
	Adjusted (NVIQ)	72.59	1.23	[70.15, 75.03]	89.79	1.18	[87.36, 92.04]	0.48*
Digit Recall[b]	Unadjusted	84.26	2.30	[79.70, 88.82]	102.63	2.21	[98.25, 107.01]	0.25*
	Adjusted (NVIQ)	84.93	2.42	[80.13, 89.73]	102.01	2.32	[97.41, 106.61]	0.19*
Backwards Digit Recall[b]	Unadjusted	73.84	2.08	[69.72, 77.97]	95.61	2.00	[91.64, 99.58]	0.07*
	Adjusted (NVIQ)	75.66	2.12	[71.46, 79.87]	92.92	2.03	[89.89, 97.96]	0.05*
Block Recall[b]	Unadjusted	86.10	2.60	[80.94, 91.26]	96.28	2.08	[91.31, 101.24]	0.36*
	Adjusted (NVIQ)	86.61	2.75	[81.16, 92.06]	95.81	2.63	[90.58, 101.03]	0.26*

Note. Adjusted group means were obtained while controlling for nonverbal IQ.

[a]Percentage of phonemes correct score reported.

[b]Standard scores reported (standardised to a mean of 10 and an *SD* of 3).

**p* < .0125 (using Bonferroni adjustment for four dependent variables).

groups performed close to floor level on this aspect of the SRT task; therefore, these non-significant group differences must be interpreted with caution as they may result from a lack of variability in performance due to task demands being too high for both groups of children.

In a follow-up MANCOVA, nonverbal IQ was included as a covariate. There was a significant multivariate group difference, Wilks' $\lambda = .92$, $F(2, 75) = 3.34$, $p = .041$, partial $\eta^2 = 0.08$. Post-hoc univariate tests showed a significant group difference for deterministic, but not for probabilistic, pattern learning (see Table 6.4). Given that procedural memory may rely on working memory (Ullman & Pierpont, 2005), and given the significant correlations between working and procedural memory scores (r_s ranged from .20–.66; see Appendix F.3), a single composite variable of all working memory scores was created ("general working memory") using principle components analysis. This lead to the creation of a single factor for use in the analysis. The solution explained 59.54% of the total variance. The factor loadings were: Nonword Repetition = .68, Digit Recall = .71, Backwards Digit Recall = .65, and Block Recall = .34. The MANCOVA with the general working memory factor included as a covariate yielded no significant multivariate group effect, Wilks' $\lambda = .98$, $F(2, 75) = 0.81$, $p = .449$, partial $\eta^2 = 0.02$ (see Table 6.2). A final MANCOVA with nonverbal IQ and the general working memory as covariates also yielded a non-significant main effect.

Declarative Memory

Visual Declarative Memory. Three scores for the Dot Locations subtest were included in the analysis: *Total, Learning*, and *Long Delay*. The MANOVA showed no statistically significant multivariate group effect, Wilks' $\lambda = .96$, $F(3, 100) = 1.46$, $p = .23$, partial $\eta^2 = 0.04$. Critical alpha level was set at .017 (to account for the three dependent variables) for univariate analyses. There were no significant group differences for any of the three aspects of visual–spatial declarative memory (see Table 6.5). These differences remained non-significant when controlling for nonverbal IQ.

Table 6.4

Summary Scores (t-statistics) for Measures of Procedural Memory

Dependent variable	Group means	DLD, *n* = 38			TD, *n* = 41			
		M	*SE*	95% CI	*M*	*SE*	95% CI	partial η^2
Deterministic pattern	Unadjusted	0.95	0.37	[0.21, 1.70]	2.69	0.36	[1.98, 3.41]	0.13*
	Adjusted (NVIQ)	1.15	0.38	[0.40, 1.90]	2.51	0.36	[1.79, 3.23]	0.08*
	Adjusted (General WM)	1.40	0.45	[0.51, 2.30]	2.28	0.43	[1.43, 3.13]	0.03
	Adjusted (NVIQ & General WM)	1.46	0.45	[0.57, 2.34]	2.23	0.43	[1.39, 3.07]	0.02
Probabilistic pattern	Unadjusted	-0.83	0.24	[-1.31, -0.34]	-0.63	0.23	[-1.10, -0.17]	0.004
	Adjusted (NVIQ)	-0.94	0.25	[-1.43, -0.45]	-0.53	0.24	[-1.00, -0.45]	0.02
	Adjusted (General WM)	-0.86	0.30	[-1.46, -0.27]	-0.60	0.28	[-1.16, 0.03]	0.004
	Adjusted (NVIQ & General WM)	-0.90	0.30	[-1.49, -0.31]	-0.56	0.28	[-1.12, 0.01]	0.01

Note. The *t*-statistic demonstrates the ratio of difference between the slope for the learning phase and the slope for the phase when the pattern was broken. A higher *t*-statistic suggested that the participant's reaction time increased in the phase where the pattern was broken, relative to the initial patterned phase. Adjusted group means were obtained while controlling for NVIQ (nonverbal IQ) and/or the general working memory (General WM) factor.

**p* < .025 (using Bonferroni adjustment for two dependent variables).

Table 6.5

Summary Scores for Measures of Declarative Memory

Dependent variable	Group means	DLD, *n* = 50			TD, *n* = 54			
		M	*SE*	95% CI	*M*	*SE*	95% CI	partial η^2
Verbal								
Learning	Unadjusted	6.94	0.43	[6.09, 7.79]	8.78	0.41	[7.96, 9.60]	0.09*
	Adjusted (NVIQ)	7.22	0.45	[6.34, 8.11]	8.52	0.43	[7.67, 9.37]	0.04
	Adjusted (Verbal ST/WM)	7.46	0.49	[6.49, 8.43]	8.30	0.47	[7.37, 9.22]	0.01
	Adjusted (NVIQ & Verbal ST/WM)	7.95	0.53	[6.89, 9.00]	7.85	0.50	[6.85, 8.85]	< .001
Total	Unadjusted	7.14	0.40	[6.35, 7.93]	9.54	0.38	[8.78, 10.30]	0.16*
	Adjusted (NVIQ)	7.47	0.41	[6.67, 8.28]	9.23	0.39	[8.46, 10.01]	0.08*
	Adjusted (Verbal ST/WM)	7.83	0.44	[6.95, 8.71]	8.90	0.42	[8.07, 9.74]	0.02
	Adjusted (NVIQ & Verbal ST/WM)	8.20	0.48	[7.25, 9.16]	8.56	0.46	[7.65, 9.47]	0.002
Delayed Recall	Unadjusted	7.30	0.43	[6.46, 8.14]	9.69	0.41	[8.88, 10.50]	0.14*
	Adjusted (NVIQ)	7.56	0.44	[6.68, 8.43]	9.46	0.42	[8.62, 10.30]	0.08*
	Adjusted (Verbal ST/WM)	8.01	0.47	[7.07, 8.95]	9.04	0.45	[8.14, 9.93]	0.02
	Adjusted (NVIQ & Verbal ST/WM)	8.20	0.53	[7.16, 9.25]	8.86	0.51	[7.86, 9.85]	0.006

Table 6.5 continued.

Dependent variable	Group means	DLD, *n* = 50			TD, *n* = 54			
		M	*SE*	95% CI	*M*	*SE*	95% CI	partial η^2
Delayed Recognition	Unadjusted	7.40	0.41	[6.60, 8.20]	11.30	0.39	[10.52, 12.07]	0.32*
	Adjusted (NVIQ)	7.79	0.41	[6.98, 8.60]	10.94	0.39	[10.16, 11.72]	0.22*
	Adjusted (Verbal ST/WM)	8.36	0.43	[7.51, 9.22]	10.40	0.41	[9.59, 11.22]	0.09*
	Adjusted (NVIQ & Verbal ST/WM)	9.03	0.45	[8.13, 9.92]	9.79	0.43	[8.94, 10.64]	0.01
Visual–spatial								
Learning	Unadjusted	9.92	0.39	[9.13, 10.71]	10.82	0.41	[10.00, 11.64]	0.02
	Adjusted (NVIQ)	10.33	0.41	[9.51, 11.15]	10.45	0.40	[9.66, 11.54]	0.003
Total	Unadjusted	10.32	0.37	[9.57, 11.07]	11.37	0.41	[10.55, 12.18]	0.03
	Adjusted (NVIQ)	10.74	0.41	[9.95, 11.54]	10.98	0.39	[10.21, 11.74]	0.00
Long Delay	Unadjusted	11.18	0.32	[10.54,11.82]	11.92	0.26	[11.40, 12.44]	0.03
	Adjusted (NVIQ)	11.39	0.30	[10.78,11.99]	11.73	0.29	[11.15, 12.31]	0.01

Note. Standard scores reported (standardised to a mean of 10 and standard deviation of 3). Adjusted group means were obtained while controlling for NVIQ (nonverbal IQ), the Verbal Short-Term/Working Memory (ST/WM) factor, and/or the General Working Memory (WM) factor.

**p* < .0125 (using Bonferroni adjustment for four dependent variables).

Verbal Declarative Memory. Four Word Pairs scores were included in the MANOVA: *Total*, *Learning*, *Delayed Recall*, and *Delayed Recognition*. There was a significant multivariate effect of group, Wilks' $\lambda = .63$, $F(4, 99) = 14.46$, $p < .001$, partial $\eta^2 = 0.37$. Critical alpha level was set at .0125 for univariate analyses. The post-hoc univariate tests yielded significant group differences, with large effect sizes, on all aspects of the verbal declarative memory task (see Table 6.5).

In a follow-up analysis, nonverbal IQ was included as a covariate to account for the potential influence of nonverbal IQ differences on verbal declarative memory performance. There was a significant multivariate group difference, Wilks' $\lambda = 0.74$, $F(4, 98) = 8.58$, $p < .001$, partial $\eta^2 = 0.26$. Post-hoc univariate analyses showed significant between-group differences for Word Pairs *Total*, *Delayed Recall*, and *Delayed Recognition* (all with large effect sizes); however, there was no significant difference for *Learning* (see Table 6.5).

The Word Pairs subtest involves the temporary storage of verbal information, and so observed group differences may be accounted for by verbal short-term and working memory deficits (Lum et al., 2015). There were significant correlations (rs ranged from .28 to .66) between each aspect of Word Pairs performance and verbal short-term memory and working memory measures (Nonword Repetition, Digit Recall, and Backwards Digit Recall). As such, a single composite variable of verbal short-term and working memory ("Verbal ST/WM") was computed using principal components analysis, which lead to the extraction of a single factor. The three measures accounted for 71.70% of the variance in the verbal short-term and working memory factor. The factor loadings were: Nonword Repetition = .77, Digit Recall = .71, and Backwards Digit Recall = .68. The MANCOVA with the inclusion of the verbal short-term and working memory factor included as a covariate yielded a significant multivariate group effect, though with a smaller effect size than the analogous model (see Table 6.2). Results of the post-hoc testing revealed that there was only a significant group difference for Delayed Recognition after controlling for the verbal short-term and working memory factor (partial $\eta^2 = 0.09$). Finally, both nonverbal IQ and verbal short-term and working memory factor were included in the model, and the group effect was no longer significant.

Discussion

This study aimed to investigate the working, declarative, and procedural memory systems in a cohort of five to eight-year-old children with and without DLD. Collectively, the results show a complex profile of impairment across the memory systems, with working memory abilities largely accounting for the observed deficits on the declarative and procedural memory tasks.

Working Memory

The group of children with DLD exhibited impaired verbal short-term memory and verbal working memory in comparison to the TD group, even when controlling for nonverbal IQ. This is consistent with evidence from a range of studies indicating that children with DLD often exhibit impaired processing for verbal information in the working memory system (Estes et al., 2007; Henry & Botting, 2016; Montgomery et al., 2010). Groups of children with DLD have consistently exhibited significant impairments in the simple storage of verbal information, as evidenced by poor performance on tasks such as nonword repetition and digit span (Alloway et al., 2009; Archibald & Griebeling, 2016; Archibald & Gathercole, 2007a; Baird et al., 2010; Duinmeijer et al., 2012; Lum et al., 2012). Evidence for deficits in verbal working memory, however, has been less clear. While many studies have identified impaired verbal working memory (e.g., backwards digit recall) performance in children with DLD (e.g., Alloway et al., 2009; Baird et al., 2010; Marini et al., 2014), others found performance to be in the average range (Archibald & Griebeling, 2016; Freed et al., 2012; Lum et al., 2015). The results of the current study showed that children with DLD exhibited a verbal working memory deficit even after controlling for scores on verbal short-term memory tasks, providing support for the notion of a dual deficit in both the phonological loop capacity and the secondary processing requirements of the central executive (Archibald & Gathercole, 2006a; Baddeley, 2012). Of note, while verbal short-term and working memory impairments are often emblematic of children with DLD, some children (i.e., approximately one quarter; Archibald & Joanisse, 2009) may not demonstrate a deficit in this area. The current research, along with the body of previous research, examined performance according to group averages, and further work should explore individual variation in working memory performance (Bishop, 2006).

Notably, the results revealed large effect sizes for all three verbal short-term and working memory measures; however, the effect size for Nonword Repetition was considerably greater (partial $\eta^2 = 0.48$) than for Digit Recall (partial $\eta^2 = 0.19$) and Backwards Digit Recall (partial $\eta^2 = 0.05$). This likely reflects the bidirectional relationship between long-term memory (in this case, existing vocabulary knowledge) and working memory (Munson et al., 2005a), and further supports the use of nonword repetition as a sensitive clinical marker of DLD (Conti-Ramsden et al., 2001). While nonword repetition reflects verbal short-term memory capacity and the influence of long-term memory, additional phonological processes are likely involved, such as phonological sensitivity and analysis (Bishop et al., 1996; Duinmeijer et al., 2012); however, specific measures of these processing skills were not included in the current study and should be further investigated.

In the current study, children with DLD also demonstrated significant impairment in visual–spatial short-term memory after controlling for nonverbal IQ. This is consistent with a body of research evidencing impaired visual–spatial storage capacity in children with DLD (Vugs et al., 2013; Yim et al., 2016); however, these impairments have not always been found (Archibald & Gathercole, 2006b; Ellis Weismer et al., 2017; Henry et al., 2012; Hutchinson et al., 2012; Lum et al., 2012; Petruccelli et al., 2012). The current study had a relatively large sample size, and was therefore sufficiently powered to yield a significant group difference. Many previous studies have been more limited in sample size, and so issues with power may have led to non-significant findings (Vugs et al., 2013). This is an issue that may be compounded when sampling children from a population with inherently heterogeneous cognitive development (Pennington, 2006). The disparity among previous findings may also reflect participant factors, with Vugs et al. (2013) highlighting the relationship between oral language severity and deficits in the visual–spatial domain of the working memory system. Given the severity of the oral language deficits in the group of children with DLD in the current study, it is possible that we sampled a “subgroup” of this heterogeneous population that are more likely to exhibit both verbal and visual–spatial storage problems (Nickisch & von Kries, 2009).

Evidence suggests that there may not be a meaningful difference between performance on tasks measuring simple visual–spatial processing in working memory (such as Block Recall as in the current study) and tasks that include a secondary component that engages additional processing or manipulation (i.e., *visual–spatial working memory*; Archibald, 2018; Gray et al., 2017). Therefore, we did not specifically include a task that might tap visual–spatial working memory. Additionally, the task battery already involved a substantial time commitment for each child. However, further research should explicitly examine performance on these tasks in order to further develop an understanding of the cognitive profile of children with DLD, such as whether there may be a "dual deficit" for visual–spatial skills (Vugs et al., 2013). Our findings lend support to a domain-general deficit account for DLD, which proposes that children with DLD tend to demonstrate deficits within the working memory system that affect processing of both verbal and visual–spatial information (Archibald, 2017; Henry & Botting, 2016).

Procedural Memory

The children with DLD were impaired at the audio-visual SRT procedural memory task, even after removing the variance associated with nonverbal IQ. This finding is consistent with a body of research highlighting impaired procedural memory in groups of children with DLD (Desmottes et al., 2016; Lum et al., 2014; Obeid et al., 2016). Of note, in the current study the group difference was found to be significant only when learning deterministic patterns, but not probabilistic patterns. This aligns with previous research showing that children may perform differently depending on whether they are learning deterministic or probabilistic sequences (Gabriel et al., 2011); however, it is important to note that in the current study, the groups of children likely performed similarly for probabilistic sequences as a result of the task demands being too high (i.e., both groups performed close to floor level, as detailed in the Results section). Further refinement of this version of the SRT task is needed to reduce task demands and potentially unmask group differences, and to improve issues related to task administration that resulted in the loss of data for this task.

Neurological evidence links procedural memory with working memory via shared neural structures (e.g., the basal ganglia; Squire & Dede, 2015), yet there is little behavioural evidence of the relationship between these two systems in children with DLD (Conti-Ramsden et al., 2015). In the current study, the group difference for procedural memory was no longer significant after controlling for the working memory factor. This suggests that an apparent procedural learning deficit for children with DLD could be accounted for by working memory impairments, and challenges the notion of a core procedural memory deficit in DLD, as per the Procedural Deficit Hypothesis (Ullman, 2013). However, we are cautious of over-interpreting these results given that our SRT task measured learning over a relatively short time frame (i.e., 30 minutes). As such, while this SRT task was designed to reflect learning in the procedural memory system, performance in this group of children appears to more strongly reflect processing of the verbal and visual–spatial stimuli in working memory, rather than long-term retention and retrieval of information from procedural memory (Lum et al., 2010). It is also possible that this version of the SRT task afforded children the opportunity to use working memory strategies to bolster performance. That is, the child was instructed to select the third item in the patterned triplet as quickly as possible. If children became aware of repeated and predictable patterns, this may have resulted in the sequenced patterns being called into explicit awareness, thus engaging the working memory system (Ashby & Maddox, 2011; Ullman, 2013).

Notably, a handful of studies have also examined procedural memory while controlling for working memory (Conti-Ramsden et al., 2015; Hedenius, 2013; Lum et al., 2012). Contrary to the current findings, these past studies identified impaired procedural memory performance in the children with DLD, even after accounting for working memory. Individual variation in cognitive abilities likely contributes to variation in findings across studies (Bishop, 2006; Pennington, 2006). Additionally, the use of different versions of the SRT task may account for these inconsistencies. Specifically, the version of the SRT used in the current study involved an auditory-verbal component, whereas the previous studies used an SRT task limited to the visuo-motor domain (Conti-Ramsden et al., 2015; Hedenius, 2013; Lum et al., 2012). It is likely that the auditory component of our task resulted in higher engagement of the working memory system to support performance (Karuza et al., 2013). Future studies should aim to use measures of procedural memory that include training over longer learning intervals in order to further unpack the complex interactions between working and procedural memory in children with DLD.

Declarative Memory

Children with DLD demonstrated intact visual–spatial declarative memory. These results are supportive of the PDH (Ullman & Pierpont, 2005), and are consistent with a body of research showing intact declarative memory for visual–spatial information in groups of children with DLD (e.g., Baird et al., 2010; Bavin et al., 2005; Lum & Conti-Ramsden, 2013; Lum et al., 2012; Lum et al., 2010; Riccio et al., 2007). In contrast, the children with DLD exhibited impaired verbal declarative memory compared with their peers, and this pattern remained after controlling for nonverbal IQ. However, these group differences were no longer apparent after controlling for the verbal short-term and working memory factor and nonverbal IQ. This is consistent with Ullman and Pierpont's (2005) model, which posits that observable verbal declarative memory deficits are secondary to verbal working memory impairments.

A small body of research has explored the relationship between the working and declarative memory systems for verbal information in children with DLD. The current results were consistent with Lum and Bleses (2012), who found that group differences on a verbal paired associates task were no longer significant after accounting for verbal working memory. Similarly, Lum et al. (2015) found that verbal declarative memory was only significantly impaired in a group of children with DLD who had low verbal working memory. These findings are also consistent with Bishop and Hsu's (2015) suggestions that verbal declarative learning in children with DLD is impacted by deficits in the initial encoding of verbal information in the working memory system, but that retention in declarative memory itself remains intact. However, the results are inconsistent with those of Lum et al. (2010), who found significant group differences on verbal declarative memory remained after controlling for verbal short-term memory abilities (nonword repetition skills), receptive vocabulary, and nonverbal IQ scores. It is not clear the relative contribution of these varied factors on verbal declarative memory performance, and further research should systematically examine the unique impact of each of these variables on verbal declarative memory.

The current findings shed light on the relationship between the working and declarative memory systems for verbal learning, and provides further evidence that working memory supports the initial encoding of information, as well as recall of information from declarative memory (Blumenfeld & Ranganath, 2006; Cabeza et al., 2002). The relationship between declarative and working memory should be systematically explored in further research. Specifically, most research has evaluated declarative learning using relatively short learning and retrieval tasks (e.g., involving a 30-minute delay; Cohen, 1997); however, further research should explore whether children with DLD also experience deficits in the later stages of declarative learning (Lukacs et al., 2017; McGregor et al., 2013a).

Conclusions

Overall, the findings of the current study highlight deficits in the working memory system for young children with DLD in both the verbal and visual–spatial domains. Additionally, the findings are somewhat supportive of the PDH: Visual–spatial declarative memory appears to be intact in children with DLD, and verbal declarative memory impairments appear to be accounted for by verbal short-term and working memory, and nonverbal IQ. However, the results show that working memory accounted for procedural memory performance, which offers a potential challenge to the notion of a core deficit in procedural memory for children with DLD.

This study is one of a small number of studies that has simultaneously investigated working, declarative, and procedural memory systems in a group of children with DLD (Lum & Bleses, 2012; Lum et al., 2010, 2012). We acknowledge that a potential limitation arises from sampling the children with DLD from a specialist language school. As a result, these children may have had a more severe presentation of DLD than those attending mainstream schools. Previous research suggests that memory impairments may be related to the severity of oral language deficits (e.g., see Archibald, 2017), and so further research could further explore this in order to build understanding of cognitive variation in the disorder. Future research is also required to substantiate the pattern of findings from the current study using a more comprehensive battery of tasks (e.g., including tasks that tap visual–spatial working memory). Further research should also explore the implications of these findings for teaching and intervention programmes. While the impact of verbal short-term and working memory deficits on language development are well-documented, particularly for vocabulary acquisition (e.g., see Montgomery et al., 2010, for a review), problems with visual–spatial storage in the working memory system may further compound language learning difficulties (Archibald & Gathercole, 2006b; Vugs et al., 2016). For instance, visual–spatial storage may contribute to success in vocabulary development, especially when the novel words can be linked with a visual referent (e.g., when learning the name of a new object). That is, mapping the physical features of the visual referent to the phonological form of new words is likely facilitated by visual–spatial processing within the working memory system (Gray et al., 2020). Functionally, a combination of deficits in short-term and working memory for verbal and visual–spatial information may therefore have a significant impact on the ability to learn language (Gathercole, 2006).

While working memory intervention is the subject of controversy (Melby-Lervåg et al., 2016; Sala & Gobet, 2017), it is crucial that further research evaluate methods for effectively teaching and training children with DLD using strategies that minimise the demands on the working memory system, such as presenting fewer pieces of new information in learning tasks (Gillam et al., 2019). Given the apparent sparing of declarative memory, it might be the case that tasks such as vocabulary learning could be supported in children with DLD through the use of strategies that capitalise on declarative learning (e.g., explicit teaching and the provision of exposures over multiple days; McGregor et al., 2013a) and reduce working memory demands (e.g., first targeting shorter and less phonologically-complex words; reducing competing attentional demands; Lum et al., 2015). The development and use of these strategies holds potential for improving language outcomes for children with DLD.

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Addendum

While this research paper presented a detailed analysis of memory differences between children at a group level (i.e., children with DLD versus those with typical language), it is important to note that memory skills are highly subject to individual variation (Pennington, 2006; Ullman et al., 2020), as outlined in the Introduction of this paper. As such, further detail regarding individual variation in memory skills is provided here.

Individual differences were explored by examining the proportion of children in the DLD and TD groups that had clinically low performance on each of the memory measures (presented in Table 6.6). For the standardised measures of working memory, *clinically low* task performance refers to achieving a standard score of 85 or less; this applied to the memory domains evaluated using the Working Memory Test Battery for Children (Gathercole & Pickering, 2001). On the Children's Memory Scale (Cohen, 1997), *clinically low* referred to a scaled score of 7 or less. For the Nonword Repetition Test, *clinically low* was set at a percentage of phonemes correct (PPC) total score of less than 81. According to Dollaghan and Campbell (1998), children who scored above this PPC could be ruled out of the impaired range with a "high degree of confidence" (p. 1143). For the SRT task, which measured procedural memory, it was not possible to determine an impaired level of performance, as this task is in the early stages of development (Kuppuraj, 2018).

Within the DLD group, the majority of children had clinically low skills on the Nonword Repetition and Backwards Digit Recall measures (82%). Approximately half of the children with DLD also had low scores for Digit Recall, Block Recall, and the Word Pairs subtests. In contrast, a relatively smaller proportion (less than approximately one quarter) scored in the clinically low range on the Dot Locations subtests. In the TD group, approximately one quarter of the children scored in the clinically low range on the Backwards Digit Recall, Block Recall, and Word Pairs Delayed Recall subtest, while all other scores mostly fell above the clinically low range. Future research may explore the degree of variation within each child from test to test, in order to further develop understanding of individual variation in memory performance.

Table 6.6

Proportion of Children in Each Group in the Clinically Low Range on the Memory Measures

Memory domain	DLD (*n* = 50)	TD (*n* = 54)
	Individuals with a clinically low score (*n*; %)	
Nonword Repetition	41; 82%	3; 6%
Digit Recall	28; 56%	8; 15%
Backwards Digit Recall	41; 82%	14; 26%
Block Recall	28; 56%	16; 30%
Word Pairs		
Learning	26; 52%	10; 19%
Total	28; 56%	9; 17%
Delayed Recall	29; 58%	12; 22%
Delayed Recognition	24; 48%	5; 9%
Dot Locations		
Learning	12; 24%	11; 20%
Total	9; 18%	7; 13%
Long Delay	5; 10%	1; 2%

Note. Nonword Repetition Test (measure of verbal short-term memory; Dollaghan & Campbell, 1998); Digit Recall (verbal short-term memory), Backwards Digit Recall (verbal working memory), and Block Recall (visual-spatial short-term memory), all subtests from the Working Memory Test Battery for Children (Gathercole & Pickering, 2001); Word Pairs (measure of verbal declarative memory) and Dot Locations (visual-spatial declarative memory), taken from the Children's Memory Scale (Cohen, 1997).

Chapter 7: Word Learning and Verbal Working Memory in Children with Developmental Language Disorder

Chapter Overview

The current chapter (Study 5) presents an empirical investigation into the word learning skills of children with DLD and their typically developing peers. This research involved the same cohort of children as described in Study 4. The participants completed the novel word learning protocol that was developed in response to the findings from the scoping review (Study 1). This protocol was designed to investigate several key aspects of the word learning process, including the learning of novel word forms, word meanings, and the form-referent links. Furthermore, this protocol facilitated investigation of the dynamic process of word learning, according to the *encoding–retention* framework.

Another aspect of this study was to investigate factors that contribute to word learning impairment in children with DLD; namely, whether memory impairments may account for these deficits. Specifically, the results from Study 3 highlighted the significant predictive capacity of verbal short-term memory deficits in fast mapping the novel word forms in children with DLD. Furthermore, the findings from Study 4 highlighted deficits in the working memory system in children with DLD, while the declarative and procedural memory systems appeared intact once deficits in working memory were taken into account. In response to these findings, and the strong theoretical relationship that exists between word learning and the ability to process verbal information within the working memory system, the current study includes verbal short-term and working memory as a potential moderating factor of the association between DLD and poor word learning performance.

The next section of this chapter presents the accepted manuscript version of an article entitled, *'Word learning and verbal working memory in children with developmental language disorder'*, published on 31st March 2021 by Sage Journals in the journal of Autism and Developmental Language Impairments. This article is available online:
https://www.sciencedirect.com/science/article/pii/S0021992417302678?via%3Dihub

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Abstract

Background and aims: Previous research into word learning in children with developmental language disorder (DLD) indicates that the learning of word forms and meanings, rather than form-referent links, is problematic. This difficulty appears to arise with impaired encoding, while retention of word knowledge remains intact. Evidence also suggests that word learning skills may be related to verbal working memory. We aimed to substantiate these findings in the current study by exploring word learning over a series of days.

Methods: Fifty children with DLD (mean age 6;11, 72% male) and 54 age-matched typically developing (TD) children (mean age 6;10, 56% male) were taught eight novel words across a four-day word learning protocol. Day 1 measured encoding, Days 2 and 3 measured re-encoding, and Day 4 assessed retention. At each day, word learning success was evaluated using *Naming*, *Recognition, Description*, and *Identification* tasks.

Results: Children with DLD showed comparable performance to the TD group on the *Identification* task, indicating an intact ability to learn the form-referent links. In contrast, children with DLD performed significantly worse for *Naming* and *Recognition* (signifying an impaired ability to learn novel word forms), and for *Description*, indicating problems establishing new word meanings. These deficits for the DLD group were apparent at Days 1, 2, and 3 of testing, indicating impairments with initial encoding and re-encoding; however, the DLD and TD groups demonstrated a similar rate of learning. All children found the retention assessments at Day 4 difficult, and there was only a significant group difference for *Recognition.* Finally, verbal working memory emerged as a significant moderator of performance on the *Naming* and *Recognition* tasks, such that children with DLD and poor verbal working memory had the lowest level of accuracy.

Conclusions: This study demonstrates that children with DLD struggle with learning novel word forms and meanings, but are unimpaired in their ability to establish new form-referent links. The findings suggest that the word learning deficit may be attributed to problems with encoding, rather than with retention, of new word knowledge; however, further exploration is required given the poor performance of

both groups for retention testing. Furthermore, we found evidence that an impaired ability to learn word forms may only be apparent in children who have DLD and low levels of verbal working memory.

Implications: When working with children with DLD, speech-language pathologists should assess word learning using tasks that evaluate the ability to learn word forms, meanings, and form-referent links to develop a profile of individual word learning strengths and weaknesses. Clinicians should also assess verbal working memory to identify children at particular risk of word learning deficits. Future research should explore the notion of optimal intervention intensity for facilitating word learning in children with poor language and verbal working memory.

Introduction

Developmental language disorder (DLD) is a neurodevelopmental condition that affects approximately 1 in 14 children (Norbury et al., 2016; Tomblin et al., 1997). DLD is characterised by persistent language problems that cannot be attributed to a biomedical condition, such as autism spectrum disorder or intellectual disability; however, DLD may co-occur with conditions such as attention deficit-hyperactive disorder (ADHD; Bishop et al., 2017). DLD is heterogeneous, which results in varied profiles of impairment in oral language and cognitive skills (Bishop, 2006; Pennington, 2006). The study reported here focuses on word learning skills, which are often impaired in children with DLD and are shown to have a persistent and detrimental impact on academic, social–emotional, and vocational development (Kan & Windsor, 2010; Law et al., 2009; Spencer et al., 2017).

A Problem with Encoding or Retention?

Word learning, or the ability to learn and establish new lexical items in vocabulary, is a critical component of language development (Beck et al., 2013). There are robust links between vocabulary and academic development, including literacy (Castles et al., 2018) and mathematics (Spencer et al., 2017), as well as social–emotional outcomes in adolescence and adulthood (Armstrong et al., 2017). Learning a novel word relies on the development of the word form (*phonological representation*), meaning (*semantic representation*), and the creation of an association between the two (*form-referent link*; Chiat, 2001). Deficits in the ability to establish these foundational representations during word learning can have an adverse impact on the ability to recognise, and therefore further refine, word knowledge in future instances (Gray et al., 2020). This can have a detrimental effect on the ability to establish syntactic, orthographic, and articulatory representations, all of which are required for effective use of words in spoken and written contexts (Castles et al., 2018).

The course of developing new word knowledge has been conceptualised as a process that centrally involves the establishment of new information in memory. Under this framework, word learning is described as involving *encoding, re-encoding,* and *retention* (McGregor et al., 2020; Storkel et al., 2019). Encoding involves several processes, including sensory perception of the novel word, recognition of the stimuli as novel, and the direction of attention to relevant environmental detail (Kane et al., 2001). Subsequently, an initial memory trace of the new form and referent is encoded (Suzuki, 2006). Following the initial encoding process, the memory trace may be forgotten (i.e., if insufficient information was stored) or retained in long-term memory (Wilhelm et al., 2012). Retention of new words relies on consolidation processes, whereby the encoded memory trace transfers to long-term memory without external input. Consolidation is driven by the passing of time, and is facilitated by sleep (Stickgold, 2005). Through consolidation, the retained memory of the novel word can become more stable, and it can integrate with existing information in vocabulary (Davis & Gaskell, 2009; McClelland et al., 1995). Retention of the word may be further strengthened (i.e., stored in more detail over a prolonged period of time) through re-encoding, whereby the word is encountered again and retrieved from long-term memory, making it susceptible to change (Desmottes et al., 2016). Through re-encoding, word knowledge can be refined in response to further input (McGregor et al., 2013a; Nader & Hardt, 2009).

It has been suggested that word learning deficits experienced by people with DLD may be attributed to impaired encoding (McGregor et al., 2013a). This likely results in problems with the retained word knowledge in long-term memory; however, the processes involved in retention itself may remain intact (i.e., in declarative memory; Bishop & Hsu, 2015). Evidence for this *encoding deficit hypothesis* has been demonstrated in a series of studies with adolescents and adults with DLD (McGregor et al., 2013a, 2017a, 2017b, 2020a). Across these studies, college students with DLD and their typically developing (TD) peers were trained on novel word forms and their associated referents. All students received an equal number of training exposures, and learning was tested via recall tasks immediately after training and one week later. McGregor et al. (2013a) found evidence of poor encoding of word forms and meanings for the DLD group, as indicated by poor performance on the immediate post-training assessment tasks. Retention of the word meanings at the one-week interval appeared intact; however, the DLD–TD gap widened over this time for word forms, indicating a potential problem with retaining phonological information. In their subsequent studies, McGregor et al. (2017a, 2017b, 2020a) controlled for potential confounds on retention and demonstrated that word learning in the DLD group was characterised by poor encoding, yet intact retention. As a result, McGregor et al. (2020a) concluded that "encoding of word forms is the primary bottleneck to word learning among people with DLD" (p. 14).

There is also evidence of an encoding deficit in children with DLD. Bishop and Hsu (2015) found that eight-year-olds with DLD were significantly worse than their TD peers at learning the names of novel animals. This deficit was observed immediately after training, yet the rate of learning over a two-week period was similar, supporting the notion of intact retention but impaired encoding. In Haebig et al. (2019) and Leonard et al. (2019), five-year-old children with and without DLD learned a set of new words through retrieval practice, whereby the new word and a definition were introduced, and learning was reinforced through repeated opportunities to retrieve the name and definition from memory. In comparison to the TD children, those with DLD demonstrated poor accuracy when naming the newly-learned words after a five-minute interval; however, their rate of learning after a one-week interval was similar to the TD group (Haebig et al., 2019; Leonard et al., 2019). While these findings point to an encoding deficit in word learning, this hypothesis requires further substantiation, as some research has failed to show a deficit for children with DLD across both encoding and retention.

For instance, Gray and colleagues measured encoding and retention of novel words that had either high or low phonotactic probability and neighbourhood density (Gray & Brinkley, 2011; Gray et al., 2012). The results of both studies showed no significant difference between the TD and DLD groups for either encoding or retention of word forms. It is possible that methodological differences contributed to the mixed findings of Gray and colleagues in comparison to those from Haebig et al.

(2019) and Leonard et al. (2019). In particular, in Gray and colleagues' studies, participants engaged in four consecutive days of word learning through a supported learning context, followed by a fifth day of retention testing. In contrast, in Leonard and Haebig's studies, the children were provided with novel word training over two consecutive days (during which time encoding was tested), followed by a post-test retention task one week later. It is possible that the more frequent learning sessions provided by Gray and colleagues allowed the children with DLD to effectively establish and refine their knowledge of the novel words (Gray & Brinkley, 2011; Gray et al., 2012). Furthermore, their administration of the post-tests at one day, instead of one week, after learning may have meant that novel word forms and meanings were subject to less decay and/or interference between each of the new memory traces (Haebig et al., 2019; Leonard et al., 2019; Mainela-Arnold et al., 2010).

Theoretically, encoding deficits in children with DLD may be underpinned by deficits within the working memory system. According to Baddeley (2003), working memory is a capacity-limited system of interacting components responsible for temporary storage and processing of verbal and visual information. This system is responsible for facilitating the transfer of new information into long-term memory, and as such is linked strongly to vocabulary development (Gathercole & Baddeley, 1989). Specifically, the encoding of novel words is thought to be supported by the components of working memory that are concerned with processing verbal information (for simplicity, we refer to this as *verbal working memory*; Archibald & Gathercole, 2006a). Verbal working memory (WM) is likely to support encoding by directing and maintaining attention to the novel phonological stimulus and refreshing the echoic memory in the phonological loop, while processing other sensory input (such as contextual information about the word, e.g., physical features; Kane et al., 2001). Deficits with verbal WM are therefore proposed to contribute to problems with encoding, which would be expected to have a subsequent impact on the ability to store an accurate memory trace in long-term memory. However, it is likely that the long-term memory system itself (i.e., declarative memory) may be unimpaired (Bishop & Hsu, 2015; Lum et al., 2015). While verbal WM is thought to be primarily occupied with the initial stage of word learning (encoding), it may also be implicated with later retrieval and monitoring of word knowledge from long-term memory;

however, the link between these processes and verbal WM has not been empirically tested (Cabeza et al., 2002; Lum et al., 2015).

A Problem with Word Forms, Meanings, or Form-Referent Links?

Understanding the nature of the word learning deficit in children with DLD is complicated by the fact that word learning requires the development of various aspects of knowledge. We focus our investigation on the processes involved in learning nouns as they are typically concrete and non-relational, and are usually imageable (Skipp et al., 2002). At a minimum, learning nouns includes establishing the *word form*, *word meaning* (such as details about the physical features of the item), and a link between the two (i.e., the *form-referent link*; Gray et al., 2020). Difficulties with learning the word form have been well-evidenced in children with DLD (Kan & Windsor, 2010). The methods for evaluating word form learning are varied, and differ in their degree of linguistic demand. Frequently, knowledge of the word form is assessed using a naming task, which involves retrieving the word form for spoken production in response to seeing the item (Jackson et al., 2019b). Recognition tasks are also commonly used, requiring identification of the target from similar-sounding foils (Alt & Suddarth, 2012). Using such measures, studies have consistently shown that children with DLD have significant deficits learning novel word forms in comparison to control groups (Kan & Windsor, 2010), and there is strong theoretical support for the notion that verbal WM deficits underlie this impairment (Baddeley, 2003; Archibald, 2016). However, only a handful of studies have directly explored this relationship (Montgomery et al., 2010).

For instance, Alt and Plante (2006), Gray (2006), and Jackson et al. (2016) showed that nonword repetition performance significantly predicted naming accuracy at encoding. Additionally, Gray (2004) highlighted a significant link between nonword repetition performance and naming accuracy across several days of word learning. This suggests that verbal WM performance may also predict retention of novel word forms, and may be important in the process of retrieving word forms from long-term memory, and holding them active, in order to complete a naming task in the days following initial learning (Baddeley, 2003; Lum et al., 2015). However, further investigation is required to understand whether impairments in encoding, re-encoding, and retention may be ascribed to deficits within the working memory system. In contrast, Gray (2006) and Hansson et al. (2004) failed to find a link between verbal WM (measured using nonword repetition) and performance on a naming task. In these two studies, naming was measured following a single session of learning, and as such was largely a measure of encoding (McGregor et al., 2013a). The inconsistency in findings may reflect the fact that nonword repetition performance varies among children; some children with DLD show unimpaired nonword repetition skills, and some TD children are impaired at nonword repetition (Archibald & Joanisse, 2009).

Evidence suggests that children with DLD are also impaired at learning novel word meanings, as demonstrated by poor performance on tasks that are expressive (e.g., describing the appearance of the item; Alt & Plante, 2006) and receptive in nature (e.g., answering "Yes/No" questions about elements of meaning; Nash & Donaldson, 2005). These findings provide support for the notion that the word learning deficit in children with DLD is multifactorial, affecting the ability to develop new word forms and meanings (Nation, 2014). It is possible that verbal WM deficits contribute to problems with learning word meanings in children with DLD (Alt & Plante, 2006); however, previous research into this relationship is limited and the findings equivocal. For instance, Alt and Plante (2006) found a significant relationship, whereas Storkel et al. (2019) did not.

Finally, there is mixed evidence regarding the ability of children with DLD to learn form-referent links for novel words (McGregor et al., 2020). This aspect of word learning is usually evaluated using an identification task, which involves hearing the novel word and selecting the target from an array of items (Jackson et al., 2019b). While Gray (2004, 2005) and Rice et al. (1990, 1992, 1994) found that children with DLD performed poorly on this task, Rice et al. (2000) and Gray (2006) found comparable performance with control groups. Gray et al. (2020) highlighted that children may be able to perform accurately on identification tasks even if they have encoded and retained weaker phonological and semantic representations, because only partial knowledge is required to create a link between the word form and its appearance. The findings of previous research indicate that verbal WM is not associated with the ability to learn form-referent links (e.g., see Gray, 2004), which may reflect the assumption that learning form-referent links places minimal demands on the working memory system (Ullman et al., 2019). However, this relationship has been the subject of little previous research, warranting further exploration.

The Current Study

Overall, the literature suggests that the initial encoding stage of the word learning process is impaired in children with DLD, with retention remaining intact. However, this pattern of impairment requires further substantiation. Further evidence is also required to determine whether learning the word forms, word meanings, and/or form-referent links is problematic. Word learning deficits – especially those impacting the learning of the word form – are likely to be driven by deficits in verbal WM; however, further investigation into the nature of this relationship is required. Thus, the current study had two primary aims:

1. Using a four-day protocol, we aimed to identify whether a word learning deficit in children with DLD could be attributed to problems with initial encoding (Day 1), re-encoding (Days 2 and 3), or retention (Day 4). To determine whether learning the word forms, form-referent links, and/or word meanings is problematic for children with DLD, word learning was evaluated using four different outcome measures across the four-day protocol:
   - Knowledge of word forms was tested using *Naming* (an expressive task) and *Recognition* (a receptive task);
   - Knowledge of word meanings was evaluated using *Description*, and;
   - Knowledge of the form-referent links was evaluated using *Identification*.

   Based on previous literature, we predicted that the children with DLD would exhibit deficits at *Naming*, *Recognition*, and *Description*, indicating an impaired ability to establish novel word forms and meanings. In contrast, we predicted that these children would perform similarly to the TD group for *Identification*, indicating an intact ability to establish form-referent links. Furthermore, we hypothesised that deficits on the *Naming, Recognition*, and *Description* tasks would be apparent for the DLD group at Day 1, indicating deficits with initial encoding. Poor performance across Days 2 and 3 was also expected, which would reflect subsequent deficits in re-encoding as a result of poor initial encoding. We expected that the gap between the DLD and TD groups would not further widen at Day 4, which would indicate intact retention for the children with DLD (Bishop & Hsu, 2015; McGregor et al., 2020a).

2. Verbal WM impairments may be a key factor contributing to the word learning deficits of children with DLD (Archibald, 2016; Baddeley et al., 1998). There is

some evidence for this link with regards to the initial encoding of novel word forms, but the link between verbal WM to word meanings and form-referent links is unclear. Furthermore, to our knowledge very few studies have explored the influence of verbal WM across the stages of encoding, re-encoding, and retention (Gray, 2004; Montgomery et al., 2010). We predicted that verbal WM ability would moderate performance across the four days of word learning for the *Naming* and *Recognition* tasks, such that poor performance would only be observed in children who have impaired verbal WM; however, this was not expected for the *Description* and *Identification* tasks.

Method

Participants

The participants were involved in a broad programme of research that involved testing memory skills and word learning in TD children and those with DLD. The data regarding word learning are pertinent for this study and have not been previously reported. The data regarding the memory skills of this cohort are comprehensively reported in Jackson et al. (2020), and data regarding verbal WM skills are reported again in the current paper.

To qualify for this research programme, all children met the general criteria of speaking English as a primary language, with no significant history of hearing, articulation, or behavioural problems. No participant had a primary developmental condition that might account for their language disorder, such as Down syndrome or intellectual disability (Bishop et al., 2017). There were three children with DLD and one typically developing child who had a diagnosis of ADHD. All participants passed a hearing screen and the Diagnostic Evaluation of Articulation and Phonology (DEAP) Diagnostic Screen (Dodd et al., 2002). Children with DLD were recruited from two specialist language schools and TD children attended three mainstream primary schools.

Children recruited from the specialist language schools had all been clinically diagnosed with DLD 12–18 months prior to recruitment, and so a full battery of oral language assessments was not required. Where the Clinical Evaluation of Language Fundamentals – 4th Edition, Australian and New Zealand standardisation (CELF-4AUZN) had been administered in the past 12 months, those scores were obtained with parental permission (Semel et al., 2006b). Otherwise, general oral language skills were reassessed to confirm eligibility for the DLD group, using the Core Language Score subtests of the CELF-4^{AUZN}. All participants with DLD obtained a Core Language Score of 85 or less (≤ 1*SD* below the mean). The children recruited from the mainstream schools for the TD group were also assessed using the Core Language subtests and achieved a standard score of 86 or higher (i.e., within or above the average range). Summary statistics describing demographic details and scores on the participant selection assessments are presented in Table 7.1.

Additionally, all participants were assessed using the Primary Test of Nonverbal Intelligence (PTONI; Ehrler & McGhee, 2008) and achieved a standard score of above 70, ruling out the presence of an intellectual disability (Bishop et al., 2017). Participants were not excluded on the basis of low-range nonverbal intelligence (IQ) scores, in line with the CATALISE guidelines for the classification of DLD (Bishop et al., 2017). Differences between groups for these variables were evaluated using independent samples *t* tests. As expected, the DLD group had significantly lower scores than the TD group on the measure of general oral language (Core Language Score). The DLD group was also significantly lower on the PTONI. In their meta-analysis, Kan and Windsor (2010) reported nonverbal IQ as a significant moderator of group differences in word learning performance. As such, we controlled for nonverbal IQ in our statistical analyses to ensure that any observed group differences on word learning were not the result of nonverbal IQ differences.

Protocol

Data Collection. Recruitment and testing followed procedures approved by the Curtin University Human Research, Department of Education, and Catholic Education Office of Western Australia ethics committees. All tests were completed individually in a quiet school room during normal school hours. As previously stated, participants in the current study completed a range of tests as part of a larger research protocol (details reported in Jackson et al., 2020; Chapter 6). The tasks required for data collection for the current study were administered across seven individual testing sessions distributed over two consecutive weeks. The first week involved administering the participant selection measures in three 30-minute sessions, and the second week involved administration of the word learning task across four consecutive days (20-30 minute sessions).

Table 7.1

Demographic Features, Summary Statistics, and Group Comparisons for Participant Selection Measures

Domain	DLD (n = 50)		TD (n = 54)			
	M (*SD*)	Range	*M* (*SD*)	Range	*p*	*d*
Age in months	83.54 (7.59)	71–104	82.04 (7.56)	70–98	.081	0.20
CLS[a]	64.16 (11.47)	40–85	101.26 (11.79)	86–134	< .001**	3.19
Nonverbal IQ[a]	87.40 (15.20)	70–141	102.93 (18.96)	76–140	< .001**	1.08
Nonword Repetition[b]	72.45 (10.54)	49–93	89.83 (5.05)	80.21–99.31	< .001**	2.10
Digit Recall[a]	84.26 (17.35)	56–121	102.63 (14.90)	73–137	.018*	1.14
Backwards Digit Recall[a]	73.84 (13.04)	56–104	95.61 (15.91)	67–141	.011*	1.50
Verbal WM factor	-0.74 (0.81)	-2.42–0.76	0.69 (0.57)	-0.71–2.21	< .001**	2.04

Note. CLS = Core Language Score; Nonverbal IQ = standard score on the Primary Test of Nonverbal Intelligence; Verbal WM factor = verbal working memory factor, calculated using principal component analysis of scores on the Nonword Repetition, Digit Recall, and Backwards Digit Recall tasks.

[a]Scores are standardised to a mean of 100 and an *SD* of 15.

[b]Score is reported as percentage of phonemes correct.

*p < .05. **p < .01.

Materials. The word learning stimuli were eight novel words (pseudowords) derived from English syllables. A large portion of English words are multisyllabic (Balota et al., 2007), and word learning success can differ depending on word length (Jackson et al., 2019a). Thus, to capture variation in performance the stimuli included two items at one, two, three, and four-syllable lengths (see Appendix G.1). An additional two-syllable nonword was included as a practice item. Pseudowords were chosen to ensure there was no prior knowledge of the stimuli, and all had low phonotactic probability to reduce the possible bias of prior lexical knowledge on learning novel word forms (Gray et al., 2012). The stimuli did not include phonemes that the younger participants may not have developed by their chronological age, such as /θ/, /ð/, /v/, and /r/. There were no consonant clusters, to minimise articulatory complexity (Bowen, 2014). Each pseudoword was randomly assigned to a concrete referent (unfamiliar "alien" creatures) made from coloured modelling clay (see Appendix G.2). Thus, the stimuli were taught as proper nouns linked to the referent, which suited our aim of testing whether the word form, meaning, or form-referent link was problematic for children with DLD (McGregor et al., 2020a). The referents were designed to be maximally different with regards to physical attributes: Each item differed from the others in at least three physical features (body shape, body colour, leg colour, and number of eyes). Photos of each were integrated into an animated video using the Moovly online program (Moovly.com). A separate animation was created for each item and for each day of the protocol. The animations were narrated by a female Australian English speaker and administered individually via iPad. The procedures for training and administration of outcome measures are described below and detailed in Appendix G.3.

Word Learning Protocol.

Encoding and Re-encoding (Days 1 – 3). Day 1 (*encoding*) and Days 2 and 3 (*re-encoding*) all followed a similar procedure: The eight stimuli were presented in a training block, which was followed by the administration of four outcome measures (*Naming, Recognition, Description*, and *Identification*). The stimuli were presented in randomised order on each day for each participant. In the training block, the stimuli were presented one at a time. For each item, the word form was modelled four times in commenting phrases interleaved with semantic description about the body shape and colour of the legs. To ensure the participant was actively engaged, they were asked to imitate the word form, and regardless of their response, the examiner repeated the name to provide an additional exposure. Throughout the task, participants were not stopped from making extraneous comments, but were always redirected back to the task. At the start of Day 1, a practice item was presented to familiarise participants with the training procedure and outcome measures. A detailed description of the protocol is provided in Appendix G.3.

Outcome Measures. On Days 1, 2, and 3, the training task was followed by the administration of the four outcome measures. Each outcome measure inherently involves additional learning opportunities (i.e., through additional exposure and/or retrieval of the word); thus, the measures were administered in fixed order to ensure consistent learning opportunities prior to testing. The tasks were scored on-line within each session (using hard copy score forms) and were also voice recorded (using a Philips Audio Recorder) for later checking. Neutral feedback was provided on each task (e.g., "You're working well") with no feedback on accuracy. Twenty percent of the tasks were later scored by an independent second scorer (an experienced speech-language pathologist) blind to groups. There was high inter-rater reliability for scoring of each outcome measure (Naming r = .91, Recognition r = .98, Identification r = .99, and Description r = .95).

Naming. Participants were asked to say the name of each item to test their ability to produce the word form. If no response was given, participants were prompted, "Try and say any of the sounds in the name". Responses were phonetically transcribed, and accuracy evaluated using the percentage of phonemes correct (PPC) method (Dollaghan & Campbell, 1998). To ensure that naming performance was not limited by restrictions in the child's phonetic inventory, the child's performance on the DEAP screener (Dodd et al., 2002) and observations of their spontaneous speech were considered to identify consistent errors in their speech. These errors were scored as correct in their *Naming* responses; any errors producing phonemes that were in their phonetic inventories were marked as incorrect (Dollaghan & Campbell, 1998).

Recognition. A mispronunciation detection task involved identifying the correct word form from three phonologically-related foils (see Appendix G.4). The foils differed from the target according to (a) initial phoneme modification, (b) final phoneme modification, and (c) syllable modification (i.e., transposition of syllables, or an added random syllable for one-syllable items). The target and foils were randomly ordered for each item and participants were not informed about the ratio of correct and incorrect choices. The participant was required to make a decision about each option as it was presented, and they pressed a green or red button if they judged the option to be correct or incorrect (Alt & Suddarth, 2012). No feedback was provided on each judgement made by the child. One point was allocated for each correct response, yielding a maximum score of 4 per item (and a total maximum score of 32), and a percentage of *Recognition* accuracy was calculated for use in the analyses.

Identification. Knowledge of the word-referent link was tested using a task in which participants saw all eight target items displayed on the screen and heard the target word in the phrase, "Point to X". Participants made their selection by pointing to the item on the screen. Responses were scored as correct (1 point) or incorrect (0 points), yielding a total maximum score of 8. A percentage of *Identification* accuracy was calculated.

Description. Knowledge of the word meaning was evaluated by asking the child to describe the item's appearance ("What does X look like?"). During the practice task at the start of Day 1, participants were trained to provide four features in their descriptions. If an incomplete description was provided, the prompt, "What else?" was given, until the description included four features or no further information could be provided. Responses were transcribed, and one point was allocated for each correct semantic feature, yielding a maximum of 4 for each item (maximum score of 32). A percentage of *Description* accuracy was calculated.

Retention (Day 4). Retention of the novel words was tested approximately 24 hours after the Day 3 session for each participant. The *Naming*, *Recognition*, and *Identification* tasks were administered, but not the *Description* task as retention testing of either the word form or meaning would require exposure to the target information, thus confounding assessment. Administration of the three outcome measures was counterbalanced for each item across participants. The same scoring procedures as above were used and no corrective feedback was provided.

Dosage. Previous studies have developed word learning protocols with the aim of training to mastery, or evaluating effective training intensities to facilitate comparable word learning among DLD and TD children (e.g., McGregor et al., 2020a; Storkel et al., 2017b). The purpose for the current study, however, was not intervention; we aimed to provide each participant with the same training opportunities in order to afford a controlled comparison of word learning abilities.

On Days 1, 2, and 3 of the protocol, 8 exposures to the word form were provided (5 through training and 3 through outcome measure administration). Thus, prior to retention testing participants had received 24 verbal models for each item.

Verbal Working Memory. Three tasks were administered to evaluate verbal WM skills. Two subtests from the Working Memory Test Battery for Children (Gathercole & Pickering, 2001) were administered: (1) Digit Recall, which requires hearing, temporarily storing, and recalling strings of digits; (2) Backwards Digit Recall, which requires hearing and temporarily storing strings of digits, and then recalling these in reverse order. Together, both tasks give a good indication of a child's verbal WM capabilities (Archibald & Gathercole, 2006a). These subtests are standardised to a mean of 100 and an *SD* of 15. The Nonword Repetition Test (Dollaghan & Campbell, 1998) was also administered, which requires the oral repetition of nonwords that increase in length. Guidelines for pronunciation and scoring outlined by Dollaghan and Campbell (1998) were followed. As with scoring of the word learning *Naming* task, responses were scored using the PPC method while taking into account each child's phonetic inventory. Responses on this task were audio recorded and 20% of the tasks were later scored by the independent second scorer, with high inter-rater reliability (r = .93).

Verbal WM for this cohort of children was reported as part of a large battery of memory measures in Jackson et al. (2020). The results showed that the DLD group scored significantly lower than the TD group on all three measures. Furthermore, scores were significantly correlated with each other (r_s were .52–.69), indicating that these measures evaluated a similar construct. As such, principal components analysis was conducted to achieve data reduction and obtain a Verbal WM Factor (full details are provided in Jackson et al., 2020).

Results

Our first aim was to examine whether word learning impairments in children with DLD may be attributed to deficits in encoding or retention. As such, word learning was evaluated across a four-day protocol (Day 1: *encoding*, Days 2 and 3: *re-encoding*, Day 4: *retention*). Across the four days, we evaluated the word learning process using four outcome measures (*Naming, Recognition, Identification*, and *Description*) in order to identify whether children with DLD have deficits with learning the word form, meaning, or form-referent link. A series of four Generalised Linear Mixed Model (GLMM) analyses were run using IBM SPSS Statistics (Version 26). For the *Naming, Recognition,* and *Identification* analyses, participant was included as a random effect. Time (Day 1, Day 2, Day 3, and Day 4), Group (DLD, TD), and the interaction between Time and Group were included as fixed effects. As described in the Method section, we noted significant group differences for nonverbal IQ, so we adjusted for this. The fixed effects for the nonverbal IQ factor for each analysis are reported in Appendix G.5. The *Description* analysis involved the same random and fixed effects; however, there were only three time points (Day 4 retention testing was not conducted for this outcome measure, as described in the Method section).

The second study aim was to explore whether verbal WM abilities moderated performance on *Naming*, *Recognition*, *Identification*, and *Description* across the four-day protocol. To explore this aim, the same GLMM analyses as above were run, with the inclusion of the Verbal WM factor as an additional fixed effect, and the three-way interaction for Group × Verbal WM × Time.

There were low rates of missing data (<2% on all variables), and these data were missing completely at random, $\chi^2(52) = 40.91$, $p = .866$. Missing data were imputed using expectation maximisation. There were two univariate outliers but these were deemed genuine scores rather than errors in data entry (and were not more than 3*SD* away from their group mean). These data points were dropped and the analyses were re-run, but they did not have an impact on the results; therefore, the reported analyses used the full data set. Descriptive statistics for all analyses (disaggregated by group) are summarised in Table 7.2. Statistics for all follow-up contrasts are presented in Appendices G.6 and G.7.

Aim 1: Encoding, Re-encoding, and Retention of Word Forms, Form-Referent Links, and Meanings

Word Forms: Naming. The main effect of time was significant, $F(3, 407) = 140.85$, $p < .001$, partial $\eta^2 = 0.51$. Follow-up contrasts for the DLD group revealed a significant increase in naming accuracy from Days 1 to 2, and from Days 2 to 3. This was followed by a significant decrease from Day 3 to Day 4. The same pattern of results was observed for the TD group. Examination of the group averages at each day showed that by Day 3, the DLD group on average attained 67% accuracy and the TD children obtained 89%. At Day 4, both groups demonstrated evidence of some retention, with accuracy levels of 35% and 36% for the DLD and TD groups, respectively. It is noteworthy that there is no chance-level performance on this task given that naming requires retrieval of the word form from memory.

The main effect of group was significant, $F(1, 407) = 42.15$, $p < .001$, partial $ŋ^2 = 0.09$. To determine whether the group effect could be attributed to problems with initial encoding (Day 1), re-encoding (Days 2 and 3), or retention (Day 4), least significant difference (LSD) contrasts between the groups were examined at each time point. The DLD group had significantly lower naming accuracy than the TD group at Day 1 (initial encoding) and at Days 2 and 3 (re-encoding). At Day 4 (retention), there was no significant difference between any of the three groups. The Group × Time interaction was significant, $F(3, 407) = 12.40$, $p < .001$, partial $ŋ^2 = 0.08$ (see Figure 7.1A); however, it appears that this interaction was driven by the accuracy score for the TD group significantly dropping at Day 4, resulting in no group difference at this point.

Word Forms: Recognition. The main effect for time was significant, $F(3, 407) = 19.46$, $p < .001$, partial $ŋ^2 = 0.13$. For the DLD group, there was a non-significant increase in average recognition accuracy from Days 1 to 2, and a significant increase from Days 2 to 3. However, accuracy declined significantly from Days 3 to 4. For TD, recognition accuracy increased significantly from Days 1 to 2, Days 2 to 3, and then declined significantly from Days 3 to 4. By Day 3, the DLD and TD groups obtained average accuracy levels of 80% and 96%, respectively. At Day 4, while there was a significant drop in accuracy (to 74% for the DLD group and 93% for the TD group), the groups were still performing above chance level (i.e.,50%, given that on each trial, the child was able to answer “yes” or “no”). As with the *Naming* task, both groups showed a similar pattern of linear increase in *Recognition* accuracy across the encoding and re-encoding phases; however, they had difficulty maintaining that level of accuracy at the retention test.

Table 7.2

Descriptive Statistics for Group Performances on the Naming, Recognition, Identification, and Description Tasks

Protocol Day	Measure	Group	*M*[a]	*M*[b]	*SE*[a]	*SE*[b]	95% CI[a]	95% CI[b]
Day 1 (encoding)	Naming	DLD	49.59	60.80	2.81	2.28	[44.06, 55.12]	[56.32, 65.28]
		TD	75.05	69.47	2.29	3.57	[70.55, 79.54]	[62.45, 76.50]
	Recognition	DLD	72.27	77.80	1.84	1.91	[69.65, 76.90]	[74.05, 81.56]
		TD	88.41	86.13	1.08	1.95	[86.28, 90.54]	[82.29, 89.96]
	Identification	DLD	94.20	93.31	1.98	2.27	[90.31, 98.09]	[88.85, 97.96]
		TD	98.00	97.40	0.70	1.05	[96.62, 99.39]	[95.34, 99.46]
	Description	DLD	69.99	72.53	2.44	2.76	[65.19, 74.79]	[67.09, 77.96]
		TD	80.38	79.91	1.70	2.41	[77.03, 83.72]	[75.17, 84.64]
Day 2 (re-encoding)	Naming	DLD	56.75	66.03	2.81	3.09	[51.24, 62.27]	[59.96, 72.10]
		TD	84.72	79.71	2.22	3.08	[80.36, 89.08]	[73.66, 85.77]
	Recognition	DLD	75.78	81.35	1.86	1.92	[71.93, 79.23]	[77.57, 85.13]
		TD	93.79	92.54	0.91	1.30	[92.01, 95.57]	[89.98, 95.10]
	Identification	DLD	95.78	95.31	1.10	1.22	[93.62, 97.94]	[92.91, 97.71]
		TD	97.99	97.06	0.82	1.46	[96.16, 99.39]	[94.19, 99.93]
	Description	DLD	70.32	75.12	2.16	2.22	[66.07, 74.56]	[70.75, 79.49]
		TD	79.57	81.25	1.92	2.52	[75.78, 83.35]	[76.30, 86.21]

Table 7.2 continued.

Protocol Day	Measure	Group	*M*[a]	*M*[b]	*SE*[a]	*SE*[b]	95% CI[a]	95% CI[b]
Day 3 (re-encoding)	Naming	DLD	67.28	78.13	3.06	2.71	[61.26, 73.30]	[72.81, 83.46]
		TD	88.53	84.61	1.94	2.81	[84.71, 92.34]	[79.09, 90.13]
	Recognition	DLD	80.40	86.90	2.21	2.88	[76.06, 84.74]	[91.23, 92.57]
		TD	96.28	95.76	0.69	0.86	[94.92, 97.64]	[94.07, 97.45]
	Identification	DLD	97.91	97.88	0.92	1.13	[96.10, 99.71]	[95.30, 100.45]
		TD	98.28	97.84	0.59	1.10	[97.13, 99.44]	[95.65, 99.98]
	Description	DLD	74.19	78.97	2.10	3.12	[70.06, 78.32]	[76.82, 85.11]
		TD	84.23	84.35	1.41	1.82	[81.47, 87.00]	[80.77, 87.94]
Day 4 (retention)	Naming	DLD	34.71	39.15	2.87	2.81	[29.07, 40.35]	[31.54, 46.75]
		TD	36.00	31.95	2.11	3.87	[31.83, 40.14]	[25.42, 38.47]
	Recognition	DLD	73.96	81.16	2.51	3.05	[69.02, 78.89]	[75.17, 87.15]
		TD	92.81	92.15	0.89	1.44	[91.05, 94.57]	[89.32, 94.98]
	Identification	DLD	43.41	45.98	3.88	5.50	[35.78, 51.04]	[35.17, 56.79]
		TD	51.34	46.87	2.99	4.47	[45.45, 57.22]	[38.10, 55.65]

Note. 95% CI = 95% confidence interval [upper, lower]. All values indicate percentage of accuracy on the tasks.

[a]Values are from the first set of GLMM analyses, which included a fixed effect to control for nonverbal IQ.

[b]Values are from the second set of GLMM analyses, which included fixed effects to control for nonverbal IQ and verbal working memory.

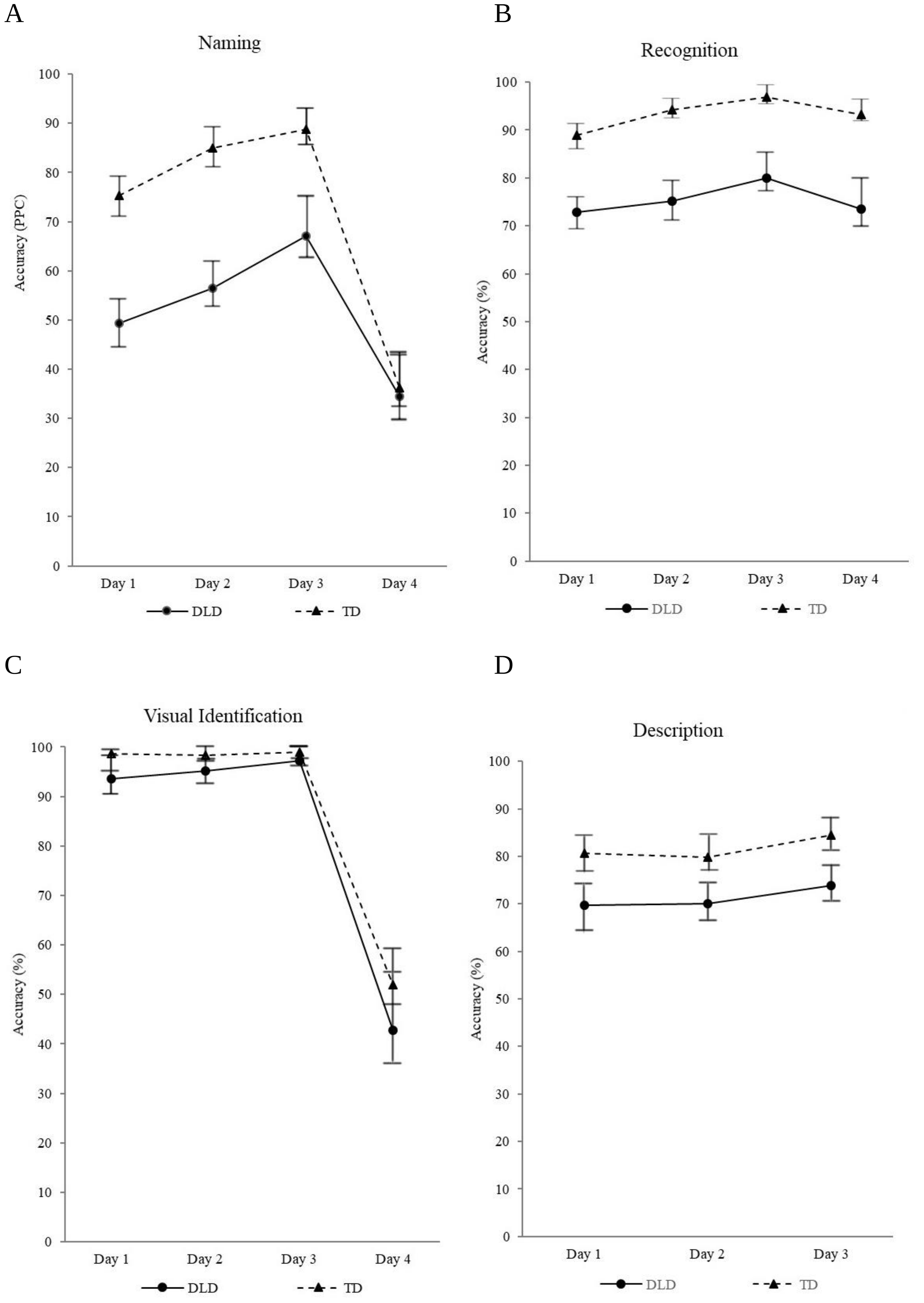
The group main effect was also significant, $F(1, 407) = 69.53$, $p < .001$, partial $\eta^2 = 0.15$, and follow-up contrasts showed a significant difference between the groups at all four time points. This indicates that the DLD group performed more poorly than the TD group across the tests of encoding, re-encoding, and retention. The Group × Time interaction was also significant, $F(3, 407) = 3.12$, $p = .026$, partial $\eta^2 = 0.02$ (see Figure 7.1B), which appeared to be driven by the DLD group dropping further in accuracy at Day 4 in comparison to the TD group.

Form-Referent link: Identification. The main effect of time was significant, $F(3, 407) = 139.09$, $p < .001$, partial $\eta^2 = 0.51$. Follow-up contrasts for the DLD group showed no changes in accuracy across the first three days. At Day 4, however, there was a significant drop in accuracy. The TD group demonstrated the same pattern. This decline in performance at Day 4 for both groups appeared to drive the time effect. While the groups exhibited a significant drop in accuracy for the retention test, both still performed above chance level (which was 12.5%) by attaining accuracy levels of 43% and 51% (DLD and TD, respectively), indicating some degree of successful retention after the 24-hour delay. The main effect of group was significant, $F(1, 407) = 5.72$, $p = .017$, partial $\eta^2 = 0.01$. However, follow-up contrasts showed no significant differences between the groups at any of the four time points, suggesting comparable encoding, re-encoding and retention for the groups. The Group × Time interaction was also non-significant (see Figure 7.1C).

Word Meanings: Description. There was a significant main effect for time, $F(2, 305) = 6.12$, $p = .002$, partial $\eta^2 = 0.04$. Follow-up contrasts for the DLD group showed a non-significant increase in description accuracy from Days 1 to 2, and a significant increase from Days 2 to 3. The TD group demonstrated the same pattern of growth. The group effect was significant, $F(1, 305) = 17.26$, $p < .001$, partial $\eta^2 = 0.05$. Follow-up contrasts revealed that the DLD group was significantly less accurate than the TD group across Days 1, 2, and 3, indicating deficits in encoding and re-encoding for semantic details. The Group X Time interaction was non-significant (see Figure 7.1D).

Figure 7.1

Performance on Measures of Naming, Recognition, Identification, and Description



Note. Panel A: Group × Time interaction on *Naming* ($p < .05$). Panel B: Group × Time interaction on *Recognition* ($p < .05$). Panel C: Group × Time interaction on *Visual Identification* ($p > .05$). Panel D: Group × Time interaction on *Description* ($p > .05$).

Aim 2: The Relationship Between Word Learning and Verbal WM

Each of the four GLMM analyses were re-run with the addition of the Verbal WM factor as a fixed effect. Notable results are described below, and findings for the fixed effects and interactions for each GLMM are presented in Tables 7.3, 7.4, 7.5, and 7.6.

Word Forms: Naming. After controlling for verbal WM, there was a significant main effect of time (see Table 7.3). The main effect of group was no longer statistically significant. The interactions for Time × Verbal WM and Group × Verbal WM × Time were also non-significant. However, the main effect of verbal WM was significant, as was the Time × Group interaction. The Group × Verbal WM interaction was also significant, indicating that verbal WM had differential effects on naming in the two groups.

Table 7.3

Main Effects and Interactions for the GLMM Analysis for Naming (Adjusted for Nonverbal IQ and Verbal Working Memory)

Fixed Effect	*F*	Degrees of freedom	*p*	partial η^2
Group	3.72	1, 399	.055	0.01
Time	63.02	3, 399	< .001**	0.32
Nonverbal IQ	0.40	1, 399	.526	0.001
Verbal WM	63.69	1, 399	< .001**	0.14
Group × Time	3.97	3, 399	.008**	0.03
Group × Verbal WM	4.41	1, 399	.036*	0.01
Time × Verbal WM	1.04	3, 399	.377	0.01
Group × Time × Verbal WM	0.74	3, 399	.526	0.01

Note. Nonverbal IQ = nonverbal intelligence, as measured on the Primary Test of Nonverbal Intelligence; Verbal WM = verbal working memory factor.
$^*p < .05$. $^{**}p < .01$.

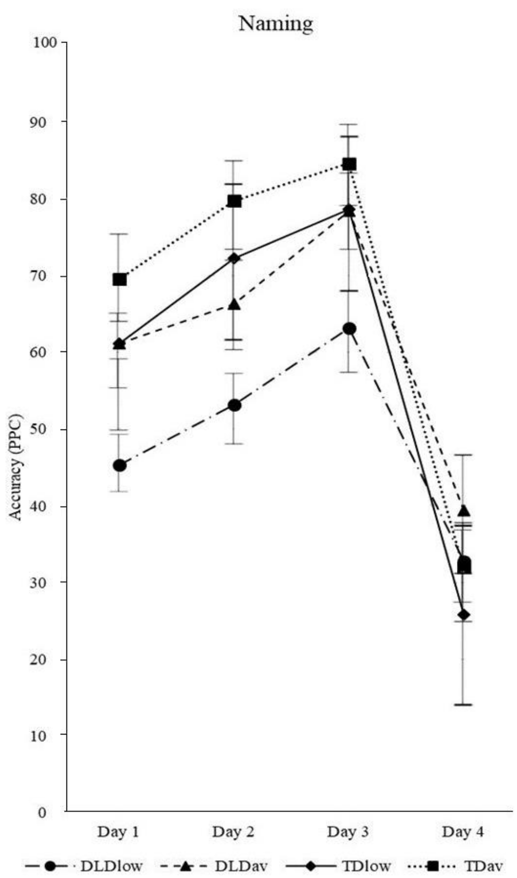
The interaction between group and verbal WM was probed by plotting the estimated values for the DLD and TD groups when verbal WM was at the mean level and at 1 *SD* below the mean. Figure 7.2A displays these estimated values for children with DLD and low verbal WM (“DLDlow”), children with DLD and verbal WM at the mean (“DLDav”), TD children with low verbal WM (“TDlow”), and TD children with average verbal WM (“TDav”).

Examination of the confidence intervals indicate that children with DLD and low verbal WM performed significantly worse than TD children (with average and low verbal WM), as well as those with DLD and average verbal WM, across the first three time points. However, performance was similar between all groups at Day 4. None of the other comparisons were significant, except for the DLDav group being significantly lower than the TDav group at Day 2 (confidence intervals are reported in Appendices G.8 and G.9).

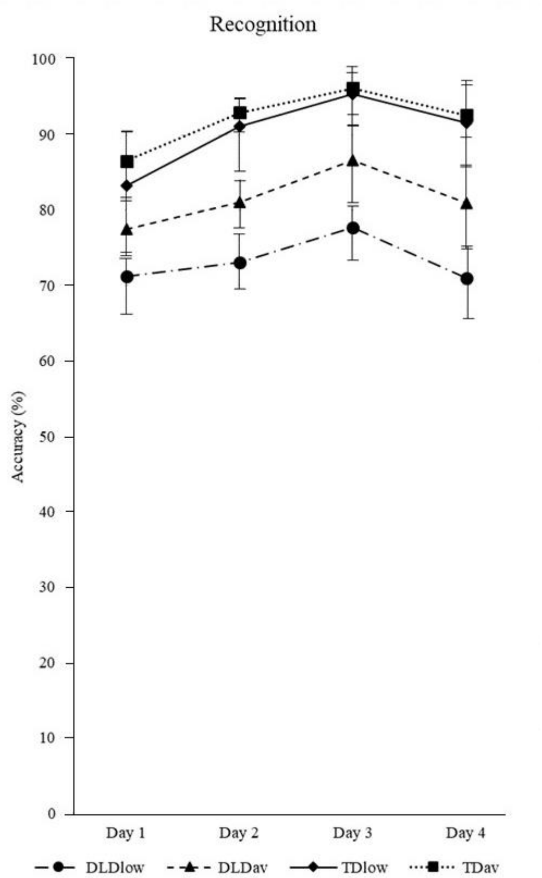
Figure 7.2

Estimated Performance on Naming and Recognition for Children with DLD and TD (Low versus Average Verbal WM)

A



B



Word Forms: Recognition. There was a significant main effect of time, group, and verbal WM (see Table 7.4). The two-way interactions for Time × Group and Time × Verbal WM were non-significant, as was the three-way interaction for Group × Verbal WM × Time. However, the Group × Verbal WM interaction was significant, indicating differential effects of verbal WM on recognition accuracy in the two groups.

As with the *Naming* analysis, to probe the Group × Verbal WM interaction, we plotted the estimated values for the DLD and TD children according to average and below-average verbal WM (i.e., DLDlow, DLDav, TDlow, TDav; see Figure 7.2B). Examination of the confidence intervals (reported in Supplemental Materials) showed that, across Days 1, 2, and 3, children with DLD and low verbal WM had significantly poorer recognition accuracy in comparison to the DLDav, TDlow, and TDav children. At Day 4, children with DLDlow were significantly lower than the TDlow and TDav children. Finally, the children with DLD and average verbal WM were significantly lower than TD children with average verbal WM across all four days.

Table 7.4

Main Effects and Interactions for the GLMM Analysis for Recognition (Adjusted for Nonverbal IQ and Verbal Working Memory)

Fixed Effect	*F*	Degrees of freedom	*p*	partial η^2
Group	17.48	1, 399	< .001**	0.04
Time	12.65	3, 399	< .001**	0.09
Nonverbal IQ	1.30	1, 399	.256	0.003
Verbal WM	20.74	1, 399	< .001**	0.05
Group × Time	0.88	3, 399	.451	0.007
Group × Verbal WM	8.30	1, 399	.004**	0.02
Time × Verbal WM	0.10	3, 399	.958	0.001
Group × Time × Verbal WM	1.05	3, 399	.370	0.007

Note. Nonverbal IQ = nonverbal intelligence, as measured on the Primary Test of Nonverbal Intelligence; Verbal WM = verbal working memory factor.

**p* < .05. ***p* < .01.

Form-Referent Link: Identification. The main effect for time was significant, which was likely driven by the significant drop in accuracy from Day 3 to 4 (see Table 7.5). The remaining main effects and interactions were all non-significant. The results suggest that verbal WM does not moderate performance for *Identification*.

Table 7.5

Main Effects and Interactions for the GLMM Analysis for Identification (Adjusted for Nonverbal IQ and Verbal Working Memory)

Fixed Effect	*F*	Degrees of freedom	*p*	partial η^2
Group	0.67	1, 399	.413	0.002
Time	66.21	3, 399	< .001**	0.33
Nonverbal IQ	3.78	1, 399	.052	0.009
Verbal WM	2.37	1, 399	.125	0.006
Group × Time	0.76	3, 399	.518	0.006
Group × Verbal WM	1.01	1, 399	.316	0.003
Time × Verbal WM	0.72	3, 399	.542	0.005
Group × Time × Verbal WM	0.10	3, 399	.958	0.001

Note. Nonverbal IQ = nonverbal intelligence, as measured on the Primary Test of Nonverbal Intelligence; Verbal WM = verbal working memory factor.
$^*p < .05$. $^{**}p < .01$.

Word Meanings: Description. The main effects of time and group were significant; however, the remaining main effects and interactions were all non-significant (see Table 7.6). The results suggest that verbal WM does not moderate performance for *Description* accuracy.

Discussion

In this study, we explored whether word learning in children with DLD is characterised by deficits in encoding, re-encoding, or retention. Across these stages, word learning was evaluated using four outcome measures that tested how well the children learned the novel word forms, form-referent links, and word meanings. Additionally, we explored verbal WM as a moderator of word learning performance. Overall, the children with DLD presented with an impaired ability to learn the word

Table 7.6

Main Effects and Interactions for the GLMM Analysis for Description (Adjusted for Nonverbal IQ and Verbal Working Memory)

Fixed Effect	*F*	Degrees of freedom	*p*	partial η^2
Group	4.97	1, 299	< .001**	0.01
Time	3.14	1, 299	.027*	0.01
Nonverbal IQ	0.39	2, 299	.532	0.002
Verbal WM	1.90	1, 299	.169	0.01
Group × Time	0.11	2, 299	.897	0.001
Group × Verbal WM	2.98	1, 299	.086	0.01
Time × Verbal WM	0.15	2, 299	.862	0.001
Group × Time × Verbal WM	1.91	2, 299	.149	0.01

Note. Nonverbal IQ = nonverbal intelligence, as measured on the Primary Test of Nonverbal Intelligence; Verbal WM = verbal working memory factor.

$^*p < .05$. $^{**}p < .01$.

forms (*Naming* and *Recognition*) and meanings (*Description*) compared to their TD peers. These deficits were apparent across the stages of encoding and re-encoding. In contrast, children with DLD exhibited an intact ability to learn the form-referent links (*Identification*). Notably, both groups exhibited problems at the retention stage for all aspects of word learning. Verbal WM significantly moderated the ability to learn new word forms, such that poor performance on the *Naming* and *Recognition* tasks was only identified in children who had DLD and low verbal WM.

The Encoding of Word Forms and Meanings is Problematic for Children with DLD

Consistent with our predictions, the group of children with DLD appeared to have intact skills for learning form-referent links of novel words (McGregor et al., 2020a). To create a link between the form and referent, the child needs to store only a partial representation of the word form in order to be able to identify the correct item upon hearing its label (Gray et al., 2020). Therefore, it seems that the children with DLD were able to store a sufficient level of phonological detail in order to create an association with the physical referent. This finding highlights the importance of evaluating word learning skills in children with DLD using a range of outcome measures, as *Identification* in isolation may fail to identify a deficit. It is also important to note that, if additional novel words were included, or if fewer exposures were presented, a group difference might become apparent. This may be further explored in future to build understanding of the nature of form-referent link learning.

Also in line with our hypothesis, the DLD group exhibited significant difficulties with learning novel word forms. These group differences were observed on both the *Naming* and *Recognition* tasks, indicating the deficit is apparent when assessing knowledge of the word form expressively and receptively (Jackson et al., 2019b). Furthermore, examination of *Naming* and *Recognition* performance showed a significant deficit for the DLD group at Day 1. Across Days 2 and 3, both groups showed a linear increase in accuracy on the tasks, with the between-groups gap remaining relatively stable. These findings indicate that difficulties with learning novel word forms originate at the initial encoding stage for children with DLD (Bishop & Hsu, 2015; McGregor et al., 2020a). Following encoding, both groups appeared to improve their knowledge of word forms through re-encoding, whereby the initially-encoded memory trace of each phonological representation was retrieved from long-term memory and further refined throughout the training task (McGregor et al., 2013a; Nader & Hardt, 2009). However, while the children with DLD clearly improved their word form knowledge through re-encoding, they did not catch up to their TD peers at this level of training intensity (Cepeda et al., 2006; Leonard et al., 2019). Difficulty encoding novel word forms has also been documented in a body of literature concerning children, adolescents, and adults with DLD (e.g., see Bishop & Hsu, 2015; Haebig et al., 2019; McGregor et al., 2013a, 2017a, 2017b, 2020a).

Notably, performance on the measures of *Naming*, *Recognition*, and *Identification* dropped significantly for both groups at retention testing (i.e., Day 4), and group differences largely disappeared. On each task, however, accuracy for each group was above chance level, indicating the retention of some new word knowledge in long-term memory (Dumay & Gaskell, 2007). It may be possible to interpret the low Day 4 scores as evidence that children with DLD have comparable retention skills to TD children. That is, while the children with DLD struggled to encode effectively, they generally managed to retain a similar level of knowledge about word forms and form-referent links as the TD children (Lukacs et al., 2017). However, it is also important to consider why performance of the TD group dropped dramatically at Day 4, to the point where the DLD–TD gap closed. We can infer that the TD children were able to most effectively take advantage of within-session opportunities to encode and re-encode across the three days of training. It is likely that stronger oral language skills facilitated their novel word learning within the training tasks, with previous evidence showing that children with typical language more effectively take advantage of strategies such as syntactic and semantic bootstrapping to learn novel words (Chiat, 2001; Eyer et al., 2002). Despite the effectiveness of within-session learning, the TD children had not retained as much information at Day 4 as training suggested. Perhaps what we observed was that training was advantageous for TD children; however, this did not necessarily translate into consolidated gains. That is, it seems that the children with and without DLD were similarly subject to memory decay after approximately 24-hours at this level of intensity (Lukacs et al., 2017).

While our findings may suggest ineffective retention across the groups, a higher degree of training intensity would likely have bolstered retention (Kan & Windsor, 2010). Recent research, such as Storkel et al. (2017b) and Leonard et al. (2019) – published after the design of our word learning protocol – showed that children with and without DLD demonstrated high levels of retention accuracy when provided with a higher degree of exposures than here. Leonard et al. (2019) provided 48 exposures over four sessions and focused on training to mastery. It is perhaps unsurprising, therefore, that the children in our study did not demonstrate effective retention in response to the provision of 24 exposures over 3 training sessions. As noted in the Methods section, however, the intention of the word learning protocol in this research was not to provide intervention, nor to ensure training to mastery. Instead, we aimed to explore patterns of word learning across different tasks (and the relationship with verbal working memory). Future research may adapt our word learning protocol to facilitate more effective retention. It would also be useful to evaluate retention after various interval periods (e.g., 24 hours, one week, one month) in order to further develop effective intervention strategies to ensure long-term retention of new vocabulary knowledge for children with DLD (McGregor et al., 2020a).

Finally, in addition to problems learning novel word forms, we predicted that children with DLD would struggle with establishing word meanings. Performance on the *Description* task highlighted a significant deficit for the DLD group; however, the small to medium effect size (partial $\eta^2 = 0.05$) indicates that the deficit was more severe for learning novel word forms. This is consistent with a body of previous research (Alt & Plante, 2006; Nash & Donaldson, 2005) and supports the notion of multifactorial word learning deficits in children with DLD (Gray et al., 2020). These findings also align with those of McGregor et al. (2013b), who found that children with DLD exhibit deficits in their vocabulary depth, such that their definitions of known words are sparser than those of children with typical language. While McGregor et al. (2013b) investigated semantic knowledge of already-established vocabulary, the findings from the present study highlight that these deficits in vocabulary depth likely originate with poor encoding of semantic knowledge in children with DLD. As a result of poor encoding, we found that there remained a significant gap in *Description* abilities between groups across Days 2 and 3, indicating that the children with DLD did not close the gap in semantic knowledge with this degree of training intensity (Storkel et al., 2019).

A key limitation of our study was the lack of inclusion of a retention test for *Description,* and so we are unable to comment on retention for either group with regards to learning word meanings. This should be the focus of future research. Additionally, the nature of the novel items were limited in range in that they were all proper nouns that differed by a few visual features. Future research should further explore a range of word types and use stimuli and outcomes measures that allow exploration into how well the children make connections in their semantic networks (Mainela-Arnold et al., 2010). These findings should also be substantiated in research tasks that more closely resemble everyday word learning situations, such as interactive book reading tasks (Storkel et al., 2017b).

The Influence of Verbal Working Memory

The second aim of our study was to explore whether verbal WM moderated performance across the four measures of word learning. As predicted, verbal WM significantly moderated performance on the tasks measuring word form learning (i.e., *Naming* and *Recognition*). Notably, poor performance was observed specifically for children with DLD who also had low verbal WM; this effect was magnified especially on the *Naming* task. These findings indicate that verbal WM is a key factor that drives the ability to learn novel phonological representations, supporting the theoretical claim that verbal WM acts as a “gateway” for vocabulary development (Baddeley et al., 1998; Lum et al., 2015). Specifically, the pattern of moderation across the four-day protocol suggests that verbal WM facilitates the initial encoding of word forms (Gathercole & Baddeley, 1989), and may also play a role in supporting the retrieval and monitoring of phonological information from long-term memory, as required in re-encoding and retention (Lum et al., 2012). Despite there being a theoretical link between verbal WM and learning novel word forms, only a handful of past studies have provided empirical evidence in support of this relationship (e.g., see Gray, 2004; Jackson et al., 2016). Furthermore, Gray (2006) and Horohov and Oetting (2004) failed to find a relationship between verbal WM and word form learning; however, this may have been the result of floor-level performances on naming tasks, resulting in a lack of variability among scores to yield a relationship (Kan & Windsor, 2010).

As predicted, verbal WM did not moderate performance on the *Identification* task. It seems that the act of establishing form-referent links bypasses weaknesses in verbal WM by placing minimal demands on phonological storage and retrieval (Gray et al., 2020). Notably, however, there was a lack of variability in performance across Days 1 to 3 that may have masked a potential association, which was due to both groups performing close to ceiling. Finally, verbal WM did not moderate learning of word meanings, which was consistent with our understanding of the theoretical contribution that verbal WM plays in the word learning process (Baddeley, 2003). Our findings indicate that stronger oral language skills (i.e., as in the TD group) facilitated better performance on the *Description* task. It is likely that existing vocabulary was used to establish new collections of semantic details for each item, and grammatical skills were drawn on to weave these details into descriptive sentences (Carr & Johnston, 2001).

Conclusions

The results of our study provide further evidence that word learning is a problematic aspect of language development for children with DLD, especially for those who have comorbid deficits in verbal WM. Our findings indicate that children with DLD are able to effectively establish novel form-referent associations.

However, they exhibit significant difficulties with developing accurate, detailed knowledge of the word forms and meanings. The problem with establishing novel word forms is compounded by poor verbal WM skills in children with DLD. Additionally, our findings support the notion that "encoding is the bottleneck that limits word learning" (McGregor et al., 2020, p. 14) in this population. While our results suggest that retention may be a relative strength, this requires further substantiation using a task that overcomes the limitations of our word learning protocol. The relationship between nonverbal IQ and word learning should also be explored in future research, as Kan and Windsor (2010) found this to be a significant moderator of word learning performance in their meta-analysis. While we controlled for nonverbal IQ, we did not have sufficient power to include an additional interaction, and therefore did not explore the nature of this relationship.

The findings of the current study are relevant for the assessment and treatment practices of children with DLD. Four specific implications emerge:

1) Word learning is a multifaceted process, and given the heterogeneous nature of DLD it is important for speech-language pathologists (SLPs) to consider that clients will present with an individual profile of word learning ability. SLPs should evaluate word learning using a range of outcome measures, and avoid using a single outcome measure such as *Identification*, which may give a false sense of word learning abilities. Understanding a child's word learning strengths and weaknesses would support the provision of individually-tailored intervention strategies (Storkel et al., 2019).
2) Children with DLD will require intervention that explicitly targets their ability to learn new word forms *and* meanings. Furthermore, they will likely benefit from a high degree of training intensity compared to their peers as a way of mitigating an encoding deficit (McGregor et al., 2013a), and long-term retention of word knowledge may be supported through the use of periodic review (McGregor et al., 2020a). Further research should explore whether there is an ideal treatment intensity that benefits children with DLD who have comorbid deficits in verbal WM (Archibald & Gathercole, 2006a). Various strategies and cues, such as the presence of orthography and gestural cues, may also prove useful for these children (Ricketts et al., 2015; Vogt & Kauschke, 2017a).

3) A theoretically-informed assessment battery for children with DLD should include measures of verbal WM (such as nonword repetition and digit span tasks). This information may allow SLPs to identify which children are at greatest risk of word learning impairments.
4) The finding that within-session learning may not transfer to retention of learned information has important implications for teaching new vocabulary in the context of intervention and classroom teaching. SLPs and teachers should monitor how effectively children have learned new words within sessions, and also after a delay (e.g., a day, week, and month) to determine whether effective retention has occurred.

Acknowledgements

We would like to sincerely thank the schools and students who contributed greatly to this research through their participation.

General Conclusions from Part Three and Implications for the Thesis

The findings from each of the three studies presented in Part Three contribute to understandings of memory, word learning, and the relationship between the two, in children with and without DLD. In Study 3, a specific aspect of word learning (*fast mapping* of the phonological form) was impaired in children with DLD when measured using a naming task. A specific aspect of the working memory system (*verbal short-term memory*) was significantly correlated with the ability to name newly learned words. This study provided preliminary support for the notion that the working memory system may underpin word learning impairments in children with DLD, which had been supported by contradictory evidence in previous literature (Alt & Plante, 2006; Gray, 2004, 2006; Hansson et al., 2004; Jackson et al., 2016). However, the investigation in Study 3 was limited in its evaluation of both word learning and memory (i.e., only measured fast mapping of phonological forms and verbal short-term memory). This limitation was apparent in light of the evidence for multifactorial deficits in memory systems and word learning across different domains in this population (Baird et al., 2010; Lum et al., 2012; Storkel et al., 2017b).

As such, prior to conducting a comprehensive investigation into the relationship between memory and word learning, further investigation of the nature of various memory systems in children with DLD was required. The objective for Study 4, therefore, was to profile skills in the working, declarative, and procedural memory systems in children with DLD and their typically developing, age-matched peers. Additionally, the relationships between these memory systems were investigated in order to explore the predictions of the Procedural Deficit Hypothesis (PDH). The findings offered a challenge to the PDH, largely in relation to procedural memory in children with DLD, and clarified the existence of significant deficits within the working memory system. These findings highlighted the need to explore the working memory system in the context of word learning in order to understand key factors underpinning vocabulary learning deficits in children with DLD.

In response, Study 5 included an investigation into verbal working memory as a moderator of word learning performance. This formed a key component of the detailed investigation of how children with DLD learn multifactorial aspects of word knowledge (word forms, meanings, and form-referent links), over a series of days (through the processes of encoding, re-encoding, and retention). The findings indicated that children with DLD have significant problems learning new word forms and meanings, and that these difficulties originate during initial encoding. Verbal working memory significantly moderated the children's ability to learn novel word forms, but not word meanings.

PART FOUR: General Discussion and Conclusions for the Programme of Research

Chapter 8: General Discussion

Chapter Overview

In this concluding chapter, the findings of the five individual studies that were presented in this thesis will be integrated and discussed in the context of relevant theory and past literature. The unique contribution made by this research will be highlighted, along with a description of key clinical implications. This chapter concludes with a discussion of the limitations of this programme of research and future directions for research in this area.

Research Overview

Children with developmental language disorder (DLD) experience multifactorial deficits in oral language (Bishop et al., 2017; Leonard, 2014). While these deficits may persist into adolescence and adulthood, early detection – aided by the use of accurate assessment methods – and the provision of targeted and intensive intervention, can mitigate these difficulties and facilitate successful outcomes for people with DLD (Ebbels, 2014; Norbury et al., 2008; Wright et al., 2018). In the case of vocabulary, people with DLD often experience deficits that contribute to significant functional impairments in the ability to communicate across oral and written modalities (Bishop et al., 2017; Snowling et al., 2016; Spencer et al., 2017). As such, the broad aim of this doctoral research was to develop an understanding of the nature of word learning deficits in children with DLD. Investigating memory skills in children with DLD was also identified as a research priority in order to build understanding of key factors that contribute to deficits with word learning (Tomas & Vissers, 2019; Ullman, 2013). This research was intended to inform understanding of theoretical underpinnings of DLD, as well as clinical practice and further research.

To address this broad aim, Studies 1 and 2 (presented in Part Two of this thesis) were designed to build understanding of current practices regarding the evaluation of word learning (in both experimental research and clinical practice). The findings of the scoping review of the literature (Study 1) revealed a substantial body of research featuring a variety of methodologies for evaluating word learning in the DLD population. In 2010, Kan and Windsor provided an overview of various evaluation methods as part of their meta-analysis of word learning abilities in children with DLD. Study 1 extended this by: reviewing an additional decade of research, including studies involving adolescents and adults, and; providing comprehensive detail on the methodological parameters of word learning assessment tasks. The scoping review aimed to profile the previous literature in this area, thus guiding the next steps of the current research programme, as well as the broader research field, in order to facilitate investigations of this critical area of language development in DLD. A gap in the literature that was identified was the paucity of research into the memory mechanisms underlying word learning deficits. In light of the considerable evidence that DLD is associated with deficits in memory (Archibald, 2016; Gray et al., 2019; Montgomery et al., 2010; Ullman & Pierpont, 2005), this gap in the literature was most pertinent to this doctoral research, and led to the development of the research aims regarding the investigation of memory and word learning in children with DLD (addressed in Part Three).

Despite the range of empirical evaluations that had been conducted into word learning, it was not clear whether these methods were being applied in clinical practice by speech-language pathologists (SLPs). As such, the first international survey of vocabulary and word learning assessment practices was conducted (Study 2). Participants were SLPs who work with a broad population of clients, rather than just those with DLD, in order to maximise participation and ensure findings were relevant to a broader range of clinicians. Clinician responses highlighted key themes related to concerns with a lack of access to assessments that are suitable for use with clients from culturally and linguistically diverse (CALD) backgrounds. Furthermore, while nearly all surveyed clinicians reported the use of static, standardised, and norm-referenced tests to evaluate existing vocabulary knowledge, fewer clinicians reported conducting word learning evaluations. In light of the scoping review (Study 1), which highlighted a considerable range of methods available to evaluate word learning in people with DLD, and other research that has involved different clinical populations (Alt et al., 2019; Tuomiranta et al., 2014), it was anticipated that more clinicians may have reported the use of such research-based methods in clinical practice. However, this was not the case. Very few (three) clinicians reported using a method of assessing word learning that had been developed for research purposes (Camilleri & Botting, 2013; Rice et al., 1992). As a way of facilitating the translation of research to practice, in Study 2, I included a bank of resources that clinicians may refer to in order to support their use of word learning evaluation approaches in clinic (presented in Appendix D.3). Additional future directions are described later in this chapter.

Throughout Studies 1 and 2, a key focus was on exploring *how* word learning assessments are conducted. Another key aim of this research programme was to build understanding of *why* word learning impairments occur, particularly for children with DLD. The scoping review discussed some previous research that explored the factors contributing to these impairments. Most commonly, previous research was framed by a *performance-based perspective*, in which novel word learning was considered in light of potential cognitive constraints that may contribute to poor performance (Evans, 2001; Kan & Windsor, 2010). Within this perspective, individual studies explored factors such as impairments in input processing (Ellis Weismer & Hesketh, 1993, 1998; Tallal et al., 1985), cognitive resource allocation (Smeets et al., 2014), and verbal short-term memory deficits (Adlof & Patten, 2017; Gray, 2006). While the evidence regarding input processing and resource allocation deficits in children with DLD is tenuous (Coady et al., 2005; Tallal et al., 1996), the literature on verbal short-term memory in children with DLD consistently demonstrates a substantial deficit (Archibald, 2017; Estes et al., 2007; Henry & Botting, 2016; Montgomery et al., 2010). However, the relationship between this aspect of the working memory system and word learning in children with DLD is equivocal, and therefore required substantiation (Alt & Plante, 2006; Hansson et al., 2004). Furthermore, in light of mounting evidence that DLD may be characterised by impairments across a range of memory systems (Lum et al., 2014; Ullman & Pierpont, 2005), it became clear that, in order to understand *why* word learning is difficult for children with DLD, investigation of a range of short and long-term memory systems was required. Thus, the aim of exploring the function of memory and its relationship with word learning in children with DLD was established. This was the focus of the three studies presented in Part Three.

Study 3 was a preliminary exploration of the relationship between word learning and memory, examining associations between verbal short-term memory and fast mapping of the phonological form. This built on earlier work completed prior to my doctoral programme, in which I found that young children with DLD exhibited deficits with the initial stages of learning novel word forms, which correlated with scores on a nonword repetition task (Jackson et al., 2016). The results of Study 3 extended these findings by showing that children with DLD were unimpaired when learning shorter words; instead, deficits were observed for longer (i.e., three and four-syllable) items. This likely resulted from impairments in verbal short-term memory capacity that led to the critical loss of phonological information during the word learning process (Alt, 2011). The findings from Study 3 also helped to clarify the role of existing vocabulary in learning novel word forms, showing that receptive vocabulary was a significant predictor of the ability to name newly-learned words. This supported the notion of a reciprocal relationship between verbal short-term memory and vocabulary (Archibald, 2018; Munson et al., 2005b). The cascading impact on the subsequent stages of word learning (beyond the single training session) and the learning of semantic representations were not explored in Study 3, which further informed subsequent investigation into word learning within this research programme (Study 5).

To form the basis of a more comprehensive investigation into the relationship between memory and word learning, Study 4 involved an in-depth exploration of the working, procedural, and declarative memory systems in children with DLD. This study contributed to the literature by conducting an exploration of these three memory systems simultaneously in children with this disorder. It was important to explore the potential complex interactions between these memory systems using a large sample size; these interactions had only been conducted in three previous studies that used relatively small sample sizes and yielded conflicting findings (Lum & Bleses, 2012; Lum et al., 2010, 2012). Study 4 identified significant working memory system deficits for the group of children with DLD, observed on verbal and visual–spatial tasks. Furthermore, while it appeared these children also had deficits in the declarative and procedural memory systems, these appeared to be accounted for by deficits in working memory.

As such, the relationship between the working memory system and word learning was explored in children with and without DLD in the subsequent, final study of this thesis. This study – Study 5 – involved the same cohort of children described in Study 4. For this final study, a novel procedure was developed to evaluate encoding, re-encoding, and retention of novel nouns. Previous studies had yielded mixed results, with Bishop and Hsu (2015), Haebig et al. (2019), and Leonard et al. (2019) finding evidence of poor encoding and intact retention in children with DLD, while Gray and colleagues found comparable encoding and retention in DLD and TD children (Gray & Brinkley, 2011; Gray et al., 2012). The findings of Study 5 substantiated the idea that word learning is characterised by impairments in learning novel word forms and word meanings, but learning form-to-referent links appears unimpaired. Furthermore, the results supported the notion that word learning impairments originate at the encoding stage, but that retention processes may be unimpaired (McGregor et al., 2017b); however, retention requires further investigation given that both groups of children dropped in accuracy at retention testing (see *Limitations and Future Directions*). Study 5 also contributed to the literature by identifying problems with word-form learning only for children with both DLD and a profile of impaired verbal working memory. This is highly relevant to clinical practice, particularly with regard to identifying children at increased risk of ongoing vocabulary learning deficits.

Theoretical and Clinical Implications

Working Memory in Developmental Language Disorder

The findings from this research programme inform understandings of the profile of memory impairment in children with DLD. This disorder has long been associated with storage capacity limitations, specifically for the short-term processing of phonological information (Gathercole & Baddeley, 1990; Montgomery et al., 2010). Beyond these simple storage limitations, however, there is equivocal evidence regarding deficits in the domain-general central executive component of the working memory system (Archibald & Gathercole, 2006a; Freed et al., 2012). The findings from Study 4 support the idea that children with DLD not only experience simple storage deficits for verbal content, but also have deficits in their ability to allocate attentional resources and manipulate information over short periods (i.e., indicating a central executive impairment), as indicated by poor performance on the backwards digit recall task. Importantly, impaired performance was found even when controlling for simple storage capacity (i.e., performance on the digit span and nonword repetition tasks). This contrasts the findings of Archibald and Griebeling (2016), who found evidence of comparable performance between children with DLD and typical language on working memory tasks involving complex processing (administered at a level adjusted for verbal short-term memory storage capacity). Archibald and Griebeling (2016) had a small sample size (e.g., DLD $n = 17$), and while statistical methods were used to reconcile this potential limitation, it is likely that reduced statistical power contributes to these contrasting findings, especially given the heterogeneity among cognitive ability in children with DLD (Archibald & Joanisse, 2009; Pennington, 2006).

A "dual deficit" in both verbal short-term and working memory is likely to be problematic during language learning (Archibald & Gathercole, 2006a). That is, the central executive component of working memory plays a role in allocating attention, which is important for determining which pieces of information encountered in the learning environment are placed into temporary stores (i.e., the phonological loop and visual–spatial sketchpad), and for facilitating the interaction of information within these stores (Baddeley, 2000). These processing capabilities would be essential for many areas of language, such as complex sentence comprehension (Montgomery & Evans, 2009) and spoken narrative comprehension (Karasinski & Ellis Weismer, 2010). In the case of word learning, a dual deficit may result in difficulty encoding novel phonological forms (particularly when the forms tax verbal short-term storage capacity), and lead to problems with learning information about new words when they are encountered in environments with high processing demands that compete for attentional resources (e.g., multiple sources of auditory, linguistic, and visual input; Barrouillet & Camos, 2001; Spaulding et al., 2008).

Study 4 also challenged the notion that working memory deficits in DLD specifically impact the verbal domain, by highlighting a significant deficit in visual–spatial short-term memory. This finding is consistent with Vugs et al.'s (2013) meta-analysis, but is in contrast to the findings of a number of studies (e.g., Alloway et al., 2009; Archibald & Gathercole, 2006a), as discussed in detail in Chapter 6. Interestingly, previous research showing a visual–spatial deficit for children with DLD indicates that this tends to be considerably less marked than the deficit for verbal processing, "leading to the suggestion that the working memory impairment in DLD disproportionately impacts the storage and processing of verbal stimuli" (Archibald, 2018, p. 425). However, Study 4 yielded similar effect sizes for between-group comparisons on verbal and visual–spatial tasks[4]. While a specific measure of *visual–spatial working memory* was not included within this study, it is likely that

[4] The effect size for block recall (partial $\eta^2 = .36$) was smaller than for nonword repetition (partial $\eta^2 = .53$), but larger than for digit span (partial $\eta^2 = .25$).

the children with DLD would have also been impaired at this task, given that the central executive is not considered modality-specific, serving both verbal (i.e., phonological loop) and visual–spatial (i.e., visuospatial sketchpad) storage mechanisms within the working memory system (Chein et al., 2011; Freed et al., 2012). This is discussed further in *Limitations and Future Directions*.

The Procedural Deficit Hypothesis

In Study 4, the working, declarative, and procedural memory systems were explored in isolation and as interacting systems. The aim was to build a profile of memory function in children with and without DLD, and to explore the predictions of the Procedural Deficit Hypothesis (PDH): a modular theory that makes predictions about the neurological basis of impaired language domains in DLD (Ullman et al., 2019). Ullman and Pierpont (2005) asserted that DLD is characterised by problems learning the rule-based aspects of language due to abnormalities affecting the neural structures and circuits underlying the procedural memory system (namely, the basal ganglia and associated circuitry). This system is associated with the acquisition of long-term knowledge and skills that are sequential or statistical in nature (Obeid et al., 2016). Non-procedural functions, including working memory, are also posited to be impaired due to a reliance on similar neural circuitry (Ullman et al., 2019). However, declarative memory, which relies on the medial temporal lobe and related circuitry, is assumed to be spared (Ullman & Pierpont, 2005).

The findings of Study 4 provided mixed support for the PDH. While it appeared that the children with DLD performed poorly on the procedural memory task, this was no longer apparent once working memory was taken into account. This does not necessarily negate the idea that abnormalities in neural structures underlying procedural memory are impaired in children with DLD, as their poor working memory performance may indeed reflect disruptions in neural circuitry of the basal ganglia (Ullman et al., 2019). However, while the serial reaction time task was intended to tap into procedural learning (i.e., the implicit detection and learning of statistical regularities; Kuppuraj et al., 2018), it may have instead prompted the engagement of working memory, whereby a child used explicit learning strategies to process and rehearse patterns that they heard and saw. As little previous research had simultaneously assessed working and procedural memory in children with DLD, this provides a novel contribution to theoretical understanding of the profile of memory impairment in children with DLD, and emphasises the need for further research to examine the nature of this relationship (Lum et al., 2014; Obeid et al., 2016).

Finally, in support of the PDH, visual–spatial declarative memory was unimpaired in children with DLD (Ullman, 2001a). Verbal declarative memory also spared in children with DLD once nonverbal IQ and verbal working memory were controlled. In keeping with the findings of Lum et al. (2015), these results suggest that an apparent deficit in declarative learning is not due to underlying deficits in the declarative memory system itself (i.e., in the medial temporal lobe), but instead reflects problems in the neural circuitry underpinning working memory that support encoding, transference, and retrieval of knowledge from declarative memory (Cabeza et al., 2002; Records et al., 1995). The implications for language learning and clinical practice are described in the sections below.

The Encoding Deficit Hypothesis

It is generally accepted that impairment within the early stages of the word learning process has a critical impact on later stages of storage and refinement of word knowledge (Chiat, 2001; Munro et al., 2012). Many investigators have explored this effect through the lens of *mapping theory* (Gray, 2004; Kan & Windsor, 2010; Nash & Donaldson, 2005), and this was the theoretical framework that informed the conception of the methodological design of this PhD research in early 2017. Mapping theory provides a clear framework for describing a child's ability to learn when provided with a brief encounter with a new word (*fast mapping*) and extended opportunities for learning (*slow mapping*). However, more recently, the lens of research has shifted to focus on cognitive limitations that may underpin deficits with initial learning and/or subsequent storage and retrieval of novel words. As such, the encoding–retention framework of word learning was adopted to frame the comprehensive investigation of word learning that was conducted within this doctoral research (presented in Study 5). The work of McGregor and colleagues on word learning in adolescents and adults with DLD (e.g., McGregor et al., 2017a, 2017b, 2020a) was particularly influential in shaping the theoretical interpretations of this study, and gave rise to exploration of the *encoding deficit hypothesis*.

The findings from Study 5 were generally supportive of the encoding deficit hypothesis, which posits that poor word learning in DLD results from impaired encoding but spared retention (McGregor et al., 2020a). The children with DLD demonstrated significant impairments in the initial encoding of novel word forms (i.e., phonological representations) as well as word meanings (i.e., semantic representations), which was expected in light of the extant literature (Bishop & Hsu, 2015; McGregor et al., 2017b). Also aligning with previous research was the finding of comparable form-referent linking in both groups of children (Gray, 2004; McGregor et al., 2020a). Interestingly, across additional learning sessions, both groups of children demonstrated re-encoding by increasing their accuracy on the tasks measuring knowledge of word forms and meanings; however, the group of children with DLD did not catch up to their peers across these additional sessions. Notably, performance on Days 2 and 3 also likely reflected consolidation, but it was not possible to unpack the relevant contribution of re-encoding and consolidation to outcomes on these tasks.

Regarding retention of novel words, both groups of children demonstrated a drop in knowledge for word forms after a 24-hour delay. Despite their decline in performance, the group of children with DLD retained a similar level of accuracy as the typically developing group at Day 4, which suggests a relative strength in their retention skills (Bishop & Hsu, 2015; McGregor et al., 2013a). It is important to note that the observed drop in knowledge post-learning has also been demonstrated in previous studies involving participants with DLD (e.g., Storkel et al., 2017b, 2019), as well as those with typical language (e.g., McGregor et al., 2017b; Riches et al., 2005). This pattern seems to indicate that a higher degree of training intensity was required for both groups of children in order to bolster retention. Further implications and future directions are described in Limitations and Future Directions.

Study 5 also showed that, as a consequence of poor initial encoding, children with DLD struggled to catch up to their peers in developing and refining word knowledge. That is, while the children with DLD did appear to further develop their phonological and semantic representations for novel words over the series of learning sessions, this was at a level significantly lower than for their typically developing peers. The implications of encoding less robust representations, especially of the phonological form, are likely to lead to poorly specified (i.e., "fuzzy") representations in long-term memory (Claessen et al., 2009). As described by Stackhouse and Wells (1997), poorly-specified phonological representations have a cascading effect on the establishment of output representations and motor programmes, which are required for the efficient and accurate retrieval and production of word forms in spoken tasks. Additionally, orthographic representations are likely to be negatively impacted, leading to additional problems with reading and spelling (Carroll & Snowling, 2004; Catts & Kamhi, 1999). Furthermore, difficulty with developing detailed, accurate semantic representations leads to sparse vocabularies characterised by limited word knowledge and limited understanding of relationships between words, further impacting functional understanding and use of vocabulary (McClelland, 1995; McGregor et al., 2012).

Word Learning and Memory: Bringing the Findings Together

It is theoretically plausible that impaired memory skills underpin the encoding deficit experienced by children with DLD. Since the 1980s, researchers have explored the relationship between the development of vocabulary and verbal short-term memory in these children (Baddeley et al., 1988; Gathercole & Baddeley, 1989). Although built on sound theoretical foundations, the findings into this relationship have been equivocal (Alt & Plante, 2006; Gray, 2006; Hansson et al., 2004). Study 3 provided empirical evidence to support the relationship between verbal short-term memory and word learning, whereby the group of children with DLD were significant less accurate at encoding (or *fast mapping*) novel phonological representations, which was predicted by performance on a measure of nonword repetition.

Study 5 then extended these findings by providing much-needed empirical support for the notion that the broader working memory system (rather than just the verbal short-term memory component) is a critical structure underpinning vocabulary development. In Study 5, a factor-analysed measure of verbal working memory was used, which combined scores on tasks measuring simple recall and processing of information (i.e., digit span, nonword repetition, and backwards recall). This verbal working memory factor significantly moderated performance on the word form tasks (*Naming* and *Recognition*). This indicates that a verbal storage impairment was indeed important for facilitating the establishment of phonological representations for new words, as was the involvement of the central executive (i.e., working memory; Archibald & Griebeling, 2016; Archibald & Gathercole, 2007a). Impairments in central executive likely limited the ability to shift attentional energy towards: identifying the phonological form within the learning task; refreshing and rehearsing material in the phonological loop, and; facilitating links between the phonological form and other cues from the environment, such as visual information (Barrouillet & Camos, 2001). Verbal working memory abilities also appear to have been involved in the ability to retrieve the newly-learned information from long-term memory, and hold it in an activated and accessible state throughout days 2, 3, and 4 of the learning procedure (Cabeza et al., 2002; Hambrick et al., 2005).

Furthermore, Study 5 presents evidence that not all children with DLD exhibit word learning impairments; it is the children who have comorbid deficits in oral language and verbal working memory that are more likely to experience problems encoding word forms. This reinforces the heterogeneity of language deficits in DLD, and may go some way to explaining the history of conflicting findings regarding a lexical deficit in children with DLD. That is, while DLD is strongly associated with hallmark deficits in morphosyntax (Ash & Redmond, 2014; Leonard, 2014), vocabulary impairments have not always been found (Clarke & Leonard, 1996; Gray et al., 2012; Hick et al., 2002; Ullman & Peirpont, 2005). This may be due to the nature of assessments used to measure lexical skills (e.g., children with DLD often perform within the average-range on lexical tasks that are receptive in nature, which may be due to the fact that only partial word-knowledge is required to correctly identify a word in a receptive manner). Furthermore, it is possible that vocabulary deficits may be impaired only in a subset of children with DLD – those with comorbid verbal working memory impairment. Research involving children with DLD often involves small sample sizes (Kan & Windsor, 2010; Lum et al., 2014), meaning that a vocabulary impairment may go undetected if the sampled children do not also present with a verbal working memory impairment.

The findings of Study 5 also shed some light on the possible involvement of long-term memory systems in word learning. An intact declarative memory system (as found in Study 4) may support the retention of novel word information for the children with DLD, although further investigation of retention is required. Furthermore, it is also possible that intact skills for learning form-referent links in children with DLD were underpinned by an unimpaired declarative memory system (McGregor et al., 2020a; Ullman et al., 2019). This raises questions regarding the retention of semantic knowledge. It is difficult to reconcile the differences between the proposal of the PDH, which suggests that an intact declarative memory system in children with DLD supports unimpaired semantic knowledge (Ullman, 2001a), and the findings of Study 5, which shows a clear deficit in learning semantic details of new words (Alt & Plante, 2006; McGregor et al., 2013b). As identified by Ullman et al. (2019), however, given the demands of the word learning environment in this and many other empirical studies, lexical learning may be impaired in situations that tax the working memory, such as in Study 5. Finally, the procedural memory system is likely implicated in the word learning process, although this was not directly explored in the current research given that performance was moderated by working memory skills. As posited by Ullman (2016), procedural memory may underpin the long-term storage of complex motoric (i.e., phonological/articulatory) patterns for words in the lexical store. These issues highlight the need for further investigation of the relationship between the declarative and procedural memory systems and word learning.

A number of clinical implications arise from the findings regarding the relationship between word learning and memory. For instance, SLPs should assess verbal working memory in children with DLD. While this recommendation has been the feature of previous studies (e.g., see Coady & Evans, 2008; Estes et al., 2007), it is not commonplace. It is therefore important to reinforce this practice, and for clinicians to understand the implications of poor performance on working memory tasks. That is, it is critical to flag children who perform below the average range (on tasks such as digit span and nonword repetition) as being at greater risk of experiencing significant problems with learning new words. In addition to these processing tasks, it would be ideal for clinicians to have access to, and be able to administer, an evaluation of word learning skills with individual clients. However, these tasks can be time-consuming, and at this stage clinicians may not have access to resources to support this practice (as indicated through the results of Study 2). As such, verbal short-term and working memory tasks are a valuable adjunct to a language battery and may serve as an efficient method for identifying children with poor word learning ability.

Furthermore, while this programme of research did not directly aim to investigate intervention effectiveness, the findings highlight the need to consider strategies for mitigating an encoding deficit when teaching new vocabulary. This is important for SLPs to consider when setting goals and planning intervention for individuals. It is also relevant to SLPs who work collaboratively with classroom teachers. The classroom represents an environment in which explicit vocabulary instruction may be delivered in rich contexts (Starling et al., 2012), and so it is important for teachers to be informed about best-practice methods for vocabulary development (Throneburg et al., 2000). It is necessary to acknowledge that, given the degree of intensity of the word learning procedure in Study 5, children with DLD and those with typical language showed difficulties with retaining the novel word forms. As described in previous intervention studies (Rice et al., 1994; Storkel et al., 2017b), it is likely that retention would be heightened through the provision of a high degree of exposures over a series of days, and multiple retrieval opportunities (Karpicke & Roediger, 2008; Leonard et al., 2019; Storkel et al., 2019). Critically, SLPs also need to monitor response to word learning instruction, as limited response to language learning opportunities can help clinicians to understand persistence of the disorder (Bishop et al., 2017).

Additionally, Study 5 highlights the need to adjust vocabulary intervention so that it is sensitive to those experiencing verbal working memory deficits. In the absence of evidence-based intervention programs that directly target working memory, Singer and Bashir (2018) proposed a clinical framework for supporting verbal working memory deficits, that would be useful to draw from when considering vocabulary intervention and teaching (e.g., providing “visual anchors”, increasing linguistic salience and structure within the learning context, and accommodating impairments through environmental manipulations).

Limitations and Future Directions

This programme of research was subject to several limitations. First, the children with DLD who participated in Studies 3, 4, and 5 were selected from specialist language development schools. This was positive in that it was possible for the researcher to efficiently recruit and test a relatively large number of children, and because the children had been previously diagnosed following clinical procedures. However, there may have been some homogeneity and bias in the sample. Specifically, children attending specialist schools may present with more severe oral language deficits; children may be referred to attend these schools because their language problems are making it difficult to learn in mainstream classrooms. Furthermore, children at the specialist schools were receiving intensive intervention and teaching during the time of data collection. In future, research should aim to involve children with DLD from the community population as a way of maximising generalisability of the findings.

While this research program was concerned with children who have DLD, it must be noted that the participants described in Study 3 more specifically met criteria for *specific language impairment*. That is, data collection for this study occurred prior to the Delphi consensus study and the subsequent change in terminology (Bishop et al., 2017). This meant that the children met criteria for impaired oral language and had nonverbal cognitive skills that fell within or above the average range. As such, the sample was limited in the sense that children with lower levels of nonverbal skill were not represented. This limitation was overcome in Studies 4 and 5, for which a new cohort of participants were recruited according to the 2017 criteria for DLD, whereby children with low-range nonverbal IQ were included (Bishop et al., 2017). Notably, in this cohort, nonverbal IQ was significantly lower in the DLD group. Consequently, nonverbal IQ was controlled for in the memory and word learning analyses in order to minimise the potential effects of these abilities as a confounding variable. However, it was not the aim of this research to delineate the impact of nonverbal skills on word learning. This relationship is identified as a priority for future research as there is some evidence for the contribution of nonverbal IQ to word learning ability (Kan & Windsor, 2010) and other language learning abilities (Goorhuis-Brouwer & Knijff, 2002).

Furthermore, there were several limitations in the battery of memory measures that were administered in Study 4; however, additional measures could not be administered given the considerable testing demands placed on the children (including administration of the four-day word learning procedure as required for Study 5). As such, it was decided that additional measures would not be included, in order to abide by ethical requirements of not overly fatiguing the children, and to minimise time spent out of the classroom. Future research might be scheduled over a longer time period so that additional measures can be included. This should include additional working memory tasks; namely, a measure of *visual–spatial working memory* (only *visual–spatial short-term memory* was measured). Furthermore, these visual–spatial measures should be explored in relation to word learning abilities. While the focus of Study 5 was on the influence of verbal working memory, visual processing and memory likely play a role (albeit a secondary role in comparison to verbal processing) in the acquisition of vocabulary (Tomas & Vissers, 2019).

In addition to working memory, other executive functions need to be further explored in children with DLD, especially given the emerging evidence suggesting that children with DLD and poor executive function exhibit the highest level of difficulty when learning new vocabulary (Kapa & Erikson, 2020; McGregor et al., 2020c). For instance, Bishop and Norbury (2005) and Marton et al. (2007) highlighted deficient inhibitory control in children with DLD, resulting in a "distractor" problem that would likely impact focus to the novel stimuli in word learning environments (Victorino & Schwartz, 2015). Attentional abilities also require further consideration. While attention was explored, in part, through including a measure of working memory (which requires attentional control), other processes such as selective attention, shifting, and sustaining attention may be problematic for children with DLD (Ebert & Kohnert, 2011; Stevens et al., 2006). These should therefore be explored in the context of word learning.

A final consideration regarding the investigation of memory within this doctoral research relates to the measurement of procedural memory. Administration problems with the serial reaction time (SRT) task that meant that data were lost during data collection for Study 4. Some of the task demands were noted to be too high for the participants, resulting in floor effects for both groups for one aspect of procedural memory (probabilistic sequence learning). Amending the task may result in a potential group difference being unmasked for this aspect of procedural learning, which could lead to the development of a more detailed understanding of this memory system in children with and without DLD (Gabriel et al., 2011). Furthermore, working memory significantly moderated performance on the SRT task, prompting the need for further task development so that it may more accurately tap into long-term learning and reduce the potential reliance on working memory (Ashby & Maddox, 2011; Ullman, 2013).

A final limitation relates to the design of the word learning task. When the task was pilot tested, there did not appear to be issues with the retention of information (i.e., at Day 4 of testing). Notably, the children involved in pilot testing were recruited using snowball techniques, meaning they were mostly the children of professionals. As such, it is possible that their language skills were stronger.

Furthermore, pilot testing occurred with children in their homes after school or on the weekends, which was dissimilar to the in-school testing environment of the study participants. Given that they did not return to classroom lessons, the new word knowledge may have been subject to less interference, thus facilitating more successful retention (McGregor, 2014; Stickgold, 2005). This phenomenon has been identified in some previous research (Mainela-Arnold et al., 2008), highlighting the need to further explore the impact of task conditions on retention in future research.

Furthermore, three factors that may have contributed to poor retention were: 1) multiple novel items being introduced in the same learning context (i.e., eight); 2) the lack of semantic diversity of the novel items, and; 3) the low phonotactic probability of the novel stimuli. First, given that eight items were introduced in each session, it is possible that the phonological forms interfered with each other (Alt & Suddarth, 2012). While it was anticipated that this may occur, in designing the word learning protocol it was decided to include multiple items, as this may reflect real-world vocabulary learning environments (Starling et al., 2012). Second, the items were all proper names of items from the same semantic category (i.e., unusual creatures), and these were potentially unlike other items within the children's existing lexicon. As such, it is possible that the newly-encoded items did not integrate effectively in the lexicon during offline consolidation (Davis & Gaskell, 2009). It is suggested that future research should utilise novel items that represent different word types and semantic categories, in order to facilitate more successful consolidation and retention (Storkel & Lee, 2011; Takashima et al., 2019). Finally, the word forms were made up of low frequency phonotactic patterns in order to minimise the influence of prior vocabulary knowledge on learning (Munson et al., 2005b). As a result, however, the novel forms were highly dissimilar to word forms in existing vocabulary, which may have minimised integration and retention of the new items within long-term memory (Mainela-Arnold et al., 2008; Takashima et al., 2019).

Finally, it is important to end with implications regarding the translation of research to practice. As identified in Study 2, there is a need for further development of clinician-friendly resources to facilitate the clinical evaluation of word learning in clients from a range of clinical populations and ages. Word learning measures have proved critical in the research literature for profiling strengths and weaknesses in vocabulary development, and these tasks provide critical information on the extent to which a person's language abilities can be modified (Bishop, 2006; Pena et al., 2001). As such, word learning assessments represent a key assessment procedure that can be used to identify individual client needs regarding responsiveness to intervention, thus aiding clinical planning (Camilleri & Law, 2007; Hasson, 2017). Furthermore, dynamic evaluations of language learning ability are considered to be critical for identifying disorder from difference in clients CALD backgrounds – a vital clinical capability for SLPs given that approximately half of the world's population speaks more than one language (Castilla-Earls et al., 2020).

Conclusion

This programme of doctoral research has explored a critical skill in language development: word learning. This skill is particularly difficult for children with DLD, and while a body of research has explored the nature of these word learning problems, there has been little multifactorial investigation that explores learning over time, and delves into the memory skills underpinning this domain. Additionally, previous research involving children with DLD had identified potential impairment across the domains of working, declarative, and procedural memory; however, findings had been equivocal, and little research had explored these three systems simultaneously. The research presented in this thesis aimed to fill these research gaps by developing a profile of working, declarative, and procedural memory systems, and exploring the multifactorial deficits in word learning, in five to eight-year-old children with and without DLD.

In the context of the broader literature, the findings of this doctoral research at times substantiated, and sometimes challenged, understanding of children with DLD. The processing of verbal and visual–spatial information in working memory was found to be a core area of deficit, which largely contributed to poor performance on declarative and procedural learning tasks. These findings build theoretical understanding of DLD, and provide insight into the neurobiological underpinning of language deficits in this disorder. Additionally, the ability to learn word forms and meanings was found to particularly challenging for children with DLD, while learning form-to-referent links remained intact. It was clear that these learning deficits originated with encoding, and had a detrimental impact on subsequent development of word knowledge. While previous literature had shown word learning deficits in children with DLD, the current findings highlighted that this deficit differentially impacted those with concomitant verbal working memory impairments. Finally, the clinician survey raised important implications regarding further translation of research into practice so that clinicians feel equipped to evaluate word learning in clinical settings.

It is hoped that this research will increase the current theoretical and clinical evidence base for speech-language pathologists, thus promoting understanding and expertise in the clinical management of word learning and memory skills in children. It is also wished that the research will encourage and guide further research in these important areas, adding to the evidence base, and thus have a continuing positive impact on communication, learning, and social development of children with developmental language disorder.

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Appendix A.2 Copyright Notice Included on the Website of the Journal of Communication Disorders (Study 3 Publication)

Appendix A.3 Permissions Approval from the Journal of Speech, Language, and Hearing Research (Study 4 Publication)

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I am happy for you to use my figure in your dissertation.
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Alan Baddeley

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Appendix C Chapter 3 (Scoping Review Paper) Appendices

Appendix C.1 Search Terms Identified for the Systematic Scoping Review of Electronic Databases

	Keyword	Text word
Concept	Word learning	Word learn*
		Fast map*
	New words	Slow map*
		Lexical map*
	Vocabulary development	Lexical learn*
		Vocabulary develop*
		Novel word*
		New word*
		Semantic map*
		Phon* map*
		Verb* learn*
		Noun learn*
		Lexical acquis*
		Word acquis*
		Incidental learn*
Target population	Developmental language disorder	developmental language disor*
		DLD
		specific language impair*
		SLI
		specific language defic*
		language impair*
		primary language impair*
		PLI
		language learning disab*
		developmental language impair*
		developmental dysphasia
		developmental aphasia
		language disord*
		vocabulary disord*

Note. * denotes Boolean phrase used in the search.

Appendix C.2 Eligibility Criteria for the Systematic Scoping Review

	Included in review	Excluded from review
Concept	Learning of new words (whole lexical items) Evaluation of the word learning process	Learning morphemes or new grammatical structures Learning only visual information about novel words Static assessment of 'word knowledge' used (e.g., standardised vocabulary measure)
Target population	Learning in primary language Diagnosis of 'DLD' (or another synonymous label)	Learning in second or third language Late talkers Insufficient evidence of impaired oral language in participant selection
Context	Behavioural evaluations	Neurological evaluations or cognitive modelling
Additional	Presents novel data Articles available in English	Commentary or review papers Articles written in another language (for which a translation is not easily available)

Appendix C.3 Data Charting Table

Demographic details						
Author(s)	Year of publication	Study location	Study design	Aims of the investigation	Study population(s), *N*, age	Participant selection measures and criteria

Methodology					
Learning context		Modality (e.g., oral or written)	Language domain	Stimuli *e.g., Word type, real / nonwords, method for selection or creation, phonological properties*	Task characteristics *e.g., learning cues*

Appendix C.4 Summary of Key Parameters of Word Learning Methodology

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli (real/nonword; word type; syllable shape)	Manip-ulation of PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Aguilar (2017)	USA	4;4 – 5;7	Live task	Oral	Phonology	Real words; nouns; CVC, CVCC, CVCV, CVCVC, CCCVCV	-	-	-	Receptive phonology (visual ID) Expressive phonology
Alt (2011)	USA	7 – 8 years	Computer task	Oral	Phonology	Nonwords; nouns; CVCVC, CVCVCVCVC	High vs low PP	-	-	Receptive phonology (recognition) Expressive phonology
Alt and Gutmann (2009)	USA	*M* = 19.2 (1.3) years	Computer task	Oral	Phonology and semantics	Nonwords; nouns; CVCCVC, CVCVC	High vs low PP	-	-	Receptive phonology (recognition) Receptive semantics
Alt and Plante (2006)	USA	4;0 – 5;11	Computer task	Oral	Phonology and semantics	Nonwords; nouns; CVCCVC, CVCVC	High vs low PP	-	-	Receptive phonology (recognition) Receptive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Alt et al. (2004)	USA	4;0 – 6;5	Computer task	Oral	Phonology and semantics	Nonwords; nouns (CVCCVC, CVCVC), verbs (CVC + inflection)	-	-	-	Receptive phonology (recognition) Receptive semantics
Alt and Spaulding (2011)	USA	7;0 – 8;0	Computer task	Oral	Phonology	Nonwords; nouns; CVCVCVCVC	High vs low PP	-	-	Receptive phonology (recognition) Expressive phonology
Alt and Suddarth (2012)	USA	7;0 – 8;0	Computer task	Oral	Phonology	Nonwords; nouns; CVCCVC, CVCVC	-	-	-	Receptive phonology (recognition) Expressive phonology
Archibald and Joanisse (2013)	USA	6;4 – 10;2	Computer task	Oral	-	Nonwords; nouns; CVCVC, CVCV	-	-	-	Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Ard (2004)	USA	4;1 – 5;0	Book share	Oral	Phonology and semantics	Nonwords; nouns (CVCVC), verbs (CVC + ing)				Receptive phonology (visual ID) Expressive phonology
Bishop et al. (2012)	UK	*M* = 14.6 (2.1) years *M* = 43.1 (13.3) years	Modified nonword repetition task	Oral	Phonology	Nonwords; *no assigned word type*; CCVCCCVCCCV, CCVCCCVCCC VCVCV, CCCVCCVCVC CVCCCVC	-	-	Frequency of exposures (across sessions)	Expressive phonology
Carr and Johnston (2001)	Canada	3;6 – 5;2	Computer task	Oral	Phonology and semantics	Nonwords; verbs; CVC	-	Syntactic cues	-	Receptive phonology (visual ID)
Chen and Liu (2014)	Taiwan	*M* = 5.4 (0.5) years	Digitised story	Oral	Phonology and semantics	Nonwords; nouns; N/A	-	-	-	Receptive phonology (recognition) Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Davis et al. (2016)	USA	3;1 – 7;4	Book share	Oral	Phonology	Real words; nouns N/A	-	-	-	Receptive phonology (visual ID) Expressive phonology
Diestelm-eier (2014)	USA	*M* = 10.3 (0.8) years	Child reading	Oral and written	Phonology, semantics, and orthography	Nonwords; nouns; CVCV, CVCVC, CCVCVC, CCVCV, VCCVC, CVCCVC	-	Phonol-ogical and semantic cues	-	Expressive semantics
Dollaghan (1987)	Canada	4;0 – 5;6	Live task	Oral	Phonology	Nonwords; nouns; CVC	-	-	-	Receptive phonology (visual ID, recognition) Expressive phonology
Ellis Weismer and Hesketh (1993)	USA	5;4 – 6;7	Live task	Oral	Phonology	Nonwords; nouns; CVC	-	Gestural cues	Rate of input (fast vs slow) Prosody (stressed vs neutral)	Receptive phonology (visual ID) Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Ellis Weismer and Hesketh (1996)	USA	*M* = 7;2 (1.1) years	Live task	Oral	Phonology	Nonwords; nouns; CVC	-	-	Rate of input (fast vs slow) Prosody (stressed vs neutral)	Receptive phonology (visual ID, recognition) Expressive phonology
Ellis Weismer and Hesketh (1998)	USA	6;8 – 9;8	Live task	Oral	Phonology	Nonwords; nouns; CVC, CVCC	-	-	-	Receptive phonology (visual ID, recognition) Expressive phonology
Eyer et al. (2002)	USA	3;6 – 5;4	Live task	Oral	Phonology and semantics	Nonwords; verbs (CVC), nouns (CVC)	-	Syntactic cues	-	Receptive phonology (visual ID)
Gladfelter (2014)	USA	5;9 – 8;5	Computer task	Oral	Phonology and semantics	Nonwords; nouns; CVCCVC	-	Rich vs. sparse semantic cues	-	Receptive phonology (visual ID) Expressive phonology Expressive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Goldman (2010)	USA	3;6 – 5;6	Live task	Oral	Phonology and semantics	Real words; nouns; N/A	-	Semantic cues	-	Receptive phonology (visual ID)
Gray (2003)	USA	4;0 – 5;11	Live task	Oral	Phonology and semantics	Real words; nouns; CVCVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology
Gray (2004)	USA	4;0 – 5;11	Live task	Oral	Phonology and semantics	Real words; nouns; CVCVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID, recognition) Expressive phonology
Gray (2005)	USA	4;0 – 5;11	Live task	Oral	Phonology and semantics	Real words; nouns; CVCVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology Expressive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Gray (2006)	USA	3 – 6 years	Live task	Oral	Phonology	Real words; nouns; CVCVC	-	-	-	Receptive phonology (visual ID) Expressive phonology
Gray and Brinkley (2011)	USA	*M* = 4.7 (0.5) years	Live task	Oral	Phonology and semantics	Nonwords; nouns; CVCVC	High vs low PP	Phonol-ogical and semantic cues	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology
Gray et al. (2012)	USA	*M* = 4.7 (0.4) years	Live task	Oral	Phonology	Nonwords; nouns; CVCVC	High vs low PP	-	-	Receptive phonology (visual ID, recognition) Expressive phonology
Gray et al. (2014)	USA	*M* = 4.7 (0.5) years	Computer task	Oral	Phonology	Nonwords; nouns; CVC	High vs low PP High vs low ND	-	-	Receptive phonology (recognition) Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Haebig (2015)	USA	*M* = 10.43 (1.27) years	Computer task	Oral	Phonology	Nonwords; nouns; CVCV	-	-	-	Receptive phonology (visual ID)
Haebig et al. (2017)	USA	8 – 12 years	Computer task	Oral	Phonology	Nonwords; nouns; CVCV	-	-	-	Receptive phonology (visual ID)
Hansson et al. (2004)	Nether-lands	8;6 – 11;4	Live task	Oral	Phonology	Nonwords; nouns; CVC, VCCV, CCVCVCV, CVCVCVC	-	-	-	Receptive phonology (visual ID) Expressive phonology
Horohov and Oetting (2004)	USA	*M* = 6.2 (0.5) years	Digitised story	Oral	Phonology and semantics	Nonwords; nouns (CVCVC, CVCCVCC, CVCV, CVCCVC) verbs (CVCVC + inflection)	-	Syntactic cues	Rate of input (fast vs slow)	Receptive phonology (visual ID) Expressive phonology Expressive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Jackson et al. (2016)	Austra-lia	5;0 – 5;11	Live task	Oral	Phonology	Nonwords; nouns; CVCVC, CVCVCVC, CVCVCVCC, CVCCVCVC, CVCVCCVCV, CVCVCVCVC, CVCVCVCVC	-	-	-	Expressive phonology
Johnson and de Villiers (2009)	USA	4 – 9 years	Live task	Oral	Phonology and semantics	Nonwords; verbs; CVC + inflection	-	Syntactic cues	-	Receptive semantics
Kiernan and Gray (1998)	USA	4;0 – 5;11	Live task	Oral	Phonology	Real words; nouns CVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Luke and Ritterfield (2014)	Germa-ny	3;4 – 5;11	Live task	Oral	Phonology	Nonwords; nouns; CVC, CCVC, CVCC, CVCV, CCVCVC, CVCVCC, CVCVCV, CCVCVCV, CVCVCVCC	-	Gestural cues	-	Receptive phonology (visual ID) Expressive phonology
McGregor et al. (2013)	USA	18 – 25 years	Computer task	Oral	Phonology and semantics	Nonwords; nouns; N/A	-	-	-	Receptive phonology (recognition) Expressive phonology & semantics
McGregor et al. (2017a)	USA	18 – 24 years	Computer task	Oral and written	Phonology, semantics and orthography	Nonwords; nouns; CVCVC, CVCCVC, CCVCVC	-	-	-	Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
McGregor et al. (2017b)	USA	M = 20.8 (1.3) years	Computer task	Oral	Phonology	Nonwords; nouns; CVCVC	-	-	-	Receptive phonology (recognition) Expressive phonology & orthography
McKean et al. (2014)	UK	3;4 – 6;9	Book share	Oral	Phonology	Nonwords; nouns; CVC	High vs low PP High vs low ND	-	-	Receptive phonology (recognition)
Moav-Scheff et al. (2015)	Israel	3;11 – 6;11	Computer task	Oral	Phonology	Nonwords; nouns; N/A	-	-	Frequency of exposures (within a session)	Receptive phonology (visual ID, recognition)
Mundrick (2012)	USA	6;8 – 11;7	Live task	Oral	Phonology and semantics	Real words; nouns CVC, VCC, CVCC, CCVCC, VCCVC, VCCV, CVCCVC, CVCVC, CVCV	-	Phonol-ogical and semantic cues	-	Receptive phonology (visual ID) Expressive phonology

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Nash and Donaldson (2005)	UK	5;5 – 9;0	Live task and book share	Oral	Phonology and semantics	Real words; nouns; VCCV, CVCV, CVCVCVC, CVCCCVC, VCCVCCVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID, recognition) & semantics Expressive phonology & semantics
Oetting (1999)	USA	*M* = 6.4 (0.6) years	Digitised story	Oral	Phonology and semantics	Nonwords; verbs; (CCVC, CVCVCV, CVC, CVCVC, CVCCV) + inflection	-	Syntactic cues	-	Receptive phonology (visual ID, recognition)
Oetting et al. (1995)	USA	6 – 8 years	Digitised story	Oral	Phonology	Real words; nouns, verbs, modifiers, affective states N/A	-	-	-	Receptive phonology (visual ID, recognition)
O'Hara and Johnston (1997)	Canada	*M* = 7.9 (1.5) years	Live task	Oral	Phonology and semantics	Nonwords; verbs; CVC	-	Syntactic cues	-	Expressive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Plante et al. (2011)	USA	4;0 – 5;11	Computer task	Oral	Phonology	Nonwords; nouns CVCCVC	High vs low PP	-	Frequency of exposures (within a session)	Expressive phonology
Proctor-Williams and Fey (2007)	USA	*M* = 7.8 (0.5) years	Live task	Oral	Phonology	Real words; verbs; CVC, CCVCC, CCV (syllable shapes N/A for all items)	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology
Rice et al. (1990)	USA	3;4 – 6;0	Digitised story	Oral	Phonology	Real words; nouns, verbs, modifiers, affective states N/A	-	-	-	Receptive phonology (visual ID)
Rice et al. (1992)	USA	4;3 – 6;9	Digitised story	Oral	Phonology	Real words; nouns, modifiers N/A	-	-	Prosody (pause vs no pause prior to target)	Receptive phonology (visual ID)
Rice et al. (1994)	USA	4;3 – 6;9	Digitised story	Oral	Phonology	Real words; nouns, verbs N/A	-	-	Frequency of exposures	Receptive phonology (visual ID)

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Rice et al. (2000)	USA	4;6 – 5;8	Digitised story	Oral	Phonology and semantics	Nonwords; nouns; CVC, CCVC, CVCV, CVCVC, CVCCVC	-	Syntactic cues	-	Receptive phonology (visual ID)
Riches et al. (2005)	UK	4;7 – 6;4	Live task	Oral	Phonology and semantics	Nonwords; verbs; CVC	-	-	Frequency of exposures (across sessions)	Receptive phonology (visual ID) Expressive phonology
Riches et al. (2006)	UK	4;7 – 6;4	Live task	Oral	Phonology and semantics	Nonwords; verbs; CCV, CVC, CVCC	-	Syntactic cues	-	Expressive phonology
Ricketts et al. (2015)	UK	8 – 13 years	Computer task	Oral and written	Phonology, semantics and orthography	Nonwords; nouns; CVC, CVVC, CVCC	-	-	-	Receptive phonology (visual ID) Expressive phonology Expressive orthography

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Rohlfing et al. (2018)	Germa-ny	*M* = 39.7 (3.5) years	Book share	Oral	Phonology	Nonwords; nouns N/A	-	-	-	Receptive phonology (visual ID)
Shulman and Guberman (2007)	Israel	3;7 – 6;0	Computer task	Oral	Phonology and semantics	Nonwords; verbs; N/A	-	Syntactic cues	-	Receptive phonology (visual ID)
Smeets et al. (2014)	Nether-lands	5;0 – 6;8	Book share (live versus digitised)	Oral	Phonology	Real words; nouns, verbs, adjectives, adverbs N/A	-	-	-	Expressive phonology
Steele and Watkins (2010)	USA	9;11 – 11;5	Child reading	Written	Semantics and orthography	Nonwords; nouns, verbs; CVC, CVVC, CCVC, CVCC	-	Syntactic cues	Frequency of exposures (across sessions)	Expressive phonology Receptive & expressive semantics
Steele (2015)	USA	9;11 – 11;5	Child reading	Written	Semantics and orthography	Nonwords; nouns, verbs; CVC, CVVC, CCVC, CVCC	-	Syntactic cues	Frequency of exposures (across sessions)	Expressive phonology Receptive & expressive semantics

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Steele et al. (2013)	USA	*M* = 10.3 (0.8) years	Child reading	Written	Semantics and orthography	Real words; nouns; VCVC, CVCV, CVCVC, CCVCVC, CCVCV, VCCVC, CVCCVC, VCCCV, CCVCCV	-	Phonological and semantic cues	Frequency of exposures (across sessions)	Expressive phonology Expressive semantics Receptive semantics
Storkel et al. (2017a)	USA	5;0 – 6;5	Book share	Oral	Phonology and semantics	Real words; nouns, verbs, adjectives N/A	-	-	Frequency of exposures (across sessions)	Expressive phonology
Storkel et al. (2017b)	USA	5;0 – 6;5	Book share	Oral	Phonology and semantics	Real words; nouns, verbs, adjectives N/A	-	-	Frequency of exposures (across sessions)	Expressive phonology & semantics Receptive semantics
Van Berkel-van Hoof et al. (2016)	Netherlands	9 – 11 years	Computer task	Oral	Phonology	Nonwords; nouns; CVCV, CVCVC	-	Gestural cues	-	Receptive phonology (visual ID)

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
van der Lely (1994)	UK	6;1 – 9;6	Live task	Oral	Phonology and semantics	Nonwords; verbs; CVC	-	Syntactic cues	-	Expressive phonology
Vogt and Kauschke (2017)	Germa-ny	3;9 – 5;9	Book share, live task, digitised story	Oral	Phonology and semantics	Real words; nouns, verbs; N/A	-	Gestural cues	-	Expressive semantics
Vogt et al. (2017)	Germa-ny	*M* = 4.5 (0.6) years	Book share, live task, digitised story	Oral	Phonology and semantics	Real words; nouns, verbs; N/A	-	Gestural cues	-	Receptive phonology (visual ID) Expressive phonology
Windfuhr et al. (2002)	UK	4;4 – 5;10	Live task	Oral	Phonology and semantics	Nonwords; nouns (CVCV), verbs (CVC + ing)	-	-	Frequency of exposures (across sessions)	Expressive phonology
Wolter and Apel (2010)	USA	5;7 – 7;0	Digitised story	Written	Semantics and orthography	Nonwords; nouns; CVC	High vs low PP High vs low OP	-	-	Receptive orthography Expressive orthography

Appendix C.4 continued.

Reference	Country	Age[a]	Learning context	Modality	Language domain	Stimuli	PP, ND, OP	Learning cues	Input variations	Outcome measures[b]
Zens et al. (2009)	New Zealand	6;3 – 8;2	Live task	Oral	Phonology and semantics	Real words; nouns; N/A	-	Phonol-ogical and semantic cues	-	Receptive phonology (visual ID, recognition) Expressive phonology Expressive semantics

Note. PP = phonotactic probability; ND = neighbourhood density; OP = orthotactic probability; ID = identification; N/A: syllable shape not available due to the article not reporting stimuli and/or syllable shape.

[a]The age range of DLD participants has been reported as years;months if this information was provided in individual articles. Otherwise, age range is reported as whole years, or the mean (and standard deviation) in years have been reported.

[b]The following outcome measures are explained in further detail: receptive phonology (recognition) – selecting the phonological form from three or four choices; receptive phonology (visual identification; ID) – selecting the target from an array of pictures or video scenes; expressive phonology – naming the target word; receptive semantics – answering questions about semantic features of the target items; expressive semantics – describing or defining the target word; receptive orthography – identifying the target written word from a range of choices; expressive orthography – spelling the target words.

*Stimuli did not conform to English syllabic shapes.

Appendix D   Chapter 4 (Clinician Survey Paper) Appendices

Appendix D.1 Distribution Materials

Information and Consent Page for Online Survey

Vocabulary and Word Learning Assessment Practices of Speech Pathologists

This survey aims to gather information about how speech pathologists assess the vocabulary and word learning skills of their clients. We hope that this information will contribute to the development of a clinically useful assessment task of word learning.

Speech pathologists who have ever assessed the vocabulary and/or word learning skills of clients (toddlers to young adults) are invited to participate.

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC2017-0836).

[Link to survey]

Contact name: [Emily Jackson] [link to email contact details]

Full Participant Information Form

HREC Project Number:	HRE2017-0836
Project Title:	Word learning in children with developmental language disorder
Chief Investigator:	Associate Professor Suze Leitão
Co-Supervisors:	Dr Mary Claessen and Dr Mark Boyes
Student Researcher:	Emily Jackson

My name is Emily Jackson and I am a PhD student and speech pathologist. I am currently conducting a study to investigate the word learning skills of children with developmental language disorder (DLD) and typically developing children.

As part of this project, I am exploring the use of assessment tasks for word learning. To supplement my background review of the research literature, I would like to better understand how speech pathologists from a range of countries assess the vocabulary and word learning skills of their clients. We hope that this information will contribute to the development of a clinically useful assessment task of word learning in the future.

We are looking for volunteers to take part in a short online survey. We welcome participation from speech pathologists who have ever assessed the vocabulary and/or word learning skills of their paediatric clients up to young adulthood. The survey involves 14 questions and takes 10-15 minutes to complete.

By completing this survey, you are providing consent to participate in this research project. Participation is entirely voluntary and anonymous, and you may withdraw at any time during the survey. No identifying information will be stored; therefore, it will not be possible to retrieve your personal information once you have completed the questionnaire.

If you would like to know more about participating in this study, please contact me, Emily Jackson (PhD student) at Emily.Jackson@postgrad.curtin.edu.au. Alternatively, you may wish to contact one of my supervisors, A/Prof Suze Leitão (S.Leitao@exchange.curtin.edu.au), Dr Mary Claessen (M.Claessen@curtin.edu.au) or Dr Mark Boyes (Mark.Boyes@curtin.edu.au).

Kind regards,

Emily Jackson
PhD Candidate

A/Prof Suze Leitão
Supervisor and Associate Professor

Dr Mary Claessen
Supervisor and Senior Lecturer

Dr Mark Boyes
Supervisor and Senior Research Fellow

School of Psychology and Speech Pathology, Curtin University

Appendix D.2 Online Survey Questions

1. For how long have you been practicing as a speech pathologist? (e.g., 4 years) [writing box]
2. Where did you graduate? (please state country) [writing box]
3. Where do you work? (please state country and, if in Australia, the state or territory) [writing box]
4. Where do you provide services?
   Please select all that apply
   - Clinic-based services
   - School-based services
   - In-home services
   - Hospital-based services
   - Telehealth
   - Other [writing box]
5. In which area of practice do you provide services?
   Please select all that apply
   - Speech
   - Language
   - Voice
   - Fluency
   - Literacy
   - Swallowing and/or feeding
   - Other [writing box]
6. What is the age group of your clients?
   Please select all that apply and allocate an approximate percentage to each group:
   - 0 – 2 years
   - 3 – 5 years
   - 6 – 10 years
   - Adolescent
   - Adult
7. Which language(s) do you speak with clients? [writing box]
8. Do you assess the **vocabulary** skills of your clients?
   Yes / No [selecting 'yes' will reveal questions 7 & 8]
9. Which tasks do you use to assess **vocabulary**?
   Please select all that apply.
   - Clinical Evaluation of Language Fundamentals, Preschool (CELF-P): Expressive Vocabulary subtest
   - CELF-4: Expressive Vocabulary subtest
   - CELF-4: Word Classes subtests
   - CELF-4: Word Definitions subtests
   - CELF-5: Word Classes subtests

- CELF-5: Word Definitions subtest
- Comprehensive Assessment of Spoken Language (CASL)
- Comprehensive Receptive and Expressive Vocabulary Test (CREVT)
- Expressive One-Word Picture Vocabulary Test (EOWPVT)
- Expressive Vocabulary Test (EVT)
- MacArthur Bates Communication Development Inventories
- Montgomery Assessment of Vocabulary Acquisition (MAVA)
- Peabody Picture Vocabulary Test (PPVT)
- Preschool Language Assessment Instrument (PLAI)
- Preschool Language Scale (PLS)
- Receptive One-Word Picture Vocabulary Test (ROWPVT)
- Test for Auditory Comprehension of Language (TACL)
- Test of Adolescent and Adult Language (TOAL)
- Test of Aided Communication Symbol Performance (TASP)
- Test of Language Development (TOLD)
- Other [writing box]

10. What do you do with the data from these vocabulary assessments?

    Please select all that apply and use the comment boxes below to provide any further information (e.g., examples of how you use the data).

- Make diagnostic decisions and determine eligibility for intervention. [writing box]
- Plan intervention. [writing box]
- Progress monitoring. [writing box]
- Other [writing box]

11. Do you evaluate a client's ability to **learn new words**? (e.g., teach new words to the client and then evaluate how well they learnt those new words)?

    Yes/No/Sometimes

    If your response was 'Yes' or 'Sometimes', please describe the tasks you use. [writing box]

12. If you have used a word learning task with a client, how did you learn about this method?

    Please select all that apply and comment further (providing any references if applicable).

- Speech pathology university course [writing box]
- Professional development [writing box]
- Reading research articles [writing box]
- Reading clinical articles [writing box]
- Information from colleagues [writing box]
- Other [writing box]

13. If you assess **word learning**, what do you do with the data?

    Please select all that apply and comment further.

- Make diagnostic decisions and determine eligibility for intervention [writing box]
- Plan intervention [writing box]
- Progress monitoring [writing box]
- Other [writing box]

14. As a final question, we would be very interested in your thoughts on the cultural appropriateness of the standardised and norm-referenced vocabulary assessments you currently use in your clinical practice for diagnosis, planning eligibility for intervention, planning goals and measuring change. Please add any comments you feel are relevant. [writing box]

Appendix D.3 Word Learning Evaluation Resources (Including Dynamic Assessment)

Table D.3.1

Word Learning Evaluation Resources Mentioned in SLPs' Survey Responses (N = 135)

Resource name, reference, and accessible link	Clients suited to this resource[a]	Administration time	Overview of procedure and purpose	Mentions in survey (*n*)
Dale's scale of vocabulary knowledge (Dale, 1965) This resource (including recent adaptations of the scale) is available via: https://doi.org/10.1080/15434300902801909	Age: unspecified *Requires the client to comprehend and engage with the self-report scale, so may be best suited to school-aged clients and older* Populations/groups: unspecified	Unspecified	• SLP/teacher selects target words and uses scale to evaluate word knowledge • Knowledge is tested using a self-report scale where the person indicates how well they know a word (e.g., 'I have seen this word, but I don't know what it means…'; 'I can define this word…') • Scale may be used before and after intervention to show changes in depth of vocabulary knowledge	1
Personal Objects Representation Independence Consolidation (Woods et al., 2010)	Age: Foundation and Key Stage 1 (UK school system) Populations/groups: • Typically developing children	Unspecified	• Provides assessment and intervention resources for conceptual language development • Assessment task can be administered before and after intervention (i.e., to support target selection and evaluate learning of conceptual language).	1

Table D.3.1 continued.

Resource information accessible at: https://www.elklan.co.uk/under-5s/poric	• Children with speech, language, and/or learning difficulties • Children with English as an additional language or dialect (EALD)		• Receptive and expressive knowledge is evaluated using picture description tasks	
Linking Language with Secondary School Learning (LINK-S; Starling et al., 2012) Resource available via: https://linksresources.com.au	Age: Secondary years (Australian school system) Populations/groups: • Secondary school teachers trained to deliver the program to students • Students in Year 8 who had a language impairment and spoke English as a primary language	Unspecified	• LINK-S is a collaborative intervention approach to train secondary school teachers in language modification strategies. Direct vocabulary instruction forms part of the intervention • 10 curricular words are identified by teachers and the SLP • Tests of each word are administered before and after explicit instruction	1
Quick incidental learning of words (Rice et al., 1992) Paper accessible via: https://doi.org/10.1044/jshr.3505.1040	Age: 5-year-olds Populations/groups: • Children with 'specific language impairment' and typically developing children	Two 15-minute sessions	• Ten unfamiliar words (5 object names, 5 attribute words) presented during two 6-minute animated videos. Training occurs over two sessions (1 day to 1 week apart) • Learning of novel words tested using a comprehension task (picture-pointing). Testing occurs before and after training	1

Table D.3.1 continued.

			• This task was designed to gather information about word learning abilities in children with language impairment	
Word Aware assessment tasks (Parsons & Branagan, 2017) Resources available at: http://thinkingtalking.co.uk/word-aware/	Age: Early years and primary school students (UK school system) Populations/groups: • Designed for whole-class implementation (i.e., for typically developing students, EALD children, children with language and/or literacy difficulties, or special educational needs)	Unspecified	• This program is designed to be a structured, whole-school approach in education settings. It can also be applied in intervention settings • Various resources are included within the program for assessing students' knowledge of selected vocabulary items: ○ Four-point self-rating scale of vocabulary knowledge ○ Student writes what they know about each word and uses it in a sentence. 3-point scoring scale used to measure word knowledge ○ Assesses skills important for word learning, including 'foundation' skills (e.g., phonological awareness and semantic skills), and 'extension' skills (e.g., describing similarities and differences between words) • Tasks can generally be administered before and after teaching or intervention	4

Table D.3.1 continued.

Dynamic Assessment of Word Learning (Camilleri & Botting, 2013) Paper available via: https://onlinelibrary.wiley.com/doi/full/10.1111/1460-6984.12033	Age: 3 and 4-year-olds (Nursery year in the UK school system) Populations/groups: • Typically developing children • Children referred for SLP services	Approx. 30 minutes	• Dynamic assessment task developed to gather information about children's word learning abilities • *Pre-test*: administered the British Picture Vocabulary Scale (BPVS; Dunn et al., 1997) to identify target words • *Teaching*: target words presented in a picture-sharing context. Conversational interactions used to explore and develop word knowledge (up to 8 targets) • *Post-test*: dynamic assessment of four non-target 'advanced' words (using graduated prompting). Aims to investigate child's ability to transfer learning strategies to new target words • Clinically-relevant findings: ○ Reliability and validity of the measure was established ○ This measure may be useful for improving accuracy of differential diagnosis, and may inform clinicians about an individual's learning processes (e.g., to guide planning of individual intervention strategies)	2

Table D.3.1 continued.

Note. This table of resources is intended to be a brief guide for readers. Further details about each resource can be found by following the links provided.

[a]Key demographic details (e.g., age, stage of schooling, oral language status, languages spoken) are provided as a guide for SLPs. These details have been provided according to whether the resource was generally designed for that population (e.g., Dale's scale), and/or whether the resource was empirically trialled or tested with that population (e.g., Camilleri & Botting, 2013). While a resource may have been designed and/or trialled with a specific population, it may also have clinical validity for use with other populations.

Table D.3.2

Additional Resources for Evaluating Word Learning

Resource name, reference, and accessible link	Clients suited to this resource[a]	Administration time	Purpose & procedure
Camilleri & Law (2007) Paper available at: https://www.tandfonline.com/doi/full/10.1080/14417040701624474	Age: 3 to 5-year-olds Population/groups: • Typically developing children • Children referred for SLP services • Monolingual and EALD children	Approx. 30 minutes	• This measure was developed with the aim of capturing additional information about children's receptive vocabulary abilities, especially in children with poor language from monolingual and EALD backgrounds • *Pre-test*: administer the BPVS; identify target words from ceiling set (e.g., 3 nouns, 3 verbs) • *Teaching*: targets taught during picture posting game. 'Hierarchy of mediation' adopted to determine the child's problem solving skills during learning • *Post-test*: word knowledge re-tested using expressive and receptive tasks • Clinically-relevant information: This task is "designed to allow children to demonstrate their ability to establish new word-referent matches, irrespective of their current receptive vocabularies or whether English was their only or an additional language" (p. 320)
Dynamic assessment of children's word learning ability (Peña et al., 2001)	Age: 3 and 4-year-olds (Preschool in the US school system)	Twelve-week procedure (pre-test, teach, post-test)	• Four-week *pre-testing* phase to measure skills in: ○ description (using The Stanford-Binet Test of Intelligence for Children – Comprehension Subtest; Roid, 2003);

Table D.3.2 continued.

Paper (which includes task materials) available at: https://doi.org/10.1044/1058-0360(2001/014)	Population/groups: • Children from CALD backgrounds with either impaired or unimpaired language Task administered in English or home language as needed		○ single-word labelling (Expressive One-Word Picture Vocabulary Test; Gardner, 1981); ○ academic concepts (on the Preschool Language Scale; Zimmerman et al., 1992) • Four-week *teaching* phase: vocabulary targets (a range of nouns) taught using a mediated learning experience. Two 30-minute sessions, 1-2 weeks apart • Four-week *post-testing* phase: (same as in pre-testing phase) • Additional measures: modifiability measures to evaluate the child's learning strategies and behaviour • Clinically-relevant information: Pre-test to post-test changes scores accurately differentiated children with typical language and low language ability
Explicit word learning measure (Kelley, 2017) Paper and supplementary material (an example task script) available via: https://pubs.asha.org/doi/10.1044/2017_AJSLP-16-0074	Age: Preschool children (US school system) Population/groups: • Typically developing children • Children with English as primary language	Four sessions (3 teaching sessions; 1 post-testing session) Length of each session unspecified	• Days 1 – 3: each teaching session involved teaching one new word (total of 3 targets: 2 nouns, 1 adjective) using explicit instruction strategies • Testing probes administered each day (definition and production). Graduated prompting used to evaluate partial word knowledge • Day 4: no teaching provided; learning tested using definition and production tasks with graduated prompting • Clinically-relevant information: ○ This task was effective for gathering information about each child's ability to learn new words, including 'partial word knowledge' through hierarchical prompting strategies

Table D.3.2 continued.

			○ The incremental scoring and hierarchical prompting guidelines can reportedly be adapted to measure learning of vocabulary targets in an intervention context (Kelley, 2017)
Dynamic assessment of word learning skills (Kapantzaglou et al., 2012) Paper available via: https://doi.org/10.1044/0161-1461(2011/10-0095)	Age: 4 to 5-year-olds Population/groups: • Predominantly Spanish-speaking children (typically developing and language impaired)	Single session (30-40 minutes)	• This task was designed and trialled as a method for identifying language impairment in bilingual children • *Pre-test*: naming task (i.e., attempt to say the names of the target items) • *Teaching*: Names of 3 unfamiliar target objects taught using scripted structured play (mediated learning experience approach) • *Post-test*: Learning tested using naming and identification tasks • *Additional measures:* Modifiability Scale and Learning Strategies Checklist used to evaluate child's responsivity, transfer of skills, and required level of support (Lidz, 1991) • Clinically-relevant findings: ○ Children with typical language showed greater modifiability (learned links between phonological and semantic representations more quickly) ○ Language impairment was most accurately identified using a combination of word learning (performance on the identification task) and Learning Strategies Checklist

Table D.3.2 continued.

Dynamic Assessment of Preschoolers' Proficiency in Learning English (DAPPLE; Hasson et al., 2012) Paper available via: https://journals.sagepub.com/doi/full/10.1177/0265659012459526 Also piloted for German use (Maragkaki & Hessels, 2017): http://www.macrothink.org/journal/index.php/jse/article/view/10392/8442	Age: Piloted with 3 – 5-year-olds Population/groups: • Bilingual children with and without language impairments	Approx. 60 minutes (includes evaluation of vocabulary, sentence structure, and phonology)	• Procedure based on Camilleri and Law (2007) • *Pre-test*: static assessment of receptive vocabulary used to identify up to six target words • *Teach*: new words are taught using a posting game; children use 'process of elimination strategies' to create new associations between word forms and meanings. Hierarchy of cues provided by the examiner • *Post-test:* name the targeted items; point to the pictures if naming is unsuccessful • Clinically-relevant findings: ○ Dynamic assessment data clearly discriminated the two groups. ○ This measure has the potential to distinguish disorder (i.e., core language deficits) from difference (i.e., due to language learning context differences).
The Dynamic Assessment of Language Learning – Word Level (Hasson, 2017) Paperback and eBook versions available through various book stockists	Age: any Population/groups: any	Unspecified	• This book presents frameworks and resources for the dynamic assessment of different areas of language (of interest here are the sections on word learning) • Specific materials relevant to dynamic word learning assessment are provided. This includes: ○ Information for planning a dynamic assessment ○ Scoring materials (e.g., scoresheets, and guides for scoring prompting hierarchies) ○ Information for interpreting dynamic assessment data

Table D.3.2 continued.

Word learning with adults (McGregor et al., 2020a) Paper available via: https://doi.org/10.1177/2396941519899311	Age: adults Population/groups: • Typically developing adults • Adults with developmental language disorder (DLD)	One training session (unspecified administration time) Learning (retention) measured 1 day, 1 week, and 1 month post-training	• This task was designed to evaluate word learning (encoding and retention) in adults with and without DLD. The task measured learning of the word form (i.e., name) and the link between the word form and referent • 15 novel words (names for unusual objects) were trained via a computer-based task. Training involved exposure to the novel word, imitating the target, and retrieval practice, until mastery at naming each item was achieved • Learning was evaluated using a naming task: ○ Immediately after training ○ After a delay of 1 day, 1 week, and 1 month • This measure was useful to gathering information about how adults with and without DLD learn novel words
Word learning in aphasia (Tuomiranta et al., 2014)	Age: adults Population/groups: aphasia (chronic nonfluent aphasia and post-semantic anomia)	Pre-training session; 4 training sessions over 8-12 days (1 hour each); 5 maintenance sessions between 1 day and 6 months post-treatment	• This case study aimed to explore word learning in a client with chronic aphasia. Different learning modality combinations were trialled (e.g., phonological, orthographic). Experiment I is described here: • *Pre-test*: name the target items (20 unfamiliar object names) • *Teaching*: computer-based training sessions that involved hearing and seeing the item, imitating the name (with feedback), and pointing to the target. Learning tested using a naming task at the start of sessions 2, 3, and 4 • *Post-test*: name the targets (with first syllable cueing if needed); visual recognition test; semantic definition task

Note. Resources were identified in a scoping review of the literature on word learning in people with developmental language disorder (Jackson et al., 2019b) and through a general review of the broader literature. Additional resources may be available that have not been included here.

Appendix E Chapter 5 (Fast Mapping Paper) Appendices

Appendix E.1 Examples of Fast Mapping Materials

Figure E.1

Images of Hand-Constructed Clay Objects for Fast Mapping Stimuli.

Note. Set 1 shown: /doʊnug/, /gɔnəpek/, and /jelæntɪfɜ/.

Figure E.2

Images of Play-Based Settings

Note. These settings were constructed by participants for the fast mapping task.

Appendix E.2 Nonword Stimuli for Fast Mapping Task

Item Length	Training	Set One	Set Two	Set Three
2-syllable	/poʊdɔd/	/doʊnug/	/jugɔɪn/	/boʊgib/
3-syllable	/kɜdəwəmb/	/gɔnəpek/	/fɪkətæmp/	/tʌgnədit/
4-syllable[a]		/jelæntɪfɜ/	/gufeʃɜgʊs/	/jɔfeʃɜged/

Note. Participants were not penalised in the scoring of this task if they produced a schwa sound instead of the final ‘ɜ’ in /jelæntɪfɜ/.

[a]No four-syllable word item was included in the training set, to aid familiarisation with the task requirements without the increased cognitive load of learning a longer phonological label.

Appendix F Chapter 6 (Memory Paper) Appendices

Appendix F.1 Methodological Details for the Serial Reaction Time Task

SRT Task Instructions

"We are going to play a game on this computer. You will see pictures and hear a lady say their names. When you see four pictures, I want you to touch the picture that you hear named with this pen [show stylus]. Remember to go as fast as you can. If you think you know what comes next, you can press the picture before you hear the lady name it. This will give you more points. Try to get the right one."

Table F.1

List of Noun Stimuli in SRT Task

Drum	Scarf	Plug	Clock
Bread	Fox	Fly	Bow
Flag	Leaf	Van	Fan
Pen	Car	Horn	Watch
Crab	Pond	Chest	Tie
Bell	Mask	Shed	Box
Desk	Bin	Bed	Moon
Boat	Cup	Arm	Sledge
Swing	Wall	Heart	Train
Witch	Clown	Hen	Lamp
Door	Vase	Eye	Bat
Jug	Wheel	Snow	Sheep
Kite	Leg	Sword	Shirt
Whale	Snail	Toad	Tree
Thief	Chain	Pie	Chair
Ring			

Note: An electronic .gif motion graphic of two consecutive triplet sequences can be viewed at https://osf.io/x4td6/.

Appendix F.2 Groups of Children with and Without SRT Data (Demographic Features and Means and Standard Deviations on Participant Selection Measures)

Variable	SRT_{AV}, n = 79			$SRT_{N/A}$, n = 25			Comparison of means	
	M	*SD*	*R*	*M*	*SD*	*R*	*t*	*p*
Age in months	82.89	7.70	70 – 104	82.36	7.53	72 – 96	0.30	.765
CLS[a]	84.39	22.27	40 – 134	80.36	21.16		0.80	.427
PTONI[a]	95.43	19.41	70 – 141	95.56	17.37		-0.03	.976
NWR	81.47	11.61		81.47	13.25		0.00	.999
DR[a]	94.62	18.59		91.20	18.83		0.80	.426
BR[a]	86.80	18.74		79.92	15.91		1.66	.101
BDR[a]	90.77	19.97		93.32	15.69		-0.58	.562
General WM[b]	0.04	1.02		-0.12	0.94		0.69	.491

Note: SRT_{AV}, = children for whom SRT data was available; $SRT_{N/A}$ = children for whom SRT data was unavailable; CLS = Core Language Score on the Clinical Evaluation of Language Fundamentals, fifth edition; PTONI = Primary Test of Nonverbal Intelligence; NWR = nonword repetition (percentage of phonemes correct score); DR = digit recall; BR = block recall; BDR = backwards digit recall; *t* = independent samples *t*-test statistic.

[a]Standard scores are provided (tests standardised to a mean of 100 and standard deviation of 15).

[b]General working memory factor created through factor analysis of four working memory subtests (nonword repetition, digit recall, backwards digit recall, block recall).

Appendix F.3 Results of Bivariate Correlations Between All Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age (months)	–																
2. Gender[a]	.12	–															
3. Nonverbal IQ	-.15	.05	–														
4. General language	-.15	-.21*	.47**	–													
5. Nonword repetition (PPC)	.07	-.07	.36**	.78**	–												
6. Digit span	-.15	.01	.24*	.62**	.61**	–											
7. Block recall	-.16	.13	.18	.36**	.26**	.40**	–										
8. Backward digit span	-.10	-.08	.36**	.69**	.61**	.52**	.33**	–									
9. DL Learning	-.07	.03	.31**	.28**	.17	.17	.16	.26**	–								
10. DL Total	-.07	.06	.31**	.28*	.18	.16	.16	.25**	.94**	–							
11. DL Long Delay	-.06	.19	.27**	.27**	.22**	.33**	.21*	.26**	.69**	.70**	–						
12. WP Learning	.02	.03	.29**	.34**	.33**	.29**	.14	.29**	.27**	.26**	.34**	–					
13. WP Total	-.12	.03	.37**	.46**	.39**	.36**	.20*	.39**	.33**	.33**	.39**	.94**	–				
14. WP Long Delay	-.04	-.15	.31**	.43**	.28**	.39**	.34**	.37**	.34**	.32**	.38**	.54**	.59**	–			
15. WP Del Recognition	.02	-.05	.44**	.64**	.59**	.38**	.20*	.66**	.34**	.36**	.37**	.42**	.51**	.43*	–		

Appendix F.3 continued.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
16. Deterministic *t*-test[b]	.01	-.08	.23*	.35*	.35*	.36*	.30*	.22	.16	.10	.19	.04	.12	.13	.32*	–	
17. Probabilistic *t*-test	.11	.02	-.17	.01	.06	-.03	-.06	.06	.10	.12	.05	.08	.06	.06	.07	.14	–

Note. Values reported are Pearson's correlation coefficients (*r*). All values reported are standard scores, unless otherwise stated. PPC = percentage of phonemes correct; DL = Dot Locations (Cohen, 1997); WP = Word Pairs (Cohen, 1997).

[a]Point-biserial correlation used to determine the strength of a linear relationship between continuous variable and nominal variable with two categories (i.e., gender).

[b]Spearman's rho correlation used due to violations in the assumption of normality, linearity, or homoscedasticity.

*$p < .05$. **$p < .001$.

Appendix F.4 Covariate Factors in MANCOVAs for Working, Declarative, and Procedural Memory Analyses

Memory system	Adjusting for	Wilks' Lambda	*F*	*p*	partial η^2	Observed power
Working memory	Nonverbal IQ	0.93	1.92	.114	0.07	0.56
Procedural Memory	Nonverbal IQ	0.89	4.50	.014*	0.11	0.75
	General WM	0.96	1.63	.203	0.04	0.33
Verbal declarative memory	Nonverbal IQ	0.88	3.32	.014*	0.12	0.83
	Verbal ST/WM	0.77	7.46	<.001**	0.23	0.99
Visual–spatial declarative memory	Nonverbal IQ	0.90	3.75	.013*	0.10	0.80

Note. General WM = General working memory factor created through factor analysis of four working memory subtests; Verbal ST/WM = Verbal short-term and working memory factor created through factor analysis of three individual subtest scores (nonword repetition, digit recall, and backwards digit recall).

*p < .05. **p < .001.

Appendix G Chapter 7 (Word Learning Paper) Appendices

Appendix G.1 Word Learning Stimuli (Pseudoword Labels)

Word Length	Training Item	Experimental Items
1-syllable	-	/nɔb/ /lɜz/
2-syllable	/poʊdɔd/[a]	/doʊnug/ /jugɔɪn/
3-syllable	-	/gɔnəpɛk/ /gɪtəmoʊk/
4-syllable	-	/hɒʃətæjɪk/ /gufəʃɜgʊs/

Note. Pseudowords were taken from Jackson et al. (2016) and Jusczyk et al. (1994) Jusczyk et al. (1994). Two- and three-syllable stimuli were pronounced with stress on the first syllable, and the four-syllable items were pronounced with emphasis on the third syllable.

[a]Only one item (two-syllable nonword) item was used for training, as pilot testing showed that training one item was sufficient for participants to understand the parameters of the task.

Appendix G.2 Screenshot of the Eight Referents (Word Learning Stimuli)

Appendix G.3 Example Script for Narration of Animated Word Learning Tasks

Day 1 (Encoding): Brief script for practice item

Training

"There is a creature in the ship who wants to get out and stretch its legs. The creature has a strange name and looks a bit funny." Item appears from rocket ship.

"This is Poudord. Can you say it?" Await participant response and provide specific feedback as required:

a) No response: "Try to tell me the name."
b) Incorrect response: "This is one is called Poudord."
c) Correct response: "Yes, it's Poudord."

"Poudord is round… Poudord has yellow legs... It's time for Poudord to go back in..." Item returns to rocket ship, and then disappears from screen.

Outcome Measures

1) *Identification test*

Three items display on screen, including the practice item and two random items (not including any of the eight experimental items). Prompt: "Can you help me find it? Point to Poudord." Await participant response and provide specific feedback as required:

a) Correct response: "That's right."
b) Incorrect response: "It's this one [point]."

2) *Naming*

Creature appears on screen. Prompt: "Tell me its name." Await response and provide neutral feedback. Items disappears after production.

3) *Description*

Screen shows only background to the task (item not visible). Prompt: "I want you to tell me what Poudord looked like. Try to tell me four things." Await response and implement graduated prompting to train participant to provide a description that includes four features:

a) Correct response (all four features correctly stated): “That’s right. You told me the colour of its body and legs, how many eyes it had, and its shape.”
b) Provide corrective feedback for any incorrect description of features: e.g., “It had a square body”; “It had four eyes.”
c) Any features omitted:
    I. Level 1 (general): “What else can you tell me?”
    II. Level 2 (specific, probing for omitted features): e.g., “Tell me its shape”, “Tell me how many eyes it had.”

4) Recognition

Provide participant with yes/no electronic buttons (coloured green and red, with “yes” and “no” in bold letters). Item reappears on screen. Prompt: “Now we’re going to play a tricky game. I’m going to say the creature’s name – sometimes right, sometimes a bit wrong. Press the green button if it is right; press the red button if it is wrong.”

Participant hears four versions of the target (one correct, three foils, in random order) and uses yes/no buttons to respond to each item. Provide feedback on each item:

a) Correct response: “That’s right.”
b) Incorrect response: “Hmm, that wasn’t the right one. Keep listening.”

Appendix G.4 Semantic Features of Word Learning Referents and Phonological Foils for Recognition Task

Item	Colour of body	Body shape	Colour of legs	Number of eyes	Phonological foils
/nɔb/	Purple	Circle	Green	4	bɛnɔb kɔb nɔʧ
/lɜz/	Black	Oval	Red	2	lɜzɛg kɜz lɜp
/doʊnug/	Pink	Circle	Purple	3	nugdoʊ foʊnug doʊnus
/jugɔɪn/	Red	Rectangle	Pink	1	gɔɪnju kugɔɪn jugɔɪʃ
/gɔnəpɛk/	Dark blue	Square	Yellow	4	pɛknəgɔ fɔnəpɛk gɔnəpɛl
/gɪtəmoʊk/	Yellow	Oval	Green	1	moʊkəgɪt nɪtəmoʊk gɪtəmoʊz
/hɒʃətæjɪk/	Green	Rectangle	Yellow	2	jɪkətæhɒʃ lɒʃətæjɪk hɒʃətæjɪm
/gufəʃɜgʊs/	Light blue	Square	Red	3	gʊsəʃɜguf ʧufəʃɜgʊs gufəʃɜgʊb

Note. Phonological foils were created by modifying syllables (i.e., syllable transposition), initial phoneme, and final phoneme.

Appendix G.5 Fixed Effects for the Nonverbal IQ Factor in the GLMMs for Naming, Recognition, Identification, and Description

Outcome measure	*F*	Degrees of freedom	*p*	partial η^2
Naming	0.15	1, 407	.698	< 0.01
Recognition	1.73	1, 407	.190	0.004
Identification	5.71	1, 407	.017*	0.01
Description	0.40	1, 407	.525	< 0.01

Note. Nonverbal IQ assessed using the Primary Test of Nonverbal Intelligence (PTONI; Ehrler & McGhee, 2008).

*$p < .05$.

Appendix G.6 Group Comparisons on Naming, Recognition, Identification, and Description Across the Four-day Protocol

	Day 1 (encoding)			Day 2 (re-encoding)			Day 3 (re-encoding)			Day 4 (retention)		
Measure	*t*	*p*	95% CI	*t*	*p*	95% CI	*t*	*p*	95% CI	*t*	*p*	95% CI
Naming	-6.77	< .001	-32.85, -8.07	-7.48	< .001	-35.31, -0.62	-5.64	< .001	-28.65, -3.85	-0.34	.732	-8.58, 6.03
Adjusted	-8.68	.044	-17.11, -0.24	-13.68	.002	-22.42, -4.94	-6.47	.103	-14.27, 1.32	7.20	.163	-2.94, 17.34
Recognition	-6.97	< .001	-19.41, -0.87	-8.53	< .001	-22.41, -4.02	-6.64	< .001	-20.59, -1.18	-6.87	< .001	-24.25, -13.46
Adjusted	-8.32	.002	-13.68, -2.96	-11.19	< .001	-15.77, -6.61	-8.86	.003	-14.78, -2.94	-10.99	.001	-17.63, -4.36
Identification	-1.77	.078	-8.34, 0.43	-1.37	.172	-4.86, 0.87	-0.33	.741	-2.62, 1.86	-1.61	.107	-17.58, 1.73
Adjusted	-4.09	.102	-9.00, 0.82	-1.75	.362	-5.52, 2.02	-0.06	.971	-3.33, 3.45	-0.89	.900	-14.83, 13.04
Description	-3.40	.001	-16.41, -4.37	-3.17	.002	-15.00, -3.50	-3.94	< .001	-15.06, -5.03	-	-	-
Adjusted	-7.38	.047	-14.67, -0.09	-6.13	.074	-12.86, 0.60	-5.39	.318	-12.52, 1.75	-	-	-

Note. Group comparisons are for the DLD to TD groups. Least significant difference contrasts are reported. 95% CI = 95% confidence interval (upper, lower). All values indicate percentage of accuracy on the tasks. 'Adjusted values' are from the second set of GLMM analyses (controlling for nonverbal IQ and verbal working memory).

Appendix G.7 Comparisons Between Each Time Point on Naming, Recognition, Identification, and Description, Disaggregated by Group

	DLD						TD					
	t	*t* adjusted	*p*	*p* adjusted	95% CI	95% CI adjusted	*t*	*t* adjusted	*p*	*p* adjusted	95% CI	95% CI adjusted
Naming												
Day 1–Day 2	-3.03	-5.24	.003	.150	-11.82, -.51	-12.36, 1.89	-5.23	-10.24	<.001	.001	-13.31, -.04	-16.10, -.38
Day 2–Day 3	-3.97	-12.10	<.001	<.001	-15.73, -.31	-19.03, 5.18	-2.39	-4.90	.017	.032	-6.94, -0.67	-9.36, -0.44
Day 3–Day 4	9.35	38.99	<.001	<.001	25.72, 9.41	29.42, 8.56	20.34	52.66	<.001	<.001	47.46, 7.62	43.20, 2.12
Recognition												
Day 1–Day 2	-1.47	-3.55	.142	.053	-5.39, 0.78	-7.15, 0.05	-5.78	-6.41	<.001	< .001	-7.21, -3.55	-9.80, -3.03
Day 2–Day 3	-3.43	-5.55	.001	.006	-7.58, -2.06	-9.48, -1.62	-3.81	-3.22	<.001	.001	-3.77, -1.21	-5.17, -1.27
Day 3–Day 4	4.45	5.74	< .001	.009	3.60, 9.29	1.44, 10.04	4.48	3.61	<.001	.010	1.95, 5.00	0.86, 6.36
Identification												
Day 1–Day 2	-0.89	-2.00	.376	.294	-5.07, 1.92	-5.74, 1.74	0.24	0.34	.808	.855	-1.64, 2.11	-3.33, 4.02
Day 2–Day 3	-1.72	-2.57	.087	.095	-4.57, 0.31	-5.58, 0.45	-0.61	-0.76	.542	.694	-2.16, 1.14	-4.53, 3.02
Day 3–Day 4	13.58	51.90	<.001	<.001	46.61, 2.38	40.82, 2.98	15.13	15.94	<.001	<.001	40.85, 3.05	41.18, 0.70

Appendix G.7 continued.

	DLD						TD					
	t	*t* adjusted	*p*	*p* adjusted	95% CI	95% CI adjusted	*t*	*t* adjusted	*p*	*p* adjusted	95% CI	95% CI adjusted
Description												
Day 1–Day 2	-0.17	-2.60	.865	.282	-4.17, 3.51	-7.33, 2.14	0.52	-1.34	.605	.580	-3.89, 2.27	-6.11, 3.43
Day 2–Day 3	-1.99	-3.85	.047	.132	-9.47, 1.06	-8.86, 1.17	-3.06	-3.10	.002	.213	-7.67, -1.67	-7.99, 1.79

Note. Least significant difference contrasts are reported. 95% CI = 95% confidence interval (upper, lower). All values indicate percentage of accuracy on the tasks. ‘Adjusted values’ are from the second set of GLMM analyses (controlling for nonverbal IQ and verbal working memory).

Appendix G.8 Confidence Intervals (95%; Upper, Lower) Indicating Between-Group Differences on Naming

	DLDlow	DLDav	TDlow	TDav
Day 1	41.06, 49.67	56.61, 65.52	49.89, 73.71	62.59, 76.34
Day 2	48.62, 57.76	60.02, 72.58	61.80, 82.53	73.98, 85.44
Day 3	57.97, 68.37	73.05, 83.76	68.67, 88.62	79.29, 89.93
Day 4	27.65, 37.98	31.81, 47.02	13.04, 38.57	25.73, 38.17

Note. DLDlow = estimated values for children with DLD and low verbal working memory; DLDav = estimated values for children with DLD and average verbal working memory; TDlow = estimated values for typically developing children with low verbal working memory; TDav = estimated values for typically developing children with average verbal working memory.

Appendix G.9 Confidence Intervals (95%; Upper, Lower) Indicating Between-Group Differences on Recognition

	DLDlow	DLDav	TDlow	TDav
Day 1	67.37, 73.04	74.71, 81.31	75.66, 90.70	82.65, 90.40
Day 2	69.79, 76.38	77.19, 84.93	86.44, 95.73	90.41, 95.47
Day 3	73.78, 80.52	81.52, 92.36	92.20, 98.54	94.47, 97.85
Day 4	66.46, 75.47	74.81, 86.92	86.32, 96.80	89.74, 95.36

Note. DLDlow = estimated values for children with DLD and low verbal working memory; DLDav = estimated values for children with DLD and average verbal working memory; TDlow = estimated values for typically developing children with low verbal working memory; TDav = estimated values for typically developing children with average verbal working memory.

Appendix H   Sample Recruitment Materials and Assessment Report

Appendix H.1 Example Curtin HREC-Approved Information Letters and Consent Forms for Recruitment of Participants for Studies 3 and 4

Emily Jackson
School of Psychology and Speech Pathology
October 2017

Principal information letter

Dear Principal,

Word learning in children with typically developing language and developmental language disorder.

My name is Emily Jackson and I am a PhD student and speech pathologist. I am conducting a study to investigate the word learning skills of typically developing children and children with developmental language disorder (DLD). Adequate word learning abilities are very important for building vocabulary to use in both written and spoken communication. The purpose of my study is to explore word learning over a number of days, and how areas of memory contribute to word learning ability. This may help schools, families and clinicians support the word learning of children struggling with vocabulary and language in the future.

My supervisors for this project are A/Prof Suze Leitão, Dr Mary Claessen, and Dr Mark Boyes from Curtin University.

What does participation in the research project involve?
I am seeking the participation of approximately 50 Year 1 and Year 2 students who have typically developing language skills. The project will involve assessments of their hearing, articulation, language, nonverbal skills, memory, and word learning over a series of days.

I would like to invite your school to participate in this research. This would involve the following steps:

1. Identification of children in Year 1 and Year 2 with typically developing language.
    - As the Principal, you would provide my research information sheet and consent forms to the parents/caregivers of children with typically developing language and no significant articulation issues.
    - The parents/caregivers will return the consent forms to the child's teacher who will return them to me. Parents/caregivers will have the opportunity to discuss any questions they may have by directly contacting me.
    - I will come to your school in Terms 1, 2 and 3 (2018) and complete data collection as per the table below. Each session will take 15-20 minutes, and sessions may be completed over a series of weeks.

Session	1	2	3	4	5	6	7	8
Tasks	Language test	Nonverbal skills test; Hearing screen; Articulation screen	Memory test	Memory test	Word learning	Word learning	Word learning	Word learning

- All of the tasks are well-recognised, standardised assessments, or have been designed specifically for use with children this age. All tasks are engaging and children will be offered breaks as required.
- If a child shows any distress during the session, the activities will cease and they will be taken back to their classroom.
- The language test involves hearing sentences and pointing to corresponding pictures; completing sentences; and labelling pictures. The nonverbal test involves looking at sets of coloured pictures and identifying pictures that do not belong.
- The memory tests involve:
  - Repeating nonsense words or strings of numbers;
  - Learning pairs of words and recalling them at a later time;
  - Learning patterns at a computer screen and having reaction times tested.
- The word learning task involves a play-based activity in which children will learn the names of unfamiliar objects. The same activity will occur on each of the four days.
- Part of the assessment will be audio-recorded so that it can be scored after the assessment session is completed. The audio recordings will be destroyed immediately following the completion and checking of scoring.

To what extent is participation voluntary, and what are the implications of withdrawing participation?
Participation in this study is completely voluntary. All potential participants and their parents/caregivers are advised of this in the information letters.

If parent/caregivers give permission for their child to participate in the research, they may withdraw their child, or the child may withdraw themselves, from participation at any time without consequence. If a child is withdrawn from participating in the study, all information and data will be destroyed immediately.

If the project has already been published at the time a participant decides to withdraw, their contribution to research data cannot be removed from the publication.

The decision about whether to participate, or to participate and then withdraw, of any participant will not affect the relationship with the research team or Curtin University.

What will happen to the information collected, and is privacy and confidentiality assured?
Information that identifies a participant or the school will be removed from the data collected. The data will be stored in a locked cupboard at Curtin University that can only be accessed by my supervisors (A/Prof Suze Leitão, Dr Mary Claessen, Dr Mark Boyes) and myself. All measurement records will be stored for 7-25 years, as per requirements for conducting research where the projects include children, after which it will be destroyed according to the Curtin University Functional Records Disposal Authority protocol.

The data are stored in this way so that, if a participant decides to withdraw, their data can be re-identified and destroyed. This is done by using a system of individual codes which are known only to the research team.

The results of this study may be published, however; no identifying information regarding the participants will be used. The identity of the participants and the school will not be disclosed at any time, except in circumstances requiring reporting under the Department of Education and Training Child Protection Policy, or in the circumstance that the research team is legally required to disclose such information. Confidentiality of participant information is assured at all other times.

What are the benefits of this research for the child's education and the school?
Results from this study will be used to inform teachers and speech pathologists about word learning in typically developing children and children with DLD. This will allow us to understand why word learning difficulties occur, and may guide teachers and speech pathologists in how to support children with difficulties in this area. It will also add to the evidence base for the effective practice of teachers and speech pathologists.

After the completion of the research, a report describing the outcomes of the research can be provided to school staff. When filling out the consent forms, parents may request to receive a summary of their child's results on the assessments of hearing, articulation, language, nonverbal skills and memory, and on the word learning task. They may also give permission for their child's individual results to be provided to school staff. This would provide information to the teacher regarding the assessed areas, and therefore may assist in highlighting effective modes of learning.

The data that are collected have the potential to identify difficulties with the assessed areas. This information is confidential and if parents/caregivers give permission, this information will be provided to the school and options for follow-up may be provided.

Are there any risks associated with participation?
There are no known risks associated with participation in this study. The assessment sessions will include breaks as needed.

Do all members of the research team who will be having contact with children have their Working with Children Check?
Yes. Under the Working with Children (Criminal Record Checking) Act 2004, individuals undertaking research that involves contact with children must pass a Working with Children Check. I have attached evidence of my current Working with Children Check.

Is this research approved?
Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number HRE2017-0836). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

Who do I contact if I wish to discuss the project further?
Please do not hesitate to contact either myself or my research supervisors if you have any questions about the study. I can be contacted by email: Emily.jackson@postgrad.curtin.edu.au. Alternatively, you may wish to contact one of my supervisors, A/Prof Suze Leitão (S.Leitao@exchange.curtin.edu.au), Dr Mary Claessen (M.Claessen@curtin.edu.au) or Dr Mark Boyes (Mark.boyes@curtin.edu.au).

How do I indicate my willingness for the school to be involved in this project?
If you have had all questions about the research project answered to your satisfaction, and are willing for your school to participate, please complete the **Consent Form** attached.

Please return this to me via the enclosed stamped and addressed envelope by the [final date TBA] if you would like your school to be involved.

Thanking you in advance.

Emily Jackson PhD Candidate	A/Prof Suze Leitão Associate Professor	Dr Mary Claessen Senior Lecturer

Dr Mark Boyes
Senior Research Fellow

School of Psychology and Speech Pathology
Curtin University

School of Psychology and Speech Pathology
October 2017

Word learning in children with typically developing language and developmental language disorder.

Consent Form for School Principal

- I have read this document and I understand the aims, procedures, and risks of this project.
- I have been given the opportunity to ask any questions I may have had, and these have been answered to my satisfaction.
- I am willing for this school to be involved in the research project, as described.
- I understand that participation in this project is completely voluntary.
- I understand that this school may withdraw its participation in this project at any time, without consequence.
- I understand that the results of this research may be published in a journal, provided that the participants or school are not identified in any way.
- I understand that the school will be provided with a copy of the research findings upon the completion of this project.
- I understand that the school may be provided with individual assessment results if parents/carers give consent.

Name of School (please print): ____

Name of School Principal (please print): ____

Signature of School Principal: ____

Date (DD/MM/YYYY): _____ / _____ / ________

Signature of researcher: ____________________________________

Emily Jackson
School of Psychology and Speech Pathology
October 2017

Parent Information and Consent Form

Dear Parent/Carer,

My name is Emily Jackson and I am a PhD student and speech pathologist. Research has shown that some children have difficulty learning new words. We need to understand how words are learned by children with and without language difficulties. The results may help schools and speech pathologists support children to develop their vocabulary.

What does participation in the research project involve and are there any risks?
I would like to invite your child to take part in this research. If you give permission for your child to participate, I will carry out tests of your child's hearing, speech, language, nonverbal skills, memory, and word learning. There are no known risks involved in taking part in this study.

The sessions will involve your child looking at pictures and playing word games. These sessions will be spread across 8 short sessions of about 15-20 minutes each (in Terms 1, 2 or 3 in 2018). Children generally enjoy tasks like these and breaks will be offered when needed. Part of the session will be audio-recorded so that I can score your child's results after the session is completed.

If your child shows any distress during the session, the activities will cease and they will be taken back to their classroom.

Does my child have to take part?
No. You do not have to give permission for your child to take part in this project. This will not affect your relationship with your child's school in any way. If you would like your child to take part, I have included a consent form for you to sign. I have also included a consent form for your child. Please talk to your child about the activities and let them know that they do not need to take part if they do not want to. Please help your child to circle the 'Yes' on the consent form, and write their name underneath, if they do want to take part.

What if either of us was to change our mind?
If you give permission for your child to take part, but then change your mind, you may withdraw your child. Your child may also withdraw themselves from the project at any time without consequence. If your child is withdrawn from the study, all of your child's information will be destroyed immediately.

Your decision about whether to take part in this project will not change your family's relationship with your child's school.

What will happen to the information collected, and is privacy and confidentiality assured?
When information is collected about your child, his/her name and any personal information will be removed and a code will be given instead. Your child's information is stored this way so that if you decide to withdraw from the project, I can find your child's information and destroy it.

The results of this project may be published, but no personal information about your child will be used. Your child's name and the name of your child's school will not be given to anyone. However, this information may be provided in a situation where the research team must legally report this information, such as to the Department of Education Child Protection Policy. Your child's information will not be provided at any other time.

What are the benefits of this research for my child's education?
The research team will send you a summary of your child's results if you tick the required box on the consent form. If you would also like us to provide your child's school with the results, please tick this box on the consent form.

If your child takes part, the testing might show that he/she has some difficulties. If this is the case, you may contact myself or one of my supervisors to discuss the results, and we can provide you with information regarding services to follow up with.

How do I know that the people involved in this research have all the appropriate documentation to be working with children?
Under the Working with Children (Criminal Record Checking) Act 2004, researchers working with children must pass a Working with Children Check. I have provided the Principal of your school with evidence of my current Working with Children Check.

Is this research approved?
Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number HRE2017-0836). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

Who do I contact if I wish to discuss the project further?
Please do not hesitate to contact either myself or my research supervisors if you have any questions about the project. I can be contacted by email (Emily.jackson@postgrad.curtin.edu.au). You may also wish to contact one of my supervisors, A/Prof Suze Leitão (S.Leitao@exchange.curtin.edu.au), Dr Mary Claessen (M.Claessen@curtin.edu.au) or Dr Mark Boyes (Mark.boyes@curtin.edu.au).

How does my child become involved in this project?
Please make sure that you:

- Talk to your child about what taking part in the project involves before you both make a decision;
- Take up my offer to ask any questions you may have about the project.

Once all questions have been answered to your satisfaction, and you and your child are both willing for him/her to take part, please both complete the attached **Consent Forms**, and return them to your child's teacher by the [final date TBA]**.**

Thanking you in advance.

Kind regards,

Emily Jackson
PhD Candidate

A/Prof Suze Leitão
Supervisor and Associate Professor

Dr Mary Claessen
Supervisor and Senior Lecturer

Dr Mark Boyes
Supervisor and Senior Research Fellow

School of Psychology and Speech Pathology
Curtin University

Curtin University

School of Psychology and Speech Pathology
October 2017

Word learning in children with typically developing language and developmental language disorder.
Parent Consent Form

- I have read this information letter and I understand the aims, procedures, and risks of this project.
- I have been given the opportunity to ask any questions and these have been answered.
- I am willing for my child to become involved in the research project, as described.
- I have talked to my child about the project, and he/she wishes to take part, as indicated by his/her completion of the child consent form.
- I understand that participation in this project is completely voluntary.
- I understand that both my child and I are free to withdraw from participation at any time, without affecting my family's relationship with my child's teacher or my child's school.
- I give permission for the contribution that my child makes to this research to be used in conference talks and published in a journal, provided that my child is not identified in any way.
- I understand that a summary of findings from the research can be made available to me and my child upon its completion.

Please also tick boxes to give permission for:

☐ my child's responses to be audio recorded to allow scoring to take place.
☐ my child's results to be released to his/her school.
☐ I would like to be provided with a summary of my child's results. *Please provide your postal address, or email if preferred:*

Unit/Street number and street name: ____

Suburb: __________________________ Postcode: ___________________________

Email: ____

Name of Child (please print): ____________________________________

Date of birth (please print): _____ / _____ / ________

Name of Parent/Caregiver (please print): ___________________________________

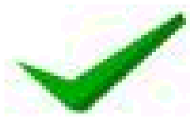
Signature of Parent/Caregiver: ____

Today's date (DD/MM/YYYY):_____ / _____ / ________

Signature of researcher: _____________________________________

Consent Form for Children

- I have talked about this project with my parents.
- I know that I can choose whether or not I want to do this project.
- I know that I can stop whenever I want without getting into trouble.
- I know that I will be looking at pictures, saying some funny-sounding words and learning new names for things.
- I know that my voice may be recorded when I answer some questions.
- I understand that I need to draw a circle around the tick on this page before I can help.



YES NO

I would like to help with the project Not this time

Name: ________________________________ Date: _____________

Signature of researcher: _____________________________________

Appendix H.2 Example Curtin HREC and Department of Education-Approved Assessment Report

School of Occupational Therapy, Social Work, and Speech Pathology
August 2019

<u>Non-Diagnostic Report</u>
Child's name: XXXX
Child's age at time of assessment: X years

Thank you for allowing your child to take part in my research project. If you wish to discuss your child's results in detail, please contact me or one of my supervisors (Suze Leitão or Mary Claessen; contact details are provided below). As per your indication on the consent form, your child's results have/have not been shared with your child's teacher and school. You may choose to share these yourself if you would like to.

HEARING SCREEN

A hearing screen with a pure tone audiometer assesses the ability to detect pure tones (sounds) of various frequencies (in Hertz). The assessment is only a *screen*, and so the results are not always 100% accurate (e.g., background noise and/or other factors may influence the results and follow-up may be required).

The results indicated that XXXX passed the hearing screen / XXXX's hearing in one / both ears may not be as good as would be expected at their age.

It is recommended that you discuss these results with your child's GP. They may recommend that XXXX have a comprehensive hearing assessment.

For more information about hearing and hearing assessments, visit the American Speech, Language and Hearing Association (ASHA) (http://www.asha.org/public/hearing/).

DIAGNOSTIC EVALUATION OF PHONOLOGY AND ARTICULATION (DEAP) – PHONOLOGY ASSESSMENT

Your child was asked to name a series of pictures. This allows us to assess their speech sound production. The results show that XXXX was able to produce all speech sounds as appropriate for his/her age / The results show that XXXX had difficulty producing the following speech sound: xxx. Children should be able to accurately produce these speech sounds by XXXX's age.

PEABODY PICTURE VOCABULARY TEST, FOURTH EDITION (PPVT-4)

This assessment measures how well a child is able to understand a variety of different words (this is known as 'receptive vocabulary'). In this task, XXXX was required to listen to a word and point to the correct picture out of four options. XXXX scored below the normal range / within the normal range / above the normal range on this task.

WORKING MEMORY ASSESSMENT

In this task your child listened to made-up words and repeated them aloud. This task gives us information about how well a child might hear and learn new words. XXXX scored below the normal range / within the normal range / above the normal range on this task.

The results show that your child's performance on the hearing / speech / vocabulary / working memory tasks were outside of the average range. You may like to follow up with your child's teacher about the difficulties that were identified in these tasks. XXXX may already be receiving additional support in the classroom and/or additional support from the speech pathologist at school for these areas of difficulty.

If you wish to discuss your child's results in detail, please contact one of my supervisors:
Suze Leitão, 9266 7620, S.Leitao@exchange.curtin.edu.au, or
Mary Claessen, 9266 3472, M.Claessen@curtin.edu.au

Thank you again for allowing your child to take part in our research study.

Emily Jackson
Speech Pathologist (CPSP)
PhD Candidate
Curtin University
Emily.jackson@postgrad.curtin.edu.au