The Efficacy of a Theoretically Motivated Past Tense Intervention for Early School-Aged Children with Developmental Language Disorder

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This thesis is presented for the Degree of
Doctor of Philosophy in Human Communication Sciences
of
Curtin University

January, 2021

Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement 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). The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (30 November, 2017: HRE2017-0835, amended 14 November, 2018), and the Department of Education Western Australia (28 March, 2018: D18/0124993 and 25 January, 2019: D19/0018955).

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Date: 26th January, 2021

Acknowledgements

Firstly, I would like to acknowledge the contribution of an Australian Government Research Training Program Scholarship in supporting my doctoral research. I would also like to acknowledge the additional funding I received from Curtin University to complete my PhD. These initiatives made it possible to dedicate the necessary time and commitment to complete the programme of research.

Next, I would like to thank my supervisors: Dr Mary Claessen, Associate Professor Suze Leitão, and Dr Susan Ebbels. To Mary and Suze- this journey began from your tutelage during postgraduate studies. Thank you for helping me to find a path where I can fuel my interest in developmental linguistics while helping those in need. Your passion for furthering our understanding of developmental language disorder and uncovering ways to help these children is why I am where I am today. Thank you for staying in touch until I pulled the trigger on enrolling in a higher degree by research. I’ll never forget the chat we had on that very warm summer day at the specialised educational programme. Thank you for always being one step ahead when I needed some emotional support, and thank you for always making me feel like a colleague, rather than a student. Thank you for the Language and Literacy in Young People (LaLYP) Christmas parties where we could just laugh and be merry. Susan- thank you for giving me that fan-boy moment years back at the specialised educational programme that ultimately led us here. Thank you for your support in designing the intervention, especially your contribution to using the SHAPE CODING™ system. Your openness to engage and support clinicians and early stage researchers has been a constant inspiration. I have learned so much about all the things that make a PhD what it is from your feedback and our conversations. To you all- I could not imagine having a better team behind me to get this project completed. I could go on, but I would run the risk of bloviating and blatterating…

Thank you to Dr Kuppuraj Sengottuvel and Professor Dorothy Bishop from Oxford University Department of Developmental Psychology for sharing and assistance with using the serial reaction time task. Thanks to Dr Karen Smith-Lock for supporting the use of the Grammar Elicitation Test and sharing intervention sessions to adapt for the purpose of this study. Thanks to Dr Welber Marinovic for his assistance with analysis in Study 5.

I would like to acknowledge the contribution of the staff and families of the specialised educational programme from which I collected my data. Without their ongoing eagerness to support such projects, the progress our research community has made over the past few years would not exist. These are the consumers of our research findings, and I cannot express my utmost gratitude sufficiently enough.

I would like to thank my blinded assessors: Taylor Gartner, Kelly Mackean, Jenni Brennan, Becky Balchin, Siobhan Kavanagh, Laura Buchan, Samantha Ward, Zeljka Danilcevic, Liza Hutton, Agnus Kwan, and Sonya Coffey. Thank you to Dr Lizz Hill, Emily Jackson, and Zoe Campbell for their assistance with blinded scoring. Thank you to Robert Wells for his assistance with blinded random assignment of participants. Special thanks to Dr Lizz Hill- thank you for being so open with your time to share resources and provide opportunities to discuss ideas and/or vent frustrations.

Thank you to all members of LaLYP for providing a network of support and a nexus of knowledge throughout my PhD. I cannot stress how much I appreciate having had such a vibrant group of researchers to call my peers over the past few years. I am proud to be amongst such incredible people.

Finally, I would like to acknowledge my friends and family. In particular, I would like to thank Dr Chris Brennan-Jones. Chris— you have always been a source of knowledge and reassurance throughout our friendship, never more so than when I went through this journey. I look forward to our future endeavours. To my extraordinarily wonderful wife, Jacqui— the debt of gratitude to which you are owed can never be honoured. I quite literally would not be here without your ceaseless support and encouragement. To be able to wake everyday with the confidence that I could achieve this project is almost entirely credited to you. Thank you for giving us our wonderful Odette Day, who has, in all probability, developed that strange nasal huffing from listening to me batter away at the computer keyboard for too many hours. And thank you for the *quid pro quo* which ended up with us rescuing our beautiful dog, Hippolyta. She has almost certainly changed my life for the better. Finally, thank you to the Bradfield/Bakers. Thank you for making me part of your family. Whenever I needed someone to be proud of me, you were always there. Special thanks to my brother-in-law, Max Bradfield. Whenever I needed to take some time away or need a kick up the rear end to stay focussed, you were there.

"Nothing of me is original; I am the combined efforts of everyone I've ever known."

~Chuck Palahniuk, Invisible Monsters.

Peer Reviewed Publications Arising from Thesis

Published

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020). Explicit grammar intervention in young school-aged children with developmental language disorder: An efficacy study using single case experimental design. *Language, Speech & Hearing Services in Schools, 51*(2), 298-316. https://doi.org/10.1044/2019_LSHSS-19-00060

Authorship attribution statement:
As lead author, I was primarily responsible for the design of the study, developing the research questions, collection and analysis of the data, and writing the drafts of the manuscript. All co-authors assisted in the conceptualisation of the study design and research questions. Co-author SE assisted in the refinement of intervention procedures. All co-authors assisted in the title and abstract. All co-authors contributed to the interpretation and discussion of results, and editing the manuscript for final approval prior to submission.

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2021). The efficacy of an explicit intervention approach to improve grammar for early school-aged children with DLD. *Journal of Speech, Language, & Hearing Research, 64*(1), 91-104. https://doi.org/10.1044/2020_JSLHR-20-00132

Authorship attribution statement:
As lead author, I was primarily responsible for the design of the study, developing the research questions, collection and analysis of the data, and writing the drafts of the manuscript. All co-authors assisted in the conceptualisation of the study design and research questions. Co-author SE assisted in the refinement of intervention procedures. All co-authors assisted in the title and abstract. All co-authors contributed to the interpretation and discussion of results, and editing the manuscript for final approval prior to submission.

Currently under review

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (under review a). A profile of expressive inflectional morphology in early school-aged children with Developmental Language Disorder. *Clinical Linguistics and Phonetics.*

Authorship attribution statement:
As lead author, I was primarily responsible for the design of the study, developing the research questions, collection and analysis of the data, and writing the drafts of the manuscript. All co-authors assisted in the conceptualisation of the study design and research questions. All co-authors assisted in the title and abstract. All co-authors contributed to the interpretation and discussion of results, and editing the manuscript for final approval prior to submission.

Calder, S. D., Claessen, M., Leitão, S., & Ebbels, S. (under review b). Evaluating two different dose frequencies and cumulative intervention intensities to improve past tense production for early school-aged children with developmental language disorder**.** *International Journal of Language and Communication Disorders.*

Authorship attribution statement:
As lead author, I was primarily responsible for the design of the study, developing research questions, collection and analysis of the data, and writing the drafts of the manuscript. All co-authors assisted in the conceptualisation of the study design and research questions. Co-author SE assisted in the refinement of intervention procedures. All co-authors assisted in the title and abstract. All co-authors contributed to the interpretation and discussion of results. Co-author SE led the primary re-analysis of data and interpretation following reviewer feedback. All co-authors contributed to editing the manuscript for final approval prior to submission.

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Date: 22nd January, 2021

Dr Susan Ebbels
Date: 21st January, 2021

Peer Reviewed Presentations Arising from Thesis

Calder, S. D. (2020, May). Explicit grammar intervention for young school-aged children with Developmental Language Disorder. Mark Liveris Research Student Seminar, Perth, Western Australia.

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020, July). The efficacy of an explicit intervention approach to improve grammar in early school-aged children with Developmental Language Disorder. Proposal accepted at the International Association for the Study of Child Language Conference, Philadelphia, Pennsylvania (postponed until 2021).

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020, September). A profile of inflectional morphology skills in early school-aged children with Developmental Language Disorder. Proposal accecpted at the 18^{th} Biennial Conference of the International Clinical Linguistics and Phonetics Association, Glasgow, Scotland (postponed until 22^{nd} – 25^{th} June, 2021).

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020, November). 10573: Explicit intervention improves past tense marking in early school-aged children with developmental language disorder. Proposal accepted at the Annual Convention of the American Speech-Hearing Association, San Diego, CA (Convention Cancelled).

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List of Abbreviations

1PW	Once Per Week
2PW	Twice Per Week
3s	Third Person Singular
CE	Central Executive
CMS	Children's Memory Scale
CONSORT	Consolidated Standards of Reporting Trials
CV	Consonant Vowel
DLD	Developmental Language Disorder
E^3BP	Evidence(3)-Based Practice
GET	Grammar Elicitation Test
GJT	Grammaticality Judgement Task
ICC	Intraclass Correlation Coefficients
NRT	Nonword Repetition Task
PDH	Procedural Deficit Hypothesis
PL	Phonological Loop
PPVT-4	Peabody Picture Vocabulary Test – Fourth Edition
PSTM	Phonological Short Term Memory
RCI	Reliable Change Index
RCT	Randomised Control Trial
SCED	Single Case Experimental Design
SLP	Speech-Language Pathologist
SPELT-3	Structured Photographic Expressive Language Test – Third Edition
SRT	Serial Reaction Time
SV/O/A	Subject-Verb/Object/Adverbial
TIDieR	Template for Intervention Description and Replication
TROG-2	Test for the Reception of Grammar – Second Edition
VSS	Visuospatial Sketchpad
WMTB – C	Working Memory Test Battery for Children
's	Possessive 's
-ed	Regular past tense

Copyright Statement

Abstract

Experimental studies are required to evaluate the efficacy of theoretically informed interventions and better understand how theory informs therapy. There is little research to date exploring the efficacy of explicit interventions to improve morphosyntax for early school-aged children with developmental language disorder (DLD). Building on a Phase I pilot study (Calder et al., 2018), this thesis reports on a program of research which designed, developed, and evaluated the efficacy of a **the**oretically **m**otivated past tense **(-*ED***) **i**ntervention (**TheMEDI**), following Robey's Phases of Clinical Research (Robey, 2004). This comprised two intervention studies, which were re-analysed to explore the effects of intervention intensity in a third study. TheMEDI was designed based on recommendations from the Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005) where metalinguistic training using the SHAPE CODING^{TM} system (Ebbels, 2007) and a systematic cueing hierarchy (Smith-Lock et al., 2015) were combined. Two additional exploratory studies were conducted to examine the relationship between long term (declarative and procedural) and short term (phonological and working) memory systems and expressive morphosyntax.

Firstly, efficacy was evaluated using a study of n = 9 children aged 5;10 – 6;8 years with DLD through single case experimental design (Phase II), and a study of n = 21 children aged 5;9 – 6;8 years with DLD through a randomised control trial (Phase III). In both studies, efficacy of TheMEDI was demonstrated. Given the positive intervention outcomes, the dose intensities (i.e., 1000 trials versus 500 trials versus control) were then compared with n = 29 children to determine if intervention provided twice versus once per week resulted in different intervention effects (Phase II-III). As a combined group, all participants demonstrated significant improvement during the intervention phase. There was a significant advantage in the twice per week group for rate of progress in past tense production, which also demonstrated significant decline in the maintenance phase. In the absence of stronger

randomised group designs, results may serve to inform clinical guidelines when translating findings to clinical practice.

From the results of these intervention studies, clinically relevant exploratory analyses were conducted (*n* = 29), including the evaluation of allomorphic categories and the influence on intervention outcomes. Results indicated past tense verbs marked for [d], [t], and [əd] improve proportionately to one another through this explicit intervention.

Exploratory analyses (*n* = 29) of measures of long term memory (declarative and procedural memory) were used to explore how these account for unique variance in treatment outcomes. There were few significant results from these analyses, suggesting that neither declarative nor procedural memory moderated intervention outcomes in this sample of children with DLD. These results may challenge the Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005), or alternatively may reflect issues with instrumentation measuring complex cognitive processes, such as declarative and procedural memory.

Finally, an exploratory analysis (*n* = 30) of pre-intervention measures of expressive inflectional morphology, including both verbal (regular past tense and third person singular) and nominal (possessive *'s*) inflection, and the relationship between measures of short term (phonological and working) memory were conducted. Analyses revealed no differences in performance between inflectional morphology categories; but syllabic allomorphs ([əd]; [əz]) were produced with significantly less accuracy than segmental allomorphs ([d], [t]; [z], [s]) across all morphological categories. There were no meaningful, significant relationships between measures of phonological short term memory or working memory, and expressive morphosyntax. Findings have implications for linguistic and processing theories explaining morphosyntactic difficulties of children with DLD. It seems that perhaps morphophonological frequency of the lexical items may explain difficulties with inflectional morphology, rather than difficulties being limited to a morphosyntactic category, such as finiteness marking. Therefore, nominal inflection should be considered as a priority for intervention targets when providing intervention to children with DLD.

Overall, through this programme of research, which adhered to accepted standards of clinical-outcome testing (Robey, 2004), efficacy of TheMEDI for early school-aged children with DLD was demonstrated. Findings include clinical recommendations for replication and translation to practice, dosage and intensity, and target selection when implementing this intervention. This makes a unique contribution the evidence-base supporting the use of explicit grammar interventions for early school-aged children with DLD. Positive results following TheMEDI also lends support to the explanatory power of the Procedural Deficit Hypothesis. However, predictions based on the memory status of children with DLD were not clearly supported, suggesting further research is needed to explore theoretical accounts of the disorder. This indicates DLD is a complex and heterogeneous disorder that perhaps no one theory can explain. Rather, the disorder may represent a population of children who share similar symptoms as a result of diverse underlying pathologies.

Thesis Overview

This programme of research aimed to evaluate the efficacy of a **the**oretically **m**otivated past tense (-***ED***) **i**ntervention (**TheMEDI**) for early school-aged children with Developmental Language Disorder (DLD). By moving through the levels of evidence with analogous research designs, this program of research has adhered to the accepted standards of clinical-outcome testing (Robey, 2004) to establish TheMEDI as an efficacious intervention protocol. In addition, the relationship between long term (declarative and procedural) and short term (phonological and working) memory and expressive morphosyntax were also evaluated to explore the explanatory power of current theories of DLD. Following the Background (Chapter 1), the findings from this program of research are arranged into two parts which are comprised of five studies.

Part One reports on the explicit intervention designed to improve past tense marking (TheMEDI) for early school-aged children with DLD. In this section, Chapter 2 provides a comprehensive description of the components of intervention to facilitate future research replication and translation to clinical practice. Chapters 3 to 5 report on the programme of research which evaluated the efficacy of TheMEDI by moving through the levels of evidence and analogous research designs (Robey, 2004). Chapter 3 (Study 1) reports on a single case experimental design (Phase II) where intervention protocols from a pilot study were refined and evaluated. Chapter 4 (Study 2) reports on a randomised control trial (Phase III) to further evaluate intervention efficacy. Chapter 5 (Study 3) reports on re-analysis of data (Phase II-III) where dosage and intensity were evaluated.

Part Two includes Chapters 6 and 7. In Chapter 6 (Study 4), data from all children who participated in the intervention studies were pooled for exploratory analyses of measures of declarative and procedural memory to explore how these long term memory systems account for unique variance in treatment outcomes. Chapter 7 (Study 5) includes exploratory analyses to develop a profile of inflectional morphology prior to intervention, and to examine the relationships between expressive morphosyntax, and phonological short term and working memory.

Finally, a General Discussion of the findings from the programme of research is presented in Chapter 8. This includes implications for theories explaining morphosyntactic difficulties experienced by children with DLD, clinical recommendations, and directions for future research.

CHAPTER 1

Background

Chapter overview

This chapter presents an overview of theories that attempt to explain the morphosyntactic difficulties experienced by children with Developmental Language Disorder (DLD), including domain-specific and domain-general theories. This overview is presented with an emphasis on identifying recommendations for intervention borne out of these theories. Of particular relevance to this chapter is the Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005), which suggests explicit interventions may be beneficial to children with DLD in the presence of potentially impaired implicit learning. Following the discussion on theoretical explanations of DLD, a review of the literature of effective grammar interventions is presented within the context of theories, including evidence supporting the use of implicit, explicit, and combined approaches. Critical elements of interventions, including dosage and intensity, and the role of inflectional allomorphs, are discussed. The SHAPE CODING™ system (Ebbels, 2007) is discussed in relation to the Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005) as a viable resource for developing a **the**oretically **m**otivated past tense (-***ED***) **i**ntervention (**TheMEDI**) for early school-aged children with DLD. This Chapter also reports on a Phase I pilot study (Calder et al., 2018), which was conducted prior to this doctoral research, exploring the elements of TheMEDI and to identify if a therapeutic effect was present. Following the summary and rationale for TheMEDI, the Chapter concludes with the statement of the objectives and significance of this programme of research which is presented in the subsequent Chapters.

Developmental Language Disorder

The term Developmental Language Disorder (DLD)[1] refers to children who experience language difficulties in the absence of known biomedical conditions such as autism spectrum disorder or acquired brain injury (Bishop et al., 2017; previously referred to as specific language impairment, see Leonard, 2014). The condition is estimated to affect approximately 7% of children (Norbury et al., 2016; Tomblin et al., 1997) who experience difficulties learning language, which can create barriers to communication and learning in everyday life. DLD can have a significant impact upon academic and social development (Clegg et al., 2005), and a range of difficulties often persist well into adolescence and adulthood (Law et al., 2009).

Compared to typically developing peers, children with DLD have a slower pace of language development, and difficulty producing and understanding language (Bishop et al., 2016). Children with DLD may exhibit difficulties with receptive vocabulary (Rice & Hoffman, 2015), fast-mapping (Chiat, 2001; Jackson et al., 2016), and morphosyntax (Spaulding et al., 2006). Specific clinical markers include nonword repetition (Bishop et al., 2006; Bishop et al., 1996; Dollaghan & Campbell, 1998), sentence recall (Archibald & Joanisse, 2009; Redmond et al., 2019), and regular past tense production (Redmond et al. 2019). Further, children with DLD often present with working memory deficits (Archibald, 2017; Gathercole & Baddeley, 1990; Jackson et al., 2020). From a grammatical standpoint, children with DLD present with difficulties in a wide range of morphosyntactic skills, such as the use and understanding of grammatical morphemes associated with tense (Conti-Ramsden et al., 2001; Rice et al., 1999; Rice et al., 1998; Ullman & Gopnik, 1999), complex syntactic structures such as passives (Norbury et al., , 2001) and *wh*-questions (van der Lely & Battell,

[1] It is acknowledged that previous research has used various terms to describe childhood language disorder in the absence of other biomedical conditions, such as specific language impairment. The term developmental language disorder (DLD) is used throughout this thesis, in line with recommendations from a recent international consensus study (Bishop et al., 2017).

2003), and verb-argument structure (Ebbels et al., 2007).

Within the area of morphosyntax, finiteness marking is understood to be a particular aspect of difficulty for children with DLD (see Leonard, 2014 for a comprehensive review). Finiteness refers to the obligatory marking of verbs which indicates subject-verb agreement and tense. In English, finiteness is marked by: affixation of morphemes *–ed* (e.g., *The girl kick**ed***) and *–s* (e.g., *The girl kick**s***) to verbs for past and present tense, respectively; morphophonological variations in lexical stems for irregular past tense (e.g., *The bird flew*), and; specific auxiliary and copula *be* (e.g., *He **is** sad*, ***Is** he sad?*; *She **is** running*) and auxiliary *do* in declarative (e.g., *I **do** want more*; *I **did** walk home*) and interrogative (e.g., ***Is** he sad?*; ***Is** she walking?*; ***Does** she walk?*) clause structures. Within English and cross-linguistically, finiteness is a quality of well-constructed clauses (Dale et al., 2018); however, in his exploration of the competing sources of input hypothesis, Leonard (2019) notes the ubiquity of non-finite bare stems within English (e.g., *Look at the girl walk**), which may interfere with learning the obligatory contexts in which finiteness is required. Nonetheless, there is evidence supporting disordered finiteness as a distinct aetiological construct and predictive marker of later language abilities for DLD (Bishop et al., 2006; Rice et al., 1998, 1999). Indeed, Bishop and Haviou-Thomas (2008) also noted that a child's difficulties with grammar are a primary source of parental concern when considering referral for clinical services.

Proficiency with linguistic skills, such as finiteness marking, is necessary to support the demands of acquisition and use of literate language at school age (Paul & Norbury, 2012; Windsor et al., 2000). Acquisition of certain finiteness markers is further complicated for young English language users, both communicatively and in their literate form, by the morphophonological constraints of the language. One example is past tense marking. In English, there are morphophonological variations, or allomorphs, of the regular past tense *-ed* morpheme, which are distributed based on the phonological properties of the verb stem. If the final sound in a verb is a voiceless posterior plosive, afficate or fricative, regular past tense is marked with [t] (e.g., *walk****ed****, watch****ed****, kiss****ed***). However, if a verb ends in a voiced posterior plosive, afficate or fricative, or a vowel, regular past tense is marked with [d] (e.g., *jogg****ed****, ag****ed****, buzz****ed***). Finally, if a verb ends in an alveolar plosive such as [t] or [d], regular past tense is marked with the unstressed syllable [əd] (e.g., *tast****ed****, wad****ed****, need****ed***). There is evidence to suggest the morphophonological properties of a verb impact a child's ability to apply regular past tense marking accurately with reference to the phonotactic probabilty of the inflected form. Marshall and van der Lely (2006) reported children aged five-to-eight years with DLD performed significantly worse in a regular past tense production task compared to age-matched typically devloping peers. Interestingly, the children with DLD were more likely to omit past tense morphemes on inflected forms that were monomorphemically impermissable. That is, verbs, that when inflected, contained 'illegal' word final clusters. For example, verbs, that when inflected, contained 'legal' word final clusters, such as *pa****ssed*** ([st]) were less likely to be omitted, compared to an 'illegal' word final cluster, such as *pe****gged*** ([gd]). No such effect was observed in typically developing children. Further, there is evidence that children meeting criteria for DLD are more likely to omit past tense inflection when they constitute an unstressed syllable [əd], such as in *tast****ed*** (Leonard & Kueser, 2019). This may be due to the relatively low probabilty of verbs marked with an unstressed syllable. That is, the syllabicity of the verb *chas****ed*** is represented phonotactically as CVCC, whereas the verb *tast****ed*** is represented as CVCCVC. The latter is a far less frequent syllabic structure in English (Owen Van Horne & Green Fager, 2015; Tomas et al., 2015).

While children shift to a literate language style during schooling, they will continue to use oral finiteness features with inconsistency (Curenton & Justice, 2004; Eisenberg et al., 2008; Greenhalgh & Strong, 2001). If oral finiteness marking can be bolstered orally in children with DLD, this may serve to reduce the demands of acquiring written language skills in early school years.

Notwithstanding the impact on social and academic language use, improving past tense marking in children with DLD may provide insight to the learning mechanisms that can be utilised to improve language more generally. That is, studies that test specific hypotheses constrained by theoretically motivated variables may serve to enlighten researchers and clinicians to interventions that will achieve optimal outcomes. If indeed finiteness marking is accepted as an endophenotype of language disorder (see Bedore & Leonard, 2001; Dale et al., 2018; Leonard et al., 1999; Rice & Wexler, 1996; Rice et al., 1995, 2009), whether or not this language feature is amenable to improvement following intervention is of great interest. Support for the efficacy of interventions may not only provide an empirical basis to improve outcomes for children in clinical care, but may provide insight to spared and impaired processes that manifest as symptoms or markers of clinical disorders.

From a clinical practice standpoint, speech-language pathologists (SLPs) are encouraged to reflect on their knowledge of theory to provide interventions suitable for the clinical populations they service. Many professional associations embody the *E^3BP* (*$Evidence^3$ Based Practice*) triangle, which encourages clinicians to draw on all three facets of clinical decision making (e.g., American Speech and Hearing Association, Royal College of Speech-Language Therapists, Speech Pathology Australia,). *Client factors* must be acknowledged, which incorporate the clients' diagnosis, strengths and weaknesses in body structure and function, impact on activities of daily living, and personal and environmental factors, including their perspectives and goals (World Health Organization, 2001). *Clinician factors* relate to the clinician's knowledge, experience and expertise, as well as service provider policies. Finally, *research evidence* refers to the best available scientific evidence that aligns with *client* and *clinician factors*. However, when there is a paucity in evidence supporting the implementation of intervention for a specific clinical difficulty for a specific clinical population, theory comes in to play with *clinician factors*. That is, in the absence of empirical evidence, what can current theory tell us about interventions that may be effective for a client? This can lead to the development of theoretically motivated interventions, which may eventually undergo the process of empirical evaluation.

The precise aetiology and contributors to DLD remain unknown. A number of existing theories attempt to account for the potential underlying causes, but these often compete and focus on different characteristics of disordered language depending on their fundamental assumptions (Bishop, 2014a). Further exploration of theoretical accounts of DLD is needed to inform the development of effective interventions for this at-risk population.

Theoretical Accounts of DLD

Many theoretical accounts of DLD have attempted to explain the difficulties children with DLD experience, and such theories may be used to consider the particular difficulties these children have with acquiring grammar. Importantly, theories must move beyond descriptive to predictive, to identify at-risk populations and develop hypotheses regarding likeliness of response to intervention. Three prominent superordinate categories of theories include: domain specific theories of DLD; processing limitations theories, and; domain-general theories.

Domain (Grammar) Specific Theories of DLD

An early account of DLD as a linguistic deficit was derived from case studies, where grammatical difficulties appeared to reflect underlying blindness to features of tense and agreement (Gopnik, 1990a, 1990b). This view was extended through subsequent analysis of broader datasets, suggesting that grammatical difficulties associated with DLD were due to an inability to form and apply implicit grammatical rules (e.g., Gopnik, 1994; Ullman & Gopnik, 1994). The feature blindness and implicit rule deficit hypotheses would suggest that children with DLD can be taught to compensate for grammatical difficulties by learning inflected forms as unanalysed lexical forms (such as learning irregular past tense) or by learning explicit rules (such as add *–ed* when something has already happened).

Perhaps one of the most widely referenced theoretical accounts of childhood language disorder is the generative linguistic model of Rice and colleagues. This theory argues that grammatical difficulties in children with DLD are due to an inherent linguistic constraint. The fundamental premise of generative theory is that the linguistic representations and mechanisms necessary for producing or understanding grammatical structures are not obligatorily used by children with DLD (Rice, 2000). Rather, children with DLD treat grammatical movement or tense marking as optional until the constraint is overcome, and therefore are inconsistent in their correct use of these aspects of morphosyntax. That is, children with DLD experience difficulties with finiteness marking due to an 'Extended Optional Infinitive' stage in morphosyntactic development (Rice & Wexler, 1996). This account is rooted in nativist linguistic theory (Chomsky, 2007), suggesting that children learn to use the rule-governed system of grammar not by linguistic input, but rather by possessing an innate internal capacity for language acquisition. Nativists suggest children who do not acquire language easily in the early years may have difficulties explained by a deficit in the innate linguistic capacity to learn grammar. This theory would suggest interventions could be designed to improve a child's use of grammar by contrasting the incorrect forms with correct 'adult' forms (Connell, 1988), which theoretically sets parameters for the child to appropriately learn the language (Poll, 2011).

A fundamental drawback to the application of the Extended Optional Infinitive account relates to cross-linguistic evidence indicating that children with DLD who speak languages such as Italian and Spanish do not appear to undergo a protracted infinitival stage affecting verbal inflection (Bedore & Leonard, 2001; Bortolini et al., 1998). In fact, Leonard (2014) reviewed cross-linguistic evidence extensively and concluded difficulties for tense and aspect, rather than finiteness alone, tends to characterise children with DLD. Wexler (2003) reported on the Extended Unique Checking Constraint account, which somewhat addresses the protracted stage of tense and agreement inconsistency in children with DLD across languages other than English. The central assumption to the account is that grammar learning in the early stages is governed by a linguistic constraint that checks only one functional category, such as tense *or* agreement. For example, in English, *She pushes/ed me* may be realised as *she push me* if checking occurred at agreement only (which also conforms to the Extended Optional Infinitive account), or *Her pushes/ed m*e if checking occurred at tense only. The Extended Unique Checking Constraint account has been applied to Swedish (Leonard, Hansson et al. 2004), Spanish (Bedore & Leonard, 2005), and French (Paradis et al., 2006), where speakers with DLD may favour the use of tense and agreement inflection compared to English speakers with DLD. Similar to interventions aligned with the Extended Optional Infinitive account, the aim would purportedly be to accelerate the diminishing role of the developmental linguistic constraint by contrasting incorrect forms with correct adult forms.

Alternative domain specific theories argue that grammatical difficulties in some children with DLD are due to an innate linguistic deficit, which results in a child's inability to compute the probabilistic, rule-governed nature of spoken grammar. That is, there is a subtype of children who have a grammar-specific language impairment (grammatical-SLI) (van der Lely, 2005). The fundamental premise posits children with grammatical-SLI do not obligate the use of linguistic mechanisms necessary for producing or understanding grammatical structures (van der Lely, 2005). In particular, the Representational Deficit for

Dependent Relations theory suggests children with grammatical-SLI have difficulties that involve the movement of constituents or features, such as those required for tense marking, subject-verb agreement, passive structures, and *wh*-questions (van der Lely & Battell, 2003). This theory was expanded to the Computational Grammatical Complexity theory (Marshall & van der Lely, 2006) to include difficulties at the level of phonology and syllabicity, suggesting a deficit in representing structural complexity. Notably, van der Lely and Ullman (2001) found that children with grammatical-SLI variably produced regular past tense *–ed* depending on the frequency of occurrence of the verb affixed for the particular inflection, whereas typically developing control children did not show such a pattern of grammatical difficulty. As discussed above, children with grammatical-SLI produced verbs affixed with a singleton consonant (e.g., *play**ed***) more accurately than verbs affixed with multi-consonant clusters (e.g., *jogg**ed***, *fenc**ed***) compared to a control group.

A large body of empirical evidence supports domain specific theories (Rice & Wexler, 1996), especially in regard to children's difficulty with tense marking (Wexler, 1994; Wexler, 1998). Although fundamental to how researchers and clinicians now understand the grammar of children with DLD, these accounts have been critiqued as, while they describe the patterns of difficulties, they do not offer a clear explanation as to *why* children with DLD have difficulty with specific aspects of grammar, such as tense marking. The concept of structural *complexity* is offered by the Computational Grammatical Complexity theory, however it is not well-defined beyond the number of sequenced consonants required to mark a verb for past tense inflection. Finally, domain specific accounts do not capture the broad range of other linguistic difficulties, as well as non-linguistic difficulties that have been observed in children with DLD, including working memory (Baddeley, 2000) and visuo-spatial memory deficits (Lum et al., 2012), and motor difficulties (Bishop, 2002; Hill, 2001). Fortunately, broader non-specific accounts of DLD exist.

Processing Limitation Theories of DLD

Surface Processing Theory. Leonard (1989) suggested a theory of processing difficulties, which posits a processing-capacity limitation in children's ability to learn grammatical morphemes. In contrast to the Extended Optional Infinitive account (Rice & Wexler, 1996), "the surface account assumes that children with SLI have no fundamental gaps in their grammatical knowledge apart from the deficiencies that arise because of their slow intake of relevant data due to processing limitations" (Leonard et al., 2003, p. 44). That is, the phonological information encapsulating grammatical morphology is too brief and rapid for children with DLD to perceive, with implications for hypothesising the morphemes' function (e.g., to mark tense) (Bedore & Leonard, 2001; Leonard & Bortolini, 1998; Leonard et al., 1997). In an experiment conducted by Leonard et al. (2003), children with DLD performed significantly below their typically developing counterparts matched for mean-length-of-utterance in their use of *–ed* inflection to mark tense and passive participles (e.g., *The boy was push**ed** by the girl*). This suggests that the use of such morphemes may be subject to the phonetic properties of the marker, as opposed to the grammatical function, as suggested by the Extended Optional Infinitive account.

Presumably, interventions grounded in processing-capacity limitation accounts serve to alleviate grammatical difficulties by offering repeated exposures and opportunities to use grammar targets for children with DLD (Camarata et al., 2009; Leonard et al., 2008). These interventions are often described as *grammar facilitation* techniques (Eisenberg, 2013; Fey et al., 2003). There is cross-linguistic evidence to support this theory (Bedore & Leonard, 2001; Leonard et al., 1997; Leonard & Bortolini, 1998), however, it has been acknowledged that other factors, such as lexical interference may impact a child's ability to comprehend interactions between grammatical structures (Leonard et al., 2013), and therefore the ultimate use of grammatical features such as tense marking. For instance, in a sentence comprehension experiment, children with DLD (age *M* = 4;6 years) and younger typically developing children (age *M* = 3;4 years) tended to demonstrate difficulty in accurately identifying test items when foils contained information that resembled the target sentence (Leonard et al., 2013).

It has also been noted that morphemes with the same phonological surface form (e.g., *–s* to mark plural, possessive and third person singular tense) may not be equally affected in children with DLD (Crystal et al., 1989), which somewhat undermines the simple surface view of processing deficits. More recently, Leonard and Deevy (2017) discuss three separate, yet not incompatible, processing theories. These theories suggest that it is not only the quantity of exposures that is necessary to consider when explaining why language learning may be impacted for children with DLD, but also the quality of language input. This has implications for planning effective interventions.

Competing Sources of Input. Leonard and colleagues have proposed the Competing Sources of Input account (Leonard, 2014; Leonard & Deevy, 2011, 2017; Fey et al., 2017). This account acknowledges that most children diagnosed with DLD receive language input in the early years which is comparable to age-matched typically developing peers. Therefore, language difficulties are not an issue of input per se, but rather how children are using the input to develop an understanding of language. This account overtly acknowledges the interaction between morphology and syntax (hence morphosyntax) in that the inconsistent omission of particular morphemes in obligatory contexts may in fact be due to a misinterpretation of certain utterances in children's input (Leonard, 2019). Specifically, Leonard and colleagues refer to the ubiquity of nonfinite lexical verbs. For example, the command *Let him push the pram* as input may be correctly computed but incorrectly analogised as the statement *Him push the pram*. Another example may be *Help the boy load the dishwasher* translating to *The boy load the dishwasher,* or *Is the boy loading the* *dishwasher*? translating to *The boy loading the dishwasher*. This theory accounts not only for the inconsistency in common grammatical issues (e.g., incorrect pronominalisation, omission of tense affixes, and auxiliaries), but also accounts for children with DLD favouring functional subject-verb sequences that may or may not be correctly inflected (Bishop, 2014b). Therefore, this theory suggests that when treating grammar difficulties, clinicians should avoid structures that use unmarked stems, e.g., *I roll the playdough*. Although grammatical, the theory suggests they may 'compete' with other finite forms and encourage the storage of incorrect representations.

Input Informativeness Approach. Again, this approach does not necessarily suggest DLD is a disorder of processing; rather, Hadley et al. (2011) suggested that the degree to which tense and agreement markers appear during input through parents' speech relates to the rate at which children develop productivity in their use of tense and agreement morphemes. The approach is grounded in the basic assumptions that children have innate knowledge of the universal principles of grammar, which act as constraints to the acquisition of tense and agreement morphology (e.g., Rispoli et al., 2009, 2012). One example is a tense parameter to reflect the differences in languages that mark tense (e.g., Spanish) and those that do not (e.g., Mandarin) (Yang, 2002). The input informativeness approach presumably suggests children with DLD have fundamental weaknesses in activating the proper setting for such a parameter despite being exposed to the probabilistically minimal amount of necessary input. Recommendations for intervention do not aim to correct this fundamental weakness, but rather aim to increase the percentage of overt tense and agreement forms through input relative to what is required for typically developing children (Hadley & Walsh, 2014; Hadley et al., 2017).

High Variability. The concept of high variability in grammar learning is derived mostly from artificial grammar studies (e.g., Gómez, 2002; Grunow et al., 2006; von Koss

Torkildsen et al., 2013). The essential finding from such studies is that there is an advantage to learning novel grammatical rules when there is greater variability in the input (e.g., *aXb* nonadjacency rules, where *X* represents free variability while *a* and *b* are held constant). Failure to learn such rules suggests that an individual may be unable to discern the difference between grammatical and ungrammatical rules in real language (Leonard & Deevy, 2017). One plausible example may be the partial learning of *–ed* inflection, where verbs with segmental allomorphs are learned correctly (e.g., *kiss**ed***, *play**ed***), but uninflected forms that would otherwise require syllabic allomorphs (e.g., *taste*, *add*) are incorrectly interpreted as correct in the same morphosyntactic contexts. The high variability approach places emphasis on the combinatorial characteristics of a particular morpheme (Leonard & Deevy, 2017), which feeds into notions of statistical learning (discussed in detail below). Unsurprisingly, the clinical implications for the high variability approach relate to using high variability input through intervention (e.g., Plante et al., 2014). Evidence suggests that there is an advantage to learning in high variability conditions compared to low variability conditions for children with DLD, indicating that enhancing input may improve intervention outcomes.

Usage-Based Accounts. Emergentism/usage-based approaches have been applied to understand language learning in younger years (e.g., de Ruiter & Theakston, 2017; Poll, 2011). In relation to grammar specifically, these approaches suggest that children acquire grammatical structures according to the frequency by which the structures occur in a child's language input (de Ruiter et al., 2018). This account has been applied to the learning of complex syntactic structures (de Ruiter et al., 2018), but relatively few studies have analysed this account in regard to the acquisition of finite morphology. Nonetheless, the relevance to the acquisition of morphosyntax is clear when considering that usage-based accounts suggest children acquire language not only by repeated exposure to language, but by the capacity to apply analogy to generalise patterns of usage. Given this necessary component of acquisition, a child that is unable to apply analogy to enhance their linguistic usage would therefore be relatively limited in their application of grammar, which may then manifest as underdeveloped, or even impaired language functioning. That is, children with DLD may in fact have difficulty with automaticity of applying analogy that is required to learn language as a result of a deficit to identify and learn the rules of morphosyntax despite it occurring within their ambient language learning environment.

Working Memory Theories. Other processing limitation theories attempt to explain surface level linguistic deficits by considering the interplay between processing of linguistic and non-linguistic information, such as working memory. Baddeley's (2012) application of the Working Memory Model (Baddeley & Hitch, 1974) suggests that children with DLD experience language difficulties due to an issue with phonological short-term memory (PSTM) (Chiat, 2001; Jackson et al., 2016; Montgomery et al., 2016). That is, children cannot temporarily store novel phonological information (such as verbal inflection) to ultimately create long-term phonological representations of the information for later retrieval and use in expressive language. There is evidence children with DLD have a PSTM deficit (e.g., Gathercole & Baddeley, 1990), supporting the claim of working memory deficits in these children (Baddeley, 2000; Baddeley, 2003a, 2003b). Although interventions targeting working memory in isolation show little transference to language ability (Melby-Lervag et al., 2012), there is evidence that verbal working memory performance can be supported by the provision of visual information for typically developing children and children with DLD (Quail et al., 2009).

Identifying patterns of absence in specific morphosyntactic structures for children with DLD makes an important contribution to the understanding of how to treat morphosyntax difficulties. However, this view may underestimate the complexity of how these children learn morphosyntax, or rather, have difficulties learning morphosyntax.

Perhaps these morphosyntactic structures are vulnerable to acquisition due to supralinguistic systems such as attention and memory (Lidz & Gagliardi, 2015). Although processing limitation accounts of DLD have some empirical support, there is evidence of other non-linguistic aspects impacting children's language (Archibald, 2017). A recent review by Montgomery et al. (2016) acknowledges the role of longer-term memory systems, such as declarative and procedural memory, as key mechanisms for understanding how children with DLD use grammar.

Domain-General Theories

The Declarative/Procedural Model and the Procedural Deficit Hypothesis. The basic premise of the Declarative/Procedural Model is that aspects of the differences between grammatical and lexical knowledge are linked to the distinction between neural structures responsible for two long-term memory systems: declarative and procedural memory (Ullman, 2001). That is, the theory is a brain-behaviour account. The declarative memory system is responsible for learning arbitrary items of information and deriving associations between them- "it underlies the learning, representation, and use of knowledge about both facts (semantic memory) and events (episodic memory)" (Ullman, 2016, p. 955). Information is encoded through the hippocampal region, and the medial temporal lobe is responsible for recall and recognition of this information (Squire, 1992), with the prefrontal cortex also considered to be involved with encoding and retrieval (Blumenfeld & Ranganath, 2006). Information may be learned rapidly, sometimes requiring only a single exposure to the stimulus, however repeated exposures strengthen memories (Ullman, 2016). Therefore, declarative memory underlies learning and *explicit* (i.e., conscious) retrieval and use of facts and events. It also may underlie the learning, storage (mappings) and use of the sounds and meanings of words that are both morphologically simple and complex (i.e., the 'mental lexicon') (Ullman, 2001; Ullman & Pierpont, 2005).

It is noted here that the influence of short-term memory systems, such as phonological short term memory and working memory, to the encoding, recall and recognition processes essential to the declarative memory system must be acknowledged. For example, the prefrontal neural regions that function to encode and retrieve information for long term store are also associated with working memory (Blumenfeld & Ranganath, 2006), which is the short term memory system responsible for the immediate storage and manipulation of information (Baddeley, 2003a, 2003b). Therefore, it is likely that the processing operations driven by working memory influence the long term storage of information in declarative memory. Neuroimaging research suggests that the prefrontal cortex regions that support working memory are activated during encoding and recognition tasks, for which declarative memory is thought to be responsible (Blumenfeld & Ranganath, 2006; Cabeza et al., 2002). This suggests that working memory may serve to re-organise and chunk information temporarily while it is encoded to declarative memory, and further serves as a temporary store while information is retrieved from declarative memory in recognition tasks. While acknowledging the influence of working memory in declarative memory processes, for the purpose of this thesis, declarative memory will be referred to as a long term memory system.

In contrast to the declarative memory system, the procedural memory system is responsible for the learning and computation of probabilistic information, such as sequencing. Various neural structures are thought to underlie the procedural memory system, such as the cerebellum (Brambati et al., 2004), basal ganglia (Eckert et al., 2005), and motor cortex (Silani et al., 2005). Information must be learned through repeated exposures to the stimulus. Therefore, procedural memory underlies the *implicit* (i.e., nonconscious) learning of skills and habits- including motor, cognitive and linguistic learning (Ullman, 2001).
There is evidence to suggest that the probabilistic nature of grammar, such as in English, is better suited to implicit learning (Evans et al., 2009; Meylan et al., 2017), and that

grammatical abilities are correlated with procedural learning in typically developing children (Lum et al., 2012; Sengottuvel & Rao, 2013). Therefore, the system may also underlie learning and use of rule-governed computations of morphological sequencing (e.g. *walk*→ *walk**ed***) (i.e., the 'mental grammar') (Ullman, 2001; Ullman & Pierpont, 2005). Importantly, these systems are not considered wholly independent; rather learning is achieved through the competitive interaction of these two systems.

Accordingly, Ullman and Pierpoint (2005) have suggested the Procedural Deficit Hypothesis (PDH). The model posits symptoms of DLD are explained by neural abnormalities which has resulted in differences in the status of memory systems within language users, specifically, a procedural learning deficit, possibly in the presence of spared declarative learning (Ullman & Pierpont, 2005). Therefore, it is conceivable that the way in which linguistic information is presented may assist with language learning. Given the competitive nature of the systems, if children with DLD indeed have impaired procedural memory, PDH posits that using cognitive strategies harnessing spared declarative memory (e.g., explicit instruction) may be more suitable than expecting children to learn language implicitly[2].

Overall, there is evidence to suggest that children with DLD have impaired procedural memory compared to typically developing peers, and this may account for observable receptive (Conti-Ramsden et al., 2015) and expressive (Hedenius et al., 2011; Tomblin et al., 2007) grammar difficulties. Findings also suggest that children with DLD may show improved learning of probabilistic information that is typically learned implicitly (e.g., grammatical rules) (Evans et al., 2009), if it is presented explicitly to harness relatively spared declarative memory, especially in the visual domain (Lum et al., 2015). Further,

[2] The Procedural Deficit Hypothesis has recently been redefined as the Procedural circuit Deficit Hypothesis (still acronymised as PDH) to reflect the anatomical basis of the theory (Ullman et al., 2020). The overall assumptions and predictions of the theory reflect those reported by Ullman and Pierpoint (2005), therefore, this thesis refers to the seminal article describing the theory.

spared non-verbal declarative memory may serve to support learning information explicitly in the presence of deficits in working memory (Lum et al., 2015). However, these findings are the result of cross-sectional studies, not of intervention studies, so empirical support for the application of explicit intervention for DLD is limited.

It also appears that findings from cross-sectional studies are equivocal. Gabriel and colleagues have demonstrated that children with DLD may present with procedural learning abilities equivalent to typically developing children (Gabriel et al., 2011, 2012, 2014). Mayor-Dubois et al. (2014) and Lum and Bleses (2012) similarly reported that both children with DLD and typically developing children demonstrated evidence procedural learning, which suggests that perhaps language difficulties for children with DLD are not underpinned by a procedural learning deficit as the PDH predicts. Interestingly, Kuppuraj et al. (2016) found that although children with DLD performed comparably to typically developing children on measures of declarative learning, results from correlation analysis did not support the proposed trade-off between declarative and procedural memory systems. Recently, Jackson et al. (2020) found that working memory skills largely account for procedural memory deficits in children with DLD. A study of 112 children found that once effects for attention were controlled, there was no significant relationship between procedural memory and measures of language attainment across all participants, suggesting procedural learning deficits may rather reflect attentional difficulties in children with DLD (West et al. 2020). In a recent study using an unselected sample of 101 children aged eight years, West et al. (2017) compared various memory measures and found low reliability in measures of procedural memory. Finally, Lammertink et al. (2020) conducted a replication and meta-analysis of studies examining potential differences between children with and without DLD on measures of procedural learning. Results indicated no case for or against group differences in procedural learning tasks. These findings have implications for further investigating the core claim of the PDH, which suggests that deficits in procedural memory are a causal risk factor for DLD (Ullman & Pierpont, 2005). Further, since most studies are cross-sectional or correlational, this impacts the ability to draw causal inferences for the relationship between declarative and procedural memory, and recommendations for effective interventions.

Statistical Learning Theory. Recently, another domain-general theoretical perspective has been explored, evaluating statistical learning, and its impact on language acquisition. Statistical learning refers to the domain-general mechanisms used by individuals to *implicitly* recognise and internalise statistical regularities across modalities of input (e.g., visual, verbal, motor) to facilitate learning (Saffran et al., 1996). More broadly, the ability to detect regularities when stimuli are presented sequentially, whether in the auditory or visual domain, can be described as: sequence learning, grammar learning, and artificial grammar learning in the context of statistical learning (Arcuili, 2017). So, in relation to language learning, it is thought that children detect regularities inputted through their ambient language's co-occurring phonology, morphology and syntax to order these linguistic structures into highly probable sequences (Haebig et al., 2017; Lammertink et al., 2017). Therefore, this process is thought to significantly overlap with procedural learning (e.g., Perruchet & Pacton, 2006).

Implicit learning has been recognised as an umbrella term, which encompasses both procedural learning and statistical learning (Haebig et al., 2017). However, in a recent review, Batterink et al. (2019) concluded current research suggests that, for healthy speakers, statistical learning can occur through both nondeclarative (i.e., *implicit*) and declarative (i.e., *explicit*) memory systems. This concept is further complicated by the way in which statistical learning and procedural learning are typically measured, i.e., through serial reaction time (SRT) tasks. SRTs require participants to react to a sequence of stimuli without necessarily being consciously aware the sequence exists. Sequences are generally deterministic or probabilistic. Deterministic sequences are always followed by the same item, and; probabilistic sequences are followed by different items with varying probabilities (Ullman et al., 2020). Although statistical learning appears to function implicitly, statistical learning tasks may indeed draw upon explicit knowledge, particularly when task instructions are used with SRT tasks (e.g., Arcuili et al., 2014; Baker et al., 2004; Bertels et al., 2015), or when SRT tasks use only deterministic sequences (e.g., Shanks et al., 1994; Shanks & Johnstone, 1999). Therefore, perhaps implicit learning may refer only to learning without consciousness. Nonetheless, researchers agree procedural and statistical learning are inextricably linked with language learning through input. This is consistent with both usage-based accounts and the Competing Sources of Input account (see above), which do not, in fact, overtly address the domain-general, or supra-linguistic, nature of language learning. Regardless of the theoretical underpinnings explaining morphosyntactic deficits in DLD, recent evidence points to a deficit in *implicit* learning, and this has implications for developing clinical interventions.

There is a body of literature which has addressed statistical learning and its impact on areas of language learning in both typically developing and language disordered populations, including syntax (Gómez & Gerken, 1999), word learning (Evans et al., 2009; Smith & Yu, 2008), as well as nonword learning in infants (Graf Estes et al., 2007). Recent meta-analyses suggest school-aged children and adolescents meeting criteria for DLD show differences in the ability to detect statistical regularities through linguistic input when compared to typically developing peers, favouring children without DLD (Lammertink et al., 2017; Obeid et al., 2016). Overall, it appears that individuals who perform better on statistical learning tasks tend to show greater language proficiency (Arcuili, 2017).

Following results of a recent meta-analysis, Lammertink et al. (2017) suggest the profile of children with DLD and their relative difficulty with statistical learning presents clear recommendations for clinical remediation through “statistical learning-based interventions” (p. 10). The example the authors draw upon is a study conducted by Plante et al. (2014), in which 18 preschool-aged children with DLD were randomly assigned to high-variability or low-variability conditions to receive *implicit* conversational recasting intervention. It was hypothesised that children in the high-variability condition would show significant improvement, arguing that grammatical rule learning is facilitated by exposure to high variability in morphemes through modelling and recasting (Alt et al., 2014; Encinas & Plante, 2016), rather than *explicit* teaching. Although children in the high-variability condition significantly outperformed children in the low variability condition, it is noted that no children approached mastery on targeted grammatical structures in either condition.

Theories Informing Intervention

Some authors suggest a distinction between the PDH account and the statistical learning account of DLD, in that the PDH distinctly links declarative memory with vocabulary and procedural memory with grammar (Haebig et al., 2017); whereas statistical learning accounts focus on the capacity of children to implicitly learn the sequential ordering and co-occurrence of syllables as units of meaning (Lammertink et al., 2017). Therefore, the key differences in the assumptions of the theories appear to be that the PDH forms recommendations for intervention based on the proposed symptomatology of children with DLD (i.e., exploit spared declarative memory in the presence of impaired procedural memory); whereas statistical learning theories make recommendations based on enhancing the statistical regularities of language input.

Interestingly, Smith-Lock et al. (2015) compared recasting alone to explicit rule instruction combined with a systematic cueing hierarchy in an intervention study. In the latter condition, children with DLD were encouraged to reflect upon their error and correct production was facilitated by gradually and systematically offering least to most support. That is, children drew upon their *explicit* awareness to learn grammatical rules. Results from the study suggest a larger treatment effect for the group receiving intervention using explicit rule instruction combined with the systematic cueing hierarchy compared to the recasting alone group. Further still, there was no treatment effect dependent on the morphophonological properties of intervention targets; only the treatment approach accounted for between group differences (Smith-Lock, 2015). This may suggest that the statistical properties of treatment input may have less influence on treatment gains compared to whether or not children are required to *explicitly* reflect on learning during intervention. This begs the question, if children with DLD show deficits in *implicit* learning, why would we treat grammar difficulties *implicitly*?

The PDH posits children with DLD may be better supported to learn linguistic information when it is presented explicitly to harness the declarative memory system. This hypothesis exists in the absence of experimental intervention studies. Thus the impetus for the current programme of research: to inform clinical practice, it is necessary to conduct theoretically informed experimental intervention studies using a systematic approach to evaluate efficacy, to better understand how to improve language outcomes with intervention in the presence of proposed spared and impaired processes. That is, for children with DLD, can grammar be improved by offering information in an *explicit* way?

Effective Grammar Interventions

Treatment for DLD aims to accelerate language growth and remove barriers to functional communication by harnessing strengths (Justice et al., 2017), while acknowledging that children with DLD present with unstable or absent representations of morphosyntax (Plante et al., 2018). Ebbels's (2014) review of the research indicates an emerging evidence-base for the effectiveness of grammar intervention for school-aged children with DLD. Current evidence can be parsed into *implicit* and *explicit* approaches to intervention. According to Ebbels's framework, *implicit intervention*s are those targeting production and understanding of grammar, using grammar facilitation techniques implicitly by responding to children's errors in a naturalistic way (Fey et al., 2003). When learning information *implicitly*, children's learning and the knowledge acquired are not necessarily associated with awareness (Shanks, 2005). *Explicit interventions* are those targeting increased awareness of the goals of intervention with a pre-established concept of the criteria for success. That is, learning is conscious and deliberate, and information can be recalled on demand (Shanks et al., 2005).

Within each approach to intervention, specific techniques can be used to improve acquisition of grammar. Two frequently cited techniques are *grammar facilitation* and *metalinguistic training*. *Grammar facilitation* aims to facilitate the acquisition of grammar by increasing the frequency and quality of target forms in input and output, which theoretically increases the likelihood that a child will learn them (Leonard, 2014). This can be understood to accelerate language growth by increasing exposure and opportunities to learn and use language. Although grammar facilitation is often considered *implicit* (Ebbels, 2014; Fey et al., 2003), there is evidence that the techniques can be used within an *explicit* teaching framework (Smith-Lock et al., 2013a, 2015). That is, grammar facilitation techniques can be used with both *implicit* and *explicit* approaches to intervention (Eisenberg, 2013). *Metalinguistic training* aims to improve children's learning of the rules of grammar by creating conscious awareness of grammar through *explicit* metacognitive teaching (Cirrin & Gillam, 2008; Ebbels, 2014), to allow children to actively reflect on language targets. Metalinguistic training aims to remove barriers to communication (e.g., weaknesses in *implicit* language learning) by enhancing meta-awareness to learn rules of grammar *explicitly* in a compensatory way.

Implicit Interventions

Implicit intervention approaches align with the view of presenting information likely to be learned through procedural memory (Ullman, 2001) or statistical learning (Plante & Gómez, 2018). Ebbels (2014) identifies two main implicit approaches: grammar facilitation and usage-based approaches. For the purpose of this Chapter, grammar facilitation is focused upon as the key implicit approach with empirical support.

This therapeutic approach was explored in detail by Fey et al. (2003) who outlined 10 principles of grammar facilitation. The impetus for the tutorial paper was driven by the issues faced by clinicians when facilitating children's grammar development in a way that is holistic to the child's needs. That is, considering other factors that may be affecting or affect development of grammar while face-to-face with a child. The tutorial is interspersed with examples of studies that support each principle; however, no studies have apparently evaluated the combined use of all principles within one intervention package or programme. Ebbels (2014) noted that most studies evaluating the efficacy or effectiveness of grammar facilitation have been conducted with preschool (e.g., Fey et al., 1993: 3;8 – 5;10 years) or early school-aged (e.g., Fey et al., 1997: ~5;0 – 6;3 years) children, with the most common approaches being imitation, modelling, focussed stimulation, and recasting. In general, focussed stimulation and recasting are the most effective grammar facilitation approaches. Focussed stimulation appears to be effective at improving the forms targeted through intervention with little generalisation to related structures. Further, these interventions rarely report mastery was achieved on the target, even with up to 96 intervention sessions (Leonard et al., 2004). Cleave et al. (2015) conducted a meta-analysis on conversational recasting, and concluded that although the quality of evidence varied greatly, the efficacy of conversational recast intervention was demonstrated. Eisenberg et al. (2020) recently published a narrative review on the use of imitation for targeting grammar. Findings indicate that the technique used in isolation does not appear to improve grammar outcomes, and intervention effects rarely appear to generalise to conversational use. The authors concluded imitation may be a viable technique to include as part of a clinical toolbox, but is not effective as a standalone approach. Lastly, there is little evidence that modelling in isolation is effective in improving outcomes (Weismer & Murray-Branch, 1989).

Recently, Fey et al. (2017) conducted an intervention study driven by the Competing Sources of Input hypothesis (discussed above). Present- and past-tense forms of both *be* and *do* auxiliaries were targeted for 20 children aged between 3;3 and 4;6 years with DLD. The intervention used story telling contexts to contrast grammar targets and recasting to ensure opportunities for accurate linguistic input. Interestingly, the intervention also contained a comprehension component. The authors reported improvement in production of targets, as well as improved comprehension of *is* questions for the experimental group compared to the control group. This is of interest, as few studies have reported on improvement in comprehension outcomes (see Ebbels, 2014).

In a recent study (Plante et al., 2018), 28 children with DLD aged between 4;3 and 6;2 received morphosyntax intervention using auditory bombardment and recasting, with the order of these reversed between groups (n = 14 each). Delivery of intervention included one-on-one, 30 minute sessions, five times per week and had a mean cumulative intervention intensity of 552 trials of grammar targets, which differed across participants depending on pre-intervention baselines. Generalisation to untrained targets was evaluated as a key dependent variable. Although significant improvement was observed on target measures of morphosyntax following intervention, mean percentage correct across groups after treatment was around 50% correct. There was a marginal difference between groups favouring children who received auditory bombardment following recasting, but these findings suggest a period of auditory bombardment in conjunction with recasting may not provide a remarkable advantage over recasting alone.

It has been suggested there is strong evidence for the superiority of interventions improving morphosyntax in children with DLD using grammar facilitation techniques in an *implicit* way, such as recasting (e.g., Cleave et al., 2015 in Plante et al., 2018). However, it is clear that the children in these studies fail to reach a level of mastery with morphosyntactic targets, even following intervention schedules with high dosage and intensity.

Explicit Interventions

Difficulties with morphosyntax often persist into school age for children with DLD (Bishop et al., 2000; van der Lely, 2005). This may suggest that children with DLD have particular difficulty learning morphosyntax through *implicit* grammar facilitation, and so an alternative approach is required. Explicit intervention approaches align with predictions of the PDH by suggesting there is benefit in presenting information likely to be learned through declarative memory (Ullman, 2001).

Compared to implicit approaches, there are far fewer studies evaluating the efficacy or effectiveness of explicit approaches. Recent evidence supports the use of grammar facilitation techniques within an explicit intervention approach with preschool-aged children (i.e., under six years) to improve the use of morphosyntax (Smith-Lock et al., 2013a). In a comparison study of 34 five-year-old children with DLD, participants who were assigned to an experimental group that received explicit direct instruction using grammar facilitation, showed greater improvement in expressive morphosyntax production than those in the control group who received intervention focused on following directions and comprehension of prepositions. Metalinguistic techniques can also be used explicitly to teach grammar through metacognitive strategies, and use of visual supports and graphic organisers (Ebbels, 2014; Cirrin & Gillam, 2008). These approaches not only align with presenting information likely to be learned through declarative memory, but further draw upon posited strengths in visual declarative memory (Lum et al., 2015) and retention of learning (Lukács et al., 2017). Balthazar et al. (2020) summarised the evidence for three explicit intervention methods

(Complex Sentence Intervention: Balthazar & Scott, 2018; the SHAPE CODING™ system: Ebbels, 2007, and; MetaTaal: Zwitserlood et al., 2015), all using metalinguistic training to improve grammar outcomes for children and adolescents with DLD. Balthazar and Scott (2018) evaluated the Complex Sentence Intervention to improve complex syntax with 30 10-14-year-old children with DLD. Participants were seen for nine weeks, and results indicated an improvement in the production of complex sentence types, particularly adverbial and relative clauses. Further analyses suggested that participants with lower pre-intervention scores achieved higher post-intervention scores, suggesting this compensatory approach may be particularly beneficial for students with persistent grammar deficits.

The SHAPE CODING™ system is an explicit teaching approach designed to teach oral and written syntax to children with language disorder through metalinguistic techniques using a system of shapes and arrows and visual support (Ebbels, 2007). Ebbels et al. (2007) conducted a randomised control trial (RCT) comparing two theoretically motivated interventions (the SHAPE CODING™ system and a semantic intervention) and a no treatment control group with 27 children aged between 10;0 and 16;1 with DLD. Participants in both intervention conditions improved significantly in their use of verb-argument structure compared to the control group, with effects generalising to untrained verbs, suggesting benefit to exploring theoretically grounded interventions. Further, Ebbels et al. (2014) conducted an RCT with 14 children aged between 11;3 and 16;1 comparing the SHAPE CODING™ system to a waiting control group. The aim of the intervention was to improve the comprehension of coordinating conjunctions for children and adolescents with severe receptive language deficits. The intervention resulted in significant improvement in the comprehension of coordinating conjunctions, which was maintained for four months. Results support the ongoing evaluation of the SHAPE CODING™ system to target morphosyntactic deficits, and potentially with younger children.

Zwitserlood et al. (2015) investigated the effects of ‘MetaTaal’, an explicit intervention approach designed to improve complex syntax for older Dutch speaking children with DLD. Twelve children with DLD and a mean age of 11;2 years participated in a within participant multiple baseline design. Results indicated that children improved in their ability to produce relative clauses, but no improvement was observed in the comprehension task. Although evidence for improvement in grammar comprehension is mixed, through explicit interventions children may be able to consciously reflect upon the rules of grammar in the presence of receptive language difficulties to improve understanding, especially older children (e.g., Ebbels et al., 2014).

Explicit approaches using metalinguistic techniques have been demonstrated to be effective in improving expressive grammar in school age children who have DLD. However, there is limited evidence for intervention improving receptive grammar (although cf. Ebbels et al., 2014), and the ages of participants to date are limited to above eight years of age (Balthazar & Scott, 2018; Ebbels, et al. 2007, 2014; Zwitserlood et al., 2015). Therefore, there is motivation to test interventions shown to be effective for older children with younger children to address the concerning gap in evidence of intervention efficacy and effectiveness to improve morphosyntax in children of younger age groups (Ebbels, 2014). Further, Ebbels suggested there is benefit to integrating intervention techniques to include grammar facilitation and metalinguistic training in a range of activities, such as those summarised by Fey et al. (2003). This combined approach is yet to be explored extensively.

Combined Interventions

Ebbels (2014) suggested that interventions may be effective when explicit teaching is used combination with grammar facilitation once the child has learned a new grammatical rule. Kulkarni et al. (2014) conducted a clinical evaluation of the SHAPE CODING™ system combined with elicited production and recasting to improve the use of past tense morphosyntax for two children aged 8;11 and 9;4 with DLD. Both children made statistically significant gains in their use of the target structure, indicating the combined metalinguistic training and explicit recasting approach may be suitable for use in a clinical context, warranting further exploration.

In an RCT, Smith-Lock et al. (2015) evaluated the effectiveness of systematic cueing to improve morphosyntax in children with DLD in combination with explicit rule instruction. Importantly, the cueing hierarchy included approaches employed in grammar facilitation methods as responses to children's errors contingent upon their response to a teaching episode. Specifically, the teaching episode began with explicitly teaching the child the grammatical target and eliciting the structure (e.g., *The [d] sound at the end of 'pull**ed**' tells us it's already happened. Say it with me…*). If a child produced a target form in error, they were cued with a request for clarification (e.g., *Try that one again.*). This serves to alert the child that an error has been made, so they are encouraged to reflect on the goal of the teaching episode. If the child continued to produce the target in error, the target was recast emphatically (e.g., *You pull**ed** the cart.*). The purpose of the recast is to provide the child with another instance of correct input to reinforce the correct representation. How emphatic recasting differs from other recasting interventions is that it provides the child with explicit feedback by drawing their attention to the grammatical target, which may also serve to remind him/her their response was incorrect. If the error continued, the child was provided with a forced choice (e.g., *You just pull the cart or you just pull**ed** the cart?*). The goal of the forced choice is essentially to enhance the goal of recasting (i.e., repeated input), but also to contrast the correct form with the incorrect form. This may serve to increase the child's awareness that they produced an incorrect form. Lastly, if the child was still producing the form incorrectly, elicited imitation was used (e.g., *You just pull**ed** the cart. Say it like me: pull**ed**.*). The cueing hierarchy is closed off with this final strategy as a way to ensure that the child not only hears the correct form again, but also to ensure that each teaching episode was completed with a correct production by the child.

The study of 31 children found systematic cueing combined with explicit teaching principles was more effective for improving individual expressive morphosyntax goals than conversational recasting alone. A key component of the intervention was the inclusion of a metalinguistic component. That is, children in the experimental group were not only aware of the goal, but were encouraged to reflect upon their own use of the targeted morphosyntactic structure through systematic cueing (Smith-Lock et al., 2015). Therefore, combining grammar facilitation approaches systematically and linking them to rules which have already been explicitly taught may indeed be more effective than using the grammar facilitation approaches in isolation. Further, results suggested that different intervention targets (i.e., regular past tense, third person singular, and possessive *'s*) did not moderate treatment outcomes, yet the intervention condition did. This suggests that this intervention approach can be used with a range of morphosyntactic structures without a grammatical complexity effect, namely, third person singular is harder than regular past tense. That is, when selecting verbs to target, the third person singular marker has been considered an extension to regular past tense since regular past tense only marks tense within syntax, regardless of subject-verb agreement (e.g., *The boy/s walk**ed***), whereas third person singular marks both tense and subject-verb agreement (e.g., *He walk**s*** vs. *They walk*), indicating that third person singular is a more complex grammatical structure for children to master (Thornton et al., 2016). Smith-Lock et al. (2015) also noted a great deal of individual variability within both groups, reinforcing the need to tailor intervention specifically for clients.

In two separate studies, Finestack and Fey (2009) and Finestack (2018) compared implicit-explicit to implicit-only approaches to teach novel verb morphology to five to eight year old children with DLD. Results revealed an advantage for learning the novel structure for the implicit-explicit intervention over the implicit-only intervention. However, the authors acknowledge that these findings may not be transferable to the learning of true grammatical morphemes.

Summary of Intervention Effectiveness

Overall, the majority of investigation into empirically supported interventions has focussed on *implicit* approaches. These appear effective, to a degree, for preschool-aged (i.e., under six years old) children with DLD. Recent research has revealed promise in the exploration of *explicit* approaches, especially for older school-aged children with DLD. Early stage efficacy studies have revealed that implicit-explicit approaches may be more advantageous than implicit-only approaches (Finestack, 2018); however, more research is needed. Nonetheless, further investigation into the efficacy of explicit intervention approaches is warranted.

Dosage, Intensity, and Language Interventions

Warren et al. (2007) claimed that there had been virtually no systematic analyses of the effects of varying intervention intensities. Consequently, these authors outlined a framework for defining intervention components to encourage researchers and clinicians to identify elements contributing to optimal intervention effectiveness. This includes clearly defining *dose*, which refers to “the number of properly administered teaching episodes during a single intervention session” (p. 71); *dose form*, which refers to “the typical task or activity within which the teaching episodes are delivered” (p. 71); *dose frequency*, which refers to “the number of times a dose of intervention is provided per day and per week” (p. 72); *total intervention duration*, which refers to “the time period over which a specified intervention is presented” (p. 72), and; *cumulative intervention intensity*, which refers to “the product of *dose* x *dose frequency* x *total intervention duration*” (p. 72). By defining the multiple variables that comprise interventions, researchers and clinicians are able to evaluate the optimal intensity required to demonstrate efficacy before effects diminish, or conversely, require a top-up to maintain effects. Warren et al. (2007) also stressed the need to look beyond the notion that massed practise is always better. For example, principles of motor learning suggest that distributed practice should in fact lead to more efficient learning than massed practice (Maas et al., 2008; Schmidt & Lee, 2005), suggesting more is *not* always better.

There have been advancements in this area since 2007, but still very few studies compare the same dose form across other intervention variables (e.g., dose frequency, total intervention duration, cumulative intervention intensity) to evaluate optimal service delivery guidelines. Further, a current survey of speech language pathology practices in the US evaluated how often clinicians were able to implement parameters, such as dose frequency, as well as probing speech language pathologists' desired dose frequency if resources were unlimited (Finestack & Satterlund, 2018). Results indicated that most clinicians provided sessions once weekly, but clinicians would prefer to provide twice the dose frequency in order to essentially double the cumulative intensity if possible. This may be at odds with the recommendation that 'more is not always better.' As such, systematically evaluating the possible differences in intervention effects resulting from various intervention intensities is of interest, clinically.

The Role of Inflectional Allomorphs in Grammar Interventions

When designing and evaluating an intervention, in addition to dosage, other factors, such as the characteristics of intervention targets, should be considered. Currently, there is a body of literature exploring the effectiveness of morphosyntactic interventions as summarised briefly above. Nevertheless, this poses a new challenge: if morphosyntax for children with DLD can be improved through explicit and/or implicit interventions, what specific targets should be prioritised?

It is reasonably well established that past tense verbs inflected with the [əd] allomorph are more challenging to learn for children with DLD (Marshall & van der Lely, 2006; Tomas et al., 2015, 2017). This is likely due to the relatively low phonotactic probability of such lexical items in English, once the verb is marked for regular past tense. For example, the syllabicity of the verb *kiss**ed*** is represented phonotactically as CVCC, whereas the verb *rest**ed*** is represented as CVCCVC where the latter is a far less frequent syllabic structure in English (Owen Van Horne & Green Fager, 2015; Tomas et al., 2015). In fact, Tomas et al. (2017) found that even in a typically developing sample, verbs inflected for past tense with the [əd] allomorph are still developing at five years old, while verbs inflected with [t] or [d] appear to already be developed. As expected, children meeting criteria for DLD were even more delayed in their acquisition of the [əd] allomorph. This is consistent with the PDH, which predicts less probable sequences of information are going to be more problematic for children with DLD. Tomas et al. (2017) therefore recommended low frequency allomorphs make ideal intervention targets. Notably, this is not consistent with the surface processing account (Leonard, 1989), which predicts phonologically weak forms are more difficult for children with DLD to learn. That is, the syllabic [əd] allomorph is more perceptually salient, and should therefore provide an advantage to learning. In fact, Leonard and Kueser (2019) suggest that lexical items with low phonotactic probability should not be prioritised for intervention, as they are hypothesised to be more challenging for children with DLD to learn.

Conversely, Owen Van Horne et al. (2017) reported on an intervention motivated by verb complexity to treat regular past tense *–ed* production for children with DLD. Children were assigned to an ‘easy’ first verb condition (*n* = 10) or ‘hard’ first verb condition (*n* = 8). ‘Easy’ verbs were phonologically simple, frequently marked for inflection and telic, and; ‘hard’ verbs were phonologically complex, infrequently marked for inflection and atelic (Owen Van Horne et al., 2017). Notably, ‘hard’ verbs were marked with the [əd] allomorph.

All 18 four to 10 year old children with DLD enrolled in the study improved their use of *–ed,* with an advantage in time for the group in the 'hard' verb group. Subsequent analysis indicated that children in the 'hard' verb group also showed greater gains in their use of *–ed* as indicated through language samples collected immediately following intervention and in delayed post-intervention testing points (Owen Van Horne et al., 2018). These findings suggest that selecting 'hard' verbs to target in intervention may result in more rapid and generalised gains in production of *–ed*.

There is also evidence to suggest that treatment success is not related to target selection, but rather to choice of treatment techniques (e.g., Smith-Lock et al., 2015). As summarised in Smith-Lock (2015), there is evidence that children with DLD are able to learn and generalise past tense marking to verbs regardless of frequency effects or phonological patterns.

The literature exploring target selection in morphosyntax intervention for children with DLD is equivocal. It appears there is an interplay between the morphosyntactic patterns with which children with DLD are likely to have difficulty (e.g., regular past tense *–ed* inflection) and the intervention approach selected. Application of theoretical frameworks to clinical trials may shed further light on which specific targets may be favourable to prioritise when treating morphosyntax difficulties in children with DLD.

The SHAPE CODING™ system and the Procedural Deficit Hypothesis

As discussed above, there is an expanding evidence base for the SHAPE CODING™ system and its use to improve grammar for older school-aged children with DLD. Further, the SHAPE CODING™ system as an explicit intervention approach using visual cues apparently aligns with recommendations from the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005). The most extensive account of a theoretical rationale for the SHAPE CODING™ system was discussed by Ebbels et al. (2007) with reference to using explicit intervention to improve verb-argument structure in older school-aged children and adolescents (aged 11;0 – 16;1 years) with DLD. However, although the therapeutic intervention investigated used the relevant aspects of the SHAPE CODING^{TM} system, it was termed semantic-syntactic therapy, to highlight the similarities and differences with the other experimental intervention (semantic therapy) in that particular study. The study was founded on identifying the level of breakdown in children with DLD when creating accurate verb-argument structure using linguistic theory. The authors firstly draw upon the notion of semantic bootstrapping in grammar development (Pinker, 1989, 1994). That is, if the semantics of the verb is the focus of therapy and improvement was seen, this would provide evidence that children can hypothesise the appropriate syntactic structure through cueing by the semantics of verbs. The authors hypothesised that the participants used a process called forward linking (Pinker, 1989) to link semantic roles to syntactic roles (e.g., Agents to Subjects, Patients to direct Objects, Locations/Instruments to Prepositional Phrases) . Notably, the process of forward linking is dependent on a well-established semantic representation for the verb, as inaccurate semantic roles would be linked to the wrong syntactic role (for example, if the child viewed the Patient of the verb *fill* as the Theme e.g., *water*, rather than the Goal e.g., *the cup*, when accurately using forward linking, they would map water into the direct Object position, resulting in an error such as *He filled the water in the cup*). If the semantics of a verb is not adequately established, this will feed forward to a syntactic issue. This is seemingly at odds with the PDH, which suggests children with DLD have intact semantics in the presence of impaired (morpho)syntax. However, due to the links between morphosyntax and semantics during verb learning, impaired morphosyntax could lead to inaccurate verb semantics. For example, if a child hears the sentence *He filled the cup with water*, s/he would use reverse linking to determine that *the cup* must have the semantic role of Patient. However, if reverse linking is a problem (which may well be the case if a child has impaired morphosyntax), the child might use observation of the event rather than the syntax and presume that the *water* might be the Patient as it moves, leading to an incorrect semantic representation. This, in turn, will lead to an incorrect production using forward linking.

Within the study, the semantic therapy was designed to teach participants the semantics of verbs in such a way that was consistent with the reverse linking deficit. That is, the children had syntactic difficulties which affected the learning of verb semantics, therefore teaching verb semantics would improve the production of verb-argument structure if forward linking was intact. The semantic-syntactic therapy (aka the SHAPE CODING™ system) was designed to teach children to learn the appropriate link between semantic and syntactic roles through visual and verbal cueing strategies and metalinguistic training. The intervention explicitly taught participants both to forward and reverse link. Therefore, if participants in the semantic therapy made observable gains, this would indicate difficulties with verb semantics was contributing to difficulties with verb argument structure, but if they did not make observable gains in verb-argument structure production, this would provide evidence that semantic intervention is not sufficient to remediate issues unless it is coupled with explicitly teaching children the links between semantic and syntactic roles. The study found that both interventions were effective at improving verb-argument agreement compared to a control group receiving an unrelated intervention (inferencing) and led to generalisation to untreated verbs, but the semantic-syntactic therapy (using the SHAPE CODING™ system) led to greater improvement in the use of optional, non-targeted arguments. This suggests that indeed verb argument structure issues in older children and adolescents are rooted in poor semantic representations of verbs (perhaps due to difficulties with reverse linking/syntactic bootstrapping), but additional intervention to increase meta-awareness of the links between semantic and syntactic roles enhances intervention effects.

From a (linguistic) surface account perspective, the SHAPE CODING^{TM} system offers many benefits as an intervention. Predominantly, children's use and understanding of inflectional morphology should not be considered as separate to syntax. Leonard (2019) discusses the reciprocal nature of syntax and tense agreement in children's language development. That is, children's difficulty with various syntactic structures in developing language can lead to inappropriate use of bare stem verb forms (e.g., the directive *Look at the dog run* may be translated to the statement *The dog run**). Conversely, tense and agreement morphemes may act as cues to interpreting syntactic structures correctly (e.g., plural/tense agreement in *The dogs run* versus *The dog runs*). This observation presents a cyclical pattern of difficulty in children with DLD: difficulties comprehending certain syntactic structures may lead children to inconsistently use certain morphemes, and the misuse of these morphemes may further inhibit children's ability to use morphological cues to interpret various syntactic structures. This indicates that the evaluation of children's morphological knowledge should always be considered in relation to the syntactic frame in which it conveys meaning. Indeed, in the pilot to this programme of research, Calder et al. (2018) (see below for a detailed summary) concluded that, in relation to general receptive and expressive grammar improvements when only regular past tense *–ed* was treated, "it could be argued that the explicit focus on syntactic components targeted hierarchically within Shape Coding had improved stored knowledge of SVO structures... That is, targeting morphology at sentence level may facilitate greater knowledge of morphosyntax, generally" (p. 12).

However, as noted throughout this thesis, domain (grammar) specific and non-linguistic processing accounts of DLD and associated grammar difficulties come up short. Namely, purely grammatical theories (e.g., Rice et al., 1995; van der Lely & Battell, 2003) do not account for other linguistic (e.g., word retrieval, phonological processing) and non-linguistic (e.g., motor) deficits, and non-linguistic processing theories (e.g., Baddeley, 2012;

Gathercole & Baddeley, 1990) fail to account for discrepancy between processing and linguistic deficits in some children. That is, why do some children with DLD have adequate working memory, and vice-versa (e.g., Archibald, 2017; Lum et al., 2015)?

Since the Ebbels et al. (2007) study, a subsequent randomised control trial evaluating the effectiveness of the SHAPE CODING™ system acknowledged the PDH as a viable theory explaining the benefits of explicit intervention to improve grammar outcomes for children and adolescents with DLD (Ebbels et al., 2014). This notion is echoed in the recent tutorial summarising the evidence for explicit interventions for use with children and adolescents with DLD (Balthazar et al., 2020). Notwithstanding these recent links to the PDH, it appears most attempts to explain why the SHAPE CODING™ system is effective at improving a range of grammar structures are either atheoretical (tested clinically) or grounded in domain (grammar) specific theory. While acknowledging the shortcomings of the explanatory power of domain (grammar) specific theories, why then, does the SHAPE CODING™ system appear to be effective for improving grammar in children with DLD?

The SHAPE CODING™ system is referred to throughout this thesis as a systematic way of visually representing syntax, morphology, and aspects of semantics with shapes, colours and arrows. That is, the SHAPE CODING™ system as a system of principles aligns with an *explicit* approach to teaching grammar, and uses metalinguistic training techniques to teach the rules of grammar. There is also evidence this may be effective to improve grammar when combined with grammar facilitation strategies such as recasting (Calder et al., 2018; Kulkarni et al., 2014), which are generally considered to align with *implicit* intervention approaches (Ebbels, 2014). When considering the PDH account of DLD, distinct parallels can be drawn between the recommendations for improving grammar outcomes (Ullman & Pierpoint, 2005) and the SHAPE CODING™ system as a potentially effective intervention. Recall, at least at a cursory glance, the PDH predicts individuals with DLD will have low grammar abilities due to impaired implicit learning which is underpinned by a procedural learning deficit compared to typically developing children; however, they will have strengths in explicit learning due to relatively spared declarative memory. A key recommendation espoused by Ullman and Pierpoint (2005) to improve language learning for children with DLD in the presence of procedural memory deficits is to exploit functional characteristics of declarative memory, such as to harness explicit learning in rich semantic contexts. Further, the authors suggest environmental modifications can reduce demands on learning through procedural memory, such as increased use of visual support. Finally, segmenting complex sequences (i.e., grammar/morphosyntax) componentially and frequently presenting new information should enhance language learning. These recommendations are highly compatible with the interventions using the SHAPE CODING™ system.

The Influence of Working Memory

Alongside the unpacking of the theoretical suitability of the SHAPE CODING™ system to address recommendations from the PDH, some exploration of differing, yet not mutually exclusive non-linguistic cognitive theory is necessary, namely, Baddeley and Hitch's (1974) Working Memory Model. It is beyond the scope of this thesis to provide a critical overview of the model, but this particular account and its updated manifestations (e.g., Baddeley, 2000, 2012; Gathercole & Baddeley, 1990) are widely accepted as models to conceptualise the multi-componential working memory system, and how it contributes to learning through short- and long-term memory systems.

There are three key components to the model: the Central Executive, the Phonological Loop, and the Visuospatial Sketchpad. It is believed these three systems work in synergy to process, interpret and store short-term memory, and eventual mapping to long-term memory. Each system has a distinct role: the Central Executive is thought to allocate data to the slave systems, Phonological Loop and Visuospatial Sketchpad. The Phonological Loop is responsible for processing and storing spoken and written information, and has two components: the Phonological Store which holds phonological (spoken) information temporarily, and the Articulatory Control Process which is responsible for producing and storing the information captured in the Phonological Store. The Visuospatial Sketchpad is responsible for processing visual and spatial information to assist individuals in being able to determine where their body is in space in relation to objects in our environment. Further, the Visuospatial Sketchpad is used to retrieve, display and manipulate visuospatial memories in long-term store, such as remembering how to drive to the shopping centre down the road. It is suggested that the two systems work more or less exclusively to process visual (Visuospatial Sketchpad) and verbal (Phonological Loop) information, and it is these two systems that are of most relevance to this thesis.

Baddeley's (2012) account of DLD suggests that children experience grammar difficulties due to an issue with phonological short-term memory (PSTM) (Chiat, 2001; Montgomery et al., 2016). There is evidence children with DLD indeed have a PSTM deficit (Gathercole & Baddeley, 1990; Jackson et al., 2016); however, there also exists counter evidence to the claim all children have PSTM deficits (see Bishop, 2006). Alternatively, it may be argued that the language difficulties of children with DLD place stress on their working memory system, which in turn affects performance on measures of working memory or PSTM that involve lexical items. Therefore, to truly test if a child has a working memory deficit, tests must assess memory without the need to use language.

Studies have investigated visual working memory abilities of children with DLD. In general, visuospatial abilities are reported to be spared in children with DLD (Alloway et al., 2009; Archibald & Gathercole, 2006a, 2006b, 2007). In a disconfirmatory investigation, Gillam et al. (1998) used an experimental serial recall task to compare abilities between 16 DLD children and 16 typically developing children aged eight to 11 years. There were no group differences when tasks were audiovisual and paired with a spoken response, but group differences were observed when visually presented items required a pointing response. The authors attempted to tease out the profile, and concluded no clear explanation, but that capacity limitations, and impact of phonological representations in combination with poor encoding and retrieval strategies (i.e., verbal rehearsal) may have contributed to observed working memory deficits, both verbally and visually.

In a study of three groups (DLD, typically developing aged matched, and typically developing language matched) of 18 children, Quail et al. (2009) found that for all groups, verbal working memory skills are enhanced by the provision of visual information as measured on digit forward and digit backward recall tasks. Interestingly, there was a significant discrepancy between performance on the digit forward recall task (posited as a Phonological Loop measure) and the digit backward recall task (posited as a Central Executive measure) for the DLD group. This provides further evidence on the componential nature of the working memory system, in which different components may be unequally affected in children with DLD.

Bavin et al. (2005) compared performance of 21 DLD children aged four and a half years with 21 age-matched controls on the Cambridge Neuropsychological Test Automated Battery. There were differences in performance between Pattern Recognition and Paired Associates Learning tasks, favouring the age-matched controls, indicating memory deficits not specific to language processing. Although, as noted by authors: "One strategy for remembering is to encode information verbally with rehearsal of the verbal information as information is processed (Baddeley, 1986). Even a visual stimulus will force a phonological representation if a verbal response to the stimulus is required (Gillam et al. 1998)" (Bavin et al., 2005, p 329).

Lum et al. (2012) evaluated whether there were group differences in working memory abilities between 51 children with DLD aged between eight and eleven years and 51 age-matched typically developing children. Using the Working Memory Test Battery for Children, results indicated significant group differences between children on Central Executive and Phonological Loop, but not the Visuospatial Sketchpad. This finding is not at odds with the PDH. In fact, the recommendations and this finding are complementary. There is neurological evidence to suggest that the brain structures responsible for declarative memory and working memory are within the same neural regions: the medial temporal lobe and dorsal lateral prefrontal cortex (Blumenfeld & Ranganath, 2006), whereas the procedural memory system is located in the basal ganglia regions (Ullman & Pierpoint, 2005). Consideration of Baddeley's model is important as we expand our understanding of how the procedural, declarative and working memory systems contribute to language learning, and how they can be exploited for therapeutic purposes.

In non-disordered functioning, the Visuospatial Sketchpad could reasonably be viewed to serve as a bridge between working memory and declarative memory, given the proposition that short term memories can be refined, strengthened and eventually retrieved from long term (declarative) memory consciously through the Visuospatial Sketchpad. The Visuospatial Sketchpad would also seem to serve as an interface between visual and verbal information processing before it is mapped to long term (again declarative) memory. For children with DLD, declarative memory would serve as a protective factor for *explicit* learning. In this sense, Visuospatial Sketchpad is a cognitive function or even a slave system to declarative memory. On the other hand, a procedural memory deficit is a risk factor to *implicit* learning, which is necessary for acquiring grammar, phonological processing, and encoding for fast-mapping of words. Given the competitive nature of the systems, for children with DLD, declarative memory may serve as a compensatory mechanism for *implicit* learning. That is, in the presence of a procedural memory deficit, declarative memory may compensate as a system to learn information in an explicit way that would otherwise be learned implicitly. In this sense, the strategies congruent with the SHAPE CODING™ system, specifically visual support, utilise the Visuospatial Sketchpad in a way that could potentially learn grammar and then recall grammar, explicitly. Therefore, this is an example of how declarative memory can act as a compensatory mechanism to impaired *implicit* learning, and a complement to *explicit* learning.

As this review of the literature has highlighted, there is evidence of variance in working memory abilities in clinical populations of children with DLD. Some children with DLD show lower performance on measures of verbal declarative memory when compared to TD children (e.g., Lum et al., 2015). This may appear logical from a brain-behaviour perspective considering both systems appear to depend upon structures in the medial temporal lobe and dorsal lateral prefrontal cortex. However, in one example, this difference was not statistically significant once verbal working memory was controlled (Lum et al., 2015). This suggests verbal declarative abilities are explained by working memory deficits in DLD children, possibly exclusively an issue with the Phonological Loop as suggested by Gathercole and Baddeley (1990). This also has implications for fast mapping of newly experienced phonological information which is consistent with Chiat's (2001) mapping theory of DLD. But what does this mean for the role of the Visuospatial Sketchpad in supporting explicit learning through the declarative memory system?

If children have concomitant procedural memory and verbal working memory deficits, the Visuospatial Sketchpad in combination with the declarative memory system may be considered imperative to explicit learning. This would provide support for the fact that whether children with DLD have concomitant working memory difficulties or not, the Visuospatial Sketchpad can be utilised to support explicit learning through declarative memory using visual support strategies such as those in the SHAPE CODING™ system. While studies have shown that explicit intervention without visual support can improve morphosyntactic outcomes (e.g., Finestack & Fey, 2008; Finestack, 2014, 2018; Smith-Lock et al., 2015), it is unclear whether or not participants in these studies presented with concomitant verbal working memory deficits.

Summary of the SHAPE CODING™ system and the PDH

The links between the SHAPE CODING™ system and the PDH as a viable vehicle for carrying out intervention recommendations have yet to be explored empirically. Theory is important for clinical practice by attempting to account for potential underlying causes of difficulty. Nonetheless, theories must move beyond descriptive to predictive to identify at-risk populations and develop hypotheses regarding likeliness of a positive response to intervention. Studies evaluating the efficacy and effectiveness of interventions that are theoretically motivated can provide insight into the mechanisms of language learning, while providing empirical support for clinical management of at-risk populations.

A Theoretically Motivated Past Tense (ED) Intervention: TheMEDI

The intervention evaluated and reported in this thesis is an explicit intervention that combines *metalinguistic training* and *grammar facilitation* techniques which was designed to improve grammar by targeting past tense production.

Metalinguistic Training (Using the SHAPE CODING™ system)

The SHAPE CODING™ system is a visual system of shapes, colours and arrows that represent morphosyntax, designed to explicitly teach children (Ebbels et al., 2007, 2014; Kulkarni et al., 2014) and adolescents (Ebbels et al., 2007, 2014)- and in one reported case, adults (Newton et al., 2017)- the rules of syntax and morphology. The system uses specific visual cues, where: colour coding is used for parts of speech (e.g. nouns, verbs, adjectives);

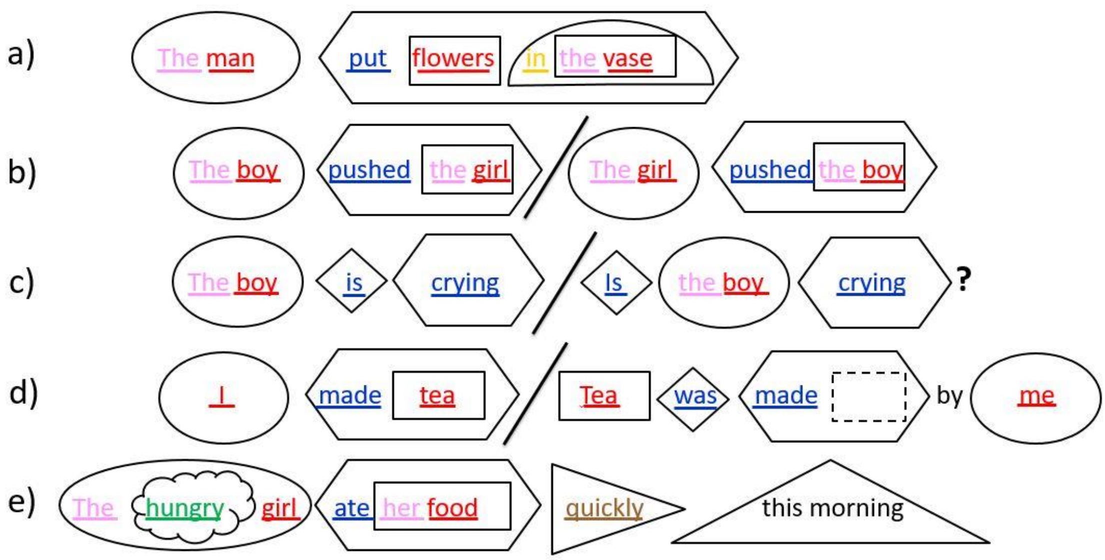
shape coding is used for phrases in accordance with position and role within sentences, and; arrows are used to depict verb morphology, such as tense.

The use of shapes in the SHAPE CODING™ system differs from other visual coding systems (e.g., Bryan, 1997) in a variety of ways, which makes it advantageous from the perspective of teaching syntax explicitly. Firstly, allowing shapes to be placed within one another depicts the hierarchical nature of grammar (e.g., the positions of certain grammatical structures are dependent on the existence of others). For example, the verb *put* requires three arguments: the external argument (the Agent which appears in the Subject position with a Noun Phrase) and two internal arguments contained within the Verb Phrase: the Patient (a Noun Phrase in direct Object position) and the Goal (in Prepositional Phrase containing a preposition and a Noun Phrase). If teaching the verb *put*, the Agent would be in an oval, outside the Verb Phrase hexagon shape., The Patient would be in a rectangle inside the hexagon. Finally, the Goal would be in a semi-circle also inside the hexagon which itself contains a preposition and another rectangle containing the Noun Phrase (see Figure 1.1a). Colours are used to represent the parts of speech, and these are linked to the shapes by indicating the required colour of the head of each phrase. Reversible sentences (e.g., *The boy pushed the girl* vs. *The girl pushed the boy*) can be addressed by the system by referencing the Agent (oval) with one shape, and the Patient (rectangle) with another. That is, the oval and rectangles represent the internal and external arguments of the verb, regardless of their syntactic positions (see Figure 1.1b). Children with DLD are reported to have difficulty learning all of the aforementioned grammatical structures.

Secondly, the shapes can be easily moved and rearranged to depict grammatical movement, i.e., altering syntax that changes the function of a sentence. For example, the statement *The boy is crying* can easily be rearranged to the interrogative *Is the boy crying?* using visuals (see Figure 1.1c). The same is true for teaching passive sentences (e.g., *I made* *tea* vs. *Tea was made by me*) (see Figure 1.1d). Linguistic and additional visual symbols serve as cues to accompany each shape outlined in the SHAPE CODING™ system when teaching grammar explicitly. Linguistic prompts include question cues, such as *WHO/WHAT* for nouns/noun phrases (both in subject and object position), *WHAT DOING* for verb/verb phrases, *WHAT LIKE/HOW FEEL* for adjectives/adjectival phrases, *WHERE* for adverbials of place/prepositional phrases, *WHEN* for adverbials of time, and *HOW* for adverbials of manner (see Figure 1.1e). Additional visual cues such as signs or symbols can be added to the system as desired.

Figure 1.1

Example sentences from the SHAPE CODING™ system depicting verb agreement hierarchies and additional linguistic concepts



In combination with the positioning of shapes, the distinction between linguistic and additional visual symbols is used to highlight the internal arguments and distinguish animacy of the heads of noun-phrases. This is particularly important when teaching passive and reversible sentences, such as *The boy knocked the bike* vs *The bike was knocked by the boy*, and *The boy knocked the bike* vs *The bike knocked the boy*, respectively, where the semantic role of Agent versus Patient is represented by the constant shape, while the animacy is indicated with the questions *WHO* versus *WHAT* and could be indicated with a sign or symbol.

Thirdly, arrows are used to explicitly teach verb morphology (or finiteness). Verbs are underlined with blue, and when marked for finiteness (e.g., third person singular *–s* such as *walk**s**,* regular past tense *–ed* such as *walk**ed***, irregular forms such as *ran*, auxiliary and copular *be* and *do* forms, and modals) a vertical arrow is added to depict the relevant tense (see Figure 1.2). Present tense is marked with an arrow that points down from the middle of the blue line, and past tense is marked with an arrow that points down from the left hand side of the blue line. Further, a non-violable constraint of English grammar is that every grammatical sentence is marked for tense. This is taught through the SHAPE CODING™ system by learning that "every [simple] sentence must have a down arrow" (Ebbels, 2007, p. 72). Although in later stages when children begin using multiclausal sentences, this constraint has to be revised to "every main clause has one (and only one) down arrow," as some subordinate clauses are non-finite.

Fourthly, the SHAPE CODING™ system can be used to teach subject-verb tense agreement (see Figure 1.3). For simple past tense structures, subject-verb tense agreement is not overtly marked when tense is indicated by affixation, e.g., *The boy walk**ed*** vs *The boy and the girl walk**ed***; there is no difference in affixation. However, in the progressive structure, subject-verb tense agreement is overtly marked by a change in the auxiliary lexeme, e.g., *The boy **was** walking* vs *The boy and girl **were** walking*. Further complications may arise when teaching present third person singular, which is marked for tense and subject-verb agreement, e.g. *The boy walk**s*** vs. *The boy and girl walk*. The SHAPE CODING™ system has a strategy to deal with this: within subject noun phrase, if the *WHO* is plural, two red lines are used (either both under a plural noun such as *boys*, or one red line under each of two coordinated

Figure 1.2

Example sentences from the SHAPE CODING™ system depicting finiteness of regular, irregular, auxiliary and modal present and past tense verbs

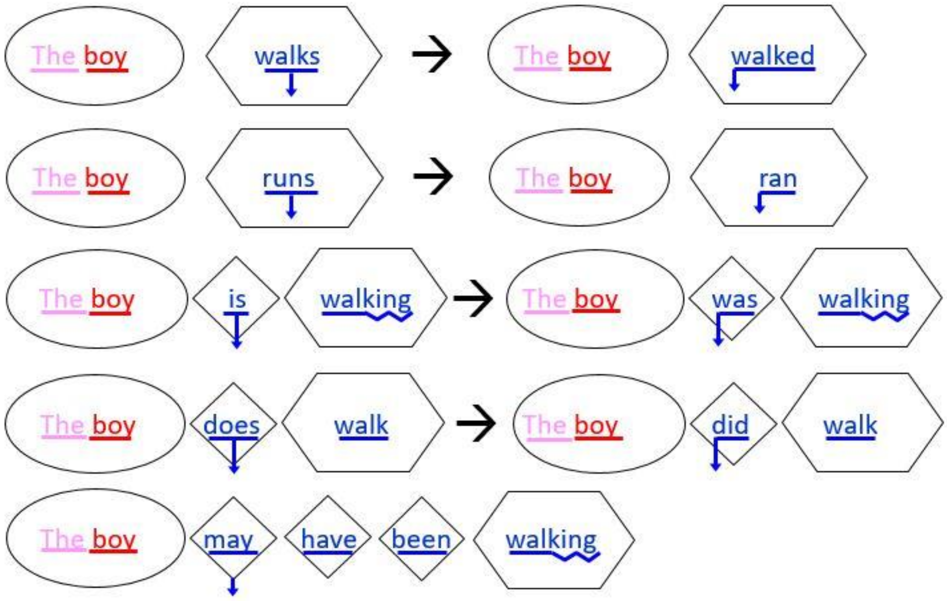
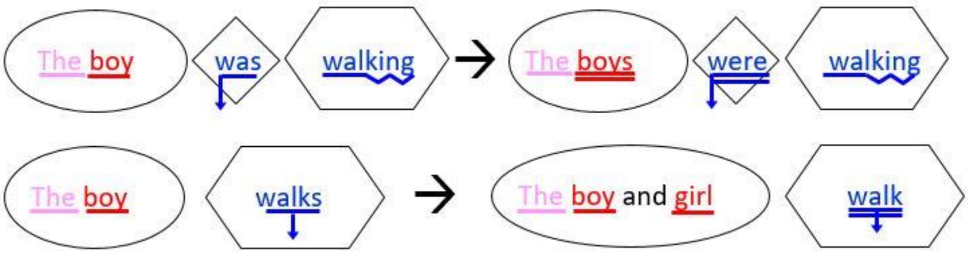


Figure 1.3

Example sentences from the SHAPE CODING™ system depicting subject-verb tense agreement of singular and plural subjects



singular nouns such as *the boy and girl*). Auxiliaries and copulas that are obligatory to plural subjects (e.g. *are, were*) are taught as always being underlined with two blue lines. This visually depicts agreement between plural subjects and the tense carrier in progressive verb phrases as well as for copulas.

Finally, the SHAPE CODING™ system allows for the coding of syntactic elements which are unrelated to verb argument structure (cf. Bryan, 1997). For example, colour and shape coding are used for determiners, adjectives (within noun phrases), conjunctions, and embedded clauses (for a comprehensive overview of the SHAPE CODING™ system and its links to the grammatical concepts of English, see here).

Ebbels (2007) noted that the entire SHAPE CODING™ system is expansive and complex. This is because it aims to be able to represent visually all sentences in English. However, certain aspects of the system can be selected to teach children with DLD specific aspects of grammar they have difficulty with, as difficulties are not uniform and change over time. Notwithstanding the breadth of the grammar structures that can be targeted by the SHAPE CODING™ system, Ebbels has suggested a somewhat uniform way to initiate and progress with the SHAPE CODING™ system as a strategy to teach grammar explicitly. Firstly, once a grammar target is selected, the 'basic system' of the SHAPE CODING™ system is introduced. The initial aim of the SHAPE CODING™ system is to establish a link between the shapes and the question words. This can be achieved by a clinician and client brainstorming vocabulary items (perhaps from some stimulus item such as a picture or a set of toys) in response to verbal cues (e.g., *WHO?*) and matching them to the respective shape (e.g., Oval). Early on, the concept of more than one word belonging to a shape is established. This may relate to nouns and its modifiers belonging to *WHO?*/Oval (e.g., *The dirty brown dog*) or plural subjects (e.g., *The man and the woman*). Perhaps more importantly, this relates to verb phrases and the *WHAT DOING*?/Hexagon cues (e.g., *dug a big hole*). These phrases are combined to build sentences, often with reference to the contrast between sentences that are semantically similar yet syntactically distinct (e.g., *The girl is smiling* vs *The girl is* *happy*). This therefore uses points of reference to establish the concept of syntax (word types + word order) as a system to communicate meaning. This can be achieved in as little as one session (e.g., Calder et al., 2018). Once the system of shapes and verbal cues are established, colour coding of individual words may be introduced. However, this is not necessary unless the goal of intervention requires focus on teaching the distinction of word types within phrases, such as in the case of teaching modifiers in noun phrases. Indeed, once the system of key concepts has been introduced, a fairly systematic intervention session structure can be adhered to, as reported in the following chapters, specifically Chapter 2 and example intervention session plans included in Appendix C.

Grammar Facilitation (Systematic Cueing)

Grammar facilitation is typically used as an implicit intervention approach to treat grammar difficulties in children. However, Smith-Lock et al. (2015) demonstrated the effectiveness of combining approaches into a systematic cueing hierarchy to provide explicit feedback on errors. The intervention reported in this thesis used the same systematic cueing hierarchy as reported in Smith-Lock et al. (2015). Within the programme of research outlined in following the Chapters, the cueing hierarchy was used consistently as an explicit teaching technique to encourage children to reflect upon incorrect responses and the goal of intervention (see Metalinguistic Training section above) by scaffolding from least to most support. Following each cue, the child was encouraged to attempt the target again. If s/he produced the target in error, the next cue was provided. Therefore, the goal of grammar facilitation was not only to provide greater input of correct forms and to increase the amount of practice, but to function to remind the child of the goal of the intervention. Hence, it is an explicit teaching strategy.

The Pilot Study

In a pilot efficacy study, Calder et al. (2018) combined the SHAPE CODING™

system with the systematic cueing hierarchy detailed in Smith-Lock et al. (2015) to improve grammar in three children aged seven years with DLD, i.e., explicit intervention combining metalinguistic training with grammar facilitation techniques. The study used an ABA multiple baseline, across participants, across behaviours, single case experimental design. Children were seen in one-on-one sessions, twice a week for five weeks in 45 minute sessions, resulting in seven and a half hours of therapy. Dose was not held constant, but children received an average of 49 trials per session. The focus of the intervention for all three children was regular past tense (*–ed*) production.

Measures included the Test of Early Grammatical Impairment (TEGI) (Rice & Wexler, 2001) as a standardised expressive grammar measure, the Test for Reception of Grammar (TROG-2) (Bishop, 2003) as a standardised receptive grammar measure, and a modified version of the Grammar Elicitation Test (GET) (Smith-Lock et al., 2003) as a criterion-referenced measure of morphosyntax production. The GET measured production of regular past tense (*–ed*) as the target form, third person singular (*3s*) as the extension to the target form, and possessive 's (*'s*) as a behavioural control measure.

Of the three children, all made significant improvement on the TEGI, Participants 1 and 3 made significant improvement on the TROG-2, and Participants 1 and 2 made significant improvement on *–ed* production. Of these, Participant 1 demonstrated a decline in performance during the five week maintenance period, while Participant 2 continued to make significant improvement. No child showed improvement on the *3s* extension measure or the *'s* control measure, further increasing confidence that improvements in *–ed* production were due to intervention.

The findings provided early evidence supporting the use of an intervention that combined explicit instruction with a systematic cueing hierarchy to improve receptive and expressive grammar, in particular, the production of *–ed*, following five weeks of intervention. However, it was acknowledged that including measures of teaching, maintenance and generalisation (e.g., Finestack & Fey, 2009) would have improved understanding of how the children responded to intervention, and that a longer period of intervention might be necessary to increase the magnitude of intervention effects. Finally, including measures of grammaticality judgement may be useful to report on improvement in grammatical knowledge as a result of intervention.

Summary

Despite equivocal recommendations from theoretical accounts of DLD, recent empirical evidence warrants further exploration of the efficacy of explicit interventions for morphosyntax difficulties (Balthazar et al., 2020). This may provide insight into the way interventions can be designed to teach essential information (e.g., grammatical rules) in a way that is well suited to a child with DLD. Evidence suggests that children with DLD have difficulty with the statistical, pattern-based learning required for proficient use of English grammar due to its probabilistic nature (e.g., Arcuili, 2017; Conti-Ramsden et al., 2015; Evans et al., 2009; Hedenius et al., 2011; Lammertink et al., 2017; Lum & Conti-Ramsden, 2013; Lum et al., 2010a, 2010b, 2014; Oebid et al, 2016; Tomblin et al., 2007). The PDH posits these difficulties may be attributable to procedural learning deficits where grammar would otherwise have been learned implicitly through the procedural memory system, or through statistical learning, as for typically developing children. Therefore, children with DLD may benefit from explicit teaching of morphosyntax, which is likely to harness relatively spared declarative memory functioning and circumvent impaired procedural memory.

Further, there is evidence of the effectiveness of metalinguistic training directly targeting enhancement of metacognition with the use of visual supports and graphic organisers (Ebbels et al., 2007; Zwitserlood, 2015). These techniques are likely to draw upon relative strengths in declarative memory of children with DLD (Ullman & Pierpoint, 2005; Lum et al., 2015), as well as enhance strengths in retention of learning (Lukács et al., 2017). There is also evidence to suggest that younger children may be responsive to implicit interventions using grammar facilitation techniques (e.g., Leonard et al., 2004), in particular, if used within an explicit intervention approach (e.g., Smith-Lock et al., 2015). The explicit use of grammar facilitation techniques such as systematic cueing hierarchies is likely to increase the opportunities and salience of teaching, and should therefore assist with probabilistic learning of grammatical information by redirecting the child to the goal of intervention, and providing an opportunity to produce the target correctly.

Combining metalinguistic training with visual support and grammar facilitation techniques not only offers information suitable to the hypothesised profile of strengths and weaknesses in children with DLD, but enhances the likelihood of accelerated language growth requiring statistical patterned-based learning and retention of morphosyntactic structures (Evans et al., 2009; Lum et al., 2014; Ullman & Pierpoint, 2005). For early school-aged children, preliminary data suggest that an explicit combined metalinguistic and grammar facilitation approach is efficacious in treating *–ed* production and for improving expressive and receptive grammar more generally (Calder et al., 2018). However, there is a need for testing beyond early stage studies of intervention efficacy. Further, such interventions should be clearly framed by the PDH to evaluate the validity of the theory and its associated predictions regarding response to intervention.

Objectives and Significance from this Programme of Research

This thesis outlines a programme of research which has designed, developed and demonstrated the efficacy of a **the**oretically **m**otivated past tense (-***ED***) **i**ntervention (**TheMEDI**) for early school-aged (six- to seven-year-old) children with DLD. The programme of research evaluated the efficacy of TheMEDI by moving through the levels of evidence and analogous research designs (Robey, 2004), including single case experimental designs (Phase II) through to a randomised control trial (Phase III). The extent to which long term memory systems (specifically declarative and procedural memory) influence intervention outcomes was analysed to test the explanatory power of the PDH. To evaluate other theoretical accounts of DLD (e.g., processing limitation theories), an exploratory analysis of the profile of pre-intervention inflectional morphology skills was also conducted, including the relationship between expressive morphosyntax, and short term memory systems (specifically phonological short term memory and working memory). Finally, clinical recommendations from the programme of research are summarised in the context of existing theories which attempt to explain morphosyntactic difficulties experienced by children with DLD, with recommendations for future research.

PART ONE

Intervention Efficacy

Chapter 2

Reporting on a Theoretically Motivated Past Tense (-*ED*) Intervention for Early School-Aged Children with Developmental Language Disorder

Chapter overview

This Chapter presents a detailed description of the intervention procedures from Studies 1-3 reported in subsequent Chapters. Findings from these studies indicated the TheMEDI is efficacious for improving past tense marking for early school-aged children with DLD. However, intervention procedures are often underreported in published research papers. This presents a challenge for researchers and clinicians to replicate interventions.

Chapter 2 provides a comprehensive overview of the TheMEDI, which combined metalinguistic training (the SHAPE CODING system) (Ebbels, 2007) with a systematic cueing hierarchy (Smith-Lock et al., 2015). This facilitates replication and translation for future research and to clinical practice. The Chapter contains tables that were included as Supplemental Material in the Accepted Manuscript version of the article entitled, *The Efficacy of an Explicit Intervention Approach to Improve Past Tense Marking for Early School-Aged Children with Developmental Language Disorder* published by American Speech and Hearing Association Journals in the Journal of Speech, Language, and Hearing Research on 14/01/2021, available online at https://doi.org/10.1044/2020_JSLHR-20-00132.

The purpose of this Chapter is to outline the development of a **the**oretically **motivated** past tense **(-*ED*)** **i**ntervention (**TheMEDI**) for children with developmental language disorder (DLD). Further, this Chapter serves to transparently report on the intervention procedures in order to facilitate replication by researchers and translation to practice for clinicians. Recently, Ludemann, et al. (2017) identified a lack of sufficiently described intervention protocols in published controlled trials within speech-language pathology literature. From 129 published articles, 162 interventions were rated using the Template for Intervention Description and Replication (TIDieR) (Hoffmann et al., 2014). As accessed in their published form, no interventions were completely described. The implications are that clinicians are unable to replicate supposedly evidence-based interventions. Therefore, this Chapter presents a response to this challenge and reports on the components of a theoretically motivated, and empirically supported explicit intervention to improve past tense marking for children with DLD within the TIDieR framework, to provide researchers with the ability to transparently and consistently report intervention procedures for future replication and translation to practice.

Transparent Reporting of Intervention Procedures

TheMEDI was developed following recommendations from the Procedural Deficit Hypothesis (PDH) account of DLD (Ullman & Pierpoint, 2005) for improving grammar in combination with an emerging evidence-base supporting the use of explicit interventions to treat grammar difficulties in this clinical population (Balthazar et al., 2020; Ebbels, 2014). Broadly, the PDH suggests explicit instruction used in the context of spaced and repeated practice enhanced with visual support will improve the learning, storage and use of grammar (Ullman & Pierpoint, 2005). The SHAPE CODING™ system incorporates many of these recommendations, however its use with early school-aged children had not been evaluated prior to the current programme of research (Calder et al., 2018; Chapter 3, Study 1: Calder et al., 2020; Chapter 4, Study 2: Calder et al., 2021; Chapter 5, Study 3: Calder et al., under review b). Further, based on the recommendations for combining elements of explicit approaches and grammar facilitation approaches (Ebbels, 2014; Finestack, 2018), explicit rule instruction for past tense was combined with a systematic cueing hierarchy (Smith-Lock et al. 2015). The intervention, with slight variations between studies, has since been evaluated with n = 32 children with DLD aged between 5;9 and 7;0 years. The elements of TheMEDI, including dosage, materials, procedures and setting, are reported using the 12 items on the TIDieR checklist, to facilitate replication and translation to clinical practice.

The essential elements of the intervention are reported in Table 2.1 as per the TIDieR checklist. As reported below, the fidelity checklist functioned as a session plan while intervention was implemented (see Table 3). Each session involved 10 steps: 1. Explicit teaching, 2. Checking the vocabulary necessary to produce target clauses, 3. Discussing the goal of the intervention session, 4. Practice, which included 25 trials with systematic cueing if necessary, and 5. Consolidation. Steps 6-9 were a repetition of 2-5 in the context of another activity. Step 10 was a Summary of the session, where the child was reminded of the goal of intervention.

One augmentation to the SHAPE CODING™ system was the addition of orthographical representations (‘d’, ‘t’, ‘ed’) to the past tense arrow to explicitly teach each allomorph for past tense *–ed* affixation ([d], [t], [əd]). The SHAPE CODING™ system only shows past tense and does not make such an explicit distinction between allomorphs when teaching regular past tense. This modification was made based on the hypothesis that children with DLD omit/use past tense *–ed* variably, and this may be dependent on the morphonology and related phonotactic structures of tensed verbs. For example, Leonard and Kueser (2019) suggest tensed verbs with less probable phonotactic structures such as CVCCVC (e.g., *tast**<u>ed</u>***) are more likely to have past tense marking omitted when compared to tensed verbs with more

Table 2.1.

Explicit grammar intervention TIDieR checklist.

TIDieR Item	**Description**
Brief name: Provide the name or a phrase that describes the intervention	Theoretically Motivated past tense (ED) Intervention (TheMEDI)
Why: Describe any rationale, theory, or goal of the elements essential to the intervention	TheMEDI was developed based on recommendations from the PDH which suggests children with DLD have impaired implicit memory and spared explicit memory. Strategies include: Explicit rule instruction; Repeated practice; Visual support. TheMEDI used the SHAPE CODING^{TM} system (Ebbels, 2007) in combination with a systematic cueing hierarchy (Smith-Lock et al., 2015).
What: Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in the intervention delivery or in training of intervention providers	Shapes and arrows from the SHAPE CODING^{TM} system were used as physical materials to teach past tense production (available here: https://www.moorhouseschool.co.uk/shape-coding). The arrows were modified to distinguish between different allomorphs for past tense (i.e., (d], [t], [əd] linked to orthography 'd', 't', 'ed', respectively). Intervention materials for activities from each session are reported in Table 2.2.
What: Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities	Detailed reporting of the 10 essential steps to each session is available in Table 2.3. Procedures involved explicit rule instruction with visual support, repeated practice of past tense production for 50 trials with systematic cueing, and consolidation exercises. Individual session plans are available from https://www.languageandliteracyinyoungpeople.com/apps-resources

Who provided: For each category of the intervention provider, describe their expertise, background and any specific training given	Intervention was provided by an SLP (author) with five years' experience working with early school-aged children with DLD. The SLP also completed the SHAPE CODING™ Part 2 advanced training with supervisor (SE). The fidelity checklist (Table 3) and session plans would facilitate implementation by other SLPs.
How: Describe the modes of delivery of the intervention and whether it was provided individually or in a group	Intervention was provided face-to-face in 1:1 sessions.
Where: Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features	Intervention was provided at the participants' school in a quiet space (e.g., onsite therapy room). The intervention could easily be provided in a clinic room.
When and How Much: Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose	Dose: 50 trials, in 45 minute (Calder et al. 2018) or 20-30 minute sessions (Chapter 3, Study 1: Calder et al., 2020; Chapter 4, Study 2: Calder et al., 2021) Dose frequency: 2x per week (Calder et al. 2018; Chapter 3, Study 1: Calder et al., 2020) or 1x per week (Chapter 4, Study 2: Calder et al., 2021) Duration: 5 weeks (Calder et al., 2018) or 10 weeks (Chapter 3, Study 1: Calder et al., 2020; Chapter 4, Study 2: Calder et al., 2021) Cumulative intervention intensity: ~490 trials over 7.5 hours (Calder et al., 2018), 1000 trials over 7-10 hours (Chapter 3, Study 2: Calder et al. 2020), or 500 trials over 3.5-5 hours (Chapter 4, Study 2: Calder et al., 2021)

Tailoring: If the intervention was planned and personalised, titrated or adapted, then describe what, why, when and how	One instance of tailoring (P6 in Chapter 3, Study 1: Calder et al. 2020), where trials were reduced to 30 per session, and the cueing hierarchy was simplified. This was to aid attention and engagement for this participant.
Modifications: If the intervention was modified during the course of the study, describe the changes	Dose was variable (Calder et al., 2018) to held constant at 50 trials (Chapters 3 and 4, Studies 1 and 2: Calder et al., 2020, 2021) to evaluate optimal dose (Chapter 5, Study 3: Calder et al., under review b). Intervention duration was increased from 5 weeks (Calder et al. 2018) to 10 weeks (Chapters 3 and 4, Studies 1 and 2: Calder et al., 2020, 2021) to evaluate whether an increase would amplify intervention effects. Dose frequency was halved from 2x per week (Chapter 3, Study 1: Calder et al., 2020) to 1x per week (Chapter 4, Study 2: Calder et al., 2021) to evaluate efficacy with a clinically relevant frequency.
How Well: Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them	Planned fidelity procedures included using session plans and intervention fidelity checklist throughout the programme of research. All sessions were video recorded so blinded raters could score percentage accuracy of inclusion of elements from a random 20% sample. Inter-observer agreement of percentage accuracy was calculated using ICC (.976)
How Well: Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned	97.95% accuracy suggests all procedures were implemented during most intervention sessions.

Notes. DLD = developmental language disorder; ICC = intraclass correlation coefficients; PDH = Procedural Deficit Hypothesis; SLP = speech-language pathologist.

probable phonotactic structures such as CVCC (e.g., *kiss**__ed__***). If it is hypothesised that children have difficulty applying rules of grammar based on probabilistic constraints of sequencing morphophonological units (e.g., McGregor et al., 2017), it stands to reason that allomorphs should be taught explicitly and distinctly, although they serve identical grammatical purposes.

Table 2.2 presents a session-by-session summary of the intervention provided throughout 10 sessions within the intervention phase for the once per week condition (Chapter 4, Study 2: Calder et al., 2021). For the twice per week condition (Chapter 3, Study 1: Calder et al., 2020), once the 10 sessions were completed, the sequence is repeated to total 20 sessions. Details include the two activities used for each session and the materials, including commercial games (e.g., "Pop Up Pirate"). Further, the verbs targeted in each session are organised according to allomorphic category. Of note, these verbs are selected on their absence from the criterion-reference test used to measure intervention effects to counteract practice effects. Therefore, practically speaking, any regular past tense verb suitable to the activity may be used. Finally, the typical syntactic frame used to elicit the verb is reported so clinicians may be mindful of the level of syntactic complexity within an activity. For example, the target Subject-Verb clause, *I marched* (Session 2, Activity 2) may be easier for a child than the Subject-Verb-Adverbial clause, *The frog flipped off the table* (Session 4, Activity 1). Additionally, whether the elicitation phrase was either 1st or 3rd person is noted. Although this is not analysed statistically, it may be of interest descriptively. For example, if the elicitation phrase was 1st person (e.g., *You roll the playdough*; Session 1/10, Activity 2), then a bare stem *roll* is provided as the antecedent to the past tense target *rolled*; whereas if 3rd person was used (e.g., *The frog flips*; Session 4, Activity 2), then third person singular *flips* is provided as the antecedent to the past tense *flipped*. Overall, out of the

Table 2.2.

Session-by-session summary of intervention

Session #	**Activities**	**Target regular past tense verbs**	**Syntactic frame; Elicitation phrase (1st or 3rd person?)**	**Materials**
1	Activity 1: Introduction	[t]: kicked [d]: hugged [əd]: skated	SVO; 3rd person (e.g., *The puppet kicks the ball. What DID it just DO?*)	Boy/girl puppets, ball, skateboard
	Activity 2: Playdough	[t]: squashed, stretched, poked, pinched, pushed, swapped, chopped [d]: rolled, pulled, flattened, rubbed [əd]: twisted	SVO; 1st person (e.g., *You roll the playdough. What DID you just DO?*)	Playdough
2	Activity 1: Rice and containers	[t]: mixed [d]: poured [əd]: tasted	SVO/A; 1st person (e.g., *You pour the rice (into the cup). What DID you just DO?*)	Rice, cups, bowls, plates, spoons
	Activity 2: Drums	[t]: marched, balanced, clapped, tapped, knocked [d]: twirled, waved [əd]: lifted, collected, rested	SV/O; 1st person (e.g., *You tap the drum. What DID you just DO?*)	Drum, drum sticks

3	Activity 1: Exploring nature	[t]: looked, searched, watched [d]: spied, viewed, explored [əd]: counted	SV/O; 1st person (e.g., *You spy the spider. What DID you just DO?*)	Binoculars, magnifying glass, creepy crawly manipulatives (e.g., spider, frog, mouse, fly)
	Activity 2: Snakes and Ladders	[t]: raced, placed [d]: wriggled, slithered, rolled [əd]: landed	SV/O/A; 1st person (e.g., *You roll the dice. What DID you just DO?*)	Snakes and Ladders board, dice, counters
4	Activity 1: Frogs	[t]: flipped [d]: dived [əd]: rested	SV/A; 3rd person (e.g., *The frog flips (into the bucket). What DID it just DO?*)	Frogs, bowl, bucket
	Activity 2: Garden creatures	[t]: chased, attacked, chirped, sipped, sucked [d]: fluttered, hummed, moved, carried, hurried, chewed [əd]: collected, visited, glided	SV/O; 3rd person (e.g., *The butterfly flutters its wings. What DID it just DO?*)	Garden creature manipulatives (e.g., butterfly, spider, bee, frog, ladybug, dragonfly, beetle)
5	Activity 1: Blocks	[t]: knocked, stacked, grouped, balanced [d]: piled, flattened, lined (up), wobbled, moved, pulled [əd]: separated, created, started, ended, counted	SVO; 1st person (e.g., *You stack the blocks. What DID you just DO?*)	Blocks

	Activity 2: “Don’t Rock the Boat”	[t]: rocked, tipped [d]: spilled [əd]: added	SV/O; 1st (e.g., *You rock the boat. What DID you just DO?*) and 3rd person (e.g., *The boat rocks. What DID it just DO?*)	“Don’t Rock the Boat” commercial game
6	Activity 1: Sea creatures	[t]: placed, pushed [d]: dived, explored [əd]: lifted, drifted	SV/O/A; 1st (e.g., *You place the dolphin (in the water). What DID you just DO?*) and 3rd person (e.g., *The dolphin dives. What DID it just DO?*)	Sea creature manipulatives (e.g., dolphin, whale, shark, seal, stingray)
	Activity 2: Farm animals	[t]: barked, chirped, clucked, quacked, oinked, honked [d]: baaed, he-hawed, meowed, mooed, neighed, purred [əd]: bleated, trotted	SV; 3rd person (e.g., *The dog barks. What DID it just DO?*)	Farm animal manipulatives (e.g., dog, bird, chicken, duck, pig, goose, sheep, donkey, cat, cow, horse, goat)
7	Activity 1: Road vehicles	[t]: pushed, stopped, raced [d]: rolled, pulled [əd]: waited	SV/O/A; 1st person (e.g., *You push the car (on the road). What DID you just DO?*) and 3rd person (e.g., *The car rolls. What DID it just DO?*)	Variety of toy road vehicles (e.g., car, truck, van), road play mat

	Activity 2: "Connect Four"	[t]: dropped, placed [d]: played, offered [əd]: connected, counted	SVO/IDO; 1st person (e.g., *You offered me a turn. What DID you just DO?*)	"Connect Four" commercial game
8	Activity 1: "Phil the Fridge"	[t]: grouped, poked, scooped, watched, switched, mixed, locked [d]: filled, opened, closed, twirled, smiled, showed [əd]: separated, wasted	SV/O/A; 1st person (e.g., *You group the pieces. What DID you just DO?*)	"Phil the Fridge" commercial game
	Activity 2: "Treasure Island"	[t]: looked [d]: turned [əd]: twisted	SVO/A; 1st person (e.g., *You looked under the barrel. What DID you just DO?*)	"Treasure Island" commercial game
9	Activity 1: Bowling	[t]: knocked, replaced, bumped [d]: hurled [əd]: lifted, collected	SVO; 1st person (e.g., *You knocked the pins. What DID you just DO?*)	Toy bowling set (i.e., 10 pins, bowling bowls)
	Activity 2: "Pop Up Pirate"	[t]: picked, placed, popped [d]: played, stabbed, moved [əd]: collected, counted, landed	SV/O/A; 1st person (e.g., *You pop the pirate. What DID you just DO?*) and 3rd person (e.g., *The pirate pops. What DID it just DO?*)	"Pop Up Pirate" commercial game

10	Activity 1: Boardgame	[t]: missed [d]: rolled [əd]: shifted	SVO; 1st person (e.g., *You shift your counter. What DID you just DO?*)	Any freely downloadable boardgame, dice, counters
	Activity 2: Playdough	[t]: squashed, stretched, poked, pinched, pushed, swapped, chopped [d]: rolled, pulled, flattened, rubbed [əd]: twisted	SVO; 1st person (e.g., *You roll the playdough. What DID you just DO?*)	Playdough

Notes. S = subject; V = verb; O = object; A = adverbial. “” indicates commercial games.

20 activities (or 40 for the 2PW group), there were 12 where the elicitation phrase was 1st person, four where the elicitation phrase was 3rd person, and four where the elicitation phrase was both 1st person and 3rd person. This has implications for other theoretical accounts of DLD and potential interventions as discussed below.

All intervention was administered by the author who is a trained speech-language pathologist (SLP). The SLP also completed the SHAPE CODING™ Part 2 advanced training with supervisor, SE in 2016. Intervention sessions were face-to-face and one-on-one with the SLP and participant. All intervention was delivered in a quiet space at the participants' school, therefore, the intervention could easily be implemented within a clinical context. Intervention sessions were provided to the participants on a variable basis regarding the time of day, week-by-week, so to not withdraw at the same time each week and avoid missing the same classroom lesson throughout the intervention phase. There was variability between studies in the amount of intervention provided. The intervention reported in Calder et al. (2018) included 2x 45 minute sessions per week for five weeks, resulting in 10 sessions over 7.5 hours. Dose was variable, as this was a pilot study, however there was an average of 49 trials across the three participants. For Study 1 (Chapter 3: Calder et al., 2020), the intervention duration increased to 2x sessions per week for 10 weeks where the trials were held constant at 50 per session totalling 1000 per participant. The intervention sessions were markedly shorter, at 20-30 minutes per session, resulting in seven to 10 hours of therapy. This was due to a refined treatment protocol following from Calder et al. (2018), and the removal of a reward game between activities for subsequent studies. This decision was made as many of the activities in which practice was embedded were themselves games, and therefore there was no need to further incentivise the participants. For Study 2 (Chapter 4: Calder et al., 2021), the intervention duration remained at 10 weeks, but the frequency was reduced to 1x per week to reflect a more clinically applicable delivery (see Finestack & Satterlund, 2018).

Intervention totalled 3.5 to five hours, and the total number of trials for each participant was halved to 500.

There was one instance of a modification, where P6 in Study 1 (Chapter 3: Calder et al., 2020) completed only 30 trials per session, and cueing was limited to request repetition and elicited imitation. This was to maintain attention and engagement from this participant.

Intervention Fidelity

A fidelity checklist (see Table 2.3 adapted from Appendix 1 in the published version of Study 1, Chapter 3: Calder et al., 2020 and Supplemental Material S3 in Study 2, Chapter 4: Calder et al., 2021) was developed to ensure consistency in the implementation of the intervention and functioned as a session plan throughout the programme of research reported in subsequent chapters. All intervention sessions in the programme of research were administered by the author and videotaped for later fidelity assessment. For each study, the author and a trained, research assistant blinded to the purpose of the studies rated 20% of intervention sessions using the fidelity checklist. Scoring was based on the presence (1) or absence (0) of the element within the intervention session to yield a total percentage accuracy. Between-observer agreement was calculated using intraclass correlation coefficients (ICC) with absolute agreement and single measures in a two-way random effects model. Interpretation of ICC values are: <.40 = poor; .40-.59 = fair; .60-.74 = good, and; .75-1.00 = excellent (Cicchetti, 1994).

For intervention provided twice per week (Chapter 3: Study 1) reported in Calder et al. (2020), the average percentage accuracy across raters was 97.1% and the ICC (two-way mixed model) between raters was .996. For intervention provided once per week (Chapter 4: Study 2) reported in Calder et al. (2021), the average percentage accuracy was 99.58% and the ICC (two-way mixed model) between raters was .995.

Table 2.3.

Intervention session plan and fidelity checklist (adapted from Calder et al., 2020, published as Supplemental Material in Calder et al., 2021)

Step	**Explanation**	**Example**	**1/0**	**Approximate timing (min.sec)**
1. Explicit teaching	Remind child of the goal of the session			
1a. Activate prior knowledge		*Last time we were working on saying sentences. We practised saying all the little parts, like /əd/ if someone did something in the past. We used these shapes and arrows to help us remember. Like this: 'We move**d** the shapes and arrows.'*	❒	0.15
1b. Explain Goals		*I want you to say sentences that have already happened with all the little parts again. We will play some games to help us practise saying really good sentences.*	❒	0.15
		ACTIVITY 1		
2. Check vocabulary	Child asked to label materials from session linked to subject/object nouns	*We are going to do things with the playdough, so you and I will be the WHO. What is this* [hold up playdough]*?* [Child responds correctly] *We are going to be DOING the things with the playdough, so playdough is the WHAT.*	❒	0.15
3. Goal	Demonstrate 3x SV/O/A sentences using one exemplar from each of the allomorphic categories. Introduce 'left down arrow cues' each alongside its corresponding shape	*First let's roll the playdough. Stop! What did we do? We rolle**d** the playdough. The /d/ at the end of rolle**d** lets us know it's already happened. Now, let's squash the playdough. Stop! What did we do? We squashe**d** the playdough. The /t/ at the end of squashe**d** lets us know it's already happened. Let's twist the playdough. Stop! What did we do? We twist**ed** the playdough. The /əd/ at the end of twist**ed** lets us know it's already happened.*	❒	0.30
4. Practice	25 trials to produce past-tense –ed with systematic cueing			6.45-11.45
4a. Coding	Lay large shapes on the floor and child to use as cues to produce SV/O/A sentences		❒	
4b. Trials	25 trials achieved	*'What did you/I do?'* on phrases containing target VERB. Work through VERBs that elicit allomorphs (/d/, /t/, /əd/)	❒	
4c. Cueing	Errors cued appropriately?	i. Request for clarification: *Try that sentence again* (point to the left down 'ed' arrow in the WHAT DOING)	❒	

		ii. Emphatic recast: *You VERBed. Try again*. (point to the left down ‘ed’ arrow in the WHAT DOING) iii. Forced choice: *You VERB or You VERBed. Here is the sentence without the past /ed/ sound* (WHO + VERB/s + WHAT; manipulate shapes)- *try again.* iv. Elicited imitation: *I’ll say the sentence, then you try (*Model and point to shapes, emphasising inflection and pointing to left down ‘ed’ arrow)		
5. Consolidation	At the end of the session, review the 3x SV/O/A sentences using one exemplar from each of the allomorphic category.			
5a. Comprehension task	Child to produce SUBJECTs, VERBs, and OBJECTs following comprehension questions	*WHO rolled the playdough?, What DID we DO? WHAT did we roll?; WHO squashed the playdough?, What DID we DO? WHAT did we squash?; WHO twisted the playdough?, What DID we DO? WHAT did we twist?*	❐	1.00
5b. Production	Child says phrase	*Did you roll the playdough? Tell me…; Did you squash the playdough? Tell me…; Did you twist the playdough? Tell me…*	❐	
5c. Repeat without shapes	Child says phrase (cue as necessary)	*Did you roll the playdough? Tell me…; Did you squash the playdough? Tell me…; Did you twist the playdough? Tell me…*	❐	0.30
5d. Monitoring task (Silly Sentences)	SP start to make errors and child corrects them	*The puppet roll* the playdough. Does that sound right?* [No] *The puppet squashed the playdough. Does that sound right?* [Yes] *The puppet twist* the playdough. Does that sound right?* [No]	❐	0.20
		ACTIVITY 2		
6. Check vocabulary	Child asked to label materials from session linked to subject/object nouns	*We are going to do things with the rice, so you and I will be the WHO. What is this* [hold up rice]*?* [Child responds correctly] *We are going to be DOING the things with the rice, so rice is the WHAT.*	❐	0.15
7. Goal	Demonstrate 3x SV/O/A sentences using one exemplar from each of the allomorphic categories. Introduce ‘left down arrow cues’ each alongside its corresponding shape	*First let’s pour the rice. Stop! What did we do? We poure**d** the rice. The /d/ at the end of poure**d** lets us know it’s already happened. Now, let’s mix the rice. Stop! What did we do? We mixe**d** the rice. The /t/ at the end of mixe**d** lets us know it’s already happened. Let’s taste the rice. Stop! What did we do? We tast**ed** the rice. The /əd/ at the end of tast**ed** lets us know it’s already happened.*	❐	0.30

8. Practice	25 trials to produce past-tense –ed with systematic cueing			6.45-11.45
8a. Coding	Lay large shapes on the floor and child to use as cues to produce SV/O/A sentences		❒	
8b. Trials	25 trials achieved	*'What did you/I do?'* on phrases containing target VERB. Work through VERBs that elicit allomorphs (/d/, /t/, /əd/)	❒	
8c. Cueing	Errors cued appropriately?	i. Request for clarification: *Try that sentence again* (point to the left down 'ed' arrow in the WHAT DOING) ii. Emphatic recast: *You VERBed. Try again*. (point to the left down 'ed' arrow in the WHAT DOING) iii. Forced choice: *You VERB or You VERBed. Here is the sentence without the past /əd/ sound* (WHO + VERB/s + WHAT; manipulate shapes)- *try again.* iv. Elicited imitation: *I'll say the sentence, then you try (*Model and point to shapes, emphasising inflection and pointing to left down 'ed' arrow)	❒	
9. Consolidation	At the end of the session, review the 3x SV/O sentences using one exemplar from each of the allomorphic category.			
9a. Comprehension task	Child to produce SUBJECTs, VERBs, and OBJECTs following comprehension questions	*WHO poured the rice?, What DID we DO? WHAT did we pour?; WHO mixed the rice?, What DID we DO? WHAT did we mix?; WHO tasted the rice?, What DID we DO? WHAT did we taste?*	❒	1.00
9b. Production	Child says phrase	*Did you pour the rice? Tell me…; Did you mix the rice? Tell me…; Did you taste the rice? Tell me…*	❒	
9c. Repeat without shapes	Child says phrase (cue as necessary	*Did you pour the rice? Tell me…; Did you mix the rice? Tell me…; Did you taste the rice? Tell me…*	❒	0.30
9d. Monitoring task (Silly Sentences)	SLP start to make errors and child corrects them,	*The puppet pour* the rice*. *Does that sound right?* [No] *The puppet mixed the rice. Does that sound right?* [Yes] *The puppet taste* the rice. Does that sound right?* [No]	❒	0.20
10. Summarise	Remind child of the goal of the session	*We've done lots of great work practising saying good sentences. We practised saying all of the little parts, like /əd/ if someone did something in the past. Remember, it is really important you say those little parts in the words. This will help your friends and teachers understand you. It's also important to listen out for those parts in words. They can help YOU understand!*	❒	0.20
		TOTAL RAW: **Percentage accuracy:**	**/21** **%**	**20.00-30.00**

Data across studies reported in Chapters 3-5 were pooled and an updated percentage accuracy and ICC value was calculated to give aggregated intervention fidelity values for the programme of research. A two-way random effects model was used, as there were more than two different raters across two samples of children to yield the aggregated value (individual studies reported in subsequent Chapters used two-way mixed models for two raters for each respective sample of children). The average percentage accuracy rating across raters for a 20% sample of all sessions was 97.95%, and the ICC was .976, indicating intervention procedures were adhered to by a single researcher (the author) throughout the programme of research, and rated with excellent consistency.

Discussion

Intervention procedures are underreported in speech-language pathology literature. This has implications for replication and translation. The TIDieR provides a framework for reporting intervention procedures clearly and concisely to address the current impact on replication and translation to practice. This Chapter outlines TheMEDI evaluated through a programme of research for early school-aged children with DLD (Calder et al., 2018; Study 1, Chapter 3: Calder et al., 2020; Study 2, Chapter 4: Calder et al., 2021; Study 3, Chapter 5: Calder et al., under review b). The efficacy of TheMEDI has been demonstrated as reported in subsequent Chapters, and the purpose of this Chapter is to provide researchers and clinicians with a tool to further evaluate and implement the intervention.

The intervention was developed to address the gap in the literature evaluating the efficacy of TheMEDI for early school-aged children (i.e., six to seven years) with DLD (Ebbels, 2014). Most research has investigated the effects of implicit interventions for younger children with DLD. It has been suggested that clinicians should perhaps favour implicit interventions for younger children as they are designed to accelerate learning of grammatical structures by enhancing language input in naturalistic ways, and place fewer demands on the developing cognitive system compared to explicit approaches (Leonard, 2014). However, there is an emerging evidence-base supporting the use of metalinguistic training to improve grammar for children with DLD, especially older school-aged children and adolescents (see Balthazar et al., 2020 for a summary).

Transparent Reporting of Intervention Procedures

The elements of TheMEDI necessary for full replication are reported in detail (see Tables 2.1-2.3). Importantly, the fidelity ratings across studies, and aggregated for the purpose of this paper demonstrate TheMEDI was implemented with excellent fidelity. This may be at least partly explained due to a single researcher designing the intervention, and using the fidelity checklist as a session plan throughout the programme of research, ensuring intervention procedures were provided consistently. However, this also highlights the value of using intervention fidelity checklists in contributing to the evidence-base by allowing researchers and clinicians to replicate intervention studies.

The session-to-session summary (see Table 2) provides the foundation for an interesting discussion. The majority of sessions elicited the past tense intervention target with an interrogative where the antecedent to the target was a bare-stem form (e.g., *You **roll** the playdough. What DID you just DO?*). A recent theory favouring the use of implicit intervention suggests that clinicians should avoid using bare-stem forms through language input, as they create ‘competing sources of input’ (Leonard & Deevey, 2017). That is, the child hears the target form (e.g., *You roll**ed** the playdough*) and the potentially agrammatical form (e.g., *You roll* the playdough*) in past tense contexts if a bare-stem is used to prime the child to produce the target. However, it appears that via explicit rule instruction, the target can be achieved despite hearing a bare-stem immediately before producing the target form. That is not to say that clinicians should over use bare-stems with children with DLD;

however, this finding challenges the notion that implicit interventions with enhanced input should solely be used with young children with DLD.

The other ways in which the target was elicited was to use a verb marked for third-person singular as the antecedent (e.g., *The puppet rolls the playdough. What DID it just DO?*). Early in the programme of research, it was reasoned this may provide sufficient input to have an intervention effect on third person singular production or grammaticality judgement. However, there was limited improvement on the third person singular measures included in those studies. This reinforces the finding that intervention goals must be highly targeted to the needs of children (e.g., Leonard et al., 2004), and that simply hearing grammatical structures through interactions with clinicians is not sufficient to create an intervention effect (e.g., Eidsvåg et al., 2019). It would be interesting to test whether there is an advantage to teaching past tense production using only bare-stem versus third person singular antecedents.

Future Directions and Clinical implications

The information provided in this Chapter functions as a resource for future research. TheMEDI should continue to be evaluated by independent research teams to investigate its effectiveness in real life clinical contexts, and to demonstrate whether other clinicians can implement the intervention with high fidelity. Further, TheMEDI could be evaluated using different service delivery models, such as small group, or whole class contexts. TheMEDI could also be modified to target other grammatical structures known to be difficult for children with DLD, such as third person singular (e.g., TheM*3S*I), and copula and auxiliary verbs (e.g., TheM*IS*I).

This Chapter also serves as a resource for clinicians translating findings to practice. Intervention procedures are often underreported (see Ludemann et al., 2017), and so implementation of empirically supported interventions can be challenging. The clear and concise reporting of TheMEDI may guide clinicians in implementing an efficacious approach to improve past tense marking for children with DLD with fidelity. Other takeaway messages useful for clinical practice were learned throughout the programme of research. For example, since TheMEDI is embedded within engaging activities, there was little need to incentivise participants with rewards. As presented in following Chapters, the time spent practising past tense production was also markedly reduced following the pilot study (Calder et al., 2018) demonstrating that 50 trials could be achieved in 20-30 minutes rather than 45 minutes. Since most sessions targeting grammar range from 45-60 minutes (Finestack & Satterlund, 2018), TheMEDI could potentially be implemented within the same session as another goal; or, the dose could potentially be doubled to achieve 100 trials per session in a clinical context. This may indeed shorten the time required to achieve stable past tense production (see Plante et al. (2019) for evidence of the benefits of condensing dose).

Conclusion

This Chapter reports on the intervention procedures developed to address a gap in the literature by evaluating the efficacy of a theoretically motivated explicit intervention to improve past tense production (TheMEDI) for early school-aged children with DLD. In particular, intervention procedures are reported clearly and transparently using a fidelity checklist and the TIDieR. This facilitates future replication and translation of findings to clinical practice as TheMEDI was implemented with excellent fidelity to yield positive outcomes for study participants. The following Chapters report on the studies that have demonstrated intervention efficacy. As discussed in the final Chapter, future research extending to the evaluation of TheMEDI effectiveness and transference to other service deliveries and treatment of other grammatical structures is warranted. The programme of research reported in this thesis demonstrates that in the absence of findings from larger clinical trials, clinicians may confidently select TheMEDI to treat past tense production for early school-aged children with DLD. Subsequent Chapters report findings in detail.

Chapter 3

Explicit Grammar Intervention in Young School-Aged Children with Developmental Language Disorder: An Efficacy Study Using Single Case Experimental Design

Chapter overview

This chapter presents an accepted manuscript of a published Phase II intervention study evaluating the early efficacy of TheMEDI with early school-aged children with DLD. As discussed in Chapter 1, there is a paucity of research evaluating the efficacy of explicit interventions for this age group. As a result of positive results from a Phase I pilot study (Calder et al., 2018), this Phase II study used single case experimental design (SCED) to refine intervention protocols and determine the presence and magnitude of efficacy by increasing the maintaining consistent dosage and doubling the dose frequency (Robey, 2004).

The current study (Study 1) aimed to evaluate the efficacy of TheMEDI to establish the foundation for further intervention protocol refinement for consistent implementation and replication for the program of research. This chapter presents the Accepted Manuscript[3] version of the article entitled, *Explicit Grammar Intervention in Young School-Aged Children with Developmental Language Disorder: An Efficacy Study Using Single Case Experimental Design* published by American Speech and Hearing Association Journals in Language, Speech, and Hearing Services in Schools on 7/04/2020, available online at https://doi.org/10.1044/2019_LSHSS-19-00060. The study was an invited contribution to a special issue on Morphosyntax Assessment and Intervention for Children. Given this is an Accepted Manuscript, there is some inevitable repetition from previous and subsequent Chapters. At the time of publication, the journal conventions required APA 6th formatting and US English spelling. This Chapter is formatted as such.

[3] Copyright permission letters of approval are provided in Appendix A

Abstract

Purpose: This study evaluated the efficacy of an explicit combined metalinguistic training and grammar facilitation intervention aimed at improving regular past tense marking for nine children aged 5;10-6;8 years with DLD.

Method: This study used an ABA across participant multiple baseline single case experimental design. Participants were seen 1:1 twice a week for 20-30 minute sessions for 10 weeks and received explicit grammar intervention combining metalinguistic training using the SHAPE CODING™ system with grammar facilitation techniques (a systematic cueing hierarchy). In each session, 50 trials to produce the target form were completed, resulting in a total of 1000 trials over 20 individual therapy sessions. Repeated measures of morphosyntax were collected using probes, including trained past tense verbs, untrained past tense verbs, third person singular verbs as an extension probe, and possessive *'s* as a control probe. Probing contexts included expressive morphosyntax and grammaticality judgment. Outcome measures also included pre-post standard measures of expressive and receptive grammar.

Results: Analyses of repeated measures demonstrated significant improvement in past tense production on trained verbs (8/9 children) and untrained verbs (7/9 children) indicating efficacy of the treatment. These gains were maintained for five weeks. The majority of children made significant improvement on standardized measures of expressive grammar (8/9 children). Only 5/9 children improved on grammaticality judgment or receptive measures.

Conclusion: Results continue to support the efficacy of explicit grammar interventions to improve past tense marking in early school-aged children. Future research should aim to evaluate the efficacy of similar interventions with group comparison studies, and determine whether explicit grammar interventions can improve other aspects of grammatical difficulty for early school-aged children with DLD.

Developmental Language Disorder (DLD) refers to children who experience language difficulties in the absence of known biomedical conditions or acquired brain injury (Bishop, Snowling, Thompson, Greenhalgh, & CATALISE-consortium, 2017). Compared to typically developing peers, children with DLD present with particular difficulties in morphosyntactic skills, such as the use (Rice, Wexler, & Hershberger, 1998) and judgment of grammatical morphemes associated with tense (Rice, Wexler, & Redmond, 1999).

Finiteness marking is challenging for children with DLD (see Leonard, 2014 for a review). Finiteness refers to the obligatory marking of verbs indicating subject-verb agreement and tense, including affixation of morphemes -*ed* (e.g. *the girl walk**ed***) and -S (e.g. *the girl walk**s***) to verbs for past- and present-tense, respectively. Within English and cross-linguistically, finiteness is a quality of well-constructed clauses (Dale, Rice, Rimfeld, & Hayiou-Thomas, 2018). There is evidence supporting disordered finiteness as a distinct aetiological construct and predictive marker of language growth for DLD (Bishop, Adams, & Norbury, 2006). Children's grammar difficulties are a primary source of parental concern when considering referral for clinical services (Bishop & Hayiou-Thomas, 2008).

Grammar interventions

Treatment for DLD aims to accelerate language growth and remove barriers to functional communication by harnessing strengths (Justice, Logan, Jiang, & Schmitt, 2017). Ebbels's (2014) review indicates an emerging evidence-base for the effectiveness of grammar intervention for school-aged children with DLD. Current evidence is parsed into implicit and explicit approaches to intervention. According to Ebbels's framework, *implicit interventions* target production and understanding of grammar using grammar facilitation techniques implicitly by responding to children's errors in a naturalistic way (Fey, Long, & Finestack, 2003). Children's learning and the knowledge acquired are not necessarily associated with awareness. *Explicit interventions* target increased awareness of the goals of intervention with a pre-established concept of the criteria for success: learning is conscious and deliberate, and information can be recalled on demand (Shanks, Lamberts, & Goldstone, 2005). Within each approach to intervention, specific techniques are used to improve acquisition of grammar.

Implicit interventions using grammar facilitation. Intervention and scaffolding techniques used in implicit approaches are described as *grammar facilitation* (e.g. Fey et al., 2003), which aims to facilitate the acquisition of grammar by increasing the frequency and quality of target forms in input and output. Greater exposure to and opportunities to learn and use language theoretically accelerates the likelihood of language growth (Leonard, 2014). Studies have empirically tested grammar facilitation techniques supporting their use with expressive morphosyntax targets, including imitation (Nelson, Camarata, Welsh, Butkovsky, & Camarata, 1996), modeling (Weismer & Murray-Branch, 1989), focused stimulation (Leonard, Camarata, Brown, & Camarata, 2004), and conversational recasting (see Cleave, Becker, Curran, Van Horne, & Fey, 2015 for a review). Recently, Van Horne, Fey and Curran (2017) reported on a primarily implicit intervention, in which procedures included a combination of sentence imitation, observational modelling, storytelling and focused stimulation, recasting, and cueing for incorrect responses. All 18 four to 10 year old children with DLD enrolled in the study improved their use of regular past tense. Notably, as participants were dismissed from the study following 36 sessions, many still did not achieve mastery of the intervention target. In general, outcomes following implicit intervention are favourable for morphosyntax in preschool-aged children (Leonard, 2014), however, mastery of intervention targets is rarely reported.

Explicit intervention using metalinguistic training. Difficulties with morphosyntax often persist into school age for children with DLD (Bishop, Bright, James, Bishop, & Van der Lely, 2000). An alternative approach may be required because children with DLD may have difficulty learning grammar through implicit grammar facilitation. *Metalinguistic* *training* aims to improve children's learning of the rules of grammar by creating conscious awareness of grammar through explicit metacognitive teaching (Ebbels, 2014) allowing children to actively reflect on language targets. Meta-awareness is enhanced, so rules of grammar are learned explicitly in a compensatory way.

Metalinguistic techniques can be used explicitly to teach grammar through metacognitive strategies using visual supports and graphic organisers (Ebbels, 2014). The SHAPE CODING™ system is designed to explicitly teach oral and written syntax to children with language disorder (Ebbels, 2007). Ebbels, van der Lely and Dockrell (2007) compared use of the SHAPE CODING™ system with semantic therapy and a no treatment control group with 27 children aged between 10 and 16;1 with DLD. The authors concluded that the SHAPE CODING™ system is a viable and efficacious treatment approach to improve verb-argument structure in older school-aged children. Although evidence for improvement in grammar comprehension is mixed (e.g. Zwitserlood, Wijnen, van Weerdenburg, & Verhoeven, 2015), children may be able to consciously reflect upon the rules of grammar through explicit interventions in the presence of receptive language difficulties to improve understanding, especially older children (Ebbels, Maric, Murphy, & Turner, 2014). Grammar intervention approaches effective for children above eight years should be tested with younger children to address the concerning gap in evidence for this age group (Ebbels, 2014). Further, Ebbels suggested there may be benefit to integrating therapy techniques to include grammar facilitation and metalinguistic training in a range of activities (e.g. Fey et al., 2003). Combined approaches are yet to be explored extensively.

Combined intervention approaches. In an early-stage efficacy study, Finestack (2018) used a combined implicit/explicit metalinguistic approach compared to an implicit approach to teach novel morphemes to six to eight year old children with DLD. The combined approach was more efficacious than the implicit approach, with gains being maintained and generalized. In a randomized control trial of 31 preschool-aged children, Smith-Lock, Leitão, Prior and Nickels (2015) used explicit teaching principles combined with a systematic cueing hierarchy, which was effective in improving use of expressive morphosyntax when compared to conversational recasting alone. Importantly, the study included a metalinguistic component where children in the explicit group were aware of the therapeutic goal (Smith-Lock et al., 2015). Kulkarni, Pring and Ebbels (2013) conducted a clinical evaluation of the SHAPE CODING™ system combined with elicited production and recasting to improve the use of past tense for two children aged 8;11 and 9;4 with DLD. Both made significant gains in their use of the target structure.

Although grammar facilitation is generally considered implicit (Ebbels, 2014; Fey et al., 2003), there is evidence that the techniques can be used explicitly. In a pilot efficacy study, Calder, Claessen and Leitão (2018) combined the SHAPE CODING™ system with the systematic cueing hierarchy detailed in Smith-Lock et al. (2015) to improve grammar in three children aged seven years with DLD. Importantly, systematic cueing as a grammar facilitation technique in this study was *explicit.* Cues ranged from least to most support, and there was a focus on teaching correct production of grammar through errors to avoid the child perceiving the error to be semantic in nature, as may be the case when using conversational recasting without stating the goal of intervention first. The findings provided early evidence supporting the use of combined intervention approaches to improve receptive and expressive grammar, particularly production of regular past tense following five weeks of intervention. Notably, participants made gains in expressive grammar following only 10 intervention sessions across five weeks, which is markedly shorter duration than reported in many intervention studies. However, the authors acknowledge that including measures of teaching, maintenance and generalization (e.g. Finestack, 2018) would have broadened understanding of treatment effects, and that a longer period of intervention might be necessary.

Grammar interventions in clinical practice. Recently, Finestack and Satterlund (2018) reported on a national survey of speech language pathology practice in the US. Past-tense verb production was a common intervention goal for practitioners in both early (40%) and elementary education settings (60%). Interestingly, overall between 60-70% used explicit presentations as an intervention procedure, despite relatively little investigation in this area until recently. Therefore, it appears explicit instruction to improve past tense may not only be supported by an emerging evidence-base, but is also frequently used in clinical practice.

The current study

For early school-aged children, preliminary data suggest that explicit combined metalinguistic and grammar facilitation approaches are efficacious in treating the use of tense marking and for improving receptive grammar more generally (Calder et al., 2018). Building on early stage studies of treatment efficacy is required to determine if treatment procedures are considered evidence-based. Fey and Finestack (2008) outline the need for a programmatic approach to pursuing intervention research, specifically noting the value of small scale studies aimed at exploring and identifying specific components of intervention approaches and their effects on specific populations. This study forms a part of a program of research to design, develop and evaluate the efficacy of an explicit combined grammar intervention in line with Robey's Phases of Clinical Research (Robey, 2004). We report on a range of measures to evaluate the efficacy of explicit intervention to improve grammar. Single case experimental design (SCED) methodology was used to test the following confirmatory hypotheses and is reported as per the Single-Case Reporting Guideline in Behavioural Interventions (SCRIBE) (Tate et al., 2016):

1. For young school-aged children (specifically, 5;10-6;8 years) with DLD, there will be a significant treatment effect on trained past tense verbs, and a generalized effect to untrained verbs across 20 sessions of explicit intervention combining metalinguistic

and grammar facilitation techniques.

2. These children will improve significantly on pre-post standardized measures of expressive and receptive grammar.

Method

Research Design

Design. The current study was an ABA across participant multiple baseline single case experimental design (SCED) including a minimum of five data points (i.e. sessions) for each phase (Kratochwill et al., 2012). Multiple baselines were conducted for varied durations across participants, and introduction of treatment to participants was staggered. Repeated measures were collected throughout the intervention phase and post-treatment maintenance phase (Dallery & Raiff, 2014), including the target behaviour (past tense verbs), an extension of the targeted behaviour (third person singular verbs) and a control behaviour (possessive *'s*). This design is noted for robustness regarding strengths of internal validity and external validity when compared to other SCEDs (Tate, et al., 2016). As a Phase I-II study, we replicated and built on findings from Calder et al. (2018) by refining intervention protocols, determining optimal dosage and evaluating duration of therapeutic effect (Robey, 2004).

Randomization. To improve internal validity further, participants were randomly assigned to one of three pre-determined staggered onset to intervention conditions. To ensure concealed allocation, participants were assigned a code which was entered into a random list generator by a blinded researcher. Participants received: five (P1, P3, P8), seven (P5, P7, P9) or nine (P2, P4, P9) pre-intervention baseline sessions over as many weeks; 20 intervention sessions over 10 weeks, and; five post-intervention sessions to evaluate maintenance. Participants were also randomized to grammaticality conditions described below.

Blinding. Participant caregivers and teachers were aware children were receiving grammar intervention but were blinded to the intervention target. Post-intervention measures were collected via blinded assessment using trained student speech-language pathologists.

Participants

Selection criteria. Participants included nine early school-aged children diagnosed with DLD. The inclusion criteria were: aged between 5;6 and 7;6; English as a primary language, and; grammar difficulties associated with DLD. Exclusionary criteria included: a neurological diagnosis, a cognitive impairment, and hearing outside normal limits. Participants were recruited from a specialized educational program for students diagnosed with DLD. Ethical approval for the study was obtained from the Curtin University Human Research Ethics Committee (Approval number: HRE2017-0835) and the Western Australian Department of Education. The principal consented school participation and then provided information letters and consent forms to the parents/carers of potential participants identified by speech-language pathologists and teachers employed at the educational program. Parents returned the completed consent forms if they wished their child to participate. The study reached capacity at nine participants so we could achieve three replications over three baseline conditions as per reporting standards (Kratochwill et al., 2012).

Participant characteristics. The participants' school enrolment package was accessed, including the assessment protocol and the most recent standardized assessment scores available. Data included Clinical Evaluation of Language Fundamentals Preschool- 2 (Wiig, Secord, & Semel, 2004); a test of non-verbal IQ, and; a comprehensive exploration of previous medical history to identify contributing factors to language difficulties, such as

Table 3.1

Demographic information

Participant ID	Sex	Age at enrolment to school (year; month)	Current year at specialised educational program	Age at initial assessment for study (year; month)
P1	Male	4;0	3rd	6;3
P2	Male	3;11	3rd	6;2
P3	Male	4;7	2nd	5;10
P4	Male	5;4	3rd	6;8
P5	Male	5;2	2nd	6;6
P6	Female	5;11	1st	6;2
P7	Male	5;3	2nd	6;7
P8	Male	3;8	3rd	6;0
P9	Male	4;9	2nd	6;1

acquired neurological damage, or hearing loss. These factors combined are considered evidence of a diagnosis for DLD (Bishop, Snowling, Thompson, Greenhalgh, & CATALISE-consortium, 2016). Participants then passed a hearing acuity test. All participants passed the Phonological Probe from the Test of Early Grammatical Impairment (Rice & Wexler, 2001) for articulation of phonemes necessary for morphosyntactic production targets.

All demographic information is presented in Table 3.1. Participants included eight males and one female aged between 5;10 and 6;8 at initial assessment. Ages at enrolment to the specialist school varied from 3;8 years to 5;11. P1, P2, P4 and P8 were in their third year of placement at the school; P3, P5, P7 and P9 were in their second, and; P6 was in her first.

Measures

Repeated Measures.

Repeated measures of morphosyntax were collected at every data point using various probes, including: trained probes, untrained probes, an extension probe and a control probe (elaborated in the following sections). Probing contexts included both expressive morphosyntax and grammaticality judgement. Grammaticality judgemnt was selected as a method of measuring grammatical progress, as there is evidence performance on such tasks mirrors production tasks (Rice et al., 1998; 1999). As grammaticality judgment is a clinical marker of DLD (Rice et al., 1999; Dale et al., 2018), identification of grammatically correct sentences in the studied participants was expected to be below chance levels of accuracy prior to intervention.

Trained probes. Regular past tense (-*ed*) repeated measures of trained verbs were probed in two conditions: 12 -*ed* verbs trained within sessions were measured, and; 12 -*ed* verbs from the previous session were measured. All -*ed* verbs were predetermined at the outset of intervention and selected based on their suitability to intervention activities. We also chose verbs that were not in the Grammar Elicitation Test (GET; described below; Smith-

Lock, Leitão, Lambert, & Nickels, 2013) to allow comparison between trained and untrained verbs. These probes were administered during the intervention phase at the end of session 2 (i.e. data point B1 the first week of intervention), and every even session thereafter.

Untrained probes. Repeated measures of untrained expressive morphosyntax probes were selected from an adapted version of the GET. This experimental test was designed to elicit multiple instances of specific expressive morphosyntax targets, including 30 items probing the treated grammatical structure (*-ed*). Repeated measures were also developed for a grammaticality judgment task including 30 *-ed* probes. Videos of actions depicting the declarative clauses containing *-ed* were created as stimuli for untrained probes. Accompanying audio for each task item, both grammatical and ungrammatical (e.g. *The girl painted a picture.* vs. *The girl paint* a picture.*) was recorded by an adult female with an Australian accent, blinded to the purpose of research. Each video with corresponding audio was embedded into a Microsoft PowerPoint presentation. Participants wore Sony noise-cancelling headphones during administration and were required to decide if the sentence 'sounded right' by pressing 'yes' or 'no' on a tablet app. Items were counterbalanced for grammaticality so participants did not receive the same combination of grammatical/ungrammatical items, and there was no pattern in presentation of grammatical/ungrammatical items to counteract a priming effect.

Complete sets of 30 untrained *-ed* verbs were probed pre- and post-intervention. Sets were randomized for administration at the initial assessment (Timepoint 1), one week prior to intervention commencing (Timepoint 2), one week following intervention (Timepoint 3) and five weeks following cessation of intervention (Timepoint 4). Both expression and grammaticality judgment were assessed.

Reduced randomized sets were generated for each other data point using nine expressive probes and 12 grammaticality judgment probes. All possible allomorphs were included (i.e. [d], [t] and [əd]) and equally distributed. Probes were administered via laptop during the pre-intervention baseline phase, at the beginning of session 3 (i.e. data point B2 in the second week of intervention) and every odd session thereafter during the intervention phase, and in the post-intervention maintenance phase.

Extension probes. Expressive repeated measures of third person singular (3S) served as an extension of the treated structure. Items included 30 probes and were taken from the GET. A grammaticality judgment task was also developed as per the untrained -*ed* probes (e.g. *The man sneezes*. vs. *The man sneeze*.*). 3S was considered an extension measure due to the structure's relative complexity compared to -*ed*, since bare stem forms are grammatical when used with first person subject pronouns or plural subject nouns (e.g. *I like ice-cream* vs. *The boys like ice-cream* vs. *The boy likes ice-cream*). We also expected there might be improvement in 3S due to the frequent instances of input during therapy (see Intervention section) and increased awareness of the need for tense marking.

Control probes. Similarly, expressive repeated measures of possessive *'s* (*'s*) served as a control probe. Items included 30 probes and were taken from the GET. As above, a grammaticality judgment task was developed (e.g. *The spider is living on a leaf. This is the spider's leaf.* vs. *The spider is living on a leaf. This is the spider* leaf.*). For *'s*, still images of nouns depicting ownership were retrieved from copyright free image sources. *'s* was considered a control as this noun possession was not taught as part of therapy and therefore should remain stable throughout the intervention period.

For extension and control probes, all possible allomorphs were included (i.e. [s], [z], [əz]) and equally distributed. Randomized sets of 9 expressive and 12 grammaticality judgment items were generated and administered as per the untrained -*ed* probes during pre-intervention, intervention, and post-intervention phases.

Pre-post.

The Structured Photographic Expressive Language Test 3rd Edition (SPELT-3) (Dawson, Stout, & Eyer, 2003) and the Test of Reception of Grammar 2nd Edition (TROG-2) (Bishop, 2003) were administered both pre- and post-intervention as expressive and receptive standardized grammar measures, respectively. The SPELT-3 measures expressive morphosyntax using 54 items across a range of structures and was normed on children aged four to nine years. To address discriminant accuracy of the test, Perona, Plante and Vance (2005) determined 90% sensitivity and 100% sensitivity at 95 cutoff (-0.33SD). This cutoff score was used for the current study based on the recommendation, although it is noted that while other studies applied this cutoff with older children (e.g. Van Horne et al., 2017), Perona et al. (2005) sampled children aged four to five years. The TROG-2 test measures a total of 20 different grammatical structure contrasts and was normed on children aged four to 16. Discriminant accuracy was evaluated on a sample of 30 children aged 6;2-10;11 which confirmed the test is sensitive to identifying communication difficulties in children (Bishop, 2003). Both tests have strong reliability and appropriate validity.

Reliability.

A blinded researcher scored 20% of all measures audio and video recorded throughout the study. Inter-rater reliability for experimental measures was calculated using intraclass correlation coefficients (ICC) using absolute agreement and single measures in a two-way mixed effects model. Interpretation of ICC values are as follows: <.40 = poor; .40-.59 = fair; .60-.74 = good, and; .75-1.00 = excellent (Cicchetti, 1994). For trained *-ed* probes, the ICC for expressive measures was .879 and ICC for grammaticality judgment was .977. ICC for expressive untrained *-ed*, 3S and *'s* probes was .937, and ICC for the grammaticality judgment of untrained *-ed*, 3S and *'s* was .985. Therefore, excellent agreement was observed across all experimental measures.

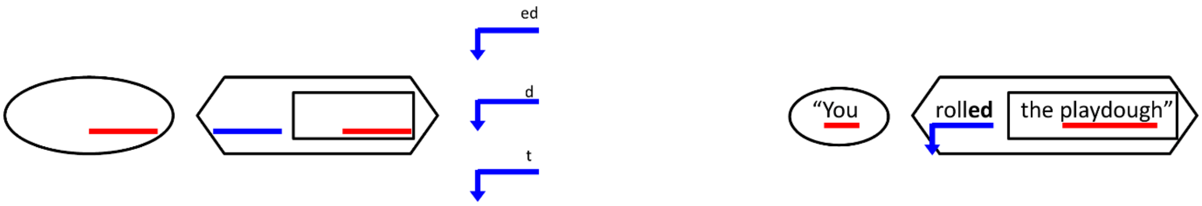
Intervention

All intervention sessions were videotaped and carried out in a quiet space at the site of the educational program. Procedures were similar to those reported by Calder et al. (2018) and are explained within the model suggested by Warren, Fey, and Yoder (2007) for describing treatment intensity. The dose was 50 trials within 20-30 minute sessions; dose form was explicit intervention combining metalinguistic training using the SHAPE CODING™ system (Ebbels, 2007) with a systematic cueing hierarchy (Smith-Lock et al., 2015); dose frequency was twice a week; total intervention duration was 10 weeks, and; cumulative intervention intensity was (50 trials x 2 times per week x 10 weeks), resulting in a total of 1000 trials over 20 individual therapy sessions through roughly 7-10 hours of therapy. This is double the intervention duration in the pilot study (Calder et al., 2018), where authors suggested that participants may demonstrate larger treatment effects following a longer duration. Training of morphosyntax was embedded within engaging and naturalistic activities suited to early school-aged children, including playdough, board games, and playing with puppets, and farm and sea creature manipulatives. Target morphemes were presented in syntactic structures as they occurred felicitously within these activities. The first author (SDC), a trained speech-language pathologist (SLP), delivered all intervention.

Each session began with a short recap of the aims: to say WHAT DOING words (verbs) that have already happened, and to add the sounds ([d], [t], [əd]) onto the end of those words. Next, the SLP would direct the child's attention to the laminated shapes and arrows used as a visual organiser throughout session activities. See Figure 3.1 for essential shapes, including the oval (subject noun phrase WHO/WHAT?), the hexagon (verb phrase WHAT DOING?) and the rectangle (object noun phrase WHO/WHAT?). Additional visual cues included three separate laminated cards that depicted a 'left down arrow' to depict *-ed*, and an orthographic representation of the allomorphs (i.e. 'd' for [d], 't' for [t], and 'ed' for [əd]).

Figure 3.1

Visual depiction of visual cues used during intervention phase

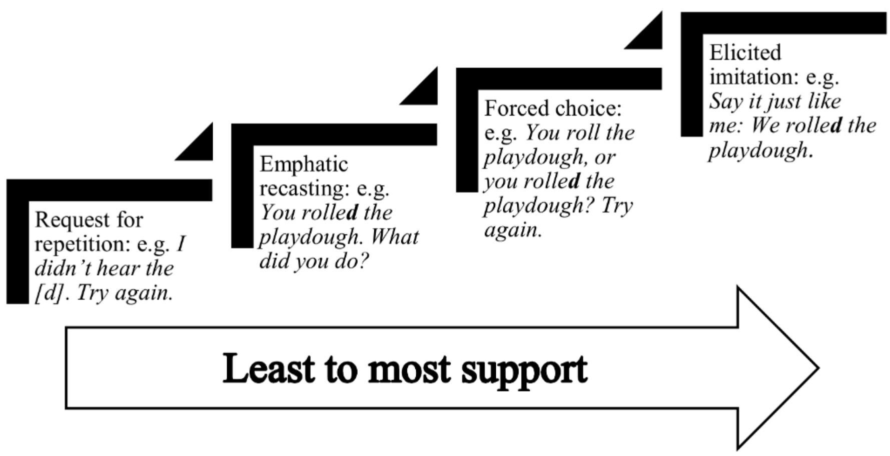


The SLP said, *“Last time, we used our shapes and arrows to help us. Like this: ‘We move our shapes and arrows. What did we do? We mov**ed*** [bring ‘d’ arrow into the WHAT DOING? hexagon] *our shapes and arrows. The [d] at the end of mov**ed** lets us know it’s already happened.”* The participant was reminded, *“I (the SLP) will say what we do in the session (i.e. present tense) and you will say what we did (i.e. past tense)”.* This was followed by two activities which were designed to give the participants ample opportunities to produce *-ed* verbs in response to an interrogative (e.g. *What did you do?; Did you just VERB? Tell me…*).

Each activity began with explicit instruction of how to apply *-ed* inflection, using one exemplar from each of the allomorphic categories. Within each activity, there were approximately 25 opportunities for the child to respond to an interrogative (e.g. *You roll the playdough! What did you do?)* using *-ed* verbs while the SLP gestured to the shapes and arrows (see Figure 1). The child was therefore encouraged to respond using a Subject-Verb-Object syntactic frame, consistently. If the child responded with an unmarked verb (i.e. bare stem) or overgeneralised form (e.g., *playded*), s/he was supported with a systematic cueing hierarchy moving from least to most support outlined in Figure 3.2. As much as possible, verbs were blocked according to allomorphs and presented from least to most difficult (i.e., [d]→[t]→[əd]) in accordance with Leonard (2014) and Marshall and van der Lely (2006). At the end of every activity, the SLP recapped what the participant had learned using the shapes and arrows, and comprehension questions. For example, if the target sentence had been ‘*I* *rolled playdough'*, the SLP would gesture to the WHO?/WHAT? oval and ask, *"WHO rolled the playdough?"* Then gesture to the WHAT DOING? hexagon while bringing down the 'd' left down arrow and ask, *"What DID you DO?"*, and finally gesture to the WHO?/WHAT? rectangle and ask, *"WHAT did you roll?"* Plausible responses to all of these questions are '*I rolled the playdough'*, giving further opportunity to reinforce production using a consistent syntactic frame. If an error occurred, the same systematic cueing hierarchy described above was employed. The shapes and arrows were then removed, and the interrogative (*What DID you DO?*) was repeated without visual support for an exemplar from all three allomorphic categories, reinforcing internalisation of the grammatical rule. If a child had achieved 80% success over three sessions on any measure, 'Silly Sentences' were introduced; a metalinguistic sub-activity whereby three sentences were said, either grammatically or ungrammatically (i.e. *-ed* morphemes were either included or omitted), and the child would decide if the sentence 'sounded right'.

Figure 3.2

Systematic cueing hierarchy used when child produced the target verb in error



These procedures were repeated for a second activity, giving 50 opportunities to use *-ed* inflection during the activity which was bookended with explicit teaching and comprehension questions using three exemplars from each allomorphic category. At the end of each session, the child was reminded of the goal of the session, and why it is important to say the sounds at the end of '*WHAT DOING?'* words that have already happened, and also to listen out for those sounds.

Procedural fidelity.

A blinded researcher scored 20% of videotaped sessions on percentage accuracy using *a priori* established criteria for intervention procedures. A total of 19 items were scored for sessions (see Appendix A for a checklist for scoring intervention procedure fidelity). Note, if children were introduced to 'Silly Sentences', sessions were scored against an additional two (total 21) items. Intra-observer agreement was calculated using ICC. The average score was 97.1% for percentage accuracy, and ICC for treatment procedures was .996.

Analysis

Single subject analyses. Treatment effects of teaching, generalization and maintenance through repeated measures of morphosyntax were statistically evaluated using *Tau-U* by combining non-overlap and trend of data (Parker, Vannest, Davis, & Sauber, 2011) across all phases and data points. *Tau-U* uses Kendall's *S* to interpret significance testing and outputs *p* values. Raw scores on probes were converted to percentage correct. Baselines were contrasted using the *Tau-U* online calculator (Vannest, Parker, Gonen, & Adiguzel, 2016), and the *Tau* value was checked for trend of baseline in pre-intervention and post-intervention phases. For pre-intervention baseline, *Tau* values above 0.40 (increasing trend) or below -0.40 (decreasing trend) were deemed unstable and corrected, as recommended by Parker et al. (2011). This was repeated for all applicable baseline versus intervention contrasts. Finally, phase contrasts were aggregated to provide an omnibus effect size for study participants, where, using Cohen's standard, 0.2 is small, 0.5 is medium and 0.8 is large.

To evaluate performance on the full sets of untrained *-ed* verbs, a concurrent within-group approach was used (e.g. Zwitserlood et al., 2015) where Friedman non-parametric two-way analysis of variance (ANOVA) tested differences between Timepoint 1 and 2 pre-intervention, and Timepoint 3 and 4 post-intervention scores. Participant scores determined a group mean and standard deviation in expressive and grammaticality judgment probes within each Timepoint. Post-hoc Wilcoxon sign-rank tests made pairwise comparisons between testing points. These statistics were computed using IBM SPSS Version 25.

Kratochwill et al. (2012) outline standards for analysis of repeated measures via visual inspection to report on a functional relation between dependent and independent variables, which includes comments on level, trend and variability within phases, and comments on immediacy, overlap and consistency between phases. For the current study, within phase level performance was evaluated with group statistics. Further, *Tau-U* handles within phase level, and trend and variability within *and* between phases, as well as overlap between phases. Therefore, reporting on visual inspection is limited to the immediacy of the functional relation between *-ed* use and understanding, and the staggered introduction of intervention across participants.

Pre-post analyses. Pre-post differences on standardised measures were tested in a case series approach by calculating the Reliable Change Index (RCI) (Unicomb, Colyvas, Harrison, & Hewat, 2015). The RCI statistic calculates whether an individual's change in score (i.e. pre-post difference in standard scores) is statistically significant by using the reliability values of a standardised test. The RCI is calculated using the formula x_2-x_1/S_{diff}, where x_1 is the participant's pre-test score, x_2 is the same participant's post-test score, and S_{diff}

is the standard error of difference between the two test scores. An RCI above 1.96 is considered statistically significant at 0.05 significance level.

Results

Sequence completed

All participants completed planned sessions within pre-intervention baseline (A), intervention (B), and post-intervention maintenance (A) phases. There was an average of 50.74 (SD= 1.2; range 48-56) trials for each participant to produce *-ed*. Out of the nine participants, six (P1, P2, P3, P4, P5, P7) demonstrated at or above 80% performance on at least one measure of *-ed* marking over three sessions. These participants engaged in the 'Silly Sentences' aspect of intervention procedures as described in the Intervention section.

Outcomes and estimation

Single subject treatment effects (expressive). Data not reported in tables are available in Supplementary Materials (and in Appendices E). Pre-intervention baselines on production of *-ed* verbs taken from the GET were stable for 4/9 participants. P1 (*Tau* = -0.70), P3 (*Tau* = -0.70), P4 (*Tau* = 0.58), P8 (*Tau* = 0.60) and P9 (*Tau* = -0.71) had baselines corrected for subsequent analyses. Data from expressive repeated measures are presented in Figures 3.3-3.5 and results from *Tau-U* analyses are reported in Table 2.2. Of the nine participants, eight (P1-P7, P9) demonstrated statistically significant trend in production of trained verbs tested within-session during the intervention phase (Figure 3.3). Phase contrasts were combined and yielded an aggregated effect size of 0.88, which is considered large. For trained verbs tested between sessions (Figure 3.4), seven (P1-P5, P7, P9) of the nine participants demonstrated statistically significant performance during the intervention phase with a large aggregated effect size of 0.83. Seven (P1-P7) of the nine participants demonstrated a statistically significant trend in production of untrained *-ed* verbs during the intervention phase (Figure 3.5) yielding a medium effect size of 0.64.

Figure 3.3

Percentage correct on expressive trained within-session probe repeated measures for Groups 1-3

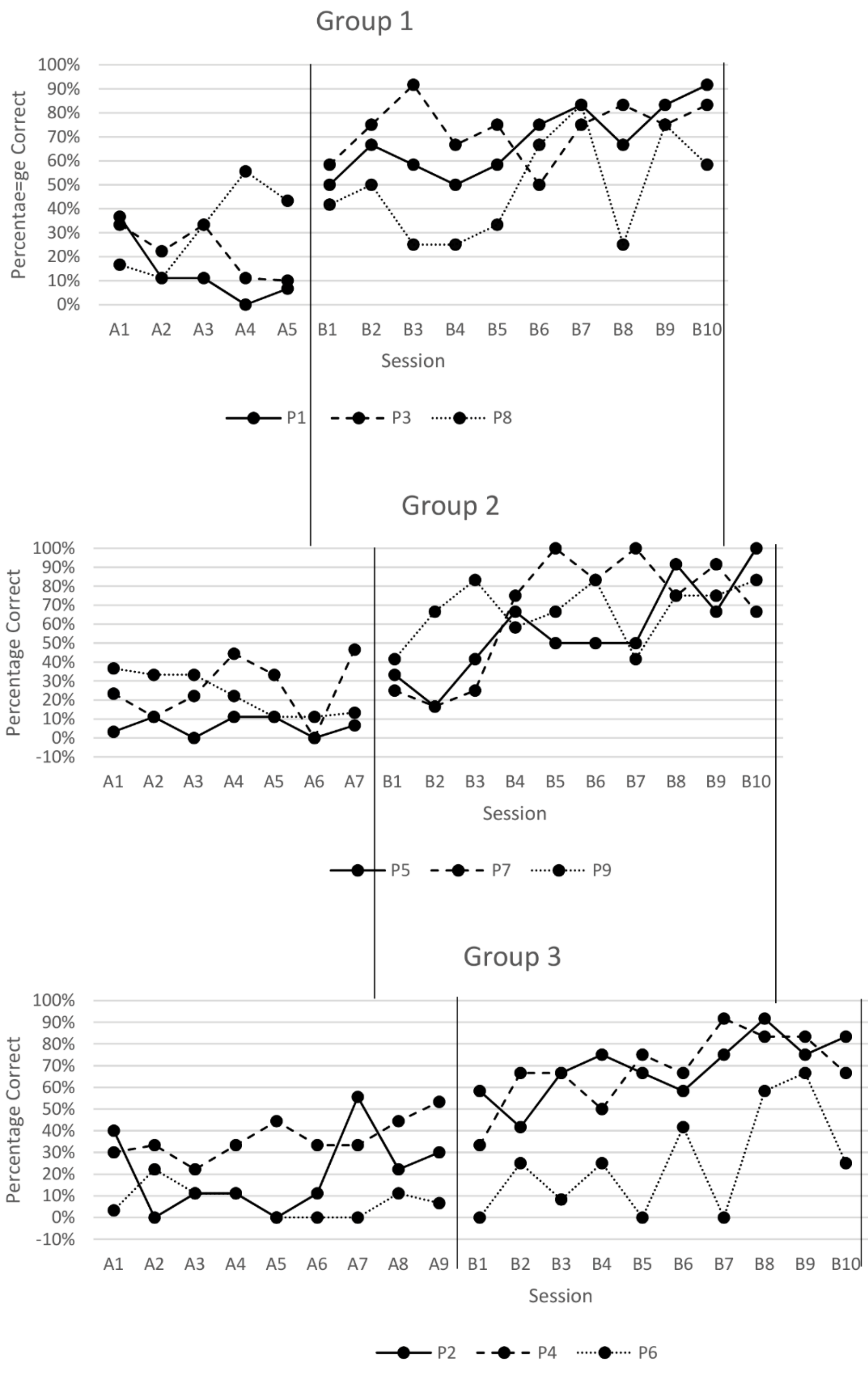


Figure 3.4

Percentage correct on expressive trained between-session probe repeated measures for Groups 1-3

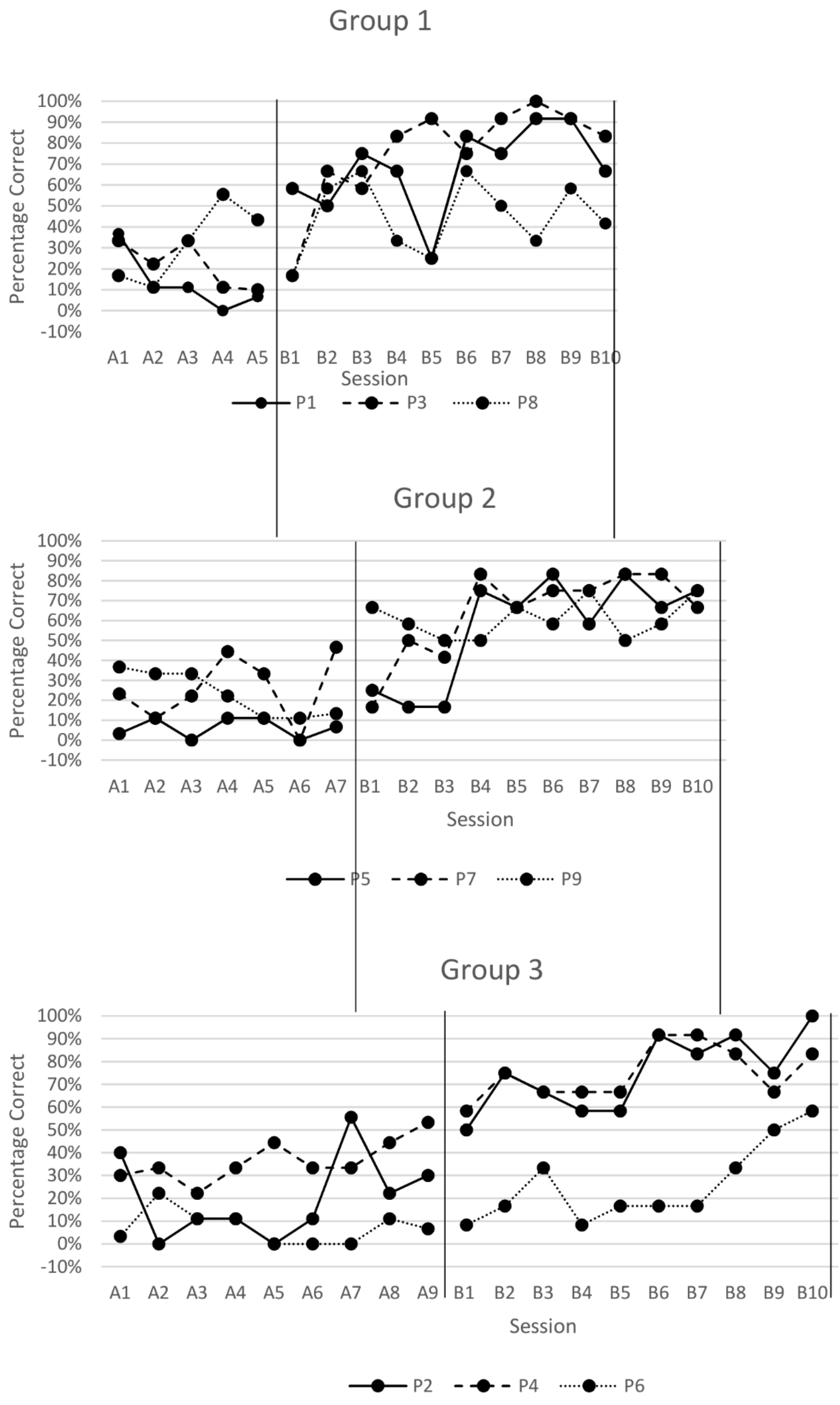


Figure 3.5

Percentage correct on expressive untrained probe repeated measures for Groups 1-3

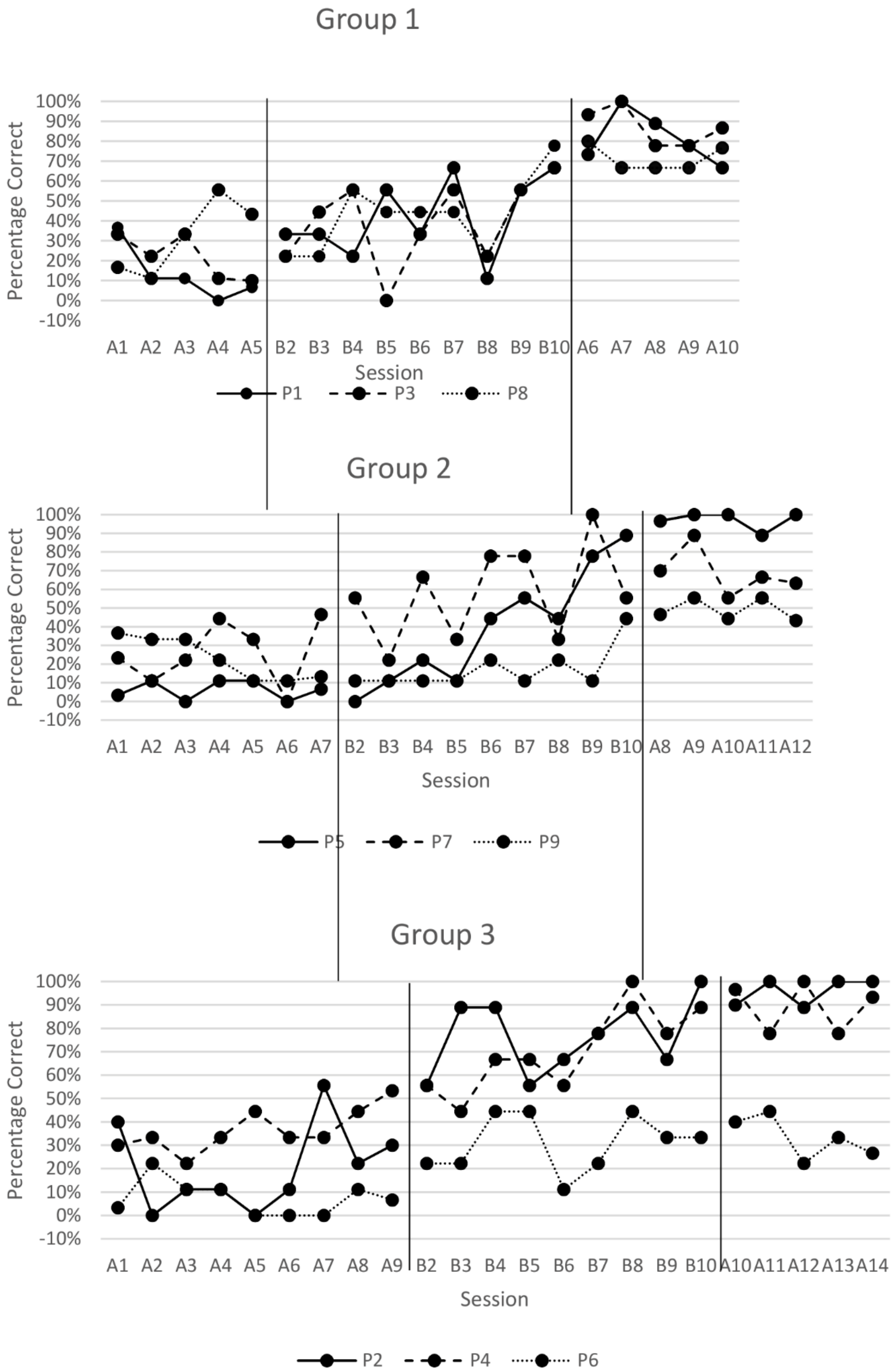


Table 3.2

Summary of expressive repeated measures baseline versus treatment phase contrasts on trained and untrained targets

Participant ID	Kendall's *S*	*z* score	*p* value	*Tau*	90% CI
WITHIN SESSION					
P1[a]	55	3.37	<0.001*	1.1	[0.56, 1]
P2	88	3.60	<0.001*	0.98	[0.53, 1]
P3[a]	51	3.12	0.002*	1.02	[0.48, 1]
P4[a]	69	2.82	0.005*	0.77	[0.32, 1]
P5	70	3.42	<0.001*	1	[0.52, 1]
P6	66	2.70	0.007*	0.73	[0.29, 1]
P7	56	2.73	0.006*	0.80	[0.32, 1]
P8[a]	15	0.92	0.36	0.30	[0.24, 0.84]
P9[a]	85	4.15	<0.001*	1.21	[0.73, 1]
				Aggregated ES	
Group	-	-	<0.001*	0.88	-
BETWEEN SESSION					
P1[a]	57	3.49	<0.001*	1.14	[0.60, 1]
P2	88	3.59	<0.001*	0.98	[0.53, 1]
P3[a]	57	3.49	<0.001*	1.14	[0.60, 1]
P4[a]	57	2.33	0.02*	0.63	[0.19, 1]
P5	70	3.42	<0.001*	1.00	[0.52, 1]

P6	37	1.51	0.13	0.41	[-0.04, 0.86]
P7	48	2.34	0.02*	0.69	[0.20, 1]
P8[a]	15	0.92	0.36	0.30	[-0.24, 0.84]
P9[a]	85	4.13	<0.001*	1.21	[0.73, 1]
				Aggregated ES	
Group	-	-	<0.001*	0.83	-
UNTRAINED					
P1[a]	40	2.67	0.007*	0.89	[0.34,1]
P2	79	3.49	<0.001*	0.98	[0.52, 1]
P3[a]	30	2.00	0.05*	0.67	[0.12, 1]
P4[a]	56	2.47	0.01*	0.69	[0.23, 1]
P5	45	2.38	0.02*	0.71	[0.22, 1]
P6	73	3.22	0.001*	0.90	[0.44,1]
P7	44	2.33	0.02*	0.70	[0.21, 1]
P8[a]	13	0.87	0.39	0.29	[0.26, 0.84]
P9[a]	-8	-0.42	0.67	-0.13	[0.62, 0.37]
				Aggregated ES	
Group	-	-	<0.001	0.64	-

Notes. CI= confidence interval; ES= effect size
*sig.
[a]unstable baseline corrected

Analysis of *Tau* scores revealed a significant negative trend in performance for P1 (*Tau* = -0.40), P6 (*Tau* = -0.40) and P7 (*Tau* = -0.40) across five datapoints in the post-intervention maintenance phase. Note the *Tau* values for these three participants is at minimum level for baseline trend (*Tau* = ±0.40) corrections according to Parker et al. (2011).

For expressive 3S extension probes, P7 (*Tau* = 0.62), P8 (*Tau* = 0.60) and P9 (*Tau* = 0.57) demonstrated an unstable baseline with a positive trend. During the intervention phase, P6 demonstrated significant improvement (p = .03) and P9 demonstrated significant decline (p = .03). Phase contrasts yielded a non-significant (p = .65) aggregated effect size of -0.05. P1 (*Tau* = 0.80), P2 (*Tau* = 0.40) and P4 (*Tau* = 0.70) demonstrated positive trend in the post-intervention maintenance phase.

For expressive *'s* control probes, P2 (*Tau* = 0.69) and P4 (*Tau* = 0.61) showed unstable baselines with positive trends, while P9 (*Tau* = -0.43) showed an unstable baseline with a negative trend. Of the nine participants, both P1 (p = .013) and P3 (p = .004) demonstrated significant improvement during the intervention phase. Phase contrasts yielded a non-significant (p = .33) aggregated effect size of 0.10. P5 (*Tau*= 0.40) continued to show positive trend in the post-intervention maintenance phase, while P7 (*Tau*= -0.50), P8 (*Tau*= -0.40) and P9 (*Tau*= -0.40) showed negative trend.

Single subject treatment effects (grammaticality judgment). Pre-intervention baselines for past tense grammaticality judgment probes were stable for all participants. Only one participant (P5) improved significantly in correctly judging grammaticality on trained verbs tested within sessions (p = 0.02). P1 (p = 0.04) and P4 (p = 0.04) improved significantly on trained verbs tested between sessions, and a small (0.26) yet significant (p=.009) effect size across participants was calculated. Only one (P2) participant demonstrated significant trend in correct grammaticality judgement of untrained *-ed* verbs during the intervention phase (p = .02).

For grammaticality judgment 3S extension probes, P8 showed an unstable baseline with negative trend, *Tau*= -0.40. P4 demonstrated significant improvement during intervention (p = .02) and P8 demonstrated significant negative trend (p = .02). P2 (*Tau* = -0.80). Phase contrasts yielded a small, yet significant (p = .03) aggregated effect size of 0.22. P8 (*Tau* = -0.40) demonstrated negative trend in the maintenance phase, while P3 (*Tau* = 0.53) demonstrated positive trend.

For grammaticality judgment *'s* control probes, P4 demonstrated negative trend, while P7 (*Tau* =0.65) and P8 (*Tau* =0.90) demonstrated positive trend during baseline. P2 demonstrated significant positive trend during intervention (p = 0.02). Phase contrasts yielded a non-significant (p = .76) aggregated effect size of 0.03. P4 demonstrated negative trend in the maintenance phase, *Tau* = -0.40.

Within-group concurrent approach. Mean scores and standard deviations for *-ed* production and grammaticality judgment at four timepoints are presented in Table 3.3. A Friedman two-way ANOVA demonstrated that production of untrained *-ed* verbs differed significantly between timepoints, $\chi^2_F = 22.47$, df =3, p <.001. Post-hoc Wilcoxon Signed Rank tests and a Bonferroni adjusted α of 0.0167 (0.05/3 comparisons: Timepoint 1 vs Timepoint 2; Timepoint 2 vs Timepoint 3, and; Timepoint 3 vs Timepoint 4) showed *-ed* production was significantly higher at Timepoint 3 (Mean Rank= 3.78) than at Timepoint 2 (Mean Rank= 1.56), z = -2.67, N-Ties = 9, p = .008. Differences between other Timepoints were non-significant, suggesting a stable pre-intervention baseline, an observable treatment effect between pre- and post-intervention testing points, and maintenance of gains at a group level. Tests for grammaticality judgment were non-significant.

Table 3.3

Mean scores on complete sets of untrained past tense verbs across four time points

	Pre-intervention		Post-intervention	
Measure	Timepoint 1	Timepoint 2	Timepoint 3	Timepoint 4
Expressive (/30)	7.44 (SD= 4)	7.44 (SD= 5.47) †	22.89 (SD= 5.97)*	21.89 (SD= 7.23) ††
Grammaticality judgment (/30)	15.22 (SD= 1.87)	16.22(SD= 1.03) †	19.25 (SD= 4.97)	18.78 (SD= 6.25)

Notes. SD= standard deviation.
†non-sig. difference between pre-intervention baseline timepoints= stable baseline.
*sig. difference between pre- and post-intervention timepoints= observed treatment effect.
††non-sig. difference between post-intervention timepoints= maintained treatment effect

Table 3.4

Pre- and post-intervention standard scores

	SPELT-3		TROG-2	
Participant ID	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
P1	69	76 (2.78)*	74	76 (0.24)
P2	90	111 (9.33)*	97	95 (0.24)
P3	79	102 (6.83)*	86	93 (0.83)
P4	71	105 (13.54)*	81	83 (0.24)
P5	57	90 (13.14)*	81	86 (0.35)
P6	72	78 (0.64)	65	58 (-0.83)
P7	84	100 (6.37)*	62	74 (1.42)
P8	69	88 (7.54)*	79	97 (2.12)*
P9	57	78 (8.33)*	65	67 (0.24)

Notes. Scores are standard scores with a mean of 100 and SD of 15. RCI= reliable change index; SPELT-3= Structured Photographic Expressive Language Test 3rd Edition; TROG-2= Test of Reception of Grammar 2nd Edition.
*statistically significant, i.e. above 1.96.

Analysis of pre-post results. Pre- and post-intervention standard scores on the SPELT-3 and TROG-2 are reported in Table 3.4. Exceeding the RCI of 1.96 indicates statistically significant improvement. All but one participant (P6) exceeded the RCI for the SPELT-3. Further, for the majority of participants, post-intervention standard scores exceeded the manual-reported confidence intervals (90% and 95%) around their pre-intervention standard scores. Note, however, that even though P1's RCI was significant, his post-SPELT-3 standard score of 76 does not exceed the 90% and 95% confidence interval around his pre-SPELT-3 standard score of 69. One participant (P8) exceeded the RCI for the TROG-2 (2.12).

Adverse events

In the case of absence during the intervention phase, participants (P5, P6, P7, P8 and P9) attended a make-up session in the final week of intervention in which within session and between session teaching probes were collected. Due to issues with attention and engagement, procedural changes occurred for P6, who received 30 trials per session, and the systematic cueing hierarchy was limited to elicited imitation.

Discussion

This study evaluated the efficacy of an explicit grammar intervention combining metalinguistic training and grammar facilitation aimed to improve regular past tense (*-ed*) marking for nine children aged 5;10-6;8 years with DLD. Intervention taught *-ed* marking through explicit rule instruction and visual supports using the SHAPE CODING™ system. A systematic cueing hierarchy (Smith-Lock et al., 2015) was used to support participants. This study contributes to the design, development and evaluation of intervention efficacy by moving through levels of evidence and analogous research designs (Robey, 2004).

Treatment effects

Single subject analyses. We hypothesized participants would improve significantly on *-ed* verbs trained and probed within sessions and between sessions. Most participants improved on expressive repeated measures of trained verbs with large effects, indicating this intervention is efficacious for improving production of *-ed* verbs taught in sessions. Further, most participants improved on untrained verbs with medium effects, suggesting generalization. Within-group Friedman non-parametric two-way ANOVA also demonstrated a generalized treatment effect, which was maintained for five weeks. For grammaticality judgment, only three participants improved on trained verbs, one improved significantly on untrained verbs, and another continued to improve five weeks post-intervention. Few gains were observed across participants on an extension measure (3S) and on control measures of *'s* both production and grammaticality judgment. Limited progress on control probes strengthens our ability to attribute improvement on *-ed* production to intervention. Results support the efficacy of intervention to improve *-ed* production on trained and untrained verbs; however, we observed limited gains on grammaticality judgment measures.

Visual inspection of expressive repeated measures reflects results from statistical analysis regarding the immediacy of the functional relation between *-ed* production and intervention. That is, positive trend is observable upon the staggered introduction of intervention across participants. Specifically, trained expressive probes appeared to improve more rapidly, as early as week one of intervention, whereas for untrained verbs gains are observable around the five-week mark across participants. Finally, visual inspection revealed production of *-ed* on untrained verbs remained relatively stable for all children during the post-intervention phase, supporting findings from within-group statistical analysis.

Pre-post comparisons. Pre-post comparisons of standard measures of expressive and receptive grammar across participants mirrored single-subject analyses. Of the nine participants, eight exceeded the RCI for expressive grammar and one child exceeded the RCI for receptive grammar. Overall, pre-post analyses suggest the intervention had a broad effect on expressive grammar captured through standardised grammar measures. However, effects on measures of grammar comprehension were modest compared to expressive grammar.

General discussion

Results from the current study support and build upon findings in the literature. Finestack (2018) demonstrated efficacy of explicit-implicit instruction using novel morphemes, suggesting that the experimental approach may yield quicker gains, and improvement closer to mastery compared to existing implicit-only intervention procedures. Further, Finestack called for an evaluation of treatment effectiveness using true English morphemes across measures of maintenance and generalization to progress the clinical applicability of research findings. Calder et al. (2018) piloted intervention with a small group of early school-age children diagnosed with DLD. Findings suggested intervention implemented over five weeks, twice per week without predefined dosage improved *-ed* production of untrained verbs and standard measures of expressive and receptive grammar. The authors concluded maintaining consistent dosage (i.e., 50 trials) and extending duration (i.e., 10 weeks) may improve production on untrained verbs and discern optimal dose to allow replication for clinical practice.

The current study applied recommended changes to intervention dose and intensity, and predictions were supported. Further, using measures of verbs trained in session and those from previous sessions allowed analysis of within- and between-session gains (e.g. Finestack, 2018). We saw that children showed greater and more rapid improvement on trained verbs probed within and between sessions compared to untrained verbs. However, gains in standard measures of receptive grammar were not observed to the extent reported in Calder et al. (2018). It is likely that reduced improvement on the measure is attributable to the baseline performance of the participants from the current study. That is, the baseline scores of the current group of participants were higher than those reported in Calder et al., which may suggest fewer gains were to be made on such a measure. This finding is consistent with literature suggesting that receptive grammar is less amenable to improvement when compared to expressive grammar (Ebbels, 2014).

From a theoretical perspective, limited improvement on receptive measures may be due to the status of internal representations of language remaining relatively fixed. However, increased production practice may establish new representations, such as those practiced within sessions, which are generalizable to similar targets, such as other verbs marked for *-ed* or 3S. This pattern was observed with two participants (P2 and P4, respectively), so future research is needed explore this claim further. Alternatively, the current standard measures of receptive grammar may fall short of their aim. Recently, Frizelle et al. (2019) found multiple-choice grammar tasks may underestimate children's abilities compared to truth-value tasks. In the current study, probing grammaticality judgment of trained and untrained verbs allowed investigation of improvement of obligatory tense marking as a specific behavior, although improvement was limited across participants. This may provide evidence of the persistent nature of language disorder (e.g. Dale et al., 2018). Alternatively, the task may be implicated by other cognitive factors, such as phonological short-term memory. Regardless, further research is needed to unpack effective methods to treat receptive language difficulties.

Current findings are comparable to recent studies targeting *-ed* marking in children with DLD. For example, in a study using similar procedures to the current study, Smith-Lock et al. (2015) demonstrated explicit rule instruction coupled with a systematic cueing hierarchy was more effective in improving morphosyntax in preschool children with DLD when compared to recasting alone. A key difference to intervention procedures reported in this study is the inclusion of visual metalinguistic training and the *explicit* use of the cueing hierarchy. That is, cues in this study were presented to highlight the targeted behavior was not observed, and so the children were encouraged to reflect on the rule they had just been taught with the support of visuals and to self-correct. Further, the current study implemented over double the cumulative intensity than Smith-Lock et al. (2015), although trials were not specified in that study, so it is challenging to make direct comparisons. Finally, Van Horne et al. (2017) reported positive treatment outcomes following intervention targeting *-ed* production. Importantly, the primarily implicit intervention procedures outlined in Van Horne et al. were effective in improving *-ed* for both studied groups following 36 sessions, which is markedly longer than dose duration reported here and by Smith-Lock et al. (2015), suggesting that explicit interventions may be more time efficient in improving expressive grammar outcomes. Future research is needed to compare the superiority of the two approaches to intervention.

This study further extends on a body of research evaluating the efficacy and effectiveness of explicit interventions using visual support strategies to improve grammatical knowledge for children with language difficulties, specifically, the SHAPE CODING™ system (Ebbels, 2007). Positive results of use of the system have been reported with older children with DLD (Ebbels et al., 2007, 2014; Kulkarni et al., 2013), younger children with DLD (Calder et al., 2018), and children with complex learning needs (Tobin & Ebbels, 2019). It should be noted that positive results were reported by Finestack (2018) where metalinguistic training without visual support was efficacious in improving grammar in young children with DLD. Continued research in this area will discern the extent to which the visual aspect of the SHAPE CODING™ system is responsible for positive treatment effects. We saw that children showed greater and more rapid improvement on verbs trained in session when compared to untrained verbs, suggesting children with DLD may have difficulty generalizing grammar skills, particularly those relying upon sequence learning, such as finiteness marking. Therefore, we are more likely to see immediate improvement in verbs trained via intervention compared to untrained verbs. We also expected there might have been improvement on verbs marked for 3S, however this was not widespread across participants, with P6 improving during intervention, and three (P1, P2, P4) improving post-intervention. This finding suggests that, generally, grammar targets should be taught directly, even if they are linguistically related to existing intervention targets for children with DLD. Further, production practice did not seem to affect grammaticality judgment, however, metalinguistic training may have. That is, regardless of practice trials being held consistent, children for whom 'Silly Sentences' were introduced (P1, P2, P3, P4, P5, P7) appeared to perform better on repeated measures of grammaticality judgment (see S10, S11, S12). Therefore, introducing the sub-activity at the onset of treatment, rather than awaiting the 80% accuracy criterion, may result in improvement of grammaticality judgment.

Other factors to consider when evaluating treatment effectiveness are environmental. For example, the participant with the lowest performance in general (P6) had attended the specialist school for the least amount of time, compared to P2 and P4, the strongest performers who were in their third year at the specialist school. It could be that these children were primed to learn during language-based tasks more so than P6. However, P6 also had the lowest pre-intervention language scores and received fewer trials throughout the intervention phase. Nonetheless, P6 still improved significantly despite these potential barriers. Through SCEDs, evaluating individual treatment responses allows researchers and clinicians to extricate factors related to responsiveness to intervention that may otherwise be lost in group treatment studies (Plante, Tucci, Nicholas, Arizmendi, & Vance, 2018).

Limitations

There are limitations to this study. Firstly, generalizability of results using SCED must be applied with caution. Although the methodology allows for analysis of treatment effects for individuals, the lack of a control group and relatively small sample size inhibits the ability to make causal inferences regarding treatment effectiveness in relation to the general population. Further, within-participant analysis does not control for the influence of external factors, such as classroom instruction, when compared to robust randomized group comparison studies. Nonetheless, SCEDs provide a useful methodology for establishing an early evidence-base for newly developed interventions (Fey & Finestack, 2008). In fact, Horner et al. (2005) suggests results from a minimum of five studies totaling at least 20 participants across three different research teams are necessary to determine intervention efficacy using high quality SCEDs prior to effectiveness being tested using clinical trials. The current study was designed using guidelines developed by Kratochwill et al. (2012) and Tate et al. (2016) to meet minimum standards for SCED to interpret treatment efficacy. Note that an independent rater did not collect repeated measures within the baseline and intervention phases as per Kratochwill et al.'s (2012) recommendation. However, strong inter-rater reliability values addressed potential observer bias. Secondly, the current study used convenience sampling to recruit participants from a specialized school designed to provide intensive language and literacy support to young children with DLD. While non-verbal IQ was not directly measured as part of this study, all participants were enrolled into an educational program for children with DLD in the presence of average non-verbal IQ. Further, socio-economic status of participants was unknown and the majority (8/9) of participants were male. Therefore, the current sample may not be representative of the population of children with DLD at large. Lastly, the current efficacy study was limited to the analysis of *-ed* production and grammaticality judgment, and standard expressive and receptive grammar scores. More naturalistic measures, such as narrative or conversation sampling, may better serve as true measures of generalization in future studies.

Clinical implications

A recent survey of US speech pathologists investigating current clinical practices for grammar intervention found that although a regular component of practice, specific aspects of

Table 3.5

Framework for conceptualising intervention components proposed by Fey and Finestack (2008)

Intervention component	Experimental intervention
Children	5;10-6;8 year old children with DLD
Goals	Regular past tense (*-ed*) production and grammaticality judgment
Service delivery	1:1 with a speech-language pathologist in clinical contexts (within a specialized school)
Dosage	50 trials, 2x sessions per week for 10 weeks: 1000 trials over 20 sessions and ~7-10 hours of intervention
Procedures	Explicit intervention using metalinguistic training with visual support combined with an systematic cueing hierarchy
Activities	Naturalistic games with opportunities to produce *-ed* verbs (e.g. playdough, puppets, board games)
Measurement of outcomes	Standard grammar measures and criterion-referenced measures of *-ed* production and grammaticality judgment

grammatical interventions are not well understood (Finestack & Satterlund, 2018). Further, *-ed* marking is often targeted as a treatment goal, and explicit presentation is often used in intervention procedures. However relatively little research has been reported using explicit intervention for teaching *-ed* to early school-aged children. Fey and Finestack (2008) proposed a framework for conceptualizing intervention components. The current intervention is summarized in Table 3.5. This framework may serve as a point of reference for clinicians planning to implement intervention to improve production of *-ed* for early school-aged children with DLD. Clear intervention procedures and maintaining consistent dose throughout the intervention phase also allows clinicians to replicate findings. It appears generally that this intervention is less efficacious for improving grammaticality judgment of *-ed*, with only a small intervention effect (0.26) observed. However, a similar effect (0.22) was observed for grammaticality judgment of 3S, but not for the production or grammaticality judgment of *'s*. Since 3S was not targeted directly but is linguistically related, perhaps improvement for some children was due to the phonological saliency of /z, s/ compared to *-ed* /d, t/ providing a learning advantage to the morpheme when combined with metalinguistic training.

Conclusions

Results continue to support the efficacy of explicit grammar interventions to improve *-ed* marking in early school-aged children. Future research should continue to evaluate the efficacy of similar interventions, for example, using more clinically relevant dosage (e.g. 1x session per week). It is also important to determine whether explicit grammar interventions can improve other aspects of grammatical difficulty for younger children with DLD, such as copula/auxiliary use, or *wh-* questions. Overall, findings contribute to the understanding of efficacious intervention procedures for early school-age children with DLD suggesting children are able to apply knowledge acquired through explicit instruction.

Chapter 4

The Efficacy of an Explicit Intervention Approach to Improve Past Tense Marking for Early School-Aged Children with Developmental Language Disorder

Chapter overview

This chapter presents the accepted manuscript of a published Phase III intervention study evaluating the efficacy of TheMEDI to improve grammar in early school-aged children with DLD. Following the Phase II study using single case experimental design (Chapter 3, Study 1: Calder et al., 2020), it was found that intervention provided twice weekly was efficacious for improving past tense production and possibly expressive grammar more broadly as measured by a standardised assessment. Recent findings from a survey of speech-language pathologists indicated that most grammar intervention is provided once weekly. Therefore, it was of interest to not only to evaluate the efficacy of TheMEDI with a stronger research design (i.e., a randomised controlled trial), but also to evaluate efficacy when delivered using a more clinically applicable dose frequency of once per week.

The current study (Study 2) used a randomised controlled trial aimed at evaluating the efficacy of TheMEDI compared to a 'treatment-as-usual' waiting control group, to further investigate the efficacy of the intervention for clinical practice. Findings from this study were accepted as a poster presentation at the International Association for the Study of Child Language Conference, Philadelphia, Pennsylvania, July 13th – 17th. However, the conference was postponed until 2021 due to the COVID-19 international pandemic which restricted international travel. This chapter presents the Accepted Manuscript[4] version of the article entitled, *The efficacy of an explicit intervention approach to improve past tense marking for early school-aged children with Developmental Language Disorder* published by American

[4] Copyright permission letters of approval are provided in Appendix A

Speech and Hearing Association Journals in the Journal of Speech, Language, and Hearing Research on 14/01/2021, available online at https://doi.org/10.1044/2020_JSLHR-20-00132. Given this is an Accepted Manuscript, there is some inevitable repetition from previous and subsequent Chapters. The journal conventions required US English spelling, so the Chapter is formatted as such.

Abstract

Purpose: To evaluate the efficacy of a theoretically motivated explicit intervention approach to improve regular past tense marking for early school-aged children with developmental language disorder (DLD).

Method: Twenty one children with DLD (ages 5;9 – 6;9 years) were included in a crossover randomized controlled trial (intervention, $n = 10$; waiting control, $n = 11$). Intervention included once weekly sessions over 10 weeks using the SHAPE CODING^{TM} system in combination with a systematic cueing hierarchy to teach past tense marking. Once the first group completed intervention, the waiting control group crossed over to the intervention condition. The primary outcome was criterion-referenced measures of past tense marking with standardized measures of expressive and receptive grammar as the secondary outcome. Ancillary analyses on extension and behavioural control measures of morphosyntax were also conducted.

Results: There was a significant Time x Group interaction ($p < .001$) with a significant difference in pre-post intervention improvement in favour of the intervention group ($p < .001$, $d = 3.03$). Further analysis once both groups had received the intervention revealed no improvement for either group on past tense production during the five-week pre-intervention period, significant improvement pre-post intervention ($p < .001$, $d = 1.22$), with gains maintained for five weeks post-intervention. No significant differences were found on pre- to post-intervention standardized measures of grammar, or on extension or control measures.

Conclusion: The efficacy of the theoretically motivated explicit grammar intervention was demonstrated. Results contribute to the evidence-base supporting this intervention to improve past tense production in early school-aged children with DLD, suggesting it is a viable option for clinicians to select when treating morphosyntactic difficulties for this population.

Compared with typically developing peers, children with developmental language disorder (DLD) are reported to have a slower pace of language development, and difficulty producing and understanding language in the absence of other biomedical factors (Bishop et al., 2017). This includes particular difficulties with a range of morphosyntactic skills, such as the use and understanding of tense related morphosyntax (Conti-Ramsden et al., 2001; Rice et al., 1999). DLD can have a significant impact on academic (Windsor et al., 2000) and social development (Clegg et al., 2005), and a range of difficulties often persists well into adolescence and adulthood (Law et al., 2009), ultimately affecting employment opportunities (Conti-Ramsden et al., 2018). The precise etiology and contributors to DLD remain unknown. However, exploration of the recommendations derived from theoretical accounts of DLD may inform the development of effective interventions for this at-risk population.

Theory Informing Practice: The Procedural Deficit Hypothesis

The Procedural Deficit Hypothesis (PDH) is based on the assumption of a domain-general deficit in implicit learning for children with DLD in the presence of spared explicit learning (Ullman & Pierpont, 2005). The hypothesis acknowledges the distinction between long term procedural and declarative memory systems. That is, through the procedural memory system, information is learned as a result of repeated exposures to the stimulus. The system underlies the implicit (i.e., non-conscious) learning of skills and habits. Learning through procedural memory is demonstrated through task performance of, for example, early motor development, such as infants learning to walk. In contrast, the declarative memory system is responsible for learning arbitrary items of information and deriving associations between them, underlying explicit (i.e., conscious) retrieval and use of facts and events. Recall or recognition demonstrates the learning of information through explicit memory, for example, events from a birthday party. Information is learned rapidly; however, repeated exposures strengthen memories (Ullman, 2016).

Linguistically, the PDH predicts children with DLD will have impaired morphosyntax learning as this relies on the procedural memory system; whereas vocabulary learning remains relatively intact as it is dependent on the spared declarative memory system (Ullman & Pierpoint, 2005). Certainly, recent evidence points to an implicit learning deficit in children with DLD (Lum et al., 2014) in the presence of relatively spared declarative memory (Lum et al., 2015), particularly in the visual domain (Lum et al., 2012). As such, the way in which linguistic information is presented may assist with language learning. Specifically, explicit instruction delivered with spaced and repeated practice, augmented with visual support, is predicted to improve the learning, storage and use of grammar. Given the competitive nature of the systems, if children with DLD have impaired procedural memory, the PDH suggests using cognitive strategies harnessing spared declarative memory (e.g., explicit intervention) would be more effective than expecting children to learn morphosyntax implicitly.

Recently, Balthazar et al. (2020) summarised the evidence for explicit interventions designed on the principles and perspectives aligned with the PDH to improve grammar for children with DLD. A key component of explicit interventions is metalinguistic training, which refers to the "…verbal description, explanation, and feedback focused on form, the functions of form, and the manipulations of forms" (Balthazar et al., p. 227). The aim of metalinguistic training is to make information conscious and available to recall upon demand. The review included three key approaches to explicit instruction, including Complex Sentence Intervention (Balthazar & Scott, 2018), the SHAPE CODING™ system (Ebbels, 2007), and MetaTaal (Zwitserlood et al., 2015). Of particular interest to the current study is the SHAPE CODING™ system.

The SHAPE CODING™ system provides a systematic way of representing syntax, morphology, and aspects of semantics. The system uses specific visual cues, including colours, shapes and arrows, where: colour coding is used for parts of speech (e.g., nouns, verbs, adjectives); shapes are used to code phrases in accordance with position and role within sentences, and; arrows are used to depict tense. It aligns with an *explicit* intervention approach, and uses metalinguistic training techniques teach the rules of morphosyntax. The system may improve the learning of spoken morphosyntax in the presence of a potential procedural memory deficit by exploiting the functional characteristics of declarative memory. That is, harnessing explicit learning in rich semantic contexts. Further, as an environmental modification, the primarily visual aspect of the system may reduce demands on learning through procedural memory by presenting linguistic information that is less transitory than the spoken modality. The system also allows the presentation of complex sequential information, such as morphosyntax, to be segmented and presented frequently to enhance learning. As such, the SHAPE CODING™ system aligns with recommendations from the PDH in many ways.

Recently, Plante and Gómez (2018) suggested explicit teaching should not be recommended as a therapeutic device, stating, "[b]y intentionally avoiding explicit teaching in favour of implicit learning, clinicians can harness the cognitive resources that support rapid learning" (p. 71). Clearly, this is at odds with the PDH, which suggests explicit teaching is necessary given implicit learning deficits. Rather, Plante and Gómez recommend principles to enhance linguistic input, which are inherently implicit.

The Effectiveness of Interventions Targeting Morphosyntax

Interventions aiming to improve morphosyntax can be considered implicit or explicit (Ebbels, 2014). Implicit interventions are those that aim to enhance the quality and quantity of language input to accelerate language growth without necessarily making the learner consciously aware of the goals of intervention. In contrast, explicit interventions aim to increase the learner's awareness of the goal of intervention, and information learned can be recalled upon demand. The latter aligns with the PDH. Most research has investigated interventions that promote implicit learning, and therefore may be considered best practice; however, there is also an expanding evidence-base supporting the efficacy of explicit interventions (Balthazar et al., 2020), specifically for spoken morphosyntax and usually with older school-aged children and adolescents.

Implicit Interventions

A systematic review and meta-analysis of recasting as an implicit intervention approach has established its effectiveness, with large effect sizes (average $d = 0.96$) on proximal measures of morphosyntax (Cleave et al., 2015). Recently, Eidsvåg et al. (2019) explored whether enhanced recasting was efficacious for improving morphological targets for 20 children aged between 4;8 and 6;7 years with DLD. Children received either individual or paired delivery, once a day, for five days over five weeks. Intervention targets included regular past tense and third person singular. They found significant mean improvement on target morphemes for both delivery conditions with a large effect ($d = 1.16$), but no transference to ambient morphemes. In a randomized controlled trial (RCT) of 18 children aged 4- to 10 years, Owen Van Horne et al. (2017) evaluated a primarily implicit intervention targeting regular past tense production provided for up to 36 intervention sessions. Children in the 'harder' past tense verb condition (i.e., phonologically complex, infrequently marked for inflection and atelic) made greater gains on untrained verbs with a large effect ($g = 1.76$) compared to those in the 'easy' condition (i.e., phonologically simple, frequently marked for inflection and telic). Findings indicated there is an advantage to learning past tense verbs that are more complex.

Explicit Interventions

Ebbels et al. (2007) conducted a randomized controlled trial (RCT) comparing two theoretically motivated interventions (the SHAPE CODING™ system and a semantic intervention) and a no treatment control group with 27 children aged between 10;0 and 16;1

with DLD. Both intervention conditions improved significantly in their use of verb-argument structure with large effects (*d* > 1.0) compared to the control group, with effects generalizing to untrained verbs, suggesting benefit to exploring theoretically grounded interventions. Further, Ebbels et al. (2014) conducted an RCT with 14 children aged between 11;3 and 16;1 comparing progress in comprehension of coordinating conjunctions for children and adolescents with severe receptive language deficits receiving intervention using the SHAPE CODING™ system to a waiting control group. The intervention group showed significant improvement with a large effect (*d* = 1.6), which was maintained for four months. These results suggest benefit in the ongoing evaluation of the SHAPE CODING™ system to target other morphosyntactic deficits, and potentially with younger children.

In a study with two younger children (aged 8;11 and 9;4) with language disorder, Kulkarni et al. (2014) conducted a clinical evaluation of the SHAPE CODING™ system combined with elicited production and recasting to improve the use of regular past tense. Both made statistically significant gains in their use of the target structure after 10 intervention sessions, indicating that further evaluation of the SHAPE CODING™ system to improve past tense marking was warranted.

In an RCT of 31 preschool children with a mean age of five years, Smith-Lock et al. (2015) evaluated the effectiveness two intervention approaches to improve morphosyntax (i.e., regular past tense, third person singular, and possessive *'s*) for children with DLD. One condition combined explicit rule instruction with systematic cueing, and the other condition was recasting alone. In the explicit rule instruction and systematic cueing condition, a cueing hierarchy was used to cue children to correct errors contingent upon their response. If an error occurred when producing a target (e.g., *pull**ed***), the child was first cued with a request for clarification (e.g., *Try that one again.*). Persistent errors were cued until a correct production was achieved, first with emphatic recasting (e.g., *You pull**ed** the cart.*), then forced choice (e.g., *You just pull the cart or you just pull**ed** the cart?*), and finally, elicited imitation (e.g., *You just pull**ed** the cart. Say it like me: pull**ed**.*). It was hypothesized that if an error occurred after being explicitly taught the grammar rule, the cueing hierarchy would provide an opportunity to produce the morphosyntactic target correctly, and therefore would be more effective than using recasts which do not require the child to produce the target. Following eight weeks of intervention, there was a significant medium – large effect ($d = 0.75$) in production for the combined explicit rule instruction and cueing group, but not for the recasting alone group.

In a pilot efficacy study, Calder et al. (2018) combined the SHAPE CODING™ system with a systematic cueing hierarchy (Smith-Lock et al., 2015) for three children aged seven years with DLD. Using a single case experimental design (SCED) the children were seen one-on-one, twice a week for five weeks in 45 minute sessions, resulting in seven and a half hours of intervention. Dose was not held constant, but the children received an average of 49 trials per session. The focus of the intervention for all three children was regular past tense (*–ed*) production. Of the three children, two made significant improvement on *–ed* production. One child demonstrated a decline in performance on *–ed* production during the five week maintenance period, while the other continued to improve significantly. All three made significant improvement on the Test of Early Grammatical Impairment (Rice & Wexler, 2001), and two of the three children made significant improvement on the Test for Reception of Grammar 2nd Edition (TROG-2) (Bishop, 2003). No child showed improvement on the third person singular (*3S*) extension measure or the possessive *'s* control measure, further increasing confidence that improvements in *–ed* production were due to intervention. This provided early evidence supporting the use of explicit intervention approaches to improve receptive and expressive grammar, particularly production of *–ed* following five weeks of intervention. However, it was acknowledged that a longer period of intervention may be necessary to increase the magnitude of intervention effects. Finally, other measures of grammatical knowledge (e.g., grammaticality judgment) would increase confidence in reporting improvement of *–ed* marking.

Efficacy of the intervention was further evaluated using a study of $n = 9$ through a SCED (Calder et al., 2020). Intervention was provided twice weekly for 10 weeks with 50 trials resulting in 1000 trials for each participant. Repeated measures were probed, including trained and untrained *–ed* verbs, an extension probe (*3S*), and a control probe (*'s*). All probes included expressive and grammaticality judgment contexts. Pre-post measures of standardized expressive grammar and receptive grammar measures were also analyzed. Of the nine children, eight made significant improvement on production of trained verbs with large effects (*Tau* = 0.88), and seven made significant improvement on production of untrained verbs with moderate effects (*Tau* = 0.64). A within-group concurrent analysis was also conducted on production of trained verbs indicating significant progress pre- to post-intervention ($p = .008$). Results suggested a stable pre-intervention phase, significant pre-post-intervention improvement, and maintenance of gains at a group level. For the grammaticality judgment probes, three participants improved significantly on trained verbs with small effects (*Tau* = 0.26), and only one improved on untrained verbs. There was limited to no improvement on extension and control probes for either expressive or grammaticality judgment contexts. For the standardized measures, eight participants exceeded the reliable change index (RCI: > 1.96) indicating significant improvement on the Structured Photographic Expressive Language Test 3rd Edition (Dawson et al., 2003), and one exceeded the RCI on the TROG-2. Results from the study demonstrated that the intervention was efficacious for improving *–ed* marking of trained and untrained verbs, and expressive grammar generally if provided twice a week for 10 weeks. Given the positive results yielded from SCEDs, evaluation of the intervention through an RCT was warranted.

The Current Study

The aim of the current study was to examine the efficacy of an explicit intervention motivated by the PDH to improve *–ed* marking, and a possible generalized effect to standardized grammar scores. The intervention involved a combination of the SHAPE CODING^{TM} system (Ebbels, 2007) as the metalinguistic training and a systematic cueing hierarchy (Smith-Lock et al. 2015). If explicit intervention is efficacious in improving morphosyntax for young children with DLD, this may inform the theoretical motivation for developing intervention procedures well suited to facilitate learning for these children. The research questions were as follows:

1. Do early school-aged children (5;9-6;9 years) with DLD show greater improvement in past tense (*–ed*) marking following 10 weeks of explicit intervention compared to a 'treatment-as-usual' waiting control group?

   It was hypothesised that the intervention group would show significantly greater progress on measures of -ed marking following intervention compared to the control group.

2. Do these children also show greater improvement on standardized expressive and receptive grammar measures following intervention for *–ed* compared to the waiting control group?

   It was hypothesized that the intervention group would show significantly greater progress on generalized measures of grammar compared to the control group.

3. Will results from ancillary analyses determine whether children also improve on a linguistically related grammatical target (third person singular: *3S*), but not on a behavioral control measure (possessive *'s*).

   It was hypothesized that the intervention group may show greater improvement on measures of 3S*, but there would be no between group differences on measures of 's.*

Method

Efficacy of the intervention was tested using a crossover randomized controlled trial (RCT) study design. Pre-post results on measures of past tense (*–ed*) were the primary variables of interest, pre-post results on standardized measures of grammar were the secondary variables of interest, and measures of third person singular (*3S*) and possessive *'s* were part of ancillary analyses. All reporting follows the Consolidated Standards of Reporting Trials (CONSORT) statement (Schulz et al., 2010) (see Supplemental Materials for CONSORT checklist (S1; Appendix F.1) and flow diagram (S2; Appendix F.2)). Ethical approval for the study was obtained from the Curtin University Human Research Ethics Committee (Approval number HRE2017-0835) and the Western Australian Department of Education (Approval number D190018955).

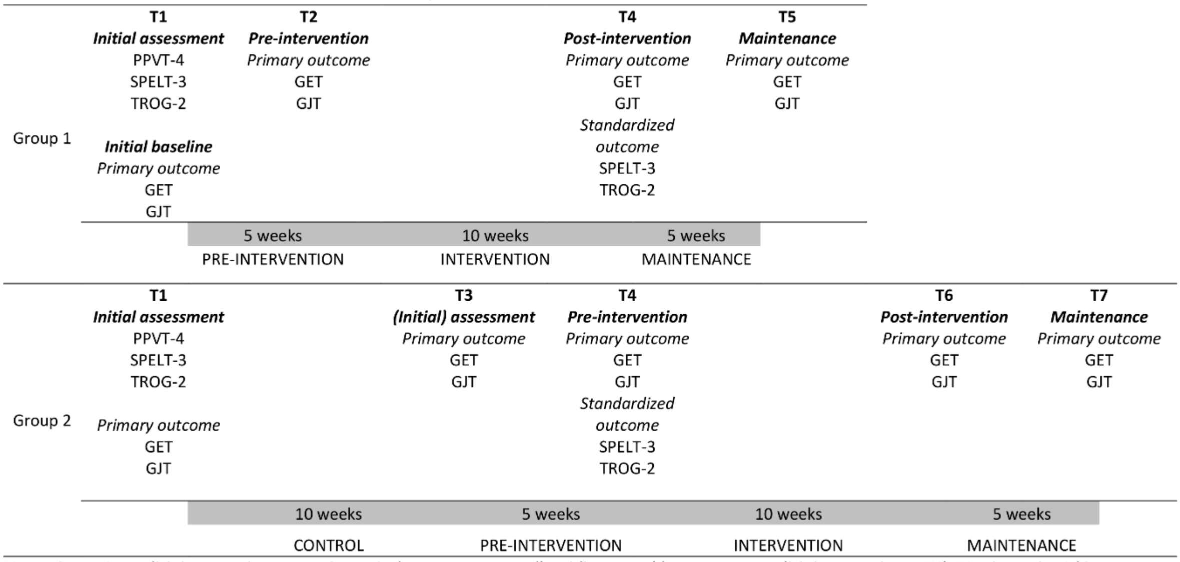
Participants

Participants were recruited from specialized educational programs for students diagnosed with DLD across three sites. The principal consented school participation, and then provided information letters and consent forms to the parents/carers of potential participants identified by speech-language pathologist (SLP) and teachers employed at the educational program. Parents then returned forms consenting to their child's participation. Participant inclusion criteria included children aged between 5;6 and 7;6; English as a primary language, and; grammar difficulties associated with DLD. Exclusionary criteria were based on factors outlined in Bishop et al. (2016) for determining a diagnosis of DLD, including a neurological and/or cognitive impairment. Accessing the participants' school enrolment packages confirmed they met criteria for DLD[5].

[5] There have been recent changes relating to the terminology and classification of DLD, and the use of non-verbal IQ criteria for diagnosis (see Bishop et al., 2016, pp.5-6). At the time of this study, entry requirements to specialized educational programs in Western Australia included non-verbal IQ in the average range.

Figure 4.1

Summary of the assessment and intervention schedule for Group 1 and Group 2



Notes. Group 1= explicit intervention group; Group 2= 'treatment-as-usual' waitlist control (crossover to explicit intervention at T4); T1= timepoint 1 (Group 1 initial assessment; Group 2 initial assessment); T2= timepoint 2 (Group 1 pre-intervention); T3= timepoint 3 (Group 2 (initial) assessment); T4= timepoint 4 (Group 1 post-intervention; Group 2 pre-intervention); T5= timepoint 5 (Group 1 maintenance); T6= timepoint 6 (Group 2 post-intervention); T7= timepoint 7 (Group 2 maintenance); GET= Grammar Elicitation Test, including –ed, 3S and 's probes; GJT = Grammaticality Judgment Test, including –ed, 3S and 's probes; SPELT-3= Structured Photographic Language Test 3rd Edition (Dawson, Stout, & Eyer, 2003); TROG-2= Test of Reception of Grammar 2nd Edition (Bishop, 2003); PPVT-4= Peabody Picture Vocabulary Test, Fourth Edition (Dunn & Dunn, 2007).

See Figure 4.1 for a full breakdown of the assessment and intervention schedule. Participants were screened in hearing acuity and passed at 20 dB for each ear at 500, 1000, 2000, and 4000 Hz. All participants passed the Phonological Probe from the Test of Early Grammatical Impairment (Rice & Wexler, 2001) which confirmed that they were able to articulate phonemes necessary for morphosyntax production targets. Participants were assessed for production of morphosyntax using criterion-referenced measures adapted from the Grammar Elicitation Test (GET) (Smith-Lock et al., 2013). This experimental test was designed to elicit multiple instances of specific morphosyntax structures, with subtests for regular past tense (GET-*ed*), third person singular (GET-*3S*), and possessive *'s* (GET-*'s*). Each subtest contains 30 probes each divided into three allomorph groups (i.e., 10x [d], 10x [t] and 10x [əd] for *–ed*; 10x [z], 10x [s], 10x [əz] for *3S* and possessive *'s*). Verbal elicitation for each probe (e.g., *This boy likes to hop. He did it yesterday. What did he do yesterday?*) was pre-recorded to ensure each child received consistent assessment procedures.

Measures of morphosyntax were also developed for a grammaticality judgment task mirroring the above morphosyntactic structures, hereafter referred to as the Grammaticality Judgment Test (GJT: GJT-*ed*, GJT-*3S*, GJT-*'s*). As with the GET, all possible allomorphs were included and distributed equally within each category of probe. Videos of actions depicted the declarative clauses containing *–ed* and *3S*. For possessive *'s*, copyright free still images depicting nouns and ownership were retrieved. As with the GET, accompanying audio for each task item, both grammatical and ungrammatical (e.g., *The boy hopped on one foot* vs *The boy hop* on one foot*), was pre-recorded for administration.

All subtests for both the GET and GJT were embedded into a Microsoft PowerPoint presentation and delivered via laptop. For the GJT, participants wore noise-cancelling headphones during administration and were required to decide if the sentence 'sounded right' by pressing 'yes' or 'no' on a tablet app. Items were counterbalanced for grammaticality so participants neither received the same combination of grammatical/ungrammatical items, nor was there a pattern in presentation of items to counteract a priming effect. For all relevant analyses, scores from the GJT were adjusted to account for 'yes bias' by computing A*'* as $A' = 0.5 + (y - x)(1 + y - x)/ 4y(1 - x)$, where y = proportion of hits (i.e., the child selected 'yes' for a grammatical item) and x = proportion of false alarms (i.e., the child selected 'yes' for an ungrammatical item) (Rice et al., 1999). Tables report percentage accuracy on the GJT for consistency with the GET.

Initial assessment measures also included the Structured Photographic Expressive Language Test 3rd Edition (SPELT-3) (Dawson et al., 2003). The test measures a range of expressive morphosyntax structures over 54 items. It has strong internal consistency reliability ($r = .86$) and appropriate construct validity. The Test of Reception for Grammar 2nd

Edition (TROG-2) was used to assess receptive grammar. Test blocks measure a total of 20 different grammatical structures. It has strong internal consistency reliability (r = .86) and appropriate construct validity. The Peabody Picture Vocabulary Test, 4th Edition (PPVT-4) (Dunn & Dunn, 2007) was administered as a yardstick for static vocabulary abilities. The test has strong internal consistency reliability (r = .94) and appropriate construct validity.

Following distribution of consent forms to the specialized education programs for children with DLD, parents of 23 children aged between 5;9 and 6;9 years provided consent to participate, and the children were assigned a code and assessed for eligibility. These codes were entered into a true random list generator by a researcher blinded to the purpose of the study to ensure concealed allocation sequence. Once the list was randomized from 1-23, the researcher assigned participants to either the intervention group (Group 1) (every odd occurrence on the list) or to the 'treatment-as-usual' waiting control group (Group 2) (every even occurrence on the list). Further to blind random assignment, assessors were blind to group assignment at all testing timepoints. Participants, their caregivers, and teachers were not made aware of the conditions. The purpose of the intervention beyond targeting morphosyntax was not disclosed to caregivers or teachers.

Of the 23 children, two males were excluded from the study because they reached ceiling on initial assessment using the GET and GJT, and were deemed unlikely to benefit from further participation. This resulted in the remaining 21 participants comprising the explicit intervention group (Group 1) (n = 10) or the 'treatment-as-usual' waiting control group (Group 2) (n =11). Group 1 comprised eight males (80%) and two females (20%) with a mean age of 6;3 years (SD = 0;4 years; range: 5;11-6;8 years) at initial assessment. Group 2 comprised seven males (63.6%) and four females (36.9%) with a mean age of 6;6 years (SD = 0;3 years; range: 5;9-6;9 years) at initial assessment.

Table 4.1

Mean and standard deviation values for demographic and initial assessment information for study participants.

	Age at initial assessment	Age at onset of treatment	Sex	GET%	GJT%	SPELT-3 (SS)	TROG-2 (SS)	PPVT-4 (SS)
Group 1	6;3 (0;4)	6;4 (0;2)	M 80%/F 20%	32.0 (23.3)	55.3 (14.9)	76.4 (18.2)	77.5 (14.5)	93.2 (14.9)
Group 2	6;6 (0;3)	7;3 (0;3)	M 64%/F 36%	23.1 (21.6)	53.9 (12.1)	69.2 (18.7)	76.7 (9.3)	90.7 (8.8)

Notes. All scores from standardized assessments are standard scores; Group 1 = explicit intervention group; Group 2 = 'treatment-as-usual' waiting control (crossover to explicit intervention at T4); GET = Grammar Elicitation Test; GJT= Grammaticality Judgment Test; PPVT-4= Peabody Picture Vocabulary Test, Fourth Edition (Dunn & Dunn, 2007); SPELT-3= Structured Photographic Language Test 3rd Edition (Dawson et al., 2003); TROG-2= Test of Reception of Grammar 2nd Edition (Bishop, 2003); M= male; F= female. SS = Scaled Score. Percentage accuracy for the GJT is presented rather than *A'* to maintain consistency with the GET.

See Table 4.1 for a summary of initial assessment data including standardized scores from assessments. Potential between group differences on age, sex, grammar scores and the PPVT-4 at initial assessment were evaluated using a one-way between group analysis of variance (ANOVA). Assumptions of normality were violated for Group 1 for age (Shapiro-Wilk statistic: $p = .04$), sex (Shapiro-Wilk statistic: $p < .001$) and the TROG-2 (kurtosis: > 1.96). Assumptions were violated using *A'* on the GJT for both groups (kurtosis: >1.96; Shapiro-Wilk statistic: $p < .001$). Therefore, differences on these variables were analysed with non-parametric Mann Whitney *U* tests. Analyses revealed no group differences on any demographic variables or the GJT *A'* (all *p*'s > .42, two-tailed). *F* tests for the SPELT-3, GET, and PPVT-4 were also non-significant (all *p*'s >.32). Therefore, there were no group differences following allocation to groups, and both groups had mean scores within normal limits on the PPVT-4 using a one *SD* cut-off.

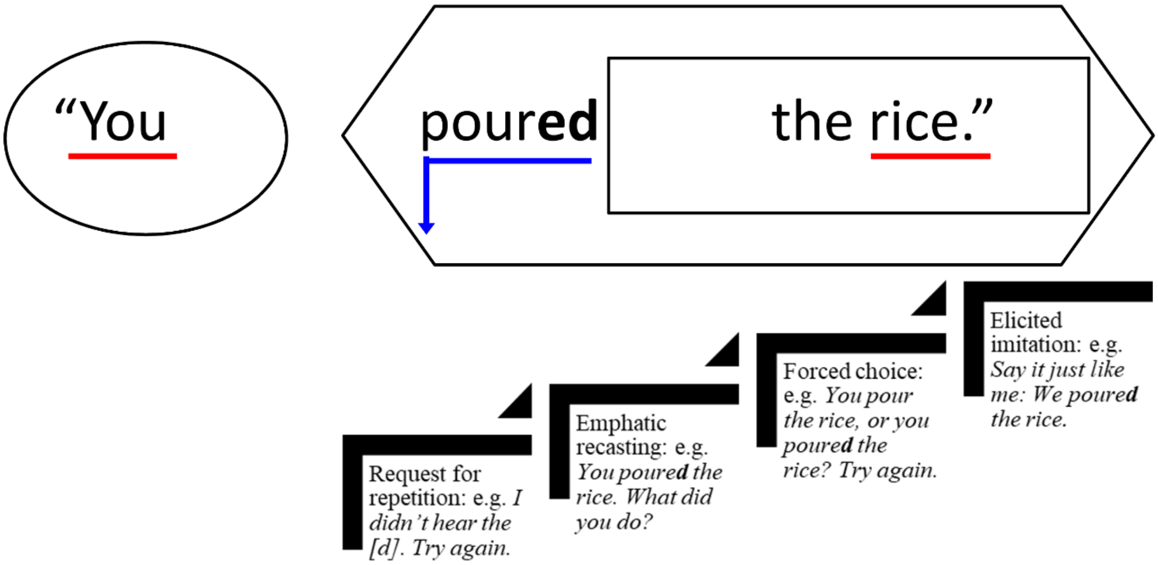
Intervention

The goal of intervention was to improve *–ed* marking. All intervention sessions were videotaped and carried out in a quiet space at the site of the educational programs. Using the framework for explaining intervention suggested by Warren et al. (2007), the dose was 50 trials within 20-30 minute sessions; dose form was explicit intervention combining metalinguistic training using the SHAPE CODING™ system (Ebbels, 2007) with a systematic cueing hierarchy (Smith-Lock et al., 2015); dose frequency was once a week; total intervention duration was 10 weeks, and; cumulative intervention intensity was (50 trials x 1 time per week x 10 weeks), resulting in a total of 500 trials over 10 individual therapy sessions through roughly 3.5-5 hours of intervention. This is half the cumulative frequency reported in Calder et al. (2020), allowing evaluation of the intervention in a more clinically relevant dose frequency (e.g., Finestack & Satterlund, 2018). Training of *–ed* was contextualized within engaging and naturalistic activities suited to early school-aged children, including playdough, board games, puppets, and farm and sea creature manipulatives. Target morphemes were presented in syntactic structures as they occurred felicitously within these activities. The first author, a trained SLP, delivered all intervention.

See Figure 4.2 for a visual representation of the SHAPE CODING ™ system and systematic cueing hierarchy. Procedures included reminding children of the goal of intervention (i.e., *–ed* marking) through explicit teaching at the beginning of the session. The SLP checked vocabulary knowledge of the participants by asking them to label materials from the session. Three Subject + Verb/ +Object (SV/O) sentences were demonstrated using one exemplar from each of the possible allomorphic categories (i.e., [d], [t] and [əd]). The shapes and arrows from the SHAPE CODING™ system were introduced. The shapes included the oval (subject noun phrase WHO/WHAT?), the hexagon (verb phrase WHAT DOING?), and the rectangle (object noun phrase WHO/WHAT?). The arrows included blue 'left down arrows' to depict orthographic representations for each of the possible *–ed* allomorphs (i.e., [d] = 'd', [t] = 't', and [əd] = 'ed'). Production of *–ed* was targeted through 25 trials in total where the child had the opportunity to respond to an interrogative following priming (e.g., *You pour the rice. What DID you DO?*), while the shapes and arrows were gestured to. Children were cued using the systematic hierarchy in the case of errors in production (e.g., unmarked bare stem *pour* or overgeneralised form *pourded*). A consolidation component included reviewing three exemplars from each allomorphic category, followed by a comprehension task where participants answered *wh-* questions related to the SV/O structures while the SLP gestured to the shapes and arrows (e.g., *WHO poured the rice*; *What DID you DO?; WHAT did you pour?*)*,* and finally the child produced sentences without the visual support of shapes and arrows. 'Silly Sentences' were used whereby three sentences were spoken by the SLP, either grammatically or ungrammatically (i.e., *–ed* morphemes were either included or omitted in the clause), and the child would decide if the sentence 'sounded

Figure 4.2

Visual cues and systematic cueing hierarchy used during intervention



right'. These procedures were repeated for a second activity until 50 trials in total were achieved. The sessions were concluded by providing a summary of the goals of intervention (i.e., to produce –*ed*). A full session plan fidelity checklist with timing breakdown (S3; Table 2.3), a summary of intervention targets and materials (S4; Table 2.2), and adherence to the template for intervention and description and replication checklist (Hoffman et al. 2014) (S5; Table 2.1) are available in the Supplemental Materials.

Intervention for the 'treatment-as-usual' waiting control involved regular attendance at a specialized educational program, which included intensified oral language instruction with a modified curriculum designed to cater to the academic needs of children with DLD. Typically, oral language instruction was embedded within narrative blocks to enhance exposure to language through strategies similar to those reported in Gillam et al. (2012) and Spencer et al. (2014). Therefore, although grammar instruction was part of the modified curriculum, it was not the primary focus of instruction for the duration of the current study.

Intervention Fidelity

The first author and a researcher blinded to the purpose of the study rated 20% of videotaped sessions on percentage accuracy for intervention procedures (see S3 for a scoring checklist). Between-observer agreement was calculated using intraclass correlation coefficients (ICC) with absolute agreement and single measures in a two-way mixed effects model. The average score across raters was 99.58% for percentage accuracy, and ICC for procedures was .995 indicating excellent agreement (Cicchetti, 1994).

Inter-Rater Reliability for Test Scoring

In addition to the first author scoring all data, a researcher blinded to the purpose of the study scored 20% of experimental measures. For the GET (including *–ed*, *3S* and *'s*), the ICC was .956. For the GJT (including *–ed*, *3S* and *'s*), the ICC was .997. Therefore, excellent between-observer agreement was demonstrated across all experimental measures.

Results

All outcomes were planned to be assessed using intention-to-treat analyses. In the case of participant loss to follow up, last-observation-carried-forward was implemented. Study compliance is reported in detail. Data from all 10 children in the intervention group were analysed for outcomes and estimations. For the waiting controls, data from all 11 children were analysed for between group analyses of an intervention effect on grammar scores, i.e., intervention (Group 1) versus 'treatment-as-usual' waiting control (Group 2). However, one participant was exited from the study following crossover into the intervention condition due to reaching ceiling on pre-intervention measures and was deemed unlikely to benefit further from participation. Therefore, this participant was excluded from further analyses. One additional child in Group 2 was unavailable for testing at the final testing point due to being absent from the specialized educational program because of illness and was unavailable for follow up. The results from this child's final data point during the maintenance phase were included in the analysis using last-observation-carried-forward. All other children participated in all intervention sessions and assessment timepoints.

Outcomes and Estimation

All means and standard deviations on outcome, extension, and control measures are reported in Table 4.2. For all between group comparisons, mixed ANOVAs were planned, with Time as the within-participant variable, and Group as the between-participant variable. All necessary post hoc pairwise comparisons included Bonferroni adjustments for α values. Following post hoc tests, effect sizes were calculated for between group comparisons on pre-post intervention improvement using Cohen's *d* to interpret small (0.2), medium (0.5) and large (0.8) effects. In the case of violated assumptions, non-parametric Kruskal-Wallis one-way ANOVAs were conducted, and scores from pre- to post-intervention were transformed by subtracting T1 from T4 to account for time as a factor when testing between group improvement. Cohen's *f* were calculated for effect sizes. All statistics were computed using IBM SPSS Version 25.

Research Question 1: Does Past Tense Marking Improve Following Intervention Compared to 'Treatment-As-Usual'?

Refer to Figure 4.1 for the full testing schedule. The GET-*ed* and GJT-*ed* were administered as primary outcome measures of past tense production and grammaticality judgment, respectively. As verbs from the GET -*ed* and GJT -*ed* were not trained as part of intervention, improvement would unlikely be attributed to practice effects alone. Items were randomized for administration at the initial assessment (T1), one week prior to intervention commencing for Group 1 (T2), one week following intervention for Group 1 (T4) and five weeks following cessation of Group 1's intervention (T5). This differed for the 'treatment-as-usual' waiting control group (Group 2), where there was an initial assessment (T1), beginning

Table 4.2

Means and standard deviations for all primary and standardized outcomes, and extension and control measures

Group 1		Pre-intervention		Post-intervention		
Outcomes		T1	T2	T4	T5	
Primary	GET-*ed* (%)	27.3 (16.1)	25.3 (21.7)	66 (14.5)* †	54.3 (22.16)	
	GJT-*ed* (%)	52.7 (13.4)	57 (9.1)	58.7 (14.5)	56.3 (16.2)	
Standardized	SPELT-3 (SS)	76.4 (17.2)	-	78.9 (11.9)	-	
	TROG-2 (SS)	77.5 (13.7)	-	84.4 (19.6)	-	
Extension	GET-*3S* (%)	29.3 (24.1)	32.3 (34.06)	45.3 (28.2)	44.7 (31.1)	
	GJT-*3S* (%)	60.3 (15.0)	58 (14.1)	57.0 (14.8)	61.3 (16.1)	
Control	GET-*'s* (%)	39.3 (26.7)	44.3 (30.5)	50.0 (33.4)	40.3 (32.4)	
	GJT-*'s* (%)	56.0 (15.3)	55.0 (14.6)	60.0 (18.0)	56.7 (19.6)	
Group 2		Pre-intervention			Post-intervention	
Outcomes		T1	T3	T4	T6	T7
Primary	GET-*ed* (%)	19.7 (16.3)	17.6 (17.1)	22.4 (21.9)†	45.3 (20.5)*	43.4 (26.0)
	GJT-*ed* (%)	55.2 (11.7)	56.7 (14.1)	60.3 (13.8)	51.3(11.4)	52.2 (8.6)
Standardized	SPELT-3 (SS)	69.0 (17.8)	-	75.7 (13.0)	82.5 (18.4)	-
	TROG-2 (SS)	76.7 (8.9)	-	81.0 (18.3)	84.0 (16.2)	-
Extension	GET-*3S* (%)	23.6 (26.8)	27.3 (22.8)	32.1 (29.6)	32.0 (28.0)	33.0 (29.5)
	GJT-*3S* (%)	52.7 (10.6)	54.8 (18.2)	60.6 (19.0)	61.0 (11.2)	54.8 (17.5)
Control	GET-*'s* (%)	26.1 (19.9)	16.3 (17.6)	31.0 (25.5)	25.3 (18.4)	33.0 (29.5)
	GJT-*'s* (%)	53.9 (13.7)	53.0 (15.5)	54.2 (14.6)	54.3 (11.6)	51.5 (6.1)

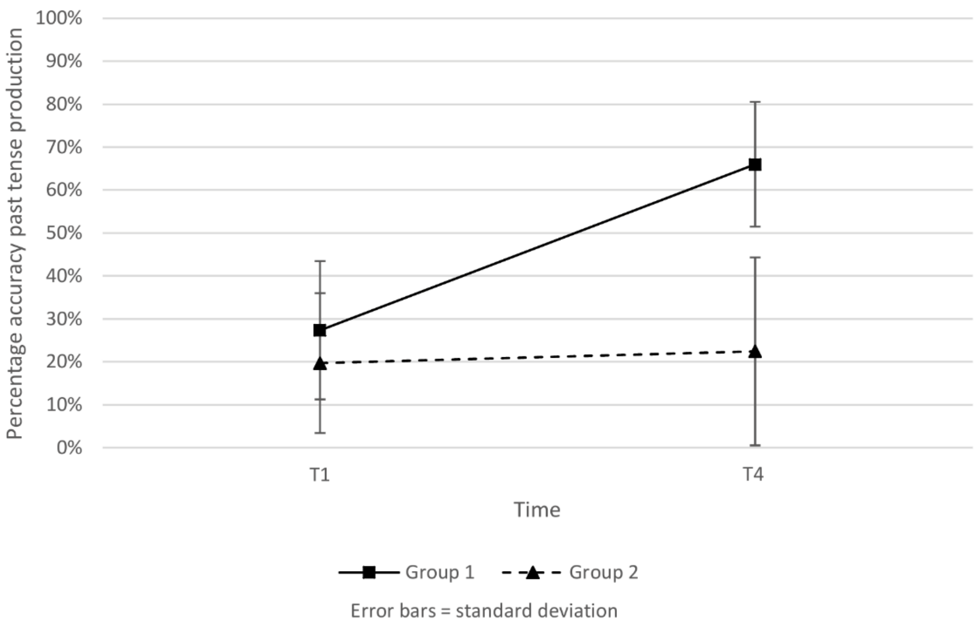
Notes. Group 1= explicit intervention group; Group 2= 'treatment-as-usual' waitlist control (crossover to explicit intervention at T4); T1= timepoint 1 (Group 1 initial assessment); T2= timepoint 2 (Group 1 pre-intervention); T3= timepoint 3 (Group 2 initial assessment); T4= timepoint 4 (Group 1 post-intervention; Group 2 pre-intervention); T5= timepoint 5 (Group 1 maintenance); T6= timepoint 6 (Group 2 post-intervention); T7= timepoint 7 (Group 2 maintenance); GET= Grammar Elicitation Test; GJT= Grammaticality Judgment Test; SPELT-3= Structured Photographic Language Test 3rd Edition (Dawson et al., 2003); TROG-2= Test of Reception of Grammar 2nd Edition. (Bishop, 2003); *-ed* = regular past tense; *3S* = third person singular; *'s* = possessive 's; SS = Standard Score; *sig. difference to pre-intervention score; †sig. between group difference. Percentage accuracy for the GJT is presented rather than *A'* to maintain consistency with the GET.

of pre-intervention (T3), one week prior to intervention commencing (T4), one week following intervention (T6) and five weeks following cessation of intervention (T7).

GET –ed: Real Time. Percentage correct of *–ed* production of untrained verbs as the primary outcome is presented in Figure 4.3. The hypothesis predicted a significant Time x Group interaction on the GET-*ed* as an evaluation of performance in 'real time'. That is, all participants were assessed on the same measures collected at the same time throughout the study (i.e., T1 and T4). Results showed a significant main effect of Group, $F(1, 19) = 11.71$, $p = .003$, $\eta^2 = .381$, in favour of Group 1. Further, there was a significant main effect of Time, $F(1, 19) = 48.87$, $p < .001$, $\eta^2 = .72$. There was a significant Time x Group interaction, $F(1, 19) = 36.84$, $p < .001$, $\eta^2 = .66$, where post hoc pairwise comparisons revealed mean difference in improvement was significant ($p < .001$) in favour of Group 1 ($M = 38.7\%$) over Group 2 ($M = 2.7\%$) ($d = 3.03$).

Figure 4.3

Between group comparison of mean percent accuracy past tense production pre- and post-intervention in real time

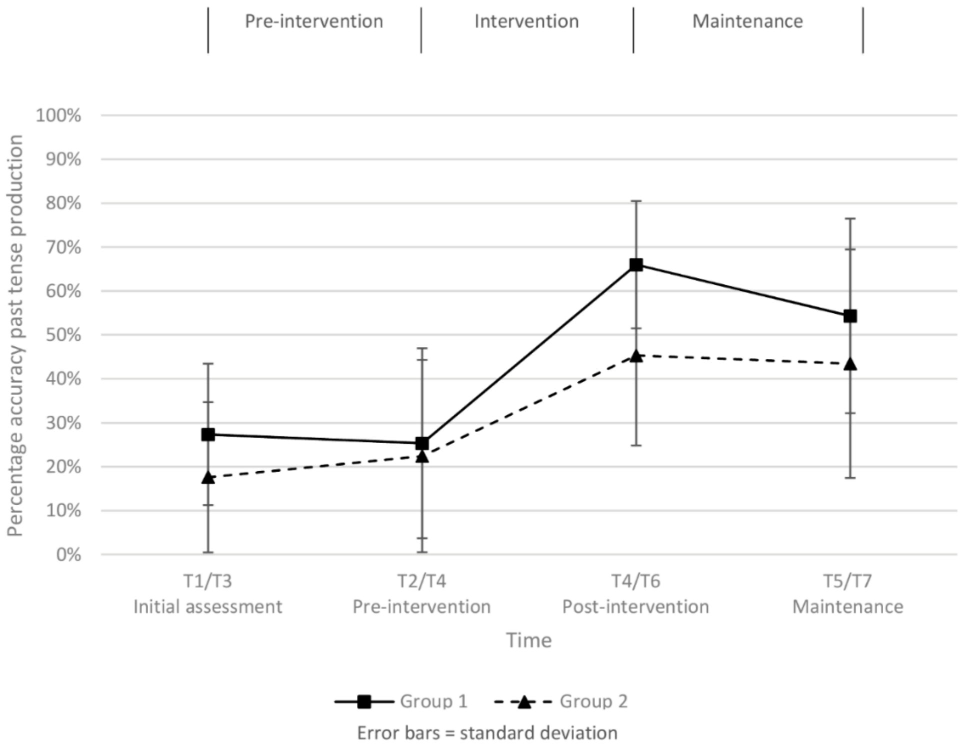


GET –ed: Relative Time. Mean percentage accuracy of *–ed* production at the 'relative' point of testing once Group 2 had crossed over into the intervention condition was compared. That is, although data were collected at different time points, the measures taken were relative to the time of receiving intervention: initial assessment (Group 1: T1, Group 2: T3); pre-intervention (Group 1: T2, Group 2: T4); post-intervention (Group 1: T4; Group 2: T6), and; maintenance (Group 1: T5, Group 2: T7). This counteracted the possibility of environmental factors that may influence analyses of data collected in 'real time'. Percentage accuracy of *–ed* production of untrained verbs is presented in Figure 4.4. The hypothesis predicted no change in performance during the pre-intervention period, but significant changes in performance following intervention between pre- and post-intervention time points for both groups, i.e., a main effect of Time only.

Results indicated no significant main effect of Group, $F(1, 18) = 2.90$, $p = .11$, $\eta^2 = .36$ or Time x Group interaction, $F(3, 54) = 1.13$, $p = .34$, $\eta^2 = .01$. However, there was a main effect of Time, $F(3, 54) = 56.28$, $p < .001$, $\eta^2 = .68$. Post hoc pairwise comparisons of mean percentage accuracy of *–ed* production from both groups combined revealed no significant difference between the initial assessment and pre-intervention timepoints ($p = 1.00$) or the post-intervention and maintenance timepoints ($p = .52$). However, both the post-intervention and maintenance timepoints were significantly higher than initial assessment and pre-intervention timepoints ($p < .001$ across all comparisons). These results suggest that once the assessment times relative to intervention were compared, there was no improvement during the pre-intervention phase ($d = -.12$), yet *–ed* production improved during the intervention period ($d = 1.22$), and this effect was maintained for five weeks ($d = -.30$).

Figure 4.4

Between group comparison of mean percent accuracy past tense production across pre- and post-intervention timepoints in relative time



GJT -ed: Real Time. Assumptions were violated on GJT-*ed* A*'* as a measure of grammaticality judgment for both groups. The test of progress between groups was non-significant, $H = 2.20$, $df = 1$, $N = 21$, $p = .138$, $f = .35$, showing both groups made a similar Amount Of Progress, Therefore No 'Relative Time' Analysis Was Conducted.

Research Question 2: Do Standardized Measures Of Grammar Improve Following Intervention for –ed Compared to 'Treatment-As-Usual'?

SPELT-3 and TROG-2. The SPELT-3 and TROG-2 were administered at T1 and T4 as standardized expressive and receptive grammar measures, respectively. For between group comparisons on the SPELT-3, the *F* test was non-significant for a Time x Group interaction, $F(1,19) = .75$, $p = .397$, $\eta^2 = .038$. Normality was violated for Group 1 at initial assessment on the TROG-2. Between group comparisons of progress with intervention were non-significant, $H = .55$, $df = 1$, $N = 21$, $p = .46$, $f = .17$.

Research Question 3: Does Third Person Singular Marking, but not Possessive 's Marking Improve Following Intervention for –ed Compared to 'Treatment-As-Usual'?

The GET-*3S* and GJT-*3S* were administered as extension measures for ancillary analyses. Since *3S* structures are linguistically related to *–ed*, and the *3S* structure was often used to prime children (e.g., *The frog flip**s**. What DID it DO?*), it was hypothesized that there may be an observable intervention effect as a result of the increased linguistic input during intervention. The GET-*'s* and GJT-*'s* were also administered as control measures for ancillary analyses. The inclusion of a linguistically unrelated control measure contributed to the internal validity of the study. The testing schedule was identical to the administration of the GET-*ed* and GJT-*ed* presented in Figure 4.1 and results are presented in Table 4.2.

GET 3S and GJT 3S (Extension). For production of *3S*, normality for Group 2 was violated. Results from between group comparison of progress between T1 and T4 was non-significant, $H = .61$, $df = 1$, $N = 21$, $p = .437$, $f = .04$. For grammaticality judgement of *3S,* normality was violated for both groups, and the between group comparison of progress with between T1 and T4 was non-significant, $H = 1.22$, $df = 1$, $N = 21$, $p = .269$, $f = .26$.

GET 's and GJT 's (Control). For the between group performance on production of *'s* as a control measure at T1 and T4, the *F* tests for an interaction were non-significant, $F(1, 19) = 1.048$, $p = .319$, $\eta^2 = .052$. Normality was violated for GJT *'s* for Group 1, and the between group comparison of progress between T1 and T4 was non-significant, $H = .85$, $df = 1$, $N = 21$, $p = .358$, $f = .21$.

Discussion

This study reports on the efficacy of an explicit intervention approach motivated by the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005) which combined metalinguistic training and systematic cueing to improve past tense (*–ed*) marking for early school-aged children with DLD. Recent pilot (Calder et al., 2018) and early efficacy (Calder et al., 2020) studies have demonstrated that explicit intervention using the SHAPE CODING^{TM} system (Ebbels, 2007) in combination with a systematic cueing hierarchy (Smith-Lock et al., 2015) significantly improves *–ed* production of untrained and trained verbs, with no improvement observed on behavioural control measures. The current study used a crossover RCT design to compare intervention provided once per week for 10 weeks (Group 1: n =10) compared to a 'treatment-as-usual' waiting control group (Group 2: n = 11). Results contribute to the understanding of viable grammar intervention options for children with DLD, particularly interventions motivated by the PDH.

Outcomes and Estimation

Research Question 1: Does –ed Marking Improve Following Intervention Compared to 'Treatment-As-Usual'?

Group comparisons in 'real time' showed a statistically significant improvement pre-post intervention for the explicit intervention group (Group 1) with a large effect (d = 3.03), but not for the 'treatment-as-usual' waiting control group (Group 2). Both groups were also compared after Group 2 had crossed over and received the intervention comparing performance in 'relative time'. Analysis showed that for both groups, there was no improvement on *–ed* production during the pre-intervention phase (d = -0.12), but improvement with intervention (d = 1.22), and although there was a decrease in the effect (d = -0.30), this was not significant, so progress was maintained for five weeks, further supporting the efficacy of the intervention. However, there was no significant difference between groups on the measure of *–ed* grammaticality judgment for any analysis. This measure evaluates knowledge of correct finiteness marking use in obligatory contexts. Rice et al. (1999) have shown that this is a clinical marker of DLD, but it has not been shown to be amenable to change through this intervention in an early stage efficacy (Calder et al., 2020) study or the current study. This may indicate DLD persists regardless of highly targeted intervention, and alternative approaches to improve grammatical judgment may be necessary.

Research Question 2: Do Standardized Measures of Grammar Improve Following Intervention for –ed Compared to 'Treatment-As-Usual'?

Between-group comparisons of standardized grammar scores were non-significant. Inconsistent with previous findings (Calder et al., 2018, 2020), mean scores on standardized assessments did not significantly improve following intervention. The current study differs in a critical aspect: the addition of a waiting control group. This allowed the exploration of whether change may have been attributable to maturation or a practice effect instead of intervention, which was not possible within the previous studies. However, the marked improvement by the majority of participants on expressive grammar scores in Calder et al. (2020), supported with analysis using the reliable change index, may suggest another important variable to consider: dosage. Calder et al. (2020) evaluated intervention delivered twice weekly for 10 weeks, whereas the current study evaluated intervention provided once weekly. Perhaps by halving cumulative intervention intensity, significant improvement was only observed on the target structure (i.e., *–ed* production). Other environmental factors cannot be ruled out without direct comparison, so this should be explored in future research.

Research Question 3: Does Third Person Singular Marking, but not Possessive 's Marking Improve Following Intervention for –ed Compared to 'Treatment-As-Usual'?

There were no differences between groups on production or grammaticality judgment of *3S* marking (the extension measure), suggesting no effect of the intervention on these measures. Similar to findings from Calder et al. (2018, 2020), the limited improvement on *3S*, suggests that even linguistically similar structures are unlikely to improve without direct intervention. This finding is consistent with existing studies (e.g., Eidsvåg et al., 2019) suggesting grammar intervention must be targeted to specific targets to yield improvement in children with DLD. Further, there were no between-group differences on production or grammaticality judgment of possessive *'s* as a behavioural control measure. Therefore, results overall support the efficacy of the intervention to improve *–ed* production, which is not attributable to maturation or other general factors such as school environment. This is further supported by a lack of between group differences on a behavioural control measure.

Theoretical Implications

The PDH suggests that in the presence of impaired implicit learning, children with DLD as a clinical population may be suited to learning grammatical information explicitly. The current intervention was designed based on recommendations from the PDH. These include the provision of intervention which modifies the way in which morphosyntax is presented for learning. Specifically, providing explicit instruction, spacing of repeated practice, and visual support to improve the learning, storage, and use of morphosyntax. Results from the current study support the PDH insofar as explicit intervention using metalinguistic training and visual support improves *–ed* production. However, without a direct comparison of explicit and implicit interventions, the explanatory power of the PDH suggesting explicit intervention is best suited to children with DLD cannot yet be confirmed.

Effectiveness of Interventions Targeting Morphosyntax

Given this study evaluated a theoretically motivated explicit intervention approach, future research may serve to compare implicit versus explicit grammar interventions to determine superiority. Findings from the current study are comparable to those of recent studies which have evaluated similar age groups and intervention targets for children with DLD. Eidsvåg et al. (2019) evaluated the efficacy of an implicit intervention using enhanced conversational recasting on children with a mean age of 5.6 years with 45 minute sessions provided five days a week for five weeks. The mean proportion correct on goals pre-intervention was 4.6% and post-intervention was 57% resulting in a mean improvement of 52.4% correct. Owen Van Horne et al. (2017) evaluated a primarily implicit intervention with children with a mean age of six years delivered for up to 36 sessions. The mean proportion correct for the group who showed the greatest advantage was 25% correct on generalisation targets pre-intervention and 60% correct post intervention, providing a mean improvement of 35%. Perhaps most relevant, Smith-Lock et al. (2015) evaluated the effectiveness of an intervention approach that combined explicit rule instruction with a systematic cueing hierarchy. Children with a mean age of 5;1 years received intervention delivered once weekly for one hour over eight weeks in small groups. Results showed that pre-intervention, children performed at 38.57% accuracy and improved to 75.97% accuracy post-intervention, demonstrating a 37.4% improvement. Importantly, the outcomes in this study were measured on the same test as the current study (i.e., the GET). The explicit intervention in the current study resulted in a mean 66% proportion correct post-intervention compared to 25.3% correct pre-intervention with a mean improvement of 40.7% when compared to a waiting control. Therefore, the explicit intervention in the current study yields mean improvement of similar, or even greater proportion to studies using implicit interventions.

Of note, the amount of time participants spent receiving intervention in the current study was markedly shorter than the studies mentioned above. For example, Eidsvåg et al. (2019) reported on an intervention duration of 18.75 hours, which is markedly longer than the 3.5-5 hours reported in the current study. Further, the current study was completed within 10 sessions, compared to 12 to 36 sessions reported in Owen Van Horne et al. (2017). This suggests the explicit intervention under investigation may be more time efficient than implicit approaches. As such, explicit interventions should indeed be considered a viable and perhaps more efficient intervention approach to improve morphosyntax in young children with DLD.

This further warrants future superiority trials comparing explicit and implicit interventions, which may shed further light on theoretical accounts of DLD.

Future Directions

Since recent findings support the use of various approaches to improve morphosyntax, including implicit and explicit, future research could aim to identify the active ingredients within interventions to test how to achieve 'optimal' outcomes. There is a body of literature supporting input-based intervention to treat verb morphology (Cleave et al; 2015; Eidsvåg et al., 2019; Owen Van Horne et al., 2017). Explicit approaches may initially appear converse to the recommendations for input-based implicit interventions. Nonetheless, explicit interventions have been shown to be efficacious in improving *-ed* production (Calder et al., 2018, 2020). Perhaps then, combining recommendations would be of interest. For example, the selection of complex *–ed* verbs (as per Owen Van Horne et al., 2017) for explicit intervention to improve production may lead to greater intervention gains on untrained forms.

Limitations

Firstly, participants were recruited using convenience sampling from a specialized educational program designed for children with DLD. This means participants may not be entirely representative of the clinical (and subclinical) population of children with DLD at large. Secondly, although RCTs are robust for comparing groups, the current design used a 'treatment-as-usual' waiting control instead of a comparison with 'gold-standard' intervention, which may better serve to determine intervention superiority. Nonetheless, the aim of the current trial was to evaluate efficacy of a theoretically motivated explicit intervention, and the implementation of a crossover phase for the control group contributes to the robustness of the current study. Next, the sample size of the current study was relatively small, even though comparable to recently published intervention studies (e.g., Eidsvåg et al., 2019; Owen Van Horne et al., 2017). Increasing sample size would allow the detection of small treatment effects which may be of clinical interest. Finally, the measures used in the current study are relatively static and may not be entirely representative of grammar used in functional communication. Future research should evaluate intervention effects on reliable measures obtained through language sample analysis.

Clinical Implications

The profile of participants from this study conform to predictions from the PDH, in that their static vocabulary skills as measured by the PPVT-4 appear to be within normal limits, whereas expressive and receptive grammar appear to be areas of deficit. Considering the positive response of the intervention group to the theoretically motivated explicit intervention compared to a 'treatment-as-usual' waiting control group examined in the current study, the use of explicit interventions should be considered a viable option for children exhibiting this clinical profile. However, this also highlights another caveat: the PPVT-4 is often used for research (cf., Rice & Watkins, 1996) and clinical (Eickhoff et al., 2010) purposes as a proxy for language skill. If children meeting criteria for DLD are, on average, performing within normal limits on such an assessment, perhaps this particular assessment will not result in the accurate grouping or characterization of children's language skills. Secondly, the limited transference of intervention effects to a linguistically related structure (i.e., *3S*) highlights the need for intervention to be highly targeted to the needs of children with DLD. Lastly, the current study does represent a more clinically relevant intervention frequency of once weekly (Finestack & Satterlund, 2018), and findings do suggest this frequency still results in intervention effects (cf. Calder et al., 2020).

Conclusion

As viewed through the lens of the PDH, the current efficacy study supports recommendations for intervention from this theory. Specifically, explicit grammar intervention using metalinguistic training with visual support and systematic cueing improves

–*ed* production in young school-aged children with DLD. Results from this efficacy study have also established the foundation for future intervention research which would further shed light on theoretical accounts of DLD and methods suited to improve morphosyntax in affected children. Perhaps by combining explicit intervention procedures with empirically supported input-based procedures, both researchers and clinicians can optimise grammar intervention effects for children with DLD.

Chapter 5

Evaluating Two Different Dose Frequencies and Cumulative Intervention Intensities to Improve Past Tense Production for Early School-Aged Children with Developmental

Chapter overview

This chapter presents a submitted manuscript of a Phase II-III intervention study comparing dose frequency and cumulative intervention intensity of TheMEDI. Results from Chapter 2 (Study 1) and Chapter 3 (Study 2) indicated TheMEDI was efficacious for improving past tense production when provided twice and once weekly, respectively. There have been few systematic analyses of the effects of dose conditions to improve intervention outcomes for interventions targeting morphosyntax. The natural progression following from the previous intervention studies was to evaluate whether children in the two different dose frequency and cumulative intervention intensity conditions differ in their response to intervention. Further, this allowed the opportunity to evaluate whether the allomorphic categories for regular past tense influenced intervention outcomes.

The current study (Study 3) grouped data, and retrospectively compared results from Studies 1 and 2. The aim was to systematically evaluate whether the participants in the two dose frequency conditions differed in their response to intervention. This information may form recommendations for future research and serve as clinical guideline for providing TheMEDI. This chapter presents the Submitted Manuscript version of the article entitled, *Evaluating Two Different Dose Frequencies and Cumulative Intervention Intensities to Improve Past Tense Production for Early School-Aged Children with Developmental Language Disorder* currently undergoing review in the International Journal of Language and Communication Disorders published by John Wiley & Sons publications. Given this is a Submitted Manuscript, some inevitable repetition from the previous Chapters is present.

Abstract

Purpose: This study compared two dose frequency conditions of an explicit intervention with 50 trials per session designed to improve past tense marking in early school-aged children with developmental language disorder (DLD). The influence of allomorphs on intervention effects was also examined.

Methods: Data from previously conducted intervention studies were combined and analysed. Participants included n = 9 (mean age = 6;6 years) who received 20-30 minute intervention sessions provided twice per week for 10 weeks (1000 trials; 400-600 minutes) and n = 20 (mean age = 6;6) who received 20-30 minute intervention sessions provided once per week for 10 weeks (500 trials; 200-300 minutes). Repeated measures included criterion-referenced probes for production of untrained past tense verbs collected throughout baseline, intervention, and maintenance phases. The rate of progress in each phase was analysed using logistic regression. The proportion of participants who produced past tense allomorphs correctly at pre- intervention, post-intervention, and maintenance testing points was analysed.

Results: Logistic regression showed a stable baseline, highly significant progress during the intervention phase, and a marginally significant shallow decline during the maintenance phase. Those in the twice per week group showed a greater rate of progress during the intervention phase leading to significantly higher scores in the maintenance period when compared with the once per week group. The allomorphic category of past tense verbs did not appear to influence outcomes.

Conclusions: Participants receiving intervention twice per week appeared to demonstrate a greater rate of progress with intervention than those receiving it once per week, although once per week was also effective. However, these results should be interpreted with caution. Limitations to study design indicate a larger randomised controlled trial is required. All past tense allomorphs improve to a similar degree when treated with this intervention.

Developmental language disorder (DLD) is experienced by roughly 7% of the population (Norbury et al., 2016). The condition affects the ability to use and understand language, with language developing at a slower pace compared to age-matched peers (Bishop et al., 2017). Children with DLD are likely to face challenges with social communication and academic participation, with the impact of oral language deficits on interaction and literacy acquisition well established (Windsor et al., 2000). Morphosyntax skills, such as tense marking, are particularly affected in this group (Bishop, 2014b).

There is a need to evaluate interventions aiming to improve those skills necessary to access school-based curriculums. Research should not only measure change on those items targeted during intervention, but also any impact on measures of generalisation (Owen Van Horne et al., 2018). Further, the components of interventions should be clearly operationalised in order to evaluate effectiveness. For example, Plante et al. (2019) evaluated whether the same number of doses delivered in half the time could be effective when treating verb morphology for 20 four to five year old children with DLD. Results from between group post-intervention testing suggests dose density can be manipulated as such, and offers evidence that dosage is an important variable to explore regarding intervention.

Warren et al. (2007) outlined a framework for defining intervention components to encourage researchers and clinicians to identify elements contributing to optimal intervention effectiveness. This includes clearly defining *dose*, which refers to "the number of properly administered teaching episodes during a single intervention session" (p. 71); *dose form*, which refers to "the typical task or activity within which the teaching episodes are delivered" (p. 71); *dose frequency*, which refers to "the number of times a dose of intervention is provided per day and per week" (p. 72); *total intervention duration*, which refers to "the time period over which a specified intervention is presented" (p. 72), and; *cumulative intervention intensity*, which refers to "the product of *dose* x *dose frequency* x *total intervention duration*"

(p. 72). For example, Calder et al. (2020) reported on an explicit intervention that included 50 properly administered teaching episodes (i.e., trials) to produce regular past tense in 20-30 minute sessions provided twice per week over 10 weeks, resulting in cumulative intervention intensity of 1000 trials over 400-600 minutes of intervention. By defining the multiple parameters that comprise intervention intensity, researchers and clinicians are able to determine if children differ in their response to receiving different intervention intensities

Warren et al. (2007) also stressed the need to look beyond the notion that more practice is always better. For instance, the Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005) suggests children with DLD experience grammatical difficulties as a result of an implicit learning deficit through impaired procedural memory. Importantly, the hypothesis predicts children with DLD have relatively spared declarative memory, which underlies learning of explicit information. Therefore, grammar, which is learned implicitly by typically developing children, may potentially be learned explicitly by children with DLD if intervention is presented as such. Notably, information learned through declarative memory is strengthened by repeated exposures (Ullman, 2016), so the theory would indicate more practice is better.

A current survey of speech language pathology practices in the US evaluated how often clinicians were able to implement intervention parameters, such as dose frequency, as well as probing speech language pathologists' desired dose frequency if resources were unlimited (Finestack & Satterlund, 2018). Results indicated that most clinicians provided sessions once weekly, but would prefer to provide twice the dose frequency in order to essentially double the cumulative intensity. Therefore, evaluating potential differences in the responsiveness to intervention through contrasting dose frequencies is of clinical interest.

Dose Frequency, Intervention Duration, Intensity, and Intervention Effectiveness

Warren et al. (2007) claimed that there had been virtually no systematic analyses of the effects of varying intervention intensities. Since this time, there have been advancements in the area, but still very few studies compare the same dose form across other intervention parameters (e.g., dose frequency, total intervention duration, cumulative intervention intensity) to determine efficacy and efficiency. Within the area of intervention targeting morphosyntax for young children with DLD, an efficacy study of 16 four-to-five year old children revealed that children receiving enhanced conversational recasting intervention in spaced (three 10 minute sessions daily) versus massed (one 30 minute session daily) conditions performed comparably at post-intervention testing points (Meyers-Denman & Plante, 2016). Results suggested daily dose frequency may be a flexible component of this particular intervention. However, it is difficult to comment on the transferability of this finding to clinical practice, as the daily provision of intervention over a period of five weeks is unlikely to suit real-life clinical contexts (see Finestack & Satterlund, 2018).

In another study of 36 five-year-old children with DLD, Smith-Lock et al. (2013b) compared a daily intervention condition (i.e., once a day for eight days) to a weekly intervention condition (i.e., once a week for eight weeks). Pre- to post-intervention between group differences revealed the once weekly condition was more effective than the once daily condition in improving individualised morphosyntax targets for children with DLD. However, single case analyses revealed individual differences between children within both groups, which stresses the need to individualise dose frequencies depending on the specific needs of each child in clinical practice. Notably, the provision of intervention in the study was at the classroom and small group level. Effects may therefore have been washed out through the provision of intervention in small group contexts. In addition, dose (i.e., trials) was not reportedly pre-determined, thus there is no way to determine if one participant received more trials than another, which may have influenced outcomes.

Another element of interest when evaluating interventions to improve regular past tense marking is that of the allomorphic categories associated with inflection. That is, in English, regular past tense is realised phonologically as [d] (as in *hugg**ed***), [t] (as in *walk**ed***) or [əd] (as in *tast**ed***). It is reasonably well established that past tense verbs inflected with the [əd] allomorph are more challenging to learn for children with DLD (Marshall & van der Lely, 2006). This is due to the relatively low phonotactic probability of such lexical items in English, once the verb is marked for regular past tense. For example, the syllabicity of the verb *kissed* is represented phonotactically as CVCC, whereas the verb *rested* is represented as CVCCVC. The latter is a far less frequent syllabic structure in English (Owen Van Horne & Green Fager, 2015; Tomas et al., 2015). In fact, Tomas et al. (2017) found that even in a typically developing sample of children, verbs inflected for past tense with the [əd] allomorph are still developing at five years old, while verbs inflected with [t] or [d] appear to already be mastered by this age. As expected, children with DLD were even more delayed in their acquisition of the [əd] allomorph. This is consistent with the Procedural Deficit Hypothesis, which predicts less probable sequences of information to be more problematic for children with DLD. Tomas et al. (2017) therefore recommended low frequency allomorphs make ideal intervention targets.

The Current Program of Research

The Procedural Deficit Hypothesis (Ullman & Pierpoint, 2005) suggests that explicit interventions may be beneficial for children with DLD to improve grammar due to an implicit learning deficit. Recent findings from Calder et al. (2018) and Calder et al. (2020, 2021) suggest explicit grammar intervention combining metalinguistic training and a systematic cueing hierarchy is efficacious for treating production of regular past tense for children aged around six years with DLD. The metalinguistic training aspect is based on the SHAPE CODING™ system (Ebbels, 2007), which uses specific visual cues such as colours, shapes and arrows to explicitly teach children rules of syntax and morphology. The systematic cueing hierarchy was developed by Smith-Lock et al. (2015) and moves from least to most support.

The primary components of the intervention are first to explicitly outline the goal of the session, which is to mark verbs for regular past tense when describing something that has already happened. Subsequent to the initial session, this also includes reminding the child that s/he had practised this in the last session. The vocabulary necessary to use the past tense verbs appropriately is checked by having the child label intervention materials. Relevant shapes from the SHAPE CODING™ system are introduced (Subject: Oval, Verb Phrase: Hexagon, Object: Rectangle; see Balthazar et al., 2020 or Ebbels, 2007 for a detailed description of the system and shapes) and linked to the intervention materials. Subject + Verb/+ Object (SV/O) clauses are modelled including target verbs marked with one allomorph from each of the allomorphic categories, e.g., "*I tap the drum. What DID I just DO? I tapp**ed** the drum. The [t] at the end of tapp**ed** lets us know it's already happened.*"; "*I twirl the drumstick. What DID I just DO? I twirl**ed** the drumstick. The [d] at the end of twirl**ed** lets us know it's already happened.*"; "*I lift the drum. What DID I just DO? I lift**ed** the drum. The [əd] at the end of lift**ed** lets us know it's already happened."* Additional visual support in the form of left "down arrows" from the SHAPE CODING™ system are highlighted at this point. For the practice component, the child is then provided 25 opportunities to produce past tense in response to an interrogative to elicit the target verbs, e.g., "*You tap the drum. What DID you just DO?*" If the child produces an error on the target verbs, s/he is cued systematically in the following sequence: 1) *request for clarification*; 2) *emphatic recasting with elicited response*; 3) *forced choice with elicited response*; 4) *elicited imitation* as per Smith-Lock et al. (2015). A consolidation component is then implemented, and the child responds to comprehension questions relating to the targeted syntactic structure, e.g. “*WHO tapped the drum?*”; “*What DID you DO?*”; “*WHAT did you tap?*” The consolidation component is repeated for one exemplar from each of the allomorphic categories providing the child with three opportunities to produce the target SV/O structure including a verb marked for regular past tense. The shapes and arrows are then removed, and the child is prompted to produce the same SV/O structures elicited at the beginning of the consolidation component. Finally, SV/O sentences are produced by the SLT either grammatically or ungrammatically (by omission of past tense *–ed*), and the child decides if it sounds right. The process is repeated with a selection of different verbs for a second activity until a total of 50 trials (i.e., doses) are achieved within the session. Each session includes a summary component where the child is reminded that it is important to include the sounds at the end of past tense verbs when describing something that has already happened.

Calder et al. (2020) reported on a single case experimental design study with $n = 9$ children. The intervention was delivered twice weekly in 20-30 minute sessions for 10 weeks where each child received a cumulative intervention intensity of 1000 trials over 400-600 minutes. Results indicated children significantly improved in the production of trained ($p < .001$, $Tau = 0.88$) and untrained ($p < .001$, $Tau = 0.64$) past tense verbs. In a subsequent study, Calder et al. (2021) conducted a randomised control trial with $n = 21$ children allocated to intervention ($n = 10$) and waiting control ($n = 11$) conditions. The intervention was delivered once weekly in individual 20-30 minute sessions for 10 weeks where each child received a cumulative intervention intensity of 500 trials over 200-300 minutes. The intervention group significantly outperformed the waiting control group on a measure of untrained past tense production ($p < .001$, $d = 3.03$), and once the control group crossed over to the intervention condition, between-group differences disappeared, but significant improvement pre-post intervention was shown for both groups combined ($p < .001$, $d = 1.22$). These results suggest this explicit intervention is efficacious for treating regular past tense for early school-aged children with DLD. Considering the relative lack of evidence evaluating grammar interventions in different dose conditions, and the reported preference to provide more intervention rather than less (see Finestack & Satterlund, 2018), re-analysis of previously reported data comparing dose frequency may provide valuable information regarding dosage to optimise efficacy.

The Current Study

The current study combines data from previously reported research to systematically analyse whether intervention for past tense provided twice per week or once per week results in a greater rate of progress on a generalised measure of untrained regular past tense production, and is therefore optimally efficacious. Such research should inform intervention protocols for determining dose to establish effectiveness in future research, and may inform clinical practice in the current absence of research with large group comparison studies. Our primary research question was:

1. Do children in the two different dose frequency and cumulative intervention intensity groups differ in their response to intervention?

   We hypothesised that intervention provided twice per week (i.e., cumulative intervention intensity 1000 trials over 400-600 minutes over 10 weeks) would result in a greater rate of progress on measures of past tense production compared to intervention provided once per week (i.e., cumulative intervention intensity 500 trials over 200-300 minutes over 10 weeks).

In addition, exploratory analyses of the characteristics of verb finiteness marking, such as allomorphic categories, may increase our understanding of patterns within disordered grammar to inform the design of interventions. Our second research question was:

2. Is there any difference in response to intervention between the three allomorphs?

We hypothesised, on average, children with DLD will show greater progress in percentage accuracy in production of past tense marking of [d] and [t] allomorphs compared to [əd].

Method

Study Design

The current study tested hypotheses by grouping data, and retrospectively comparing results from previously conducted studies. Data from n = 9 children receiving intervention twice per week for 10 weeks as part of a single case experimental design (2PW) (Calder et al., 2020) were compared to data from n = 20 children who received the same intervention once per week for 10 weeks as part of a randomised control trial (1PW) (Calder et al., 2021).

Participants

Ethical approval for the study was obtained from the Curtin University Human Research Ethics Committee (Approval number: **HRE2017-0835**) and the Western Australian Department of Education (Approval number: **D190018955)**. All participants were recruited through specialised educational programmes designed to cater for the needs of children with DLD. Recruitment involved consent from the programmes' principals, and identification of potential study participants by programme staff. Once identified, parents of the children were sent information letters and consent forms, as well as child friendly forms for the children to complete. Forms were returned to the school to confirm consent.

The inclusion/exclusion criteria were based on those outlined by Bishop et al. (2016) for determining a diagnosis of DLD, including: language skills significantly below age expectancy as determined by a standardised assessment; absence of other biomedical conditions, such as autism spectrum disorder; no history of hearing loss, and; no diagnosis of intellectual disability. Further, functional impact was evidenced through various sources, including language samples, student achievement reports, parent report, and teacher observation. The participants' school enrolment packages were accessed to confirm they met criteria for a diagnosis of DLD. Additional inclusion criteria included: aged between 5;6 and 7;6; English as a primary language, and difficulties with marking grammatical inflection associated with DLD as identified by classroom teachers.

The participants in the twice per week condition were not randomly assigned as this study used single case experimental design (Calder et al., 2020). Rather, study enrolment was capped at $n = 9$ to meet standards for single case reporting (Kratochwill et al., 2012). Participants in the once per week condition were randomly assigned to either the intervention condition ($n = 10$) or a waiting control ($n = 11$) by a researcher blinded to the purpose of the study (Calder et al., 2021). Of note, one child was exited from the waiting control group prior to receiving intervention, and their data have been excluded from all analyses resulting in $n = 29$. Therefore, group assignment was not randomised for the purpose of evaluating efficacy relative to dosage in the current study. The intervention for the two studies was also provided at different times. These are considered limitations.

Refer to Table 5.1 for demographic information. Between group differences for the twice per week group (2PW) and the once per week group (1PW) on age and sex were evaluated. There were no significant differences between groups on age an initial assessment, $t(27) = -.151$, $p = .881$, or onset of intervention, $t(27) = -.480$, $p = .635$, and no differences in distribution of sex, $U = 77.50$, $z = -.839$, $p = .401$.

Initial Assessment

Upon entry to the intervention studies, participants were screened in hearing acuity and passed at 20 dB HL for each ear at 500, 1000, 2000, and 4000 Hz. Additionally, all participants passed the Phonological Probe from the Test of Early Grammatical Impairment (Rice & Wexler, 2001) which confirmed they were able to articulate phonemes necessary for morphosyntax production targets.

Table 5.1

Demographic and initial assessment information for all study participants.

Participant ID	Age at initial assessment	Age at onset of intervention	Sex	SPELT-3	TROG-2	GET -ed (%)
2PW						
P01	6;3	6;4	M	69	74	36.7
P02	6;2	6;5	M	90	97	40.0
P03	5;10	5;11	M	79	86	33.3
P04	6;8	6;11	M	71	81	30.0
P05	6;6	6;7	M	57	81	3.3
P06	6;2	6;5	F	72	65	3.3
P07	6;7	6;9	M	84	62	23.3
P08	6;0	6;2	M	69	79	16.7
P09	6;1	6;3	M	57	65	36.7
M(SD)	6;4 (0;3)	6;6 (0;3)	88.9%/11.1%	69 (17.8)	76.7 (8.9)	24.8 (13.3)
1PW						
P10	6;0	6;2	F	78	79	26.7
P11	5;11	6;1	M	98	72	46.7
P12	6;1	6;3	F	98	74	36.7
P13	6;1	6;3	M	82	88	23.3
P14	6;4	6;6	M	82	111	50.0
P15	6;0	6;1	M	72	69	3.3
P16	6;0	6;2	M	57	74	20.0
P17	6;4	6;5	M	55	79	10.0
P18	6;8	6;9	M	48	55	10.0
P19	6;3	6;5	M	94	74	46.7
P20	6;7	7;0	M	63	72	16.7
P21	5;9	61	M	105	90	43.3
P22	5;10	6;2	M	81	81	13.3
P23	6;7	7;0	M	59	76	3.3

P24	6;2	6.6	F	63	65	3.3
P25	6;2	6;7	F	82	83	33.3
P26	6;7	7;0	M	48	72	3.3
P27	6;2	6;6	M	40	65	6.7
P28	6;4	6;9	M	61	83	16.7
P29	6;7	7;1	F	71	90	23.3
M(SD)	6;3 (0;)	6;6 (0;4)	75%/25%	71.9 (18.0)	77.6 (11.5)	21.8 (15.7)

Notes. 2PW= intervention 2x per week; 1PW= intervention 1x per week; CONTROL= 'treatment-as-usual' waitlist control group; GET -ed= Grammar Elicitation Test-regular past tense; SPELT-3= Structured Photographic Language Test 3rd Edition (Dawson et al., 2003); TROG-2= Test of Reception of Grammar 2nd Edition (Bishop, 2003); M= male; F= female; SD= standard deviation. All scores on standardised assessments reported in this table are scaled scores.

All participants were assessed on standardised tests of grammar. The Structured Photographic Expressive Language Test 3rd Edition (SPELT-3) (Dawson et al., 2003) measures expressive morphosyntax using 54 items across a range of structures and was normed on children aged 4-9 years. The recommendation to address discriminant validity of the SPELT-3 at 90% sensitivity and 100% specificity with a 95 standard score cutoff (-0.33 standard deviation) (Perona et al., 2005) was implemented for the current study to descriptively report on the profile of children with DLD, although it is noted that Perona et al. sampled children aged 4–5 years. The Test for Reception of Grammar 2nd Edition (TROG-2) (Bishop, 2003) measures the comprehension of a total of 20 different grammatical structure contrasts and was normed on children aged 4-16. Both tests are reported to have strong reliability and appropriate validity.

There were no significant group differences on the SPELT-3, $t(27) = -.022$, $p = .982$. Assumptions of normality were violated for 1PW on the TROG-2 (kurtosis = 2.53). Therefore, a Mann-Whitney U test was conducted, which was non-significant, $U = 87.50$, $z = -.118$, $p = .906$. Of note, overall two participants were considered within normal limits on the SPELT-3 at initial assessment using the 95 cut score (Perona et al., 2005), and four participants would be considered within normal limits on the TROG-2 using a one standard deviation cut-off. These participants were still included in the study due to the presence of DLD as determined by their enrolment in the specialised educational programme, and their low score on measures of past tense production at age six years as indicated by the measure explained below in Outcomes.

Intervention

The intervention procedures are described in an earlier section, where the SHAPE CODING™ system (Ebbels, 2007) was used in combination with a systematic cueing hierarchy (Smith-Lock et al., 2015) to explicitly teach children with DLD when to mark regular past tense verbs. Intervention was carried out in a quiet space on site at the participants' educational programme. Each session was videoed for later reliability scoring. Scoring for reliability involved the first author and two separate blinded researchers for each study rating 20% of total sessions on percentage accuracy for inclusion of intervention components, including explicit instruction with visual scaffolds, number of verbs elicited, errors cued correctly, and an intervention session plenary. Between-observer agreement was calculated using intraclass correlation coefficients (ICC) with absolute agreement and single measures in a two-way random effects model. The average score across raters was 97.95% for percentage accuracy, and ICC for procedures was .976 indicating excellent agreement.

For convenience, the dose, duration, and intervention intensity conditions are summarised briefly here. For the 2PW group, the dose was 50 trials within 20-30 minute sessions; dose form was explicit intervention combining metalinguistic training using the SHAPE CODING™ system (Ebbels, 2007) with a systematic cueing hierarchy (Smith-Lock et al., 2015); dose frequency was twice weekly; total intervention duration was 10 weeks; resulting in a cumulative intervention intensity of 1000 trials over 400-600 minutes over 10 weeks. The only difference for the 1PW group was that dose frequency was once weekly, halving the cumulative intervention intensity to 500 trials over 200-300 minutes over 10 weeks. All intervention was delivered within age-appropriate and engaging activities, such as snakes and ladders, and playing with animal manipulatives. All intervention was delivered in 1:1 sessions by the first author, who is an experienced speech-language pathologist. The study involving the twice weekly sessions was carried out before the study involving once weekly sessions.

Outcomes

Past Tense Production

To measure improvement in past tense production, the *–ed* subset of the Grammar Elicitation Test (GET) (Smith-Lock, Leitão, Lambert, & Nickels, 2013a) was administered. This criterion-referenced subtest includes 30 items evenly distributed for all possible allomorphs (i.e. 10x [d] verbs, 10x [t] verbs, and 10x [əd] verbs). Importantly, verbs included in the GET-ed were not trained as part of intervention, and therefore served as measures of generalisation of past tense production. Verbal elicitation procedures for each item were pre-recorded for the purpose of consistency in administration and embedded within a Microsoft PowerPoint to be delivered via laptop. The full 30-item GET-ed subtest was administered to all participants at initial assessment, immediately prior to the commencement of intervention, immediately following the cessation of the 10-week intervention phase, and at the end of the five-week maintenance phase. The sequence of presentation was randomised at each testing point. For the 2PW group, baseline phases differed in duration from five-, seven- and nine-weeks. All participants in the 1PW group had a five-week baseline phase. There were no between group differences on the GET-ed at initial assessment, $t(27) = .479$, $p = .635$, or at the onset of intervention, $t(27) = .404$, $p = .689$.

Repeated Measures. Sets of nine past tense verbs, were probed during baseline, intervention, and maintenance phases. During the intervention phase, past tense production was probed at the beginning of the second intervention session, and every even session in both the 2PW and 1PW conditions during the intervention phase. The verbs were equally distributed for allomorphs and randomly selected from the GET-ed at each timepoint.

Results

The primary aim of this study was to systematically evaluate whether the participants in the two dose frequency conditions differed in their response to intervention. We also conducted an exploratory analysis of whether allomorphs differ in response to intervention.

Outcomes and Estimation

Past Tense Production

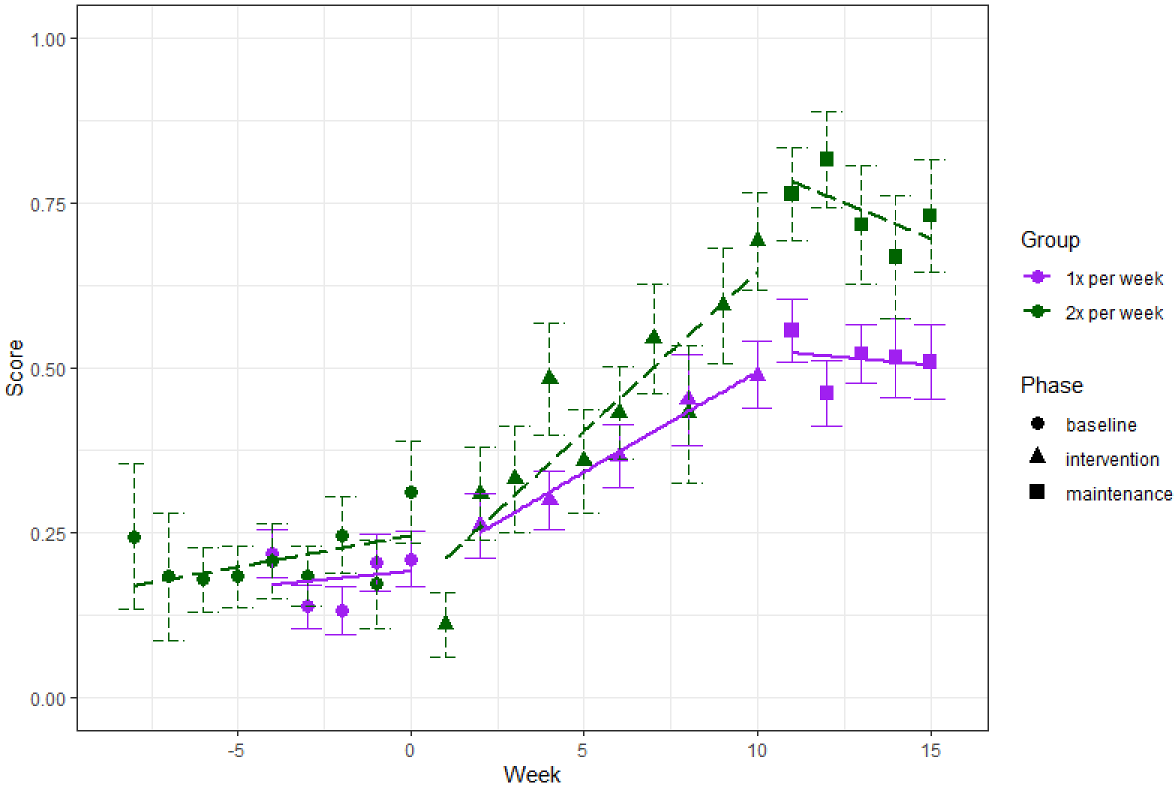
All data for past tense production, including initial assessment, pre-intervention, post-intervention and maintenance (i.e., GET-ed /30), as well as repeated measures probed throughout baseline, intervention and maintenance phases (i.e., GET-ed /9) were included for analysis. Figure 5.1 shows mean scores and standard errors at each week together with fitted regression lines for each phase, split by group. Visual inspection of the graph indicates little change by week during the baseline period, a linear increase from week 1 to week 10 during the intervention period for both groups, and a shallower decline across the maintenance period. The 2PW per week group appeared to have higher scores during the maintenance period.

Data in each Phase was analysed separately using logistic regression. This type of general linear model (Howell, 2010) is used for a binomially distributed dependent variable (i.e., correct versus incorrect), and accounts for random effects, such as differences between individuals. We predicted the proportion of correct responses with the fixed effects of Week and Group (1PW vs 2PW). The interaction between Group and Week was our primary interest, i.e., did receiving one versus two sessions per week affect the rate of progress during the intervention phase, or the retention of any progress during the maintenance phase? Because of this, we ran the full interaction model at each Phase. The models also included a random intercept for participants to model individual differences in initial performance. Analyses were carried out in R version 4.0 using the glmmTMB package (version 1.0.2.1). The results are shown in Table 5.2.

Week was not a significant predictor during the baseline phase, indicating a stable baseline, but was a significant predictor in the intervention and maintenance phases. In the intervention phase, for the reference group (1PW), the odds of a correct response increased significantly by Week ($p < .001$), whereas during the maintenance phase, this decreased

Figure 5.1

Mean percent accuracy of past tense production during baseline, intervention, and maintenance phases for the two groups



(although this decline was of marginal significance, $p = 0.04$). A marginally significant interaction of Group with Week in the intervention phase ($p = 0.04$), indicates that the rate of progress differed between groups in favour of the 2PW condition. The odds of a correct response were also significantly higher at the start of the maintenance phase for the 2PW group compared with the reference group of 1PW ($p = 0.003$). Although it appears their decline during this phase was steeper, this did not reach significance ($p = 0.07$).

The results therefore suggest that while progress with intervention was significant in the 1PW group, the rate of progress with intervention was steeper in the 2PW group. In addition, the 2PW group showed significantly higher scores in the maintenance phase, but with indications of a steeper decline. This suggests that while intervention once per week

Table 5.2

Results from the logistic regression with week and group as predictors of past tense production in baseline, intervention, and maintenance phases

	Baseline Phase		Intervention Phase		Maintenance Phase	
Predictors	*Odds Ratios*	*p*	*Odds Ratios*	*p*	*Odds Ratios*	*p*
Group [2PW]	1.42 (0.61 – 3.28)	0.412	0.88 (0.37 – 2.09)	0.774	16.01 (2.51 – 102.29)	**0.003**
Week	1.01 (0.94 – 1.09)	0.815	1.17 (1.11 – 1.23)	**<0.001**	0.94 (0.88 – 1.00)	**0.040**
Group [2PW] x Week	1.03 (0.93 – 1.13)	0.603	1.09 (1.00 – 1.17)	**0.040**	0.89 (0.79 – 1.01)	0.070
Random Effects						
σ^2	3.29		3.29		3.29	
τ_{00}	0.95 $_{ID}$		0.76 $_{ID}$		1.24 $_{ID}$	
ICC	0.22		0.19		0.27	
N	29 $_{ID}$		29 $_{ID}$		29 $_{ID}$	
Observatios	163		190		139	
Marginal R^2 / Conditional R^2	0.004 / 0.228		0.077 / 0.251		0.080 / 0.332	

leads to significant progress, there may be an advantage to receiving intervention twice per week. Limitations to this interpretation are presented in the Discussion.

The rate of progress on past tense production for each individual participant through baseline, intervention and maintenance phases is presented in Figure 5.2. This figure demonstrates that although there was significant improvement in both dose conditions when the participants were considered as a group, there was great variability in individual performance in response to the intervention, regardless of how often the dose was administered.

Figure 5.2

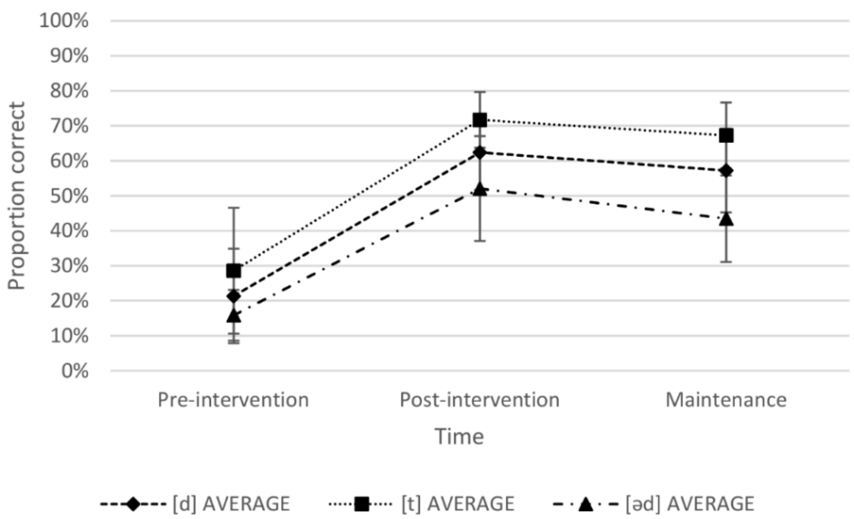
Rate of progress in past tense production for all individual participants during baseline, intervention and maintenance phases

Analysis of Allomorphs

Data for past tense production from immediately pre-intervention, post-intervention and maintenance testing points (i.e., GET-ed /30) were included for analysis. Performance from all participants who completed intervention, including the waiting controls, in both previously reported studies (Calder et al., 2020, in press) (n = 29) were combined. Responses to past tense production probes were organised according to allomorphs ([d], [t], [əd]). Correct/incorrect responses for each item (*Total* = 30) across participants were summed and converted to percentage of participants correct at pre- and post-intervention, and maintenance testing points, i.e. *X*% of participants produced item *Y* correctly pre- intervention, *X*% of participants produced item *Y* correctly post-intervention, *X*% of participants produced item *Y* correctly at the maintenance testing point. To evaluate whether allomorphic categories accounted for variance in intervention effects, a 3x3 mixed design ANOVA was used where time (pre- vs. post-intervention vs. maintenance) was the within-subject variable and allomorphic category ([d] vs. [t] vs. [əd]) was the between-subject variable (see Figure 5.3). This analysis was carried out using IBM SPSS version 25.

Figure 5.3

Average past tense performance across past tense allomorphs



There was a significant main effect of Time, $F(2, 54) = 151.71, p < .001, \eta^2 = .85$. Post hoc pairwise comparisons with Bonferroni adjusted α values indicated significant differences between the total number of items produced correctly at all testing points, *p*s < .005, with a mean improvement of 40.1% between pre-intervention and post-intervention, and a mean decline of 6.1% between post-intervention and the maintenance testing points. There was also a significant main effect of Allomorphic Category, $F(2, 27) = 8.38, p = .001, \eta^2 = .38$. Post hoc pairwise comparisons with Bonferroni adjusted α values revealed a significant difference of 18.7% between the total number of [t] allomorphs and [əd] produced correctly, $p = .001$. All other pairwise comparisons were non-significant. However, there was no significant Time x Allomorphic Category interaction, $F(4, 54) = .91, p = .465, \eta^2 = .06$. These results suggest that all allomorphic categories improved to a similar extent as a result of intervention, with a shallow decline during the maintenance phase.

Discussion

The primary aim of this study was to evaluate whether children aged between 5;9 – 7;1 years with DLD in two different dose frequency groups, resulting in different cumulative intervention intensities, differ in their response to an explicit intervention to improve past tense marking in children. Data from previously reported intervention studies were analysed. We evaluated rate of progress on criterion-referenced measures of past tense production (i.e., the GET-ed) probed during baseline, intervention, and maintenance phases. Dose conditions included an explicit intervention provided twice weekly (2PW) (1000 trials over 400-600 minutes) and once weekly (1PW) (500 trials over 200-300 minutes) over an intervention duration of 10 weeks. On the assumption that more is better regarding dosage, we hypothesised intervention provided twice per week would result in a higher rate of progress in past tense production during the intervention phase.

Additionally, we conducted exploratory analysis of past tense production and allomorphic categories of regular past tense verbs (i.e., [t], [d], and [əd]) by grouping data pre- and post-intervention from all participants who completed intervention in previously reported studies (Calder et al., 2020, 2021) to determine if the type of allomorph contributes to the intervention effect, i.e., are some allomorphs easier/harder to learn than others? Based on previous research (Marshall & van der Lely, 2006; Tomas et al. 2015, 2017), we expected less phonotactically probable verbs (i.e., marked with [əd] inflection) to be more difficult to learn for children with DLD.

Intervention Effect

The explicit intervention was designed to improve past tense production. Intervention effects were measured on the GET-ed, which included only untrained verbs. Previous studies in this program of research indicated a statistically significant difference in mean scores of past tense production of untrained verbs following intervention compared with a baseline period prior to intervention (Calder et al., 2020) and compared to a waiting control group (Calder et al., 2021). Both groups, showed significant progress with intervention and a shallower decline in performance during the maintenance phase. In line with our hypothesis regarding the current study, the rate of progress during the intervention phase appeared to show a marginal statistical advantage in providing intervention for past tense production twice per week compared to once per week. The 2PW group also had higher scores during the maintenance phase. Visual inspection of the plotted data in Figure 5.1 suggests the 2PW group continued progress in the first two weeks of the maintenance phase before performance started to decline to a reasonably stable level of around 70% correct (which was similar to the immediate post-intervention score), whereas the 1PW group's performance showed an increase for one week before decreasing again to near the post-intervention score of around 50% correct. Thus, it appears that both groups maintained progress made during intervention, but that due to the greater rate of progress during the intervention period, the 2PW group had higher scores.

Notably, individual response to the intervention varied regardless of dose frequency condition (see Figure 5.2). For example, Participants 4 and 5 in the 2PW condition and Participant 13 in the 1PW condition showed a relatively stable baselines, positive progress in the intervention phase, and stable performance in the maintenance phase. Participant 16 in the 1PW condition showed a similar profile with the exception of a steep decline in the maintenance phase, whereas Participants 15 and 25 continued to improve in the maintenance phase. In contrast, Participants 22 and 29 showed little progress during the intervention phase, but demonstrated higher performance in the maintenance phase compared to the baseline phase, and Participants 24 and 28 demonstrated little improvement throughout any phase. Similar to Smith-Lock et al. (2013b), the existence of individual differences regardless of dose frequency conditions demonstrates the heterogeneity of this clinical population. Therefore, intervention procedures will likely need to be tailored to the individual needs of children while taking into account evidence on dose frequency within clinical contexts.

Analysis of Past Tense Allomorphs

A secondary aim of this study was to evaluate whether there is any difference between the three possible past tense allomorphs in response to intervention. Verbs marked with the [əd], which are phonotactically less probable, are suggested to be more difficult for children with DLD than verbs marked with [t] or [d] (Marshall & van der Lely, 2006; Tomas et al., 2017). Consistent with the existing literature, there was a main effect of Allomorphic Category, and pairwise comparisons indicated that, fewer children produced past tense of verbs marked with [əd] correctly compared to verbs marked with [t]. The significant main effect of Time with no interaction of Allomorph and Time indicates an effect of our explicit intervention on past tense production that, contrary to our hypothesis, was equivalent for all three allomorphs. Therefore, clinicians should not favour one allomorph over another when selecting intervention targets if using this explicit intervention approach. Further, this may provide evidence that this explicit intervention circumvents a potential implicit learning deficit, and that children with DLD can learn through relatively spared declarative learning capacity. This is consistent with the Procedural Deficit Hypothesis account of DLD (Ullman & Pierpoint, 2005). That is, while the less probable lexical items are more difficult to learn due to a procedural learning deficit, the phonotactic probability of a past tense verb has no effect on learning through explicit intervention, as gains are similar to those of more phonotactically probable verbs. Findings from the current study also demonstrate this skill is generalisable to learning untrained verbs.

Dose Frequency, Intervention Duration, Intensity, and Intervention Effectiveness

Prior to implementing effectiveness research with large-scale randomised control trials, it is useful to conduct efficacy studies evaluating parameters of intervention intensity. Recent research into the intervention for morphosyntax suggests varying dose in terms of daily frequency (Meyers-Denman, 2016) or dose density within sessions (Plante et al., 2019) does not appear to influence intervention efficacy when other dosage and intensity parameters are held constant (i.e., delivered once a day for five days for five weeks). Although in both studies participants were probed on performance throughout intervention, Meyers-Denman (2016) analysed between group effects based on performance on post-intervention correct use of morphemes only, and Plante et al. (2019) compared effect sizes and post-intervention correct spontaneous production of morphemes. Thus the richness of the repeated measures data was not utilised.

Smith-Lock et al. (2013b) evaluated the effects of dose frequency (daily versus weekly) while maintaining cumulative intervention intensity (in minutes) for an expressive grammar intervention with five year old children with DLD. The weekly dose frequency condition was more effective than the daily condition, however, it is important to note that dose was not specified as part of the dosage and intensity parameters. They analysed between group effects on pre-post intervention progress using analysis of variance, and single case analyses were reported. Single case analyses indicated that responsiveness to intervention within each group was dependent on individual profiles.

Unlike the aforementioned studies, we used repeated measures throughout the baseline, intervention, and maintenance phases to analyse potential between group differences using logistic regression. The repeated measures provided much richer data than just pre- and post-intervention measures and logistic regression could include random participant factors (which is important given the individual variation). Indeed, inspection of Figure 1 suggests if we had used only the assessments delivered pre- and post-intervention, this may have led to misleading results, as the pre-intervention score for the 2PW group appears to be an outlier.

Another key aspect to consider is the ways in which dosage and intensity parameters differ across studies, despite operational definitions provided by Warren et al. (2007). Table 5.3 reports how these parameters have been defined by authors in the aforementioned studies. Differences across studies tend to be by how dose frequency and total intervention duration are defined. For example, Plante et al. (2019) define duration in days, Meyers-Denman and Plante (2016) define duration in weeks, and Smith-Lock et al. (2013b) define duration in days and weeks. As a variable in the equation for which cumulative intervention intensity is a product, this has implications for how intervention procedures have been defined. In fact, the differences between intervention parameters in Plante et al. (2019) cannot be captured with the terminology presented by Warren et al. (2007). It seems the purpose of the Plante et al. (2019) study was therefore to highlight this by examining how the manipulation of doses within a set number of minutes within individual intervention sessions may influence outcomes. Specifically, comparing dose spacing between sparse (24 dose over 30 minutes) and dense (24 doses over 15 minutes) conditions. This may be a more clinically salient way to conceptualise dosage, as it provides specific information to clinicians in the context of one-to-one contact with the child.

Alternative definitions for cumulative intervention intensity have been reported. For example, Smith-Lock et al. (2013) referred to Gillam's (2012) definition, *session duration* x *dose frequency* x *total intervention duration*, which reportedly omits *dose* from intensity in favour of *session duration*. This is seemingly due to the perceived difficulty in accurately controlling and reporting dose in research and clinical contexts (Smith-Lock et al., 3013b). Schmitt et al. (2016) report cumulative intervention intensity as "the product of dose (i.e., average time spent targeting language skills per each session), frequency (i.e., number of sessions each child received), and total frequency duration (over one academic year)" (p. 159). Given the potential difficulty in controlling for the precise number of doses as 'teaching episodes' (Warren et al., 2007), perhaps defining dose in terms the time spent targeting a specific skill is more clinically salient. However, therein lies the issue of operationally defining 'targeting a specific skill' within an intervention session, or alternatively, a single therapeutic event (Plante et al., 2019).

It appears, overall, greater consensus is needed to re-define parameters that contribute to cumulative intervention intensity in ways that inform the design of interventions for empirical evaluation, which are ultimately clinically applicable. Nonetheless, based on the previous evidence-base, it appears intervention targeting morphosyntax is efficacious if it is delivered once daily, five days a week, for five days (Meyers-Denman, 2016; Plante et al. 2019). Although these studies were designed to evaluate efficacy of intervention, providing intervention daily does not align with current speech-language pathologist practices (see Finestack & Satterlund, 2018). Further, there is evidence that spacing dose frequency (in

Table 5.3

Summary of intervention studies evaluating elements of dosage and intensity to improve morphosyntax in young children with DLD as reported by the authors

Study	Sample size	Dose Form	Dose	Dose Frequency	Total Intervention Duration	Cumulative Intervention Intensity	Analysis
Plante et al. (2019)	*n* = 10 per group (total *n* = 20)	Enhanced conversational recasting	Single therapeutic event (p. 1234)	24 doses per session (p. 1237) Session frequency 1x day, 5x days per week (p. 1237)	Up to 25 days (p. 1237)	Mean 566.4 recasts (range = 528 – 600)	Two-tailed *t* test comparing effect sizes and post-intervention spontaneous correct morpheme use: No group differences
Meyers-Denman & Plante (2016)	*n* = 8 per group (total *n* = 16)	Enhanced conversational recasting (p. 340)	24 recasts (p. 340)	3x sessions *versus* 1x session per day (p. 340)	~5 weeks (p. 340)	600 recasts (range = 504 – 624) over an average of 750 min (range = 630 – 780) over 25 days (range = 21 – 26)	Two-tailed *t* test comparing post-intervention correct morpheme use: No group differences
Smith-Lock et al. (2013b)	*n* = 19 daily, *n* = 15 weekly (total *n* = 34)	Expressive grammar programme	Not reported	1x daily *versus* 1x weekly (p. 261)	8 days *versus* 8 weeks (p. 261)	480 minutes (p. 261)	Analysis of variance in pre-post intervention gain between groups: Weekly intervention more effective than daily.
Calder et al. (current)	*n* = 9 2PW, *n* = 20 1PW (total *n* = 29)	Explicit intervention	50 trials	1x 20-30 minute session, 2x per week *versus* 1 x 20-30 minute session, 1x per week	10 weeks	1000 trials over 400-600 minutes over 10 weeks *versus* 500 trials 200-300 minutes over 10 weeks	Logistic regression: Twice weekly more effective than once weekly

sessions) over weeks rather than days may be more effective than blocking sessions within weeks (Smith-Lock et al., 2013b).

Findings from the current study suggest there may be an advantage to providing twice the cumulative intervention intensity (in doses and minutes) over 10 weeks to improve past tense marking through explicit intervention procedures. Ullman and Pierpoint (2005) have suggested that there is benefit to teaching grammar to children with DLD through explicit intervention in the presence of an implicit learning deficit. Since the declarative memory system is responsible for learning explicit information and functions to store episodic and semantic information (Ullman, 2016), it was hypothesised that repeated exposures to stimuli (i.e., increased trials) would strengthen memories and thus be efficiently retrieved for use in expressive language. Further research is required to determine if the total amount of intervention (i.e., twice per week for 10 weeks versus once per week for 20 weeks) results in similar intervention effects. If so, this may suggest cumulative intervention intensity is more important to consider than spacing when delivering this intervention.

Limitations and Future Directions

We cannot draw conclusive inferences for clinical practice as a result of this study due to the following limitations. Firstly, evaluation of rate of progress on past tense production was a post hoc re-analysis of data from previously reported intervention studies conducted at different times. Therefore, drawing causal inferences from findings should be done with caution. Nonetheless, given the relative paucity of evidence related to dose and grammar interventions, findings from this study may provide the foundation for future randomised controlled trials with larger sample sizes. In addition, evaluating the effects of differing intervention intensities on maintenance performance is urgently needed, as this could have important implications for clinical practice. Secondly, not all participants received the intervention at the same time, so the overall provision of the intervention may have improved by the time the 1PW group received the intervention. Thirdly, the participants may not be entirely representative of the DLD population at large as they were recruited through convenience sampling from specialised educational programmes (Redmond et al., 2019). Finally, the primary outcome of this efficacy research was a relatively static measure of morphosyntax production, which may not reflect use in functional communication. Naturalistic measures of expressive grammar, such as those attained through language sample analysis, are required to report on the effectiveness of explicit grammar interventions confidently.

Conclusions

This study retrospectively, yet systematically, evaluated different dose frequencies, resulting in different intervention intensities, of an explicit grammar intervention to improve past tense production in young school-aged children with DLD. Factors relating to cumulative intervention intensity, such as dose frequency, affected the rate of change in past tense production throughout the intervention phase. However, due to the design limitations of this study, further research using large-scale randomised control trials is required before drawing strong conclusions for clinical practice. Notably, the allomorphic category of regular past tense verbs does not appear to influence response to this intervention, with all three possible allomorphs improving equivalently. Our results continue to provide evidence of the efficacy of explicit grammar interventions for children with DLD, provided both once and twice per week, and thus should be considered a viable treatment option for this clinical population.

PART TWO

Exploratory Analyses of the Relationship between Measures of Grammar and Memory

Chapter 6

The Moderating Effects of Memory in Intervention Outcomes Following Explicit Intervention for Children with Developmental Language Disorder

Chapter overview

As discussed in Chapter 1, the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005) suggests children with DLD present with impaired procedural memory necessary for implicit learning in the presence of relatively spared declarative memory responsible for explicit learning. The theory predicts that children with DLD who have poor procedural memory and average declarative memory will benefit from explicit interventions. The moderating effects of these memory systems on morphosyntax intervention outcomes have not yet been explored. Findings from Study 4 may shed light on the explanatory power of the PDH, and lend theoretical support to the SHAPE CODING system as a beneficial intervention for children with DLD.

This Chapter reports on exploratory analyses of long term (declarative and procedural) memory systems and explores the relationship with measures of grammar. The extent to which these variables account for unique variance in intervention outcomes is explored.

It is recognised that Developmental Language Disorder (DLD) is a heterogeneous and multi-faceted neurodevelopmental disorder (Bishop et al., 2016; Tomas & Vissers, 2019). There is evidence that children with DLD share comorbidities with motor (e.g., Hsu & Bishop, 2014; Iverson, 2010), attention (Ebert & Kohnert, 2011; Spaulding et al., 2008; Stevens et al., 2006), and memory (Archibald, 2017; Baddely, 2003a, 2003b; Ellis Weismer et al., 1999; Tomblin et al., 2007) deficits. In particular, the relationship between memory and language within the disorder has been widely explored (e.g., Archibald, 2017; Ellis Weismer et al., 1999; Gillam et al., 2019; Montgomery, et al., 2016). Overall, the evidence points to a complex relationship between cognitive functions and language proficiency. These findings somewhat challenge theories that account only for linguistic differences in children with DLD compared to typically developing children (e.g., Rice & Wexler, 1996; van der Lely, 2005), suggesting a much broader domain general deficit may exist. By understanding which cognitive functions are implicated in DLD, interventions that account for impaired, and harness spared processes, may continue to be developed.

Declarative/Procedural Model

From a linguistic standpoint, the basic premise of the Declarative/Procedural (DP) Model is that aspects of the differences between grammatical and lexical knowledge are linked to the distinction between two long-term memory systems: declarative and procedural memory (Ullman, 2001). The declarative memory system is responsible for learning arbitrary items of information and deriving associations between them- “it underlies the learning, representation, and use of knowledge about both facts (semantic memory) and events (episodic memory)” (Ullman, 2016, p. 955). Information may be learned rapidly, sometimes requiring only a single exposure to the stimulus to be stored in long term memory[6], however repeated exposures strengthen memories (Ullman, 2016). Therefore, declarative memory underlies learning and *explicit* (i.e., conscious) retrieval and use of facts and events. It also may underlie the learning, storage and use of the sounds and meanings of words that are both morphologically simple and complex (i.e., the 'mental lexicon') (Ullman, 2001; Ullman & Pierpont, 2005).

In contrast to the declarative memory system, the procedural memory system is responsible for the learning and computation of probabilistic information, such as sequencing. Information must be learned through repeated exposures to the stimulus. Therefore, procedural memory underlies the *implicit* (i.e., non-conscious) learning of skills and habits, including motor, cognitive and linguistic learning (Ullman, 2001). There is evidence to suggest that the hierarchically sequential and probabilistic nature of grammar in English is better suited to implicit learning (Evans et al., 2009; Meylan et al., 2017), and that grammatical abilities are strongly correlated with procedural learning in typically developing children (Lum & Bleses, 2012; Lum et al., 2012; Sengottuvel & Rao, 2013a). Procedural memory may also underlie learning and use of rule-governed computations of morphological sequencing (e.g., *talk* + *ed* → *talk**ed***) (i.e., the 'mental grammar') (Ullman, 2001; Ullman & Pierpont, 2005). Importantly, these declarative memory and procedural memory systems are not considered wholly independent; rather, learning is achieved through the competitive interaction of these two systems.

Accordingly, Ullman and Pierpoint (2005) have suggested the Procedural Deficit Hypothesis (PDH). This brain-behaviour account posits symptoms of DLD are explained by

[6] As discussed in Chapter 1, the influence of short-term memory systems, such as phonological short term memory and working memory, to the encoding, recall and recognition processes essential to the declarative memory system is acknowledged. While acknowledging the influence of working memory in declarative memory processes, for the sake of brevity, declarative memory will continue to be referred to as a long term memory system for the purpose of this thesis.

differences in the status of neural structures responsible for memory systems within language users that has resulted in a procedural learning deficit, possibly in the presence of spared declarative learning (Ullman & Pierpont, 2005). As such, it is conceivable that the way in which linguistic information is presented to children with DLD may assist with language learning. Given the competitive nature of the systems, if children with DLD indeed have impaired procedural memory, PDH posits that using cognitive strategies harnessing spared declarative memory (e.g., explicit instruction) may be more suitable than expecting children to learn language implicitly.

Measures of Declarative and Procedural Memory

There is great variability in how both declarative and procedural memory are measured in research studies, in which tasks have been standardised, developed for specific experiments, and administered across different age ranges. Further, the measures differ in the proposed construct they measure in relation to declarative and procedural memory. Table 6.1 summarises a number of instruments that have been used to measure both declarative and procedural memory to compare performance between typically developing children and those with DLD.

Declarative Memory

Declarative memory is responsible for the learning, recall and retrieval of episodic and semantic information (Squire, 2004). This memory system has been further divided into non-verbal and verbal declarative memory. One widely used instrument for measuring both aspects of declarative memory is the Children’s Memory Scale (CMS) (Cohen, 1997), a standardised, norm-referenced assessment which has been validated for administration on children aged five to 15 years. Two of the subtests (Dot Locations, Family Pictures) assess learning and retrieval of non-verbal declarative memory, and three subtests (Word Pairs, Word Lists, Stories) assess learning and retrieval of verbal declarative memory. Although the

Table 6.1

Summary of instruments used to measure declarative and procedural memory in those with and without DLD

Measure	Proposed construct/task type	Studies
Declarative memory		
Verbal declarative memory		
CMS (Cohen, 1997)		
CMS (Word Pairs Subtest)	Learning and retrieval of verbal declarative memory List learning/retrieval Learning Recall Delayed recall Delayed recognition	Conti-Ramsden et al., (2015) (*n* = 91; mean age = 9.8; age range = 8.5 – 11.4) Lum et al. (2010) (*n* = 30; mean age = 7.0; age range = 5.6 – 8.3) Lum et al. (2012) (*n* = 102; mean age = 9.9; age range = 8.5 – 11.4) Lum & Bleses (2012) (*n* =33; mean age = 7.8; age range = 6.6 – 9.7) West et al. (2018) (*n* = 101; mean age = 8.2)
CMS (Word Lists Subtest)	Learning and retrieval of verbal declarative memory List learning/retrieval Learning Recall Delayed recall Delayed recognition	Lum et al. (2015) (*n* = 115; mean age = 9.9; age range = 8.6 – 11.4)

CMS (Stories Subtest)	Learning and retrieval of verbal declarative memory Story recall/recognition	Conti-Ramsden et al., (2015) (*n* = 91; mean age = 9.8; age range = 8.5 – 11.4)
WMRAL (Hartman, 2007) (Verbal Learning Subtest)	Verbal declarative memory List learning/retrieval Story recall /recognition	Baird et al. (2010) (*n* = 90; mean age = 9.9; age range = 6.0 – 16.9) Dewy & Wall (1997) (*n* = 35; mean age = 8.2; age range = 6.0 – 10.1)
CVLT-C (Fine & Delis, 2011) (List Recall Task)	Verbal declarative memory - List learning/retrieval	Duinmeijer et al. (2012) (*n* = 73; mean age = 7.7; age range = 6.1 – 9.8)
CVLT-C (Fine & Delis, 2011) (Learning Efficiency subtest)	Verbal declarative memory - List learning/retrieval	Nichols et al. (2004) (*n* = 57; mean age = 9.2; age range = 6.0 – 15.0) Shear et al. (1992) (*n* = 24; mean age = 8.6; age range = 8.0 – 9.5)
RAVLT (Schmidt, 1996)	Verbal declarative memory - List learning/retrieval	Records et al. (1995) (*n* = 56; mean age = 20.8; age range = 17.0 – 25.0)
Vocabulary learning task (Bishop & Hsu, 2015)	Verbal declarative memory	Bishop & Hsu (2015) (*n* =56; mean age = 8.8; age range = 7.0 – 11.0)
Immediate serial recall (West et al., 2018)	Verbal declarative memory Recall for sequences of nameable pictures based on initial component of Hebb repetition learning task	West et al. (2018) (*n* = 101; mean age = 8.2)
Non-verbal declarative memory		
CMS (Cohen, 1997)		

CMS (Dot Locations Subtest)	Learning and retrieval of non-verbal declarative memory List learning/retrieval Dots and abstract pictures Faces Pictures showing everyday events	Lum et al. (2012) (*n* = 102; mean age = 9.9; age range = 8.5 – 11.4) Riccio et al. (2007) (*n* = 60; age range = 6.0 – 12.0) West et al. (2018) (*n* = 101; mean age = 8.2)
CMS (Family Pictures Subtest)	Visual declarative memory	Lum et al. (2013) (*n* =115; mean age = 9.8; age range = 8.6 – 11.4)
RMIE (Brain and Language Lab at Georgetown University)	Nonverbal declarative memory Encoding (real vs. novel) Recognition (10 and 60 sec following encoding)	Kuppuraj et al. (2016) (*n* = 60; mean age = 11.2; age range = 8.0 – 13.0)
Visual Paired Associate task (Vakil & Herishanu-Naaman, 1998)	Nonverbal declarative memory - Recall from declarative memory following encoding	Kuppuraj et al. (2016) (*n* = 60; mean age = 11.2; age range = 8.0 – 13.0)
WMRAL (Hartman, 2007) (Visual Learning Subtest)	Nonverbal declarative memory List learning/retrieval Dots and abstract pitcures Pictures showing everyday events	Baird et al. (2010) (*n* = 90; mean age = 9.9; age range = 6.0 – 16.9)
CANTAB (Sandberg, 2011)	Nonverbal declarative memory List learning/retrieval	Bavin et al. (2005)(*n* = 42; mean age = 4.5; age range = 4.0 – 5.5) Lum et al. (2010) (*n* = 30; mean age = 7; age range = 5.6 – 8.3)

Nonverbal paired associate learning task (Bishop & Hsu, 2015)	Nonverbal declarative memory	Bishop & Hsu (2015) (*n* = 56; mean age = 8.8; age range = 7.0 – 11.0)
Immediate serial recall (West et al., 2018)	Non-verbal declarative memory Recall for sequences of abstract symbols Based on initial component of Hebb Repetition learning task	West et al. (2018) (*n* = 101; mean age = 8.2)
Combined verbal and non-verbal declarative memory		
Modified-RMIE (Brain and Language Lab at Georgetown University)	Verbal and nonverbal declarative memory Encoding (real words vs. nonwords; real vs. novel objects) recognition/initial learning (10 minute delay) retention (24 hours)	Lukács et al. (2017) (*n* = 42; mean age = 8.9)
Procedural memory		
Verbal procedural memory		
Hebb repetition learning task	Verbal sequence learning	Hsu & Bishop (2014) (*n* = 68; mean age = 8.8; age range = 7.0 – 11.0) West et al. (2018) (*n* = 101; mean age = 8.2)
SRT task (Gabriel et al., 2014)	Verbal procedural memory Auditory statistical learning SOC 8 sequence: 1-3-4-2-3-1-2-4	Gabriel et al. (2014) (*n* = 32; mean age = 9.9; age range = 6.8 – 13.2)
Artificial Grammar Learning task	Verbal implicit/statistical/procedural learning	Lukács & Kemény (2014) (*n* = 29; mean age = 9.1)
Verbal procedural memory task (Saffran, et al., 1997)	Auditory statistical learning	Evans et al. (2009) (*n* =113; mean age = 8.8; age range = 5.6 – 14.3)

		Mayor-Dubois et al. (2014) (*n* = 18) (mean age = 10.0; age range = 8.0 – 14.0)
Verbal SRT task (Hartman, Knopman, & Nissen, 1989)	Verbal implicit sequencing Four nameable pictures using probable sequence 121342314324 & improbable sequence 123413214243 (Schwaneveldt & Gomez, 1998)	West et al. (2018) (*n* = 101; mean age = 8.2)
Nonword repetition priming task (Gupta et al., 2004)	Verbal procedural learning Five-syllable nonwords presented 20 times over 9 experimental blocks For each block, 10 of 20 nonwords primed, and 10 were nonprime (only occurred once)	Lee & Tomblin (2015) (*n* = 48; mean age = 22.2; age range = 19.0 – 25.0)
Non-verbal procedural learning		
Nissen & Bullemar's SRT task (1987)	Visuo-spatial SRT- nonverbal procedural memory Visual statistical learning SOC 8 sequence: 1-3-4-2-3-1-2-4 (Gabriel et al., 2012) SOC 12 sequence: 21323413412 (Kuppuraj et al., 2016) SOC 12 sequence A: 314324213412; sequence B: 431241321423 (Shanks et al., 2003)	Conti-Ramsden et al., (2015) (*n* = 91; mean age = 9.8; age range = 8.5 – 11.4) Kuppuraj et al. (2016) (*n* = 60; mean age = 11.2; age range = 8.0 – 13.0) Kemény & Lukács (2010) (Adults: *n* = 16; mean age = 20.4) (Children: *n* = 32; mean age = 11.3) Mayor-Dubois et al. (2014) (*n* = 18) (mean age = 10.0; age range = 8.0 – 14.0)Gabriel et al. (2012) (*n* = 30; mean age = 10.3; age range = 7.6 – 12.6)

		Lum & Bleses (2012) (*n* =33; mean age = 7.8; age range = 6.6 – 9.7) West et al. (2018) (*n* = 101; mean age = 8.2)
SRT task (Tomblin et al., 2007 adapted from (Thomas & Nelson, 2001)	Visuo-spatial SRT- nonverbal procedural memory Sequence 1-3-2-4-4-2-3-4-2-4	Tomblin et al. (2007) (*n* = 132; mean age = 14.9) Hsu & Bishop (2014) (*n* = 68; mean age = 8.8; age range = 7.0 – 11.0)
SRT task (Meulemans et al., 1998)	Visuo-spatial SRT- nonverbal procedural memory - SOC sequence: 121423413243	Lukács & Kemény (2014) (*n* = 29; mean age = 9.1)
SRT task (Gabriel et al., 2011)	Visuo-spatial SRT- nonverbal procedural memory Statistical learning through probabilistic sequencing SOC 12 sequence A: 3-4-2-3-1-2-1-4-3-2-4-1; sequence B: 3-4-1-2-4-3-1-4-2-1-3-2 (Gabriel et al., 2013)	Gabriel et al. (2011) (*n* = 32; mean age = 10.2; age range = 7.8 – 13.2) Gabriel et al. (2013) (*n* = 46; mean age = 9.6; age range = 7.1 – 11.9)
SRT task (Lum & Kidd, 2012)	Visuo-spatial SRT- nonverbal procedural memory Statistical learning through probabilistic sequencing Sequence 4-2-3-1-3-2-4-3-2-1	Lammertink et al. (2020) (n = 70; mean age = 9.1; age range = 7.7 – 10.3)

ASRT task (Hedenius et al. 2011)	Visuo-spatial SRT- nonverbal procedural memory Visual statistical learning Random blocks are interspersed throughout sequenced blocks 8 sequence: 1r2r4r3r	Hedenius et al. (2011) (*n* =48; mean age = 10.0)
AD-SRT task (Sengottuvel & Rao, 2013b)	Visuo-motor learning: Progress in sequence learning over trials Compares reaction times on random trials to sequenced trials Sequence A: 1324124324, sequence B: 1324124324	Sengottuvel & Rao (2013a) (*n* =40; mean age = 9.8; age range = 9.1 – 10.5) Kuppuraj & Rao (2014) (*n* = 56; mean age = 10.1)
Interleaved SRT task (Rauch et al., 1997)	Visuo-spatial SRT- nonverbal procedural memory Sequence 1-2-1-4-2-3-4-1-3-2-4-3 presented in the following block order: Random-Pattern-Random-Pattern- Random-Pattern-Random	Lee & Tomblin (2015) (*n* = 48; mean age = 22.2; age range = 19.0 – 25.0)
Pursuit Rotor Task (Life Science Associates, Inc., Bayport, New York)	Motor learning- nonverbal procedural memory	Hsu & Bishop (2014) (*n* = 68; mean age = 8.8; age range = 7.0 – 11.0) Lee & Tomblin (2015) (*n* = 48; mean age = 22.2; age range = 19.0 – 25.0)
Weather prediction task (Knowlton et al., 1994)	Probabilistic category learning	Kemény & Lukács (2010) (Adults: *n* = 16; mean age = 20.4) (Children: *n* = 32; mean age = 11.3)

		Lee & Tomblin (2015) (*n* = 48; mean age = 22.2; age range = 19.0 – 25.0)Lukács & Kemény (2014) (*n* = 29; mean age = 9.1)

Notes. AD-SRT = Adapted serial reaction time; ASRT = Alternate serial reaction time; CANTAB = Cambridge Neuropsychological Test Automated Battery; CMS = Children's Memory Scales; CVLT-C = California Verbal Learning Test for Children; RAVLT = Rey Auditory Verbal Learning Test; RMIE = Recognition memory after incidental encoding; SRT = Serial reaction time; SOC = Second order conditional; WMRAL = Wide Range Assessment of Memory and Learning. Mean age and age range in years is reported where values were available.

CMS is perhaps the most widely used instrument for measuring declarative memory (e.g., Conti-Ramsden et al., 2015; Lum et al., 2013; West et al., 2018), other experimental measures have been developed.

Most experimental measures of declarative memory involve elements of encoding and recognition (e.g., Hedenius et al., 2013) as well as serial recall based on Hebb repetition tasks (West et al., 2018). Indeed, Lee (2018) has suggested that experimental measures of declarative learning may be more sensitive to the effects of encoding, recall and recognition that underlie declarative memory. Nonetheless, standardised measures of declarative learning, such as the CMS, have been used to verify the presence of spared declarative memory in typically developing children and children with DLD, and the accessibility of such a tool facilitates the replication of research findings.

Procedural Memory

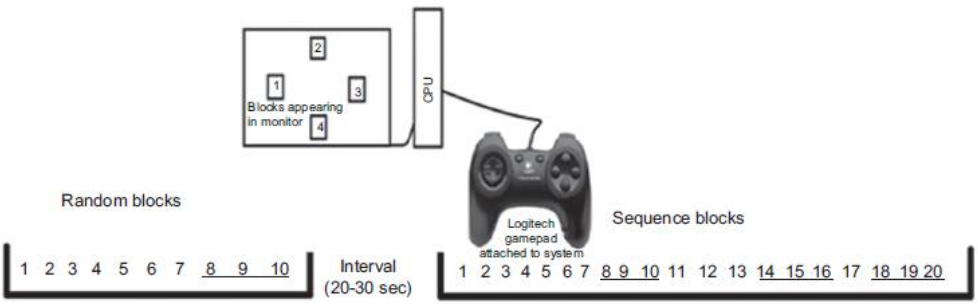
Procedural memory is responsible for rule-learning and for acquiring and performing skills involving sequences (Shanks et al., 2005). The establishment of memories through procedural learning, and the memories themselves, are not generally available to conscious access. For example, an infant learning to walk. Typically, procedural memory is assessed using a serial reaction time (SRT) task. These are designed to assess implicit learning of visuo-spatial sequences (Nissen & Bullemer, 1987). Children are usually required to respond to an indicator that matches the location of visual stimulus in a triplet sequence delivered repeatedly over a series of blocks (see Figure 6.1).

Importantly, the visual stimulus in the triplet during blocks is repeatedly presented without the participant knowing the sequence is predefined. After the predefined sequence has been presented multiple times over a series of blocks, a random pattern of stimuli is presented. Following successive trials, responses to sequenced blocks are hypothesised to be shorter and more accurate than responses to random trial sets, indicating sequence learning.

Therefore, if there is sequence learning, response times for locating the item during the predefined sequenced blocks will be shorter than for locating the item during random blocks. This is considered evidence of intact procedural learning. There are also tasks that use verbal stimuli, such as word segmenting, which have been used to test procedural memory (e.g., Evans et al., 2009; Karuza et al., 2013), and have shown differences in learning between typically developing and DLD populations.

Figure 6.1

Image depicting a non-verbal serial reaction time task. Children are required to press a Logitech gamepad button that matches the location of the visual stimulus in Sengottuvel and Rao (2013b)[7]



It has been suggested other factors may be implicated in tasks that assess procedural learning given the complex and multi-faceted nature of the memory system (Arcuili, 2017). Although Sengottuvel and Rao (2013b) found that attention and inhibition were equivalent across groups of DLD and typically developing children when participating in the task, West et al. (2020) suggested that evidence of procedural learning deficits may indeed reflect attentional difficulties instead of a procedural learning deficit in children with DLD. A study of 112 children found that once effects for attention were controlled, there was no significant

[7] Please see copyright permission in Appendix H

relationship between procedural memory and measures of language attainment across all participants (West et al. 2020). The authors suggested that previous studies that have found a significant relationship between procedural learning and language abilities may be confounded by the participants' ability to maintain sustained attention during the task. Further, in a study of 101 children aged between seven and eight years, West et al. (2017) found that there were no relationships between procedural learning and language attainment, and the SRT task used in the study showed poor test-retest reliability, suggesting the task itself may indeed be invalid. The authors surmised that fatigue and disengagement cause issues with validity of task, particularly the administration of long, repetitive and seemingly meaningless information.

Interestingly, Hirshorn et al. (2012) found procedural memory tasks that accounted for differences in children who had experienced hearing loss compared to those who had typical hearing were dependent entirely on the use of verbal stimuli; whereas non-verbal tasks yielded no group differences. Von Koss Torkildsen et al. (2018) explored this finding further and found sequence learning could be evaluated between groups of individuals with language deficits if task items include highly familiar stimuli with automised verbal labels. However, using unfamiliar items and non-automised labels yielded non-significant between group results.

Kuppuraj et al. (2018) developed an audio-visual SRT task in an attempt to account for issues with validity and reliability, as well as the attentional and motivational issues associated with children completing the task. Notably, the task uses verbal stimuli rather than non-verbal items. The authors asserted that the use of audio stimuli is more aligned with exploring the relationship of procedural learning and language. In essence, the task uses highly familiar, automised verbal labels to form predetermined sequences, much like an artificial grammar (e.g., Evans et al. 2009). It was also assumed the use of verbal labels would enhance engagement in younger users. Importantly, test-retest reliability was assessed in a pilot study with adults, and yielded positive results (*r* = .67), suggesting the tool may show improved validity to measure procedural learning compared to tools used in earlier studies.

Additional benefits of this SRT task include the use of deterministic as well as probabilistic sequences. As pointed out by West et al. (2020), most studies using SRTs to evaluate procedural learning use only deterministic sequences compared to random sequences. Given that deterministic sequences use a fixed target to measure reaction times, it may be difficult to separate accurately responding to targets as non-declarative learning from declarative learning (see Shanks et al., 1994; Shanks & Johnstone, 1999). Alternatively, the use of probabilistic sequences, where target positions are not pre-determined, minimises the influence of drawing upon declarative learning skills. That is, with the use of deterministic sequences, the stimulus is presented in the same location through the task, so a child may memorise the location of a stimulus item through rapid and repeated exposure throughout. This type of learning is thought to be aided through the declarative memory system. Much like many multiple choice language assessments (e.g., the Test for Reception of Grammar), the location of the correct choice for each test item is deliberately randomised to counteract the influence of these kinds of learning effects for test results. Ultimately, the learning of information through procedural memory is a multicomponent ability, which is likely to be implicated by attention, processing speed, and long- and short-term memory function, with variability between individuals in the efficiency of each of these functions (Arcuili, 2017).

Research into the Procedural Deficit Hypothesis

Few published studies have empirically tested the PDH directly for children with DLD. Tomblin et al. (2007) evaluated procedural learning abilities of 85 adolescents with DLD compared to aged-matched peers using an SRT task developed specifically for the study, modelled after an SRT developed by Thomas and Nelson (2001). Response times indicated slower learning rates for those with DLD, and participants taking significantly more trials to learn patterns than typically developing peers. Where grammar performance was associated with lower sequential pattern learning, poor vocabulary was not directly associated with performance on procedural memory tasks. These findings align with the PDH.

A meta-analysis demonstrated the extent to which seven to 15 year old children with DLD showed deficits in procedural learning on a SRT task compared to age-matched typically developing peers (Lum et al., 2014). The range of tasks included Nissen and Bullemer's (1987) SRT task as well as those developed for specific experiments (e.g., Gabriel et al., 2011). All tasks included in the meta-analysis used a rebound in reaction time when a random block is introduced following sequenced blocks, such as the Nissen and Bullemer (1987) SRT task. Results from the meta-analysis align with the PDH, in that children with DLD had significantly slower reaction times on the SRT tasks indicating impaired procedural learning. Further, increased exposure to stimuli and higher age resulted in smaller effect sizes between groups. These findings suggest procedural learning may improve with increased trials, and that declarative memory may serve as a compensatory system with increased age.

Lee and Tomblin (2015) investigated procedural learning across a range of tasks in 48 young adults with a range of language abilities, and found that poor language was associated with poor performance on a range of procedural memory tasks tapping into various domains, including an interleaved SRT task (Rauch et al., 1997) (visuo-spatial domain), a pursuit rotor task (Mueller, 2010) (motor domain), a weather prediction task (Knowlton et al., 1994) (cognitive domain), and a nonword repetition priming task (Gupta et al., 2004) (linguistic domain). Evidence that variance in language abilities was associated with procedural learning in different domains perhaps provides further support that indeed procedural memory is implicated in language functioning. The authors suggest though, that rather than constituting a clinically distinct population as suggested by the PDH, individuals with language difficulties as a result of a procedural learning deficit represent the lower end of a continuous spectrum of procedural/language abilities (e.g., Dollaghan, 2011; Leonard, 2009).

Lukács et al., (2017) examined declarative learning and retention in 9-year-old children with DLD compared to age matched typically developing children in nonverbal and verbal domains using the Modified Recognition Memory after Incidental Encoding task (Brain and Language Lab at Georgetown University). For non-verbal declarative memory, the DLD and typically developing groups showed above-chance performance for both learning and retention tasks. Results for verbal declarative memory were similar, with the exception that children with DLD had difficulty learning new items compared to typically developing children. Nonetheless, although immediate retention (i.e., a matter of minutes) was impaired in children with DLD, longer-term retention (i.e., overnight) was similar to age-matched, typically developing peers. These findings are similar to those of Bishop and Hsu (2015), who used a novel vocabulary learning task to measure verbal declarative memory, and a novel non-verbal paired association task to measure non-verbal declarative memory. This suggests that consolidation of declarative learning takes longer in children with DLD.

Studies have also provided evidence to counter the PDH. Gabriel and colleagues have demonstrated that children with DLD may present with procedural learning abilities equivalent to typically developing children. For example, Gabriel et al. (2011) found that 16 children with DLD and 16 typically developing children aged between seven and 13 years showed no between-group differences on performance on a visuo-spatial probabilistic SRT task. Further, Gabriel et al. (2012) found similar results comparing 15 children with DLD and 15 typically developing children on a visuo-spatial SRT task that used deterministic sequences. Gabriel et al. (2014) also compared 16 children with and without DLD on both a visuo-spatial SRT task and an auditory SRT task, and found no group differences. In all of these studies, both children with DLD and typically developing children demonstrated evidence of sequence learning on the measures used, which suggests that perhaps language difficulties for children with DLD are not underpinned by a procedural learning deficit as the PDH predicts. Similar results were reported by Mayor-Dubois et al. (2014) on both visuo-spatial and auditory SRT tasks, as well as by Lum and Bleses (2012) who measured procedural learning on a visuo-spatial SRT task with Danish speaking children with and without DLD. Notably, however, Gabriel et al. (2013) found that on procedural learning tasks that use second-order conditional sequences, which are longer and more complex than other measures (e.g., Nissen and Bullemer's SRT task), children with DLD showed longer reaction times with no evidence of sequence learning when compared to typically developing peers. Therefore, the consideration of instrumentation when considering whether or not procedural learning is indeed impaired in children with DLD is important and ongoing.

Finally, a recent study aimed at replicating findings, whether for or against the PDH, was unable to produce a conclusive result (Lammertink et al., 2020). Thirty five children with DLD and 36 typically developing children with a mean age of 9;1 years were compared on their performance on a visuomotor SRT (Lum & Kidd, 2012) as well as exploring the relationship between task performance and grammatical proficiency. Findings revealed no case for or against group differences in the sensitivity to detect sequential regularities, with both groups revealing evidence of sequence learning as well as evidence of no sequence learning. A similar pattern was found with regard to the association between performance on the SRT and grammar proficiency. These findings mirrored those in an accompanying meta-analysis to the experimental study. Again, the equivocality of recent findings reiterates the need to further explore the predictions of the PDH, especially in the context of influencing intervention outcomes to potentially inform clinical practice.

The Current Study

Overall, there is evidence to suggest that children with DLD have impaired procedural memory compared to typically developing peers, and this may account for observable receptive (Conti-Ramsden et al., 2015) and expressive (Hedenius et al., 2011; Tomblin et al., 2007) grammar difficulties. Findings also suggest that children with DLD may show improved learning of probabilistic information that is typically learned implicitly (e.g., grammatical rules) (Evans et al., 2009), if it is presented explicitly to harness relatively spared declarative memory, especially in the non-verbal domain (Lum et al., 2015). Further, spared non-verbal declarative memory may serve to support learning information explicitly in the presence of deficits in working memory (Lum et al., 2015). However, findings are equivocal (see Gabriel et al., 2011, 2012, 2014; Lum & Bleses, 2012; Mayor-Dubois et al., 2014). Further, studies using traditional SRT tasks have found low reliability between measures of procedural memory (West et al., 2018). These findings have implications for further investigating the core claim of the PDH, which suggests that deficits in procedural memory are a causal risk factor for DLD (Ullman & Pierpont, 2005). Finally, most studies are cross-sectional or correlational, which impacts the ability to draw causal inferences. That is, these studies do not analyse the relationship between memory systems and intervention outcomes.

The PDH posits children with DLD may be better supported to learn linguistic information when it is presented explicitly to harness the declarative memory system. However, this hypothesis has not been tested using experimental intervention studies. This is the impetus for the current programme of research: to inform clinical practice, it is necessary to conduct theoretically informed experimental intervention studies to better understand how to improve language outcomes with intervention in the presence of proposed spared and impaired processes. That is, for children with DLD, can language be improved by offering information in an explicit way?

This study included analysis of data from previously reported intervention studies (Chapters 3-5; Studies 1-3) to answer the following exploratory research question: In accordance with predictions from the PDH, do declarative memory and procedural memory account for unique variance in pre-post intervention outcomes?

It was hypothesised, in general, children with DLD will have average declarative memory and low procedural memory. Given the way in which procedural memory was measured (see below in Methods), procedural memory will be negatively associated with pre-post intervention progress as children with low procedural memory and average declarative memory will show greater pre-post intervention improvement following explicit intervention.

Method

Participants

Data from all children aged 5;6-7;6 years who completed the intervention (n = 29), reported in previous Chapters, were included in Study 4.

Materials

Predictor Variables (Memory Measures)

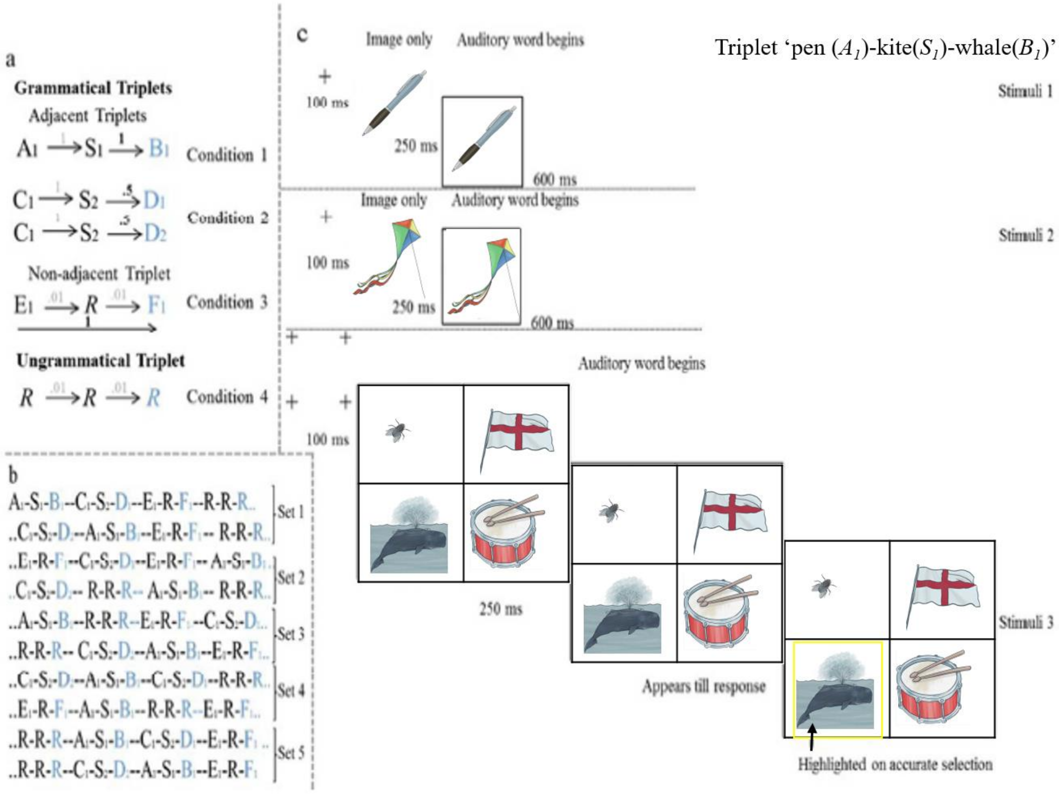
Declarative Memory. Declarative memory was measured using the Children's Memory Scales (CMS) (Cohen, 1997). Non-verbal declarative memory was measured using the Dot Locations subtest which measures learning and retrieval of non-verbal declarative memory through immediate, and delayed recall, and recognition of test items. Verbal declarative memory was measured using the Word Pairs subtest which measures learning and retrieval of verbal declarative memory through immediate, and delayed recall, and recognition of test items. Median internal consistency reliability ranges from .71-.91 for Non-verbal and Verbal subtests, .72-.84 for Delayed Recall, .75-79 for Delayed Recognition. The test has appropriate construct validity. This assessment is completed in approximately 30 minutes.

Procedural Memory. Procedural memory was assessed using a recently developed audio-visual SRT task (Kuppuraj et al., 2018). Similar to visuo-spatial SRT tasks (e.g., Nissen & Bullemer, 1987), procedural learning is measured by comparing reaction times to prompted items during blocks of sequenced blocks compared to random blocks, with a series of triplets presented in each block. For each triplet, a high frequency noun was presented visually and verbally in isolation. The visual presentation lasted for 250ms before the verbal presentation and highlighting of the visual for a total of 870ms. This procedure was repeated for a second high frequency noun. The third item in the triplet was presented with three distractors in a 2x2 grid for 250ms. Participants were required to select the named item as quickly as possible. The participants' reaction time was then measured. This process was continued for the next triplet where the target item randomly positioned in the 2x2 grid (see Figure 6.2).

A total of eight blocks with 30 sequences were administered. The first six blocks consisted of sequences using different types of statistical patterns. For the task used in the current study, deterministic sequence was included, where A + B always predicted C, i.e., 'pen' followed by 'kite' predicted 'whale'. A probabilistic sequence was also included, where D + E either predicted F or G, i.e., 'drum' followed by 'bread' predicted either 'swing' or 'flag'. It was expected that reaction times would decrease over the first six blocks. It was also expected that reaction times would be faster for deterministic triplets than for probabilistic triplets, and that the inclusion of probabilistic triplets would minimise the influence of declarative memory in learning. The final two blocks consisted of random triplets. It was anticipated that reaction times would increase during random block

Figure 6.2

Figure 6.2a Design of test triplets. Figure 6.2b Example of triplets’ presentation within a set. Five sets make a block. Figure 6.2c Example of stimuli presentation of deterministic triplet ‘pen(A_1)-kite(S_1)-whale(*B1*)’ adapted from Kuppuraj et al. (2018)[8]



The SRT task was administered via Microsoft SurfacePro 4 tablet and run using MATLAB Version: 9.1.0.441.6.55 (2016). The participants selected the third item in the triplets using a stylus pen. A practise block was completed prior to the six sequenced and two random blocks. The task took approximately 30 minutes to administer for each participant. Results from a pilot study with adults demonstrated acceptable test-retest reliability ($r = .67$).

Indices of procedural learning from the SRT task were extrapolated using regression discontinuity, rather than using the average reaction time across random blocks minus the

[8] Please see copyright permission in Appendix I

average reaction time across sequence blocks. This approach is thought to increase sensitivity in the measure of procedural learning (Kuppuraj et al., 2018), and was achieved by using the random triplets as a control for increased reaction times during the sequenced blocks. Reaction time slopes were plotted for both the deterministic triplet and the probabilistic triplets across the sequenced blocks and compared to the reaction time slope when the sequenced blocks were broken in the final two random blocks. A significant difference in slopes would determine whether learning had occurred. That is, there is a detectable rebound in reaction time during the random blocks after the sequenced blocks. Corresponding *t* values and *p* values for deterministic, probabilistic and random triplets were outputted. The higher the *t* value for sequenced blocks, the more evidence there was an increase in reaction time during the random block compared to the sequenced blocks. The threshold for learning was set at a *t* value ≥2.0 ($p < .05$) as per the pilot study (Kuppuraj et al., 2018).

Outcome Variables (Language Measures)

Expressive Grammar. The Structured Photographic Expressive Language Test (SPELT-3) (Dawson et al., 2003) was administered both pre- and post-intervention as an expressive grammar measure. The SPELT-3 was normed on 1580 children aged four to nine years. The test measures expressive morphosyntax using 54 items across a range of structures. It has strong test-retest reliability (.940) and appropriate construct validity. This assessment is completed in approximately 15 minutes.

Receptive Grammar. The Test of Reception for Grammar 2nd Edition (TROG-2) was used to assess receptive grammar. The test was normed on 792 children aged four to 16 years. Test blocks measure a total of 20 different grammatical structure contrasts. It has strong internal consistency reliability (r =.877) and appropriate construct validity. This assessment is completed in approximately 15 minutes.

Past Tense Production. An adapted version of the Grammar Elicitation Test (GET) (Smith-Lock et al., 2013) was used to assess past tense production. The criterion-referenced test was designed to elicit multiple instances of specific expressive morphosyntax targets, including 30 probes targeting the past tense *–ed*. All possible allomorphs are included (i.e. [d], [t] and [əd]), and targets are distributed equally within each category of probe. The past tense subset of the GET is administered in seven minutes.

z scores

Raw scores from each assessment were converted into *z* scores relative to the group mean for analysis. The primary motivation for this was to allow for all variables to be analysed on the same scale. That is, the *t* scores yielded for the SRT again represent learning on a different scale to the raw scores from the SPELT-3, TROG-2, GET and CMS raw scores. Therefore, using *z* scores as an index of how far away each participant scored from the group average in units of standard deviations was appropriate. That is, for each measure, *z* scores were calculated for each participant by subtracting the sample mean raw score from the individuals' raw score, then dividing by the standard deviation of the sample.

Further motivation for using *z* scores was to allow the creation of composite scores for memory measures from the various subtests within each measure. For example, raw scores from the Learning, Total, and Recall components of the Dot Locations subtest of the CMS were summed from the *z* transformed raw scores to yield a non-verbal declarative memory composite variable to ensure each subtest was equally weighted (e.g., Ackerman & Cianciolo, 2000). Prior to converting transformed *z* scores into composites, data from each participant were pooled and correlations were run between each subtest for both the Dot Location and Word Pairs subtest to determine whether it were appropriate to create a composite. Out of a possible nine correlations for declarative memory, eight were significant ($r > .900$) with the only non-significant correlation being between Learning and Delay on the Word Pairs subtest.

This was considered sufficient evidence to create composite non-verbal and verbal declarative memory scores for analysis.

Procedure

Data were collected over three ~45 minute sessions within one week. Standardised grammar assessments (SPELT-3, TROG-2) were administered the first day, and the GET and CMS were administered on the second, with the GET serving as the elapsed time between recognition and recall tasks on the CMS. The SRT was administered on the third day. For the pre- post-intervention change in score data on grammar measures, the pre-intervention testing point was completed following a baseline period of either five-, seven-, or nine-weeks after initial assessment. The post-intervention testing point was administered following 10 weeks of intervention. Pre- to post-intervention progress on grammar measures were used as an outcome variable where the score was transformed by subtracting pre-intervention scores from post-intervention scores.

Statistical Analyses

To test whether declarative memory and procedural memory accounted for unique variance in pre- to post-intervention progress as measured by grammar scores, multiple linear regression models were run, with declarative memory and procedural memory scores as predictor variables, and intervention progress as outcome variables. Pre-intervention scores for the relevant outcome variable were also included in the regression models to evaluate whether pre-intervention performance accounted for variance in intervention outcomes. Since this was an exploratory analysis, all predictors were entered into the regression simultaneously to determine: how much variance in pre-post intervention progress can be accounted for by pre-intervention and memory scores in combination, and; the extent to which each predictor uniquely contributes to the regression model. Assumption testing for multiple linear regressions requires $n = 50 + 8(k)$ (where k is the number of predictors) to find medium effects (Tabachnick & Fidell, 2007). Since the sample size in this study was n = 29, post hoc power analysis indicated that the model wouldonly be adequately powered to find very large effects (i.e., $f^2 > .40$). This is a limitation of the study.

Results

Means, standard deviations and the range of scaled, criterion-referenced and *t* scores on the variables of interest are presented in Table 6.2. The mean scaled scores on the SPELT-3 and TROG-2 were at least 1.5 standard deviations below the norm reference mean of 100 indicating expressive and receptive grammar difficulties compared to the norm-referenced sample. Conversely, non-verbal declarative memory scores were within one standard deviation on the norm reference mean of 10 indicating non-verbal declarative memory within the average range for the age expected scores of the participants. Overall, scaled verbal declarative memory scores were lower than non-verbal. For procedural memory, both mean deterministic and probabilistic *t* scores were below the 2.00 threshold for learning.

Memory Accounting for Unique Variance in Intervention Progress

Multiple regression analyses were used to assess whether declarative memory or procedural memory predicted pre-post intervention improvement on grammar scores of expressive grammar (SPELT-3), receptive grammar (TROG-2), and past tense production (GET -ed).

A summary of the coefficients and correlations for each predictor in the expressive grammar (SPELT-3) model is presented in Table 6.3. In combination, pre-intervention SPELT-3 scores, and declarative and procedural memory systems accounted for 52.3% of variance in expressive grammar, $R^2 = 0.523$, adjusted $R^2 = .419$, $F(4,24) = 5.045$, $p = .003$, $f^2 = 1.12$. Pre-intervention SPELT-3 scores were the only significant predictor, accounting for

Table 6.2

Summary of memory and grammar measures: scaled, criterion-referenced and t values

Variable	Mean	Standard Deviation	Range
Memory measures			
Non-verbal declarative memory (CMS-Dot Locations)			
Learning	8.40	3.26	3 – 15
Total	8.73	3.18	4 – 16
Delay	9.23	2.69	4 - 14
Verbal declarative memory (CMS-Word Pairs)			
Learning	6.43	2.79	1 – 11
Total	7.07	2.62	1 – 11
Delay	7.43	3.02	2 – 12
Recognition	7.50	4.48	1 – 13
Procedural memory (SRT-Deterministic)	1.00	1.07	-1.46 – 2.82
Procedural memory (SRT-Probabilistic)	-1.02	1.02	-3.32 – 0.92
Grammar measures			

Expressive grammar (SPELT-3)	72.43	16.04	40 – 105
Receptive grammar (TROG-2)	76.97	11.24	55 - 111
Past tense production (GET-ed) /30	7.13	4.72	1 – 16

Notes. CMS = Children's Memory Scale (Cohen, 1997); GET-ed = Grammar Elicitation Test: regular past tense (Smith-Lock et al. 2013a); SPELT-3 = Structured Photographic Expressive Language Test 3rd Edition (Dawson et al., 2003); SRT = Serial Reaction Time task (Kuppuraj et al., 2018); TROG-2 = Test for Reception of Grammar 2nd Edition (Bishop, 2003). Scaled scores are reported for the CMS-Dot Locations and Word Pairs, SPELT-3, and TROG-2. Criterion-referenced scores are reported for the GET-ed. *t* values are reported for the SRT-Deterministic and Probabilistic.

Table 6.3

Regression analysis modelling pre-intervention expressive grammar and memory measures as predictors of pre- to post-intervention progress of expressive grammar (SPELT-3)

Variable	B [95% CI]	Beta	sr^2	p
Pre-intervention expressive grammar (SPELT-3)	-.815 [-1.156, -.475]	-.832	.511	**< .001**
Non-verbal declarative memory	-.053 [-.056, .162]	.156	.021	.323
Verbal declarative memory	.037 [-061, .136]	.123	.013	.439
Procedural memory-Deterministic	-.244 -.574, .086]	-.255	.048	.140
Procedural memory-probabilistic	.181 [-.143, .505]	.188	.028	.260

Table 6.4

Regression analysis modelling pre-intervention receptive grammar and memory measures as predictors of pre- to post-intervention progress of receptive grammar (TROG-2)

Variable	B [95% CI]	Beta	sr^2	p
Pre-intervention receptive grammar (TROG-2)	-.214 [-.653, .224]	-.233	.042	.322
Non-verbal declarative memory	.023 [-.114, .160]	.070	.005	.729
Verbal declarative memory	.062 [-.082, .205]	.210	.033	.383
Procedural memory-Deterministic	-.137 [-.512, .238]	-.149	.024	.458
Procedural memory-probabilistic	-.245 [-.635, .146]	-.264	.068	.208

51.1% of the unique variance in pre-post intervention expressive grammar progress. See Table 6.4 for a summary of the model for pre-post intervention progress of receptive grammar. Predictors accounted for a non-significant 17.0% of variance in receptive grammar, $R^2 = .170$, adjusted $R^2 = -.010$, $F(5,23) = .943$, $p = .472$, $f^2 = .111$.

A summary of the model for re- post-intervention progress on past tense production is reported in Table 6.5. Memory systems accounted for a non-significant 21.3% of variance in past tense production, $R^2 = .213$, adjusted $R^2 = .042$, $F(5, 23) = 1.248$, $p = .320$, $f^2 = .045$.

Table 6.5

Regression analysis modelling pre-intervention past tense production and memory measures as predictors of pre- to post-intervention progress of past tense production (GET)

Variable	B [95% CI]	Beta	sr^2	*p*
Past tense production (GET)	-.270 [-.695, .155]	-.257	.070	.202
Non-verbal declarative memory	.086 [-.059, .231]	.245	.062	.231
Verbal declarative memory	.044 [-.085, .173]	.140	.021	.487
Procedural memory-Deterministic	.104 [-.294, .502]	.105	.013	.593
Procedural memory-probabilistic	-.218 [-.626, .189]	-.220	.065	.279

Discussion

The underlying premises and predictions of the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005) were explored by analysing the relationship between measures of pre-intervention grammar and memory, and pre-post intervention grammar progress. The extent to which declarative memory and procedural memory accounted for unique variance in grammar outcomes was evaluated. It was hypothesised that if procedural memory was negatively associated with pre-post intervention progress, the predictions of the PDH would be supported. That is, children with low procedural memory and average declarative memory will show greater pre-post intervention improvement because explicit intervention circumvents a procedural learning deficit in the presence of spared declarative memory.

Memory Accounting For Unique Variance in Grammar Outcomes

There were few significant findings. Inspection of the data shows obvious differences in memory scores, with the current sample of DLD children performing more strongly on scaled scores of non-verbal declarative memory. This is consistent with findings from Lum et al. (2012) and Lum et al. (2014), suggesting that learning for this memory system is spared for non-verbal information. However, no memory measures appeared to account for variance in grammar outcomes following intervention, with the only finding of significance being pre-intervention expressive grammar (SPELT-3) scores predicting pre-post intervention progress on the same measure. Given the lack of significant associations between other measures of grammar and memory, the significant negative association between pre-intervention and pre-post intervention SPELT-3 scores may be a case of regression to the mean.

Preliminarily, these findings may suggest that there is no advantage for learning explicitly for children with low procedural memory. This may be interpreted as a rejection of the PDH. On the other hand, given that previous chapters have shown that the theoretically motivated intervention (TheMEDI) improves past tense marking for the children in the current sample, perhaps explicit teaching is equally beneficial for children with DLD regardless of procedural memory status since no measure of procedural memory accounted for variance in intervention outcomes.

An alternative explanation may suggest the non-significant findings are due to the ways in which procedural memory was measured. The mean *t* score for procedural learning among the entire sample was below 2.00, indicating that as a group, this sample of DLD still performed below the threshold for learning with reference to the pilot study (Kuppuraj et al., 2018). Therefore, although some children did demonstrate procedural learning with the upper range of scores being above 2.00, the majority of children still performed below the learning threshold. The majority of children indeed demonstrated low procedural memory on the audio-visual SRT task. Perhaps then, the analysis could not truly capture a difference in the benefits of intervention for children with lower versus higher capacity for procedural memory. If the PDH stands true, this may in fact never be possible. That is, although some may, in general, children with DLD are unlikely to show proficiency in procedural learning. As pointed out by Lee and Tomblin (2015), it may indeed be likely that procedural memory is implicated in language proficiency; however, rather than DLD representing a distinct clinical population based on categorical procedural memory functioning, perhaps the children who exhibit lower grammar skills than others also demonstrate lower proficiency in procedural learning. That is, these children represent the lower end of a continuous spectrum of procedural/language learning abilities (see Dollaghan, 2011; Leonard, 2009).

Another explanation for the lack of findings is methodological. The current sample size was n = 29, which meant the regression analyses had low power to reveal any findings except very large effects. This means small effects between variables may have gone undetected. This is likely a key contributing factor to the outcome of this study. A final explanation is simply practical. Although the measures were collected over three ~45 minute sessions, which is reflective of standard clinical practice and is presumably within the realms of sustained engagement for 6-7-year old children, perhaps the volume of assessments affected the results of the participants. Nevertheless, the presence of non-significant associations between memory and grammar variables may suggest that the complex and multifaceted nature of memory makes measuring functioning difficult (see Arcuili, 2017). This appears to be the case when the current literature on the PDH account of DLD is explored.

Declarative Memory in Typically Developing and DLD Populations

Findings in the literature regarding the presence or absence of spared declarative learning in children with DLD are equivocal. Studies have also shown that performance on non-verbal declarative memory measures are equivalent between groups of typically developing and DLD samples (Bishop & Hsu, 2015; Lukács et al., 2017; Lum et al., 2010, 2012, 2013, 2014). However, Lum et al. (2012) found non-verbal declarative memory showed no relationship with grammatical abilities for typically developing children or children with DLD. Therefore, there may have been less likelihood of observing an effect using the Dot Locations composite as a measure of non-verbal declarative memory in the current study. Further, Bishop and Hsu (2015) and Lum et al. (2012) also found differences in verbal declarative memory favouring typically developing children; whereas Bavin et al. (2005) and Kuppuraj et al. (2016) found differences between groups on measures of non-verbal declarative memory. However, Lum et al. (2015) reported that once working memory is controlled, there are no significant differences between groups of DLD and typically developing children on measures of verbal declarative memory tasks, lending support to the claim that word learning may indeed be implicated in working memory (see Archibald, 2017).

Lee (2017) has suggested the discrepancy in findings may be methodological. That is, standardised measures of general memory function, such as the CMS, may not be sensitive enough to unpack deficits in the processes of encoding, recall and recognition that underlie declarative memory. Interestingly, Kuppuraj et al. (2016) found that children with DLD did more poorly than typically developing children on a task of item-specific encoding (i.e., information relating to a specific item), whereas relational encoding (i.e., information that is related across classes) was comparable. Further, retrieval of information through recognition was comparable between groups. This suggests that the deficit may indeed be within the encoding process of information through declarative memory, which may be washed out in the use of the CMS as a more generalised measure.

Procedural Memory in Typically Developing and DLD Populations

Studies comparing the performance on procedural learning tasks between typically children and those with DLD are not clear-cut either. Many studies and meta-analyses have shown that there are group differences on procedural learning measured through SRT tasks (Hedenius et al., 2011; Lum et al., 2010, 2012, 2014; Tomblin et al., 2007) as well as verbal procedural learning tasks (Evans et al., 2009; Karuza et al., 2013). However, a number of studies have also shown that there are no differences between groups on measures of procedural learning (Gabriel et al., 2011, 2012, 2015; Lum & Bleses, 2012; Mayor-Dubois et al., 2014). Equivocality of findings makes it unclear whether the PDH correctly suggests a procedural memory deficit is at the core of language learning difficulties for children with DLD. Recent findings from Lammertink et al. (2020) contribute to the equivocality with failure to replicate findings either for or against a procedural learning deficit in children with DLD, or; spared procedural learning in typically developing children, for that matter. Previously unclear findings of differences between typically developing and DLD children may be the result of methodological differences in use of instruments with questionable validity and reliability. West et al. (2018) found that widely used SRT tasks show poor test-restest reliability, which may mean previously reported findings are confounded. Further, West et al. (2020) found that poor performance on procedural learning tasks may be more representative of an attentional issue, rather that underlying language difficulties. Or perhaps that procedural learning may be such a complex and multifaceted a process that no one tool can measure it (Arcuili, 2017).

Nonetheless, Kuppuraj et al. (2018) developed an SRT task, which was used in the current study, that may potentially be more suitable for DLD children, and therefore may rule out any influence of attention and inhibition (see Sengottuvel & Rao, 2013b). The task is beneficial because it is presented in the audio-visual domain using high-frequency verbal stimuli, which is potentially more engaging for early school-aged children. Additionally, the task measures learning of deterministic as well as probabilistic sequences. The sole use of deterministic sequences may ineffectively rule out the influence of the declarative memory system (Shanks & Johnstone, 1999). Finally, the SRT task has demonstrated adequate test-retest reliability, further contributing to the validity of the measure (Kuppuraj et al. 2018). Therefore, although there are issues with tools designed to measure procedural learning, generally, the audio-visual SRT task used in the current study (Kuppuraj et al., 2018) is potentially more robust than those used in previous studies.

Findings from the current study suggest a procedural learning deficit may be present as measured by an audio-visual SRT task alongside spared (non-verbal) declarative memory, but it is unclear whether this difference sets the children apart from typically developing children without comparison to a control group. Further, the relationship between procedural learning and pre- and pre-post intervention grammar skills were limited, which further challenges the PDH. What remains clear is that children with low and high procedural memory benefitted from the explicit intervention. Therefore, whether or not children with DLD indeed have a procedural learning deficit which impacts grammatical development, TheMEDI is a viable option for the treatment of past tense production.

Concluding Remarks

The clinical presentation of children with DLD is heterogeneous with many aspects of language implicated, such as grammar (e.g., Ebbels, 2014), word retrieval (e.g., Dockrell, et al., 1998) and phonological processing (e.g., Claessen et al., 2013). Further, there is evidence to suggest the disorder is not specific to language (e.g., Bishop & Hsu, 2015). Brain-behaviour accounts, such as the PDH offer insight to the mechanisms that may underlie spared or impaired cognitive processes contributing to language disorder. These offer explanatory power over domain (grammar) specific accounts (Rice & Wexler, 1996; van der Lely, 2005), which do not account for other linguistic (e.g., word retrieval, phonological processing) and non-linguistic (e.g., motor) deficits. The PDH predicts neural abnormalities in structures responsible for procedural system, i.e., frontal/basal ganglia circuits. Further, the hypothesis predicts deficits in functions dependent on the procedural system, e.g., grammar, lexical retrieval, phonological processing (consider learning multisyllabic words), and motor sequencing. Finally, the hypothesis predicts strengths in word learning (especially lexical comprehension and recognition), lexical organisation (semantics), and episodic memory- both non-verbal and verbal (e.g., narrative macrostructure).

Recommendations for the treatment of grammar difficulties from the PDH suggest exploiting the functional characteristics of declarative memory (Ullman & Pierpoint, 2005). Primarily, information should be presented explicitly in rich semantic contexts, broken down into component parts, and practise should occur repeatedly and frequently.

The findings of significance from the program of research suggest that these recommendations have informed an efficacious intervention. That is, in general, children who perform poorly on expressive (i.e., SPELT-3) and receptive (i.e., TROG-2) standardised measures of grammar, but well on standardised measure of static vocabulary (i.e., PPVT-4) respond well to TheMEDI to improve past tense marking. This lends support to the theory's explanatory power. However, the testable predictions from the theory regarding measuring memory were not upheld using current tools (i.e., the CMS and an audio-visual SRT task). This contributes to the equivocality of findings in the literature regarding whether or not a distinction in declarative or procedural memory between children with DLD and those who are typically developing does indeed exist.

Chapter 7

A Profile of Expressive Inflectional Morphology in Early School-Aged Children with Developmental Language Disorder

Chapter overview

This chapter reports on exploratory analyses of inflectional morphology skills (i.e., regular past tense *–ed*, third person singular *3s*, and possessive *'s* production) and their relationship to short term memory systems to investigate the explanatory power of linguistic and processing theories, respectively.

The previous Chapter (Study 4) explored the relationship between long term (declarative and procedural) memory systems and morphosyntax. There were few findings of significance, which may challenge the PDH. Most previous research into the morphosyntactic skills of children with DLD has focussed on verbal inflection (e.g., *-ed* and *3s*), where nominal inflection skills (e.g., *'s*) remain relatively unexplored. Linguistic theories, such as the 'Extended Optional Infinitive' account, suggest nominal inflection is generally unaffected for these children (Rice & Wexler, 1994). Alternatively, processing accounts of DLD suggest impaired short term (phonological and working) memory systems result in morphosyntactic deficits, since the phonological input necessary for inflectional marking is too rapid for children to be able to store stable representations for later retrieval and use (e.g., Leonard et al., 2003; Gathercole & Baddeley, 1990; Baddeley, 2012). Further research into the selection of intervention targets for clinical practice when treating morphosyntactic difficulties for children with DLD is also required (e.g., Owen Van Horne & Green-Fager, 2015; Tomas et al., 2015, 2017).

Study 5 profiled the expressive inflectional morphology skills of children with DLD prior to intervention, and explored the relationship with short term memory systems. The findings from this study were accepted as a presentation for the 18th Biennial Conference of the International Clinical Linguistics and Phonetics Association, Glasgow, Scotland, September 1st – 4th. However, the conference was postponed due to the COVID-19 international pandemic which restricted international travel. This chapter presents the submitted Manuscript version of the article entitled, *A profile of expressive inflectional morphology in early school-aged children with Developmental Language Disorder* which is currently undergoing third-round revisions in the journal Clinical Linguistics & Phonetics published by Taylor & Francis as part of a special issue of pre-conference proceedings. Given this is a submitted Manuscript, there is some inevitable repetition from previous and subsequent Chapters. Taylor & Francis provide specific formatting guidelines for submission, so this Chapter is formatted as such.

Abstract

Previous research has established that children with Developmental Language Disorder (DLD) have difficulties producing inflectional morphology, in particular, finiteness marking. However, other categories of inflectional morphology, such as possessive *'s* nominal inflection remain relatively unexplored. Analyses of the characteristics for marking inflection, such as allomorphic categories, may increase our understanding of patterns within disordered grammar to inform the design of interventions and target selection. Data from *n* = 30 early school-aged children (*M* = 75 months, *SD* = 3.38, range = 69-81 months) with DLD were analysed to develop a profile of inflectional morphology skills. Morphological categories included expressive regular past tense, third person singular, and possessive 's. Skills were profiled using an elicitation task. The relationships between expressive morphosyntax, and phonological short term memory and working memory were also explored. Children demonstrated low accuracy in performance across all inflectional categories, including possessive *'s*. There were no significant differences between productions of different morphemes, but syllabic allomorphs ([əd]; [əz]) were produced with significantly lower accuracy than segmental allomorphs ([d], [t]; [z], [s]) across all morphological categories. All correlations between expressive morphosyntax and measures of memory were non-significant. Children with DLD show broad deficits in the ability to mark for inflection, including possessive *'s*; this has implications for theories explaining DLD. Findings may contribute to the design of urgently needed interventions for this clinical population.

Introduction

Developmental Language Disorder (DLD) is a neurodevelopmental condition which results in a slower pace of language development compared to typically developing (TD) peers in the absence of other known biomedical conditions (Bishop et al., 2017). Previous research has established that children with DLD present with particular difficulties using inflectional morphology. Within the study of English grammar, inflectional morphology refers to marking of lexical items with affixation (e.g., *walk* + *ed* or change of vowel *run* → *ran* to denote past tense) to distinguish items from other grammatical categories. In typical development, inflectional morphemic development in the early years is proposed to follow a predictable order of acquisition: plural (-*s*), possessive (*'s*), regular past tense (-*ed*), then third person singular *(3s*) (Brown, 1973).

Children with DLD demonstrate weakness in the ability to use and understand finiteness marking. An example of inflectional morphology, finiteness refers to marking verbs in subject-verb contexts to indicate the obligatory syntactic relationship for tense and agreement. For example, *The man jogg**ed*** for *–ed*, or *The woman run**s*** for *3s*. Nominal inflection refers to marking nouns rather than finiteness, such as plural –s in *The two boy**s*** or to indicate possession, as in *The boy'**s** ball*. Most research into the grammatical difficulties in DLD has focussed on finiteness marking (see Leonard, 2014 for a comprehensive review).

Inflectional morphology development in children with and without DLD

Extended Optional Infinitive account of DLD

Several theories attempt to account for the morphosyntactic development of inflectional morphology in TD children compared to children with DLD[9]. For example, a seminal linguistic theory rooted in nativist accounts of linguistic development, suggests that children with DLD experience delays with finiteness marking due to an 'Extended Optional Infinitive' stage in morphosyntactic development (Rice & Wexler, 1996). This suggests that once children with DLD activate hypothesised obligatory movement constraints necessary for finiteness marking in English, morphological acquisition occurs at a similar rate to TD children; however, this activation is delayed. Deficits or delays in finiteness marking are clearly useful clinical markers in the identification of children with DLD (Redmond et al., 2019; Rice et al., 1998).

However, Leonard (2014) reviewed cross-linguistic evidence extensively and concluded there is no universal feature of grammar (including finiteness) that characterises morphological development in children with DLD. For example, English-speaking children with DLD produce possessive *'s* less consistently than younger TD children matched for mean length of utterance (Leonard, 1995), which suggests nominal inflection, as well as finite inflection may be affected in children with DLD. Alternative theories draw upon the interplay of morphophonological properties of inflectional morphology to explain the patterns of development in children with and without DLD.

Processing accounts

Leonard and colleagues suggested accounts of processing difficulties, which posit a processing-capacity limitation in children's ability to learn morphemes as a result of their low perceptual salience as a phonological unit of meaning (e.g., Leonard, 1989; Leonard et al., 2003). In contrast to the Extended Optional Infinitive account, "the surface account assumes that children with SLI [*aka DLD*] have no fundamental gaps in

[9] It is acknowledged that previous research has used various terms to describe childhood language disorder in the absence of other biomedical conditions, such as specific language impairment. The term Developmental Language Disorder (DLD) is used throughout this paper, in line with recommendations from a recent international consensus study (Bishop et al., 2017).

their grammatical knowledge apart from the deficiencies that arise because of their slow intake of relevant data due to processing limitations" (Leonard et al., 2003, p. 44). This then has implications for hypothesising the morphemes' function (e.g., inflection) (Leonard & Bortolini, 1998; Leonard et al., 1997). For example, children with DLD performed significantly below their TD counterparts matched for mean-length-of-utterance in their use of *–ed* inflection to mark tense and passive participles (e.g., *The boy was push**ed** by the girl*) (Leonard et al., 2003). This suggests that the use of such morphemes may be subject to the phonetic properties of the marker, as opposed to the grammatical function, as proposed by the Extended Optional Infinitive account.

Low perceptual salience of inflectional morphology plausibly interacts with proposed deficits in non-linguistic cognitive systems for children with DLD. Baddeley's (2012) application of the Working Memory Model (Baddeley & Hitch, 1974) suggests that children with DLD experience grammar difficulties due to an issue with phonological short-term memory (PSTM) (Jackson et al., 2016). That is, children cannot temporarily store novel phonological information (such as verbal and nominal inflection) to ultimately create long-term phonological representations of the information for later retrieval and use in expressive language. However, few studies have linked working memory deficits to expressive morphosyntax skills. Therefore, it is of interest to consider the measurement of such cognitive functions, such as PSTM and working memory, when considering a profile of inflectional morphology for children with DLD.

A body of work has indicated that acquisition of the plural *–s* morpheme is driven by perceptual salience in typical development, with segmental allomorphs [s] and [z] perceived earlier than the syllabic [ez] allomorph in early childhood (Davies et al., 2017, 2020). Perhaps salience driving the order of acquisition of *–s* allomorphs ([s], [z], [əz]) for the respective morphemes (plural *-s*, *'s*, *3s*) is also applicable to morphological development in children with DLD. Notably, plural *–s* has been considered a relatively spared feature in the grammar of children with DLD (e.g., Crystal et al., 1989). Given plural *–s* shares the same phonological surface form as the markedly affected *3s* morpheme, this somewhat undermines the simple view of processing deficits. However, it has been argued that the effect of utterance position on perceptual salience accounts for this finding, as *3s* usually occurs in utterance medial position, leading to shorter durations (Leonard et al. 1997). The argument for perceptual salience for both surface processing and working memory theories would suggest that there should be an advantage to learning morphemes that are perceptually more salient, such as the syllabic [əd] *–ed* allomorph, as in *tast**ed*** (Leonard et al., 1997). However, it appears that even for TD children acquiring *-ed*, allomorph [əd] is latest to develop.

A recent body of work has demonstrated an effect of syllabicity across the production of verbal (*-ed*, *3s*) and nominal (*'s*) inflection for preschool children with DLD as well as TD children. Thirty children with DLD aged 4;6 to 5;11 years were tested on expressive measures of morphosyntax and produced syllabic morphemes (i.e., [əd] and [əz]) with significantly lower accuracy than segmental morphemes (i.e., [d], [t] and [z], [s]) suggesting a robust effect of syllabicity across all inflectional categories (Tomas et al., 2015).The effect of syllabicity on the production of morphological inflection in children with DLD was further supported in a comparison study of 13 five-year-olds with DLD and 19 TD age-matched controls (Tomas et al., 2017). Both groups showed more difficulty producing syllabic allomorphs than segmental allomorphs for novel verbal inflection, with poorer performance in the DLD group overall (Tomas et al., 2017).

The effect of syllabicity across morphological categories suggests that even for TD children, the pattern of development of inflectional morphology cannot be solely accounted for by linguistic theories suggesting a general delay in morphosyntactic acquisition in children with DLD (e.g., Rice & Wexler, 1996). Further, the later acquisition of the syllabic [əd] allomorph challenges the notion of processing theories and associated perceptual salience effects for *-ed*. That is, processing theories would suggest the perceptual salience of an added syllable should aid morphological acquisition for children with DLD.

Domain-general theories

Domain-general theories suggest difficulties with morphological inflections in children with DLD may be explained by a deficit in the ability to implicitly detect statistical regularities in their ambient linguistic environment (Plante & Gomez, 2018; Ullman & Pierpoint, 2005). There is evidence to suggest that the probabilistic nature of grammar is better suited to implicit learning (Evans et al., 2009), and that grammatical abilities are correlated with implicit learning in TD children (Lum et al., 2012). Therefore, the difficulties in DLD may arise in the learning and use of rule-governed computations of morphological sequencing (e.g., *walk* → *walk**ed***; *walk* → *walk**s***; *boy* → *boy**'s***), likely to be influenced by morphophonological effects, such as phonological complexity and lower relative frequencies of lexical items and specific allomorphs occurring through language input.

Several studies have evaluated the effects of phonological complexity on performance of inflectional morphology for children with and without DLD. For example, *3s* inflections with consonant + s coda (e.g., *nee**ds***) are more phonologically complex than those with a singleton -s coda (e.g., *see**s***) and this seems to affect production by TD 2-year-olds (Song et al., 2009); however, phonological complexity does not appear to affect their production of *'s* morphemes (Mealings & Demuth, 2014).

In relation to *–ed* inflection, inflected forms without monomorphemic counterparts (e.g., voiced obstruent + /d/: *ro**bbed***, *hu**gged***, *ju**dged***), are produced with lower accuracy by children with DLD compared to TD children (Marshall & van der Lely, 2006). Segmental *–ed* allomorphs inflected as consonant + [d]/[t] codas (e.g., *squee**zed***, *ho**pped***, *jum**ped***) are also produced with lower accuracy than the less phonologically complex singleton + [d]/[t] codas (e.g., *cr**ied***, *st**irred***, *pl**ayed***) (Oetting & Horohov, 1999; Tomas et al., 2015). Notably, many previous analyses appear not to acknowledge the effect of syllabic allomorphs on phonological complexity. For example, Owen Van Horne and Green-Fager (2015) found words ending in obstruents and alveolars were less likely to be produced accurately by both children with and without DLD; however, words that facilitated [ed] marking (e.g., *wai**ted***) were not considered independently from other alveolar items (e.g., *ki**ssed***). Therefore, it is not clear whether phonological complexity can explain the effect of syllabicity observed in the development of inflectional morphology in children with and without DLD.

To further investigate the effect of syllabicity across categories of inflectional morphology, Tomas et al. (2015) reported on a corpus analysis which indicated across *–ed*, *3s*, and *'s* morphemes, syllabic allomorphs occurred with lower frequency compared to segmental allomorphs, suggesting frequency effects may explain lower accuracy in production of syllabic allomorphs. For children with DLD, it has been suggested that difficulties producing *3s* compared to plural *–s* are due to the higher relative frequency of lexical items marked for nominal inflection, especially in utterance final position (Leonard, 1989; Leonard & Bortolini, 1998). In relation to *–ed* inflection, children with DLD appear to produce low frequency verbs with lower accuracy than high frequency verbs; however, this frequency effect was not observed with TD children (Ullman & van der Lely, 2001). Owen Van Horne and Green-Fager (2015) suggest lexical frequency, phonological complexity, and lexical aspect all influence *–ed* acquisition in both DLD and TD populations. Specifically, for both TD children and children with DLD, verbs that are frequently marked for *–ed* (e.g., *play**ed***), phonologically simple (e.g., *cri**ed***), and highly telic (e.g., *clos**ed***) are likely to be produced with greater accuracy than verbs that are infrequently marked for *–ed* (e.g., *fish**ed***), phonologically complex (e.g., *jump**ed***), and atelic (e.g., *walk**ed***).

Summary

Overall, it appears many factors may influence or explain the inflectional morphology difficulties of children with DLD. Most research has focussed on finiteness marking as a primary area of deficit, whereas other categories of inflectional morphology, such as possessive *'s* nominal inflection remain relatively unexplored (Leonard, 2019). Recent evidence indicates that there are widespread effects of syllabicity across categories of inflectional morphology. This has implications for processing accounts in which perceptual salience is a driving factor for explaining inflectional morphology development in children with DLD. Many studies have identified frequency effects, which may indicate the delay in acquisition of syllabic allomorphs for both TD children and children with DLD may be the result of infrequent exposure to items within their ambient linguistic environment.

Morphological inflection and intervention effectiveness for children with DLD

Results from intervention studies add value to theoretical accounts of DLD and inform which treatment targets should be prioritised. For example, studies of *–ed* intervention suggest targeting verbs that are frequently marked for *–ed* as determined by corpus analysis appears to provide an advantage to production accuracy (Marchmen et al., 1999; Oetting & Horohov, 1997). Conversely, results from a recent randomised control trial suggest that targeting low frequency, phonologically complex, and atelic verbs results in more rapid and generalised intervention effects when compared to targeting high frequency, phonologically simple, and telic verbs (Owen van Horne et al., 2017).

There appears to be very little generalisation following intervention to grammatical categories which are untreated, yet linguistically similar (Eidsvåg et al., 2019; Leonard et al., 2004). For example, in a series of intervention studies where *–ed* was targeted, there appeared to be little transference to *3s* as a related morphosyntactic structure despite *3s* structures being used to prime production of *-ed*, e.g., *The frog flips. What did it do?* (Calder et al., 2020, 2021). This suggests increased input may be insufficient to improve outcomes, and intervention must be highly targeted to optimise effectiveness.

Finally, nominal inflection is relatively unexplored in intervention research. In Ebbels' (2014) review of the literature, only two included studies specifically targeted nominal inflection (Smith-Lock et al., 2013a, 2013b). Interestingly, in an intervention study where *-ed*, *3s* and *'s* were targeted, Smith-Lock et al. (2015) found that inflectional category did not moderate intervention outcomes. That is, one way to mark inflection is not harder to learn with intervention than another. As such, further research is needed to determine which morphosyntactic targets should be prioritised through interventions.

Research questions

Since predictions of theories and empirical findings are equivocal regarding the predicted morphosyntactic deficits experienced by children with DLD, it is pertinent to develop profiles of inflectional morphology skills. This study draws upon pre-intervention data collected as part of a series of intervention studies to treat morphosyntax difficulties for children with DLD. The research questions were as follows. For children with DLD:

1. Is there a significant difference in accuracy of inflectional production across

morphological categories (i.e., *-ed*, *3s*, *'s*)

2. Is there a significant difference in accuracy of inflectional production across allomorphic categories (i.e., syllabic allomorphs: [əd], [əz]; segmental voiced: [d], [z], and; segmental voiceless: [t], [s])?

In addition, as part of the program of research evaluating the efficacy of a grammar intervention, pre-intervention measures of cognitive functioning, such as phonological short term memory and working memory, were collected. We present two exploratory research questions:

3. Is there a relationship between expressive inflectional morphology and phonological short term memory as measured by performance on a non-word repetition test?
4. Is there a relationship between expressive inflectional morphology and measures of working memory?

Methods and materials

Ethical approval was obtained from the Curtin University Human Research Ethics Committee (Approval number: **HRE2017-0835**) and the Western Australian Department of Education (Approval number: **D190018955)**.

Participants

Data analysed for the current study were collected as part of a programme of research evaluating grammar intervention efficacy. Demographic information is presented in Table 7.1. Participants were *n* = 30 children diagnosed with DLD (mean age = 75 months, SD = 3.38, range = 69-81 months; 66.67% male, 23.33% female), who all attended a specialised educational program. Enrolment to the program requires that children meet criteria for DLD as reported by Bishop et al. (2016), including language skills below that expected given their age based on an extensive assessment process; the

Table 7.1

Demographic information and means, standard deviations and ranges of variables of interest

Demographics and variables	Mean	Standard deviation	Range
Age (months)	75	3.38	69 – 81
Sex	23 Male (76.67%)/7 Female (23.33%)		
SPELT-3	72.43	16.04	40 – 105
GET Total Time 1 (/90)	7.60	6.26	0 – 24
GET Total Time 2 (/90)	9.02	8.08	0 – 28
NRT	73.19	9.47	42 – 94.80
WMTB-C (VSS)	86.20	22.14	55 – 129
WMTB-C (PL)	78.10	12.90	56 – 113
WMTB-C (CE)	78.83	13.09	57 – 105

Notes. GET = Grammar Elicitation Test; NRT= Nonword Repetition Test; SPELT-3 = Structured Photographic Expressive Language Test 3rd Edition; WMTB-C = Working Memory Test Battery for Children ; VSS = Visuospatial Sketchpad; PL = Phonological Loop; CE = Central Executive. Standard scores are reported for all standardised assessments.

absence of other biomedical and developmental disorders, such as autism spectrum disorder or intellectual disability, and; no history of hearing loss.

Participants were recruited on the basis of inclusion in an intervention study targeting expressive morphosyntax. Therefore, this sample may not be entirely representative of the DLD population at large. This is considered a limitation. Notably, although participants were in receipt of specialised classroom support, no participant had or was receiving targeted intervention for morphosyntax prior to involvement in the studies.

Measures

Baseline assessment included a hearing screen, testing acuity at 20 dB HL for each ear at 500, 1000, 2000, and 4000 Hz for each ear. The Phonological Probe from the Test of Early Grammatical Impairment (Rice & Wexler, 2001) was administered to ensure each participant could articulate the phonemes necessary to produce inflectional morphology markers.

Mean scores of relevant dependent variables are presented in Table 7.1. Overall, there was considerable variability in scores across all measures for the current sample, which was not unexpected given the heterogeneity of presentation of skills in the DLD population (Bishop et al., 2016). The Structured Photographic Expressive Language Test 3rd Edition (SPELT-3) (Dawson et al. 2003) was administered as a standardised expressive grammar measure. The test was normed on 1580 children aged four to 10 years and measures expressive morphosyntax using 54 items across a range of structures. Test-retest reliability is strong (0.94), and construct validity is appropriate. The discriminant validity of the SPELT-3 was evaluated by Perona et al. (2005), where at 90% sensitivity and 100% specificity, a scaled cutoff score of 95 (i.e., -0.33 standard deviation below the mean) is recommended to identify language disorder. The mean standard score on the SPELT-3 indicated the participants presented with expressive grammar difficulties. Of the 30 participants, 3 scored above the 95 cut-off, however were still included due to their poor overall performance on the Grammar Elicitation Test (detailed below), indicating difficulties with expressive morphosyntax.

Expressive morphosyntax

The Grammar Elicitation Test (GET) was administered to measure expressive inflectional morphology skills. The criterion-referenced assessment is reported in detail by (Smith-Lock et al., 2013a), and was designed to identify areas of difficulty and measure change following intervention. The past tense (*-ed*), third person singular (*3s*), and possessive ‘s (*‘s*) subtests of the GET were administered. Each subtest includes 30 items, totalling 90. Within each morphological category, all possible allomorphs are distributed equally. That is, for the *–ed* subtest, there are 10 items for the voiced [d] allomorph (as in *crawl**ed***), 10 for the voiceless [t] allomorph (as is in *lick**ed***), and 10 for the syllabic [əd] allomorph (as in *land**ed***). For the *3s* subtest, there are 10 items for each of the voiced [z] (as in *smil**es***), the voiceless [s] (as is in *skip**s***), and the syllabic [əz] allomorph (as in *kiss**es***). Finally, for the *‘s* subtest, there are 10 items for each of the voiced [z] (as in *dog’**s***), the voiceless [s] (as is in *sheep’**s***), and the syllabic [əz] allomorph (as in *horse’**s***). The test was administered at initial assessment, and immediately prior to intervention following a baseline phase of five weeks. The second testing point was included in this study to evaluate test-retest reliability of the GET. Dichotomous scoring was used, where participants’ responses were scored as ‘correct’ if they produced the appropriate allomorph for the target, whereas omissions and overgeneralisations were scored as ‘incorrect’.

Validity and reliability of the GET. Given the experimental nature of the test, we report on analyses of the validity and reliability of the GET as a measure of expressive inflectional morphology. Concurrent validity was assessed using a bivariate Pearson's (*r*) product-movement correlation. The relationship between the GET and raw scores on the SPELT-3 was positive and strong, $r(30) = 0.61$, $p < 0.001$, with 37.7% of the variability in the participants' GET scores accounted for by variability in their SPELT-3 scores.

Cronbach's alpha assessing the internal consistency of the GET across the morphosyntax structures (*-ed*, *3s*, and *'s*), was 0.70, which is considered acceptable. Further calculations assessed the internal consistency of allomorphs within the structures. Cronbach's alpha for allomorphs within the *–ed* structure ([d], [t], [əd]) was 0.69, indicating borderline acceptable consistency. The mean score of [əd] production was lower than that of [d] and [t]. For *3s*, Cronbach's alpha was 0.84, and for *'s,* 0.83, suggesting good internal consistency amongst allomorphic categories within these structures. The internal consistency of the GET as a measure of expressive morphosyntax was supported.

To assess the test-retest reliability of the GET, a Pearson's *r* was calculated using the scores from the two pre-intervention testing points. Data from $n = 6$ participants were excluded from this analysis as they had baselines of differing lengths compared to the remaining $n = 24$ (Calder et al., 2020). The bivariate correlation between two testing points that was positive and strong, $r(24) = 0.66$, $p < 0.001$. r^2 indicated 43.6% of the variability in participants' scores at the second testing point was accounted for variability at the initial testing point.

Memory measures

Phonological short term memory. The Nonword Repetition Task (NRT) (Dollaghan & Campbell, 1998) requires participants to repeat 16 nonwords with four items of each syllable length, ranging from one to four syllables. The nonwords were recorded prior to administration and delivered via laptop to ensure consistency of the verbal stimuli. Responses were audio recorded and scored for total phonemes correct and percentage phonemes correct (PPC) as per guidelines outlined by Dollaghan and Campbell (1998).

Working memory. Three subtests of the Working Memory Test Battery for Children (WMTB-C) (Pickering & Gathercole, 2001) were administered. The Block Recall subtest was used to measure participants' visuo-spatial sketchpad (VSS). This subtest uses a corsi-block test where the administrator points to a series of blocks in sequences that gradually increase, and the participant then points to the series in turn. The Digit Recall subtest requires participants to repeat strings of digits which increase in length, to measure participants' phonological loop (PL). The Backward Digits Recall subtest was used to measure the participants' central executive (CE), requiring participants to repeat a string of digits back to the administrator in reverse order which also increases in length. It is thought that the VSS, PL and CE contribute to the working memory system as separate components within the one cognitive system (see Baddeley, 2012).

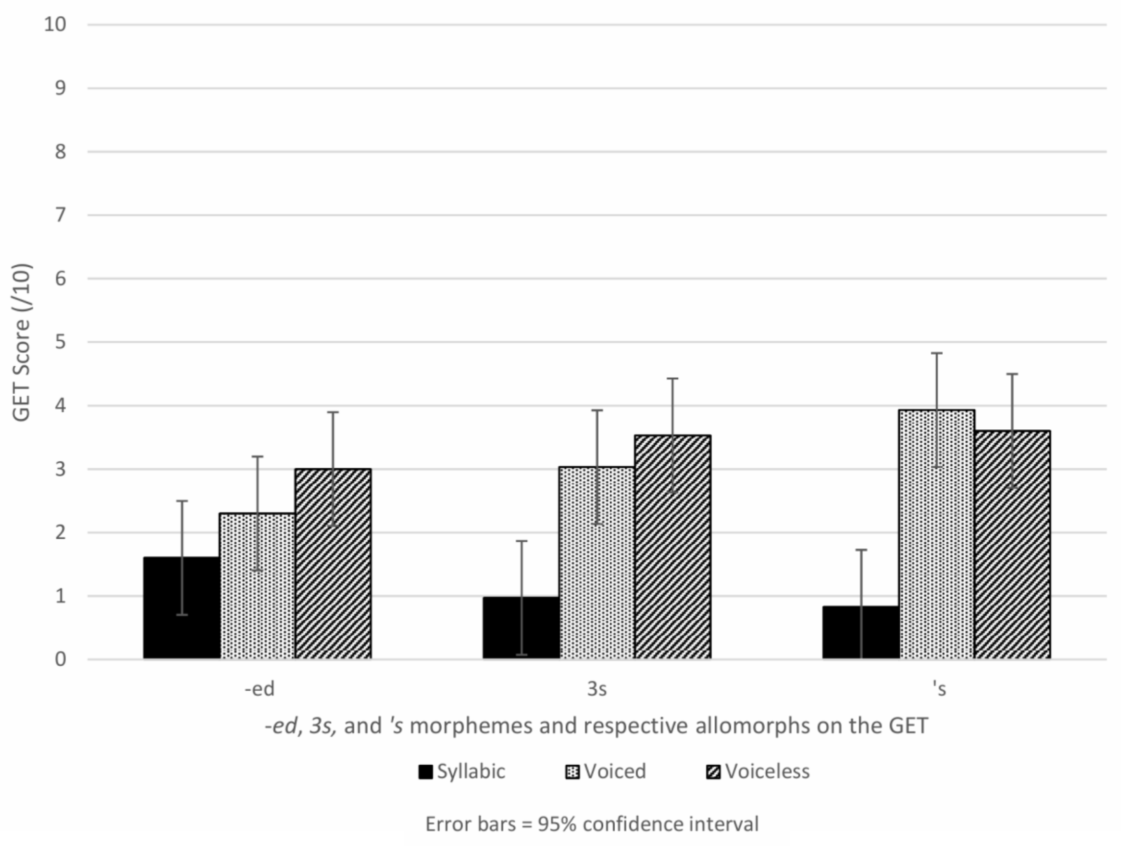
Results

***Research questions: 1. Is there a significant difference in accuracy of inflectional production across morphological categories, 2. Is there a significant difference in inflectional production across allomorphic categories*?**

The mean correct production of each allomorph within each category of morphological inflection is presented in Figure 7.1. Visual inspection suggests that syllabic allomorphs were produced with lower accuracy across the three categories. A 3x3 factorial analysis of variance (ANOVA) was used to test for differences in production of inflectional morphology across 30 children at initial assessment (GET Total Time 1). Responses

Figure 7.1

Mean items correct on the GET past tense (-*ed*), third person (*3s*) and possessive (*'s*) subtests across the three allomorphs within each inflectional category.



were grouped into morphemic categories (-*ed*, *3s*, *'s*) and allomorphic categories within morphemic categories (syllabic [əd], segmental voiced [d], and voiceless [t] for –*ed*; syllabic [əz], segmental voiced [z] and voiceless [s] for *3s* and *'s*). All necessary post hoc pairwise comparisons included Bonferroni adjustments for α-values.

The main effect of morpheme was non-significant, $F(2, 261) = 0.870$, $p = 0.420$, $\eta^2 = 0.007$, indicating no differences in the mean production between –*ed*, *3s*, or *'s* (see Figure 1). There was a main effect for allomorphic categories, $F(2, 261) = 21.56$, $p < 0.001$, $\eta^2 = 0.142$, where pairwise comparisons revealed syllabic allomorphs ($M = 1.13$, $SD = 1.81$) were produced with less accuracy than voiced ($M = 3.09$, $SD = 2.73$) and voiceless ($M = 3.38$, $SD = 2.86$) segmental allomorphs (all *p*s < 0.001, *d*s < 0.80). There was no significant difference between voiced and voiceless segmental allomorphs (p = 1.0, d = 0.10). The interaction between morphemic category and allomorphic category was not significant, $F(2, 261) = 1.844$, $p = 0.121$, $\eta^2 = 0.027$.

Lexical frequency analysis

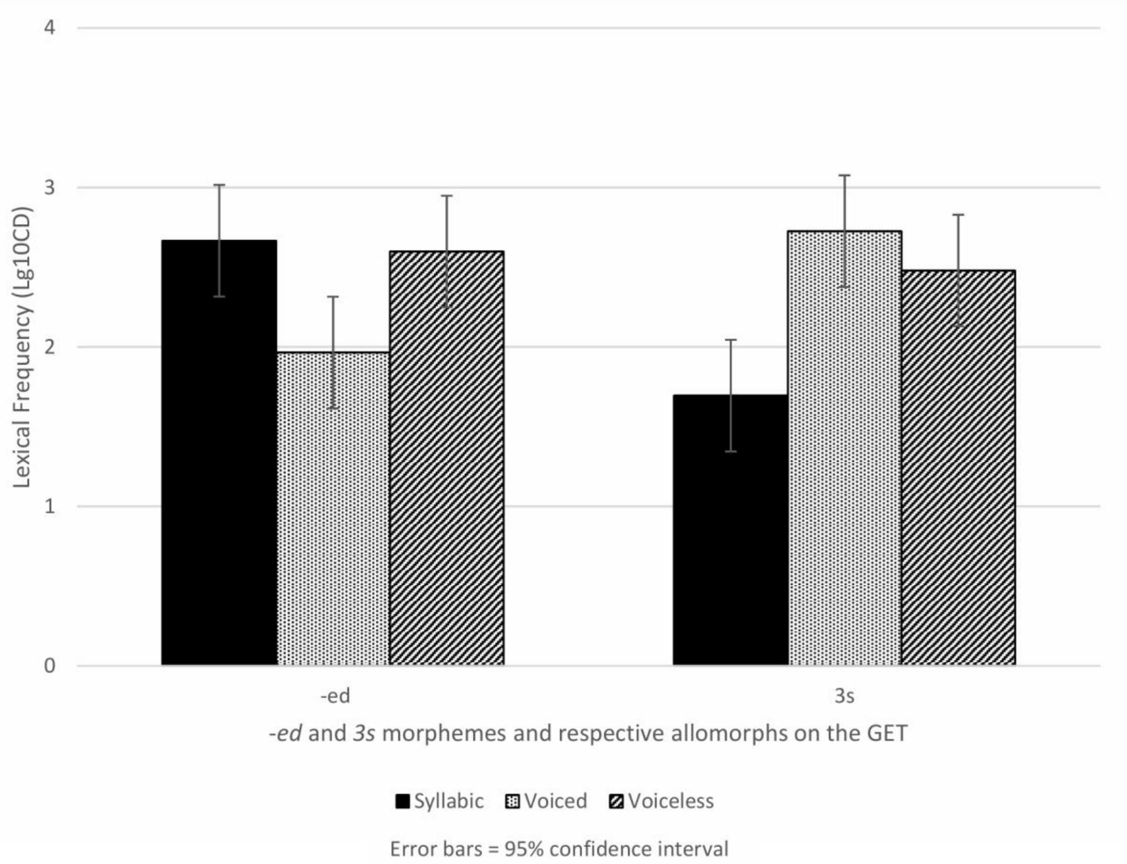
Given there was no effect of morpheme, but a main effect of allomorph, we were interested in exploring whether lexical frequency of items on the GET may explain this effect. Using the free-to-access online SUBTLEX corpus (http://www.lexique.org/shiny/openlexicon/), we determined the lexical frequency of individual *–ed* and *3s* items (as marked for inflection) using the Lg10CD value for each item (Brysbaert & New, 2009) (see Figure 7.2). Frequencies could not be determined for *'s* items, as the corpus search function is not sensitive to punctuation. A 2x3 factorial ANOVA was used to test differences in lexical frequency between verbal morphemes and allomorphs. Items were grouped into morphemic categories (*-ed*, *3s*) allomorphic categories within morphemic categories (syllabic [əd], segmental voiced [d], and voiceless [t] for *–ed*; syllabic [əz], segmental voiced [z] and voiceless [s] for *3s*).

The main effect of morpheme was non-significant, $F(1, 54) = 0.595$, $p = 0.444$, η^2 = 0.011, indicating no differences in the mean lexical frequency of *–ed* versus *3s*. The main effect of allomorph was also non-significant, $F(2, 53) = 2.111$, $p = 0.131$, η^2 = 0.073. However, there was a significant interaction between morpheme and allomorph, $F(2, 54) = 12.330$, $p < 0.001$, $\eta^2 = 0.313$.

To further explore the interaction, separate one-way between groups ANOVAs were run for both *–ed* and *3s* morphemes to compare mean frequencies of allomorphs within each morphological category. The *–ed* ANOVA revealed a significant effect of allomorph on lexical frequency, $F(2, 29) = 5.380$, $p = 0.011$. Post hoc tests indicated

Figure 7.2.

Mean lexical frequency of the items on GET past tense (*-ed*) and third person (*3s*) subtests across the three allomorphs within each inflectional category.



that syllabic [əd] allomorphs ($M = 2.67$, $SD = 0.40$) had significantly higher lexical frequency than voiced segmental [d] allomorphs ($M = 1.97$, $SD = 0.52$), $p = 0.016$, $d = 1.51$. All other comparisons were non-significant.

The effect of allomorph was also significant for *3s*, $F(2, 29) = 8.767$, $p = 0.001$. Post hoc tests indicated that syllabic [əz] allomorphs ($M = 1.70$, $SD = 0.75$) had significantly lower lexical frequency than voiced [z] ($M = 2.73$, $SD = 0.51$), $p = 0.001$, $d = 1.61$, and voiceless [s] ($M = 2.48$, $SD = 0.41$), $p = 0.014$, $d = 1.29$, segmental allomorphs. There was no significant difference between voiced and voiceless segmental allomorphs.

Exploratory research questions

Research questions 3 and 4: Is there a relationship between expressive inflectional morphology and phonological short term memory as measured with a non-word repetition test, and/or working memory?

A total of four bivariate correlations were run to explore the relationship between inflectional morphology and measures of memory. Since the GET showed overall acceptable/good internal consistency, the GET Total score (i.e., *-ed*, *3s* and *'s* combined) was considered an appropriate overall measure of inflectional morphosyntax to explore potential relationships. Correlations between the GET Total score, and NRT (r = 0.19) and WMTB-C CE (r = -0.06), PL (r = 0.23) and VSS (r = 0.01) raw scores were non-significant.

Discussion

Children with DLD show broad deficits in their ability to mark inflection, especially finite verbs. However, whether other aspects of inflectional morphology, such as possessive *'s* nominal marking, are also implicated for children with DLD remains relatively unexplored. Broader deficits in inflectional morphology marking beyond finiteness marking have implications for existing theories explaining DLD and identifying targets to prioritise through intervention.

In this study, we found no significant differences in performance between production of *–ed*, *3s*, or *'s*. This suggests that, prior to intervention, these inflectional morphemes may be equally affected in early school-age (69 – 81 months) children with DLD. This finding somewhat challenges the notion that children with DLD are characterised by a period of protracted use of morphological non-finiteness compared to TD peers (Tomas et al., 2017). Alternative theories suggest morphemes may/may not be perceived adequately depending on their phonetic properties due to a processing deficit (e.g., Leonard et al., 2003). Similar to findings of TD children (Davies et al., 2017), processing theories suggest perceptual salience of morphemes drives learning for children with DLD. This could also be considered in the context of exploring the relationship between PSTM and working memory, and expressive morphology. However, in the current sample of children with DLD, there was no apparent advantage to learning the more perceptually salient syllabic [əd] allomorph for *–ed*, (indeed we found a disadvantage). Further, there were no relationships between PSTM and working memory, and expressive morphology

The concept of phonological complexity suggests segmental allomorphs, especially those preceded with obstruent codas (e.g., Marshall & van der Lely, 2006) are more difficult to produce than phonologically simple allomorphs. However, many previous analyses did not account for syllabic allomorphs. Although overall production across allomorphs was low for participants in the current study, there was a clear effect of syllabicity. This may be explained by the low frequency of syllabic allomorphs compared to segmental allomorphs that occur in children's linguistic input (Tomas et al., 2015).

To explore this observation in more detail, we determined the lexical frequency of GET items targeting verbal inflection using the SUBTLEX corpus. Results for *3s* mirrored findings from Tomas et al. (2015), suggesting that the effect of syllabicity may be accounted for by the relative lower frequency of *3s* verbs marked with the [əz] allomorph. Interestingly, however, *-ed* items marked with the syllabic [əd] allomorph were more frequent than items marked with voiced segmental allomorphs, yet these items were produced in error significantly more than the segmental allomorphs by the children with DLD. Perhaps then, frequency effects are a more relevant estimate of linguistic input, as for TD children (Davies et al., 2017). Further, accurate production of allomorphy seems to be dependent on the morphophonological properties of the lexical item (i.e., syllabic allomorphs are produced with lower accuracy) rather than the morphosyntatic function of the lexical item (i.e., there are no differences between verbal and nominal inflection). And although items for syllabic –ed allomorphs had higher overall frequency compared to items for syllabic 3s allomorphs, syllabic allomorphs for both –ed and 3s are less frequent than the respective segmental allomorphs (Tomas et al., 2015). This may then provide evidence of a difficulty in the children's ability to detect inflectional allomorphs (especially syllabic allomorphs) as meaningful units of information. This aligns with domain-general accounts of DLD (Plante & Gomez, 2018; Ullman & Pierpont, 2005), which suggest a difficulty implicitly detecting statistical regularities in the ambient linguistic environment.

For the current sample, the effect of syllabicity was greater than that of inflectional category. This finding mirrors important contributions to the evidence-base (Tomas et al., 2015, 2017) with a different group of children with DLD using different methodology, further challenging theories explaining DLD as simply a delay in development of inflectional morphology. Given the generally low performance across measures of morphosyntax, the effect of syllabicity may be characterised by a complex interplay between morphology, allomorphy, and frequency.

Morphological inflection and intervention effectiveness in children with DLD

It is well established that intervention treating morphosyntax must be highly targeted, and generalisation across inflectional class is not typically observed (Calder et al., 2020, 2021; Eisdvåg et al., 2019; Leonard et al., 2004). However, recent intervention studies targeting *–ed* marking have demonstrated explicit rule instruction using metalinguistic training and visual support results in generalised improvement to non-taught lexical items within the same inflectional class (Calder et al., 2020, 2021). This may suggest that children with DLD may not learn how to correctly apply inflectional morphemes (especially syllabic allomorphs) through exposure alone, but explicit intervention helps activate rule awareness (e.g., verbs ending in alveolar obstruents are marked with [əd] for *–ed*), and then subsequent application of the rule.

Further, it has also been observed that the selection of targets from an inflectional class, whether verbal or nominal, may have little effect on treatment outcomes. That is, the type of intervention, not the target, may influence outcomes when treating inflectional morphology (e.g., Smith-Lock et al., 2015). Findings from the current study indicate no differences in pre-intervention performance on measures of *-ed*, *3s* or *'s*, which is similar to existing studies (e.g., Tomas et al., 2015). So, if lexical items occuring with lower frequency in terms of morphophonology are less likely to be learned through ambient linguistic environments, they should perhaps be considered priorities for intervention targets.

Findings also highlight a gap in the literature exploring interventions to target *'s* inflection for children with DLD (Ebbels, 2014). Given the recent demonstrated efficacy of an explicit approach to treat *–ed* production (Calder et al., 2020, 2021), and the benefit of selecting of complex verbs (Owen Van Horne et al., 2017), perhaps these principles could be applied to interventions to improve *'s* for children with DLD.

Limitations and future directions

The current sample of children was recruited for intervention studies, so there is risk of ascertainment bias. Future research should profile expressive inflectional morphology skills through random recruitment with large samples (e.g., Redmond et al., 2019). Further, although the GET was piloted on 30 TD five-year-old children who reached ceiling (reported in Smith-Lock et al., 2013a), there has never been a direct comparison of TD children and children with DLD on GET across a range of ages to determine its discriminant validity. Strong correlations with the SPELT-3 are reassuring, however, a direct comparison of randomly sampled TD and DLD populations on the GET would be truly illustrative of the inflectional morphology profile of these developing populations.

Given the current findings challenge pre-established theories of DLD, it may also be pertinent to include measures of nominal plural marking in future studies (cf. Crystal et al., 1989: Leonard et al., 1997) as similar effects of allomorphy and frequency may be uncovered (Davies et al., 2020).

Despite a non-significant interaction between morpheme and allomorph from the statistical analysis, results may still indicate a complex interplay between morphology, allomorphy, and frequency as discussed. Perhaps for higher-frequency segmental allomorphs (Tomas et al., 2015), verbal inflection is indeed more affected for children with DLD than nominal inflection, but this effect was negated by poor performance on the more complex syllabic allomorph items across GET subtests. The interaction could be further investigated using higher a powered study with an increased sample size. Nonetheless, findings from the current study contribute to the evidence-base suggesting children with DLD experience broad deficits in inflectional morphology, especially syllabic allomorphs within morphological categories. This shows clearly that nominal, as well as verbal inflectional morphemes, especially those that are syllabic should be considered priorities for intervention research.

Conclusions

For the current sample of children with DLD, production of nominal inflection (i.e., *'s*) appears to be an area of difficulty as well as verbal inflection (i.e.,*-ed, 3s*). Further, there appeared to be no relationship between expressive inflectional morphology skills, and PSTM and working memory, suggesting processing accounts may not explain difficulties with morphosyntax for all children with DLD. More research is needed to unpack the difficulties with morphosyntax experienced by children with DLD, such as the ability to detect probabilistic regularities in linguistic input. Nonetheless, findings from this study highlight the need to consider nominal inflection as an area of deficit in children with DLD, and to look beyond verbal inflection as a priority for intervention.

CHAPTER 8

General Discussion

Chapter overview

The final Chapter of this thesis summarises the findings from this programme of research which designed, developed, and evaluated the efficacy of a theoretically motivated explicit intervention to improve past tense marking (TheMEDI) following Robey's Phases of Clinical Research (Robey, 2004). This programme of research is reported in two parts: Part One evaluated the efficacy of TheMEDI for early school-aged children with DLD. This intervention was motivated by the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005). The efficacy of such an intervention had not yet been explored systematically with this age group. Part Two included exploratory analyses of morphosyntax skills, and long term (declarative and procedural) and short term (phonological and working) memory systems to further investigate the explanatory power of the PDH, as well as other linguistic and processing accounts of DLD. The implications for current theories explaining the morphosyntactic difficulties experienced by children with DLD are presented with clinical recommendations, as well as future directions for research.

Summary Of The Programme Of Research

Part One: Intervention Efficacy

In response to a call to action to improve the reporting of intervention procedures (Ludemann et al., 2017), the procedures employed in this research are reported in detail in Chapter 2 to facilitate replication and translation to clinical practice (the full programme of research has been made available here). Efficacy of the **the**oretically **m**otivated past tense (-***ED***) **i**ntervention (**TheMEDI**) was evaluated using a series of studies (Chapter 3, Study 1: Calder et al., 2020; Chapter 4, Study 2: Calder et al., 2021). Overall, results indicate that TheMEDI was efficacious for improving past tense production for children with DLD aged between 5;9 and 6;9 years. Since grammar intervention is generally provided once weekly (see Finestack & Satterlund, 2018), it was pertinent to systematically analyse dose frequency and cumulative intervention intensity, comparing the delivery conditions (Chapter 5, Study 3: Calder et al., under review b). Further analysis indicated that the intervention is indeed efficacious whether provided twice or once weekly; however, there there is an advantage to providing intervention twice per week. Due to study design limitations, further research using randomised control trials is urgently needed to increase confidence in the interpretation of findings. Clinically relevant exploratory analyses were also conducted, evaluating the allomorphic categories of regular past tense production and any influence on intervention outcomes. Results suggest verbs marked for [d], [t] and [əd] improved proportionately to one another as a result of explicit intervention.

Part Two: Exploratory Analyses of Long And Short Term Memory Systems

Although the predictions of the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005) were met insofar as explicit intervention was efficacious, the relationship between long term (declarative and procedural) memory systems, and intervention outcomes was yet to be explored. The PDH suggests that children with DLD have impaired procedural memory in the presence of relatively spared declarative memory, therefore measures of these systems should moderate intervention effects. As a result, measures of declarative and procedural memory were used to explore how these account for unique variance in intervention outcomes (Chapter 6, Study 4). There were few significant results from these analyses. These findings may challenge the PDH, or alternatively, reflect issues with current instruments measuring the relationship between such complex cognitive processes (Arcuili, 2017), and/or the limited statisical power of the study.

Finally, since the predictions of the PDH were not met in relation to measures of long term memory, exploratory analyses of expressive inflectional morpholgy, including both verbal (regular past tense and third person singular) and nominal (possessive *'s*), and the relationship between measures of short term (phonological and working) memory were conducted (Chapter 7, Study 5: Calder et al., under review a). Analyses revealed no differences in performance between inflectional morphology categories; however, syllabic allomorphs (i.e., [əd]; [əz]) were produced with significantly less accuracy than single consonant allomorphs (i.e., [d], [t]; [z], [s]) across all morphosyntactic categories. This has implications for linguistic accounts of DLD which suggest nominal inflection remains relatively unaffected for these children. Further, there were few meaningful, significant relationships between measures of phonological short term or working memory, and expressive morphosyntax. This has implications for processing accounts of DLD which may suggest phonological short term and working memory deficits are responsible for morphosyntactic difficulties in children with DLD. It seems rather the morphophonological frequency of lexical items may explain difficulties with inflectional morphology. Results also suggest nominal inflection should indeed be considered as a priority for intervention targets.

Summary

The efficacy of TheMEDI for early school-aged children with DLD was demonstrated. Exploratory analyses revealed many findings that may be of use when translating findings to clinical practice in the management of this clinical population. However, analyses of memory measures and their relationship to morphosyntax revealed few findings of significance. Implications for theories explaining grammar difficulties in children with DLD are explored in the following section.

Theory and Implications for Intervention

Many theoretical models exist to account for morphosyntactic difficulties experienced by young children with DLD. These theories often result in recommendations for clinical practice to resolve or remediate challenges to learning morphosyntax. The PDH posits children with DLD may be better supported to learn linguistic information when it is presented explicitly and visually to exploit the declarative memory system, and further, learning environments may be shaped to lessen demands on procedural memory. These recommendations align with elements from the SHAPE CODING™ system, an approach designed to support the explicit teaching of syntax and morphology using metalinguistic training and visual support. Findings from the studies reported in Chapters 3 to 5 support the PDH in that explicit teaching of grammar is shown to be of benefit to children with DLD. However, a systematic comparison of explicit versus implicit intervention is required to confirm whether one is more beneficial than the other. Additionally, the profile of average static vocabulary skills in combination with poor expressive and receptive grammar was observed in the participants who took part in the studies, further supporting the PDH (e.g., Yarian et al., 2019). However, results reported in Chapter 6 revealed few meaningful findings regarding the relationship between declarative and procedural memory, and intervention outcomes. This may suggest the PDH is not supported, yet methodological issues explained in detail in Chapter 6 may also account for the lack of findings. Alternatively, the PDH may account for some, but not all children with DLD. That is, children with DLD may experience an array of pathologies (e.g., procedural memory deficit, statistical learning deficit, working memory deficit), which result in similar symptoms, such as impaired morphosyntax (Lee & Tomblin, 2015).

Reflections on Alternative Theories of DLD.

The findings of this programme of research can also be viewed through the lens of other explanatory theories of the grammar difficulties experienced by children with DLD.

Statistical learning theory. Of particular relevance is the domain-general statistical learning account of DLD. Statistical learning theory suggests that children with DLD experience difficulties with morphosyntax due to a reduced ability to implicitly detect statistical regularities in their ambient linguistic environment (e.g., Plante & Gómez, 2018).

Therefore, learning may indeed be fostered if these statistical regularities are enhanced through linguistic input.

Results from Chapter 6 indicate children may indeed have difficulty with statistical learning as measured through an audio-visual serial reaction time task, with mean *t* values below the 2.0 ($p < .05$) threshold for learning (Deterministic $M = 0.99$, $SD = 1.07$; Probabilistic $M = -1.02$, $SD = 1.02$) (see Table 6.2 and Appendix D). This could indicate support for an approach that increases linguistic input and presents children with more opportunities to detect statistical regularities.

Another perspective would be to acknowledge the potential that input-based, implicit interventions based on statistical learning principles, such as that described by Plante and Gómez (2018) are not entirely incompatible with recommendations from the PDH account. For example, *regularity* refers to the frequency of occurrence and consistency of the input for learning. The *regularity* of input enables language learners to establish superordinate and subordinate semantic categories during word learning. This notion is also valuable for designing implicit grammar interventions. For example, high *variability* in language input, specifically of non-target items, can increase *regularity* and saliency of target items for language learners, enabling them to track patterns of these items, probabilistically. This supports the notion that language learners are able to encode these patterns through input to build representations in memory. However, given children with DLD are suggested to have deficits in the integration of various memory processes that support encoding (e.g., Thiessen, 2017), enhancing input following the principles outlined above should assist in language learning, especially if targets are less probable to occur through naturalistic interactions.

In a study of 18 children aged 4;0 to 5;11 years, Plante et al. (2014) found enhanced conversational recasting intervention for the treatment of verbs in a high variability condition resulted in significant change in children's use of trained morphemes, compared to a low variability condition. The high variability in presentation of targets in enhanced recasting interventions highlights to participants how tense-agreement combines with the rest of the syntactic frame to facilitate rule learning. This could easily be combined with explicit procedures to enhance increased conscious awareness of the goal of intervention in the presence of implicit learning deficits.

Further still, in a randomised control trial (RCT) of 18 children aged 4- to 10 years, Owen Van Horne et al. (2017) determined intervention targets based on the assumption that correct production of words within grammatical structures is probabilistically determined depending on the *frequency* of the word in the child's ambient linguistic environment. Findings indicated there is an advantage to learning past tense verbs that are produced with less frequency based on the probability of them occurring in the child's pre-existing lexicon. Again, principles of statistical learning could be applied to explicit interventions targeting morphosyntax.

For example, following explicit instruction for *–ed* production, if non-target items are presented in high variability contexts, and target items are held constant during input, this may enable learners to detect the probabilistic *regularity* of target items and foster learning. Further, if verbs that occur with less *frequency* are selected as per Owen Van Horne et al. (2017) (e.g., *rest**ed***), perhaps greater gains to untrained forms would be observed following provision of intervention.

Both statistical learning theory and the PDH suggest that the grammatical difficulties experienced by children with DLD may be explained by a deficit in the ability to implicitly detect statistical regularities in their ambient linguistic environment. Certainly, recent evidence points to an implicit learning deficit in children with DLD (Arcuili, 2017; Conti-Ramsden et al., 2015; Evans et al., 2009; Hedenius et al., 2011; Lammertink et al., 2017; Lum & Conti-Ramsden, 2013; Lum et al., 2010a, 2010b, 2014; Oebid et al, 2016; Tomblin et al., 2007). A key point of difference between the theories is that statistical learning theory suggests interventions should be inherently implicit and enhance principles of natural language learning through input (e.g., Plante & Gómez, 2018). Alternatively, the PDH suggests interventions should exploit potentially spared declarative memory by offering information explicitly through spaced and repeated practice, possibly with the aid of visual support (Ullman & Pierpoint, 2005).

Domain-Specific Theory. An alternative account is the 'Extended Optional Infinitive' account of childhood language disorder (Rice & Wexler, 1996). This theory suggests an innate linguistic deficit, which affects children's ability to understand and use the obligatory movement constraints required for finiteness marking. Importantly, the Extended Optional Infinitive account by implication, suggests nominal inflection, such as possessive *'s* marking remains unaffected for children with DLD. Seemingly, implications suggest interventions could be designed to improve a child's use of finiteness marking by contrasting the incorrect forms with correct 'adult' forms (Connell, 1988), which theoretically sets parameters for the child to appropriately learn the grammar (Poll, 2011). This is compatible with explicit instruction, where procedures could be used to demonstrate that in fact the use of past tense forms is not optional. Nonetheless, given the success of an intervention based on a theory (i.e., the PDH) that somewhat challenges purely linguistic theories (i.e., the Extended Optional Infinitive account), exploratory analyses of the profile of inflectional morphology of the sample population were carried out. Findings revealed children with DLD may present with broader deficits in inflectional morphology, which include nominal as well as verbal inflection. That suggests that the Extended Optional Infinitive may not account for all children meeting diagnostic criteria for DLD.

Processing Limitation Theory. Surface processing accounts may suggest an effect of saliency when learning for children with DLD (e.g., Leonard, 1989; Leonard et al., 2003).

However, Study 5 (Chapter 7) reported the more perceptually salient syllabic morphemes were produced with the lowest accuracy across inflectional categories, suggesting no advantage to learning for these allomorphs. Given the evidence for difficulties with input tasks by children with DLD and the lack of significant findings related to the long term memory systems, the relationships between short term (phonological and working) memory systems and grammar skills were explored. Impairments of short term memory systems align with processing accounts, which suggest that the (phonological) linguistic information required to mark for inflection is too brief for children with DLD to be able to establish stable enough representations for later retrieval and use (e.g., Baddeley, 2012; Chiat, 2001; Gathercole & Baddeley, 1990; Montgomery et al., 2016). The implications for intervention may be to improve working memory, however, interventions targeting working memory in isolation show little transference to language ability (Melby-Lervag et al., 2012). As such, interventions which prioritise carefully selected, non-competitive target structures have been proposed (Leonard, 2014; Leonard & Deevy, 2011, 2017; Fey et al., 2017). In fact, explicit instruction may serve to further increase saliency of morphemes known to be troublesome for children with DLD. However, in Chapter 7, few meaningful relationships between short term memory systems and morphosyntax skills were reported. Indeed, there was a significant spread of phonological short term and working memory scores on the measures used. Again, this speaks to the heterogeneity in presentation of children with DLD, suggesting that there may be many plausible explanations for the grammatical deficits they experience.

Summary. The evaluation of intervention outcomes cannot directly inform theoretical explanations alone. It appears explicit instruction is somewhat conducive to the theories discussed throughout this thesis, despite differing and even contrdictory underlying assumptions. However, the analyses in Chapter 6 evaluated the relationship between intervention outcomes and performance on tasks measuring declarative and procedural memory. Although findings do not clearly support a single theory, the methodologies used in this programme of research demonstrate a paradigm for how theories can be evaluated in future studies.

Implications for Clinical Practice

Findings from this programme of research suggest this explicit intervention is efficacious for improving past tense production for early school-age children with DLD. Specifically, the explicit intervention exploits the functional characteristics of declarative memory by harnessing explicit learning in rich semantic contexts. Additionally, TheMEDI utilises visual support as an environmental modification to reduce demands on learning through procedural memory by presenting linguistic information that is less transitory than the spoken modality. Finally, TheMEDI allows for the frequent presentation of complex sequential information, such as morphosyntax, in a segmented manner to enhance learning.

The use of visual support may be especially noteworthy when delivering this intervention to children with DLD. As discussed in Chapter 1, the Visuospatial Sketchpad component of the working memory system may plausibly function as a protective factor for explicit learning. There is evidence that visual support can enhance verbal working performance for children with DLD (Quail et al., 2009). The current sample of children indeed demonstrated relative strength in their Visuospatial Sketchpad compared to other components of working memory, such as the Phonological Loop and Central Executive (see Chapter 7 and Appendix D), as well as unimpaired visual declarative memory (see Chapter 6 and Appendix D). Therefore, cognitive systems that integrate visual information may serve to compensate for memory deficits that are responsible for the processing of verbal information.

Most research into grammar interventions has evaluated implicit interventions, primarily with children under the age of five (Ebbels, 2014). That is, interventions that do not require the child to consciously reflect on the goal of therapy. Often, these interventions are input-based, so there is very little expectation that the child produces the target form during child-clinician interactions. The notion being generally, that these interventions avoid interrupting the flow of communication, so are more naturalistic and engaging for the child (Camarata et al., 1996). Although these interventions may improve the targeted morphosyntactic form, studies of clinical effectiveness have shown preschool-aged children with DLD may not reach levels of mastery after as many as 96 sessions (Leonard et al., 2004, 2006, 2008). Recent studies of implicit interventions which have procedures 'enhanced' by integrating statistical learning principles appear to improve intervention outcomes for preschool-age children with DLD; however, intervention was generally provided for 30 minute sessions, five days a week, for five weeks (see Kapa et al., 2020 for a summary of enhanced conversational recasting studies of n = 105 five year old children with DLD in total). Results from studies of implicit interventions indicate targeted morphosyntax improves, however the lengthy intervention durations, or high density of intervention frequency may suggest these interventions are not necessarily time efficient or achievable in most clinical settings (see Finestack & Satterlund, 2018).

Alternatively, explicit interventions, which make the child aware of the goal of intervention, so s/he can think overtly about the rules of grammar, have an expanding evidence-base (Balthazar et al., 2020). An example of such an approach is the SHAPE CODING™ system, which uses a system of shapes and arrows to teach the rules of grammar with visual support. The literature supporting the use such explicit interventions has been limited mainly to older school aged children and adolescents (Ebbels et al., 2007, 2012, 2014). As such, this programme of research aimed to contribute to the evidence-base outlining the efficacy for an explicit intervention with younger school-aged children. Another key aspect that sets TheMEDI apart from implicit interventions is a focus on production: the child is required to say the target form, and following an incorrect production, s/he was cued systematically. Although intervention effects were primarily limited to past tense production (i.e., the aim of the intervention), some participants improved to levels near mastery with as little as 3.5-5 hours of therapy over 10 weeks. This is markedly shorter than many previously reported interventions making it more efficient as well as efficacious. Therefore, it appears that there is value in the continued evaluation and clinical implementation of explicit interventions such as the one evaluated with this programme of research.

Although on average, participants demonstrated sustained maintenance of intervention gains over five weeks, it may be possible that the efficacy of the metalinguistic aspect of the intervention diminishes without protracted reinforcement. There is also evidence that retention of learning in children with DLD may be comparable to typically developing children in the non-verbal domain (Lukács et al., 2017), which may theoretically draw upon spared non-verbal declarative memory. Therefore, it is plausible that children with DLD may need average or above average non-verbal declarative learning capacity to demonstrate improvement and maintenance of gains through TheMEDI. This may also highlight the necessity to include the visual aspect of TheMEDI, given children with DLD may indeed present with deficits in verbal declarative learning (Bishop & Hsu, 2015; Lum et al., 2012) especially when associated with working memory (Jackson et al., 2020; Lum et al., 2015; Quail et al., 2009). Although neither verbal nor non-verbal declarative memory moderated intervention outcomes, the mean (scaled score = 7.07) and range (scaled scores = 1 – 11) of verbal declarative memory scores may reflect a deficit relative to mean (scaled score = 8.73) and range (scaled scores = 4 – 16) of non-verbal declarative memory scores (see Table 6.2). This information may be pertinent when considering the profiles of individuals and their suitability for TheMEDI in clinical practice.

Clinical Recommendations from the Programme of Research

The results of this programmatic approach to evaluating intervention efficacy indicate recommendations for clinical practice. These include the efficacy of TheMEDI for early school-aged children with DLD, intervention dosage and intensity to optimise efficacy, and which regular past tense targets should be selected for intervention.

The Efficacy of TheMEDI

TheMEDI involved a combination of metalinguistic training (the SHAPE CODING™ system) and explicit grammar facilitation (systematic cueing hierarchy) delivered in a one-on-one context to children with DLD aged between 5;9 and 6;9. There are 10 components to the intervention (reported in detail in Chapter 2, Table 2.3).

The programmatic approach to this research increases confidence in replicability of findings and translation to practice. In particular, Chapter 2 (Table 2.1) includes the Template for Intervention Description and Replication (TIDieR) (Hoffman et al., 2014) to report on intervention procedures clearly and transparently. Although there was variability in the profiles and performance of participants within the programme of research, results from the intervention studies reveal past tense production was the primary area of improvement. Despite promising findings from an early efficacy pilot study (Calder et al., 2018), in general, standardised measures of expressive (SPELT-3) and receptive (TROG-2) grammar did not improve. This is likely due to the highly targeted nature of TheMEDI, and the repeated finding that intervention effects rarely generalise to other (even related) skills for children with DLD (e.g., Eidsvåg et al., 2019; Leonard et al., 2004, 2006, 2008). That is, the grammar assessments test a variety of grammatical constructions, so it is unlikely that TheMEDI would have resulted in generalised improvement to those structures that were failed at initial assessment. In fact, the SPELT-3 assesses one regular past tense structure out of 53 items, and the TROG-2 assesses no regular past tense structures. Therefore, the positive results on the SPELT-3 in Study 1, Chapter 3 may reflect regression to the mean. Further still, grammatical comprehension is not a unitary skill; rather, it involves several components and levels of processing from the reception of acoustic signals, which are related to the mental lexicon and encoded within word order and grammatical inflections, and finally interpreted in social and environmental contexts (Bishop, 2014c). Intervention that would result in effects on comprehension would likely require detailed consideration of these components and levels of processing to discern mechanisms of change appropriately.

A measure of grammaticality judgement was also included in this programme of research to help discern whether children with DLD improve in their ability to detect violations to obligatory tense marking as a result of intervention. Such a finding would suggest the establishment of a stable metacognitive awareness of finiteness marking, which may serve as a compensatory strategy that could be taught to alleviate other areas of weakness for children with DLD. However, in general, the participants in the programme of research did not improve their grammaticality judgement. This suggests that such metacognitive awareness may not be achieved with TheMEDI within a period of 10 weeks for early school-aged children with DLD. Further, grammaticality judgement may represent a stable clinical marker of DLD from preschool-age (Rice et al., 1999) into later school-age and adolescence (Dale et al., 2018). Alternatively, a lack of change may be due to the way in which grammaticality judgement was measured in this programme of research. Although scores were converted to *A'* to account for 'yes bias' (e.g., Rice et al., 1999), the binary nature of the task may have been too crude to capture an effect of change in stored knowledge of morphosyntax through metalinguistic training. Alternative scoring systems, such as the graded acceptability judgements for sentences and individual lexical forms show promise for use with children as young as 4;6 years (Ambridge, 2012). A further benefit of such a system includes no need to convert raw scores for statistical analysis.

Dosage and Intensity

Dosage and intensity are often considered within the framework suggested by Warren et al. (2007), where: *dose* refers the number of presentations of the target per session, (e.g., 50); *dose frequency* refers to the number of sessions per week (e.g., twice); *intervention duration* refers to the time an intervention is provided (e.g., 10 weeks), and; *cumulative intervention intensity* refers to *dose* x *dose frequency* x *intervention duration*, (e.g., 50 x twice per week x 10 weeks = 1000 trials).

This programme of research examined the efficacy of a cumulative intervention intensity of 1000 trials (Chapter 3, Study 1: Calder et al., 2020) and 500 trials (Chapter 4, Study 2: Calder et al., 2021), and the results are reported in Chapter 5 (Study 3: Calder et al., under review b). Participants receiving intervention twice per week appeared to demonstrate an advantage in their rate of progress during the intervention phase. From a clinical standpoint, since grammar interventions are typically provided once weekly, at least in the US (see Finestack & Satterlund, 2018), clinicians may opt to use a once weekly dose frequency when providing this intervention. This could possibly allow a greater number of children to be serviced. Additionally, TheMEDI is provided within 20-30 minute sessions, which is shorter than the reportedly typical 45-60 minute sessions usually delivered by clinicians when treating grammar difficulties (see Finestack & Satterlund, 2018). Finally, some children in the current programme of research achieved levels of near mastery after as few as 10 sessions (three and half to five hours of intervention), which is markedly shorter than reported implicit interventions, which may take as many as 36 (Owen van Horne et al., 2017) to 96 (Leonard et al., 2004) sessions.

There were no between group differences on any measure which may indicate a general profile of participants better suited to once or twice weekly intervention. However, inspecting the individual profiles of participants may illustrate patterns for potential responsiveness to intervention. For example, Participants 4 and 5 in the twice per week condition demonstrated significant progress during the intervention phase and maintenance of intervention gains. These participants presented with relative strengths in receptive grammar (TROG-2 standard scores = 81) relative to expressive grammar (SPELT-3 standard scores ≤ 71), and receptive vocabulary in the average range (PPVT-4 standard scores ≥ 93). Therefore, relative strengths in receptive language may be optimal when receiving intervention twice weekly, potentially accommodating the high metalinguistic load of the intervention. Interestingly, Participant 5 had a scaled score = 5 for non-verbal declarative memory, indicating moderate difficulties, but a standard score = 111 for non-verbal working memory. Therefore, perhaps strengths lay in rapid encoding of visual information for later retrieval of grammatical information through verbal pathways. Participant 13 in the once weekly condition demonstrated a similar responsiveness profile, but showed greater strengths in expressive grammar (SPELT-3 standard score = 98; GET-ed = 46.7%), with lower receptive grammar (TROG-2 standard score = 72) but average receptive vocabulary (PPVT-4 standard score = 102). Perhaps relative strengths in expressive grammar traded off weakness in receptive grammar and receipt of fewer intervention sessions. Participant 16 showed a similar profile to Participant 13 with the exception of a steep decline in the maintenance phase. The key difference in profiles was a lower receptive vocabulary score (PPVT-4 standard score = 90) and higher non-verbal working memory score (WMTB-C VSS standard score = 103), which may suggest a longer period of intervention where learning is enhanced through visual means would be required to retain gains.

Regardless, the findings from this programme of research align with Eisenberg's (2013) review of the literature, which suggests that intervention should be scheduled once or twice weekly. Importantly, the review also suggested intervention should include introducing new grammar features and periodically cycling back to prior goals over sessions. This would be important to consider with the clinical implementation of TheMEDI.

The systematic analysis of varying language intervention intensities remains relatively scarce. Most studies have manipulated more than one variable, such as dose frequency as well as intervention duration (e.g., Meyers-Denman & Plante, 2016; Smith-Lock et al., 2013), which kept the cumulative intervention intensity constant. This should be considered in the context of clinical relevance, as often the aim of intervention research is to ultimately reduce the amount of time clients are under the care of clinicians through the achievement of client-driven function outcomes generalised to everyday settings. Further, previous studies evaluated intervention provided over highly blocked conditions, for example once a day for five days. This is a seemingly uncommon option for the provision of grammar intervention (see Finestack & Satterlund, 2018). Throughout this programme of research, only one variable (dose frequency) was manipulated, which has allowed a comparison of different cumulative intervention intensities, which in effect dictates how long a client may be under the care of a clinician in real-life contexts. However, as reported in Chapter 5 (Study 3: Calder et al., under review b), the definitions of the various parameters of cumulative intervention intensity are often interpreted differently. This highlights the need to conduct further research into the area of dosage and intensity to clearly define parameters that facilitate replication and translation to clinical practice.

Target Selection

An increasingly expanding area of research into grammar intervention efficacy and effectiveness relates to target selection. Until recently, most research focussed on the morphosyntactic skills (e.g., Rice & Wexler, 1996, Rice et al., 1998, 1999) and treatment of verbal inflection (e.g., Fey et al., 1993, 1997, 2017; Leonard et al., 2004, 2006, 2008) for children with DLD. This may be due to the theoretical underpinnings that have driven these bodies of research. However, it is becoming apparent that other areas of inflectional morphology, such as nominal inflection, are also affected in this population (Tomas et al., 2015, 2017). Findings reported in Chapter 7 (Study 5: Calder et al., under review a) indeed reflect these recent findings, indicating that deficits in inflectional morphology are broader than those required only for finiteness marking.

Pre-intervention, there were no differences across participants in their accuracy of production of regular past tense, third person singular, or possessive *'s*. However, similar to recent findings, (Tomas et al., 2015, 2017), there appears to be an effect of syllabicity. That is, whether marked for verbal or nominal inflection, lexical items marked with syllabic allomorphs (e.g., [əd], [əz]) are produced with significantly less accuracy than those marked with single consonants (e.g., [d], [t]; [z], [s]). Therefore, syllabic allomorphs represent a specific area of vulnerability, where the category for morphological inflection may not, necessarily. Consequently, regular past tense, third person singular, and possessive *'s* should be considered with equal importance in terms of a priority for intervention, with particular emphasis on syllabic allomorphs.

Importantly, it has been relatively well established that intervention effects are not observed on morphosyntactic skills unless they are directly targeted through intervention (e.g., Leonard et al., 2004, 2006, 2008). That is, although children may be exposed to different yet linguistically related targets throughout the process of intervention, transference to spontaneous production is rarely observed (e.g., Eidsvåg et al., 2019). Within this programme of research, it was initially hypothesised that there may be an observed intervention effect on third person singular as well as regular past tense. This was since the structures are linguistically related, and third person singular was used to prime participants for production of past tense (e.g., *The frog flip**s**. What DID it DO?* See Chapter 2 and Table 2.2 for more detail). However, there was no improvement on measures of third person singular at the group level. This indicated no intervention effect, despite third person singular functioning as language input throughout intervention.

Related research has demonstrated that following intervention, the inflectional morphology category (i.e., regular past tense, third person singular, or possessive 's) did not moderate intervention outcomes, but intervention conditions (i.e., explicit teaching and systematic cueing versus recasting alone) did (Smith-Lock et al., 2015). This indicates that perhaps not one of these structures is harder to learn than the other; however, the choice of intervention is clearly critical. Owen van Horne et al. (2017) also demonstrated that selecting 'harder' verbs, typically marked with syllabic allomorphs, results in more rapid and generalised intervention effects for early school-aged children with DLD. This programme of research has demonstrated that all three past tense allomorphs (i.e., [əd], [d], [t]) improve pre- to post-intervention proportionately to one another following explicit intervention (see Chapter 5, Study 3: Calder et al., under review b). This, in combination with findings from Chapter 7 (Study 5: Calder et al., under review a) and previously reported findings (e.g., Tomas et al., 2015, 2017), suggests that although syllabic allomorphs are produced with significantly lower accuracy prior to intervention, these items are no more difficult for children with DLD to learn following explicit intervention using metalinguistic training. Of particular importance, the verbs measured to inform this finding were untrained as part of intervention. Therefore, the findings indicate a generalised intervention effect to improve regular past tense regardless of the allomorph.

Limitations and Future Directions

TheMEDI was delivered with excellent adherence to protocol (97.95% accuracy) and rated with excellent consistency (intraclass correlation coefficient = .976) throughout the programme of research. However, only a single researcher implemented the entire programme of intervention with strict adherence. Further, TheMEDI has not been evaluated for effectiveness in various contexts and delivered by other clinicians. So it is unclear whether similar effects would be seen if the intervention is delivered by other clinicians in other contexts. This further reinforces the need to implement TheMEDI with the fidelity checklist, and to continue evaluating the effectiveness of this intervention through replication. Of note, the items on the fidelity checklist are weighted equally, which may not necessarily reflect the distribution of importance regarding the active ingredients of TheMEDI. For example, achieving the fully intended 50 trials equates to only 2 points on the checklist, which is plausibly one of the most critical aspects of the intervention. Future research may serve to validate such a checklist through robust methodology (e.g., Behn et al., 2019).

TheMEDI has been evaluated rigorously and systematically. However, it has been evaluated on a relatively small sample of children with DLD. Participants were also recruited using convenience sampling from a specialised educational programme designed for children with DLD, and as such, are subject to ascertainment bias (Redmond et al., 2019). Further, the use of single case experimental design in the Phase II study (Chapter 3, Study 1: Calder et al., 2020) means generalisability of findings from the twice per week study to the broader population is limited. Given the paucity of evidence supporting the use of effective grammar interventions with early school-aged children with DLD, clinicians should be confident in implementing this theoretically motivated intervention to improve past tense marking. Further replication and translation to effectiveness trials is required to strengthen that confidence.

Importantly, the predictions of the PDH cannot be supported by this programme of research beyond the claim that explicit intervention is more efficacious than ‘treatment-as-usual’. Measures of memory did not appear to moderate intervention outcomes (as reported above, this may be due to methodological issues such as sample size and instrumentation), and the claim that explicit intervention is more beneficial than implicit intervention for children with DLD cannot be supported without direct comparison in superiority trials. Future research is warranted, particularly exploring the implications for working memory as discussed above. In the meantime, as reported in Chapter 4 (Study 2: Calder et al., 2021), TheMEDI easily be combined with statistical learning principles (Plante & Gómez, 2018), such as *variability* (Plante et al., 2014) and *frequency* (Owen van Horne et al., 2017, 2018) to optimise outcomes, both for research purposes, and clinical translation.

Future research may also serve to directly compare explicit intervention using visual support with explicit intervention that does not. Although the visual aspect of TheMEDI seems theoretically crucial, there is evidence to suggest that explicit interventions can be efficacious (Finestack & Fey, 2009; Finestack, 2018) and effective (Smith-Lock et al., 2015) without a visual component. It is worth noting that any differences between study effect sizes following such interventions will likely be small, so large sample sizes would be required. Nonetheless, comparing explicit interventions that do and do not use visual support and evaluating the potential moderating effects of cognitive systems, such as declarative and procedural memory, and working memory, may serve to discern how (or if) information is ultimately transferred to long-term storage for later retrieval and used through competitive interaction between the systems. Findings from such a study may shed light on whether children with DLD indeed utilise cognitive systems responsible for integrating visual information as compensatory and/or enhancement mechanisms for processing verbal information.

TheMEDI is a combination of two approaches to morphosyntactic intervention: the SHAPE CODING™ system (Ebbels, 2007) and a systematic cueing hierarchy (Smith-Lock et al., 2015). Further analysis of the levels of cueing required to successfully achieve a trial through intervention which accounts for variance in intervention outcomes may help tease apart the potential active ingredient/s to intervention. Subsequently, a direct comparison of both approaches may serve to determine if both approaches are necessary for intervention efficacy.

Overall strengths in receptive vocabulary skills in the current sample also provides implications for future research. The participants in the current programme of research demonstrated a mean scaled score of 94.53 (SD = 12.06) on the PPVT-4 as a measure of receptive vocabulary (see Appendix D), which would be considered within the average range. This may indicate that lexical knowledge is a strength that can be drawn upon through intervention (Yarian et al., 2019). Perhaps if intervention had focused on developing verb semantics with familiar vocabulary items as the foundation of a strong representation for syntactic frames, this could bootstrap children to learn to apply verb morphology more readily (see Ebbels et al., 2007). Indeed, recent research suggests children with relatively higher vocabulary scores demonstrate higher gains through intervention (Kapa et al., 2020). Alternatively, focussing initially on verb semantics for children with low vocabulary scores may increase the processing burden inherent to metalinguistic training. For example, the participants with below average vocabulary scores may have made greater intervention gains if verb semantics was the initial focus for intervention. Regardless, developing verb semantics is in-built with elements from the SHAPE CODING™ system, namely the *wh*-questioning. Further research could aim to evaluate a cumulative intervention, beginning with teaching verb semantics to establish semantic meaning relations and progress to the affixation of morphology, and further to the elaboration and expansion of syntax to complex sentences through explicit intervention. Current data suggest children have difficulty with all measured aspects of inflectional morphology, including possessive *'s* (Chapter 7, Study 5: Calder et al., under review a), which is rule governed and determined through sequence learning. This proposed cumulative approach could serve to address these deficits.

Finally, it would be of great interest to evaluate whether the findings from the current programme of research can be generalised cross-linguistically. Leonard (2014) and Leonard and Kueser's (2019) review of cross-linguistic research suggests we must move beyond viewing DLD as a disorder characterised by a singular universal grammatical deficit (such as finiteness). However, could principles of explicit intervention, such as metalinguistic training using visual support and grammar facilitation using systematic cueing, be applied to address areas of morphosyntactic deficit in languages other than English?

The literature exploring target selection in morposyntax intervention for children with DLD is equivocal. It appears there is an interplay between the morphosyntactic patterns with which children with DLD are likely to have difficulty (e.g., past tense inflection), properties within those morphosyntactic patternes (e.g., morphophonology/allomorphy), and the intervention approach selected. Application of theoretical frameworks to clinical trials may shed further light on which specific targets may be favourable to prioritise when treating morphosyntax difficulties in children with DLD. Future research may serve to evaluate grammatical elements known to be affected in children with DLD, such as sentence constituents, pronouns, verb form elaboration, negative and interrogative sentences, noun phrase elaboration, and complex sentences (Eisenberg, 2013). Further, the components of intervention (reported with the TIDieR in Chapter 2) could be shaped around recommendations from Fey et al. (2003). That is, selecting targets based on *typical development*; identifying forms children *attempt*, but *use incorrectly* in speech/writing, and; targeting forms that have *functional impact* on the child.

Conclusions

Speech-language pathologists are encouraged to reflect upon *client factors, clinician factors,* and *research evidence* when selecting appropriate interventions for specific clinical populations. In the absence of empirical evidence (i.e., *research evidence*), speech-language pathologists may draw upon theory (i.e., *clinician factors*) to select, or even develop interventions suitable for use with their clients (i.e., *client factors*). This three tiered approach to clinical practice is referred to as E^3BP (Evidence(3)-based practice), which is the driving force behind this programme of research.

This thesis reports on a programme of research which designed, developed, and evaluated the efficacy of a theoretically motivated past tense intervention for 5;9-6;9 year old children with DLD. The intervention was motivated by the Procedural Deficit Hypothesis (PDH) (Ullman & Pierpoint, 2005), which suggests children with DLD may be better equipped to learn grammar explicitly through spared declarative memory in the presence of impaired procedural memory which implicates implicit learning. The PDH purports this results in a profile of skills where children with DLD have impaired grammar in the presence of relatively spared vocabulary. Although in general, this profile was observed in the sample population of children with DLD, there was great variability across measures of language and memory functioning taken both pre- and post-intervention from participants within each study. Indeed, this reaffirms children with DLD represent a heterogeneous clinical population (Bishop et al, 2016).

Results from this programme of research contribute to the equivocality of findings in the literature regarding whether or not a distinction in procedural or declarative memory between children with DLD and those who are typically developing does indeed exist. Given the diversity of performances from individuals on various pre- and post-intervention measures from a sample population of children who share a common clinical diagnosis, perhaps the shared symptoms experienced by these children are the result of the interplay between distinct underlying pathologies, rather than a categorical endophenotype, such as a procedural learning deficit.

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Appendices

Appendix A

Copyright Permissions for Published Manuscripts

Re: Permission for Inclusion of Accepted Manuscripts in PhD Thesis

PA Permissions Asha <Permissions@asha.org>
Fri 1/8/2021 11:00 PM
To: Samuel Calder

Good morning Samuel,

Your email below was copied to ASHA's Permissions.

Permission is granted to use the articles referenced below in your email in your forthcoming thesis.

We request that you cite ASHA as the source and provide a link back to the articles on our website.

If your thesis is published at a later date, additional permission will be needed at that time.

Good luck with your thesis!

From: Samuel Calder <samuel.calder@postgrad.curtin.edu.au>
Sent: Wednesday, January 6, 2021 8:19 PM
To: ASHA Journals <ASHAJournals@asha.org>
Subject: Permission for Inclusion of Accepted Manuscripts in PhD Thesis

Dear ASHA Production Team,

I am writing to request permission to include two articles published in ASHA journals as part of my PhD thesis. The request pertains to including "the final, accepted manuscript(s) along with the abstract from the final, published article(s) when available, provided that the publication information (including the Web address of the journal site) is provided as applicable".

The full references for the articles are as follows:

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020). Explicit grammar intervention in young school-aged children with developmental language disorder: An efficacy study using single case experimental design. *Language, Speech & Hearing Services in Schools, 51*(2), 298-316. https://doi.org/10.1044/2019_LSHSS-19-00060

Calder, S. D., Claessen, M., Ebbels, S., & Leitão, S. (2020). The efficacy of an explicit intervention approach to improve past tense marking for early school-aged children with Developmental Language Disorder. *Journal of Speech, Language, & Hearing Research,* 1-14. https://doi.org/10.1044/2020_JSLHR-20-00132

Many thanks in advance,
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CRICOS Provider Code 00301J

Appendix B

Sample Recruitment Forms, Non-diagnostic Treatment Summary Report Templates, and Progress Notes Templates

Appendix B.1

Example Curtin HREC and Department of Education, Western Australia Approved Information Letters and Consent Forms for Recruitment of Study 1

School of Psychology and Speech Pathology

March 2018

(LDC Principal information letter)
Samuel Calder
PhD Candidate Human Communication Sciences
School of Psychology and Speech Pathology
Curtin University
GPO Box U 1987, Perth
Western Australia, 6845

Dear Principal,

An early efficacy investigation of an explicit intervention approach to improve grammar in early school-aged children with DLD

My name is Samuel Calder, and I am a PhD candidate from Curtin University. My study will investigate the efficacy of an explicit and direct grammar intervention approach for Year 1 children with grammar difficulties associated with developmental language disorder. Developmental Language Disorder (DLD) is a common developmental disorder that affects how children think about, understand and use language. The results from this study will be used to inform Speech Pathologists and schools about effective intervention programmes for this population. Supervisors for this project are Dr Mary Claessen and Associate Professor Suze Leitão from Curtin University.

What does participation in the research project involve?
I am seeking the participation of 9 Year 1 students who have developmental language disorder and associated grammar difficulties The project will involve five to nine weeks of baseline testing, grammar intervention for 10 weeks and five weeks of follow-up testing (full details are in a table at the end of the letter).

I would like to invite your school to participate in this research.

This would involve the following steps:
As the Principal, you will provide my research information sheet and consent forms to the parents/carers of children in the Year 1 classes who have been identified as having grammar difficulties, and who meet inclusion and exclusion criteria.

Inclusion criteria include: children are between the ages of 5;6-7;6, speak English as a primary language, and have grammar difficulties associated with DLD.
Exclusion criteria include: a neurological diagnosis, a cognitive impairment, and hearing outside normal limits, accessing Speech Pathology intervention outside of the Language Development Centre.
(This information is accessible from enrolment packages and standard data management practices at the Language Development Centre. This selection screening process will be used to ensure only parents/carers of children meeting inclusion/exclusion criteria receive Parent Information Sheets and Consent Forms.)
The parents/carers of children who are considered to meet inclusion/exclusion criteria will return completed consent forms to you as the Principal to pass on to me. Parents/carers will have the opportunity to discuss any questions they may have with me
Baseline assessment will then take place with children who have consent to take part.
Any children who do not meet criteria following baseline assessment will have their assessment results summarised and reported to parents, and with their permission, to NEMLDC staff or external speech pathologists which may be used for intervention planning.
After the required number of nine participants has been met, parents of any remaining children that have provided consent will be informed that capacity has been reached for this study.
Following initial baseline assessment, participants will be randomly assigned to one of three groups: Group 1 has 5 weeks of baseline assessment, Group 2 has 7 weeks of baseline assessment, and Group 3 has 9 weeks of baseline assessment.
I will see each child at school on two separate days per week for 10 weeks to conduct the intervention. The intervention will take 45 minutes each day for each child (see overview of intervention timeline attached below).
Steps will be taken to closely monitor participants' progress throughout the study. I will provide, with parental consent, weekly updates on participants' progress to the school Speech Pathology and Administration team to ensure the therapy is best suited to the needs of the children. If a participant does not demonstrate improvement in targeted areas over three consecutive weeks of intervention, a meeting will be arranged to discuss the participant's ongoing involvement in the study.
The baseline measures, intervention sessions and pre and post assessments will be audio-recorded and video-recorded, so that scoring can take place after the sessions are completed. The audio recordings and video recordings will be deleted immediately after scoring is completed.
The post-treatment assessments (two standardised tests and two grammar tests) will be administered, recorded and scored by final year Curtin student Speech Pathologists blinded to the study, for all participants. I will conduct all other repeated measurements during post-treatment.
With permission from parents, I will provide pre-treatment standardised assessment scores unrelated to grammar (for example the Preschool and Primary Inventory for Phonological Awareness) to teachers which may assist with classroom planning. Results from grammar assessments can be provided at the end of the treatment period in the form of a Treatment Summary Report.
I will provide an overall summary of the project to the Language Development Centre staff.

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 are advised of this in the information letters.

If parent/carers 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 their 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 the principal investigator (Samuel Calder) and supervisors (Dr Mary Claessen, Associate Professor Suze Leitão). All measurement records will be stored for a minimum period of 25 years, after which they 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 or the school 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 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. In order to protect the identity of the NEMLDC, in reports it will be referred to as: an educational program for students diagnosed developmental language disorder.

The results from assessments completed both before and after the project will be summarised in a Treatment Summary Report for parents. With parent consent, the report will be made available to the child's teacher.

What are the benefits of this research for the child's education and the school?
The results from this study will be used to inform Speech Pathologists and classroom teachers whether explicit and direct intervention delivered to children by a Speech Pathologist is efficacious. The findings of this study will be very practical in the clinical environment and in the planning of intervention and resources. It will add to the evidence base on treatment approaches for grammatical impairment. If the therapy is found to have a positive significant impact on a child's grammar difficulties, further research into the effectiveness of such approaches and of different service delivery agents (e.g. teachers) may be conducted. This will improve the quality and cost effectiveness of planning individual grammar intervention.

Are there any risks associated with participation?
There are no known risks associated with participation in this study. All sessions will include a range of fun activities and breaks will be provided where necessary.

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. Student Speech Pathologists who will be used for post intervention testing will also have their Working with Children made available to you and the Department of Education.

Is this research approved?

Curtin University Human Research Ethics Commitee (HREC) has approved this study (HREC number HRE2017-0835). 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) 92667093 or email hrec@curtin.edu.au.
This research has met the policy requirements of the Department of Education as indicated in the attached letter.

Who do I contact if I wish to discuss the project further?

Please do not hesitate to contact me or the co-investigators if you have any questions about the project. I can be contacted by email (Samuel.Calder@postgrad.curtin.edu.au). You may also wish to contact one of the co-investigators, Dr Mary Claessen (M.Claessen@curtin.edu.au), Associate Professor Suze Leitão (S.Leitao@exchange.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 **6th of April, 2018** if you would like your school to be involved.

Kindest regards,

Samuel Calder	Dr Mary Claessen	A/ Prof Suze Leitão
Speech Pathologist	Speech Pathologist	Speech Pathologist
PhD Candidate Curtin University	Senior Lecturer Curtin University	Associate Professor Curtin University

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au

Summary of assessment administration and intervention times

Session	Testing	Time
Pre-treatment assessment session 1	Primary Inventory of Phonological Awareness (PIPA) Child Memory Scales (CMS)	30 + 30 = 60 mins
Pre-treatment assessment session 2	Serial Reaction Time (SRT) task Children's Test of Nonword Repetition (CNRep)	30 + 15 mins = 45 mins
Pre-treatment baseline session 1	Test of Reception of Grammar (TROG) Test of Early Grammatical Impairment (TEGI) Grammar Elicitation Test (GET) (90 items) Grammar Comprehension Test (GCT) (90 items)	10 + 20 + 10 + 10 = 50 mins
Pre-treatment baseline sessions Group 1 (2-5)	Reduced GET (27 items) Reduced GCT (36 items)	5 + 5 = 10 mins per session Total: 40 mins over 4 weeks
Pre-treatment baseline sessions Group 2 (2-7)	Reduced GET (27 items) Reduced GCT (36 items)	5 + 5 = 10 mins per session Total: 60 mins over 6 weeks
Pre-treatment baseline sessions Group 3 (2-9)	Reduced GET (27 items) Reduced GCT (36 items)	5 + 5 = 10 mins per session Total: 90 mins over 9 weeks
Intervention sessions	2x 45 minute intervention sessions per week over 10 weeks	(2 x 45) x 10 = 15 hours over 10 weeks
Post-treatment baseline session 1	Test of Reception of Grammar (TROG) Test of Early Grammatical Impairment (TEGI) Grammar Elicitation Test (GET) (90 items) Grammar Comprehension Test (GCT) (90 items)	10 + 20 + 10 + 10 = 50 mins
Post-treatment baseline sessions Group 1, 2, 3 (2-5)	Reduced GET (27 items) Reduced GCT (36 items)	5 + 5 = 10 mins per session Total: 40 mins over 4 weeks

Overview of Assessment and Intervention Timeline

Time Frame	**Activity**	**People Involved**
30th April-4th May (over 1 week) (30 minutes per child)	Baseline Assessment Measures: Primary Inventory of Phonological Awareness	Researcher (Samuel Calder)
30th April-4th May (over 1 week) (30 minutes per child)	Baseline Assessment Measures: Child Memory Scales	Researcher (Samuel Calder)
30th April-4th May (over 1 week) (30 minutes per child)	Baseline Assessment Measures: Serial Reaction Time Task	Researcher (Samuel Calder)
30th April-4th May (over 1 week) (15 minutes per child)	Baseline Assessment Measures: Children's Test of Nonword Repetition	Researcher (Samuel Calder)
7th- 11th May (over 1 week) (20 minutes per child)	Baseline Outcome Measures: Pre–test: Test of Early Grammatical Impairment	Researcher (Samuel Calder)
7th- 11th May (over 1 week) (10 minutes per child)	Baseline Outcome Measures: Pre–test: Test of Reception of Grammar-2	Researcher (Samuel Calder)
7th- 11th May (over 1 week) (10 minutes per child)	Baseline Outcome Measures: Pre-test: Expressive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	Researcher (Samuel Calder)
7th- 11th May (over 1 week) (10 minutes per child)	Baseline Outcome Measures: Pre-test: Receptive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	Researcher (Samuel Calder)
7th- 11th May	Children assigned to one of three baseline conditions: Group 1, Group 2 or Group 3	Researcher (Samuel Calder)
11th May-8th June (4 weeks) (1x10 minute sessions per child per week)	Group 1: Repeated Measures conducted across 4 sessions for 3 children 27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	Researcher (Samuel Calder)
14th May-22nd June (6 weeks) (1x10 minute sessions per child per week)	Group 2: Repeated Measures conducted across 7 sessions for 3 children	Researcher (Samuel Calder)

	27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	
14th May-6th July (8 weeks) (1x10 minute sessions per child per week)	Group 3: Repeated Measures conducted across 10 sessions for 3 children 27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	Researcher (Samuel Calder)
11th June-6th July (4 weeks); HOLIDAYS; 23rd July-31st August (6 weeks) (2x 45 minute intervention sessions per week per child)	Group 1: 10 weeks of intervention	Researcher (Samuel Calder)
25th June- 6th July (2 weeks); HOLIDAYS; 23rd July-14th September (8 weeks) (2x 45 minute intervention sessions per week per child)	Group 2: 10 weeks of intervention	Researcher (Samuel Calder)
28th July- 29th September (10 weeks) (2x 45 minute intervention sessions per week per child)	Group 3: 10 weeks of intervention	Researcher (Samuel Calder)
3rd-7th September (over 1 week) (20 minutes per child)	Group 1: Outcome Measures: Post–test: Test of Early Grammatical Impairment	1x Final Year Curtin Speech Pathology Students (one to administer and score)
3rd-7th September (over 1 week) (15 minutes per child)	Group 1: Outcome Measures: Post–test: Test of Reception of Grammar-2	1x Final Year Curtin Speech Pathology Students (one to administer and score)
3rd-7th September (over 1 week) (10 minutes per child)	Group 1: Outcome Measures: Post-test: Expressive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to

		administer and score)
3rd-7th September (over 1 week) (10 minutes per child)	Group 1: Outcome Measures: Post-test: Receptive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to administer and score)
10th-28th September (over 3 weeks); HOLIDAYS; 15th-19th October (1 week) (1 x 10 minute session per child)	Group 1: Post-treatment Repeated Measures conducted across 4 sessions for 3 children 27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	Researcher (Samuel Calder)
17th-21st September (over 1 week) (20 minutes per child)	Group 2: Outcome Measures: Post–test: Test of Early Grammatical Impairment	1x Final Year Curtin Speech Pathology Students (one to administer and score)
17th-21st September (over 1 week) (over 1 week) (10 minutes per child)	Group 2: Outcome Measures: Post–test: Test of Reception of Grammar-2	1x Final Year Curtin Speech Pathology Students (one to administer and score)
17th-21st September (over 1 week) (10 minutes per child)	Group 2: Outcome Measures: Post-test: Expressive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to administer and score)
17th-21st September (over 1 week) (10 minutes per child)	Group 2: Outcome Measures: Post-test: Receptive Grammar Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to administer and score)
24th – 28th September (over 1 week); HOLIDAYS; 15th October 2nd November (over 3 weeks) (1 x 10 minute session per child)	Group 2: Post-treatment Repeated Measures conducted across 4 sessions for 3 children 27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	Researcher (Samuel Calder)

15th-19th October (over 1 week) (20 minutes per child)	Group 3: Outcome Measures: Post–test: Test of Early Grammatical Impairment	1x Final Year Curtin Speech Pathology Students (one to administer and score)
15th-19th October (over 1 week) (15 minutes per child)	Group 3: Outcome Measures: Post–test: Test of Reception of Grammar-2	1x Final Year Curtin Speech Pathology Students (one to administer and score)
15th-19th October (over 1 week) (10 minutes per child)	Group 3: Outcome Measures: Expressive Grammar Baseline Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to administer and score)
15th-19th October (over 1 week) (10 minutes per child)	Group 3: Outcome Measures: Receptive Grammar Baseline Measures are conducted for each of the 9 children using 90 probes (30 targeting the grammatical structure, 30 targeting generalisation structures and 30 to be used as a control).	1x Final Year Curtin Speech Pathology Students (one to administer and score)
22nd October- 16th November (over 4 weeks) (1 x 10 minute session per child)	Group 3: Post-treatment Repeated Measures conducted across 4 sessions for 3 children 27 expressive grammar probes (9 targeting grammatical structure, 9 targeting generalization and 9 to be used as a control) 36 receptive grammar probes (12 targeting grammatical structure, 12 targeting generalization and 12 to be used as a control)	Researcher (Samuel Calder)

School of Psychology and Speech Pathology

March 2018

An early efficacy investigation of an explicit intervention approach to improve grammar in early school-aged children with DLD

Consent Form for Language Development Centre 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 participant baseline measures, pre and post measures, baseline and intervention sessions will be audio recorded and video recorded to allow scoring to take place.

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 and the Department of Education will be provided with a copy of the overall research findings upon the completion of this project.

I understand that the school may be provided with pre-treatment test results unrelated to grammar and/or a summary of each child's progress in therapy after the study if parents/carers give consent.

Name of School (please print): ____

Name of School Principal (please print): ____

Signature of School Principal: ____

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

Name of Investigator (please print): ____

Signature of Investigator: ____

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

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au.

School of Psychology and Speech Pathology

March 2018

(LDC Parent information letter)

Samuel Calder
PhD Candidate Human Communication Sciences
School of Psychology and Speech Pathology
Curtin University
GPO Box U 1987, Perth
Western Australia, 6845

Dear Parent/Carer,

An early efficacy investigation of an explicit intervention approach to improve grammar in early school-aged children with DLD

My name is Samuel Calder and I am a PhD candidate from Curtin University. I will be studying the efficacy of a grammar programme for children with developmental language disorder. Developmental Language Disorder (DLD) is a common developmental disorder that affects how children think about, understand and use language. My findings will be shared with speech pathologists and teachers who can then use the programme. Supervisors for this project are Dr Mary Claessen and Associate Professor Suze Leitão from Curtin University.

What does participation in the research project involve and are there any risks?
I would like to invite your child to take part in my study. If you give permission for your child to participate, I will provide your child with therapy focussing on grammar difficulties. There are no known risks associated with this research, as this programme is very similar to intervention provided by community Speech Pathologists for children with grammar difficulties. Grammar therapy sessions will involve talking and playing with toy figures and board games so that children find them fun and engaging.

So that we can collect evidence on the success of the programme, I will need to assess your child both before therapy commences. The assessments will be the Primary Inventory of Phonological Awareness (PIPA), two measures of memory, the Test of Early Grammatical Impairment (TEGI) and Test of Reception of Grammar-2 (TROG-2). These are commonly used assessments and overall this will takes about 2 hours and 45 minutes. Two grammar assessments specific to the research called the Grammar Elicitation Test (GET) and the Grammar Comprehension Test (GCT) will be administered before and after therapy. These take 10 minutes each to administer. The TEGI, TROG-2, GET and GCT will also be administered at the end of the intervention period. At this time they will be administered by final year Speech Pathology students who are not aware of the aims of my study, which will increase the strength of my research. These students will be close to graduation and will have Working With Children Checks. I will also see your child for between five and nine short sessions before therapy, and five after therapy, where I ask him/her to name a set of pictures. These sessions will take about 10 minutes each and will involve board games to make the sessions fun for your child. I will also be asking your child to name a set of pictures at the beginning of each therapy session.

Therapy will take place twice a week for 10 weeks, at the LDC during terms 2-4, 2018. Each session will consist of games and will last for 45 minutes. As per usual practice at the LDC, your child's progress will be monitored closely to ensure the therapy is best suited to your child's needs. With your permission, progress will be discussed with the school's Speech Pathology and Administration team on a weekly basis. If your child does not demonstrate improvement in targeted areas over three consecutive weeks of intervention, I will arrange a meeting with you to discuss your child's ongoing involvement in the study.

The child's baseline measures, intervention sessions and pre and post assessments will be audio-recorded and video-recorded, so that scoring can take place after the sessions are completed. The audio recordings and video recordings will be deleted after we have completed and checked the scoring. Test forms will be stored in a secure location until your child turn 25 years of age, or 5 years after any research outcome based on the data, whichever is the longer.

Does my child have to take part?
No. You do not have to give permission for your child to take part in this project. 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 if they do want to take part. If you consent to your child to take part after the required number of children has been met, you child may be waitlisted in case a previously recruited child does not take part in the study. In the case that your child does not meet requirements for the study following assessment, assessment results will be summarised and passed on to NEMLDC staff or external speech pathologists which may be used for intervention planning with your permission. This information can be made available to you and your child's classroom teacher by checking the relevant boxes at the end of the form.

What if either of us was to change our mind?
If you give permission, but then change your mind, you may withdraw your child, or your child may withdraw themselves, at any time without consequence. If your child is withdrawn from the study, all of your child's information will be destroyed immediately. Please note, if the project has already been published at the time you or your child decides to withdraw, your contribution to research data cannot be removed from the publication.

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 take part and then 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, according to the Department of Education Child Protection Policy.

The results from assessments conducted before therapy that do not test grammar may be shared with your child's classroom teacher to help with classroom planning. The results from grammar assessments completed both before and after the project will be summarised in a Treatment Summary Report to report whether your child made progress as indicated by standardised tests of grammar comprehension and production. This information can be made available to you and your child's classroom teacher by checking the relevant boxes at the end of the form.

What are the benefits of this research for my child's education?
Your child will receive 20 therapy sessions focussed on his/her grammar difficulties and it is anticipated that his/her grammar will improve as a result of taking part in this study.
In order to support your child's learning at the LDC we also ask your permission to make progress notes and therapy summary reports available to staff at the LDC.

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 that work 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 HRE2017-0835). 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) 92667093 or email hrec@curtin.edu.au.

This research has met the policy requirements of the Department of Education.

What if I have further questions about this research project?
Please do not hesitate to contact me or the co-investigators if you have any questions about the project. I can be contacted by email (Samuel.Calder@postgrad.curtin.edu.au). You may also wish to contact one of the co-investigators, Dr Mary Claessen (M.Claessen@curtin.edu.au) or Associate Professor Suze Leitão (S.Leitao@exchange.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 the classroom teacher if you would like your child to be involved.

Thank you,

Samuel Calder	Dr Mary Claessen	A/ Prof Suze Leitão
Speech Pathologist	Speech Pathologist	Speech Pathologist
PhD Candidate Curtin University	Senior Lecturer Curtin University	Associate Professor Curtin University

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au

An early efficacy investigation of an explicit intervention approach to improve grammar in early school-aged children with DLD

Consent Form for Parents

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, 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.
I understand that my child's pre and post assessments, baseline and intervention sessions will be audio recorded and video recorded to allow scoring to take place.

Please also tick these boxes to give permission for:

☐ My child's progress to be reported to LDC Speech Pathology and Administration teams on a weekly basis to ensure therapy is best suited to my child's needs.

☐ My child's before therapy test results that do not relate to grammar to be reported to LDC Speech Pathology and Administration teams to assist with classroom planning. In the case that my child does not meet criteria for the study, all test results are to be reported to LDC Speech Pathology and Administration teams to assist with classroom planning.

☐ My child's progress notes and Treatment Summary Report (including standardised test results) to be released to his/her school which may be used for classroom planning purposes.

☐ I would like to be provided with a Treatment Summary Report (including standardised test results) of my child's results (please provide your address).

____

____.

Please confirm you child meets the following criteria:
☐ Is enrolled at the Language Development Centre
☐ Is between the ages of 5.5 and 7.5 years (in Year 1)
☐ Speaks English as their primary language
☐ Does NOT have a neurological diagnosis, cognitive impairment or hearing outside normal limits
☐ Is NOT accessing speech pathology services outside of the Language Development Centre

Name of Child (please print): ___________________________________
Date of birth (please print): _____ / _____ / ________
Name of Parent/Carer (please print): ___________________________________
Signature of Parent/Carer: _______________________________________
Date (DD/MM/YYYY):_____ / _____ / ________

Name of Investigator (please print): ___________________________________
Signature of Investigator: _______________________________________Date (DD/MM/YYYY):_____ / _____ / ________

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au

Curtin University
School of Psychology and Speech Pathology

March 2018

Consent Form for Children

I have talked about this project with my parents.

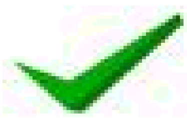
I know that I can choose whether or not I want to do this project.

I know that I can stop whenever I want without getting into trouble.

I know that I will be looking at pictures, playing with toys and talking.

I know that I will have my voice recorded and I will be videoed.

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 of child: ______________________ Today's Date: / /

Signature of Investigator: ______________________ Today's Date: / /

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au.

Appendix B.2

Example Curtin HREC and Department of Education, Western Australia Approved Non-diagnostic Report and Progress Note Templates for Study 1

Curtin University

School of Occupational Therapy, Social Work and Speech Pathology

October 2018

Non Diagnostic Language Report (For Parent and LDC)

Child's name:

Thank you for allowing your child to take part in this research project. With your consent, your child's results have been given to your child's school, and we have provided a summary of them below for your records. Please talk to your child's teacher or speech pathologist at the LDC, me, or co-investigators (Mary Claessen 9266 3472 or Suze Leitão 9266 7620) if you wish to discuss your child's results in detail.

Your child's grammar was assessed on the Structured Photographic Expressive Language Test, 3rd Edition (SPELT-3) and Test of Reception of Grammar, 2nd Edition (TROG-2) prior to intervention. At this stage his/her expressive grammar score was__ and his/her receptive grammar score was__. Results indicated that your child had difficulty with grammar. The focus of the research study was to improve production and understanding of **regular past-tense** (for example *The boy walk**ed***, The girl jogg***ed***, *The boy lift**ed** the chair*). This was the focus of intervention with your child. Prior to intervention beginning, your child was able to produce regular past-tense with __% accuracy when describing pictures. Your child was able to understand sentences using regular past-tense with __% accuracy when listening to sentences.

Your child attended 20 sessions of intervention with me. A summary of the results from intervention are provided in the table below.

Measure	**Pre-intervention**	**Post-intervention**
SPELT-3		
TROG-2		
Producing past-tense		
Understanding past tense		

After intervention your child's speech was re-assessed on the SPELT-3 and TROG-2. His/her expressive grammar score was__. This is within normal limits/still below what we would expect for his/her age. He/she has improved on this measure. His/her receptive grammar score was__. This is within normal limits/still below what we would expect for his/her age. He/she has improved on this measure. After intervention your child is now able to produce regular past-tense with __% accuracy when describing pictures. After intervention you child is now able to understand regular past-tense with __% accuracy when listening to sentences. This improvement has been maintained for 5 weeks.

Further, your child improved on their production of regular past-tense verbs that were trained in sessions. Producing and understanding verbs were measured in the same session as well as from the previous session. This is summarised in the table below.

Measure	**First session**	**Last session**
Producing past-tense (same session)		
Understanding past-tense (same session)		

Producing past-tense (previous session)		
Understanding past-tense (previous session)		

These results suggest your child was able to produce and understand regular past-tense verbs taught in intervention sessions. Your child was able to apply this knowledge to verbs that were not taught in sessions. Overall, results suggest this intervention was beneficial to your child.

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

Regards,
Samuel Calder
Speech Pathologist
PhD Candidate
E samuel.calder@postgrad.curtin.edu.au

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au

Progress notes
CHILD
(1.X); Term X, 2018

Date & rx type	Notes
B1.1 Grammar	CHILD was seen for a 30 minute intervention session with Samuel Calder (speech pathologist). His/her behaviour was managed and he/she participated enthusiastically in all conversation and session activities. **GOALS**: A) For CHILD to produce past tense –ed accurately on 80% of targeted verbs across 3 sessions with no support B) For CHILD to understand past tense –ed accurately on 80% of targeted verbs across 3 sessions with no support **ACTIVITIES**: Introduction to Shape Coding Playdough **PRESENTATION, PERFORMANCE & DATA**: A) CHILD produced past –ed verbs in 50 trials throughout the session. Generalised production of past tense verbs was measured using the Grammar Elicitation Test. CHILD produced X/9 (X%) verbs correctly B) Generalised understanding of past tense verbs was measured using the Grammar Comprehension Test. CHILD identified X/12 (X%) verbs to be grammatically correct. This is below chance performance. **PLAN**: Continue to target accurate production and understanding of past tense –ed at sentence level. Samuel Calder Speech Pathologist PhD Candidate Curtin University

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HRE2017-0835-05). The committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval for this study can be obtained by contacting the Committee: Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845. Telephone: 9266 9223, Email: hrec@curtin.edu.au

Appendix C

Example Intervention Session Plans

Full programme of research available at
https://www.languageandliteracyinyoungpeople.com/apps-resources

Explicit teaching of Shape Coding prompts (Session 1, Activity 1)

<table>
<tr><td colspan="3">Goal: To familiarise child with the SHAPE CODING™ system visuals</td></tr>
<tr><td>Target</td><td>Activity</td><td>Materials</td></tr>
<tr><td>[t]
kicked

[d]
hugged

[əd]
skated</td><td>Sit at a table next to the child.
We are going to be doing some fun work together. We are going to play lots of fun games that will help us with saying sentences about things that have already happened. We are going to use these shapes to help us make sentences. (Lay out SUBJECT OVAL, VERB HEXAGON, OBJECT RECTANGLE)
Here we have the oval that tells us the WHO in a sentence (point to oval)
Here we have the hexagon that tells us WHAT the who is DOING (point to the hexagon)

You choose a puppet. Here is a boy/girl (show puppet). Here is a ball. What is this? (hold up boy/girl). What is this? (hold up ball). The boy/girl likes to kick the ball. Listen to my sentence: here… the boy/girl kicks…. What is the WHO in my sentence? (point to oval; TARGET: the boy/girl). That's right! The boy/girl is the WHO.
***[if the child has difficulty, say sentence again and place boy on oval].
WHAT is the boy DOING? (TARGET: kicks). That's right! Kicks is the action; kicks is the WHAT DOING.
***[if the child has difficulty, say sentence again and act out kicking].
Now, what do you think the boy kicks? (TARGET: the ball). That's right! The ball is the WHAT.
*** [if the child has difficulty, repeat the sentence 'The boy kicks the ______', pause and point to the ball']
That is the WHAT in our sentence. It goes with the hexagon (point to rectangle). It is WHAT the WHO kicks (point to shapes). The WHAT always goes inside the WHAT DOING shape. We sometimes have sentences just with a WHO + WHAT DOING (The boy kicks), and also a WHO + WHAT DOING + WHAT (the boy kicks the ball) (manipulate shapes to demonstrate).
Here are our sentence shapes: WHO, WHAT DOING, WHAT (point to shapes). We can say the sentence to go with it: The boy/girls kicks the ball (place items in corresponding shapes as they are referred to).</td><td>2x Boy puppet
2x Girl puppet
Small ball
Small skateboard

Shape Coding visual prompts:
SUBJECT (oval, red)
VERB (hexagon, blue)
OBJECT (rectangle, red)
Left down arrows
/əd/, /d/, /t/
(left down arrows are available if teaching phonological difference between inflections as a specific goal or strategy to achieve the goal)</td></tr>
</table>

	*Now, this sentence is happening now (re-enact sentence). We are going to talk about actions or WHAT DOING that have already happened. When we say actions have already happened, we add a /t/, /d/ or /əd/ to the end of the WHAT DOING word. Like this: Yesterday, the boy/girl kick**ed** the ball. Did you hear the /t/ sound at the end? That sound is important, because it tells us that something has happened. This can be really tricky, so we can use this special arrow to help us remember to say the past /t/, /d/ or /əd/ sounds at the end of the WHAT DOING word (show blue left down ed arrow and place it in the HEXAGON). (Say sentence again and emphasise /t/). You have a try of the sentence (have child act it out), and point to the shapes to help.* ****[if the child has difficulty, repeat previous step but have child point and say the sentence at the same time].* *Let's try another one! Here is a boy/girl. He/she likes to hug the girl/boy (Show the action). The boy/girl hugg**ed** the girl/boy. That was a different sound that time. I heard a /d/ at the end of the WHAT DOING word (bring out blue left down ed arrow and place it in hexagon). Watch again (re-enact sentence; have child act it out). WHAT did the boy/girl DO? (Target: The boy/girl hugged the girl/boy).* ****[if the child has difficulty, repeat as above]* *Let's try another one! Here is a boy/girl. He/she likes to skate (show the action). The boy/girl skat**ed.** That was a different sound that time. I heard a /ed/ at the end of the WHAT DOING word (bring out blue left down /ed/ arrow and place it in hexagon). Watch again (re-enact sentence; have child act it out). WHAT did the boy/girl DO? (Target: The boy/girl skated).* ****[if the child has difficulty, repeat as above]* *So, we have learned that there are different sounds that go at the end of WHAT DOING words that have already happening.* *(Show sentences again).* *Now we are going to practise these sentences again.* *[repeat eliciting past tense sentences until 25 trials are achieved]*	
	Cueing hierarchy: Request clarification: *Try that sentence again* (point to the left down 'ed' arrow in the WHAT DOING) Recast: *You VERB**<u>ed</u>**. Try again*. (point to the left down 'ed' arrow in the WHAT DOING) Forced choice: Yo*u VERB or You VERB**<u>ed</u>**. Here is the sentence without the past /ed/ sound* (WHO + VERB/s + WHAT; manipulate shapes)- *try again.*	

	Elicited imitation: *I'll say the sentence, then you try* (Model and point to shapes, emphasising inflection and pointing to left down ed arrow)	
Time: 15min	***If difficulty with articulating the inflection persists, select monosyllabic verbs, preferably those ending with /s/ (as long as phonetic production is not an issue). Try using specific down left /t/ and /d/ arrows to draw attention to different phonological realisations of morpheme.	

Past Tense Session 1 Activity 2 (Playdough)

Goal: To elicit –ed by stating actions that happened in the past		
Target	**Activity**	**Materials**
/d/ **rolled,** **pulled,** **flattened,** **rubbed** /t/ **squashed,** **stretched,** **poked,** **pinched,** **pushed,** **swapped,** **chopped** /ed/ **twisted**	NB: Make reference to use of first person subject (I) and second person subject (you) as WHO in explicit teaching component prior to activity Sit at desk Check-up/teach vocabulary through acting out tasks SUBJECTS: I, you, we VERBS: e.g., rolled, squashed, twisted OBJECTS: playdough **SHAPE:** Introduce the sentence coding. Highlight the link between SUBJECT and OBJECT as indicated through verb. *Remember, the WHO is doing the action, and the WHAT goes inside the WHAT DOING.* Target: Target SV/O sentences one at a time using steps 4-7. Introduce each alongside its corresponding shape. Action: Student and SP take turns to say a sentence and match it to the template. *We're going to make some things with this playdough. I'm going to tell you what to do and I want you to tell me what you did.* *Let's **roll** the playdough. Look, we rolled the playdough. We rolled it flat; we rolled it long. What did you do? You roll**<u>ed</u>** the playdough.* *When we talk about an action that someone has done, we add a /**d**/, /**t**/ or /ə**d**/ sound to the end of the word. Listen to the sound at the end of **roll<u>ed</u>**. The last sound is /**d**/.* Then prompt again: e.g. *"Roll the playdough. What did you do? You roll**ed** the playdough."* Do steps 4-7 for sentences with a variety of verbs (from list). Repeat changing between First person subject (I), second person subject (you, we). For each verb/sentence you act out and prompt for, do steps 6 & 7. Repeat steps 4 & 5 using target VERBs and different subjects **if necessary.** *Now you will say some sentences about us and WHAT DOING that have already happened.*	Playdough Shape Coding visual prompts: - SUBJECT (oval, red) - VERB (hexagon, blue) - OBJECT (rectangle, red) -Left down ed arrows

<table><tr><td></td><td>

Coding: Lay large shapes on the floor and student to use as cues to produce SV/O sentences- they can act out the sentences if necessary, then explain what is happening. **Show blue left down ed arrow and place it in the WHAT DOING**. **Explain**: *We use the arrow that points to the left and down to tell us it has already happened. Any arrow that points this way tells us the WHAT DOING has already happened.*

Questions: Student to answer *'What did you/I do?'* on phrases containing target VERB. Work through VERBs that elicit allomorphs (/d/, /t/, /əd/)

EG
I/you roll the playdough (with action). Roll is the WHAT DOING word. Now stop! What did I/you do?
I/you squash the playdough (with action). Squash is the WHAT DOING word. Now stop! What did I/you do?

[REPEAT FOR ALL VERBS IN THE LIST UNTIL 25 trials are achieved]

***** Cueing hierarchy:**

Request clarification: *Try that sentence again* (point to the left down 'ed' arrow in the WHAT DOING)
Recast: *You VERB<u>ed</u>. Try again*. (point to the left down 'ed' arrow in the WHAT DOING)
Forced choice: Yo*u VERB or You VERB<u>ed</u>. Here is the sentence without the past /ed/ sound* (WHO + VERB/s + WHAT; manipulate shapes)- *try again.*
Elicited imitation: *I'll say the sentence, then you try* (Model and point to shapes, emphasising inflection and pointing to left down ed arrow)

NOTE: you may need to explicitly teach the student the specific sound that needs to be added to the end of the word. E.g. *We are working on words that have ED endings- WHAT DOING words that happened in the past. Now we are going to say WHAT DOING words that end with /d/, like 'poured'.* There are left down arrows for each sound pattern- note that this relies on students to have sound-letter knowledge. Teach verbs for each patterns in blocks initially to avoid confusion, i.e., /d/ ending (rolled), /t/ ending (squashed), and then /ed/ (twisted).

Consolidation:

At the end of the session, review the VERBs covered in the session
Comprehension task

</td><td></td></tr></table>

	SP say phrase (SUBJECT VERBed/OBJECT) Student to select SUBJECTs and OBJECTs and place them on shapes or point to the shapes following comp questions (e.g. *WHO VERBed the [WHAT]?, What DID the [WHO] DO? WHAT did the [WHO] VERB?*) Production Student say phrase Repeat without shapes, but bring them back to check responses as necessary (RECORD) Monitoring task: SP start to make errors and student corrects them (e.g. The puppet roll the playdough) First with templates Then without	
Time: 15 minutes	***If difficulty with articulating the inflection persists, select monosyllabic verbs, preferably those ending with /s/ (as long as phonetic production is not an issue). Try using specific down left /t/ and /d/ arrows to draw attention to different phonological realisations of morpheme.	

Appendix D

Summary of Initial Assessment Measures for All Participants Included for Analyses in Studies 1-5

Demographics			Grammar/Morphosyntax								Receptive Vocabulary	Declarative Memory		Procedural Memory		Working Memory/PSTM			
ID	Age	Sex	SPELT-3	TROG-2	GET-ed	GET-3s	GET-'s	GJT-ed	GJT-3s	GJT-'s	PPVT-4	CMS-DL	CMS-WP	SRT-DET	SRT-PROB	WMTB-C CE	WMTB-C PL	WMTB-C VSS	NRT (PPC)
P1	6;3	M	69	74	36.7	10.0	30.0	56.7	53.3	43.3	110	6	7	2.82	0.92	62	83	129	74
P2	6;2	M	90	97	40.0	50.0	36.7	53.3	53.3	53.3	94	6	11	1.69	-0.61	89	80	58	67
P3	5;10	M	79	86	33.3	36.7	53.3	46.7	50.0	60.0	116	10	9	0.07	-3	78	83	76	59
P4	6;8	M	71	81	30.0	23.3	60.0	56.7	70.0	50.0	93	12	8	1.31	-0.96	77	113	70	79
P5	6;6	M	57	81	3.3	13.3	0.0	43.3	46.7	46.7	94	5	10	1.74	-1.97	94	80	111	78
P6	6;2	F	72	65	3.3	23.3	16.7	50.0	50.0	43.3	86	5	7	1.95	0.33	57	65	67	42
P7	6;7	M	84	62	23.3	23.3	13.3	40.0	30.0	50.0	89	4	11	-0.85	-0.4	77	70	70	70
P8	6;0	M	69	79	16.7	6.7	46.7	90.0	43.3	50.0	113	12	5	1.54	-0.89	84	62	94	65
P9	6;1	M	57	65	36.7	10.0	6.7	50.0	46.7	43.3	111	7	1	1.01	0.62	84	69	111	69
P10	6;0	F	78	79	26.7	6.7	33.3	46.7	56.7	50.0	86	11	4	-	-	78	80	116	76
P11	6;7	M	63	72	16.7	46.7	30.0	36.7	46.7	63.3	91	11	3	0.49	-0.12	83	80	60	71.9
P12	5;9	M	105	90	43.3	53.3	46.7	63.3	63.3	60.0	80	10	8	-0.83	-1.97	89	83	72	89.5
P13	5;11	M	98	72	46.7	66.7	63.3	60.0	66.7	50.0	102	12	8	1.17	-1.55	57	87	76	78.1
P14	5;10	M	81	81	13.3	3.3	46.7	46.7	60.0	36.7	96	7	3	1.59	-0.62	66	80	85	72.9
P15	6;7	M	59	76	3.3	0.0	6.7	60.0	46.7	46.7	94	8	6	0.53	-1.15	93	65	103	74
P16	6;1	F	98	74	36.7	76.7	16.7	43.3	80.0	46.7	90	12	6	1.03	-0.12	84	73	103	78.1
P17	6;1	M	82	88	23.3	36.7	46.7	50.0	53.3	63.3	106	16	9	-0.19	-1.15	89	90	116	76
P18	6;2	F	63	65	3.3	0.0	13.3	43.3	46.7	50.0	85	4	2	-0.15	-1.68	57	73	63	59.4
P19	6;4	M	82	111	50.0	23.3	50.0	86.7	93.3	96.7	111	9	10	2.44	-1.53	89	90	116	67.7
P20	6;2	F	82	83	33.3	73.3	33.3	50.0	46.7	43.3	100	6	6	0.67	-1.72	100	101	116	94.8
P21	6;0	M	72	69	3.3	10.0	3.3	50.0	50.0	50.0	67	6	6	1.13	-0.05	78	62	72	65.6
P22	6;7	M	48	72	3.3	3.3	6.7	53.3	46.7	46.7	93	6	10	0.24	0.00	72	70	60	81.3
P23	6;0	M	57	74	20.0	13.3	73.3	43.3	53.3	46.7	98	13	8	1.48	-3.32	89	98	98	80.2
P24	6;9	F	88	67	53.3	56.7	60.0	73.3	76.7	76.7	81	9	8	0.65	-1.76	61	56	55	75

P25	6;4	M	55	79	10.0	0.0	26.7	63.3	60.0	66.7	99	11	10	2.51	-0.83	78	94	85	72.9
P26	6;2	M	40	65	6.7	3.3	3.3	50.0	36.7	40.0	81	7	10	0.97	-2.57	84	76	103	71.9
P27	6;4	M	61	83	16.7	0.0	0.0	53.3	50.0	80.0	89	4	8	2.18	0.26	105	73	89	79.2
P28	6;8	F	71	90	23.3	20.0	40.0	76.7	60.0	50.0	108	14	6	0.45	-1.21	88	56	98	70.8
P29	6;8	M	48	55	10.0	23.3	0.0	40.0	40.0	43.3	70	10	5	2.79	-1.52	61	75	56	82.3
P30	6;3	M	94	74	46.7	36.7	80.0	43.3	50.0	46.7	103	9	7	-1.46	-1.09	62	76	58	75
MEAN	6;5	M 76.7%; F 23.3%	72.4	77.0	23.8	25.0	31.4	54.0	54.2	53.1	94.5	8.7	7.1	1.00	-1.02	78.8	78.1	86.2	73.2
SD	0;4		16.0	11.2	15.7	22.8	23.2	13.0	12.9	12.8	12.1	3.2	2.6	1.07	1.02	13.1	12.9	22.1	9.5

Notes. CMS-DL = Children's Memory Scales-Dot Locations (Cohen, 1997); CMS-WP = Children's Memory Scales-Word Pairs (Cohen, 1997) GET = Grammar Elicitation Test (Smith-Lock et al., 2013a); GJT= Grammaticality Judgment Test; *-ed* = regular past tense; *3S* = third person singular; *'s* = possessive 's; PPVT-4= Peabody Picture Vocabulary Test, Fourth Edition (Dunn & Dunn, 2007); NRT (PPC) = Nonword Repetition Test (Percentage Phonemes Correct) (Dollaghan & Campbell, 1998); SPELT-3= Structured Photographic Language Test 3rd Edition (Dawson et al., 2003); SRT-DET = Serial Reaction Time task-Deterministic (Kuppuraj et al., 2018); SRT-PROB = Serial Reaction Time task-Probabilistic (Kuppuraj et al., 2018); TROG-2= Test of Reception of Grammar 2nd Edition (Bishop, 2003); WMTB-C = Working Memory Test Battery for Children ; VSS = Visuospatial Sketchpad; PL = Phonological Loop; CE = Central Executive M= male; F= female.
All scores from standardised assessments are scaled scores. Scores from the GET and GJT are represented as percentages. Scores from the SRT are represented as *t* scores.

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Appendix E

Supplemental Materials included for Published Version of Study 1, Chapter 3: Calder et al. (2020)

Appendix E.1 Expressive raw scores of participants on trained past-tense verbs within-session

Participant ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Additional
P1	7/12	6/12	9/12	8/12	3/12	10/12	9/12	11/12	11/12	8/12	-
P2	6/12	9/12	8/12	7/12	7/12	11/12	10/12	11/12	9/12	12/12	-
P3	2/12	8/12	7/12	10/12	11/12	9/12	11/12	12/12	11/12	10/12	-
P4	7/12	9/12	8/12	8/12	8/12	11/12	11/12	10/12	8/12	10/12	-
P5	3/12	2/12	2/12	9/12	8/12	10/12	7/12	-	10/12	8/12	9/12
P6	1/12	2/12	4/12	1/12	2/12	2/12	2/12	-	4/12	6/12	7/12
P7	2/12	6/12	5/12	-	10/12	8/12	9/12	9/12	10/12	10/12	8/12
P8	-	2/12	7/12	8/12	4/12	3/12	8/12	6/12	4/12	7/12	5/12
P9	8/12	7/12	6/12	-	6/12	8/12	7/12	9/12	6/12	7/12	9/12

Appendix E.2 Expressive raw scores of participants on trained past-tense verbs between-session

Participant ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Additional
P1	6/12	8/12	7/12	6/12	7/12	9/12	10/12	8/12	10/12	11/12	-
P2	7/12	5/12	8/12	9/12	8/12	7/12	9/12	11/12	9/12	10/12	-
P3	7/12	9/12	11/12	8/12	9/12	6/12	9/12	10/12	9/12	10/12	-
P4	4/12	8/12	8/12	6/12	9/12	8/12	11/12	10/12	10/12	8/12	-
P5	4/12	2/12	5/12	8/12	6/12	6/12	6/12	-	11/12	8/12	12/12
P6	0/12	3/12	1/12	3/12	0/12	5/12	0/12	-	7/12	8/12	3/12
P7	3/12	2/12	3/12	-	9/12	12/12	10/12	12/12	9/12	11/12	8/12
P8	-	5/12	6/12	3/12	3/12	4/12	8/12	10/12	3/12	9/12	7/12
P9	5/12	8/12	10/12	-	7/12	8/12	10/12	5/12	9/12	9/12	10/12

Appendix E.3 Expressive raw scores of participants on untrained past-tense verbs

ID						Pre-treatment baseline						Intervention						Maintenance					
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A10	A11	A12	A13	A14
P1	11/30	1/9	1/9	0/9	2/30	-	-	-	-	3/9	3/9	2/9	5/9	3/9	6/9	1/9	5/9	6/9	22/30	9/9	8/9	7/9	20/30
P2	12/30	0/9	1/9	1/9	0/9	1/9	5/9	2/9	9/30	5/9	8/9	8/9	5/9	6/9	7/9	8/9	6/9	9/9	27/30	9/9	8/9	9/9	30/30
P3	10/30	2/9	3/9	1/9	3/30	-	-	-	-	2/9	4/9	5/9	0/9	3/9	5/9	2/9	5/9	6/9	28/30	9/9	7/9	7/9	26/30
P4	9/30	3/9	2/9	3/9	4/9	3/9	3/9	4/9	16/30	5/9	4/9	6/9	6/9	5/9	7/9	9/9	7/9	8/9	29/30	7/9	9/9	7/9	28/30
P5	1/30	1/9	0/9	1/9	1/9	0/9	2/30	-	-	0/9	1/9	2/9	1/9	4/9	5/9	4/9	7/9	8/9	29/30	9/9	9/9	8/9	30/30
P6	1/30	2/9	1/9	1/9	0/9	0/9	0/9	1/9	2/30	2/9	2/9	4/9	4/9	1/9	2/9	4/9	3/9	3/9	12/30	4/8	2/9	3/9	8/30
P7	7/30	1/9	2/9	4/9	3/9	0/9	14/30	-	-	5/9	2/9	6/9	3/9	7/9	7/9	3/9	9/9	5/9	21/30	8/9	5/9	6/9	19/30
P8	5/30	1/9	3/9	5/9	13/30	-	-	-	-	2/9	2/9	5/9	4/9	4/9	4/9	2/9	5/9	7/9	24/30	6/9	6/9	6/9	23/30
P9	11/30	3/9	3/9	2/9	1/9	1/9	4/30	-	-	1/9	1/9	1/9	1/9	2/9	1/9	2/9	1/9	4/9	14/30	5/9	4/9	1/9	13/30

Appendix E.4 Expressive scores of participants on third person singular (extension measure)

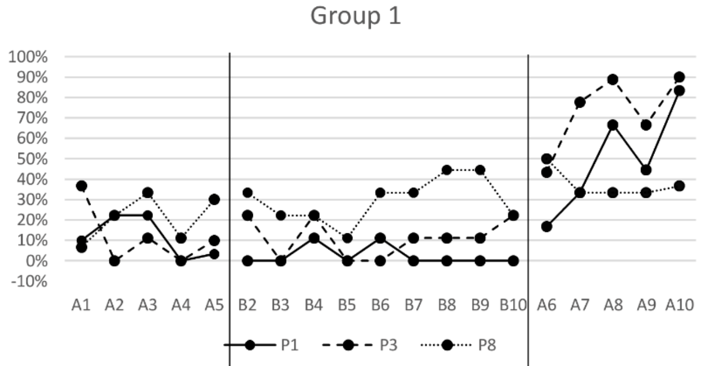
ID						Pre-treatment baseline						Intervention						Maintenance					
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A11	A12	A13	A14	A15
P1	3/30	2/9	2/9	0/9	1/30	-	-	-	-	0/9	0/9	1/9	0/9	1/9	0/9	0/9	0/9	0/9	5/30	3/9	6/9	4/9	25/30
P2	15/30	5/9	2/9	1/9	5/9	7/9	5/9	5/9	19/30	1/9	3/9	6/9	7/9	5/9	5/9	7/9	7/9	9/9	26/30	9/9	9/9	9/9	30/30
P3	11/30	0/9	1/9	0/9	3/30	-	-	-	-	2/9	0/9	2/9	0/9	0/9	1/9	1/9	1/9	2/9	13/30	7/9	8/9	6/9	27/30
P4	7/30	2/9	2/9	3/9	2/9	4/9	2/9	2/9	15/30	2/9	4/9	1/9	1/9	1/9	4/9	3/9	4/9	2/9	25/30	7/9	8/9	8/9	29/30
P5	4/30	0/9	1/9	1/9	0/9	0/9	1/30	-	-	1/9	0/9	1/9	0/9	0/9	0/9	0/9	0/9	0/9	1/30	1/9	0/9	1/9	1/30
P6	7/30	2/9	4/9	1/9	0/9	1/9	1/9	1/9	7/30	2/9	4/9	3/9	2/9	3/9	3/9	2/9	3/9	3/9	14/30	2/9	5/9	2/9	15/30
P7	7/30	1/9	3/9	3/9	5/9	5/9	12/30	-	-	2/9	2/9	5/9	2/9	5/9	5/9	4/9	4/9	5/9	20/30	7/9	5/9	7/9	15/30
P8	2/30	2/9	3/9	1/9	9/30	-	-	-	-	3/9	2/9	2/9	1/9	3/9	3/9	4/9	4/9	2/9	15/30	3/9	3/9	3/9	11/30
P9	3/30	3/9	4/9	4/9	2/9	6/9	14/30	-	-	1/9	4/9	1/9	2/9	5/9	1/9	0/9	1/9	2/9	16/30	5/9	5/9	4/9	8/30

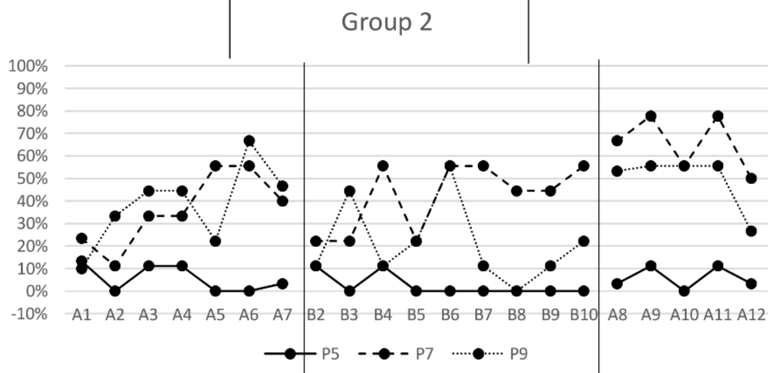
Appendix E.5 Summary expressive repeated measures baseline versus treatment phase contrasts on untrained third person singular targets (extension measure)

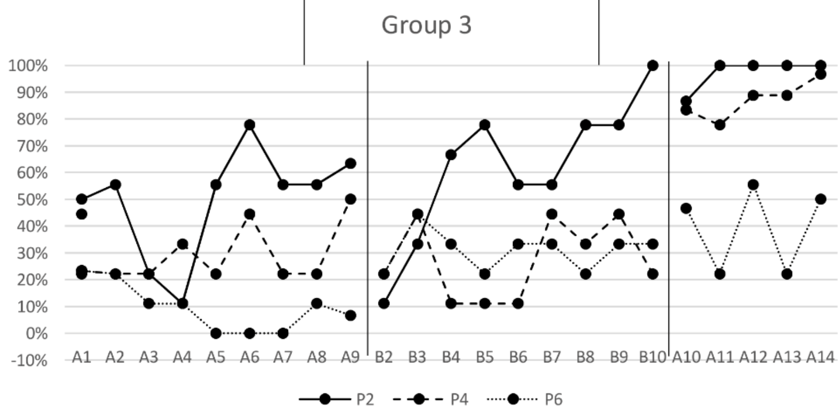
Participant ID	Kendall's *S*	*z* score	*p* value	Tau	90% CI
P1	-26	-1.73	0.08	-0.58	[-1,-0.03]
P2	29	1.28	0.20	0.36	[-0.10,0.82]
P3	6	0.40	0.69	0.13	[-0.42,0.68]
P4	-13	-0.57	0.57	-0.16	[-0.62,0.30]
P5	-22	-1.16	0.24	-0.35	[-0.84,0.14]
P6	49	2.16	0.03*	0.61	[0.15,1]
P7[a]	-2	-0.11	0.92	-0.03	[-0.53,0.46]
P8[a]	8	0.53	0.59	0.18	[-0.37,0.73]
P9[a]	-41	-2.17	0.03	-0.65	[-1,-0.16]
			Aggregated ES		
			.65	-0.05	

Notes. CI= confidence interval; ES= effect size
*sig. [a]unstable baseline corrected

Appendix E.6 Graph of % correct on expressive third person singular repeated measures (extension).







Appendix E.7 Expressive raw scores of participants on possessive ‘s (control measure)

Participant ID					Pre-treatment baseline						Intervention						Maintenance					
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A11	A12	A13	A14	A15
P1	13/30	5/9	4/9	4/9	15/30	-	-	-	-	6/9	4/9	6/9	6/9	6/9	6/9	5/9	6/9	5/9	21/30	6/9	7/9	6/9	21/30
P2	16/30	4/9	5/9	5/9	6/9	6/9	8/9	8/9	17/30	3/9	5/9	5/9	5/9	4/9	8/9	9/9	5/9	8/9	25/30	9/9	9/9	9/9	29/30
P3	18/30	2/9	2/9	3/9	10/30	-	-	-	-	6/9	4/9	5/9	7/9	5/9	6/9	6/9	6/9	5/9	19/30	9/9	7/9	9/9	27/30
P4	15/30	7/9	5/9	6/9	7/9	8/9	7/9	9/9	24/30	6/9	9/9	9/9	9/9	9/9	9/9	9/9	9/9	9/9	27/30	8/9	9/9	8/9	29/30
P5	14/30	0/9	1/9	1/9	0/9	0/9	0/30	-	-	0/9	0/9	0/9	0/9	0/9	0/9	0/9	0/9	0/9	23/30	9/9	9/9	9/9	30/30
P6	13/30	2/9	0/9	1/9	1/9	0/9	1/9	1/9	0/30	1/9	0/9	0/9	0/9	1/9	0/9	1/9	0/9	0/9	2/30	1/9	1/9	1/9	2/30
P7	15/30	2/9	1/9	1/9	0/9	1/9	4/30	-	-	1/9	1/9	2/9	0/9	1/9	0/9	1/9	0/9	3/9	16/30	3/9	2/9	2/9	8/30
P8	15/30	3/9	6/9	4/9	17/30	-	-	-	-	6/9	5/9	6/9	3/9	6/9	6/9	4/9	5/9	6/9	20/30	7/9	7/9	6/9	19/30
P9	13/30	1/9	2/9	1/9	0/9	0/9	0/30	-	-	0/9	0/9	0/9	0/9	0/9	0/9	0/9	0/9	0/9	1/30	0/9	0/9	0/9	0/30

Appendix E.8 Summary of expressive repeated measures baseline versus treatment phase contrasts on untrained possessive ‘s targets (control measure)

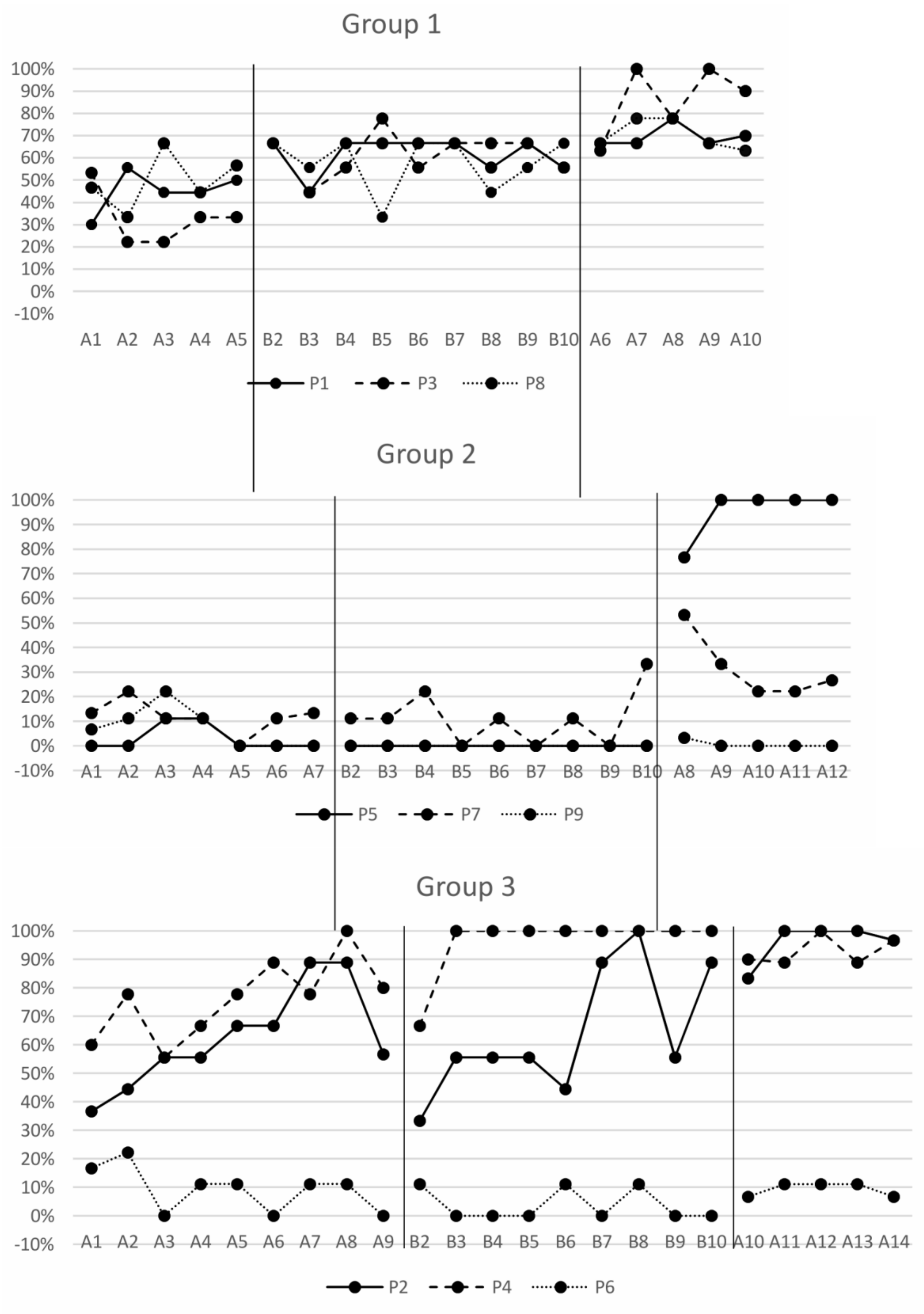
Participant ID	Kendall's *S*	*z* score	*p* value	Tau	90% CI
P1	37	2.47	0.01*	0.82	[0.27,1]
P2[a]	-29	-1.28	0.20	-0.36	[-0.82,0.10]
P3	43	2.87	0.004*	0.96	[0.41,1]
P4[a]	39	1.72	0.08	0.48	[0.02,0.94]
P5	-18	-0.95	0.34	-0.29	[-0.78,0.21]
P6	-18	-0.80	0.43	-0.22	[-0.68,0.24]
P7	-13	-0.69	0.49	-0.21	[-0.70,0.29]
P8	16	1.07	0.29	0.36	[-0.19, 0.90]
P9[a]	-27	-1.43	0.15	-0.43	[-0.92,0.07]
				Aggregated ES	
			.33	0.10	

Notes. CI= confidence interval; ES= effect size

*sig.

[a]unstable baseline corrected

Appendix E.9 Graph of % correct on expressive possessive ‘S repeated measures (control).



Appendix E.10 Grammaticality judgment raw scores of participants on trained past-tense verbs within-session

Participant ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Additional
P1	8/12	5/12	6/12	8/12	9/12	11/12	5/12	8/12	6/12	7/12	-
P2	6/12	6/12	6/12	7/12	5/12	9/12	7/12	9/12	10/12	9/12	-
P3	6/12	6/12	6/12	6/12	6/12	6/12	6/12	7/12	7/12	10/12	-
P4	5/12	8/12	5/12	7/12	6/12	6/12	6/12	9/12	12/12	11/12	-
P5	6/12	6/12	6/12	8/12	8/12	7/12	12/12	-	9/12	8/12	9/12
P6	6/12	2/12	7/12	7/12	7/12	6/12	8/12	-	5/12	6/12	6/12
P7	7/12	4/12	8/12	-	5/12	6/12	7/12	6/12	6/12	9/12	10/12
P8	-	7/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	7/12	6/12
P9	10/12	7/12	4/12	-	6/12	3/12	4/12	7/12	5/12	6/12	6/12

Appendix E.11 Grammaticality judgment raw scores of participants on trained past-tense verbs between-session

Participant ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Additional
P1	12/12	8/12	6/12	8/12	10/12	9/12	9/12	7/12	6/12	7/12	-
P2	6/12	6/12	6/12	11/12	7/12	8/12	7/12	7/12	10/12	11/12	-
P3	5/12	6/12	6/12	6/12	7/12	5/12	7/12	5/12	7/12	10/12	-
P4	6/12	8/12	8/12	7/12	9/12	7/12	7/12	9/12	11/12	12/12	-
P5	5/12	8/12	6/12	6/12	6/12	7/12	5/12	-	7/12	10/12	9/12
P6	6/12	3/12	3/12	6/12	7/12	3/12	5/12	-	8/12	8/12	8/12
P7	5/12	7/12	6/12	-	7/12	6/12	5/12	6/12	8/12	9/12	7/12
P8	-	7/12	6/12	6/12	6/12	8/12	6/12	6/12	6/12	7/12	5/12
P9	8/12	9/12	7/12	-	6/12	8/12	4/12	6/12	8/12	8/12	5/12

Appendix E.12 Grammaticality judgment raw scores of participants on untrained past-tense verbs

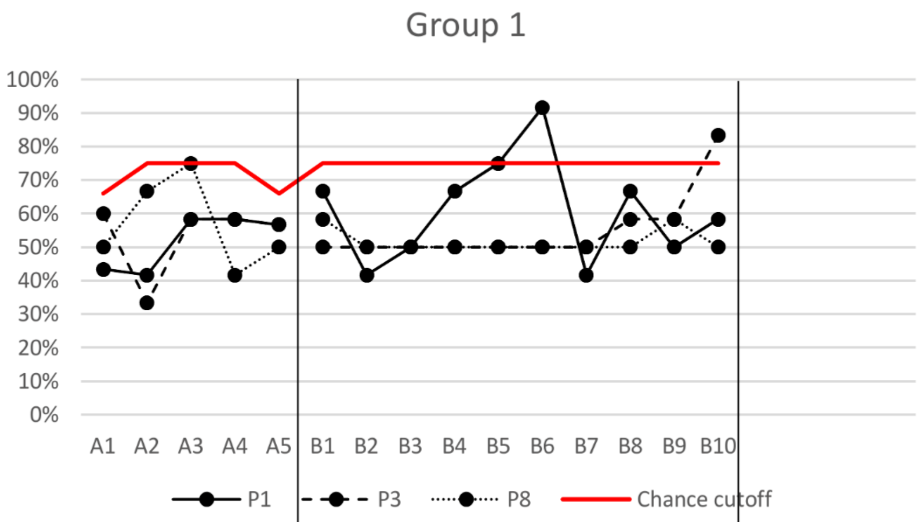
ID	Pre-treatment baseline									Intervention									Maintenance				
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A11	A12	A13	A14	A15
P1	17/30	5/12	7/12	7/12	17/30	-	-	-	-	5/12	5/12	6/12	6/12	8/12	7/12	9/12	7/12	4/12	14/30	7/12	7/12	6/12	15/30
P2	16/30	5/12	5/12	8/12	7/12	9/12	7/12	6/12	16/30	9/12	7/12	8/12	9/12	7/12	8/12	9/12	8/12	10/12	24/30	11/12	12/12	9/12	28/30
P3	14/30	4/12	7/12	7/12	17/30	-	-	-	-	5/12	5/12	6/12	6/12	6/12	6/12	6/12	6/12	7/12	14/30	6/12	5/12	8/12	22/30
P4	17/30	5/12	6/12	6/12	4/12	9/12	8/12	7/12	18/30	8/12	7/12	7/12	6/12	7/12	6/12	8/12	10/12	11/12	28/30	10/12	10/12	9/12	26/30
P5	13/30	8/12	6/12	6/12	5/12	5/12	17/30	-	-	7/12	7/12	6/12	6/12	7/12	9/12	7/12	9/12	6/12	24/30	11/12	8/12	10/12	25/30
P6	15/30	7/12	6/12	6/12	6/12	5/12	6/12	5/12	15/30	9/12	6/12	5/12	6/12	9/12	4/12	6/12	5/12	4/12	17/30	7/12	5/12	6/12	16/30
P7	12/30	6/12	5/12	7/12	7/12	6/12	15/30	-	-	7/12	5/12	3/12	4/12	4/12	1/12	7/12	5/12	7/12	17/30	6/11	6/12	6/12	13/30
P8	18/20	8/12	9/12	5/12	15/30	-	-	-	-	8/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	16/30	3/12	6/12	7/12	9/30
P9	15/30	7/12	5/12	4/12	5/12	7/12	16/30	-	-	10/12	6/12	8/12	4/12	4/12	4/12	6/12	8/12	8/12	17/30	5/12	5/12	6/12	15/30

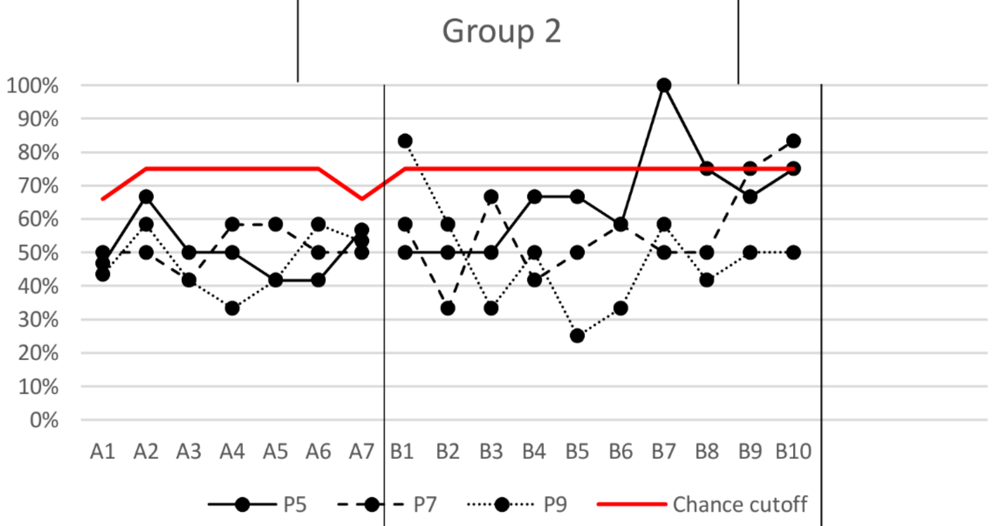
Appendix E.13 Summary of grammaticality judgment repeated measures baseline versus treatment phase contrasts on trained targets

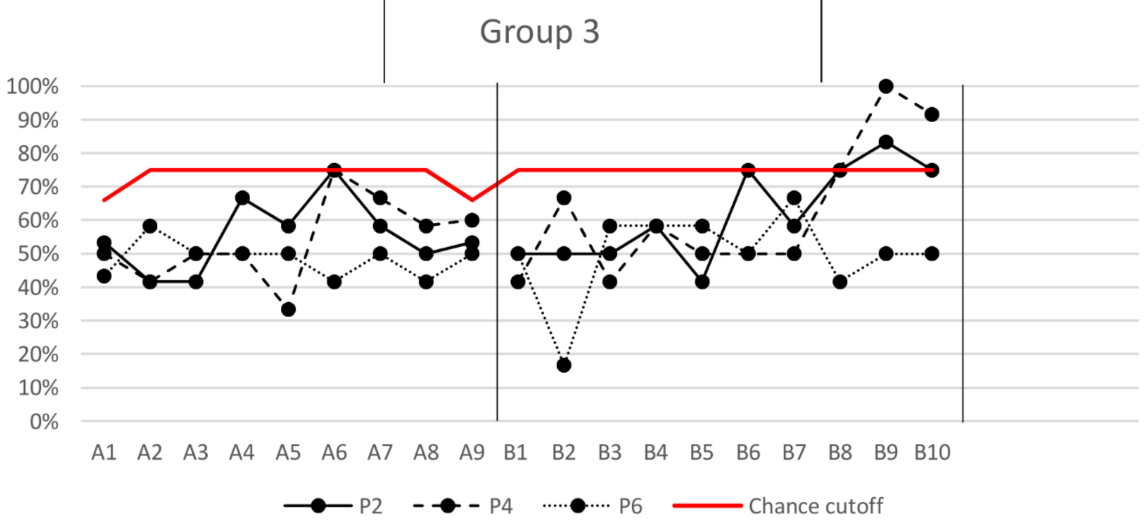
Participant ID	Kendall's *S*	*z* score	*p* value	Tau	90% CI
WITHIN SESSION					
P1	18	1.10	0.27	0.36	[-0.18, 0.90]
P2	20	0.82	0.41	0.22	[-0.23, 0.67]
P3	-14	-0.86	0.39	-0.28	[-0.82, 0.26]
P4	22	0.97	0.33	0.27	[-0.19, 0.73]
P5	47	2.29	0.02*	0.67	[0.19, 1]
P6	25	1.02	0.31	0.28	[-0.17, 0.73]
P7	15	0.73	0.46	0.21	[-0.27, 0.70]
P8	-6	-0.37	0.71	-0.12	[-0.66, 0.42]
P9	-2	-0.10	0.92	-0.03	[-0.51, 0.45]
				Aggregated ES	
	-	-	0.06	0.19	-
BETWEEN SESSION					
P1	34	2.08	0.04*	0.68	[0.14, 1]
P2	29	1.18	0.24	0.32	[-0.13, 0.77]
P3	-10	-0.61	0.54	-0.20	[-0.74, 0.34]
P4	50	2.04	0.04*	0.56	[0.12, 1]
P5	23	1.12	0.26	0.33	[-0.15, 0.81]
P6	5	0.20	0.84	0.06	[-0.39, 0.50]
P7	14	0.68	0.50	0.20	[-0.28, 0.68]
P8	-6	-0.37	0.71	-0.12	[-0.64, 0.42]
P9	33	1.61	0.11	0.47	[-0.01, 0.95]
				Aggregated ES	
	-	-	0.009	0.26	-
UNTRAINED					
P1	1	0.07	0.95	0.02	[-0.53, 0.57]
P2	54	2.38	0.02*	0.67	[0.21, 1]
P3	-23	-1.53	0.12	-0.51	[-1, 0.04]
P4	32	1.41	0.16	0.40	[-0.07, 0.86]
P5	37	1.96	>0.05	0.59	[0.09, 1]
P6	-8	-0.35	0.72	-0.10	[-0.56, 0.36]
P7	-25	-1.32	0.19	-0.40	[-0.89, 0.10]
P8	-6	-0.40	0.69	-0.13	[-0.68, 0.42]
P9	12	0.64	0.53	0.19	[-0.30, 0.68]
				Aggregated ES	
	-	-	0.35	0.01	-

Notes. CI= confidence interval; ES= effect size.
*sig.

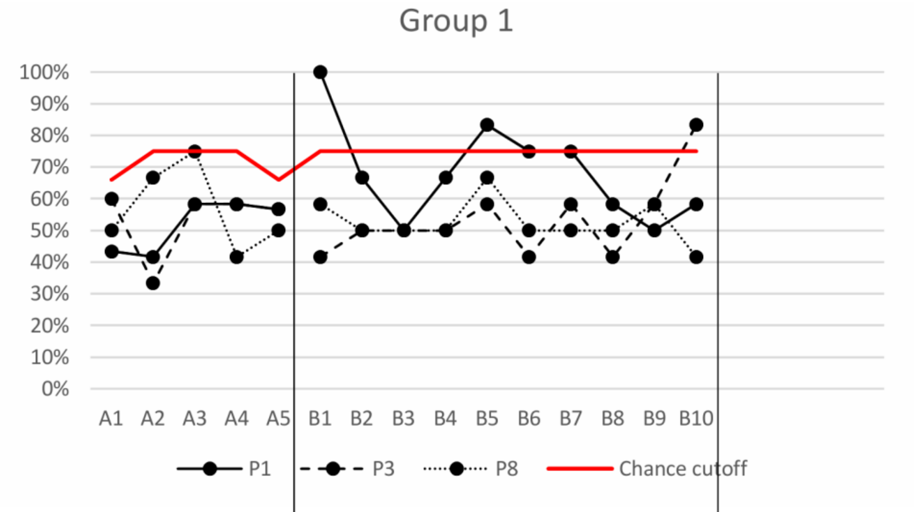
Appendix E.14 Graph of % correct on grammaticality judgment within-session repeated measures.

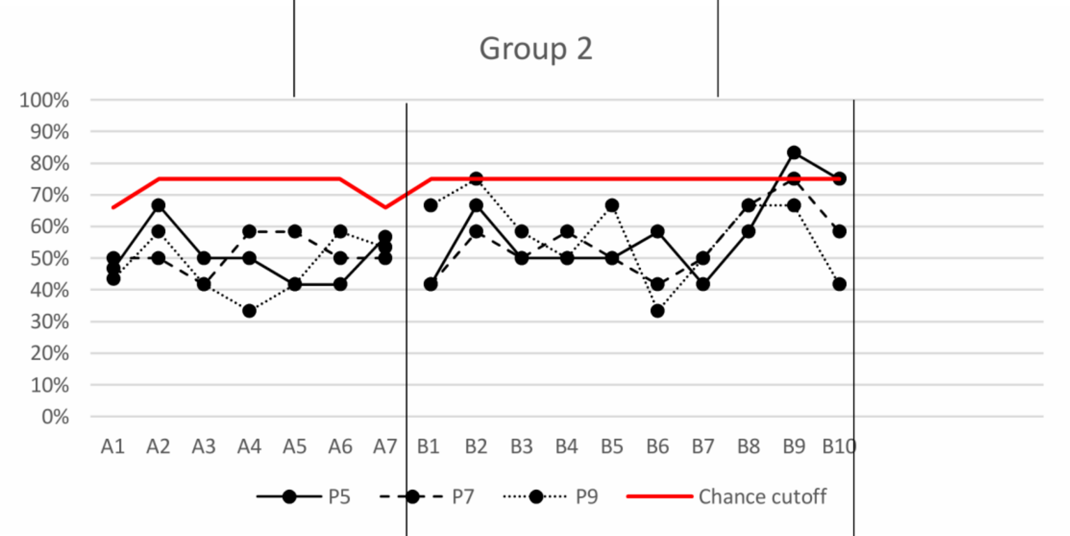


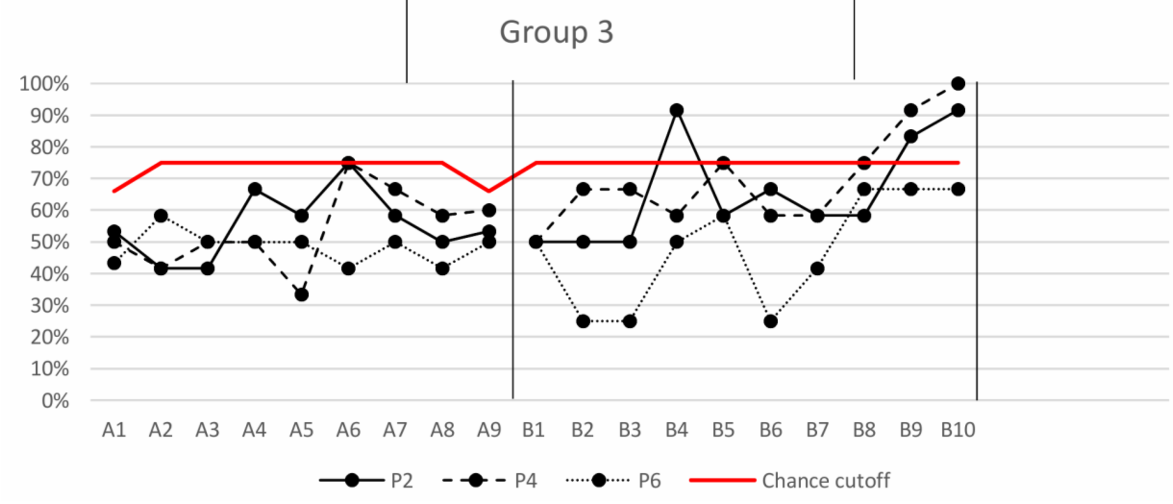




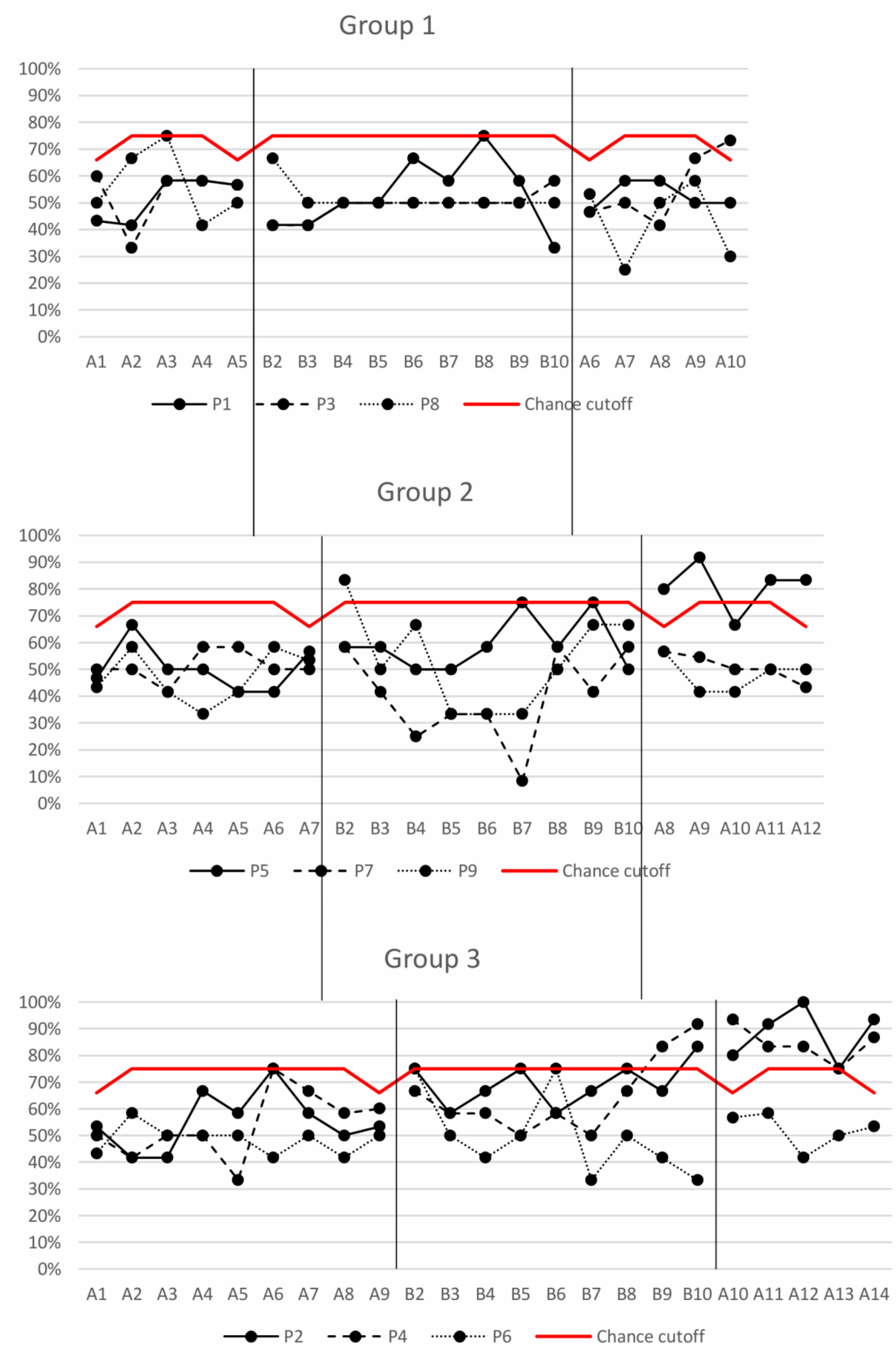
Appendix E.15 Graph of % correct on grammaticality judgment between-session repeated measures.







Appendix E.16 Graph of % correct on expressive untrained repeated measures.



Appendix E.17 Grammaticality judgment raw scores of participants on third person singular (extension measure)

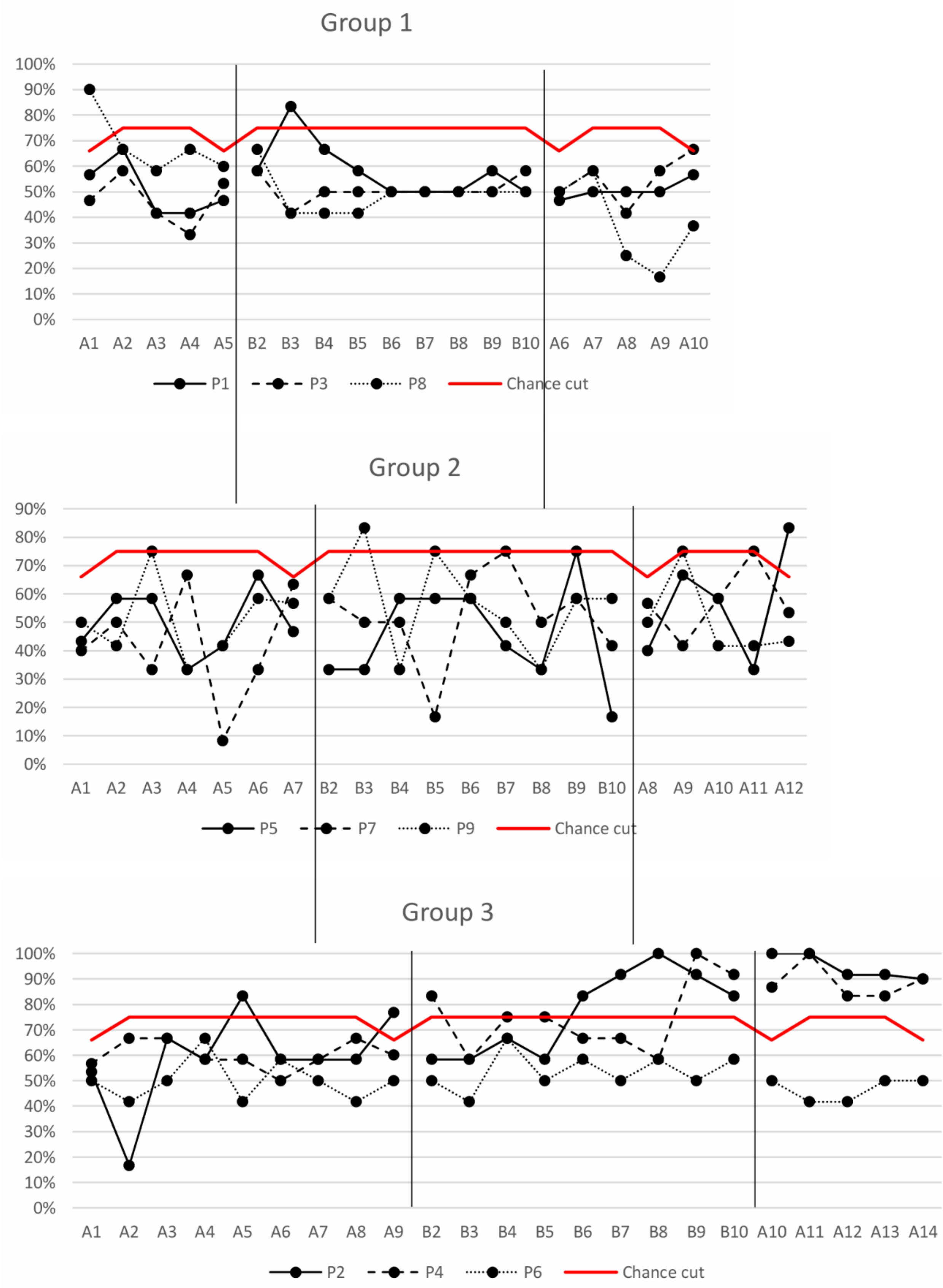
Participant ID						Pre-treatment baseline						Intervention						Maintenance					
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A11	A12	A13	A14	A15
P1	16/30	8/12	5/12	5/12	14/30	-	-	-	-	7/12	10/12	8/12	7/12	6/12	6/12	6/12	7/12	6/12	14/30	6/12	6/12	6/12	17/30
P2	16/30	2/12	8/12	7/12	10/12	7/12	7/12	7/12	23/30	7/12	7/12	8/12	7/12	10/12	11/12	12/12	11/12	10/12	30/30	12/12	11/12	11/12	27/30
P3	15/30	7/12	5/12	4/12	16/30	-	-	-	-	7/12	5/12	6/12	6/12	6/12	6/12	6/12	6/12	7/12	15/30	7/12	5/12	7/12	20/30
P4	21/30	8/12	8/12	7/12	7/12	6/12	7/12	8/12	18/30	10/12	7/12	9/12	9/12	8/12	8/12	7/12	12/12	11/12	26/30	12/12	10/12	10/12	27/30
P5	14/30	7/12	7/12	4/12	5/12	8/12	14/30	-	-	4/12	4/12	7/12	7/12	7/12	5/12	4/12	9/12	2/12	12/30	8/12	7/12	4/12	25/30
P6	15/30	5/12	6/12	8/12	5/12	7/12	6/12	5/12	15/30	6/12	5/12	8/12	6/12	7/12	6/12	7/12	6/12	7/12	15/30	5/12	5/12	6/12	15/30
P7	9/30	6/12	4/12	8/12	1/12	4/12	19/30	-	-	7/12	6/12	6/12	2/12	8/12	9/12	6/12	7/12	5/12	17/30	5/12	7/12	9/12	16/30
P8	13/30	8/12	7/12	8/12	18/30	-	-	-	-	8/12	5/12	5/12	5/12	6/12	6/12	6/12	6/12	6/12	15/30	7/12	3/12	9/12	11/30
P9	14/30	5/12	9/12	4/12	5/12	7/12	17/30	-	-	7/12	10/12	4/12	9/12	7/12	6/12	4/12	7/12	7/12	15/30	9/12	5/12	5/12	13/30

Appendix E.18 Summary grammaticality judgment repeated measures baseline versus treatment phase contrasts on untrained third person singular targets (extension measure)

Participant ID	Kendall's *S*	*z* score	*p* value	Tau	90% CI
P1	22	1.47	0.14	0.49	[-0.06,1]
P2	44	1.94	>0.05	0.54	[0.08,1]
P3	12	0.80	0.42	0.27	[0.28, 0.82]
P4	53	2.34	0.02*	0.65	[0.19,1]
P5	-13	-0.69	0.49	-0.21	[-0.70,0.29]
P6	24	1.06	0.29	0.30	[-0.16,0.76]
P7	21	1.11	0.27	0.33	[-0.16,0.83]
P8[a]	-34	-2.27	0.02*	-0.76	[-1,-0.21]
P9	17	0.90	0.37	0.27	[-0.22,0.76]
				Aggregated ES	
			.03	0.22	

Notes. CI= confidence interval; ES= effect size
*sig.
[a]unstable baseline corrected

Appendix E.19 Graph of % correct on grammaticality judgment third person singular repeated measures (extension).



Appendix E.20 Grammaticality judgment raw scores of participants on possessive ‘s (control measure).

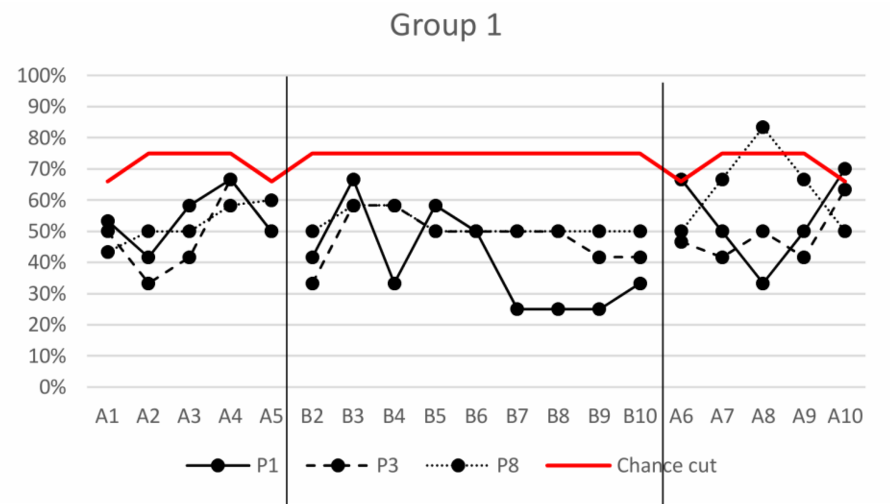
ID	Pre-treatment baseline									Intervention									Maintenance				
	A1	A2	A3	A4	A5	A6	A7	A8	A9	B2	B3	B4	B5	B6	B7	B8	B9	B10	A11	A12	A13	A14	A15
P1	13/30	5/12	7/12	8/12	15/30	-	-	-	-	5/12	8/12	4/12	7/12	6/12	3/12	3/12	3/12	4/12	20/30	6/12	4/12	6/12	21/30
P2	16/30	7/12	7/12	4/12	9/12	6/12	5/12	6/12	20/30	8/12	6/12	7/12	8/12	11/12	8/12	10/12	9/12	8/12	26/30	10/12	10/12	11/12	27/30
P3	18/30	4/12	5/12	8/12	15/30	-	-	-	-	4/12	7/12	7/12	6/12	6/12	6/12	6/12	5/12	5/12	14/30	5/12	6/12	5/12	19/30
P4	15/30	8/12	8/12	8/12	7/12	7/12	6/12	6/12	19/30	8/12	5/12	7/12	9/12	9/12	6/12	7/12	7/12	9/12	25/30	9/12	4/12	7/12	21/30
P5	14/30	5/12	9/12	8/12	6/12	6/12	19/30	-	-	6/12	5/12	6/12	8/12	5/12	7/12	6/12	8/12	9/12	19/30	9/12	8/12	7/12	27/30
P6	13/30	9/12	6/12	4/12	7/12	7/12	6/12	9/12	15/30	7/12	7/12	7/12	6/12	7/12	5/12	6/12	6/12	9/12	15/30	5/12	5/12	6/12	14/30
P7	15/30	6/12	5/12	6/12	8/12	8/12	18/30	-	-	5/12	7/12	8/12	5/12	7/12	8/12	6/12	10/12	7/12	20/30	7/12	7/12	9/12	19/30
P8	15/30	6/12	6/12	7/12	18/30	-	-	-	-	6/12	7/12	7/12	6/12	6/12	6/12	6/12	6/12	6/12	15/30	8/12	10/12	8/12	15/30
P9	13/30	7/12	4/12	4/12	7/12	8/12	17/30	-	-	10/12	4/12	6/12	3/12	5/12	5/12	7/12	7/12	6/12	16/30	7/12	6/12	5/12	18/30

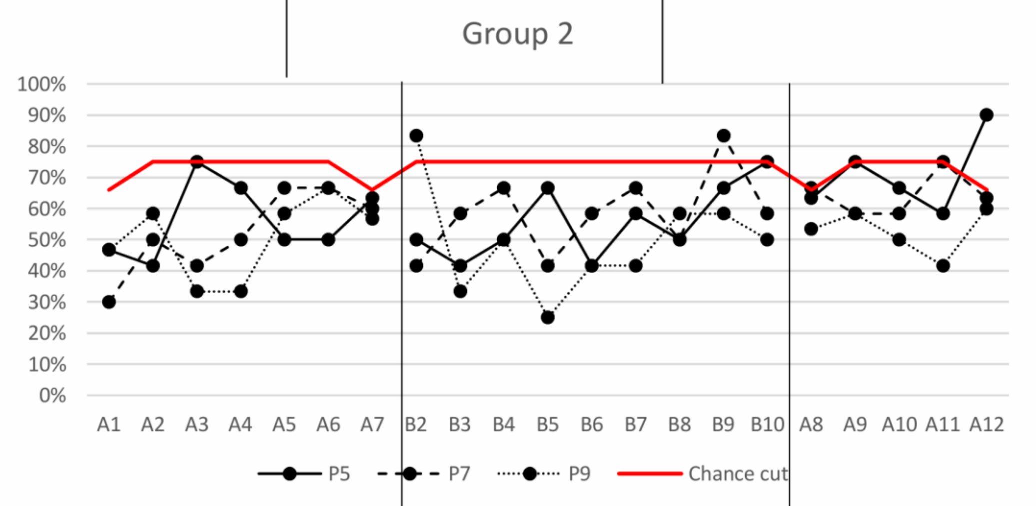
Appendix E.21 Summary grammaticality judgment repeated measures baseline versus treatment phase contrasts on untrained possessive ‘s targets (control measure).

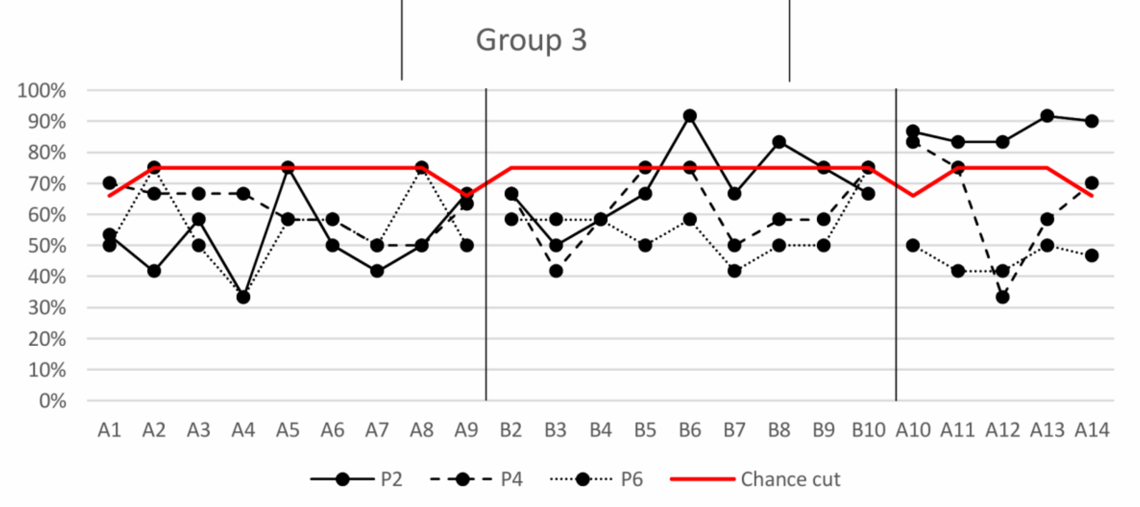
Participant ID	Kendall’s *S*	*z* score	*p* value	Tau	90% CI
P1	-25	-1.67	0.10	-0.56	[-1,-0.01]
P2	53	2.34	0.02*	0.65	[0.19,1]
P3	2	0.13	0.89	0.04	[-0.50,0.59]
P4[a]	29	1.28	0.20	0.36	[-0.10,0.82]
P5	0	0	1.00	0	[-0.49,0.49]
P6	3	0.13	0.90	0.04	[-0.42,0.50]
P7[a]	-2	-0.11	0.92	-0.03	[-0.53,0.46]
P8[a]	-12	-0.80	0.42	-0.27	[-0.82,0.28]
P9	-7	-0.37	0.71	-0.11	[-0.60,0.38]
				Aggregated ES	
			.76	0.03	

Notes. CI= confidence interval; ES= effect size
*sig.
[a]unstable baseline corrected

Appendix E.22 Graph of % correct on grammaticality judgment possessive ‘s repeated measures (control).







Appendix F Supplemental Materials Included for Published Version of Study 2, Chapter 4: Calder et al. (2021)

(excluding Supplemental Materials S3, S4, and S5 which are included in Chapter 2)

Appendix F.1 2010 Checklist of Information to Include When Reporting a Randomised Trial (Schulz., Altman, & Moher, 2010)

Section/Topic	Item #	Checklist item	Reported on page #
Title and abstract			
	1a	Identification as a randomised trial in the title	N/R
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts (see Hopewell S Clarke, Moher, Wager, Middleton, Altman, Schulz, & CONSORT Group, 2008a; Hopewell S Clarke, Moher, Wager, Middleton, Altman, Schulz, & CONSORT Group, 2008b)	91
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	91-94
	2b	Specific objectives or hypotheses	94
Methods			

Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	94
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	94
	4b	Settings and locations where the data were collected	96
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	Supplemental Material S3, Supplemental Material S4
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	95 (Figure 1); 97-100
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	N/R
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A

Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	95
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	95
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	95
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	95
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	95-96
	11b	If relevant, description of the similarity of interventions	96-97
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	97-100

	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	N/A
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Supplemental Material S2
	13b	For each group, losses and exclusions after randomisation, together with reasons	97
Recruitment	14a	Dates defining the periods of recruitment and follow-up	N/R
	14b	Why the trial ended or was stopped	96
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	96 (Table 1)
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	97
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the	97-100

			estimated effect size and its precision (such as 95% confidence interval)	
		17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
	Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	100
	Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms (see Ioannidis, Evans, Gøtzsche, O'Neill, Altman, Schulz, Moher, & CONSORT Group, 2004)	N/A
Discussion				
	Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	102
	Generalisability	21	Generalisability (external validity, applicability) of the trial findings	102
	Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and	100-101

		considering other relevant evidence	
Other information			
Registration	23	Registration number and name of trial registry	N/A
Protocol	24	Where the full trial protocol can be accessed, if available	N/A
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	102

Notes. N/R = not reported. N/A = not applicable.

References

Hopewell, S., Clarke, M., Moher, D., Wager, E., Middleton, P., Altman, D. G., Schulz, K. F., & CONSORT Group. (2008a). CONSORT for reporting randomised trials in journal and conference abstracts. *Lancet, 371*. 281–283. https://doi.org/10.1016/S0140-6736(07)61835-2.

Hopewell, S., Clarke, M., Moher, D., Wager, E., Middleton, P., Altman, D. G., Schulz, K. F., & CONSORT Group. (2008b). CONSORT for reporting randomized controlled trials in journal and conference abstracts: explanation and elaboration. *PLoS Med.,5.* e20. https://doi.org/10.1371/journal.pmed.0050020

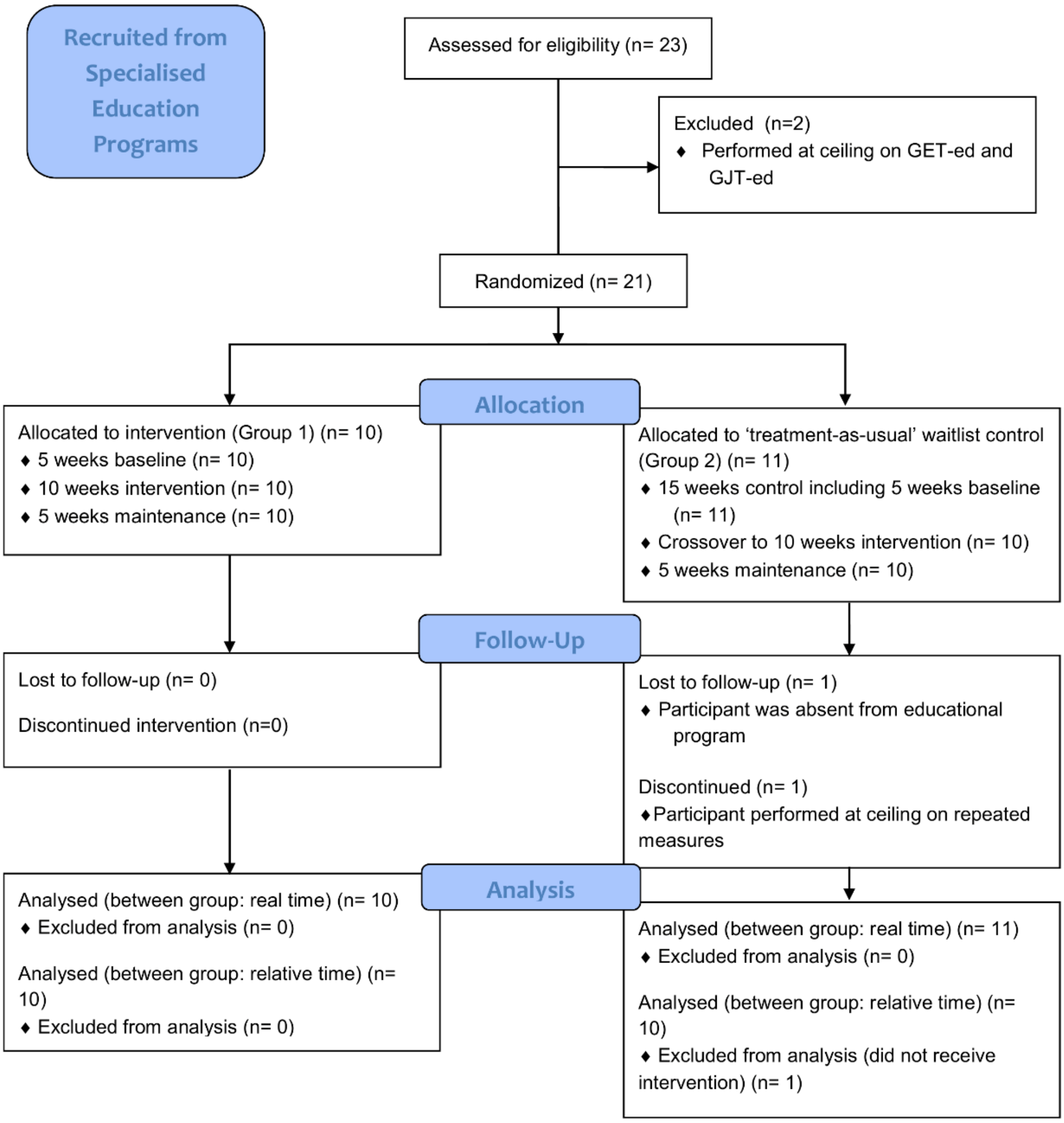
Ioannidis, J. P., Evans, S. J., Gøtzsche, P. C., O'Neill, R. T., Altman, D. G., Schulz, K., Moher, D., & CONSORT Group (2004). Better reporting of harms in randomized trials: an extension of the CONSORT statement. *Annals of Internal Medicine, 141*. 781-8. https://doi.org/10.7326/0003-4819-141-10-200411160-00009

Schulz, K. F., Altman, D. G., & Moher, D. (2010). CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *BMJ, 340*, c332. https://doi.org/10.1136/bmj.c332

Appendix F.2 CONSORT 2010 Flow Diagram

CONSORT
TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram



Appendix G

Expressive Raw Scores of Participants in the Once Per Week (1PW) Condition on Untrained Past Tense Verbs during the Baseline, Intervention, and Maintenance Phases.

ID	Baseline					Intervention phase					Maintenance phase				
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	A6	A7	A8	A9	A10
P10	8/30	0/9	0/9	2/9	6/30	1/9	3/9	3/9	2/9	3/9	18/30	5/9	6/9	2/9	16/30
P11	14/30	4/9	6/9	6/9	21/30	8/9	7/9	9/9	9/9	8/9	26/30	9/9	8/9	9/9	30/30
P12	11/30	2/9	3/9	4/9	15/30	4/9	4/9	3/9	6/9	6/9	21/30	5/9	5/9	7/9	25/30
P13	7/30	2/9	2/9	2/9	8/30	2/9	4/9	4/9	6/9	7/9	21/30	4/9	6/9	4/9	20/30
P14	15/30	3/9	1/9	2/9	3/30	4/9	2/9	5/9	7/9	6/9	18/30	5/9	6/9	4/9	15/30
P15	1/30	0/9	1/9	0/9	3/30	0/9	1/9	3/9	5/9	3/9	17/30	2/9	4/9	8/9	15/30
P16	6/30	2/9	1/9	2/9	2/30	3/9	3/9	4/9	7/9	7/9	25/30	4/9	5/9	4/9	8/30
P17	3/30	0/9	0/9	0/9	0/30	1/9	4/9	3/9	1/9	3/9	13/30	4/9	4/9	5/9	12/30
P18	3/30	0/9	1/9	1/9	4/30	1/9	1/9	2/9	1/9	3/9	14/30	2/9	4/9	3/9	8/30
P19	14/30	4/9	3/9	5/9	14/30	2/9	5/9	5/9	8/9	6/9	25/30	4/9	5/9	2/9	14/30
P20	5/30	2/9	0/9	0/9	7/30	2/9	1/9	3/9	6/9	2/9	15/30	6/9	6/9	3/9	14/30
P21	13/30	0/9	0/9	1/9	6/30	2/9	2/9	1/9	0/9	3/9	12/30	5/9	5/9	4/9	12/30
P22	4/30	0/9	1/9	2/9	2/30	2/9	0/9	2/9	1/9	3/9	15/30	5/9	4/9	4/9	14/30
P23	1/30	2/9	1/9	1/9	6/30	3/9	2/9	2/9	5/9	6/9	11/30	-	-	-	15/30
P24	1/30	0/9	0/9	0/9	0/30	0/9	2/9	1/9	2/9	1/9	6/30	2/9	1/9	1/9	4/30
P25	10/30	1/9	2/9	4/9	13/30	5/9	5/9	6/9	5/9	7/9	27/30	4/9	6/9	8/9	30/30
P26	1/30	0/9	0/9	1/9	1/30	1/9	0/9	3/9	1/9	3/9	8/30	2/9	3/9	3/9	6/30
P27	2/30	0/9	0/9	1/9	1/30	0/9	4/9	3/9	3/9	5/9	10/30	3/9	4/9	5/9	10/30
P28	5/30	1/9	1/9	1/9	6/30	2/9	2/9	1/9	1/9	3/9	10/30	1/9	1/9	-	-
P29	7/30	2/9	1/9	2/9	8/30	4/9	2/9	3/9	5/9	3/9	22/30	7/9	6/9	5/9	22/30

Appendix H

Copyright Permissions for Figure 6.1 from Sengottuvel and Rao (2013)

PR

Prema Rao <rao.prema@gmail.com>
Thu 12/17/2020 10:16 AM
To: Samuel Calder

I am pleased to permit Mr. Samuel Calder to use Figure no.2 from a paper co-authored by me with Dr. Kuppuraj Sengottuvel (who met his untimely demise) titled ‘An Adapted Serial Reaction Time Task for Sequence Learning Measurements’ in his thesis with due citation to our work.
Dr. Prema Rao

Appendix I

Copyright Permissions for Figure 6.2a-6.2c from Kuppuraj et al. (2018)

Re: Request for permission to use figure in thesis

DB Dorothy Bishop <dorothy.bishop@psy.ox.ac.uk>
Thu 1/21/2021 3:01 PM
To: Samuel Calder

Hi Sam

That's all fine with me.

On 21 Jan 2021, at 02:59, Samuel Calder <samuel.calder@postgrad.curtin.edu.au> wrote:

Dear Professor Bishop,

I am emailing to request permission to use an adapted version of a figure from a paper you published with Kuppu for my PhD thesis. Specifically, **Figure 2** in Kuppuraj, S., Duta, M., Thompson, P., & Bishop, D. (2018). Online incidental statistical learning of audiovisual word sequences in adults: a registered report. *Royal Society Open Science, 5*(2), 171678. https://doi.org/10.1098/rsos.171678. I have attached the version of the figure I have adapted to reflect the triplets that were administered to the children, i.e., 'pen', 'kite', 'whale' for the deterministic sequence, as opposed to 'bat', 'box', 'tie' which was used for the adults.

Please let me know if this is acceptable to you. Of course, the figure and task will be referenced and appropriately in the thesis and included in the acknowledgements.

I'll look forward to hearing from you.

Regards,
Sam.

Samuel Calder
BA, MSpeechPath(Curtin), CPSP
PhD Candidate

School of Occupational Therapy, Social Work and Speech Pathology
Faculty of Health Sciences
Curtin University

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