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Exploring Associations between Language and Working Memory Abilities in Children with Specific or Combined Impairments in Language and Working Memory

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Abstract

Children with disproportionate deficits in language, known as Specific Language Impairment (SLI), often demonstrate deficits in nonverbal cognitive abilities, such as working memory. Such findings have prompted much debate on the association between language and working memory functioning. The primary aim of this thesis was to examine the connection between working memory and language abilities among children with specific or combined impairments in these domains. Study 1 examined the potential of narrative retell performance to indicate impairment in language or working memory among 17 children with specific or combined impairment in language or working memory as well as 9 controls. Quantitative analysis using logistic regression revealed that language impairment was predicted best by the interaction between mean length of utterance, percent grammatical utterances, and age, whereas working memory impairment was best predicted by the interaction between events recalled and subordinate clauses per utterance. Exploratory qualitative analysis using qualitative descriptors differentiated narratives of children with and without impairment and revealed clusters of descriptors that identified contrasting speaking styles. Study 2 tested domain-specific interventions in language or working memory using a single subject design. Chapter 3 reports the effects of a narrative-based language intervention for 10 children with language impairment with or without working memory impairment. Results showed gains on narrative ability for most participants, and broader linguistic gains for half of the participants. Intervention effects on related domains (i.e., working memory, reading, math) were evident for some participants as well. Chapter 4 reports the effects of a working memory training program for 7 children with working memory impairment with or without language impairment. Results showed training effects on working memory tasks similar to training tasks for all participants. Transfer to language ability was seen for 4 participants, and transfer to reading or math was evident for 3 participants. Responder analyses for Study 2 showed associations between intervention effectiveness and baseline cognitive abilities, age, speaking style, and intervention intensity. Results support the view that working memory and language are separable but closely related cognitive processes. Responder analyses highlight the importance of considering heterogeneity among children with impairments in research and clinical settings.

Keywords

language impairment, working memory impairment, narrative retell, narrative-based language intervention, working memory training, single subject design, responder analysis

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Table of Contents

Abstract ... i

Acknowledgements ... iii

Table of Contents ... iv

List of Tables ... x

List of Figures ... xii

List of Appendices ... xiii

Chapter 1 Introduction ... 1

Specific language impairment ... 2

Definition, prevalence, and diagnostic criteria ... 2

Characteristics of SLI ... 4

Lexical abilities ... 4

Grammatical abilities ... 5

Fluency ... 5

Discourse ... 7

Nonverbal abilities ... 9

Heterogeneity ... 10

Working memory ... 10

Phonological loop ... 11

Visuospatial sketchpad ... 12

Central executive ... 13

Episodic buffer ... 14

Working memory and SLI ... 14

Verbal short term memory ... 14

Verbal working memory ... 15

Visuospatial short term memory ... 17

Visuospatial working memory ... 18

Theories of SLI ... 19

SLI as a phonological deficit ... 19

SLI as a short term memory deficit ... 20

Linguistic theories of SLI ... 20

Domain-general accounts of SLI 22
Testing theories of SLI 24
Epidemiological approach 24
Intervention studies 25
Methodological considerations 26
Narrative sampling 26
Single subject design 28
Language intervention 31
Working memory intervention 32
Overall objective 33
References 35
Chapter 2 Linguistic and cognitive processes contributing to narrative retell 63
Introduction 63
Language impairment and narrative assessment 64
Working memory and narrative assessment 65
Performance indicators of narrative retell 67
Productivity 68
Grammaticality 69
Fluency 70
Trade-off effects 73
Study purpose 74
Methods 75
Participants 75
Procedure 79
Quantitative scoring 80
Quantitative analysis 82
Qualitative analysis 84
Results 86
Predicting impairment status 86
Preliminary analysis 86
Predicting language impairment 88

Predicting working memory impairment ... 93
Qualitative descriptions of narrative samples ... 97
Discussion ... 104
Differentiating impairment based on narrative retell performance ... 105
Lessons from qualitative analysis ... 109
Simplifiers and Risk Takers ... 110
Study limitations ... 112
Clinical implications ... 113
Conclusion ... 114
References ... 115
Chapter 3 Narrative-based language intervention for children with specific language impairment with or without working memory impairment ... 125
Introduction ... 125
Childhood discourse genres ... 126
Narrative macrostructure and microstructure ... 127
Cognitive demands of narrative retell ... 129
Children with SLI ... 129
Narrative ability ... 130
Syntax ... 131
Narrative-based language intervention (NBLI) ... 131
NBLI for children with language impairment ... 135
Narrative language and related domains ... 140
Methodological considerations ... 142
Study purpose ... 144
Methods ... 144
Participants ... 144
Procedures ... 147
Study timeline ... 147
Intervention ... 149
Initial goal selection ... 149
Intervention materials ... 150

Intervention procedure ... 150
Treatment fidelity ... 154
Outcome measures ... 155
Probe measures ... 155
Assessment battery ... 158
Analysis ... 161
Results ... 165
Probe measures ... 165
Narrative retell and standardized measures ... 173
Overall results ... 178
Responder analysis ... 179
Responders, simplifiers, and Risk Takers ... 183
Discussion ... 184
Conclusion ... 190
References ... 192
Appendices ... 208
Chapter 4 Cognitive and linguistic effects of working memory training in children with specific working memory impairment or language and working memory impairment ... 220
Introduction ... 220
Working memory ... 221
Working memory and language ... 222
Working memory and academic abilities ... 223
Working memory impairment ... 224
Working memory training ... 226
Evidence base for working memory training ... 227
Near transfer ... 227
Far transfer ... 228
Study purpose ... 231
Methods ... 232
Participants ... 232

General procedure 234
Intervention materials 234
Intervention procedure 234
Study timeline and outcome measures 236
Analysis 237
Treatment fidelity 238
Results 239
Treatment fidelity 239
Probe measures 240
Standardized measures 248
Overall results 250
Responder analysis 251
Responders, Simplifiers, and Risk Takers 254
Discussion 255
Conclusion 260
References 262
Chapter 5 General discussion 270
Working memory and language ability in narrative retell 270
Summary of results 272
Implications of findings 273
Narrative-based language intervention 275
Summary of results 276
Implications of findings 278
Working memory training 280
Summary of results 281
Implications of findings 282
General discussion 283
Theoretical implications: Working memory and language 283
Clinical implications 284
Heterogeneity 284
Far transfer 285

Research implications: Responder analyses 286
Conclusions 286
References 288
Appendix A: Ethics approval 294
Appendix B: Curriculum Vitae 295

List of Tables

Table 2.1 Descriptive Statistics of Participants According to Impairment 79
Table 2.2 Narrative Retell Outcome Measures 81
Table 2.3 Performance on Narrative Language Measures According to Impairment Status 87
Table 2.4 Correlational Analysis of Narrative Language Outcome Measures for all Participants 88
Table 2.5 Model Testing to Predict LI Status 89
Table 2.6 Model Statistics of LI-Model 2.1a for Predicting Language Impairment . 90
Table 2.7 Model Testing to Predict WMI Status 93
Table 2.8 Model Testing to Predict WMI Status 95
Table 2.9 Model Statistics of WM-Model 2.6 for Predicting Working Memory Impairment 95
Table 2.10 Descriptors for Coding Linguistic Features of Narrative Samples 97
Table 3.1 Participant Age, Sex, Language, Working Memory, and Nonverbal Intelligence 147
Table 3.2 Intervention Session Structure 152
Table 3.3 Description of Probe Measures 156
Table 3.4 Effect Sizes of Probe Measures 172
Table 3.5 Summary of Results from Probes, Narrative Retell, and Standardized Measures of Language, Working Memory, Reading, and Math 173
Table 3.6 Microstructure Measures of Narrative Retell Task 174
Table 3.7 Macrostructure Measure of Narrative Retell Task 175
Table 3.8 Standardized Measures of Language 175
Table 3.9 Standardized Measures of Short Term Memory and Working Memory . 176
Table 3.10 Standardized Measures of Reading 177
Table 3.11 Standardized Measures of Math 177
Table 3.12 Baseline Scores for Measures of Working Memory, Language, Reading, and Math 181
Table 3.13 Comparison of Baseline Linguistic and Working Memory Ability for Language Responders and Nonresponders 181
Table 3.14 Comparison of Baseline Linguistic and Working Memory Ability for Working Memory Responders and Nonresponders 182
Table 4.1 Participant Age, Sex, Language Ability, Working Memory, and Intelligence 234

Table 4.2 Compliance and Progress Scores 240
Table 4.3 Effect Sizes of Probe Measures 247
Table 4.4 Summary of Results from Probes and Standardized Measures of Working Memory, Language, Reading, and Math 247
Table 4.5 Standardized Measures of Short Term Memory and Working Memory . 249
Table 4.6 Standardized Measures of Language 249
Table 4.7 Standardized Measures of Reading 250
Table 4.8 Standardized Measures of Math 250
Table 4.9 Baseline Scores for Measures of Working Memory, Language, Reading, and Math 253
Table 4.10 Progress Scores from Working Memory Training Performance 253

List of Figures

Figure 2.1 Interaction between percent grammatical C-units (%GCU) and MLUw .. 91

Figure 2.2 Interaction between Errors per C-unit and MLUw 92

Figure 2.3 Interaction between subordinate clauses per C-unit (SubC-unit) and number of story events (Events) 96

Figure 2.4 The distribution of four common descriptors across all participants 101

Figure 2.5 Decision tree for identifying impairment according to narrative retell performance 103

Figure 3.1 Study timeline 148

Figure 3.2 Shapes and sample design for puzzle completion probe 158

Figure 3.3 Sample dot arrays for number comparison probe 158

Figure 3.4 Illustration of the proportion/frequency approach to demonstrate intervention effect 162

Figure 3.5 Illustration of the lower 1 *SD* proportion/frequency approach to demonstrate intervention effect 163

Figure 3.6 Sentence coming probe 166

Figure 3.7 Nonword repetition probe 169

Figure 3.8 Puzzle completion probe 170

Figure 3.9 Number comparison probe 171

Figure 3.10 Responder analysis cross-referenced with narrative speaking style 185

Figure 4.1 Puzzle completion probe 242

Figure 4.2 Nonword repetition probe 243

Figure 4.3 Sentence combining probe 244

Figure 4.4 Number comparison probe 246

Figure 4.5 Responder analysis cross-referenced with narrative speaking style 256

Figure 5.1 Responder analysis cross-referenced with narrative speaking style 278

List of Appendices

Appendix 3A Developmental progression of complex sentences ... 208

Appendix 3B Dynamic assessment of complex sentences ... 210

Appendix 3C Correspondence regarding permission to use story materials from Kids Can Press ... 216

Appendix 3D Correspondence regarding permission to use story materials from Annick Press ... 217

Appendix 3E Fidelity checklist ... 218

Appendix A Ethics approval ... 294

Appendix B Curriculum Vitae ... 295

Chapter 1

Introduction

Specific Language Impairment (SLI) refers to a developmental disorder characterized by disproportionate deficits in language (Leonard, 2014). Early on, however, children with SLI were found to perform poorly on nonlinguistic tasks (e.g., Johnston & Ellis Weismer, 1983; Roth & Clark, 1987). Such findings have sparked inquiry into the domain-general abilities of children with SLI as well as the interfacing of verbal and nonverbal processes in general. Working memory is one such domain-general process that has received much attention as a possible contributing factor to language impairment. Working memory is thought to be responsible for short term storage and processing of information in the current focus of attention (Baddeley & Hitch, 1974; Engle, Kane, & Tuholski, 1999). Many studies have shown deficits among children with SLI in working memory tasks with either storage demands only or storage and processing demands (Archibald & Gathercole, 2006a, 2007a; Botting, Psarou, Caplin, & Bevin, 2013; Vugs, Cuperus, Hendriks & Verhoeven, 2013). Nevertheless questions remain regarding the involvement of working memory in language impairment and the collaboration or separation of the two domains. This thesis explores the extent to which working memory and language are separable or discrete domains implicated in children with impairments. This will be accomplished by examining the contributions of working memory and language to a linguistic task, and by testing the domain-specific and cross-domain effects of interventions in language or working memory in children with impairments in language, working memory, or both.

Specific Language Impairment

Definition, Prevalence, and Diagnostic Criteria

Children with SLI present with deficits in linguistic ability despite otherwise typical neurological development and hearing ability (Leonard, 2014). As toddlers and preschoolers, children with SLI are often slower to acquire vocabulary and combine words relative to typical peers (Morley, Court, Miller, & Garside, 1955; Rudolph & Leonard, 2016; Trauner, Wulfeck, Tallal, & Hesselink, 2000). These patterns persist as children with SLI enter elementary school, demonstrating impoverished vocabularies (McGregor, Oleson, Bahnsen, & Duff, 2013), trouble with morphological word endings (e.g., -ed, -third person singular –s; Rice, Wexler, & Hershberger, 1998), and limited use and understanding of complex syntax (Nippold, Mansfied, Billow, & Tomblin, 2009; Thordardottir & Ellis Weismer, 2002). As children with SLI mature, they demonstrate difficulty with word-finding (Coady, 2013; Kail & Leonard, 1986), metalinguistic awareness (Kamhi, 1987), and figurative language such as idioms and similes (Cain & Towse, 2008; Norbury, 2004; Rinaldi, 2000). In the classroom setting, linguistic deficits of SLI may lead to trouble with reading (Catts, Fey, Zhang, & Tomblin, 1999), navigating peer relationships (Brinton & Fujiki, 1999; Fujiki, Brinton, & Todd, 1996), and understanding and producing both narrative (e.g., Colozzo, Gillam, Wood, Schnell, & Johnston, 2011; Liles, 1985; Newman & McGregor, 2006; Ukrainetz & Gillam, 2009) and expository texts (e.g., Koutsoftas & Gray, 2012; Scott & Windsor, 2000)

The prevalence of SLI varies somewhat depending on the assessments, cut-offs, and criteria employed in each study. Nevertheless, two population studies in the United States (Tomblin, Records, & Zhang, 1996) and in the United Kingdom (Norbury et al., 2016) have found that approximately 7% of children aged 4 to 5 years present with language impairment in the absence of deficits in nonverbal intelligence. In general, the diagnosis of SLI is applied when children demonstrate a language impairment that cannot be attributed to any other disability or neurodevelopmental disorder. In practice, this has meant that children must demonstrate language skills below what is expected for their age and meet a number of other criteria in order to rule out possible explanations for the language impairment. To meet these criteria, children have traditionally demonstrated language deficits in the absence of hearing impairment, major psychiatric disorders, and neurological deficits. A final criterion often included has been a discrepancy between nonverbal intelligence and language ability. In addition, the language impairment needs to be demonstrated across multiple measures, including measures of vocabulary, grammar, and narrative abilities in both production and comprehension modalities (e.g., Leonard, 2014; Stark & Tallal, 1981; Tomblin et al., 1996).

Recently, both the definition and terminology for SLI has been a matter of considerable debate, with particular attention on the IQ discrepancy criterion. Although the merit of the IQ discrepancy has been questioned for some time (e.g., Aram, Morris, & Hall, 1992; 1993; Bishop 2004; Plante, 1998), a recent movement among researchers and clinicians has stimulated a transition toward relaxing this exclusionary criterion. Among other suggested changes, Bishop and colleagues have proposed that the IQ discrepancy be dropped in favour of allowing children with low nonverbal abilities to be included within the definition of SLI (Bishop, Snowling, Thompson, Greenhalgh, & CATALISE consortium, 2016; Bishop, Snowling, Thompson, Greenhalgh, & CATALISE-2 consortium, 2017). The transition has also included a change in terminology from SLI to Developmental Language Disorders (DLD). These changes have been motivated in part by an interest in more accurately reflecting the children served by Speech-Language

Pathologists and reducing the number of children excluded from services (e.g., Ebbels, 2014). In the present study, however, the original criteria for SLI was employed in an effort to reduce potential confounding variables.

Characteristics of SLI

Lexical abilities. Lexical deficits in SLI first present as late acquisition of first words, with children with SLI producing their first word as late as 23 months, a year after their typically-developing counterparts (Trauner et al., 2000). With the acquisition of more words, children with SLI continue to have smaller vocabularies than do peers (Gray, Plante, Vance & Henrichsen, 1999), with particular deficits in acquiring verbs (Eyer et al., 2002; Fletcher & Peters, 1984). Deficits in the breadth and depth of vocabulary knowledge have been shown to persist into adolescence (McGregor et al., 2013; Rice & Hoffman, 2015). These vocabulary deficits are supported by findings of experimental word learning studies, which show that children with SLI generally require more exposures to a novel word before they are able to demonstrate evidence of learning (see Kan & Windsor, 2010 for review). The difference between children with and without SLI is greater for children under 6 years of age (Gray, 2003), with greater group differences in receptive language ability (Horohov & Oetting, 2004), and when children with SLI have lower nonverbal IQ relative to age-matched peers (Alt & Plante, 2006). In addition, group differences are larger in studies offering a greater number of exposures to the novel words (Kan & Windsor, 2010) and those targeting verbs as opposed to nouns (Beverly & Estis, 2003; Eyer et al., 2002). Finally, children with SLI show poor retention of learned vocabulary (Oetting, 1999), perhaps one of the most daunting problems in vocabulary acquisition.

Grammatical abilities. Children with SLI show a number of morphosyntactic deficits. Early on, they may be late to combine words (Rudolph & Leonard, 2015; Trauner et al., 2000), and the semantic relations expressed in those combinations appear to be similar to those of younger typically developing peers (e.g., Leonard, Bolders, & Miller, 1976). As they mature, children with SLI show difficulties with and later mastery of tense marking morphemes, particularly past tense *-ed* and third person present tense *-s* (Rice et al., 1998). Common syntactical deficits include omission of obligatory arguments (Grela & Leonard, 1997; Owen & Leonard, 2006; Thordardottir & Ellis Weismer, 2002), omission of *to* in infinitive clauses (Owen & Leonard, 2006), and omission of obligatory clause markers such as *that* or *wh-* words in relative clauses (Schuele & Tolbert, 2001). Studies of expressive language in naturalistic contexts have shown that children with SLI produce fewer elaborated noun phrases (Greenhalgh & Strong, 2001), fewer subordinate clauses (Nippold et al., 2009) and less sophisticated sentence structure in general (Thordardottir & Ellis Weismer, 2002). Children with SLI seem to have particular difficulty with comprehension and production of complex syntax structures that require movement, such as relative clauses (Frizelle & Fletcher, 2014; Riches, Loucas, Baird, Charman, & Simonoff, 2010), passive voice (Bishop 1979; Norbury, Bishop, & Briscoe, 2002; van der Lely & Ullman, 2001; van der Lely, 1996), or wh- questions (Deevy & Leonard, 2007). In a number of cases, children with SLI were able to produce the morphological or syntactical structures of interest, but did so less frequently than peers (Leonard, 1995; Marinellie, 2004).

Fluency. Fluency here refers to the flow of speech output. It is often assessed by measuring disfluencies such as pauses, false starts, mazes, fillers, or repetitions of words or phrases. It is important to note that the types of disfluencies of interest to this study are different from stutter-like disfluencies, such as blocks, prolongations, or part-word repetitions. The reason for verbal disfluencies is not well understood, leading to many suggestions about their origin. It has been suggested that disfluencies are indicative of speaker anxiety (Christenfeld & Creager, 1996; Goldman-Eisler, 1961) or language formulation problems such as grammatical encoding (e.g., Goldman-Eisler, 1968; Leadholm & Miller, 1992; Levelt, 1983; Rispoli, Hadley, & Holt, 2008) or lexical search processes (Christenfeld, 1994). Others have proposed that certain types of disfluencies, such as mazes and word repetitions, are signs of self-monitoring and reparation of speech errors (e.g., Hartsuiker, 2014; Levelt, 1989; Postma & Kolk, 1993). The most robust empirical finding regarding the reason for disfluencies is an association between an increase in disfluencies with an increase in task demands or language complexity (e.g., Leadholm & Miller, 1992; MacLachlan & Chapman, 1988; McDaniel, McKee, & Garrett, 2010; Ratner & Sih, 1987; Yaruss, Newman, & Flora, 1999).

According to many of these findings and the possible causal connection between task demands and disfluency rates, children with language impairment would be expected to show elevated rates of disfluencies relative to typically developing peers. In reality, relevant findings have lacked consistency. For instance, children with SLI have shown higher rates of mazing relative to MLU-matched peers but not age-matched peers (Thordardottir & Ellis Weismer, 2002), or higher mazing rates when calculated as a proportion of propositions rather than a simple frequency tally (Miranda, McCabe, & Bliss, 1998). With respect to pausing, children with SLI have demonstrated higher rates of silent pauses of only a certain duration (i.e., 500–1000ms; Guo, Tomblin, & Samleson, 2008), and no difference in filled pauses in one study (Guo et al., 2008) but fewer filled pauses in another (Thordardottit & Ellis Wesimer, 2002). Such discrepancies are indicative of the complexities of measuring disfluencies; results appear to be affected by multiple factors, such as the comparison group, speaking task, disfluency type, and whether the disfluencies are counted or calculated as a ratio in reference to utterances, propositions, or words. It is also possible that fluency is affected by factors beyond language or measurement methods. One such factor is working memory, which is considered in Chapter 2 of this manuscript. Early evidence of the association between working memory and fluency has been demonstrated in a dual-tasking study, where occupying working memory in a secondary task resulted in a slower speaking rate among adults (Eichorn, Marton, Schwartz, Melara, & Pirutinsky, 2016). Similarly, deficits in speech rate were accounted for by differences in verbal short term memory among children with and without SLI (Marini, Gentili, Molteni, & Fabbro, 2014).

Discourse. Discourse ability is an important indicator of a child's ability to use linguistic skill for the purposes of communication. For children with SLI, three particularly relevant discourse genres are conversation, narrative, and expository language because they are commonly employed in forming and maintaining friendships (Davidson, Walton, Kansal, & Cohen, 2016; Preece, 1987) and learning in the classroom (Westby, 2005). Performance on these tasks depends to a degree on the type of task and the demands it places on the speaker. Conversation, for instance, seems to place the least demands on the speaker linguistically (e.g., Nippold et al., 2014; Thordardottir, 2008; Westerveld & Vidler, 2016). In these contexts, children with SLI may demonstrate shorter utterances and more verb errors relative to peers with typical language (e.g., Redmond, 2004; Thordardottir, 2008), fewer instances of complex syntax (Marinellie, 2004), but similar rates of mazing (MacLachlan & Chapman, 1988; Redmond, 2004). Some children with SLI have also demonstrated difficulty with the pragmatic aspects of conversation, showing lower responsiveness and limited use of nonverbal communication (Bishop, Chan, Adams, Hartley, & Weir, 2000).

Typically, narrative texts are centred around a setting, a collection of characters, a particular problem, and attempts to resolve the problem (Mandler & Johnson, 1977; Stein & Glenn, 1979). Compared with conversation, which tends to be related to the immediate context, narrative requires the speaker to use more complex language features in order to convey sufficient details of the story such as the setting or characters' motivations (Greenhalgh & Strong, 2001). This heightening of linguistic demand is often associated with reduced output and more morphosyntactical errors among children with low language. Relative to peers with typical language abilities, children with SLI have been shown to produce shorter narratives in some cases (Colozzo et al., 2011; Pearce, James, & McCormack, 2010), but not others (Vandewalle, Boets, Ghesquière, & Zink, 2012). Other common features of narratives by children with SLI include lower MLU (Duinmeijer, de Jong, & Scheper, 2012; Fey, Catts, Prctor-Williams, Tomblin, & Zhang, 2004; Marini et al., 2014), higher rates of grammatical error (Colozzo et al., 2011; Norbury & Bishop, 2003; Reilly, Losh, Bellugi, & Wulfeck, 2003), poor cohesion (Liles, 1985), and in some cases, more verbal disruptions in the flow of ideas (Marini et al., 2014; Wetherell, Botting, & Conti-Ramsden, 2007a; but see Scott & Windsor, 2000).

A third discourse genre studied among school age children is expository discourse, which refers to the communication of factual information, such as descriptions, instructions, or cause-effect relations. Unlike narratives, which follow the chronological actions of an agent, expository texts require more logical thinking to express abstract ideas (e.g., Scott, 2010; Ward-Lonergan, 2010). Expository texts are more relevant for older children in classroom settings, where they are required to gather information from textbooks and instructional lectures (Lundine & McCauley, 2016; Westby, 2005). As well, the complexity of the content often requires additional syntactic complexity (Nippold, Hesketh, Duthi, & Mansfield, 2005; Westby, Culatta, Lawrence, & Hall-Kenyon, 2010), which may result in higher rates of morphsyntactic error (Thordardottir, 2008). As a result, expository tasks offer the greatest challenge to speakers. Although less studied than narrative ability, expository ability among children with language impairment tends to be weaker relative to peers with typical language. Children with language impairment tend to produce expository samples with fewer and shorter utterances, less complex language, higher rates of errors, and less relevant content (Nippold, Mansfield, Billow, & Tomblin, 2008; Scott & Windsor, 2000; Ward-Lonergan, 2010).

Nonverbal abilities. Although the definition of SLI includes typical nonverbal intelligence, many nonlinguistic deficits have been found among children with SLI. One such deficit is in mental representation, which has been measured using a variety of tasks such as mental rotation and symbolic play (Johnston & Ellis Weismer, 1983; Roth & Clark, 1987; Savich, 1984). Other nonlinguistic deficits include slower processing speed (Miller, Kail, Leonard, & Tomblin, 2001; Windsor, Kohnert, Loxtercamp, & Kan, 2008), ineffecient hypothesis-testing (Kamhi, Catts, Koenig, & Lewis, 1984), poor sustained attention (Ebert & Kohnert, 2011), poor inhibitory control (Pauls & Archibald, 2016), and difficulty with nonverbal conceptual knowledge such as relations of space, number, or classification (Johnston, 1982; Kamhi, Minor, & Mauer, 1990). A recent meta-analysis on nonverbal cognition found that children with SLI scored on average 0.69 standard deviations below their typical peers (Gallinat & Spaulding, 2014).

Heterogeneity. Despite efforts of researchers to exclude confounding factors, children with SLI are a heterogeneous population. This has resulted in many attempts to categorize children with SLI into more specific subgroups (e.g., van Weerdenburg, Verhoeven & van Balkom, 2006). In the most common classification, children are grouped according to whether their impairment is expressive, receptive, or both. A number of other classification systems have been proposed with anywhere from three to six groups (Beitchman et al., 1989; Conti-Ramsden, Crutchley, & Botting, 1997; Pecini et al, 2005; Tambyraja, Schmitt, Farquharson, & Justice, 2015). Attempts to classify subtypes have been complicated further by developmental changes. For instance, two of these classification systems were tested with follow-up testing and found that 45 to 60% of participants had shifted to a different subtype (Conti-Ramsden & Botting, 1999; Tambyraja et al., 2015).

These sorts of findings have implications for intervention research like the studies reported in this dissertation. It is possible that children with varying abilities will respond differently to intervention or benefit more from interventions tailored to their strengths and weaknesses. For this reason, intervention research would do well to examine participant-specific moderating factors of the intervention effects. Such information could inform developmental interventions and proper selection of intervention options to make the best use of limited therapy time. One cognitive ability requiring attention in the profile of children with language impairment is working memory, which is considered here.

Working Memory

Working memory is the domain-general limited capacity cognitive resource that enables short term storage and manipulation of information that either has been selectively pulled from long term memory or extracted from environmental stimuli (e.g., Engle, Kane, et al., 1999). In addition, the mental representations held in working memory are maintained in an active state so they may be reconfigured or bound with other activated representations (Oberauer, 2009; Oberauer, Süß, Wilhelm, & Wittman, 2003). Although there are many models of working memory, one of the most studied models of working memory comes from Baddeley and Hitch (1974), who proposed a multicomponent model of working memory. Specifically, working memory was thought to be comprised of the phonological loop, visuospatial sketchpad, central executive, and episodic buffer (Baddeley, 2000).

Phonological Loop

The phonological loop describes verbal short term memory; it is responsible for short term retention of verbal information and maintenance of that information through subvocal rehearsal. Without rehearsal, contents of verbal short term memory are subject to decay over time or to interference from other verbal material (Baddeley, 1986). A number of features of verbal short term memory have been well researched. For instance, storage of verbal information can be unintentional, as in the irrelevant sound effect, or used to support retention of visual information. The irrelevant sound effect, that phonological material is granted obligatory access to the phonological store, is demonstrated by poorer retention of information in the presence of other background verbal material (e.g., Colle & Welsh, 1976; Salamé & Baddeley, 1982). Retention of visual information is supported by verbally encoding visually presented material and storing the verbal code in verbal short term memory, provided the items can be named (e.g., Colle & Welsh, 1976; Conrad & Hull, 1964). In addition, the capacity of verbal short term memory is believed to be limited to 2 seconds worth of phonological material.

This is supported by the word length effect, wherein a list of longer words (e.g., university, hippopotamus, refrigerator) is more difficult to recall than a list of single syllable words (e.g., pen, cap, tub) (Baddeley, Thomson, & Buchanan, 1975).

Retention of information is affected by a number of factors including various features of the items themselves and availability of rehearsal processes. The phonological similarity of the items have been shown to influence retention in that phonologically similar items (e.g., map, man, cap, can) are more difficult to recall than phonologically distinct items (e.g., bus, tree, ham, pit) (Baddeley, 1966; Conrad & Hull, 1964). Other research has shown that knowledge in long term memory supports retention in short term memory. Evidence for this comes from findings of better recall for known words rather than nonwords (e.g., Hulme, Maughan, & Brown, 1991), for words with higher phonotactic frequency (e.g., Gathercole, Frankish, Pickering, & Peaker, 1999), and in some cases, for higher frequency words (e.g., Hulme, Stuart, Brown, & Morin, 2003). Importantly, retention of material in the phonological store is supported by rehearsal. Recall performance drops when participants repeatedly articulate an irrelevant syllable (e.g. the, the, the), known as articulatory suppression, which prevents rehearsal (Baddeley et al., 1975).

Visuospatial Sketchpad

The visuospatial sketchpad functions in parallel to the phonological loop, as the short term storage of visual and spatial material (Baddeley & Hitch, 1974). Like verbal short term memory, visuospatial short term memory has a limited capacity (Phillips, 1974). Evidence of dissociations between storage of visual, spatial, and kinesthetic information has led researchers to suggest that visuospatial short term memory is separable into subcomponents (Baddeley & Lieberman, 1980; Logie, 1986; Smyth &

Pendleton, 1990). Logie and colleagues (e.g., Logie, 1995; Salway & Logie, 1995) have conceptualized these subcomponents as the visual cache, which stores information on shape and colour, and the inner scribe, which stores information about movement sequences.

Central Executive

In Baddeley's earlier models of working memory, the central executive was thought to be responsible for the control of attention (Baddeley & Hitch, 1974). Later on, the role of the central executive was delineated as a set of executive processes (Baddeley, 1996), including coordinating information from the two short term stores (e.g., Baddeley, Logie, Bressi, Della Sala, & Spinnler, 1986), switching between retrieval strategies (Baddeley, 1996), selectively attending to a single task or stream of stimuli while ignoring others (e.g., Baddeley, Emslie, Kolodny, & Duncan, 1998), and temporarily activating items from long term memory (Baddeley, 1998). The central executive was originally thought to act as a domain-general component that controls the two slave systems (the phonological loop and the visuospatial sketchpad). However, subsequent research has shown that instead of acting only as a slave system, verbal short term memory, as described by the phonological loop, has been shown to aid in attentional control by continuously articulating cues to orient the participant to the task at hand (e.g., Emerson & Miyake, 2003). Close associations between measures of visuospatial short term memory and the central executive have led some researchers to question the dissociation between those two components (e.g., Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Others have argued for the dissociation of the central executive and visuospatial short term memory, suggesting that the central executive is recruited for visuospatial tasks simply to maintain attentional engagement (Shipstead & Yonehiro, 2016). Other support for separate domain-specific storage and domain-general processing is found in a number of factor analyses (e.g., Alloway, Pickering, & Gathercole, 2006; Bayliss, Jarrold, Gunn & Baddeley, 2003; Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004; Oberauer et al., 2003; Swanson, 2017).

Episodic Buffer

The episodic buffer was added to the model later on (Baddeley, 2000) as a mental work space that facilitated binding of both visual and phonological form into integrated episodes. Because of its capability for holding multidimensional representations, the episodic buffer was thought to function as a link between perception, working memory, and long term memory. This amendment was made to account for findings that could not be explained by the original model, namely, the ability to manipulate both visual and phonological information simultaneously (Logie, Della Sala, Wynn, & Baddeley, 2000) and to recall a quantity of material that typically exceeds the capacity of short term memory (Baddeley, Vallar, & Wilson, 1987).

Working Memory and SLI

Verbal Short Term Memory

The working memory abilities of children with SLI have been measured extensively. The most robust finding is that of poor verbal short term memory as measured by nonword repetition tasks (Archibald & Gathercole, 2006a; Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Ellis Weismer et al., 2000; Gathercole & Baddeley, 1990; Gray, 2006). A meta-analysis comparing children with and without SLI on nonword repetition found that on average children with SLI performed 1.27 standard deviations lower than children without SLI (Graf Estes, Evans, & Else-Quest, 2007). Similar but less profound deficits have been found on other measures of verbal short term memory such as serial recall and digit recall (Archibald & Gathercole, 2006a; Hick, Botting, & Conti-Ramsden, 2005). This verbal storage deficit is evident throughout childhood (Gray, 2006) and adolescence (Conti-Ramsden, Botting, & Faragher, 2001), and is so consistently associated with language ability that nonword repetition has been proposed to be a useful tool in assessing children for language impairment (Archibald, 2008; Coady & Evans, 2008; Ellis Weismer et al., 2000).

Despite earlier perceptions, recent research has shown that performance on a nonword repetition task is not a pure measure of verbal short term memory. For instance, the finding that the SLI deficit is greater for repetition of multisyllabic than equivalent single syllable lists of nonwords (Archibald & Gathercole, 2006a, 2007b) suggests that short term memory span is not the only contributing factor to performance on the nonword repetition task. Findings show that nonword repetition ability is influenced by linguistic factors, such as phonological processing ability (Bowey, 1996; Metsala, 1999; Rispens & Baker, 2012), and vocabulary knowledge (see Snowling, Chiat, & Hulme, 1991). Nevertheless, despite the linguistic contributions to nonword repetition ability, difficulty retaining verbal information for a short time has been recognized recently as a characteristic deficit of children with SLI, based on the substantial evidence supporting verbal short term memory deficits (Bishop et al., 2017).

Verbal Working Memory

Verbal working memory is often measured using complex span tasks, that is, tasks that require both storage and processing of verbal information (e.g., Bayliss et al., 2003; Conway et al., 2005; Redick et al., 2012). Complex span tasks are thought to rely on both verbal short term memory and central executive (Baddeley & Logie, 1999; Bayliss et al., 2003; Lobley, Baddeley, & Gathercole, 2005). One example of a verbal complex span task is the Competing Language Processing Task (CLPT), in which participants hear a series of statements, decide whether each statement is true or false, and then recall the last word of each sentence in order (Gaulin & Campbell, 1994). Many studies have found children with SLI to score below typical peers on similar complex span tasks (e.g., Archibald & Gathercole, 2006a, 2007a; Ellis Weismer, Evans, & Hesketh, 1999). Specifically, groups tend to differ on the storage component of the task, not the processing component (Archibald & Harder-Griebeling, 2016).

Deficits in verbal complex span tasks have often been interpreted as a sign of limited processing capacity among children with SLI (e.g., Archibald & Gathercole, 2006a, 2007a; Marton & Schwartz, 2003; Montgomery & Evans, 2009). This is supported by findings that group differences in simple storage span cannot account for the complex span deficit in children with SLI (Archibald & Gathercole, 2007a). Other studies have found that children with SLI struggle when the presentation rate of to-be-recalled items was increased; researchers have interpreted these findings as further evidence of limited central executive capacity (e.g., Fazio 1998; Hoffman & Gillam, 2004).

In contrast, it has also been suggested that poor performance on complex span tasks is due not to limitations of the central executive, but to impairments in the systems with which verbal working memory works, namely verbal short term memory and language processing (Briscoe & Rankin, 2009; Mainela-Arnold, Evans, & Coady, 2010). According to this view, the central executive is intact, but is supported or constrained by reduced short term memory span or language processing abilities. For example, Mainela-Arnold et al. (2010) found that recall accuracy on the CLPT was significantly affected by the frequency of the target words, and suggested that verbal complex span tasks were heavily reliant on linguistic processing rather than domain-general capacity. Additional support for developmentally appropriate processing capacity among children with SLI has been demonstrated in a recent study (Archibald & Harder-Griebling, 2016). In this study, children with low language completed several complex span tasks that varied systematically in their processing load and storage load. When the storage load was adjusted to the span of the individual and held constant, there was no difference between children with and without low language as the processing load was increased. Taken together, this body of research gives clear evidence of functional deficits on verbal working memory tasks for children with SLI. Those deficits, however, appear to be heavily mediated by a number of factors, including but perhaps not limited to, short term memory span, processing speed, and linguistic ability.

Visuospatial Short Term Memory

Typical measures of visuospatial short term memory require participants to recall locations of items briefly presented on a screen, such as in the Corsi block task (e.g., Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000). Reports of visuospatial memory abilities of children with SLI have been less consistent and somewhat more controversial. Some studies comparing children with and without SLI found a significant difference favouring typical children (e.g., Bavin, Wilson, Maruff, & Sleeman, 2005; Hoffman & Gillam, 2004; Kleemans, Segers, & Verhoeven, 2011; Vugs, Hendriks, Curperus, & Verhoeven, 2014); however, other studies found that children with SLI performed at par with or even better than their typical peers (Archibald & Gathercole, 2006b, 2007a; Henry, Messer, & Nash, 2012; Petruccelli, Bavin, & Bretherton, 2012; Williams, Stott, Goodyer, & Sahakian, 2000). A recent meta-analysis found that on average the visuospatial working memory deficit in children with SLI was 0.49 standard deviations below typical peers (Vugs et al., 2013), which the authors noted was considerably smaller than the nonword repetition deficit of 1.27 standard deviations (Graf Estes et al., 2007).

The reason for discrepancies between studies on visuospatial short term memory is still unclear. One possibility is that visuospatial storage deficits are found only in children with more severe language impairment. This was the case in the meta-analysis, where studies that required children with SLI to present with more widespread evidence of language impairment showed a greater visuospatial storage deficit (Vugs et al., 2013). Alternatively, it has been suggested that typical children may support storage of visuospatial stimuli using verbal encoding, a process that may be inefficient in children with SLI (Archibald & Gathercole, 2006b; Botting et al., 2013). It is possible that some tasks lend themselves to verbal encoding more than others. Vugs et al. (2013) have argued, however, that this explanation does not account for the SLI deficits in children younger than 7 years of age (e.g., Bavin et al., 2005; Kleemans et al., 2011; Vugs et al., 2014) because children that young do not engage in verbal rehearsal (Gathercole, Adams, & Hitch, 1994).

Visuospatial Working Memory

As with verbal working memory, visuospatial working memory is measured using complex span tasks comprised of a processing component and a storage component. One example of a visuospatial complex span task is *Spatial Span* from the *Automated Working Memory Assessment* (Alloway, 2007), in which participants are required to mentally rotate shapes to compare their orientation, and later recall the location of a feature on each of the target shapes. Relatively few studies have been conducted to examine the visuospatial working memory capacity of children with SLI. Again, the findings are mixed. Although some studies report lower scores among children with SLI (Karasinski

& Ellis Weismer, 2010; Miller & Wagstaff, 2011; Vugs et al., 2014), others report no difference between groups (Archibald & Gathercole, 2006b; Bavin et al., 2005; Williams et al., 2000). Overall, a recent meta-analysis found that children with SLI scored 0.63 standard deviations lower than peers on measures of visuospatial working memory (Vugs et al., 2013).

Theories of SLI

The complex cognitive linguistic profile of children with SLI has prompted researchers to theorize about the underlying cause of SLI. Understanding the basis of SLI would be helpful for developing interventions and projecting outcomes for children. Summarized here are a range of theories, including those suggesting an underlying deficit in domain-general processes, and those suggesting that SLI is specific to the linguistic domain.

SLI as a Phonological Deficit

The phonological-deficit hypothesis proposes that a deficit in speech perception causes a phonological deficit, which is the root of language impairment in SLI (Joanisse, 2004; Joanisse & Seidenberg, 1999, 2003). According to this theory, a phonological deficit leads to difficulty maintaining phonological representations of sentences in memory, which in turn results in poor comprehension and impaired syntactic development (Joanisse & Seidenberg, 2003). Specifically, difficulty holding a sentence in mind limits the opportunity for syntactic parsing and resolution of syntactic relationships. In addition, difficulty maintaining representations of novel words has negative implications on word learning. Using computational modeling, Joanisse and Seidenberg have demonstrated that such a phonological deficit can explain some linguistic errors common among children with SLI, such as verb morphology (Joanisse & Seidenberg, 1999) and pronominal referencing (Joanisse & Seidenberg, 2003).

SLI as a Short Term Memory Deficit

Based on the findings reviewed above of markedly poor verbal short term memory in children with SLI, Gathercole and Baddeley (1990) proposed the phonological storage deficit hypothesis. According to this theory, deficits in verbal short term memory may lead to language impairment under the notion that poor retention of verbal material will prevent sufficiently thorough encoding of incoming linguistic stimuli. This view has been supported by later work demonstrating the importance of the phonological loop, or verbal short term memory, in learning language and novel words (Baddeley, Gathercole, & Papagno, 1998; Gathercole, 2006; Gathercole, Hitch, Service, & Martin, 1997; Majerus & Boukebza, 2013). Although some children with low verbal short term memory span go on to acquire vocabulary normally (Gathercole, Tiffany, Briscoe, Thorn, & The ALSPAC team, 2005), it is likely that such a deficit is a contributing factor to language impairment.

Linguistic Theories of SLI

One of the more popular linguistic accounts of SLI began as the Extended Optional Infinitive (EOI) account (Wexler, 1994). This account was formulated following the observation that all young children appear to go through a stage in which they may or may not mark tense on the main verb of the utterance, choosing instead to replace the inflected verb with the infinitive form. Wexler referred to this as the optional infinitive stage, and posited that children alternate between the infinitive and inflected verb forms until they understand that tense marking is obligatory. Children with SLI also pass through the optional infinitive stage, although this stage tends to last longer for them (Rice, Wexler, & Cleave, 1995). According to the EOI account, children with SLI will show a higher proportion of infinitive forms in place of inflected forms relative to both age-matched and language-matched peers, and take longer to learn that tense marking is obligatory for the main verb of the utterance.

Later on, the EOI account was expanded in order to account for utterances such as "*Her pushed me*" which could not be explained by the original account. It was argued that these utterances were evidence that agreement was also optional in the grammar of children, an argument that formed the basis of the Agreement/Tense Omission Model (ATOM; Schütze & Wexler, 1996; Wexler, Schütze, & Rice, 1998). Finally, the model was modified a second time to explain why children rarely substitute infinitive for inflected forms in null-subject languages such as Spanish and Italian. Wexler (1998, 2003) proposed in the Extended Unique Checking Constraint (EUCC) account that an early appearing constraint permits checking of either tense or agreement, but not both. As in the EOI account, the EUCC account assumes that children with SLI will experience this stage longer than children with typical language ability. This account explains why children with SLI are likely to produce utterances such as "*Him kicked me*" (where checking occurred for tense only) and "*She kick me*" (where checking occurred for agreement only) even after their typical peers have begun to correctly mark tense and agreement.

A second linguistic theory of SLI proposes that a subset of children with SLI, first called Grammatical SLI (G-SLI), have a core deficit in computing the underlying hierarchy required for structurally complex forms (van der Lely, 1994, 1998; van der Lely & Stollwerck, 1996). This core deficit affects one or more components of grammar in both expression and comprehension. The Representational Deficit for Dependent Relationships (RDDR) hypothesis was developed to account for these deficits (van der

Lely, 1998), proposing that children with G-SLI treated syntactical movement as optional (e.g., wh-movement; van der Lely & Battell, 2003). Subsequent findings prompted an expansion of the RDDR hypothesis to include phonology and morphology. This expansion, the Computational Grammatical Complexity (CGC) account (Marshall & van der Lely, 2006, 2008), proposed that the deficit in children with G-SLI lies in representing structural complexity.

Domain-General Accounts of SLI

A major limitation of the language-specific accounts of SLI is that they cannot account for the nonlinguistic deficits common among children with SLI (e.g., Ebert & Kohnert, 2011; Johnston & Ellis Weismer, 1983; Nelson, Kamhi & Apel, 1987). These cognitive deficits have prompted researchers to consider the possibility that domain-general impairments may be a core feature of SLI. Specifically, researchers have proposed that reduced processing speed or limited capacity could result in impaired language by interfering with encoding or processing. The generalized slowing hypothesis (Kail, 1994) proposes that a reduced general processing speed is responsible for the language deficits among children with SLI. This reduction in processing speed is typically assessed by measuring reaction time on a variety of processing tasks. Indeed, many studies have reported a slower reaction time for children with SLI on both linguistic (e.g., Leonard, Nippold, Kail, & Hale, 1983; Wulfeck, Bates, Krupa-Kwiatkowski, & Saltzman, 2004) and nonlinguistic tasks (Miller et al., 2001, 2006; Schul, Stiles, Wulfeck, & Townsend, 2004; Windsor et al., 2008). According to the generalized slowing hypothesis, children with SLI will perform all processing tasks slower than peers by a constant proportion (Kail, 1994). Although this proportional slowing is a fairly robust finding, there is evidence that not all children with SLI exhibit slowing (Edwards &

Lahey, 1996; Lahey & Edwards, 1996; Miller et al., 2001, 2006; Windsor & Hwang, 1999). Moreover, the degree of slowing does not appear to correlate with the severity of language impairment (Lahey, Edwards, & Munson, 2001).

A second body of research on domain-general accounts of SLI explores the view that the language deficit is caused by limitations in processing capacity. Processing capacity can be conceptualized as a smaller mental workspace or the potential to perform operations with increased load or storage demands. It is important to note that processing speed and capacity are closely related: a faster processing speed could enable more efficient use of available capacity (Ellis Weismer, 1996). However, a recent study examined the speed and capacity of children with SLI using confirmatory factor analysis and found that the best fitting model separated the two, supporting the distinction of processing speed and capacity (Leonard et al., 2007). According to the limited capacity view, children with SLI are capable of performing single operations but struggle when multiple operations must be performed simultaneously (Bishop, 1992; Ellis Weismer, 1996). Support for this view comes from studies showing that children with SLI perform below peers as task demands are increased (e.g., Ellis Weismer, 1996; Ellis Weismer et al., 1999; Johnston & Smith, 1989; Montgomery 2000a, 2000b).

One challenge to domain-general theories of SLI is explaining the disproportionate difficulty with language. One theory that attempts this is the surface account, put forward by Leonard and colleagues (Leonard, 1989, 1992; Leonard, Eyer, Bedore, & Grela, 1997; Leonard, McGregor & Allen, 1992). The surface account assumes a general processing capacity limitation restricts children's ability to both perceive and hypothesize the function of grammatical morphemes. This is particularly applicable in English because many grammatical morphemes take the form of single phonemes or unstressed syllables, which have a brief duration. According to the surface account, children with SLI are able to perceive these morphemes, but their limited processing system is overly taxed by the need to process the significance of grammatical morphemes under such time constraints. This imbalance between processing load and processing capability results in incomplete processing of the morphemes; therefore, children with SLI require a greater number of exposures to acquire these brief morphemes.

Finally, a more recent processing theory takes into account both the complexity of linguistic input and the processing limitations of children with SLI. This account, the Competing Sources of Input (CSI) hypothesis (Fey, Leonard, Bredin-Oja, & Deevy, 2017), suggests that utterances such as *"Her laughing"* or *"She laughing"* are modeled after grammatical forms that have been processed only partially (e.g., *I heard her laughing* or *Was she laughing?*). This hypothesis proposes that all children experience a phase where they cannot detect a difference between subject-verb strings that can stand on their own as declarative sentences (i.e., finite strings such as *John feeds the dog*), and those that are embedded in a larger construction (i.e., non-finite strings as in *Help John feed the dog*). Children with SLI, however, will take longer to learn the rules about these contexts because of their processing limitations.

Testing theories of SLI

Epidemiological Approach

In broad terms, the theories presented above represent competing views of SLI: namely, that SLI is a manifestation of impairment in either domain-specific knowledge or domain-general capacity. This debate is fueled by some uncertainty surrounding the relationship between linguistic and working memory abilities. It is possible that one of these views is correct—that the root of SLI is an isolated deficit—and that poor performance across domains is explained by carryover effects and the difficulty of assessing a single domain in isolation. A second possibility is that both views carry some truth. If this is the case, studies with large samples should reveal varying profiles of children with impairments in one or both domains. Two studies have taken this approach. In a group of 400 children (ages 5 to 9 years), Archibald and Joanisse (2009) found cases where language impairment or working memory impairment occurred in isolation, and cases with comorbid deficits associated with severe deficits in one domain. Similarly, in a study of 431 children (ages 5 to 7 years), Kapantzoglou, Restrepo, Gray, and Thompson (2015) found two groups with impairment, one characterized by poor grammar ability and the other by poor working memory. Taken together, these findings lend evidence to the dissociation of language and working memory, but also demonstrate the close relationship between the two.

Intervention Studies

Given the evidence that impairments in language and working memory may be separable, another method of examining the connections across these cognitive resources would be to explore the effects of intervention in one area on the other. In one study, school age children with language impairment who received a combined language intervention and phonological awareness intervention showed significant gains on measures of verbal short term memory and verbal working memory (Park, Ritter, Lombardino, Wisehart, & Sherman, 2014). Similarly, gains in verbal short term memory, in particular those measured by nonword span tasks, were noted for preschool children with language impairment after participating in a phonological awareness intervention (Gillam & van Kleeck, 1996; van Kleeck, Gillam, & Hoffman, 2006). These findings suggest a connection between working memory and language and that intervention in one domain has the potential to influence performance in the other. In contrast, however, findings from another study suggest that working memory may function independent from domain-specific knowledge. Kindergarten children with typical language abilities did not improve on a word span task following phonological awareness intervention (Schneider, Küspert, Roth, Visé, & Marx, 1997). These contrasting results may be due to simple differences in measuring working memory, or they may point to different relationships between working memory and linguistic ability in children with and without impairment. It is possible that broad effects of domain-specific intervention are more likely among children with core deficits in the area targeted by the intervention.

Methodological Considerations

Narrative Sampling

When studying children with SLI, it is important to consider the cognitive demands of the tasks employed in assessment. Researchers should ensure that tasks are measuring what they are intended to measure, particularly when the cognitive constructs of interest are so closely connected, as is the case with language and working memory. For instance, as was discussed earlier, vocabulary and phonological knowledge have been shown to support performance on recall of both words and nonwords (e.g., Casalini et al., 2007; Gathercole et al., 1999; Hulme et al., 1991; Jones, Tamburelli, Watson, Gobet, & Pine, 2010). Similarly, working memory ability has been shown to play a role in grammaticality judgment when the grammatical error appears later in the sentence (Noonan, Redmond, & Archibald, 2014). In both of these cases, an impairment in the non-tested domain could result in poorer performance and potentially a misrepresentation of the domain being tested. Misidentification of impairment could lead to improper selection of intervention and may explain why some studies have found only moderate response to intervention (e.g., Fey, Finestack, Gajewski, Popescu, & Lewine, 2010; Swanson, Fey, Mills, & Hood, 2005). This highlights the need to better understand how working memory and language contribute to performance on assessments used to identify children with language or working memory impairment. Narrative retell is one tool that has been traditionally used as a measure of language despite possibly placing demands on domain-general processing as well (e.g., Montgomery, Polunenko, & Marinellie, 2009). The study in Chapter 2 examined working memory and language contributions to narrative retell ability by testing performance on the task across groups with impairments in one or both of language and working memory.

Spontaneous language samples like narratives are a valuable assessment tool because of their high ecological validity. Narratives are a meaningful assessment tool for school age children because they not only provide an accurate picture of functional communication ability, they are also useful in predicting later language, literacy, peer adjustment, and school success (Bishop & Edmundson, 1987; Botting, 2002; Davidson et al., 2016; Dickinson & McCabe, 2001; Griffin, Hemphill, Camp, & Wolf, 2004). Moreover, advances in recording equipment and transcription software make the collection and analysis of language samples more feasible, extending the possibilities of functional language assessment for speech language pathologists.

As a language assessment, narrative samples are valuable for their flexibility. Because language samples can be analyzed according to many performance indicators, they can offer a wealth of information about the speaker's abilities, such as syntax, morphology, and fluency (e.g., Gillam & Johnston 1992; Guo et al., 2008; Marini et al., 2014; Scott & Windsor, 2000). Compared with conversation, narratives tend to elicit more complex syntax (Nippold et al., 2014), longer utterances (Thordardottir 2008), and a greater amount of verbal output (Wetherell et al., 2007b) but also higher rates of morphological errors (Thordardottir 2008) and stalls and repairs, particularly among children with language impairment (MacLachlan & Chapman, 1988). Therefore, narratives give an excellent indication of a child's linguistic abilities.

Single Subject Design

Given the heterogeneity in SLI and the potential variation in underlying impairments in language and working memory, it is important to both tailor interventions to individuals and examine individual response to intervention; therefore, single subject design (SSD) was employed in the present study. SSDs offer a number of advantages for intervention studies with populations with impairments. One advantage is that the intervention can be tailored to suit the abilities of the individual without compromising the strength of the study (Borden & Abbott, 2011; Rapoff & Stark, 2008). A second advantage of SSDs is that change is measured at the level of the individual. This enables exploration of participant characteristics that may influence response to intervention (Barlow & Hersen, 1973; McReynolds & Thompson, 1986). Children with language impairment are a heterogeneous population; therefore, SSD is an ideal approach to investigating what type of intervention will be most effective and which children are likely to receive the greatest benefit from these interventions. Third, SSDs are a viable way to establish causal relationships between intervention and outcomes with a limited number of participants (Bordens & Abbott, 2011; Horner, Swaminathan, Sugai, & Smolkowski, 2012; Perdices & Tate, 2009). Although large group designs such as randomized controlled trials (RCTs) tend to be favoured as the gold standard for intervention studies, the use of SSDs has been championed recently in many fields including special education (Horner et al., 2005), neuropsychological rehabilitation

(Perdices & Tate, 2009), learning disabilities (Kratochwill, Altschaefl, Bice-Urbach, & Kawa, 2013), and communication sciences and disorders (Byiers, Reichle, & Symons, 2012). In addition, recent reviews have noted that SSDs are commonly used to test interventions for children with communication disorders (Baker & McLeod, 2011; Cirrin & Gillam, 2008).

Three common concerns surrounding SSDs are experimental control, generalizability, and data analysis. Unlike RCTs, SSDs do not include control participants. Instead, control can be achieved in two ways: by establishing a stable baseline before offering intervention and by repeated assessment of targeted and non-targeted behaviours. The baseline is important for demonstrating not only the level of the participant's ability but also the persistence of impairment; a sufficiently lengthy baseline phase (i.e., a minimum of 3 data points; Kazdin, 2011; Tate et al., 2008) provides evidence that the impairment will not resolve on its own (Kazdin, 1981). In this way, the baseline phase acts as each participant's own control. As well, using probes to repeatedly assess both targeted and non-targeted behaviours serves as a second form of control. Treatment effect is established when participants show improvement on only those probes designed to assess behaviours targeted in the intervention. Stability of control probes throughout the intervention is further evidence that the impairment would not have improved without the intervention.

The generalizability of findings from SSDs is often criticized; however, there are many ways to improve the external validity of SSDs. The first is through replication across multiple participants or even to other settings or researchers (Hersen & Barlow, 1976; Perdices & Tate, 2009). For instance, Logan, Hickman, Harris, and Heriza (2008) argue that findings can be considered to be generalizable if they are replicated across 3 or more participants. Other ways to enhance the generalizability of findings include detailed descriptions of the participants, study context, and any factors affecting participants' baseline behaviour (Horner et al., 2005). In other words, the level of detail inherent in SSDs facilitates generalization by describing the contexts and participants most likely to benefit from the intervention in question.

Finally, the best method of data analysis for SSD is a matter of ongoing debate. Visual inspection was one of the primary approaches historically, and continues to be used, although it has been criticized widely for being unreliable and prone to Type I error (Byiers et al., 2012). In addition, studies have found low interrater agreement for visual inspection (Harbst, Ottenbacher, & Harris, 1991; Ninci, Vannest, Willson, & Zhang, 2015; Ottenbacher, 1993) and variable agreement between visual and statistical analysis of single-subject data (Bobrovitz & Ottenbacher, 1998; Jones, Weinrott, & Vaught, 1978). Such findings have lead researchers to advocate for the use of statistical analysis either in addition to or in place of visual analysis, particularly when the baselines are unstable or when the effect is weak (Harbst et al., 1991; Hersen & Barlow, 1976; Kazdin, 1982; Zahn & Ottenbacher, 2001). Unfortunately, there are many statistical procedures for both detecting effect and measuring the magnitude of effect with little agreement among researchers on which approach to use (e.g., Olive & Smith, 2005; Parker & Brossart, 2003). As a result, many researchers employing SSDs in language intervention studies have conducted both visual and statistical analysis of their data, which is the approach taken in the present studies (Ebert, Rentmeester-Disher, & Kohnert, 2012; Gillam, Hartzheim, Studenka, Simonsmeier, & Gillam, 2015; Petersen et al., 2014; Spencer, Kajian, Petersen, & Bilyk, 2013).

Language Intervention

A recent surge in research with school age children has uncovered a number of intervention factors that are likely to improve the effectiveness of language therapy. Reviewed here are findings that are particularly relevant to the design of the intervention study in this dissertation. One factor influencing intervention effectiveness is the explicitness of the instruction. On one hand, explicit instruction seems appropriate considering that children with SLI have difficulty learning linguistic structures implicitly (e.g., Bishop, Adams, & Rosen, 2006; Ebbels, Marić, Murphy, & Turner, 2014; Rice et al., 1998; Schuele & Dykes, 2005). On the other hand, naturalistic interventions are thought to promote generalization sooner than drill-based approaches (see Nelson, Camarata, Welsh, Butkovsky, & Camarata, 1996). One possible solution is to combine the two by embedding explicit instruction within a meaningful context such as narratives (Eisenberg, 2013, 2014). This approach has been successfully adopted in a number of cases (e.g., Fey, Cleave, & Long, 1993; Gillam, Gillam, & Reece, 2012).

One way to contextualize explicit instruction is by employing explicit recasting methods during story retells. Noncorrective or nonimitative recasting has often been implemented with younger children (e.g., Camarata, Nelson, & Camarata, 1994; Hassink & Leonard, 2010; Nelson et al., 1996); however, it has been suggested that older children may benefit from more explicit approaches (Ebbels, 2014; Ebbels et al., 2014). For older children, recasting may be made more explicit by prompting the child to imitate the clinician's recast, or by prompting the child to expand on her own utterance (Eisenberg 2013; Schwartz, Chapman, Terrell, Prelock, & Rowan, 1985).

Child: *The dog has a party.*

Clinician: *When does the dog have the party?*

Child: *After the owners go out.*

Clinician: *Can you say that all together? The dog…*

Findings regarding therapy dose are also important to consider when designing intervention. Recasting studies have shown that relative to children with typical language, children with non-specific language impairment (LI) require a greater number and higher density of recasts in order to learn the targeted structure or vocabulary (e.g., Proctor-Williams, 2009; Proctor-Williams & Fey, 2007). In addition, children with SLI require many different exemplars in order to better extract the targeted grammatical pattern (Kiernan & Snow, 1999; Plante et al., 2014; Torkildsen, Dailey, Aguilar, Gómez & Plante, 2013).

Working Memory Intervention

Working memory intervention is a topic of much debate in current research. The approach receiving the greatest attention is computer-assisted working memory training (e.g., Klingberg et al., 2005). Studies on the efficacy of this type of working memory training often find improvements on tasks similar to those targeted in intervention with little evidence of long term maintenance or transfer to other skills that depend on working memory such as language, reading, or math (Banales, Kohnen, & McArthur, 2015; Holmes et al., 2010; Melby-Lerväg, Redick, & Hulme, 2016). Such limitations in generalization have prompted criticism from researchers, who have argued that without far transfer working memory training has little merit (Melby-Lerväg et al., 2016). One limitation with existing literature, however, is that very few studies test participants with working memory impairment. For instance, in two recent meta-analyses, only 3 to 7% of studies included participants with tested working memory deficits (Melby-Lerväg & Hulme, 2013; Schwaighofer, Fischer, & Bühner, 2015). It is possible that working memory training is more beneficial for participants whose working memory ability is in the impaired range rather than for those whose working memory is average or above average. For example, studies of children with low working memory have shown positive improvements in both working memory and academic performance (Dunning, Holmes, & Gathercole, 2013; Holmes & Gathercole, 2014; Holmes, Gathercole, & Dunning, 2009).

Overall Objective

Children with SLI present with a complex profile that includes deficits in language and possibly other nonverbal cognitive processes such as working memory. The interconnectedness of language and working memory has been examined extensively with some studies showing a close association between the two domains (Archibald & Gathercole, 2006a; Graf Estes et al., 2007; Vugs et al., 2013) and others suggesting a greater degree of separability (Archibald & Joanisse, 2009; Kapantzoglou et al., 2015). Investigation of working memory and language among children with SLI is complicated further by the heterogeneity in the population, indicating a need for research to be conducted at the level of the individual in order to account for individual differences. The primary purpose of this thesis was to examine both the dynamic relationship of working memory and language in children with impairments in these domains as well as individual factors that may influence that relationship.

The aim of Chapter 2 was to examine the degree to which performance on a language task, narrative retell, could predict speakers' impairments in language or working memory, thereby investigating contributions of language and working memory ability to narrative retell performance. Chapters 3 and 4 report a second study that tested the effectiveness of domain-specific interventions for children with impairments in one or both domains of working memory and language. Chapter 3 examines the effects of narrative-based language intervention on the language, working memory, and academic abilities of children with language impairment with or without working memory impairment. Chapter 4 examines the effects of a computerized working memory training program on the working memory, language, and academic abilities of children with working memory impairment with or without language impairment. In addition, both Chapters 3 and 4 investigate the influence of participant-specific characteristics on the effectiveness of the interventions. Collectively, these studies contribute to a better understanding of the nature of the relationship between working memory and language in children with impairments in one or both of these domains. The findings presented here will inform the development and selection of appropriate assessments and interventions for children with these deficits.

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Chapter 2

Linguistic and Cognitive Processes Contributing to Narrative Retell

Introduction

Analysis of spontaneous language samples has long been heralded as an important element of the language assessment protocol for school-age children because of its ecological validity (Crais & Lorch, 1994) and usefulness when working with children from diverse linguistic backgrounds (e.g., Boerma, Leseman, Timmermeister, Wijnen, & Blom, 2016; Kit-Sum To, Stokes, Cheung, & T'sou, 2010; Mäkinen, Loukusa, Laukkanen, Leinonen, & Kunnari, 2014). Moreover, there are many ways to analyze language samples, making them a valuable tool for assessing different aspects of linguistic development, such as syntax (Nippold et al., 2014), lexical diversity (Scott & Windsor, 2000), or pragmatics (Botting, 2002). Performance on language sampling tasks has been shown to differentiate age groups (Leadholm & Miller, 1992) as well as children with and without language impairment (Vandewalle, Boets, Boons, Ghesquière, & Zink, 2012). The majority of literature on language sampling focuses on its utility as a measure of linguistic development or impairment; however, it has also been suggested that other cognitive processes, working memory in particular, contribute to successful formulation of fluent speech with age-appropriate syntax (see Dodwell & Bavin, 2008; Duinmeijer, de Jong, & Scheper, 2012; Marini, Gentili, Molteni, & Fabbro, 2014). If this is the case, the role of working memory in language samples should be examined to determine which performance indicators are more closely related to linguistic ability and which are attributable to working memory capacity. Doing so will help us understand more about the role of domain-general processes in language production and will inform assessment procedures for linguistic or working memory deficits.

Language Impairment and Narrative Assessment

Specific language impairment (SLI) is an impairment in language ability despite otherwise typical neurological development, normal hearing ability, and adequate exposure to language (Leonard, 2014). The spoken language of children with SLI is typically characterized by morphological errors (Rice, Wexler, & Hershberger, 1998), omission of obligatory arguments (Grela & Leonard, 1997), restricted vocabulary (McGregor, Oleson, Bahnsen, & Duff, 2013; Rice & Hoffman, 2015), and less sophisticated sentence structure (Thordardottir & Ellis Weismer, 2002). Assessing the narrative ability of children with SLI is a particularly useful technique because all of these aspects of linguistic skill are involved in narratives and many measures can be compared to normative data (e.g., Leadholm & Miller 1992; Westerveld & Vidler, 2016). As well, assessing language in the context of continuous speech represents a more naturalistic use of language and taps linguistic skills not well measured in norm-referenced testing, as indicated by nonsignificant to moderate correlations between the two testing formats (Bishop & Donlan, 2005; Ebert & Scott, 2014; Norbury & Bishop, 2003).

A number of methods can be employed to elicit a narrative, of which the two most common are narrative retell, in which the child recounts an orally presented story (e.g., The Bus Story Test; Renfrew, 1997), and narrative generation, in which the child constructs a narrative based on a wordless picture book or one or more pictures (e.g., Marini et al., 2014; Pearce, James, & McCormack, 2010). When compared with story generation tasks, narrative retell has been shown to elicit longer sentences (Vandewalle et al., 2012), greater syntactic complexity (Duinmeijer et al., 2012), and longer stories (Merritt & Liles, 1989); therefore, it is more likely to present a truer representation of the child's linguistic ability.

Working Memory and Narrative Assessment

Although narrative retell is typically used to assess linguistic skill, it likely places additional demands on cognitive domains beyond language, such as working memory (Montgomery, Polunenko, & Marinellie, 2009). According to Baddeley and Hitch's (1974) model, working memory consists of two storage components for short term retention of verbal or visuospatial material (in the phonological loop and visuospatial sketchpad, respectively) and a central executive, which is responsible for allocating attention and retrieving information from long term memory. Later on, the model was updated to include the episodic buffer, which integrates information from auditory and visual sources either from long term memory or external input and forms a coherent single episode (Baddeley, 2000).

Deficits in working memory commonly occur in a number of populations, such as children with Attention-Deficit/Hyperactivity Disorder (ADHD; Alderson, Kasper, Hudec, & Patros, 2013; Barkley, 1997), traumatic brain injury (McDowell, Whyte, & D'Esposito, 1997), dyslexia (Jeffries & Everatt, 2004), and those with difficulty learning mathematics (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007). Recently, however, Archibald and Joanisse (2009) have identified working memory impairment in children in the absence of other developmental or neurological disorders. These children, described as having specific working memory impairment (SWMI), scored in the impaired range on a standardized measure of working memory but in the normal range on standardized measures language and nonverbal intelligence. Early exploration of the phenotypic profile of children with SWMI has revealed a connection between isolated working memory impairment and language-related behaviours. In an observational study, the classroom behaviours of children with specific or combined impairments in language and working memory as well as typical controls were recorded and analyzed (Archibald, Joanisse, & Edmunds, 2011). Disruptive or off-topic behaviours were recorded and later rated as language-related or memory-related. Analysis of behaviours revealed that children with working memory impairment displayed a high number of language-related behaviours, such as needing help to spell or define a word. If children with SWMI demonstrated difficulty with language-related tasks in a classroom, it is possible that narrative retell abilities may also be affected.

One way working memory may be involved in narrative retell is in encoding the narrative and integrating the story details (Botting, 2002; Montgomery et al., 2009). Before a story can be recalled, a mental representation of it must be formed in memory, which requires not only storing each piece of information but also incorporating new information with earlier story elements as they are being presented. Therefore, developing a mental representation of the narrative requires simultaneous retrieval and integration of information, processes which rely heavily on working memory (Montgomery et al., 2009). Evidence for the role of working memory in recalling narrative content comes from findings of correlations between the two in studies with children with traumatic brain injury (Chapman et al., 2006), autism spectrum disorder (Kuijper, Hartman, Bogaerds-Hazenberg, & Hendriks, 2017), attention deficit hyperactive disorder (Kuijper et al., 2017; Papaeliou, Maniadaki, & Kakouros, 2012) and SLI (Dodwell & Bavin, 2008).

A second way working memory may be implicated in narrative retell is in supporting language production. Although much research has investigated the role of working memory in comprehension (e.g., Daneman & Merikle, 1996; Kidd, 2013), less is known about its role in language production. Evidence from dual tasking studies suggests that working memory may be involved in the formulation of syntactically complex sentences (Kemper, Herman, & Lian, 2003) and possibly subject-verb agreement (Martin & Slevc, 2014). Importantly, the negative effect of cognitive load on language production is augmented for subjects with low memory span (Kemper, Schmalzried, Herman, Leedahl, & Mohankumar, 2009), or in other cases, apparent among only those subjects with low memory span (Hartsuiker & Barkhuysen, 2006). It would follow from these findings that children with working memory impairment may have difficulty with a task like narrative retell, which requires both formulation of linguistic output and maintenance and retrieval of story elements.

Performance Indicators of Narrative Retell

Most often, performance on narrative tasks is used to supplement findings from standardized tests of language competency; however, recent research has examined the potential of certain performance indicators to identify language impairment using narrative tasks alone (Eisenberg & Guo, 2016; Guo & Schneider, 2016). Rates of morphosyntactic errors, specifically verb errors, in narrative tasks have been shown to distinguish children with LI from those with typical language with accuracy rates ranging from 79% to 89% depending on the age of the children (Guo & Schneider, 2016). Although these preliminary results are encouraging, efforts to distinguish typical and atypical ability may be premature without sufficient consideration of other cognitive abilities supporting narrative ability, such as working memory. Given the involvement of working memory in narrative retell and language production in general, it is possible that some performance indicators may be more closely tied to linguistic ability and others to working memory. The following sections outline three categories of narrative performance indicators commonly used as measures of language ability that may be influenced by working memory.

Productivity. Measures of productivity aim to capture the amount of linguistic output in a language sample as measured in number of utterances, number of words, or number of correct story events recalled. To ensure consistency during transcription, narratives are segmented into utterances called communication units (C-units; Loban, 1976), which are defined as an independent clause with all its associated dependent clauses. When measured in number of C-units or words, narratives have been shown to increase in length with age (Leadholm & Miller, 1992; Loban, 1976; Tilstra & McMaster, 2007) into adulthood (Nippold, Hesketh, Duthie, & Mansfield, 2005).

Children with language impairment have been shown to produce shorter narratives than same-age peers (Colozzo, Gillam, Wood, Schnell, & Johnston, 2011; Greenhalgh & Strong, 2001; Pearce et al., 2010; Scott & Windsor, 2000) though not always (Guo, Tomblin, & Samelson, 2008; Norbury & Bishop, 2003). Short narratives have also been attributed to children with impairments beyond language. For example, Fey and colleagues found no difference in narrative length when comparing children with low nonverbal intelligence to peers with SLI (Fey, Catts, Proctor-Williams, Tomblin, & Zhang, 2004). Similarly Reilly, Losh, Bellugi, and Wulfeck (2003) found no group differences when examining number of propositions in narratives of children with SLI, focal brain damage, or Williams syndrome. Other research has shown that working memory ability may affect narrative length. Correlational studies have shown associations between working memory ability and recalled story content in children with language impairment (Dodwell & Bavin, 2008; Tsimpli, Peristeri, & Andreou, 2016) and in children with other neurological deficits (Kuijper et al., 2017; Papaeliou et al., 2012).

Based on this evidence, we could expect that children with working memory impairment, like those with language impairment, might also produce short narratives.

Grammaticality. A second set of analytical measures aims to capture grammatical competency by analyzing the level of complexity and number of errors in the narrative. When measured in mean length of utterance (MLU) or clauses per C-unit, grammatical complexity has been shown to increase with age (Leadholm & Miller, 1992; Loban, 1976). Likewise grammatical errors characteristic of young children have been shown to decrease with age in typically developing children (Loban, 1976). Analyzing grammatical complexity separate from grammatical error paints a more complete picture of linguistic ability than examining only one aspect and can be important when comparing groups. For example, Wetherell, Botting, and Conti-Ramsden (2007) found no effect of language impairment when comparing adolescents with and without SLI on sentence complexity, but did find a higher number of errors among those with SLI.

Narratives of children with language impairment tend to have lower MLUs relative to typical peers (Duinmeijer et al., 2012; Thordardottir, 2008; Vandewalle et al., 2012), but group comparisons according to subordinate clause use have shown mixed results (Bishop & Donlan, 2005; Norbury & Bishop, 2003; Reilly et al., 2003; Scott & Windsor, 2000). Considering the processing demands of formulating lengthy sentences or those with multiple clauses, it is possible that children with working memory deficits may also produce fewer complex sentence constructions particularly when task demands are high. For example, research has shown positive correlations between working memory measures and sentence complexity on narrative tasks among children with typical and impaired language (Mills, 2005; Tsimpli et al., 2016) and other neurological deficits (Kuijper et al., 2017; Youse & Coelho, 2005).

Analysis of grammatical error, whether measured in percent grammatically correct utterances or errors per utterance, consistently reveals less grammatically accurate narratives among children with language impairment relative to peers with typical language ability (Duinmeijer et al., 2012; Gillam & Johnston, 1992; Liles, Duffy, Merritt, & Purcell, 1995; Scott & Windsor, 2000). In contrast, evidence to either confirm or deny the role of working memory in grammatical accuracy of narratives is currently limited and mixed. For example, Marini et al. (2014) found that differences in phonological short term memory could account for differences between children with SLI and typical language in erroneous substitutions of bound and free morphemes. However, Thordardottir (2008) showed no correlation between verbal working memory and accuracy of verb morphology in children with SLI. Based on these findings, it is possible to speculate that both children with LI and those with working memory impairment might produce syntactically simple sentences, but that grammatical errors may be relatively more common among children with LI.

Fluency. Speech disruptions such as mazing and pausing are thought to reflect cognitive processing required for speech planning (Guo et al., 2008; MacWhinney & Osser, 1977) and indicate difficulty with utterance formulation (Leadholm & Miller, 1992). Mazing refers to verbal disruptions of fluent linguistic output, including repetitions, revisions, and hesitations such as ‘uh’ or ‘um’ (Dollaghan & Campbell, 1992; Guo et al., 2008). Mazing rates have been shown to increase with the use of more syntactically complex utterances (McDaniel, McKee, & Garrett, 2010; Ratner & Sih, 1987) and in more cognitively demanding tasks, such as in narratives as opposed to conversation (Leadholm & Miller, 1992; MacLachlan & Chapman, 1988). In contrast, silent pausing longer than 2 seconds has been interpreted as indication of difficulty with language production processes such as grammatical encoding (Rispoli, Hadley, & Holt, 2008) or word retrieval (Miller, Andriacchi, & Nockerts, 2011).

Speech disruptions are not unique to children with language impairment (MacLachlan & Chapman, 1988), although some studies have shown different rates of certain types of mazing among children with language impairment. In a narrative generation task, children with SLI produced higher rates of silent pauses relative to age-matched controls, but only for pauses that were 500 to1000ms long (Guo et al., 2008). There were no group differences found for pauses shorter than 500ms, pauses longer than 1000ms, or vocal hesitations, specifically filled pauses, interjections, whole-word or part-word repetitions, or revisions. Boscolo, Ratner, and Rescorla (2002) found that children with a history of SLI had a higher rate of disfluencies in their narratives relative to controls. That difference, however, disappeared when removing the stutter-like disfluencies and comparing groups on only normal disfluencies, which are more congruent with the mazing behaviours reported elsewhere. Similarly, Thordardottir and Ellis Weismer (2002) found that children with SLI used significantly more mazes in a 50-utterance narrative sample than MLU-matched peers but not relative to age-matched peers. Surprisingly, these children with SLI also used fewer filled pauses (hesitations such as “um,” “uh,” and “like”) than both control groups. On the other hand, Scott and Windsor (2000) found no difference between children with language learning disabilities (LLD) and controls in the proportion of utterances with mazes. Consider, however, that the narratives of children with LLD in Scott and Windsor’s study also contained fewer and shorter utterances. Perhaps the results would have been different had the groups produced samples of comparable length and complexity. On a similar note, Miranda, McCabe, and Bliss (1998) found no differences between children with SLI and age-matched peers in the frequency of reformulations (i.e., revisions) but did find a group difference when measuring revisions in proportion to the number of propositions in the narratives. Taken together, these inconsistent findings indicate first that there is a need for greater uniformity in measuring and reporting fluency in language sample analysis, and second that language impairment alone may not necessarily lead to increases in speech disruptions such as mazing and pausing behaviours.

It may be that mazing is also related to other cognitive abilities, such as working memory. According to Levelt (1989), mazing behaviours such as false starts and revisions arise in the planning stages of language production and are the result of the speaker formulating a message while retrieving information from memory. If this is the case, then it is plausible that a working memory impairment may limit a speaker's ability to manage both retrieval processes and language formulation, resulting in higher rates of mazed words. Early support for working memory influences on mazing can be seen in Marini et al.'s (2014) findings that the SLI deficit in speech rate disappeared after controlling for differences in phonological short term memory as measured by nonword repetition.

Evidence from other research suggests that pausing also may be influenced by working memory. Eichorn and colleagues found that typical adults reduced their speaking rate in a spontaneous language task while simultaneously completing a secondary working memory task (Eichorn, Marton, Schwartz, Melara, & Pirutinsky, 2016). If limiting working memory results in a slower speaking rate, it is plausible that working memory impairment might also lead to a slower speaking rate and an associated increase in pauses. Based on these findings, we could expect that children with language impairment would produce mazes and pauses at rates similar to typical peers whereas children with working memory impairment would have higher rates of mazing and pausing.

Trade-Off Effects

A final aspect of narrative measurement that warrants discussion is the limitation of single outcome measures. The majority of literature reviewed here has examined narrative outcome measures as stand-alone indicators of linguistic ability. In some respects, this approach to measuring narrative competence is ideal because it simplifies scoring for clinicians and allows for transparent comparison between groups of interest. On the other hand, each measure represents only one aspect of the narrative and may not accurately represent the child's linguistic skill. Consider, for example, the trade-off effects found for grammatical complexity and accuracy. Thordardottir (2008) found that English-speaking children with SLI spoke in longer sentences in narrative retell and expository samples relative to conversation, but also made more verb morpheme errors. This trade-off between sentence complexity and verb accuracy has been documented elsewhere with children with SLI (Grela & Leonard, 2000; Owen, 2010). These findings suggest that more advanced syntactical structures are not impossible for children with SLI, but are produced at the expense of grammatical accuracy. Other research has demonstrated a trade-off between utterance length and fluency among school-age children (MacLachlan & Chapman, 1988), preschool-age children (Wagner, Nettelbladt, Sahlén, & Nilholm, 2000), and toddlers (Rispoli & Hadley, 2001). Interestingly, Costanza-Smith (2004) found that the cost of increasing complexity may depend on age. In a sentence elicitation task, prompts for sentences with greater complexity resulted in more grammatical errors for younger children (ages 7;3–8;7) but more mazes for older children (ages 10;3–11;10). Other findings have shown that younger children (ages 3;11–6;4) do produce more mazes and stutter-like disfluencies when required to formulate more syntactically complex sentences in a sentence elicitation task (Ratner & Sih, 1987). Taken together, these findings suggest that a single outcome measure may not offer enough information to adequately portray or identify a child's linguistic or working memory ability, particularly when including children from a wide age range. Rather, the interaction between one or more measures is likely to be more informative.

Study Purpose

Narrative retell is an important skill and a useful assessment tool. Traditionally, clinicians and researchers have treated narrative retell as a language skill, but recent research suggests that other domain-general processes such as working memory may be involved as well. Findings from the research reviewed here suggests that some narrative retell outcome measures typically attributed to linguistic skill in fact may be measures of working memory ability. This question was investigated more closely in this paper by examining which narrative retell measures better predicted working memory or language ability among children with impairments in language and working memory as well as controls.

Based on previous research, a number of predictions were asserted. It was hypothesized that language impairment would be better predicted by measures of grammatical complexity and accuracy, but less so by measures of productivity or fluency. On the other hand, it was postulated that working memory impairment would be predicted by measures of productivity, grammatical complexity, and fluency, but less so by grammatical accuracy. Finally, it was thought that interactions between these variables would be important predictors of working memory or language impairment.

Considering the complexity of language production, it is possible that quantitative measures may not adequately capture linguistic features of a spoken language. Instead, it may be necessary to consider data qualitatively to examine the characteristics associated with underlying impairment on language production. In the present study, an explorative qualitative analysis was conducted by employing an iterative coding process to assign descriptive codes to narrative sample characteristics. Codes were then compared within and across impairment types for patterns and consistent profiles within impairment groups.

Methods

Participants

A total of 17 participants with impairments participated in the present study. Sixteen were recruited from an existing database of 5 to 9 year old children who had participated in a previous study (Archibald, Oram Cardy, Joanisse, & Ansari, 2013). As part of the previous study, all children completed standardized tests of language, working memory, and nonverbal intelligence at each of two time points approximately one year apart. As a measure of language skills, all children completed the four subtests of the *Clinical Evaluations of Language Fundamentals – Fourth Edition* (CELF–4; Semel, Wiig, & Secord, 2003) appropriate to the child's age to complete the *Core Language Score* (CLS). All children completed the subtests *Concepts and Following Directions, Formulating Sentences*, and *Recalling Sentences*. In Concepts and Following Directions, children were required to point to a series of objects in response to increasingly lengthy verbal instructions. In Formulating Sentences, children used a given word to produce a sentence about a corresponding picture. In Recalling Sentences, children repeated sentences spoken by the examiner. Children under 9 years of age also completed the subtest *Word Structure*, in which morphosyntactic structures were elicited using a model sentence and a sentence starter. Children 9 years of age and older completed the subtest *Word Classes 2*, in which children were required to select semantically associated words from a list and explain how they related.

As a measure of working memory, children completed three subtests from the *Automated Working Memory Assessment* (AWMA; Alloway, 2007) that were found to load on a working memory factor separate from language in a previous study (Archibald, 2013). In all subtests, children were required to recall sequences of items in order. Sequences increased in length after a child correctly recalled 4 trials at one level and the test was discontinued as soon as the child erred on 3 trials within one level. In a verbal working memory subtest, *Counting Recall*, children tallied the number of red circles in arrays of triangles and circles, and at the end of the trial recalled the tallies of each array. The number of arrays increased with each level. In *Odd One Out*, a measure of visuospatial working memory, children first identified from rows of three shapes which shape was unique. At the end of each trial, children recalled the location of the unique shapes by tapping on the screen in the order they appeared. A second measure of visuospatial working memory was *Spatial Recall*, in which children first determined whether two matching shapes were oriented in the same direction. This decision required the mental rotation of one of the shapes, which also had a red dot on one end. At the end of each trial, children recalled the positions of the red dot by tapping on the screen. Based on results of factor analysis examining working memory, language, and fluid reasoning skills in children (Archibald, 2013), a composite working memory score was created by averaging the standard scores from Counting Recall, Odd One Out, and Spatial Recall.

For nonverbal reasoning, children under 6 years of age completed the 3 subtests from the *Wechsler Preschool and Primary Scale of Intelligence – Third Edition* (WPPSI–III; Wechsler, 2002) necessary to complete the *Performance Intelligence Quotient* (PIQ), a measure of nonverbal intelligence. In *Block Design*, children were timed as they assembled red and white cubes to match models from the examiner for the initial trials or images from a book for later trials. For the *Matrix Reasoning* subtest, children selected from an array a picture to complete a given set of pictures based on a visual pattern. In *Picture Concepts*, children selected two images from separate arrays based on some semantic relation between the images. Children 6 years and older were required to complete the 2 subtests for the PIQ on the *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999): *Block Design*, and *Matrix Reasoning*. Procedures were identical for the two age groups but the trial items were more challenging for the older group. As well, parents were asked at the first time point to indicate whether they were concerned about their child's language, reading, and math abilities. Teachers were asked at both time points to indicate on a 3-point scale (1= Not at all concerned; 2=Somewhat concerned; 3=Definitely concerned) possible concern regarding the child's attention, reading, oral expression, math abilities, social interaction, and memory skills.

For the purposes of the present study, children were considered to have an impairment in either language or working memory if they earned a score of 87 or lower on the CLS or the composite working memory score at the second time point and if teacher concern was reported for any aspect of the child's development. In addition, participants were included only if their impairment was considered to be apparent already at the first time point, as evidenced by scores in the impaired range, or reported concern from the child's parents or teacher. Children were also required to score 85 or higher on the PIQ at both time points. Despite controversy regarding the use of an IQ criterion (e.g., Bishop et al., 2017; Plante, 1998), this cut-off was implemented in order to maintain some congruence with previous studies on narrative ability in children with SLI (e.g., Colozzo et al., 2011; Dodwell & Bavin, 2008; Greenhalgh & Strong, 2001; Merritt & Liles, 1989; Vandewalle et al., 2012).

A total of 42 children in the database met these criteria. From this list, 29 children could be contacted and invited to participate in the study, of which 16 agreed to participate (11 males; M_{age} = 10.28 years, SD_{age} = 1 year). An additional participant with working memory impairment was self-recruited to the study based on 1) parent report of ongoing concerns in working memory for more than 1 year, and 2) appropriate performance on standardized measures. Specifically, this participant met criteria for impaired working memory ability according to the working memory composite, typical nonverbal intelligence (PIQ), and age appropriate language abilities as assessed with 3 subtests from the CELF-4: Concepts and Following Directions, Recalling Sentences, and Formulated Sentences. Table 2.1 presents demographic information and descriptive data for language, working memory, and nonverbal intelligence according to whether participants had a language impairment without consideration of working memory status or a working memory impairment without consideration of language status. Overall, 12 of 17 participants met the criteria for language impairment (9 males, M_{age} = 10.36 yrs, SD_{age} = 1.12 yrs) and 9 of 17 participants met criteria for working memory impairment (5 males, M_{age} = 10.07 yrs, SD_{age} = 1.26 yrs). Of these, 4 participants met criteria for both impairment types and have been included in both groups (2 males, M_{age} = 10.58 yrs, SD_{age} = 1.52 yrs). The time span from the most recent assessment point in the previous study until data collection for the current study varied from 11 to 24 months depending on the participant.

An unselected control group of children in the same age range as the participants with impairments and with the same sex distribution was recruited from the Developmental Psychology Participant Pool at the University of Western Ontario (*n* = 10). One child in the control group was excluded from the study after data collection because he came from a non-English speaking home, reducing the number of children in the control group to 9.

Table 2.1

Descriptive Statistics of Participants According to Impairment

				Time 1			Time 2		
Group	N	Males	Age[a] (yrs)	CLS[b]	WMC	PIQ	CLS	WMC[c]	PIQ[c]
LI	12	9	10.36 (1.12)	84.36 (5.77)	88.09 (15.37)	97.91 (8.51)	77.42 (2.78)	92.94 (12.49)	101.92 (12.46)
WMI	9	5	10.07 (1.26)	88.57 (7.70)	83.62 (9.38)	102.00 (6.43)	88.13 (11.48)	81.99 (6.42)	102.89 (7.98)
Controls	9	6	9.9 (1.05)	--	--	--	--	--	--

Note. [a] Age at point of data collection for current study. [b] Data missing from one participant who met criteria for both LI and WMI. [c] Includes scores from the self-recruited participant.

Procedure

All children completed a narrative retell task, *Lost in Space* (Warr-Leeper, 1990), as well as other measures not reported here, in a single, individual session conducted in a quiet room at each participant's home or school by a trained research assistant or the author. In this task, the examiner read the story to the child and asked the child to retell the story without delay. The story is about a futuristic family who becomes lost while travelling in space and must find a new planet to live on. The story is comprised of 20 events. No pictures accompany the narrative, although for 2 of the events, the examiner is instructed to use gestures and exaggerated intonation to emphasize the size and appearance of the creatures described in those events.

The original source of Lost in Space is unknown; however, the task was employed in an unpublished work to establish local London, Ontario norms for children in grades 2 to 5 by Warr-Leeper in 1990. For each child, audiorecordings of the story were made for offline analysis. All audiorecordings were transcribed by a research assistant and checked by the first author. Any discrepancies between transcribers were resolved through discussion.

Quantitative scoring. Table 2.2 summarizes the productivity, fluency, grammatical complexity, and grammatical accuracy story retell measures. Transcriptions were divided into communication units (C-units; Loban, 1976) in SALT (Systematic Analysis of Language Transcripts; Miller & Iglesias, 2012) following the rules outlined in the SALT software manual (Miller et al., 2011). Specifically, each C-unit consisted of one independent clause and any associated subordinate clauses. Any independent clauses joined by a coordinating conjunction (e.g., and, but) were divided into two C-units. In the case of compound predicates where two verb phrases are associated with a single subject (e.g., The family went off again and found their way back to earth), the entire utterance was coded as one C-unit. The number of C-units served as both a measure of productivity and a reference point for calculating grammatical complexity and accuracy measures. A second productivity measure was number of unmazed words, which was the total number of words included in the narrative after removing mazes (see below for definition of mazes). The number of C-units and number of unmazed words were retrieved from the

SALT output. The third measure of productivity was the number of story events recalled from the original story; the highest possible score was 20.

Table 2.2

Narrative Retell Outcome Measures

Measure	Description
Productivity	
C-units	Number of C-units.
Number of Unmazed Words (NUW)	Number of words not included in mazes.
Events	Number of events correctly recalled.
Fluency	
Pauses	Number of pauses 2s or longer divided by NUW.
% Maze	Number of mazed words and part words divided by NUW.
Grammatical Complexity	
MLUw	NUW divided by number of C-units.
SubC-unit	Number of finite subordinate clauses divided by number of C-units.
Grammatical Accuracy	
Percent Grammatical C-units (%GCU)	Number of C-units without any morphosyntactic errors divided by total number of C-units.
Errors/C-unit	Number of morphosyntactic errors divided by number of C-units.

Next, coding for fluency was comprised of marking mazes and silent pauses. Mazes included filled pauses, fillers, repetitions, or revisions (Dollaghan & Campbell, 1992; Fiestas, Bedore, Peña, & Nagy, 2005; Finneran, Leonard, & Miller, 2009). Filled pauses were nonwords such as *uh, um,* or *er*, whereas fillers were defined as full words that added no meaning to the story (e.g., *like, you know*). Repetitions and revisions were acknowledged at the level of phrases, words, or part-words. Repetitive uses of conjunctions at the beginning of C-units were also coded as mazes (e.g., *and then you get your racket and then you hit the ball*; Fiestas et al., 2005). As a second measure of fluency, silent pauses in the audiorecording were measured using an acoustical analysis software program, Praat (Boersma & Weenink, 2013). Any silent pause 2 seconds or longer was noted in the SALT transcript (Dollaghan & Campbell, 1992). Rates of mazing and pausing were retrieved from SALT.

Grammatical complexity was measured by the mean length of C-unit in words (MLUw, retrieved from SALT), and the number of subordinate clauses per C-unit (SubC-unit). All finite subordinate clauses were coded in each sample, and included adverbial, relative, and nominal clauses (Nippold et al., 2005). SubC-unit was calculated by dividing the total number of subordinate clauses by the number of C-units in the sample.

Coding of grammatical error followed Guo and Schneider's (2016) procedure, which included tense marking errors, incorrect pronoun use, grammatical morpheme errors, omission of required argument elements, and any other syntactic errors or semantic irregularities. In the present study, common errors that were categorized as other syntactic errors included omission of obligatory free morphemes (e.g., prepositions or conjunctions) and subordination errors, which were marked by either omission or improper use of subordinate conjunctions. Any C-unit containing one or more errors was considered grammatically incorrect. Percent Grammatical C-units (%GCU) was obtained by calculating the ratio of the grammatically correct C-units to the total number of C-units. Errors/C-unit was calculated by tallying the number of coded errors and dividing the total by the number of C-units.

Quantitative analysis. The quantitative analysis, which was completed using R (R Core Team, 2016), explored the extent to which combinations of narrative task scores could predict language or working memory impairment. A planned preliminary correlational analysis examined patterns across all narrative task measures to inform variable selection both within and across the measure groupings of productivity, fluency, grammatical complexity, and grammatical accuracy (Hmisc package; Harrell, 2016). High correlations between several measures were taken to reflect redundancy, and a single representative measure was chosen for further analysis. The aim was to reduce the number of measures for further analyses to accommodate the small sample size. In order to predict group status, separate logistic regressions were planned to predict language or working memory impairment using a combination of variables. In the first model, all of the identified variables were included. In the event of model overfitting, we planned to test smaller combinations of the selected variables in rotation. If model overfitting was still present after reducing the number of variables, we planned to fit the models using Firth's bias reduction method (using the logistf package; Heinze & Ploner, 2016), a penalized likelihood estimation method designed as a solution for overfitting in logistic regression (Firth, 1993; Heinze & Schemper, 2002).

Model fit was evaluated according to a number of parameters. First, the performance of each model was examined by testing for a significant reduction in deviance from the null model using a chi-square test. The second indicator was the Akaike Information Criterion (AIC), where smaller values indicated a better fit relative to other models (Burnham & Anderson, 2002). The third parameter was McFadden's pseudo R-squared (pscl package; Jackman, 2015), a statistic designed for logistic regression models, with measures ranging from 0 to 1, where larger values were indicative of models with greater predictive ability (McFadden, 1974). After testing models with all of the variables, backward elimination was planned to carry forward only those variables that contributed significantly to the model. Initially, variables were retained if they reached a *p* value < .2, a deliberately generous criterion to avoid discarding potentially important variables (Tsimpli et al., 2016). If models were restricted to two variables, a criterion of $p < .05$ was used (Wren, Miller, Peters, Emond, & Roulstone, 2016). Nested models were compared using ANOVA to ensure that removing the identified variables did not reduce the explanatory power of the model. In a final step, age was added as a variable to the best fitting model and examined using the chi-square test in ANOVA.

Qualitative analysis. The initial coding process for the qualitative analysis was guided by coding procedures employed in Grounded Theory, a qualitative research methodology (Glaser & Strauss, 1967). Specifically, codes were created through an inductive and iterative process to reflect the data and refined by comparing across participants. Codes were adapted until it was felt that all the data were well-represented by the codes and all codes were necessary to describe the data. A more detailed description of the process follows here.

Before conducting analysis, all identifying information was removed from the transcripts so the coder was blind to the speaker's impairment group. Narrative transcripts of narrative samples used for this coding process were divided into utterances based on the speakers' intonation and marked with pauses longer than 2 seconds. In the first round of coding, narratives were read through multiple times and assigned descriptors based on common features within the samples. For example, the descriptor 'Odd Phrases' was used in the first round to describe wording such as "they lose their place to earth." When descriptors were reused from previous narratives, the samples in question were briefly compared to determine whether the descriptor was being used to depict approximately similar features. Following this, all descriptors were compiled, and comparable descriptors were collapsed under one name. For example, the descriptors ‘Simple Sentences,’ ‘Short Sentences,’ and ‘Small Sentences’ were collapsed under the code ‘Short Sentences.’ In the second phase of coding, narratives were read through again and assigned descriptors from the compiled list, creating new descriptors where necessary and combining similar ones where possible until there were no further changes to the list of descriptors. For example, ‘Abbreviated,’ ‘Short,’ ‘Missing Content,’ and ‘Sparse,’ were initially collapsed into one code, but upon further reading, it was deemed that two codes were necessary to distinguish gradations of story length; therefore ‘Short’ and ‘Missing Content’ were retained.

The third phase of coding was designed to ensure consistency of labeling by comparing all narratives with a certain descriptor against all other narratives, and reassigning descriptors where appropriate. During this process, definitions were drafted for each descriptor along with criteria for assigning it. This final phase was continued until it was deemed that each descriptor was assigned consistently and each narrative was adequately represented by its list of descriptors.

After coding was complete, qualitative data were assessed by comparing descriptors of each narrative sample across subjects while considering the ages and impairment type of each subject. Through visual inspection, the compiled data were examined for patterns in the descriptors and within impairment type, specifically, which descriptors were assigned concurrently, and which were assigned to a particular impairment type or age grouping. Finally, the predictive power of the qualitative descriptors was tested by constructing a decision tree that differentiated children with impairment from those with typical language and working memory based on the descriptors assigned to the narratives. When used for classification, a decision tree is built in a multi-stage approach by examining which variables best discriminate the data into the prescribed groups (e.g., Safavian & Landgrebe, 1991; Salmon et al., 2002; Weakley, Williams, Schmitter-Edgecombe, & Cook, 2015). In the current study, this was performed by manually splitting the data into impaired and typical groups, and identifying which descriptor or combination of descriptors was associated with only one group (either children with impairments or those without impairments). The classified participants were removed from the sample and the process was repeated with the remainder of participants until all participants were classified. Although decision trees are commonly built using computer software (e.g., Salmon et al., 2002; Weakley et al., 2015), a manual approach was taken in the present study because the sample size was small and the variables were binary.

Results

Predicting Impairment Status

Preliminary analysis. Table 2.3 presents descriptive statistics for performance on all narrative task outcome measures based on the presence or absence of either language or working memory impairment. Results of the correlational analysis completed to inform variable selection for the logistic regression are shown in Table 2.4. Consider first the productivity measures: C-units, NUW, and Events. All of the productivity measures were highly and significantly correlated with each other, but showed no consistent pattern of relationship to the remaining measures. There was a significant correlation between number of unmazed words and mean length of utterance in words suggesting that MLUw also reflected productivity. Next, the grammatical complexity measures (MLUw, SubC-unit) were moderately but significantly correlated with each other ($r = 0.66$, $p < .01$), as were the grammatical accuracy measures (%GCU, Errors/C-unit; $r = -0.78$, $p < .01$). Interestingly, the complexity and accuracy measures were not consistently related with each other, with the exception of a moderate correlation between SubC-units and Errors/C-unit, suggesting that measures of grammatical complexity and accuracy might reflect different aspects of grammatical competency. Unlike MLUw, subordinate clauses per C-unit and the error measures were not significantly correlated with any of the productivity measures. As well, the grammatical complexity and accuracy measures were not consistently related to the fluency measures, with the exception of a moderate correlation between Pauses and Errors/C-unit. Finally, the measures of fluency did not correlate with each other ($r = 0.01$, $p > .05$) indicating that mazing and pausing might reflect different aspects of fluency. Taken together, these results suggest that measures of productivity, grammatical complexity, grammatical accuracy (%GCU, specifically), pausing, and mazing would best represent the data. Given the need to limit the number of variables for further analyses, MLUw was selected to capture both productivity and grammatical complexity.

Table 2.3

Performance on Narrative Language Measures According to Impairment Status

Group	C-units	NUW	Events	Pauses	%Maze	MLUw	SubC-unit	%GCU	Errors/ C-unit
Controls	12.11 (3.18)	114.11 (36.98)	11.89 (2.57)	0.43 (0.66)	13.89 (6.92)	9.32 (1.39)	0.30 (0.25)	67.41 (13.16)	0.45 (0.26)
LI	15.00 (5.17)	126.83 (50.83)	11.42 (3.03)	3.34 (4.03)	13.00 (8.85)	8.49 (2.06)	0.20 (0.16)	72.58 (11.47)	0.37 (0.21)
WMI	14.22 (6.82)	133.89 (75.91)	11.22 (3.83)	2.98 (2.14)	10.78 (5.33)	9.29 (2.19)	0.20 (0.16)	74.52 (8.22)	0.34 (0.16)

Note. C-units = Number of C-units, NUW = Number of unmazed words, Events = Number of events correctly recalled, Pauses = Ratio of pauses (≥ 2s) to NUW, %Maze = Ratio of mazed words and part words to NUW, MLUw = Average NUW per C-unit, SubC-unit = Finite subordinate clauses per C-unit, %GCU = Percent of C-units without morphosyntactic errors, Errors/C-unit = Morphosyntactic errors per C-unit.

Table 2.4

Correlational Analysis of Narrative Language Outcome Measures for all Participants

	Productivity		Fluency		Grammaticality			
	NUW	Events	Pauses	%Maze	MLUw	SubC-unit	%GCU	Errors/ C-unit
C-units	**0.90***	**0.74***	0.00	0.14	0.05	0.02	0.15	-0.15
NUW		**0.80***	-0.10	0.13	**0.47***	0.30	0.11	-0.01
Events			-0.08	0.15	0.37	0.11	0.07	-0.14
Pauses				0.01	-0.23	-0.34	0.38	**-0.43***
%Maze					-0.05	0.05	-0.01	-0.09
MLUw						**0.66***	-0.08	0.33
SubC-unit							-0.16	**0.39***
%GCU								**-0.78***

Note. Asterisks indicate significant *r* values at the $p < .05$ level.

Predicting language impairment. A logistic regression was completed to predict language impairment status with the four selected measures included as predictors (MLUw, %GCU, %Maze, and Pauses). The model with all four variables was unsuccessful due to overfitting; therefore, a series of models with each combination of three variables and their interactions were tested one at a time (see Table 2.5). Of the 3-variable models, the model with MLUw, %GCU, and Pauses (LI-Model 3.2) demonstrated the best fit according to significance testing and fit indices. Testing of LI-Model 3.2 revealed significance for both MLUw (B = -22.47, SE = 10.81, $p < .2$) and %GCU (B = -2.63, SE = 1.26, $p < .2$); therefore a 2-variable model was tested (LI-Model 2.1). The model with MLUw and %GCU (LI-Model 2.1) was statistically significant (X^2 = 10.778, $p < .05$). Statistical comparison with ANOVA revealed no significant difference between LI-Model 3.2 and LI-Model 2.1 (X^2 = 6.746, $p > .05$), indicating that the restricted model did not perform any worse than the fuller model. As well, LI-Model 2.1 showed a low AIC and a pseudo-R^2 that was higher than two of the 3-variable models. Testing of LI-Model 2.1 revealed significant contributions from each term: MLUw (B = -

13.43, *SE* = 6.49, $p < .05$), %GCU (*B* = -1.47, *SE* = 0.73, $p < .05$), and MLUw x %GCU (*B* = 0.17, *SE* = 0.08, $p < .05$); therefore, no other terms were dropped from the model. Lastly, age was added to LI-Model 2.1 to account for the range of ages included in the sample. This model (LI-Model 2.1a) was statistically significant ($X^2 = 23.347$, $p < .05$), produced the best model fit indices compared with all previous models (AIC = 28.543, pseudo-$R^2 = 0.651$), and was a significantly better fit to the data than LI-Model 2.1 ($X^2 = 12.569$, $p < .05$). Testing of the LI-Model 2.1a terms revealed some large standard error values, which may be indicative of overfitting due in part to small sample size (see Table 2.6). Therefore, LI-Model 2.1a was tested again using bias correction, which showed that the model was trending toward significance (likelihood ratio test = 11.73, $p = .11$), supporting the original results.

Table 2.5

Model Testing to Predict LI Status

Model	Variables	AIC	McFadden's pseudo-R^2	X^2	*p*	Compared to Model	Deviance Explained (*p*)
3.1	MLUw, %GCU, %Maze	39.705	0.340	12.185	.09		
3.2	MLUw, %GCU, Pauses	34.366	0.488	17.524	.01		
3.3	MLUw, Pauses, %Maze	45.814	0.169	6.076	.53		
3.4	%GCU, Pauses, %Maze	46.804	0.142	5.086	.65		
2.1	MLUw, %GCU	33.112	0.300	10.778	.01	3.2	6.746 (ns)
2.1a	MLUw, %GCU, age	28.543	0.651	23.347	.001	2.1	12.569 (.01)

Table 2.6

Model Statistics of LI-Model 2.1a for Predicting Language Impairment

	Coefficient	Std. Error	z	*p*
(Intercept)	-3.343e+03	2.330e+03	-1.435	.15
MLUw	3.879e+02	2.657e+02	1.460	.14
%GCU	4.337e+01	3.014e+01	1.439	.15
Age	3.131e+01	2.144e+01	1.460	.14
MLUw x %GCU	-5.075e+00	3.455e+00	-1.469	.14
MLUw x Age	-3.623e+00	2.442e+00	-1.484	.14
%GCU x Age	-4.025e-01	2.752e-01	-1.463	.14
MLUw x %GCU x Age	4.694e-02	3.150e-02	1.490	.13

In order to best illustrate LI-Model 2.1a, age groups were created by dividing the sample based on school grade at the time of testing. Participants in grades 3 and 4 were assigned to the young group, while those in grades 5 and 6 were assigned to the old group. This resulted in 16 children in the young group (6 LI, 10 normal language, ages 9;7 to 10;3) and 10 children in the old group (6 LI, 4 normal language, ages 10;6 to 12;6). Figure 2.1 shows the interaction between %GCU and MLUw when participants are grouped according to LI status and age group. In both young groups, percent of grammatically correct C-units decreases as the length of the C-unit increases, indicating a trade-off between grammatical accuracy and complexity. In contrast this accuracy-complexity trade-off was not present in either of the old groups. Instead, grammatical accuracy improved with increases in C-unit length. A positive association between MLUw and %GCU was unexpected, prompting further examination of error patterns.

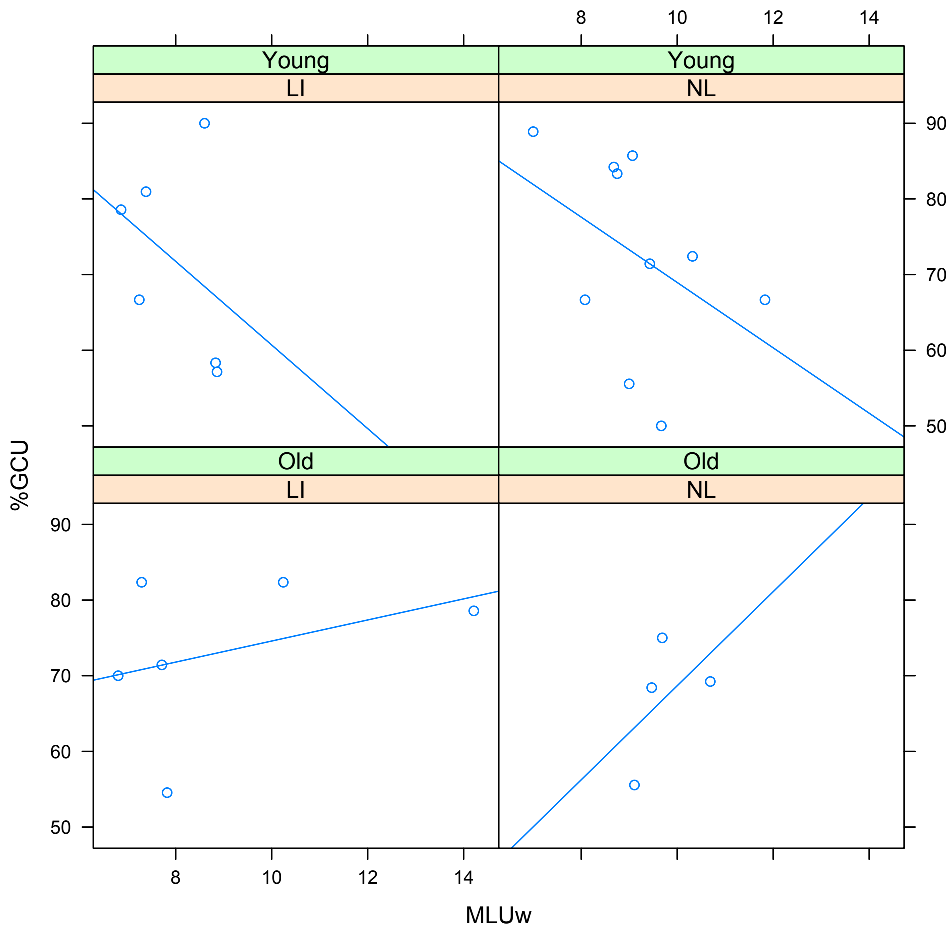

Figure 2.1. Interaction between percent grammatical C-units (%GCU) and MLUw. Participants are grouped according to age (Young = grades 3 and 4, Old = grades 5 and 6) and language impairment (LI = language impairment, NL = normal language).

Figure 2.2 shows the interaction between errors per C-unit and MLUw again grouped according to age and LI status. Both young groups showed increases in errors with increases in MLUw, which is congruent with the %GCU findings. The old NL group showed a negative association between errors per C-unit and MLUw, again confirming the findings from the %GCU analysis that children who speak with longer C-units are more likely to use correct grammar. The old LI group, however, appeared to mimic the pattern seen in the young groups by increasing errors with longer C-units. At first, the two results for the old LI group appear incongruent (i.e., increases in both percent grammatical C-units and errors per C-unit as the average C-unit length increases). However, taken together, these results suggest that the grammatical errors were dispersed among only a few C-units, presumably those C-units that were longer and more syntactically demanding to produce (e.g., “When the first planet they saw, they when they landed on was a nice planet, but was covered with hairy, ginormous, big-fanged gorillas.”).

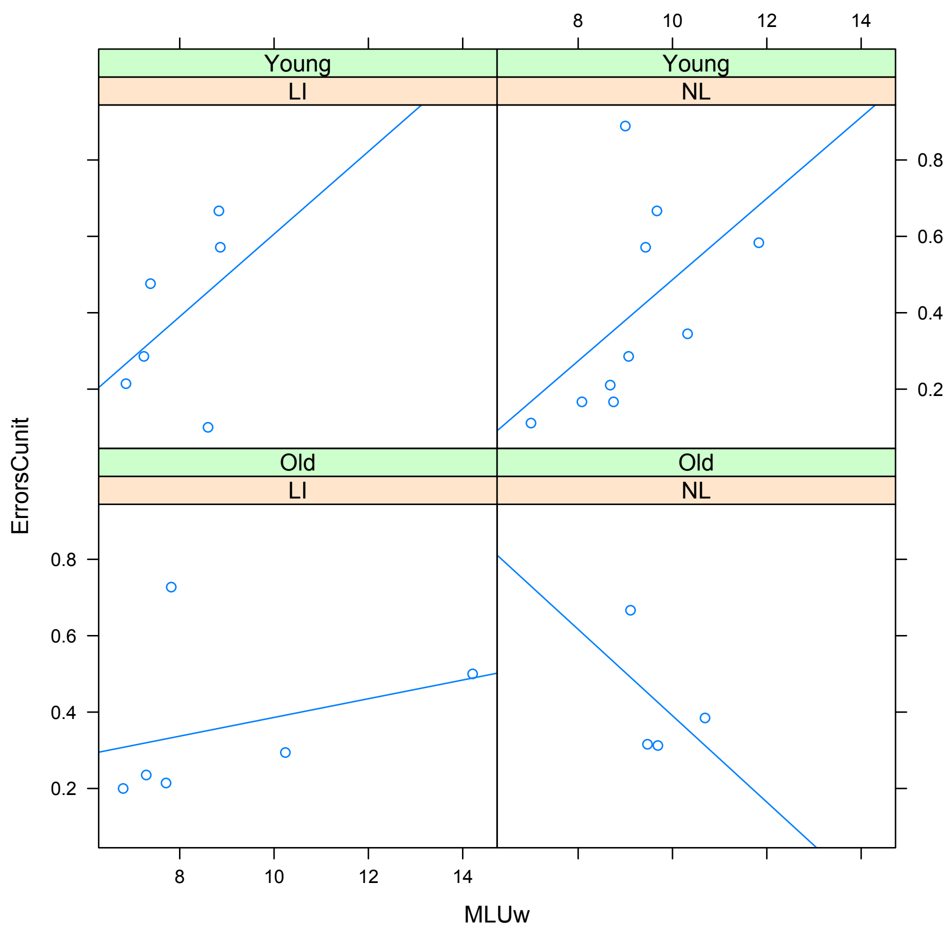

Figure 2.2. Interaction between Errors per C-unit and MLUw. Participants are grouped according to age (Young = grades 3 and 4, Old = grades 5 and 6) and language status (LI = language impairment, NL = normal language).

Predicting working memory impairment. A logistic regression was completed to predict working memory impairment status using the variables MLUw, %GCU, %Maze, and Pauses. Again, the four-variable model was unsuccessful due to overfitting; therefore models were tested with three variables at a time (see Table 2.7). Of the three-variable models, two were not significant (WM-Models 3.1 and 3.4) and two were unsuccessful due to overfitting (WM-Models 3.2 and 3.3). When tested again with Firth's bias reduction, neither of the two WM-Models 3.2 and 3.3 were significant. Taken together, the results of these models suggest that this combination of variables may not be important in predicting working memory impairment.

Table 2.7

Model Testing to Predict WMI Status

Model	Variables	AIC	McFadden's pseudo-R^2	X^2	*p*
3.1	MLUw, %GCU, %Maze	40.472	0.270	9.07	.25
3.2	MLUw, %GCU, Pauses			9.87[a]	.20
3.3	MLUw, Pauses, %Maze	33.977	0.464	15.565	.03
3.3a	MLUw, Pauses, %Maze			5.51[a]	.60
3.4	%GCU, Pauses, %Maze	38.283	0.336	11.259	.13
2.1	MLUw, %GCU	38.571	0.089	2.971	.40
2.2	%GCU, Pauses	37.597	0.118	3.945	.27
2.3	Pauses, MLUw	37.528	0.120	4.014	.26
2.4	MLUw, %Maze	38.979	0.076	2.563	.46
2.5	Pauses, %Maze	39.082	0.073	2.46	.48

Note. [a]Due to initial overfitting, WM-Models 3.2 and 3.3a were fit with Firth's bias reduction method; therefore the likelihood ratio test statistic is reported in place of the chi-square. AIC and McFadden's R^2 are not reported for Firth's method.

A second combination of variables was selected based on theoretical considerations and research findings to date. Events (number of recalled story events) was selected based on correlations found between working memory ability and recalled story content (Dodwell & Bavin, 2008; Tsimpli et al., 2016). As well, SubC-unit (number of subordinate clauses per C-unit) was selected based on the suggestion of working memory's involvement in the production of syntactically complex utterances (Kemper et al., 2003), and on findings showing a positive correlation between working memory ability and rates of subordination (Tsimpli et al., 2016). Mazing and Pausing were retained to test our prediction that they would be associated with working memory impairment. Again, the model with all four variables was unsuccessful due to overfitting, so model testing proceeded by testing each combination of three variables and their interactions (Table 2.8). Of the three-variable models, the model with Events, SubC-unit, and Pauses (WM-Model 3.6) best fit the data according to significance testing and fit indices. Testing the components of WM-Model 3.6 revealed that both Events and SubC-unit were significant at the $p < .2$ level: Events (B = -1.46, SE = 0.88, p = .10), SubC-unit (B = -70.89, SE = 47.80, p = .14); therefore, a more restricted model was tested. The model with Events, SubC-unit, and their interaction (WM-Model 2.6) was statistically significant (X^2 = 9.012, p <. 05) and had better model fit than WM-Model 3.6 as shown by a lower AIC. Statistical testing comparing WM-Model 2.6 to WM-Model 3.6 was not significant (X^2 = 6.290, p > .05), which indicated that the simpler model did not explain any less of the deviance than the fuller model. Testing the components of WM-Model 2.6 (Table 2.9) showed that all terms contributed significantly to the model: Events (B = -0.99, SE = 0.44, p < .05), SubC-unit (B = -41.20, SE = 20.29, p < .05), and Events x SubC-unit (B = 3.45, SE = 1.59, p < .05); therefore, no further variables were eliminated from the model. Finally, age was added to account for the range of ages in the sample (WM-Model 2.6a). Results showed, however, that WM-Model 2.6a was not significant (X^2 = 11.475, $p > .05$), leaving the model with Events and SubC-unit (WM-Model 2.6) as the best fitting model.

Table 2.8

Model Testing to Predict WMI Status

Model	Variables	AIC	McFadden's pseudo R2	X^2	*p*	Compared to Model	Deviance Explained (*p*)
3.5	Events, SubC-unit, %Maze	36.102	0.401	13.440	.06		
3.6	Events, SubC-unit, Pauses	34.238	0.456	15.304	.03		
3.7	Events, Pauses, %Maze	41.806	0.231	7.736	.36		
3.8	SubC-unit, Pauses, %Maze	43.733	0.173	5.809	.56		
2.6	Events, SubC-unit	32.527	0.269	9.015	.03	3.6	6.290 (ns)
2.6a	Events, SubC-unit, age	38.067	0.342	11.475	.12		

Table 2.9

Model Statistics of WM-Model 2.6 for Predicting Working Memory Impairment

	Coefficient	Std. Error	z-value	*p*
Intercept	10.66	5.00	2.131	.03
Events	-0.99	0.44	-2.254	.02
SubC-unit	-41.20	20.29	-2.03	.04
Events x SubC-unit	3.45	1.59	2.17	.03

Figure 2.3 depicts the relationship between subordinate clauses per C-unit and number of story events according to working memory impairment. Notably, children with typical working memory showed a negative association between subordinate clauses per C-unit and number of events, whereas children with WMI showed a positive association between the two measures.

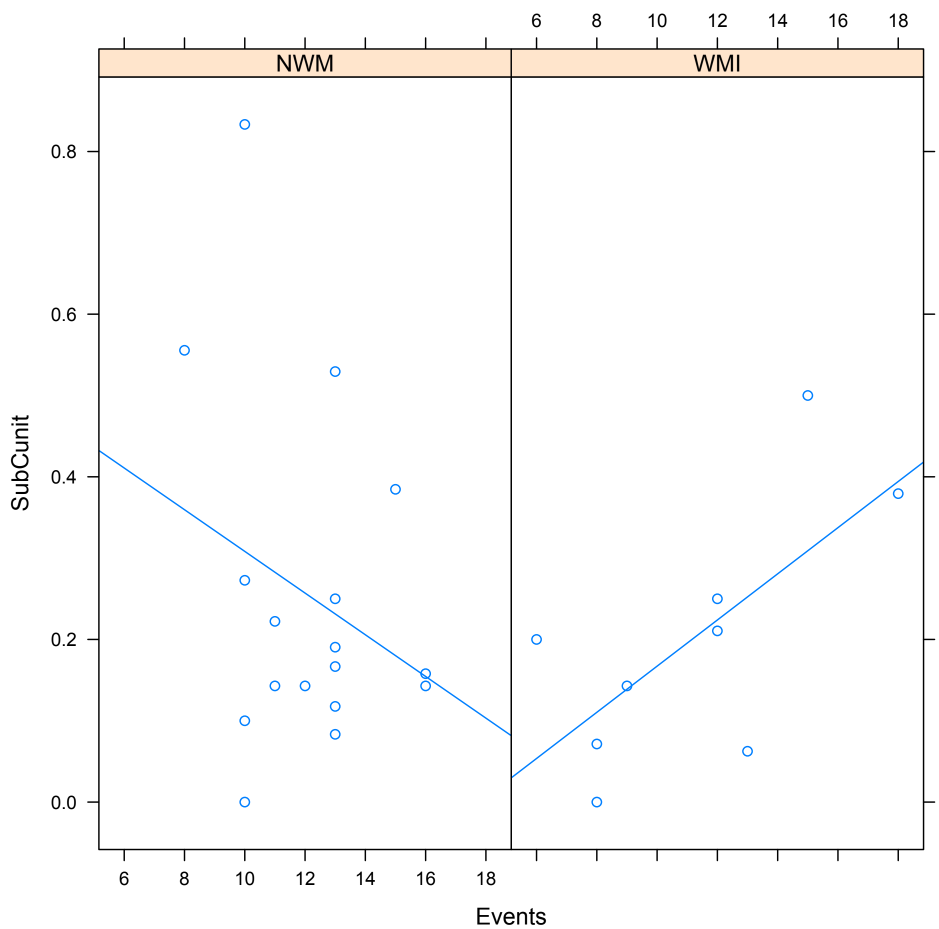

Figure 2.3. Interaction between subordinate clauses per C-unit (SubC-unit) and number of story events (Events). Participants are grouped according to WM status (NWM = normal working memory, WMI = working memory impairment).

Qualitative Descriptions of Narrative Samples

The first goal of the exploratory qualitative analysis was to identify features that characterized narratives of children with known underlying impairment. Following three rounds of coding, 22 descriptors were identified (Table 2.10). Comparing descriptors across impairment type revealed that many of the linguistic features were present in narrative samples from children in all groups. There were a few exceptions, however. First, only narratives of children with LI (with or without WMI) were assigned 'Blundering,' 'Added Content,' or 'Low Attention to Phonological Detail.' Second, 'Trailing Off,' 'Repeated Content,' and 'Pauses' were only assigned to samples of children with impairment of any type. Third, none of the narratives of children in the WMI group were assigned the codes 'Hesitations' or 'Expressive Vocabulary.' Finally, the only sample that received the descriptor, 'Filler Phrases,' was from a participant in the control group who repeatedly used "like" as a slang interjection.

Table 2.10

Descriptors for Coding Linguistic Features of Narrative Samples

Descriptor	Definition	Coding Criteria
Disfluencies	Verbal forms of disruptions, e.g., part-word and some whole word repetitions.	General characteristic of linguistic style.
Hesitations	Uhs, ums.	General characteristic of linguistic style.
Effortful recall	Some demonstration of work required to remember content, e.g., pauses interspersed by uhs or ums, or trailing off with some confession of forgetting.	Minimum one instance.
False starts	Repetitions (whole word, part word or short phrase) at the beginning of the utterance.	General characteristic of linguistic style.

Descriptor	Definition	Coding Criteria
Revisions	Going back and changing what was said. Often occurred later in an utterance. Sometimes included a repeated word or two.	General characteristic of linguistic style
Blundering	Talking with little content or without evidence of monitoring output, e.g., using lexical items with little meaning like “thing” or “stuff”, repeating content, using many generic phrases	General characteristic of linguistic style
Filler phrases	Repeated use of empty vocabulary: “like”, “and that”, “stuff”	General characteristic of linguistic style
Trailing off/Incomplete thought	Includes abandoned utterances and sentences without verbs.	Minimum one instance.
Elaborate/Detailed	Story is either nearly complete or elaborately described.	General characteristic of narrative. May not be assigned in combination with either Short or Missing Content.
Short	Concise, lacking detail.	General characteristic of narrative. Maybe not be assigned in combination with either Elaborate/ Detailed or Missing Content.
Missing content	Some significant story event is lacking (e.g., setting up characters, setting, describing either of the planets or why they left).	General characteristic of narrative. May not be assigned in combination with either Elaborate/ Detailed or Short.
Repeated content	Some part of the content is reiterated.	Minimum one instance
Mixed up content	Some aspect of original the story is misplaced within the narrative.	Minimum one instance.
Added content	Details that were not included in original story or could not be inferred from story.	Minimum one instance.

Descriptor	Definition	Coding Criteria
Expressive vocabulary	Use of vocabulary that stood out as more advanced and not from original story either because of the word itself or because of the morphemes affixed to it (e.g., big-fanged, mistakenly).	Minimum 2 instances.
Pauses	Pauses 2 seconds or longer occurring regularly throughout the sample.	General characteristic of linguistic style
Odd Wording	Lexical error, odd combination of words (e.g., "an also nice looking one," "it's not supposed to be fighting").	Minimum one instance. Does not apply to strange wording attributable to attempts at subordination.
Long sentences	Subjective appraisal of average sentence length.	General characteristic of linguistic style. May not be assigned in combination with Short Sentences.
Short sentences	Subjective appraisal of average sentence length. Perception of length includes mazed words.	Subjective appraisal of average sentence length. May not be assigned in combination with Long Sentences.
Morphological Errors	Errors or omissions of obligatory morphemes such as tense marking or agreement.	Minimum one instance.
Clumsy links	Evidence of difficulty joining ideas via subordination or other means, e.g., incorrect or omitted conjunction, word order error, revisions, or repetitions.	Minimum one instance.
Low attention to phonological detail	Omission or distortion of syllables or phonemes not attributable to articulation error, e.g., "aventure," "they 'cided," "they hadda to find."	Minimum one instance.

Although few individual descriptors could offer much insight into speech patterns of the groups, some combinations of descriptors were more telling. For example, verbal mazing behaviours, specifically 'Hesitations,' 'False Starts,' and 'Revisions,' were present in a total of 9 samples, including 6 of 17 (35%) children with impairment, and 3 of 9 (33%) controls. However, closer examination revealed that verbal mazes were found in narratives of two groups of children: most of the younger controls (3 of 4 TD who were ≤ 115 mos), and about half of the older children with LI (6 of 11 LI who were ≥ 118 mos).

A second pattern in the results emerged from a near dichotomy between the descriptors 'Short Sentences' and 'Clumsy Links.' Of the 22 samples with these descriptors, only one was characterized by both. Although this pattern depicts a simple truth—that attempting to join multiple ideas requires stringing together more words—it also points to two broad linguistic styles, namely, those participants who prefer to use simpler grammar and those who are willing to make errors in order to attempt more complex grammar. The narratives with 'Short Sentences' seemed more likely to be labeled as 'Short' (22%) or 'Missing Content' (66%) than were those with 'Clumsy Links' (8% 'Short,' 29% 'Missing Content'). Similarly, none of the narratives with 'Short Sentences' were characterized by any type of mazing behaviour (i.e., 'Hesitations,' 'False Starts,' or 'Revisions'), but 6 (43%) of those with 'Clumsy Links' were assigned at least one of these labels. The relationship of these descriptors is illustrated in Figure 2.4. Descriptors are represented by the circles, and groups of participants with like descriptors are represented by letters. For example, narratives of participants in group D were assigned 'Missing Content' and 'Clumsy Links.' Notably, this organization of these four descriptors accounts for all but one study participant. Using Figure 2.4 as a reference, participants falling into groups toward the left of the diagram (e.g., groups A and B) might represent those children who simplify their linguistic output by using short sentences, reducing the content in the narrative, or both. Conversely, participants in groups situated toward the right of the diagram might be those who are attempting formulations that are pushing the limitations of their linguistic knowledge.

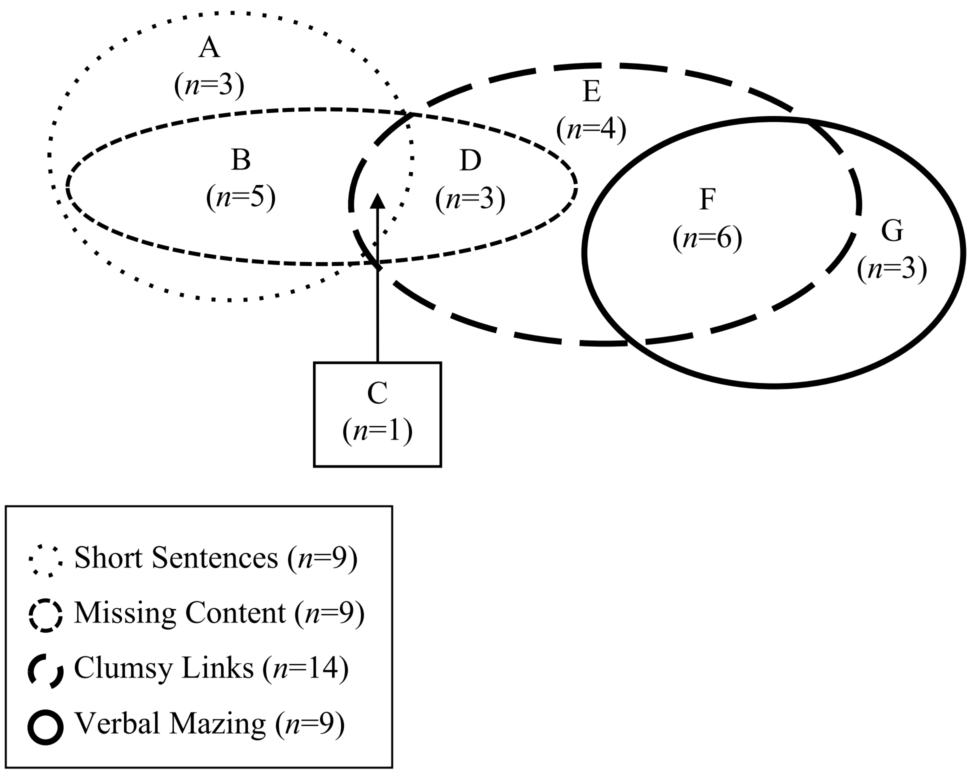

Figure 2.4. The distribution of four common descriptors across all participants. Descriptors are represented by the circles. Groups of participants with matching descriptors are represented by letters. Verbal Mazing includes Hesitations, False Starts, and Revisions.

Regarding identification of impairment, the descriptors in Figure 2.4 offer limited information. There were more children from the control group with ‘Clumsy Links’ or ‘Verbal Mazing’ (groups E, F, or G, n = 6, 66%) than with ‘Short Sentences’ (groups A or B, n = 2, 22%). Similarly, more of the children with WMI had ‘Clumsy Links’ or

‘Verbal Mazing’ (groups E, F, or G, n = 6, 66%) than ‘Short Sentences’ (groups A or B, n = 3, 33%). In contrast, the children with LI were more evenly divided, with 5 children (42%) with Short Sentences (groups A or B) and 6 (55%) with ‘Clumsy Links’ or ‘Verbal Mazing’ (groups E, F, or G).

The second goal of the descriptive analysis was to distinguish groups based on patterns of features. To that end, a decision tree was devised by identifying groups of participants in succession who were all either impaired or not and who shared common descriptors or absence thereof. Due to some overlap in features between children with and without impairment, it was impossible to group them with complete accuracy. Figure 2.5 illustrates the decision tree that correctly identifies most of the participants.

For each step in the decision tree, participants were divided according to presence or absence of any impairment. For the first step, visual inspection of the data showed that only narratives of children with impairment had multiple descriptors assigned from ‘Repeated Content,’ ‘Added Content,’ ‘Low Attention to Phonological Detail,’ ‘Trailing Off,’ ‘Pauses,’ and ‘Effortful Recall.’ This criteria identified 11 of 17 (65%) participants with impairment (42% of study sample). In the second step, it was found that the absence of the descriptors ‘Disfluent,’ ‘Hesitations,’ ‘False Starts,’ ‘Morphological Errors,’ and ‘Revisions’ usually indicated the absence of impairment. These criteria correctly classified 6 of the 9 (66%) children in the typical group (40% of remaining sample) and misclassified 2 of the 6 remaining children from the impaired group. In the third step, it was found that of the remaining children, only those with impairment were in grade 5 or higher. This criterion identified 3 of the 4 (75%) remaining children with impairment (43% of remaining sample). Lastly, the status of the remaining 4 participants could be differentiated according to the presence of mazes. Those narratives assigned ‘Disfluent,’ ‘Hesitations,’ or ‘False Starts’ were from the 3 remaining participants in the typical group, but the final participant with impairment was assigned none of those descriptors. In total, this decision tree correctly classified 24 of 26 (92%) participants. Of those with impairment, 88% were classified as such, and 100% of those with typical working memory and language were classified as typical. According to this decision tree, different

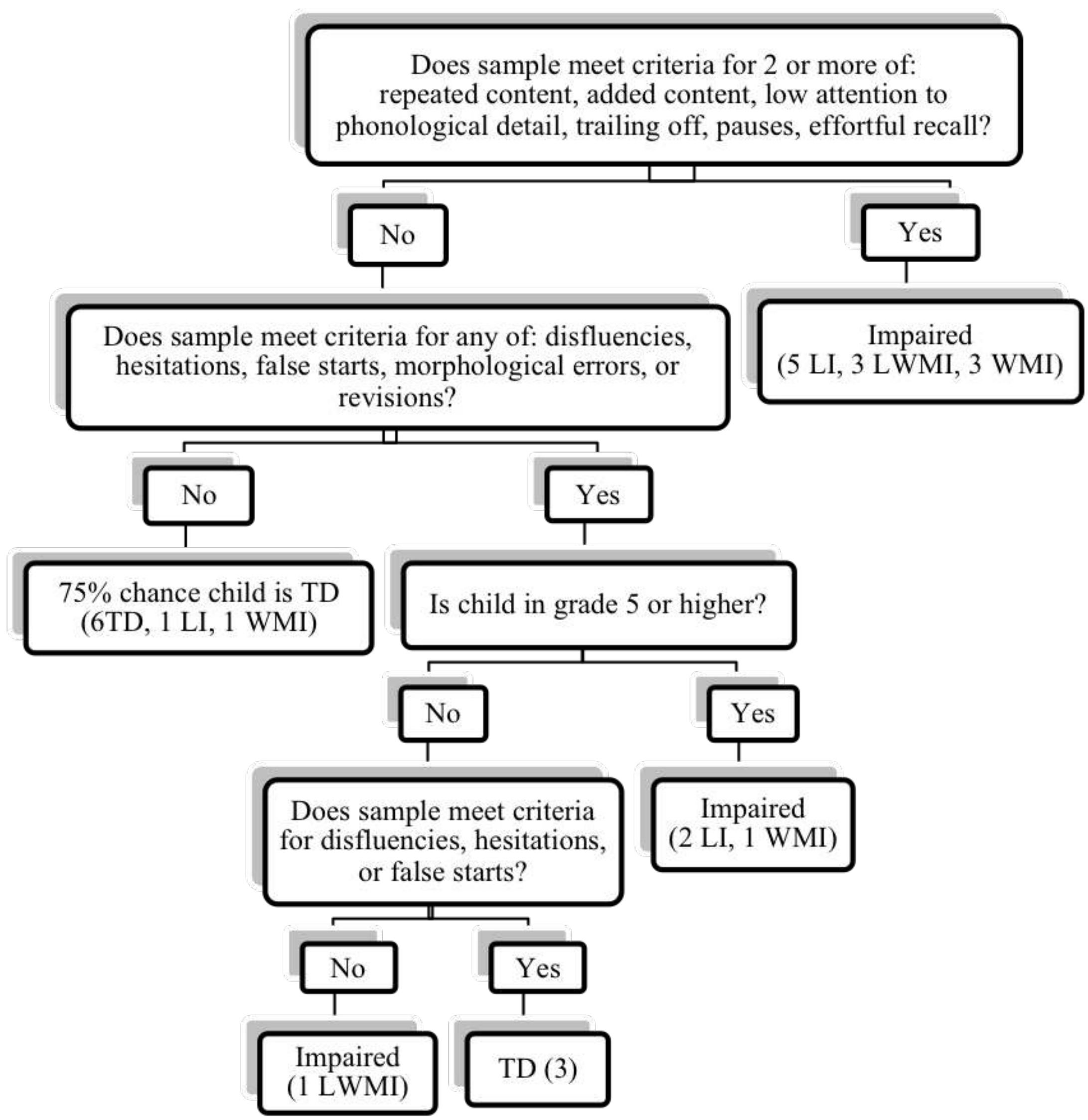

Figure 2.5. Decision tree for identifying impairment according to narrative retell performance.

combinations of qualitative descriptors can suggest the presence or absence of impairment. In this study, 13 of 16 participants with impairment could be identified either if their narrative showed two of ‘Repeated Content’ or ‘Added Content,’ ‘Low Attention to Phonological Detail,’ ‘Trailing Off,’ ‘Pauses,’ and ‘Effortful Recall,’ or by being in grade 5 or higher with a narrative with ‘Disfluencies,’ ‘Hesitations,’ ‘False Starts,’ ‘Morphological Errors,’ or ‘Revisions.’ In contrast, a narrative with none of those features was more likely to come from a child without impairment, unless the child was in grade 4 or lower, in which case the descriptors ‘Disfluencies,’ ‘Hesitations,’ or ‘False Starts’ identified children without impairment. It was not possible, however, to differentiate between language impairment and working memory impairment due to the number of similar features across impairment groups.

Discussion

This study examined whether outcome measures from narrative retell could indicate the presence of language impairment (LI) or working memory impairment (WMI). This was tested quantitatively by predicting LI and WMI using logistic regression. Qualitative analysis addressed the same general question by asking which descriptors of linguistic features were characteristic of narratives from children with impairment and controls. Across all analyses, children with impairment were consistently differentiated from controls based on their narrative samples. Nevertheless, quantitative analysis revealed that the variables that best differentiated groups differed based on whether language or working memory status was being considered. Measures of grammatical complexity, productivity, and grammatical accuracy (as well as age) differentiated those with LI from those without LI whereas measures of productivity and grammatical complexity (but not accuracy or age) differentiated those with WMI from those without WMI. Qualitative descriptors could be used to differentiate typical development from impairment in 24 of 26 children, but could not distinguish one impairment type from the other. Descriptors were able to depict a continuum of speaking style varying from abbreviated content and sentence length to verbal mazing and awkward attempts at complexity.

Perhaps the least surprising and more straight-forward finding in the present study was that children with impairment could be differentiated from controls based on their narrative samples. This was demonstrated by significant regression models for both LI and WMI and confirmed by the decision tree in the qualitative analysis. Differentiating children with LI from controls was an expected finding and is consistent with results of many other studies (e.g., Guo & Schneider, 2016; Vandewalle et al., 2012). In contrast, relatively few studies have compared children with WMI to controls on narrative retell and those who have done so tested WMI in the context of other more complex disorders such as ADHD (Kuijper et al., 2016; Papaeliou et al., 2015). Regardless, the results of previous studies have shown an effect of working memory on narrative tasks. The present study extended previous research by being the first to predict working memory impairment based on performance on a narrative retell task.

Differentiating Impairment Based on Narrative Retell Performance

With regards to language impairment status, results of the quantitative analysis revealed that presence or absence of language impairment among children in the present study was best differentiated based on a complex interaction between narrative sample measures capturing both productivity and grammatical complexity, grammatical accuracy, and age. Specifically, the model showed that the relationship between a measure of productivity and grammatical complexity (utterance length) and a measure of grammatical accuracy (percent of grammatically correct clauses) was moderated by age and language impairment status. For younger children, it appeared that longer sentences were associated with a higher rate of grammatical errors, which is suggestive of a trade-off between grammatical accuracy and complexity. In other words, those children who attempted longer utterances sacrificed grammatical correctness. This exchange has been noted in previous studies of children up to 8 years old (Constanza-Smith, 2004; Grela & Leonard, 2000; Owen, 2010). Conversely, it appeared that a different relationship was found for older children. Like the younger groups, older children with LI tended to produce more grammatical errors with increases in utterance length. Unlike those of the younger children, however, these grammatical errors were limited to only a small percentage of utterances—specifically, the longer or more syntactically complex utterances. In contrast, the older control children showed a decline in error rate with increases in sentence length. One interpretation of this behaviour among the older controls is that those who are prone to grammatical errors are more likely to simplify their output in order to avoid more errors whereas those children with greater linguistic competence are more likely to attempt longer sentences and can do so with correct grammar. Although this finding opposes previous findings of concomitant increases in error rates with utterance length among children both with and without LI, relevant research has either focused on younger participants than those in the present study (e.g., Grela & Leonard, 2000; Owen, 2010), or analyzed data at the group level rather than at the level of the individual (e.g., Scott & Windsor, 2000). The more nuanced analyses adopted in the present study points to a more complex interaction between linguistic competence and productivity.

Interestingly, the variables in the model found to best predict language impairment status did not predict working memory impairment status. Guided by previous findings and theoretical considerations, variables included in a significant model differentiating presence or absence of working memory impairment included measures of productivity (the number of correctly recalled story events) and grammatical complexity (the number of subordinate clauses per Communication Unit). Among children with typical working memory, increases in correctly recalled events were associated with decreased rates of subordination. This pattern is much like the trade-offs found for grammatical accuracy and complexity in that greater effort devoted to one aspect of the task (recalling events) results in limited resources for other aspects (in this case, subordination). This trade-off pattern did not hold for children with WMI, which is a surprising finding. Instead, children with WMI who correctly recalled a greater number of events also spoke with higher rates of subordination. Perhaps for children with WMI, subordination had a facilitative effect on event recall. Trabasso and van den Broek (1985) have suggested that the extent to which an event is causally connected to other events in the narrative has a positive influence on the likelihood of that event being recalled. This theory has been demonstrated in adults (Fletcher & Bloom, 1988), children in grade 4 (Slater, 1993), and in 4- and 6-year-olds (van den Broek, Lorch & Thurlow, 1996), all of whom remembered more story events with many rather than few causal connections. In order to encode and express causal relations between story events, it is necessary to link the events through subordination. For example, to understand and articulate the causal connection between the events "Sally is tired" and "She played outside for a long time," the participant would need to join them together with a subordinate clause, "Sally is tired because she played outside for a long time." If this is the case, then greater use of subordination would lead to better encoding of causally tied story events and better recall of the events. This idea was tested by Bishop and Donlan (2005) who asked children with and without language impairment to first tell a story based on a series of pictures and recall it after a delay. They found that the number of ideas included in the delayed recall was correlated with the number of subordinate clauses in the initial telling. Reflecting back on the present study, it is possible that a similar relationship is at play among children with WMI. Perhaps subordinate clause use in narrative retell demonstrates a better understanding of causal ties between story events, which supports recall of those events. In other words, those children who could encode the causal ties between events were better at recalling those events and expressing that link through subordination because they were encoded as a connected unit. Understandably, this use of context to support encoding and retell could be particularly effective for children with working memory impairment.

One question that arises from the proposed connection between subordination and memory for events is the role of linguistic ability. Presumably, children with LI might also struggle with narrative recall because of difficulty causally connecting events through subordination. Recall that in the present study, children with LI were included in both the normal working memory group and the working memory impairment group. It is possible that event recall of children with both impairments was doubly affected, resulting in short narratives with limited causal ties expressed via subordination. In contrast, the relatively intact working memory of children with only LI may aid in narrative encoding despite having only limited support from linguistic knowledge. Such encoding may result in longer stories with fewer instances of subordination.

Differences between the models for LI and WMI call attention to the relative contributions of linguistic and cognitive abilities to narrative retell. The LI model was driven by the interaction between grammatical measures and age, whereas the WMI model seemed to be driven by group differences in integrating and encoding verbal material for later recall. These models suggest that although linguistic ability influences the grammatical complexity and accuracy of narrative retell, performance on other measures, such as productivity, may be influenced by working memory. In this study, working memory ability appeared to play a role in the way information was divided into chunks and stored. The findings from these models support the notion that working memory and language play unique but complementary roles in narrative retell.

Lessons from Qualitative Analysis

The qualitative analyses could correctly classify 92% of participants as impaired or typical, but failed to differentiate impairment type. This failure may be due to the sensitivity of the measures; the quantitative outcome measures are likely to be more sensitive to the subtleties of linguistic constructions and errors that may go unnoticed or be misinterpreted by an observer. Initial evidence of this was seen in an observational study of children with LI, WMI, both, or neither, where observers showed difficulty distinguishing between impairment types (Archibald et al., 2011). The same result is true of the present study. The variables included in the successful regression models do not map well onto the qualitative descriptors drawn from the narratives. For example, children with LI were predicted by grammatical accuracy, length of utterances, and age. The possible corresponding qualitative descriptors ('Morphological Errors,' 'Short Sentences,' 'Long Sentences') either do not encode the linguistic features in as much depth as the quantitative measures, or have contrasting definitions. For example, judgment of sentence length in the qualitative descriptors included maze words, whereas mazes were removed for the calculation of MLUw. What appeared to be a long sentence to the listener might have actually been a short sentence bogged down with revisions and repetitions. In other words, although a listener could spot obvious characteristics of the speaker sufficient to identify some type of impairment, the level of detail needed to differentiate impairment type could only be achieved through detailed offline analysis.

The failure of the qualitative analysis to differentiate impairment type may also be due to the relative simplicity of the qualitative analysis. Recall that the regression models were driven in large part by the interactions between continuous variables. The qualitative analysis would not have been able to capture this type of complexity because the features of the narratives were coded in a binary fashion. Although the decision tree accounted for the interaction between age and mazing, it could not account for other interactions.

One similarity between the decision tree and model findings was an effect of age. According to the LI model, the interaction between grammatical complexity and grammatical accuracy differed depending on the age of the participants. Likewise, in the decision tree, the presence of verbal mazing behaviours was indicative of an impairment for older children, but not necessarily for younger children. Taken together, these results suggest that features indicating language impairment in younger children may not be as informative when assessing older children and vice versa.

Simplifiers and Risk Takers. The qualitative analysis conducted in this study offered insight into linguistic characteristics that did not clearly map onto impairment status. Consider the clustering of the four descriptors, Short Sentences, Missing Content, Clumsy Links, and Verbal Mazes (i.e., Hesitations, False Starts, and Revisions) as depicted in Figure 2.4. These four descriptors together appear to describe contrasting speaking styles. One speaking style was that of "Simplifiers," that is, children who produced short narratives, short sentences, or both. In terms of the trade-offs described above, narratives of these children would be expected to use short and simple sentences, include a minimal amount of story content, and have few instances of revisions or hesitations. They seem to prefer a fluent but pared down approach to story telling. The other speaking style could be called “Risk Takers,” referring to participants who demonstrated mazing behaviours and awkward attempts to link ideas. These children would be expected to attempt longer sentences with complex syntax, but appear to have difficulty formulating these structures. One possible interpretation of the Risk Taker speaking style is that these children were producing sentences that placed high demands on their linguistic knowledge, thereby leading to many formulation struggles. Rispoli and Hadley (2001) came to similar conclusions after finding higher rates of disruptions in sentences with more advanced grammar. However, the remarkable finding with respect to Simplifiers and Risk Takers is that they did not appear to differentiate children with impairment from those without impairment. Instead there were children with and without impairments in among both Simplifiers and Risk Takers, suggesting that cognitive and linguistic abilities are not the only factors contributing to these speaking styles.

At a very basic level, the main difference between Simplifiers and Risk Takers could be attributed to mazing behaviours. The current understanding of mazing is limited at best. Previous research has attributed mazing to language production problems (Levelt, 1989) but other research has reported no difference in speech disruptions in children with and without language impairment (e.g., Guo et al., 2008; MacLachlan & Chapman, 1988; Scott & Windsor, 2000). Findings from both the qualitative and quantitative analysis in this study suggest that the relationship between mazing and cognitive linguistic ability is complex and possibly mediated by other factors. First, quantitative measures of pausing and mazing did not predict working memory or language impairment, suggesting that mazing may not be an assumed result of impairment. Second, the cluster analysis of the qualitative descriptors showed mazing bevahiours among both impaired groups. Third, in the decision tree, the presence of mazing behaviours pointed to typical abilities for one age group, but impaired abilities for another. Finally, though it was not analyzed here, narrative or utterance length may have affected mazing; it is possible that children who produced more mazes were attempting longer utterances or longer narratives. The results of the present study would suggest that mazing may be the result of a complex interaction between linguistic and cognitive ability, age, and speaking style (i.e., Risk Taker or Simplifier). Results of other research would suggest that task demands would also be a factor in this interaction (e.g., MacLachlan & Chapman, 1988; Ratner & Sih, 1987; Wagner et al., 2000). Future research systematically examining the effect of these variables at the level of the individual is needed in order to test the strength of this hypothesis.

Study Limitations

One limitation of the present study is the small sample size. Because of the small number of participants, regression modeling was limited to only a few variables, potentially leaving out other informative predictors. In addition, particularly small *n*-sizes resulted from grouping participants according to age and LI status, which may have influenced the results. Small sample size also prevented the direct comparison of impairment groups, which would have offered useful insight pertinent to differential diagnosis. Second, it should be noted that a number of the language samples in this study were quite short. A study Heilmann, Nockerts, and Miller (2010) and Thordardottir (2016) demonstrated that sample length had a limited effect on outcome measures in general in narrative and conversational samples in children aged 2 to 13 years. However, low reliability was found for percent maze words, leading the authors to suggest that longer samples would be more appropriate for in-depth analysis of mazes. Therefore, it is possible that sample length may have influenced the results of the present study.

Finally, this study only focused on three major areas of language sample analysis: productivity, fluency, and grammaticality. Given the interconnectedness of performance on these three aspects, they likely do not represent the whole picture. Working memory has been shown to influence other aspects of narrative ability such as referencing (e.g., Whitely & Colozzo, 2013). Future research analyzing referencing alongside the measures tested here would offer further insight into the influence of working memory ability on narrative retell.

Clinical Implications

Three main clinical implications arise from this study. First, results have shown that poor performance on narrative retell is not specific to children with language impairment; deficits were also found for children with working memory impairment both with and without language impairment. Because of this, attempts to identify LI from language sampling alone would do well to compare children with LI to children with other developmental deficits affecting language production. Second, impairment groups were best predicted by combinations of measures. Although other research has suggested that percent grammatical utterances can identify children with language impairment (Guo & Schneider, 2016), the present findings suggest that one measure may not be sufficient, particularly when attempting to distinguish different types of impairment across a wide span of ages.

Third, results from both the qualitative and quantitative analyses revealed that mazing behaviours did not aid in identifying children with either LI or WMI. Rather, behaviours such as hesitations or filled pauses, false starts, repetitions, and revisions were associated with all linguistic and working memory abilities, and seemed to divide the participants along an alternate dimension. These findings suggest that mazing should not be implemented as an indicator of linguistic or working memory ability, and highlight again the necessity of considering outcome measures in the context of other measures and assessment tools.

Conclusion

Findings from present study confirm deficits in narrative retell among children with language impairment and working memory impairment. Results of logistic regression indicated that impairments were predicted by different outcome measures from the narratives, suggesting that the two domains contribute uniquely to narrative retell. Findings from qualitative analysis revealed that differences between narratives from children with language impairment may not be easily distinguished from those of children with working memory impairment without careful offline analysis. In addition, the qualitative analysis did reveal two speaking styles (i.e., Simplifiers and Risk Takers) that are present in both controls and impairment groups. Taken together, results of this study highlight the complexity of narrative language and the wealth of information it can provide in assessment.

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Chapter 3

Narrative-Based Language Intervention for Children with Specific Language Impairment with or without Working Memory Impairment

Introduction

Of all the discourse genres, the ability to tell a story is particularly important for school age children; narrative ability has been linked to better outcomes both socially (Davidson, Walton, & Cohen, 2013; Davidson, Walton, Kansal, & Cohen, 2017; Dray, Selman, & Schultz, 2009) and academically (Fazio, Naremore, & Connell, 1996; Griffin, Hemphill, Camp, & Wolf, 2004). The cognitive demands of generating or retelling a narrative are quite high, requiring support from a range of cognitive-linguistic resources (Duinmeijer, de Jong, & Scheper, 2012; Montgomery, Polunenko, & Marinellie, 2009). One population that has particular difficulty with narratives is children with specific language impairment (SLI), who demonstrate linguistic deficits despite otherwise typical neurological development, normal hearing, and adequate exposure to language models (Leonard, 2014). Children with SLI have demonstrated difficulty with many aspects of narration, such as making logical connections between story events (e.g., Reilly, Losh, Bellugi, & Wulfeck, 2003), establishing a sense of continuity (e.g., Liles, 1985), or describing characters' feelings or intentions (e.g., Klecan-Aker & Kelty, 1990). Because of the importance of narratives in both social and academic realms, recent research has explored various narrative interventions for children with SLI. Results, however, have not always been favourable (e.g., Green & Klecan-Aker, 2012), possibly due in part to heterogeneity among children with SLI. The present study addressed this problem by testing the effectiveness of a narrative-based language intervention for school age children with SLI with a single-subject design and examining factors influencing response to the intervention. Also examined were effects on related domains, including working memory, reading, and math. It should be noted that the study reported here was conducted in conjunction with the working memory training program reported in Chapter 4.

Childhood Discourse Genres

As children progress through elementary school, they are under increasing demand to tailor their language usage to particular discourse genres. Two genres that are common in classroom discourse are narration, which includes both personal and fictional narratives, and expository language, which includes explanations and descriptions to share information (e.g., McFadden, 1991; Scott & Windsor, 2000; Westby, 2005). Although there are striking differences between narrative and expository texts in structure and content, both of these genres are important for literacy development and both elicit more complex syntax than conversation does (e.g., Nippold, Hesketh, Duthie, & Mansfield, 2005; Nippold, Mansfield, Billow, & Tomblin, 2008; Nippold et al., 2014). The role of narratives in particular has been well documented in both social and academic realms of childhood. One study found that anecdotal narratives made up the majority of conversations among young children (Preece, 1987), while another found that elements of narrative ability in grades 3 and 4 predicted peer adjustment the following year, specifically victimization and loneliness (Davidson, Walton, Kansal, & Cohen, 2017). Both of these studies highlight that narrative ability is a critical skill for maintaining friendships and fitting in with peers. In particular, the type of complex syntax required in narratives has been positively associated with peer acceptance and social communication abilities among children with language impairment (Laws, Bates, Feuerstein, Mason-Apps, & White, 2012).

Academically speaking, narrative and receptive syntactic ability have been shown to predict later reading comprehension even after controlling for nonverbal IQ and initial reading ability (Botting, Simkin, & Conti-Ramsden, 2006). Other research has demonstrated that narrative skill can predict a variety of academic outcomes between 1 and 7 years later. For example, narrative ability in kindergarten has been shown to correlate with reading comprehension at 8 years of age (Griffin et al., 2004), vocabulary and reading comprehension in grade 7 (Dickinson & McCabe, 2001), and whether or not a child received academic remediation in the first two years of school (Fazio et al., 1996).

Narrative Macrostructure and Microstructure

Key components of a well-crafted story can be categorized broadly as either macrostructural or microstructural elements (Liles, Duffy, Merritt, & Purcell, 1995). Macrostructure, also called story grammar, refers to the global framework of the narrative, or the way the content of the story is organized (van Dijk & Kintsch, 1983). Narrative macrostructure has been analyzed by examining a number of aspects, such as episodic structure (i.e., sequences containing an initiating event, an attempt to resolve the event, and a consequence; Merritt & Liles, 1987, 1989) or the story grammar (i.e., the elements of the story including the setting, characters, problem, the characters' plan to address the problem, the resolution of the problem, and an ending; see Stein & Glenn, 1979). Understanding the typical macrostructural framework for narratives facilitates not only generation of stories but also comprehension of oral narratives. According to Kintsch's (2013) construction-integration framework for reading comprehension, readers must formulate a mental representation of the text's macrostructure in order to fully understand the text. This requires the listener to weave together the elements of the story and properly situate each one within the larger framework. The same process is true for oral narratives; the listener must integrate incoming information with other elements of the story to form a basic gist or overall representation of the narrative. If this is the case, a basic understanding of features common to narratives would facilitate the integration of elements in novel stories.

Whereas macrostructure refers to the global organization of a narrative, microstructure refers to the word- and sentence-level components of a story, such as the variety of vocabulary, clarity of cohesion or pronominal references (e.g., Liles, 1985), or complexity of syntax (e.g., Liles et al., 1995). Like macrostructure, narrative microstructure can be examined through different lenses. For one, analysis could be conducted as it would for any other genre of spontaneous language sample: through calculations of utterance length, clausal density, lexical breadth, grammatical error, or other such measures of generic linguistic ability. In contrast, other researchers have examined microstructure by looking for features that are thought to be particularly important for narratives and genres requiring the use of decontextualized language. These linguistic features, known as literate language features, include conjunctions, elaborated noun phrases, mental and linguistic verbs, and adverbs (Westby, 2005), and are thought to add narrative detail important for listener comprehension (Segal & Duchan, 1997). Elaborated noun phrases refer to nouns that have been modified with adjectives, determiners (e.g., articles, demonstratives), and/or qualifiers such as prepositional phrases (e.g., "the tree *in the garden*"; see Curenton & Justice, 2004; Greenhalgh & Strong, 2001; Westby, 2005). Mental verbs express cognitive processes (e.g., *think, remember, know, guess, forget*), and linguistic verbs express linguistic processes (e.g., *tell, call, respond*; Greenhalgh & Strong, 2001; Westby, 2005).

Cognitive demands of narrative retell. The preceding description of narrative microstructure highlights the demands that narrative retell places on linguistic knowledge. However, it is possible that narrative ability may also rely on other cognitive resources such as working memory, which is responsible for manipulation and temporary storage of information (Baddeley & Hitch, 1974). It has been suggested that working memory may be important for encoding and incorporating components of a story into an integrated mental representation of the narrative (Botting, 2002; Montgomery et al., 2009). This hypothesis has broad support from other studies reporting correlations between working memory ability and narrative comprehension and recall (Chapman et al., 2006; Dodwell & Bavin, 2008; Duinmeijer et al., 2012).

Children with SLI

Specific language impairment (SLI) refers to a disproportionate deficit in linguistic ability in the absence of neurological deficits, hearing impairment, or impoverished language exposure (Leonard, 2014). Compared with typical peers, children with SLI typically demonstrate simpler syntax (e.g., Marinellie, 2004; Nippold, Mansfield, Billow, & Tomblin, 2009; Thordardottir & Ellis Weismer, 2002), higher rates of grammatical error (e.g., Owen & Leonard, 2006; Rice, Wexler, & Hershberger, 1998), and greater difficulty acquiring new vocabulary (e.g., Kan & Windsor, 2010). Although a number of generalizations can be asserted about SLI, it is important to note the heterogeneity among children with SLI. Efforts to delineate classification systems for children with SLI have resulted in inconsistent findings across studies, demonstrating the complex nature of the disorder (e.g., Conti-Ramsden, Crutchley, & Botting, 1997; Tambyraja, Schmitt, Farquharson, & Justice, 2015). One factor contributing to the heterogeneity among children with SLI is working memory capacity. It is well-established that children with

SLI demonstrate limited verbal short term memory (Archibald & Gathercole, 2006; Graf Estes Evans & Else-Quest, 2007; Conti-Ramsden, Botting, & Faragher, 2001); however, there is evidence that only some children with SLI show deficits in working memory capacity (Archibald & Joanisse, 2009). This variation in presentation is likely to affect performance on tasks known to correlate with working memory, such as narrative tasks (e.g., Chapman et al., 2006; Dodwell & Bavin, 2008; Duinmeijer et al., 2012).

Narrative ability. Not surprisingly, children with SLI have demonstrated many weaknesses in narrative ability. In regard to content and story structure, narratives by children with LI include fewer complete episodes (Merritt & Liles, 1987), poorer coherence, (Liles, 1985) and more off-topic comments and disordered sequences of events (Miranda, McCabe, & Bliss, 1998) relative to peers. Children with SLI tend to produce shorter narratives (Colozzo, Gillam, Wood, Schnell, & Johnston, 2011) with little elaboration (Ukrainetz & Gillam, 2009) using fewer cognitive state terms (Bishop & Donlan, 2005) and fewer elaborated noun phrases (Greenhalgh & Strong, 2001). In addition, narratives of children with SLI are often grammatically weaker than their peers' narratives, as demonstrated by shorter sentences (Fey, Catts, Proctor-Williams, Tomblin, & Zhang, 2004; Scott & Windsor, 2000), fewer dependent clauses (Bishop & Donlan, 2005), less variety of complex syntactical structure (Reilly et al., 2003) and fewer instances of combining different complex forms within one T-unit (Gillam & Johnston, 1992). Weaker grammatical ability is also seen in higher rates of grammatical error for children with SLI than typical peers (Colozzo et al., 2011; Gillam & Johnston, 1992; Marini, Gentili, Molteni, & Fabbro, 2014; Norbury & Bishop, 2003; Reilly et al., 2003). As well, narratives of children with SLI have been judged to be of poorer quality even when rated by laypersons or teachers (McFadden & Gillam, 1996; Newman &

MacGregor, 2006). Finally, poor narrative ability among children with SLI has been shown to persist into adulthood (Wetherell, Botting, & Conti-Ramsden, 2007).

Syntax. Further evidence of syntactic deficits among children with SLI has been demonstrated in contexts other than narrative retell. Of particular relevance is the ability of school age children with SLI to comprehend and express complex syntax. For the purpose of this paper, complex syntax refers to grammatical constructions that contain more than one verb other than auxiliaries (Limber, 1973). Such structures include complement clauses (i.e., clauses functioning as an argument of the verb), relative clauses (i.e., clauses modifying nouns), and other embedded or subordinate clauses. Children with SLI have been shown to make more errors, such as omitting obligatory markers of finiteness (Owen & Leonard, 2006), relative clauses (Schuele & Tolbert, 2001), or infinitive clauses (Barako Arndt & Schuele, 2012). Compared with peers, children with SLI produced more errors when repeating sentences with relative clauses, and showed a complexity effect such that they made more errors on sentences of greater complexity (Riches, Loucas, Baird, Charman & Simonoff, 2010). Additionally, children with SLI tend to use complex syntax less often than peers whether in elicited contexts (Steel, Rose, & Eadie, 2016), in conversation (Marinellie, 2004), in the retelling of a lecture (Ward-Lonergan, 2010), or when generating a narrative (Bishop & Donlan, 2005).

Narrative-Based Language Intervention (NBLI)

The combined deficits in narrative ability and complex syntax among children with SLI highlight the need for remediation in both of these areas. The majority of research on narrative intervention is aimed at children up to 8 years old; however, the narrative abilities of older children with SLI is also worthy of support. For one, linguistic competency continues to develop past the primary years: the typical developmental trajectory of narrative ability extends beyond 8 years up to 11 and even 14 years of age (see Crais & Lorch, 1994). Similarly, the linguistic deficits of SLI and their negative ramifications extend beyond the first years of schooling (e.g., Conti-Ramsden, Botting, Simkin, & Knox, 2001). Despite these long lasting deficits, it has been suggested that children with SLI are capable of making gains through adolescence (Ebbels et al., 2017). The potential for improvement among older children with SLI suggests that they may be responsive to a narrative-based language intervention targeting both story grammar and syntax. Given the association between narrative language and other abilities, such as working memory and academic performance, it is possible that improvement in linguistic ability may lead to carry over gains in related domains. Therefore, the present study aimed to test the effectiveness of a narrative-based language intervention on language and related abilities among children with SLI aged 8 to 11 years.

One main feature of narrative-based language intervention is that it can target macrostructure in conjunction with microstructure goals. Although macrostructure and microstructure elements of narration represent different skill sets (Liles et al., 1995), they complement each other well as language targets (e.g., Gillam & Ukrainetz, 2006). One advantage of pairing the two together is that discussing stories provides a naturalistic and meaningful context in which clinicians can target sentence-level goals by employing evidence-based language stimulation strategies such as focused stimulation, scaffolding, and dialogic reading. In focused stimulation, the clinician orchestrates the discourse so that the child is exposed to frequent exemplars of the targeted structure and has many opportunities to attempt them (Cleave & Fey, 1997; Ellis Weismer & Robertson, 2006; Fey, Cleave, Long, & Hughes, 1993). Scaffolding approaches are slightly different in that the clinician provides naturalistic feedback after the child's utterance to demonstrate how to use the targeted form in that context. Some scaffolding strategies include recasting and vertical structuring (e.g., Eisenberg, 2013). Recasts include expansions of the child's utterance by adding grammatical elements, or extensions of the child's utterance by adding semantic content (Camarata, Nelson, & Camarata, 1994; Cleave, Becker, Owen van Horne, & Fey, 2015; Nelson, Camarata, Welsh, Butkovsky, & Camarata, 1996). On the other hand, vertical structuring involves eliciting additional information from the child, then combining the new information with a previous utterance to form a more complex or complete utterance (e.g., Schwartz, Chapman, Terrell, Prelock, & Rowan, 1985; Skarakis-Doyle & Murphy, 1995).

For example:

Child: *She's buying a banana.*

Clinician: *Why is that?*

Child: *The monkey is hungry.*

Clinician: *Right. She's buying a banana because her monkey is hungry.*

Dialogic reading involves the use of elaborative questions to engage a child in dialogue during book reading. The adult can then offer either repetitions or expansions based on the child's responses (Crain-Thoreson & Dale, 1999; Lever & Sénéchal, 2011; Valdez-Menchaca & Whitehurst, 1992; Whitehurst et al., 1988;). In a direct comparison study of narrative-based language intervention and drill-based intervention, children receiving the narrative-based language intervention showed greater gains for more measures of sentence level and narrative ability following the intervention (Gillam, Gillam, & Reece, 2012). These findings point to the benefit of targeting sentence level language goals within a discourse genre such as narrative. It is possible that encountering complex linguistic structures in the context of familiar narratives offers the scaffolding necessary to support comprehension (Kamhi, 2014).

Second, the linguistic demands of narration present many opportunities for integrating a variety of complex syntactical structures within a single context. For example, sequencing events requires the use of temporally related or causally related subordinate clauses (e.g., "They went to the party after they finished their chores"). Describing characters' motivations or emotional responses to events provides the opportunity to use full propositional complements (e.g., "Sally was disappointed that the car broke down"). Finally, telling a story to an unfamiliar listener requires the speaker to use language that is descriptive enough to recreate scenes and events without support from common knowledge or visual images. Such descriptive language is built not only with adjectives and adverbs, but also with relative clauses (e.g., "the woman who won the election") and participle phrases (e.g., "the man wearing a hat"). In this way, the context of the narratives supports learning of syntactical structures, and development of syntax supports comprehension and generation of narratives.

Narrative-based language interventions have been examined in several contexts with various populations. Studies have shown positive results for children with cochlear implants (Justice, Swanson, & Buebler, 2008), autism spectrum disorder (Gillam, Hartzheim, Studenka, Simonsmeier, & Gillam, 2015; Petersen et al., 2014), learning disabilities (Klecan-Aker, Flahive, & Fleming, 1997), mixed reading disabilities (Westerveld & Gillon, 2008), preschool children with language impairment (see Petersen & Spencer, 2016 for review), or children with typical abilities (Short, Yeates, & Feagans, 1992). In many cases, the interventions were designed specifically for each study, suggesting that the principles of narrative-based language intervention can be broadly applied and still lead to significant gains. In other cases, intervention programs have been iteratively tested to develop a packaged curriculum, such as Story Champs for preschoolers (e.g., Spencer, Kajian, Petersen, & Bilyk, 2013; Spencer & Slocum, 2010) or SKILL for school age children (Supporting Knowledge in Language and Literacy; Gillam & Gillam, 2016).

NBLI for Children with Language Impairment

Of particular interest to the present study are those studies testing narrative-based language intervention among school age children with language impairment. In some studies, participants showed improvements on both story grammar and linguistic outcome measures even though only macrostructure goals were targeted. For example, Davies, Shanks, and Davies (2004) offered instruction on story grammar to 34 children (mean age 5;11) who had been identified by teachers for their communication difficulties. Intervention sessions focused on identifying who, where, when, what happened, and why in familiar stories and stories told by peers. Strategies included using cue cards to identify the story elements, creating unique endings to familiar stories, generating stories using puppets and role-play, and instructing peers on the strategies they had learned. Follow-up testing 3 months after completion of the intervention showed clinically significant improvement in the number and type of additive, temporal, and causal connections used in the *Renfrew Bus Story Test* (Renfrew, 1991), a narrative retell measure. Improvements were also seen on grammar and the amount of information included in picture descriptions on the *Renfrew Action Picture Test* (RAPT; Renfrew, 1988), in which prompts for picture description are designed to elicit specific morphological or syntactical constructions.

Contrasting results were found in another study, where 24 children with language learning disabilities (aged 6;3 to 9;6) participated in a 13-week intervention focusing on story grammar elements, including initiating event, action, consequence, internal responses, and setting (Green & Klecan-Aker, 2012). Children were taught to identify the story elements, generate stories given story starters, and create entire stories. Assessment with a narrative generation task showed improvements in story length and the developmental story level, an index reflecting the story's completeness. However, no increases were seen on words or clauses per utterance or on words per clause, demonstrating that grammatical complexity does not necessarily improve following instruction of story grammar elements alone.

Both of these intervention studies resulted in some improvement in story structure and preliminary evidence of carry over effects into language abilities. Both showed increases in quantity of narrative output, although only the Davies et al. (2004) study showed improvements in expressive grammatical ability. This discrepancy may have been due to differences in assessment procedure. Children may be more likely to attempt a challenging grammatical structure when it is specifically elicited, as in the Davies et al. (2004) study, than in a more free-from narrative generation task, as was employed in the Green and Klecan-Aker (2012) study.

Other studies examining narrative intervention have targeted both story grammar and other language goals such as syntax. In a feasibility study, Swanson, Fey, Mills, and Hood (2005) offered 18 sessions (6 weeks) of narrative based language intervention to 10 children (ages 6;11–8;9) with expressive language impairment. The intervention targeted both story grammar components and syntactical structures such as subordinating conjunctions or verb phrase elaboration. Treatment sessions consisted of story retell and story generation tasks with summarizing, scaffolding, and recasting by the clinicians to encourage more elaborate stories and complex syntax, much like the current study. Unlike the present study, children in the Swanson et al. (2005) study also completed a sentence imitation task. Post-intervention testing showed improvements on narrative generation as measured by a narrative quality rating (from Fey et al., 2004), but not number of different words, a measure of lexical diversity. As well, no improvements were seen on other measures of grammatical ability, specifically the *Recalling Sentences* subtest from the *Clinical Evaluation of Language Fundamentals – Third edition* (CELF-3; Semel, Wiig, & Secord, 1995) and the *Developmental Sentence Score* (DSS; Lee, 1974) based on a conversational language sample.

In another study (Fey, Finestack, Gajewski, Popescu, & Lewine, 2010), 23 children with LI (6–8 years) were offered twelve 60-minute sessions of narrative-based language intervention targeting both macrostructure and microstructure elements. Each child was assigned two microstructure goals, such as coordinated and subordinated clauses and conjunctions, relative clauses, appositives, verb phrases elaborated with auxiliaries, and regular past tense. As in the present study, intervention activities included free recall of stories, and component-by-component paraphrasing of stories with clinician recasting. Other activities included a sentence imitation task with sentences containing the targeted syntactical structures, and a clinician-assisted story generation task. Pre- and post-treatment testing with the *Test of Narrative Language* (TNL; Gillam & Pearson, 2004) revealed improvement on the Narrative Language Index, a standard comprehensive score from the TNL. However, no improvement was seen on the grammatical aspects of these narratives when they were scored for verb complexity (the main verb score from DSS) and the number of constructions containing conjunctions other than “and” or “then.”

Both macrostructure and microstructure goals were targeted in a study with three children (ages 6;3–8;1) with neuromuscular impairment, co-morbid moderate to severe language impairments, and average nonverbal intelligence (Petersen, Gillam, Spencer, & Gillam, 2010). Over ten 60-minute sessions, participants completed a variety of narrative generation and recall tasks with fading support from the clinician and story grammar icons. The primary microstructure goal was causality, as marked by causal terms or clauses with causal properties. Temporal subordinate clauses were targeted as a second microstructure goal for the last three sessions. Language and narrative goals were targeted using strategies such as repetition, recasting, modeling, expansion, and asking questions to promote deeper thinking about the narrative. All three participants demonstrated improvement on macrostructure and causality on a story generation probe. Additional gains were seen on adverbs and elaborated noun phrases and two of the participants improved on mental and linguistic verbs even though none of these linguistic features were targeted. No improvements were seen on temporal subordinate clauses.

Finally, in a series of studies, Gillam, Gillam and colleagues developed and tested a narrative-based language intervention on a number of populations, including children with language impairment, in individual, small group, and classroom settings (Gillam & Gillam, 2014; Gillam et al., 2008; Gillam et al., 2012; Gillam et al., 2014; Gillam et al., 2015). The final program, known as SKILL (Supporting Knowledge in Language and Literacy), consists of a minimum of 43 sessions that consist of explicit instruction in story grammar elements, syntax, and vocabulary (Gillam & Gillam, 2016). Over three phases, children are taught the basic elements of a story, techniques for making a more elaborate story (e.g., complex syntax, dialogue, character emotions), and metacognitive tools for evaluating their own stories. Intervention activities include explicit instruction, co-telling and retelling stories, evaluating generated stories, and answering comprehension questions. Throughout the intervention, narrative generation and retell are supported by wordless picture books, icons to represent story grammar elements, or pictures. Syntax targets include coordinated clauses, subordinated clauses, mental/linguistic verbs, adverbs, and elaborated noun phrases. Notably, testing of earlier versions of this intervention showed that narrative performance led to greater improvement following explicit instruction in story grammar compared with implicit instruction (Gillam & Gillam, 2014). In general, results from these studies indicated improvements on both measures of microstructure and macrostructure.

In all of these studies targeting both macrostructure and microstructure goals (Fey et al., 2010; Gillam & Gillam, 2016; Petersen et al., 2010; Swanson et al., 2005), participants showed gains on the macrostructure, or story grammar, in their narratives. In contrast, only two led to improvement in microstructure targets (Gillam & Gillam, 2016; Petersen et al., 2010). Reasons for this discrepancy are likely multifaceted. First, there are a discrete number of story grammar elements, the use of which can be cued with visual support. In contrast, grammatical concepts such as causality and relative clauses can be difficult to demonstrate, explain, or visually represent due to their abstract nature. It may be that learning a list of story components is simpler than incorporating new linguistic processes into spontaneous speech. Second, it may be that impairment severity plays a role in microstructure outcomes. Unlike participants in the other studies, the children in the Petersen et al. (2010) study had severe language impairment; therefore they may have had more to gain from the language intervention. Finally, the SKILL intervention (Gillam & Gillam, 2016) is substantially longer and more in depth than others reported here. It may be that language skills are more likely to improve following such an intensive intervention.

Narrative Language and Related Domains

Narratives have been shown to tap other cognitive mechanisms such as memory (Botting, 2002; Montgomery et al., 2009). Therefore, it is plausible that intervention targeting narrative ability might affect memory or other academic skills that share similar cognitive demands, such as reading and math, a question that was examined in the present study. Broad support for working memory effects following language intervention is provided by studies showing transfer to verbal short term and working memory after phonological awareness interventions (Park, Ritter, Lombardino, Wiseheart, & Sherman, 2014; van Kleeck, Gillam, & Hoffman, 2006). However, the effect of narrative intervention on working memory is seldom measured. One study (Swanson et al., 2005) found that narrative-based language intervention had no effect on verbal short term memory as measured by a nonword repetition task. As was pointed out in the study, the intervention did not target phonological skills directly, which may explain the null effect. Instead, the manipulation of verbal material required in a narrative intervention may be more likely to carry over into measures of verbal working memory rather than short term memory.

Findings of associations between reading comprehension and both oral language (Kendeou, Brock, White, & Lynch, 2009; Nation, Clarke, Marshall, & Durand, 2004) and narrative ability (Feagans & Apelbaum, 1986; Roth, Speece, Cooper, & De La Paz, 1996) have prompted researchers to advocate for the use of oral narrative language intervention as a strategy to support reading (Perfetti, Landi, & Oakhill, 2005; Scott, 2009). Earlier studies repeatedly demonstrated that explicit instruction in story grammar led to improvements in reading comprehension of narratives among children with learning disabilities (see Gersten, Fuchs, Williams, & Baker, 2001 for review). Although, such positive results have not been found in all cases (Westerveld & Gillon, 2008). A more recent study (Clarke, Snowling, Truelove, & Hulme, 2010) found that an oral language intervention targeting story grammar alongside other language goals (e.g., vocabulary, figurative language) led to better long term reading comprehension gains than a parallel text-based intervention among children with poor reading comprehension (8–9 years).

Studies of language and math have shown associations between language ability and performance on a wide variety of mathematical tasks (Kleemans, Segers, Verhoeven, 2018; Purpura & Ganley, 2014), and between language and word problems in particular (Fuchs et al., 2006, 2008, 2010). These associations are reinforced by findings of poor math skills among children with SLI (Cowan, Donlan, Newton, & Lloyd, 2005; Donlan, Cowan, Newton, & Lloyd, 2007). The influence of language on math has been demonstrated further by studies showing that vocabulary, phonological awareness, and listening comprehension were predictive of math ability 2 and 4 years later (LeFevre et al., 2010; Vukovic & Lesaux, 2013). Finally, higher math scores were found among children demonstrating strength in narrative ability relative to syntax or vocabulary (Feagans, & Appelbaum, 1986), suggesting a unique link between narrative ability and math. This link is strengthened by findings that narrative ability in preschool was related to math performance 2 years later (O'Neill, Pearce, & Pick, 2004). The strength of the association between math and language suggests that a language intervention may lead to improvement in math ability.

Methodological Considerations

The moderate intervention effects in previous studies may be related to methodological factors. One possible reason is that group studies may be less sensitive to change. As well, the grammatical measures used in previous studies may have been too broad to capture subtle improvements. These factors are complicated when conducting studies with heterogeneous populations like children with SLI because participants may not respond in the same way to the intervention. These issues were addressed in the present study by employing a single-subject design. Such a design is ideal for studying heterogeneous populations because it is situated at the level of the individual; intervention can be tailored to individual abilities, and change is measured at the individual level, rather than group level, allowing for further investigation of participant characteristics that may influence intervention effects (Barlow & Hersen, 1973; McReynolds & Thompson, 1986). Importantly, single-subject designs offer sufficient design strength to establish a causal relationship between the intervention in question and the outcome, even with only a few subjects (Bordens & Abbott, 2011; Horner, Swaminathan, Sugai, & Smolkowski, 2012; Perdices & Tates, 2009). Heterogeneity among children with SLI was acknowledged further by conducting responder analyses to examine which participant factors influenced response to intervention. Similar analyses with younger participants have found a positive association between baseline language abilities and benefits from intervention targeting vocabulary (Penno, Wilkinson, & Moore, 2002) or language and literacy (Johanson, Justice, & Logan, 2016; Justice et al., 2010). It is possible that similar factors could influence intervention gains in school age children as well.

The strength of single-subject designs is due in large part to the ongoing collection of probe measures. Multiple-probe designs include test probes that measure the skills targeted in the intervention as well as control probes that are unrelated to the intervention. In order to provide evidence of a treatment effect, probe measures should reveal both stable performance for an extended baseline period and selective improvement on only the probes measuring the targeted abilities (Kazdin, 1981, 2011; Tate et al., 2008). If no improvements are seen on the control probe, then improvements on test probes can be more confidently attributed to intervention effects.

Historically, analysis of probe results has relied on visual inspection. Because of the numerous weaknesses of visual analysis, many researchers have advocated that statistical approaches be employed in conjunction with visual inspection (e.g., Zahn & Ottenbacher, 2001). Recent developments in statistical analysis of probe measures have added strength to single-subject designs by increasing replicability of data interpretation (Perdices & Tate, 2009). One group of analytic approaches are centered on detecting a statistically reliable effect. Bloom, Fischer, and Orme's (2006) proportion/frequency approach was employed in the present study. Briefly, this approach defines a 'typical zone' of behaviour based on baseline performance and compares performance during the intervention to the typical zone in order to determine whether the participant's behaviour has changed significantly. A second group of analytic approaches aim to quantify the treatment effect. Busk and Serlin's (1992) standard mean difference (SMD) has been recommended above other approaches in part because it results in an easily understood effect size statistic (*d*; Olive & Smith, 2005). This method has the additional advantage of placing no assumptions on the data (Busk & Serlin, 1992). Lastly, and importantly for the present study, this SMD has been employed in other intervention studies with children with language impairment (e.g., Ebert, Rentmeester-Disher, & Kohnert, 2012). For this study, a SMD of 0.8 or greater was interpreted as a clinically significant treatment effect when comparing either intervention or follow-up phases to the baseline phases (Ebert et al., 2012; Gillam, Crofford, Gale, & Hoffman, 2001).

Study Purpose

The present study tested the effectiveness of a narrative-based language intervention in promoting knowledge and use of story grammar and complex syntax among school age children with language impairment both with and without working memory impairment. Considering the cognitive demands of narrative retell and the importance of narrative ability for later academic success, this study also examined carry over effects on related domains such as working memory, reading, and math abilities. All children were offered language intervention following the same basic structure and using the same story books; however, the intervention was individualized by adjusting the targeted level of sentence complexity to suit each child's abilities. Intervention effects were measured using probes, which were completed throughout the baseline, intervention, and follow-up phases. Additionally, an assessment battery was administered before, immediately after, and 3 months after completion of the intervention to measure language, working memory, reading, and math abilities. To account for heterogeneity among children with language impairment, responder analyses examined how the effectiveness of the intervention was affected by participant characteristics, including speaking style and baseline ability in language, working memory, reading, and math.

Methods

Participants

Participants were 10 children who had been recruited from a database of children from a previous study (Archibald, Oram, Joanisse, & Ansari, 2013), and were included in the participant group for the study reported in Chapter 2. For the previous study

(Archibald et al., 2013), children completed an assessment battery on two occasions approximately one year apart. The battery included standardized measures of language, working memory, and nonverbal intelligence. Parent and teacher reports were collected at time one only. Details of these measures and reports are outlined in Chapter 2.

Of relevance to the present study are additional measures of math and reading that were administered at both time points in the previous study (Archibald et al., 2013). All children completed the *Math Fluency* subtest from the *Woodcock-Johnson-III Tests of Achievement* (WJ-III; Woodcock, McGrew, & Mather, 2001). In this subtest, children were given 3 minutes to solve simple addition, subtraction, and multiplication questions. Children 6 years and older completed additional standardized measures of math and reading. As a second measure of arithmetic, the *Calculations* subtest from the WJ-III was administered, in which children solved increasingly difficult arithmetic problems. Reading ability was assessed with the *Test of Word Reading Efficiency* (TOWRE; Torgensen, Wagner, & Rachotte, 1999). In the *Phonemic Decoding Efficiency* (PDE) subtest, children were given 45 seconds to read as many nonwords as possible. In the *Sight Word Efficiency* (SWE) subtest, children were given 45 seconds to read as many words as possible. For each subtest, the score was the total number of words read correctly. A second measure of reading ability was the *Reading Fluency* subtest from the WJ-III, in which children read sentences and made truth judgments about them, completing as many as possible in 3 minutes.

For the purposes of the present study, children were considered to have an impairment in language if at the second time point in the previous study (Archibald et al., 2013) they earned a score of 85 or lower on the *Core Language Score* (CLS) from the *Clinical Evaluations of Language Fundamentals – Fourth Edition* (CELF–4; Semel, Wiig, & Secord, 2003) and if teacher concern was reported for any aspect of the child's development. In addition, participants were included only if impairment was considered to be apparent already at the first time point, as indicated by two or more of the following: a low score (≤ 87) on the CLS, reported concern from a parent or teacher, or a low score (≤ 87) on one or more measures of reading or math. Children were also required to score in the normal range (≥ 85) on the PIQ, a nonverbal intelligence score, at both time points. PIQ scores were obtained from the appropriate subtests from either the *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999) or the *Wechsler Preschool and Primary Scale of Intelligence – Third edition* (WPPSI-III; Wechsler, 2002) as was appropriate for the participant's age.

Participants were additionally categorized based on their performance on their working memory abilities at the second time point in the previous study (Archibald et al., 2013). To meet criteria for SLI in the absence of working memory impairment, children were required to earn a working memory composite score that was both in the normal range (≥ 86) and a minimum of 10 points higher than the CLS score. The working memory composite was an average of 3 working memory subtests from the *Automated Working Memory Assessment* (AWMA; Alloway, 2007; see Chapter 2 for details). In contrast, criteria for combined impairment in language and working memory were a working memory composite that was both in the impaired range (≤ 86) and a maximum of 7 points higher than the CLS score.

A total of 29 children in the database met criteria for either language impairment without a working memory impairment (SLI; *n* = 19) or language impairment with a concomitant working memory impairment (LWMI; *n* = 10). From this list, 19 children could be contacted and invited to participate in the study, of which 13 agreed to participate. Of these, 8 met criteria for SLI and were enrolled in the intervention. The remaining 5 children met criteria for LWMI. Through random assignment, 3 of the children with LWMI were enrolled in the present language intervention and the remaining 2 received working memory training (see Chapter 4). One participant with LWMI was withdrawn from the study due to the participant's limited availability, reducing the number of participants receiving the language intervention to 10. It should be noted that one participant (SLI-8) was exposed to both Vietnamese and English in the home. As well, another participant (SLI-6) experienced learning difficulties in addition to the language deficits measured here, as reported by the classroom teacher. Descriptive statistics for participant sex, age, and scores on the criterion measures are presented in Table 3.1. The amount of time between the most recent assessment in the previous study and the initial measures taken for the present study ranged from 10 to 23 months.

Table 3.1

Participant Age, Sex, Language, Working Memory, and Nonverbal Intelligence

	n	Male	Age (yrs)	CLS	WM comp	PIQ
SLI	8	7	10.24 (0.97)	77.25 (3.24)	99.83 (7.06)	101.88 (13.51)
LWMI	2	1	9.83 (1.41)	78.50 (0.71)	76.67 (14.14)	103.50 (20.51)
All participants	10	8	10.16 (0.99)	77.5 (2.92)	95.19 (12.51)	102.20 (13.75)

Procedures

Study timeline. The study consisted of three phases: baseline, intervention, and follow up (see Figure 3.1). Participants completed all intervention and assessment sessions individually in a quiet room in their school. An initial assessment battery consisted of standardized tests of language, working memory, math, and reading, as well as language samples and a bespoke complex syntax measure, which informed intervention goal setting. Four probe measures were completed 2 times per week throughout the baseline phase, intervention phase, and for the first 4 weeks of the follow-up phase. For the final 3 months of the follow-up phase, probe measures were administered once per month.

During the intervention phase, children completed three 40-minute intervention sessions each week for 5 weeks. The assessment battery was readministered immediately following the completion of the intervention phase and again at the end of the follow up phase, approximately 6 months after the first assessment date. All research sessions were completed by trained research assistants. Different research assistants completed the assessment, probe measures, and intervention sessions. All research assistants were blinded to the language and working memory status of the participant, and those administering the assessment and probe measures were blinded additionally to the purpose of the study.

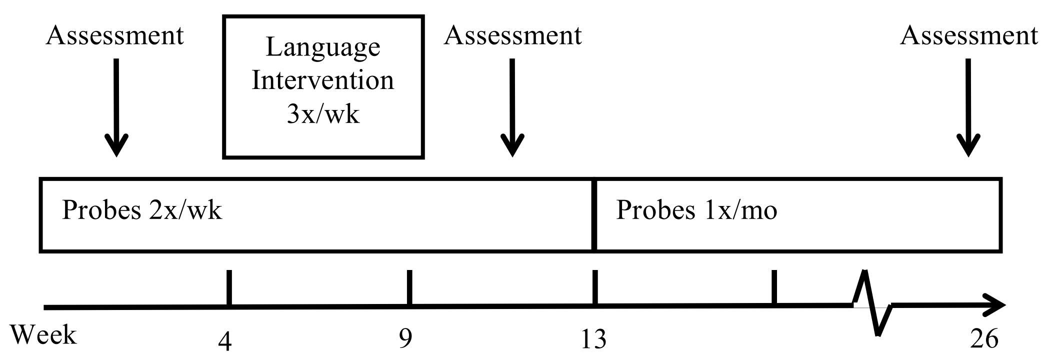


Figure 3.1. Study timeline.

Intervention

Initial goal selection. The narrative-based language intervention targeted both macrostructure and microstructure goals. The macrostructure goals were the same for all participants, namely to promote understanding and use of story grammar components. In contrast, microstructure goals were based on three measures completed during the initial assessment battery for this study. Performance on these measures was compared to a developmental progression of complex syntax based on the work of Covington, He, Brown, Naçi, & Brown (2006) and Steffani (2007; see Appendix 3A). The first measure was the narrative retell task, *Lost in Space* (Warr-Leeper, 1990; see Chapter 2 for further description). The second was an expository language sampling task, in which the child described the rules and procedures of a game or sport of the child's choosing (Nippold et al., 2005). For this task, the children were shown a card with cues for various elements of a sport (e.g., How it starts, How you score, How it ends) and asked to explain each aspect of the chosen game or sport. After this practice, the child was recorded while independently explaining each element of the game or sport.

The third task used to inform intervention goal selection was a dynamic assessment of complex syntax, which was designed for this study in order to assess expressive syntactical abilities. For each of 21 trials, children were required to produce sentences with given words or phrases (e.g., Make a sentence with the phrase, "you to go"). If the child either did not use the given phrase or did not provide a complete sentence, the child received a sentence starter (e.g., You could start your sentence with "I want…"). If the child was still unsuccessful, the clinician modeled a complete sentence with a similar structure (e.g., You could say something like "I need Bob to move it"). Trials were designed to prompt increasingly complex syntax, ranging from structures with simple infinitive to those with multiple instances of embedding, as reflected by the complexity levels in the developmental progression of complex syntax (see Appendix 3B).

Specific syntax structures were identified as suitable intervention targets when a child showed difficulty with them across the three measures but demonstrated readiness by responding to extra prompts in the dynamic assessment of complex sentences. A target level from the developmental progression of complex syntax was then chosen for each child to match these structures. In total, level 4 structures were targeted for three participants, level 5 for six participants, and level 6 for one participant.

Intervention materials. The narrative intervention was adapted from existing studies (e.g., Gillam et al., 2012; Swanson et al., 2005) and incorporated materials from published children's books: Small Saul (Spires, 2011); Stanley's Party (Bailey, 2003); The Boy Who Loved Bananas (Elliott, 2005); Purple, Green, and Yellow (Munsch, 1992); and Willow's Whispers (Button, 2010). For each book, adapted versions of the text were created to include more exemplars of the syntactical structures targeted at different complexity levels. One adaptation targeted level 3, a second targeted structures in levels 4 and 5, and a third targeted structures in levels 6 and 7. As well, children used TuxPaint (2011), a computerized paint program on a laptop, to aid in retelling the stories. Images of settings and characters from each of the stories were added to the program (used with permission of the publishers; see Appendices 3C, 3D), which included other paint features that allowed for manipulation of the images. This program allowed participants to recreate scenes of the stories as they retold them.

Intervention Procedure

Children were seen individually at their schools for a total of 15 intervention sessions over 5 weeks. For one participant (LWMI-1), intervention sessions were spread over a longer time span (7 weeks) due to frequent absences from school. Each week focused on a different story book and followed the same basic pattern of activities for each of Day 1, 2, and 3. Each session was comprised of an introductory discussion of the theme, interactive readings and retellings of the story, and additional activities to promote deeper understanding of vocabulary and story structure. Each session ended with the child providing spontaneous language samples, which were recorded and later transcribed.

Intervention activities for each day are outlined in Table 3.2. On Day 1, the research assistant began by introducing the theme for the session. In order to activate existing knowledge, the research assistant led the child in brainstorming known concepts related to the theme and thinking of questions to guide learning about the topic. During the introduction, the research assistant highlighted relevant vocabulary terms by discussing their meaning and drawing attention to their phonological features. Where possible, the research assistant provided images and sketched drawings to support comprehension. The introductory activity was followed by an initial reading of the story book and factual comprehension questions. While reading, the research assistant engaged in dialogic reading by periodically interrupting the story text to engage the child in conversation about new vocabulary, characters' feelings, possible story outcomes, and personal connections to story events. For the third activity, the research assistant and the child collaboratively retold the story using the paint program on a laptop. Throughout the retelling, the research assistant offered scaffolding by using story grammar terms, pointing out new vocabulary, and recasting the child's comments into complete complex sentences using grammatical structures at the child's microstructure goal level. For the fourth Day 1 activity, the child was asked to recall pertinent vocabulary from the story based on given semantic and phonological clues. The final activity consisted of the child providing an unaided retelling of the story as well as an expository sample expounding on an aspect of the theme.

Table 3.2

Intervention Session Structure

Activity	Day One	Day Two	Day Three
Introduction of Theme	• Introduce main theme • Brainstorm known concepts related to theme • Highlight related vocabulary, with visual support	• Review main theme • Introduce secondary theme using strategies from Day One	• Review themes, key vocabulary • Discuss concepts learned in previous sessions
Interactive Story Reading	• RA leads interactive reading of story • While reading, clarify new vocabulary, discuss characters' feelings, make predictions and personal connections • Child answers comprehension questions	• RA leads interactive reading using scripts adapted for child's syntax targets • While reading, discuss implied meanings or character motivations, imagine alternative outcomes	• Child retells story • RA prompts with sentence starters, probes for elaboration where necessary
Retell	• Child retells story using paint program • RA offers scaffolding for story grammar terms and complex syntax	• Child retells story from perspective of secondary character, using paint program	• Discuss conflicts in story: how they were addressed, related personal experiences, alternate solutions
Comprehension Activity	• Child solves riddles targeting relevant story vocabulary	• Given a story event, child indicates when it occurred and which events preceded and followed it	• Child points to details in illustrations based on given clue
Independent Retell	• Unaided story retell • Spontaneous expository sample on related topic	• Unaided story retell • Spontaneous expository sample on related topic	• Unaided story retell • Spontaneous expository sample on related topic • Retell new story

The opening activity on Day 2 included a brief review of the story and main theme as well as an introduction of the secondary theme. Themes were discussed in the same manner as on Day 1. For the interactive story reading on Day 2, the research assistant read from the version of the script that was adapted to include more exemplars of the child's syntax targets. Throughout the reading, the research assistant stopped periodically to ask the child about aspects of the story not explicitly stated in the text, such as the characters' motivations or the meaning of idiomatic phrases, and to engage the child in imagining possible alternative events to those in the story. For the story retell activity, the child recounted the story from the perspective of a character other than the main character, again using the computerized paint program for visual support. This method of story retell promoted deeper understanding of story grammar elements by discussing the motivations and actions of the character of choice and by examining which scenes and settings were relevant to him or her. The fourth activity on Day 2, Before-or-After, tested the child's understanding of the story timeline. The child was given an event from the story and required to indicate whether it was from the beginning, middle, or end of the story and to describe events immediately leading up to and following the given event. The session ended with another expository and narrative sample.

On Day 3, the introductory activity was comprised of reviewing key vocabulary and the main and secondary themes. The research assistant referred back to the concepts brainstormed on Day 1, and asked the child what he or she had learned about the concepts or still wanted to learn. The interactive story reading for Day 3 involved the child to a greater degree than previous sessions. Instead of reading the text, the research assistant provided starter phrases targeting the child's microstructure goal level, and prompted the child to complete the sentences. If the child produced an incomplete sentence or a simpler structure, the research assistant offered an appropriate model and asked the child to repeat it. Throughout the story, children were asked to elaborate on the story by adding further details about the settings, the characters' feelings, or minor events as prompted by the illustrations in the book. Instead of a story retell activity, children and research assistants discussed each of the problems or conflicts in the story, attempts to address the conflicts in the story, possible alternate solutions to the conflict, and any related personal experiences. For the fourth activity, children were asked to point to details in the illustrations based on clues from the research assistant. For example, "Point to the part of the picture that tells you that Matthew would not eat his supper." The final spontaneous speech samples included the same expository and narrative retell samples as the other days as well as retell of a new story, which had a plot structure similar to the theme story.

Treatment Fidelity

Intervention sessions were conducted by 6 different coaches, including 2 speech-language pathologists (SLPs), 3 masters students in an SLP program, and 1 research assistant. All coaches completed rigorous training with one of the SLPs, which involved instruction in complex syntax structures, viewing videotapes of sessions conducted by one of the SLPs, and role playing aspects of the sessions, such as interactive story reading and recasting complex sentences. In addition, 19% of the sessions were observed by one of the SLPs, and monitored for essential criteria as outlined in the Fidelity Checklist (see Appendix 3E).

Frequent school absences affected data collection for two participants. As a result, one participant (LWMI-1) received the intervention over the course of 7 weeks instead of the prescribed 5 weeks. Follow-up data collection for another participant (LWMI-2) was limited to a single time point.

Outcome Measures

Probe measures. Four probe measures were completed twice each week for the 4 weeks leading up to the intervention, the entire duration of the intervention, and the 4 weeks following the intervention, after which the probes were administered 3 more times on a monthly basis. A summary of the probes is presented in Table 3.3. In the Sentence Combining probe, children were required to formulate sentences based on information from 2 simple sentences read aloud by the research assistant and repeated as often as needed for the child. For example, given the sentences "Selena flies her kite" and "It is not very windy," a child might say "Selena flies her kite even though it isn't windy." For each of 3 trials, a child was asked to produce 2 sentences, resulting in 6 sentences for each session. The child's sentences were transcribed verbatim by the research assistant and scored by calculating the propositional density of each one. According to Kintsch and Keenan (1973) and Turner and Greene (1977), propositions are the main conceptual units within a text. This definition loosely maps onto specific structural elements of a sentence, namely, the main verb with its arguments and other descriptive elements that could be true or false (whether present or absent), including adjectives, adverbs, and qualifiers (Brown, Snodgrass, Kemper, Herman & Covington, 2008; Covington, 2009). For example, the sentence "The light jacket is for summer when it is very hot" contains 5 propositions, which are represented by the words: light, is, when, very, hot. Propositional density (PDensity) was calculated by dividing the number of propositions by the number of words in each sentence. The Sentence Combining probe score was the average propositional density of all sentences produced in a session. Secondary scoring procedures included average words per sentence and average propositions per sentence for each session. The Sentence Completion probe was designed to tap syntactical knowledge. Memory demands were minimized by providing as many repetitions of the verbal material as was necessary.

Table 3.3

Description of Probe Measures

Probe	Task	Scoring	Demands
Sentence Combining Probe	• For each of 3 trials, child is given 2 simple sentences. • Child has 2 attempts for each trial to combine the given sentences into a complex sentence.	• Propositional density. • Average words per sentence. • Average propositions per sentence.	• Syntactical knowledge.
Nonword Repetition Probe	• For each of 3 trials, four 3-syllable nonwords are presented. • Some nonwords are spoken by a female voice, others by a male voice. • Child repeats nonwords spoken by one of the voices.	• Percent correctly recalled target syllables	• Verbal short term memory.
Puzzle Completion Probe	• For each of 3 timed trials, child views the outline of a design for 5s. • Given 7 plastic shapes, child recreates the design using some of the shapes.	• Ratio of correctly identified shapes to time required for completion.	• Visuospatial working memory.
Number Comparison Probe	• Given pairs of dot arrays on a worksheet, child must cross out the array with more dots. • Timed task.	• Percent correct items.	• Minimal demands placed on language or working memory.

In the Nonword Repetition probe, children listened over personal headphones via an mp3 player to 3 audiorecorded trials of four 3-syllable nonwords (e.g., da-moy-cho, tay-chee-dow, tow-doy-foo, voo-ta-yee), some of which were spoken by a male voice and some by a female voice. At the beginning of each session, either the male or female voice was identified as the target voice for the session. Children were instructed to listen for the

1 or 2 nonwords spoken by the target voice and recall those words at the end of each trial. The Nonword Repetition score was the percent of target syllables correctly recalled. A syllable was counted as correct if it occurred in the correct serial position and contained the correct phonemes. For example, if the target nonword was tay-chee-dow and the child said “tay-mee-chee,” only the first syllable would be counted as correct. The Nonword Repetition probe places demands primarily on verbal short term memory. It is possible, however, that additional cognitive resources would be recruited to support the maintenance of select nonwords in short term memory while ignoring other irrelevant verbal stimuli.

In the Puzzle Completion probe, children were shown a design for 5 seconds and were provided with 7 plastic shapes to recreate the design from memory (see Figure 3.2). Only 3 or 4 shapes were required to reconstruct any given design. Three trials were completed in each session. Children were timed from the moment the design was removed from view until the child declared he or she was finished. For each trial, the research assistant also recorded the number of shapes correctly identified by the child as belonging in the design. The score for each session was calculated by dividing the total number of shapes selected correctly by the total time required to recreate all three designs. The Puzzle Completion probe was designed to tap visuospatial working memory and short term memory. The mental image of the design is held in short term memory while working memory is required to mental deconstruct the image, rebuild it with selected shapes, and compare the constructed shape with the design held in memory.

For the final probe, Number Comparison, children were shown 56 to 60 pairs of dot arrays on a worksheet and required to cross out the array from each pair that contained the greater number of dots (see Figure 3.3). This task was also timed. The score for each session was percent correct items. Because of the limited demands placed on working memory or language, children were expected to show no gains on this probe.

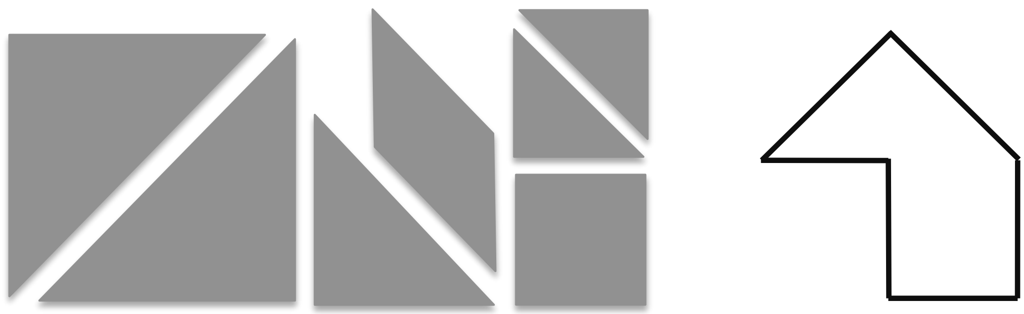


Figure 3.2. Shapes and sample design for puzzle completion probe. When provided the shapes on the left, children were required to recreate designs such as the example on the right using whichever shapes were necessary.

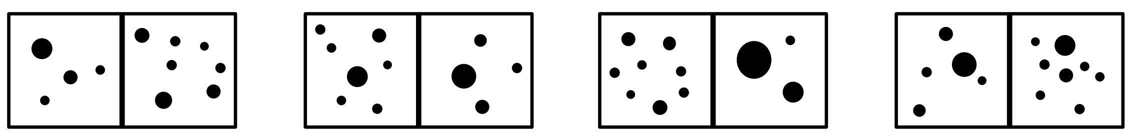


Figure 3.3. Sample dot arrays for number comparison probe.

Assessment battery. A collection of language, working memory, reading, and math tests was administered at the initial assessment (Time 1), immediately following the intervention (Time 2), and 6 months following the initial assessment (Time 3; see figure 1). The main narrative assessment measure was the narrative retell task, Lost in Space. Narrative samples were analyzed for changes in macrostructure and microstructure to reflect the intervention goals. Using the Narrative Scoring Scheme (NSS; Heilmann, Miller, Nockerts, & Dunaway, 2010), story macrostructure was rated on seven parameters: Introduction, Character Development, Mental States, Referencing, Conflict and Resolutions, Cohesion, and Conclusion. Character Development measures the ongoing description of the characters, differentiation between main and supporting characters, and the use of dialogue. Mental States refers to the inclusion of cognitive state terms (e.g., didn't understand, wondered) and affective states (e.g., surprised, discouraged) to describe the motivations and emotions of the characters. Referencing captures the child's ability to use pronouns and referents when referring to characters and settings, whereas Cohesion indexes the ordering of events and transitions between them. The remaining three, Introduction, Conflict and Resolution, and Conclusion, refer to basic story grammar elements such as the introduction of the theme, characters and setting, the struggles of the characters, and the ending of the story. Although many of these aspects were not directly targeted in the present intervention, the NSS was selected because it captures the use of story grammar components along with other more sophisticated story telling features, such as cohesion and referencing. NSS ratings were completed independently by the author and a research assistant otherwise uninvolved in the study, both of whom completed the NSS online training course offered by SALT software (Miller & Iglesias, 2008). Parameters of each narrative were awarded scores from 0 to 5, where a score of 5 reflects proficiency, a score of 1 reflects an immature performance, and a score of 0 reflects an incomplete task or unintelligible response. To facilitate consistency of scoring, a rubric was created specific to Lost in Space, modeled after the story specific rubrics available on the SALT website (see Appendix 3D). Scores on all seven parameters were summed to derive the NSS Index, an indicator of general narrative quality. For one participant, the beginning of the narrative was not recorded due to a microphone malfunction. Therefore, the score for that child's Introduction was removed from further analysis. Reliability of rating was determined through a point-by-point comparison of the two scorers' parameter scores for all language samples. In total, 49%

of remaining data points matched exactly between raters and 51% differed by only 1 point. Scores that differed by 1 point were averaged to form the participant's score.

Microstructure goals for all children aimed to increase production of more complex verb forms; therefore, changes in narrative microstructure were assessed by testing for increases in complexity level and frequency of complex structures. For this analysis, narratives were segmented first into C-units (Loban, 1972), which is defined as an independent clause with all its dependent clauses. Utterances were excluded from further analysis if they were unrelated to the story, directed toward the examiner (e.g., "It's gonna be hard to remember"), or contained an unintelligible speech segment (Fey et al., 2004). Utterances were marked as incomplete if they lacked an obligatory subject or main verb, or had such poor sentence structure or word order that the intended meaning could not be deciphered (e.g., "And they were on a recruit space finding a home, finding planet"). It was expected that children would produce sentence formulation errors as they attempted more complex structures; therefore, utterances with minor errors were included in the analyses provided the general meaning of the sentence was clear. Acceptable errors included omitted articles, tense and agreement errors, or minor word order errors. These C-units, along with those free of grammatical errors, were coded as complete C-units.

All complete C-units were then assigned a complexity level according to the developmental progression of complex sentences (Appendix 3A), and coded for main verbs and embedded verbs. Embedded verbs were defined as all verbs other than the main verb and included both finite forms (e.g., relative clauses, complement clauses) and nonfinite forms (e.g., infinitival phrases, gerunds, and past participles functioning as adjectives). This scoring was designed to reflect the structures targeted in the intervention. The resulting microstructure measures were Average DPCS Level (average level of complexity according to the developmental progression of complex sentences), Embedding Rate (proportion of embedded verbs to main verbs), and % Complex C-units (percent of C-units containing a main verb and at least one embedded verb). All microstructure analyses were completed by the author.

Additional measures in the assessment battery included standardized measures of language, in particular, two subtests from the CELF-4: *Concepts and Following Directions*, in which children pointed to objects as indicated by increasingly lengthy verbal instructions, and *Recalling Sentences*, in which children repeated sentences read aloud by the examiner. As measures of working memory, children completed 3 subtests from the AWMA: *Digit Recall*, *Counting Recall,* and *Spatial Recall.* In Digit Recall, children repeated lists of numbers of increasing length. In Counting Recall, children first counted red circles in arrays of mixed shapes, and at the end of the trial recalled their tallies. In Spatial Recall, children recalled locations of a red dot after first completing a mental rotation task on a shape associated with the red dot. In all AWMA subtests, children were required to successfully complete 4 trials at each level before attempting the next level with a greater number of trials. Measures of reading and math were the same as those completed in the previous study (Archibald et al., 2013), Sight Word Efficiency and Phonemic Decoding Efficiency (TOWRE) and Reading Fluency, Math Fluency, and Calculations (WJ-III).

Analysis

The effect of the intervention was measured in three ways: probe measures, standardized measures, and a narrative retell task. Analysis of probe data was conducted visually and statistically to assess for statistically significant change and clinically significant change (Bloom et al., 2006, Heyvaert, Wendt, Van den Noortgate, &

Onghena, 2012; Morgan & Morgan, 2009). Statistically significant change was tested using the proportion/frequency approach (Bloom et al., 2006). In this method, baseline performance is used to calculate a 2 standard deviation band, which is taken to be the zone of typical behaviour. This 2 *SD* band was then used to examine all data points from each participants' intervention and follow-up sessions. Intervention and follow-up data points were categorized as successes if they exceeded the upper limit of the 2 *SD* band or failures if they did not. The principles of binomial probability were used to determine whether a child's rate of success in the intervention or follow-up phase (i.e., the ratio of successes to all intervention data points) was probable or improbable based on the rate of success in the baseline phase. Improbable improvements in success rate during the intervention or follow-up phases were interpreted as treatment effects (see Figure 3.4).

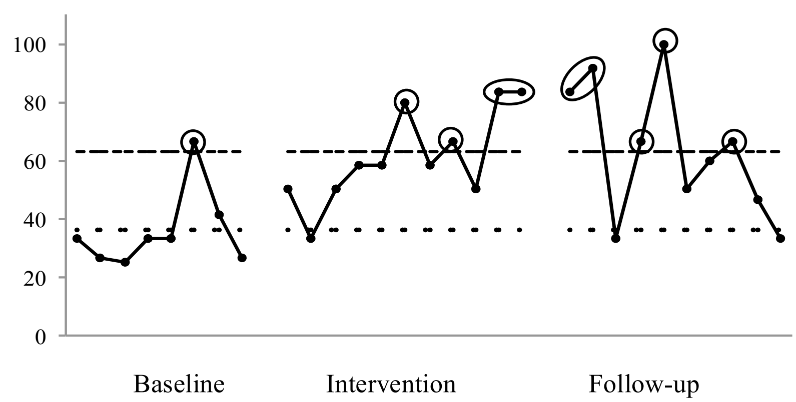


Figure 3.4. Illustration of the proportion/frequency approach to demonstrate intervention effect. The dotted line represents the mean of baseline performance. The dashed line denotes the upper limit at 2 *SD* above the baseline mean. The circled values exceed the 2 *SD* band. Given a baseline success rate of 1/8, the intervention success rate (4/11) and follow-up success rate (5/10) are highly unlikely. Therefore, it is probable that the increase in success rate is attributable to the intervention.

A modified version of the 2 *SD* proportion/frequency approach was used for the Sentence Combining probe. First, a more lenient cut-off of 1 *SD* was used in order to capture the subtle changes commonly found following language intervention. Second, improvement was examined by looking at both the upper and lower bounds of the child's performance. An upper 1 *SD* limit was calculated by adding 1 *SD* onto the baseline mean, and a lower 1 *SD* limit was calculated by subtracting 1 *SD* from the baseline mean. Improvements at the upper limit were determined as for the 2 *SD* bands in other probes. Improvements at the lower limit were examined by first determining the rate of failure at baseline, i.e., the percentage of data points that fell below the 1 *SD* band. Next, failure rates were computed for the intervention and follow-up phases and compared to baseline failure rates. Again, using the principles of binomial probability, we can determine whether decreases in a child's failure rate are probable based on baseline performance. Improbable decreases in failure rate in the intervention or follow-up phases were interpreted as positive treatment effects (see Figure 3.5).

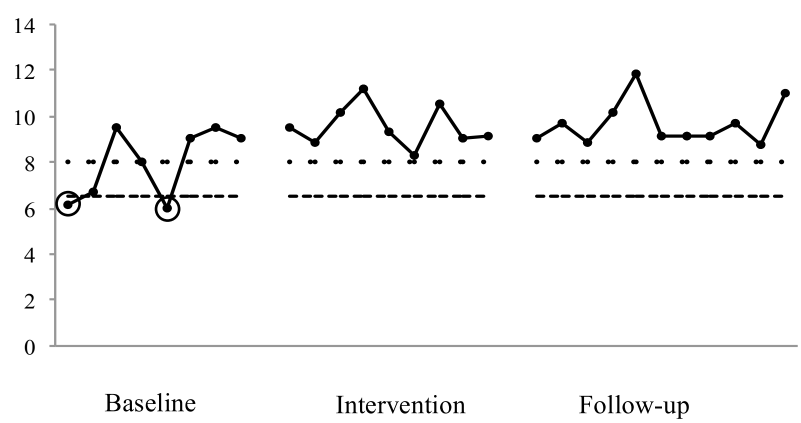


Figure 3.5. Illustration of the lower 1 *SD* proportion/frequency approach to demonstrate intervention effect. The dotted line represents the mean of baseline performance. The dashed line denotes the lower limit 1 *SD* below the baseline mean. The circled values exceed the lower 1 *SD* limit. Given a baseline failure rate of 2/8, the intervention failure rate (0/9) and follow-up success rate (0/11) are highly unlikely. Therefore, it is probable that the decrease in failure rate is attributable to the intervention.

A second analysis of the probe measures aimed to examine the clinical significance of the treatment. To that end, effect sizes were calculated to capture the magnitude of the treatment effect. To calculate standard mean difference (SMD; Busk & Serlin, 1992), the difference between the intervention mean and baseline mean is divided by the standard deviation of the baseline. The resulting output is broadly comparable to Cohen's *d* (Cohen, 1988).

Treatment effects as indicated by the probe measures were verified with results of the standardized measures and a narrative retell task. Improvement on these measures was deemed to be clinically significant if the score increased by 0.8 *SD* or greater (Ebert et al., 2012; Gillam et al., 2001). For measures standardized around a mean of 100, this translated to a minimum increase in 12 standard points. For the two scaled measures standardized around a mean of 10, a minimum increase of 3 points was required (rounded up from 2.4 because only integer scores were assigned for these measures). For the narrative retell scores, the 0.8 *SD* improvement criteria was calculated from the mean and standard deviation of a local database of narratives, which included participants with both typical abilities and impairments in language and working memory. Improvement on narrative retell was attributed to the intervention if increases were equal to or greater than 0.64 for Average DPCS Level, 0.31 for Embedding Rate, 14% for %Complex C-units, and 2.5 for the NSS Index.

Additional analyses were conducted to examine for possible factors affecting response to the intervention. Participants were grouped according to their response to the intervention and the extent of training effects on related domains. Factors considered were concurrent improvement on other measures and baseline measures of language, working memory, reading, and math. These responder analyses were conducted both qualitatively and quantitatively. Response to intervention was further examined in light of each child's speaking style as determined by performance on a baseline narrative retell measure (as reported in Chapter 2).

Results

Probe Measures

Figures 3.6 through 3.9 illustrate performance on the probes and indicate significant improvement according to the *SD* bandwidth calculations. Large effects ($d \geq 0.8$) are also included on these figures. All effect sizes are presented in Table 3.4. Consider first the results for the Sentence Combining probe (Figure 3.6). According to analysis with the 1 *SD* cut-off, improvements in propositional density (PDensity) were seen for only one participant (SLI-2) during the intervention with a moderate effect, and no improvements were seen during follow-up (see Figure 3.6, left column). According to secondary analyses of words or propositions per trial (Figure 3.6, right column), increases were seen for half of the participants. Two participants (SLI-4, LWMI-2) showed improvements for both words and propositions per sentence at intervention and follow-up as measured by effect size and the 1 *SD* bandwidth method. A third participant (SLI-6) demonstrated large significant increases in words per sentence and significant but moderate improvements in propositions. Two additional participants (SLI-1, SLI-2) showed gains at follow-up only. SLI-1 showed significant but small increases in propositions per sentence, and SLI-2 showed significant moderate increases in both word and propositions per sentence. Visual analysis reveals probable upward trajectories for SLI-4 for words and propositions and SLI-2 for propositional density. Possible upward trajectories were noted for SLI-1 and SLI-6 for words and propositions. However, the baselines for SLI-2 and LWMI-2 appear relatively stable.

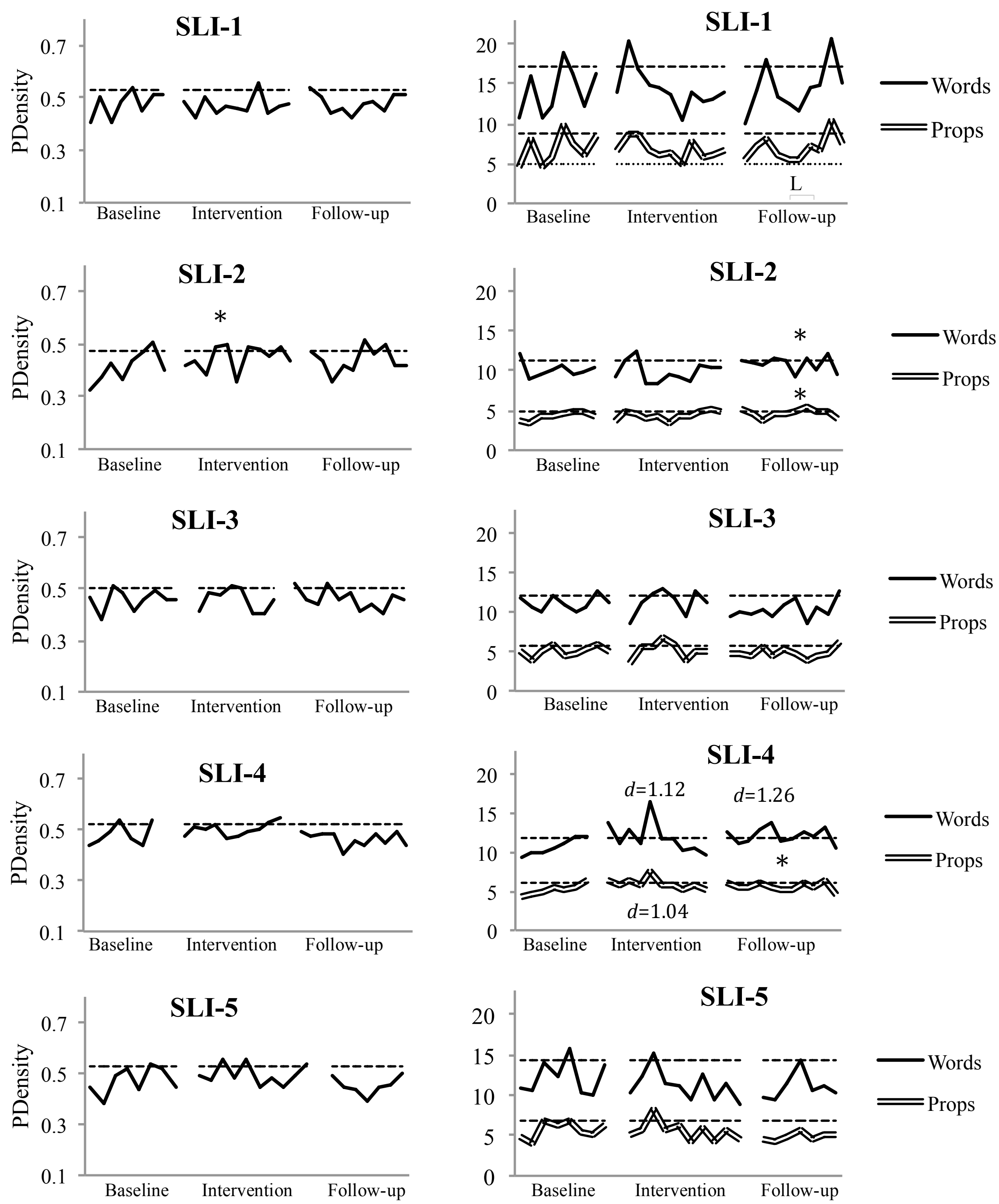


Figure 3.6. Sentence combining probe. Graphs represent three scores averaged over each session: the ratio of propositions to words (PDensity; left column), words per trial, and propositions per trial (right column). Dashed line represents 1 *SD* above mean baseline performance. Dotted line represents 1 *SD* below mean baseline performance. Asterisks indicate significance according to +1 *SD* limit. L indicates significance according to *-1* *SD* limit. All unmarked effect sizes $d < 0.8$.

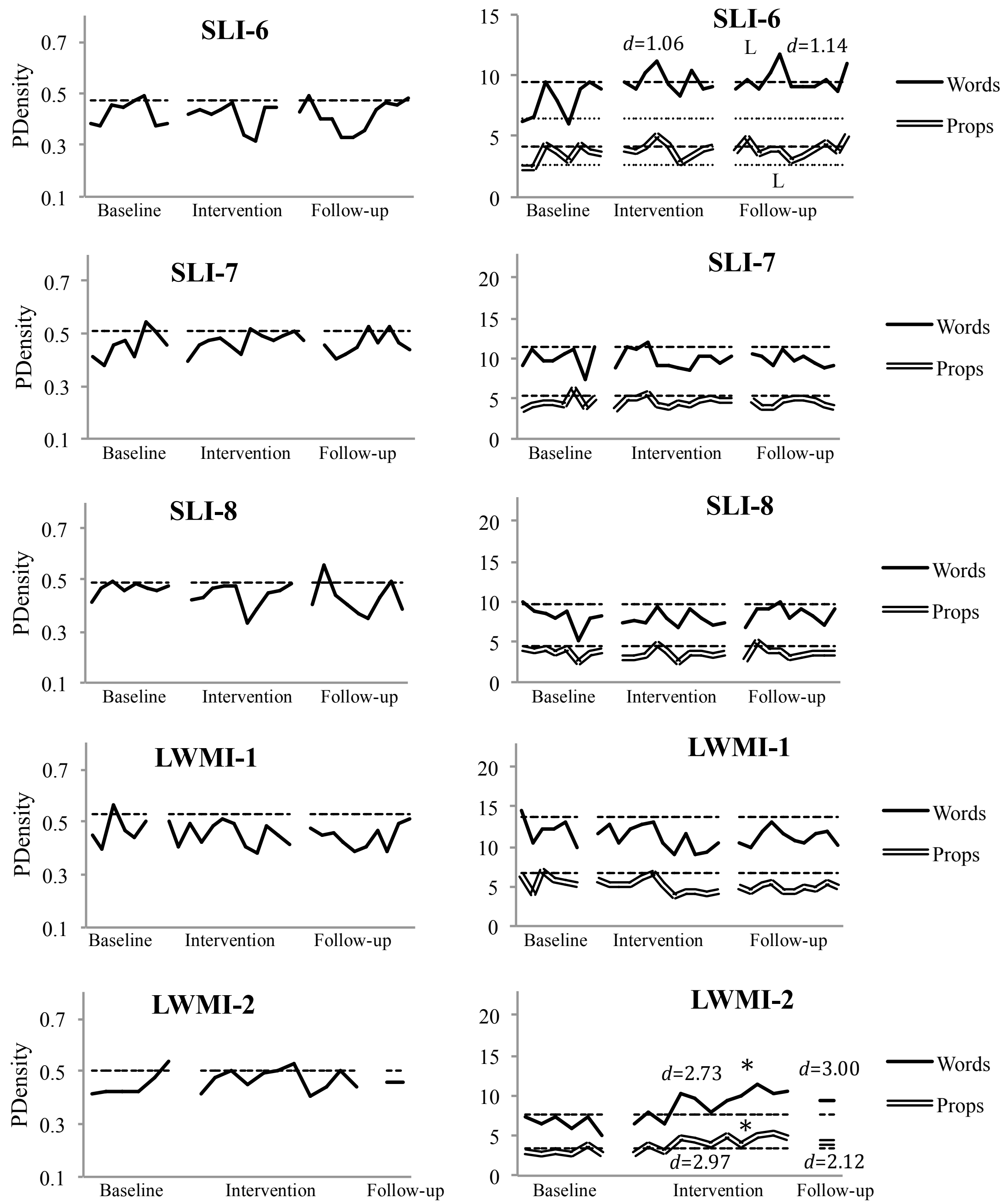


Figure 3.6 cont'd. Sentence combining probe.

Performance on the Nonword Repetition probe (Figure 3.7) revealed intervention effects for three participants. SLI-1 showed large significant effect sizes in both the intervention and follow-up phases, and SLI-6 showed large but nonsignificant effect sizes in both phases. In contrast, SLI-2 demonstrated a large but nonsignificant treatment effect during the intervention phase only. Visual analysis of data for SLI-2 shows, however, that the intervention results are largely overlapping with the baseline performance, with the exception of two particularly strong data points in the intervention. Although baselines for these three participants fluctuate considerably, there appears to be no upward slope.

Results from the Puzzle Completion probe (Figure 3.8) showed large significant effects for 5 participants (SLI-1, SLI-3, SLI-4, SLI-7, LWMI-1). Of these, SLI-7 showed improvement during intervention only, and both SLI-3 and SLI-4 showed improvements at follow-up only. SLI-1 showed a large significant effect in intervention but only a large effect at follow-up. LWMI-1 showed a large effect in intervention and a large significant effect at follow-up. An additional participant (SLI-8) demonstrated a large effect in intervention that did not meet significance criteria according to the proportion/frequency approach. Visual analysis of baseline data for these participants revealed upward trajectories for three (SLI-1, SLI-7, LWMI-1) but stable baselines for the other participants.

On the Number Comparison probe (Figure 3.9), the 2 *SD* band exceeded 100% accuracy for all participants; therefore, the 2 *SD* limit was set to 100%. Despite high accuracy scores and a lenient cut-off, none of the participants showed ceiling effects. In addition, no participants showed gains on the Number Comparison probe according to either the proportion/frequency approach or effect size calculations.

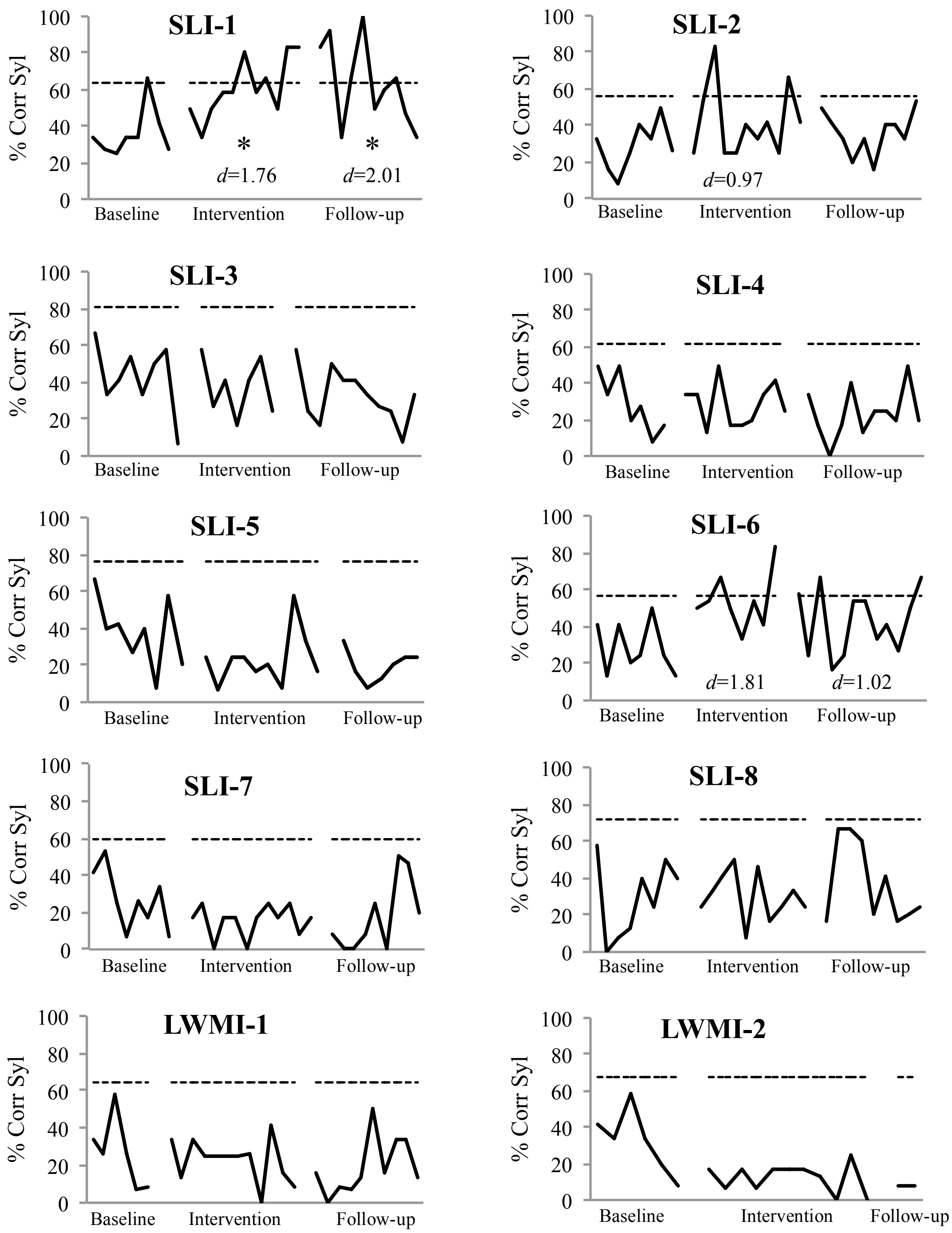


Figure 3.7. Nonword repetition probe. Graphs present the percent of syllables correctly recalled in each session. Dashed line represents 2 *SD* above the mean baseline score. Asterisks indicate significant improvement over baseline using 2 *SD* limit. All unmarked effect sizes $d < 0.8$.

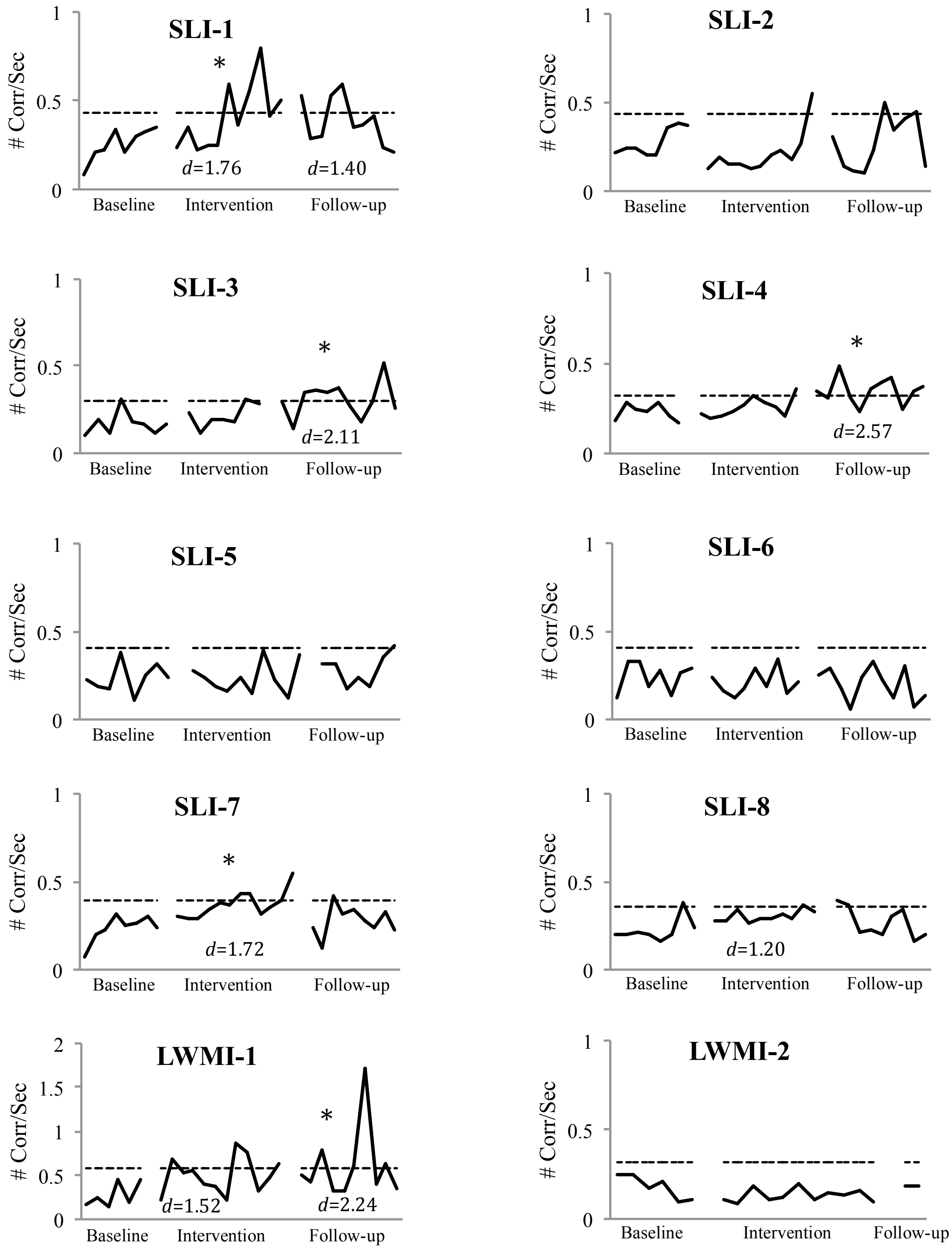


Figure 3.8. Puzzle Completion probe. Graphs present the correct number of shapes selected per second averaged over all three trials for each session. Dashed line represents 2 *SD* above mean score at baseline. Asterisks indicate significant improvement using 2 *SD* limit. All unmarked effect sizes $d < 0.8$.

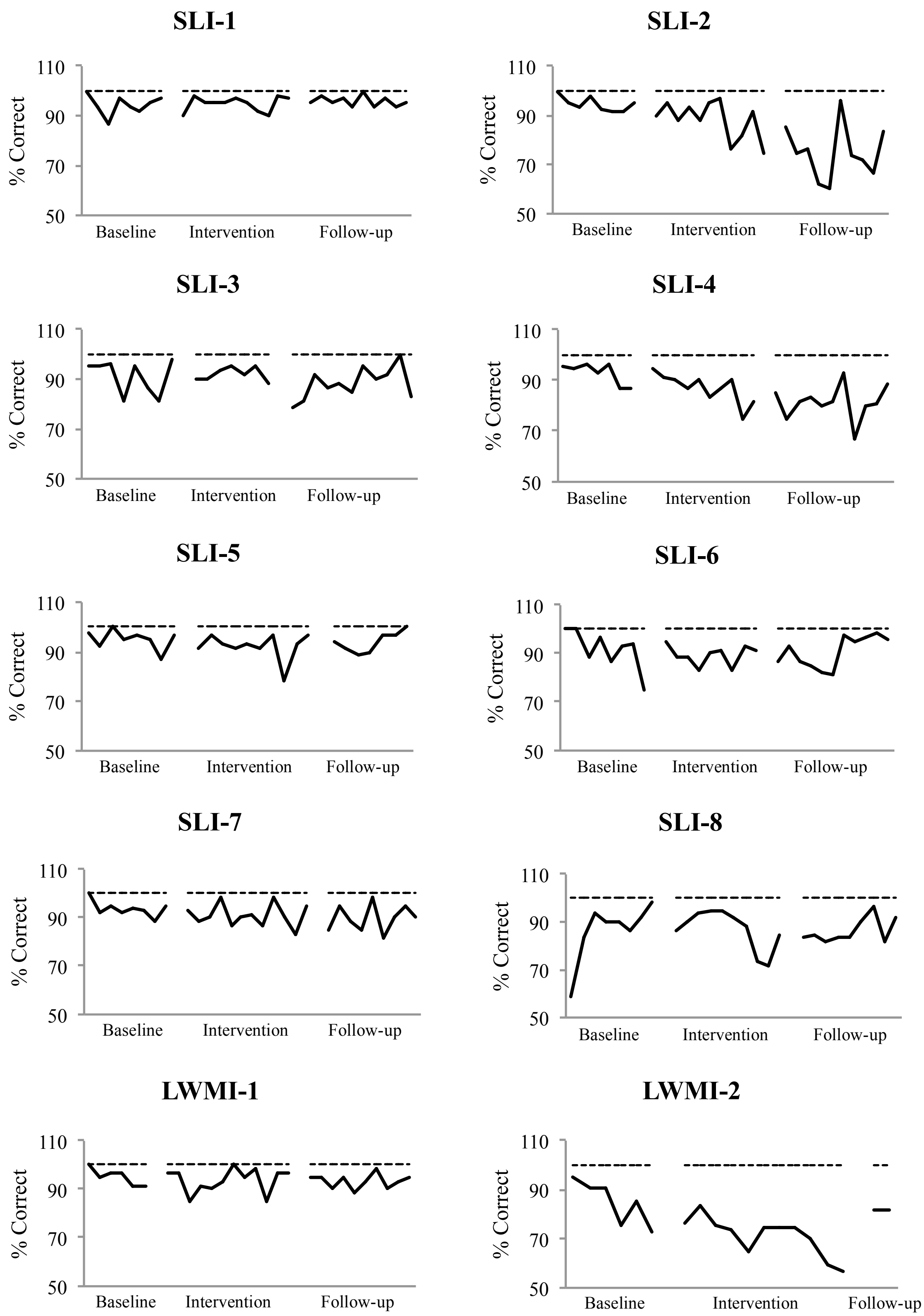


Figure 3.9. Number Comparison probe. Graphs present percent items correct from each session. Dashed line indicates 100% items correct in place of 2 *SD* limit.

Table 3.4

Effect Sizes of Probe Measures

	Sentence Combining						Nonword Repetition		Puzzle Completion		Number Comparison	
	Density		Words		Props							
Participant	I	F	I	F	I	F	I	F	I	F	I	F
SLI-1	-0.15	0.07	0.10	0.12	-0.06	0.04	**1.86**	**2.01**	**1.76**	**1.40**	0.13	0.40
SLI-2	0.57	0.44	-0.29	0.67	0.15	0.77	**0.97**	0.34	-0.85	-0.07	-2.09	-6.46
SLI-3	-0.04	0.07	0.20	-0.92	0.16	-0.59	-0.28	-0.54	0.68	**2.11**	0.09	-0.42
SLI-4	0.52	-0.45	**1.12**	**1.26**	**1.04**	0.57	-0.06	-0.35	0.63	**2.57**	-1.34	-2.60
SLI-5	0.45	-0.34	-0.48	-0.59	-0.17	-0.81	-0.74	-0.91	0.01	0.59	-0.66	-0.25
SLI-6	-0.22	-0.18	**1.06**	**1.14**	0.72	0.77	**1.81**	**1.02**	-0.40	-0.51	-0.28	-0.12
SLI-7	0.28	0.12	-0.09	-0.13	0.13	-0.03	-0.67	-0.53	**1.72**	0.54	-0.90	-1.28
SLI-8	-1.02	-1.48	-0.23	0.19	-0.23	-0.33	0.05	0.37	**1.20**	0.63	0.04	-0.02
LWMI-1	-0.31	-0.45	-0.64	-0.59	-0.68	-0.81	-0.21	-0.40	**1.52**	**2.24**	-0.47	-0.60
LWMI-2	0.37	0.23	**2.73**	**3.00**	**2.97**	**2.21**	-1.10	-1.07	-0.72	0.09	-1.57	-0.36

Note. I = Intervention phase, F = Follow-up phase. Large effect sizes ($d \geq 0.8$) in bold.

Taken together, results of the probe measures show treatment effects for 5 participants according to performance on the Sentence Combining and Nonword Repetition probes (SLI-1, SLI-2, SLI-6, SLI-4, LWMI-2; see Table 3.5). Of these participants, 3 made gains on both of these probes (SLI-1, SLI-2, SLI-6), and 2 improved on the Sentence Combining probe only (SLI-4, LWMI-2). Two of these 5 participants also made improvements on the Puzzle Completion probe (SLI-1, SLI-4). Four other participants showed increases on the Puzzle Completion probe despite making no improvements on either the Sentence Combining or Nonword Repetition probes (SLI-7, SLI-8, LWMI-1, SLI-3). One participant (SLI-5) showed no improvements on any probe measure. No participants improved on the control probe, Number Comparison.

Table 3.5

Summary of Results from Probes, Narrative Retell, and Standardized Measures of Language, Working Memory, Reading, and Math

	Probes				Narrative Retell		Standardized Measures			
	Sent Comb	Nwd Rep	Puzz Comp	Num Comp	Micro	Macro	Lang	WM	Reading	Math
SLI-1	✔[F]	✔[IF]	✔[IF]		ER[IF] DPCS[IF]		CFD[I]	CR[IF] SR[IF]	PDE[F]	
SLI-2	✔[IF]	✔[I]			%Comp[I] DPCS[IF]	✔[F]	RS[IF]	CR[I] SR[I]		MF[I]
SLI-6	✔[IF]	✔[IF]				✔[F]		CR[I]		
SLI-4	✔[IF]		✔[F]		DPCS[I]					
LWMI-2	✔[IF]				ER[I] DPCS[IF]	✔[I]		SR[F]		
SLI-5					%Comp[IF] ER[F] DPCS[IF]	✔[F]				
SLI-7			✔[I]		%Comp[IF]				PDE[F]	
SLI-8			✔[I]		DPCS[I]	✔[IF]		SR[I]	PDE[I] RF [IF]	
LWMI-1			✔[IF]		ER[F]	✔[IF]				
SLI-3			✔[F]				CFD[F] RS[I]	DR[F] SR[F]		

Note. ✔ Improvement in probes according to either proportion/frequency or effect size calculations. [I] Improvement during or post-intervention. [F] Improvement during or at follow-up. Sent Comb = Sentence Combining probe, Nwd Rep = Nonword Repetition probe, Puzz Comp = Puzzle Completion probe, Num Comp = Number Comparison probe, DPCS = Developmental Progression of Complex Sentence complexity level, ER = Embedding Rate, %Comp = percent complex sentences, CFD = Concepts and Following Directions, RS = Recalling Sentences, CR = Counting Recall, DR = Digit Recall, SR = Spatial Recall, PDE = Phonemic Decoding Efficiency, RF = Reading Fluency, MF = Math Fluency.

Narrative retell and standardized measures

The results of the narrative microstructure analysis are presented in Table 3.6. Eight participants showed improvement of 0.8 *SD* or greater (SLI-1, SLI-2, SLI-4, SLI-5, SLI-7, SLI-8, LWMI-1, LWMI-2). Of these 8, five showed increases on more than one measure or at more than one time point (SLI-1, SLI-2, SLI-5, SLI-7, LWMI-2). Results of macrostructure analysis using the Narrative Scoring Scheme are presented in Table 3.7.

Improvement on narrative macrostructure was seen for 6 participants (SLI-2, SLI-5, SLI-6, SLI-8, LWMI-1, LWMI-2). In total, 9 participants demonstrated some degree of improvement on narrative retell, and 5 of these improved on both macrostructure and one or more microstructure measures (SLI-2, SLI-5, SLI-8, LWMI-1, LWMI-2).

Finally, results from standardized measures of language, working memory, reading, and math are presented in Tables 3.8 through 3.11. According to the criteria set *a priori*, improvements on subtests from the CELF-4 were noted at either intervention or follow-up for three participants (SLI-1, SLI-2, SLI-3; see Table 3.8). In one case (SLI-2), improvement following intervention was maintained at follow-up. In the other 3 cases, increases were seen at either post-intervention or follow-up only.

Table 3.6

Microstructure Measures of Narrative Retell Task

	% Complex C-units			Embedding Rate			Average DPCS level		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SLI-1	54%	65%	63%	0.67	1.29*	1.11*	1.33	2.95*	2.00*
SLI-2	46%	60%*	58%	0.45	0.70	0.58	1.27	2.00*	3.17*
SLI-3	59%	27%	42%	1.24	0.55	1.00	2.88	1.55	2.00
SLI-4	36%	50%	20%	0.55	0.83	0.20	1.50	2.50*	0.60
SLI-5	27%	64%*	47%*	0.36	0.64	0.74*	1.23	2.00*	1.90*
SLI-6	33%	0%	44%	0.42	0	0.50	1.15	0	1.56
SLI-7	35%	60%*	52%*	0.65	0.67	0.76	1.62	1.67	1.82
SLI-8	39%	50%	53%	0.50	0.71	0.68	1.56	2.43*	1.75
LWMI-1	25%	31%	29%	0.25	0.31	0.71*	0.88	0.79	1.26
LWMI-2	29%	33%	40%	0.29	0.67*	0.40	0.29	2.17*	1.40*

Note. *Clinically significant improvement over baseline performance; minimum requirement was determined by calculating 0.8 *SD* from local database, which was equivalent to 14% for %Complex C-units, 0.31 for Embedding Rate, and 0.64 for Average DPCS Level.

Table 3.7

Macrostructure Measure of Narrative Retell Task

	NSS Index		
	Pre	Post	Follow-Up
SLI-1	23.5	19	23.5
SLI-2	12	10.5	14.5*
SLI-3	17.5	14	16.5
SLI-4	11.5	13	9.5
SLI-5	15.5	16	20*
SLI-6	14	8.5	18*
SLI-7	23.5	15.5	25
SLI-8	16.5	19*	25*
LWMI-1	10.5	14.5*	17*
LWMI-2	10.5	13.5*	9

Note. *Clinically significant improvement over baseline performance; minimum requirement was 2.5 points, as determined by calculating 0.8 *SD* from a local database. NSS Index: Narrative Scoring Scheme Index.

Table 3.8

Standardized Measures of Language

	Concepts & Following Directions			Recalling Sentences		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SLI-1	8	13*	6	4	1	4
SLI-2	10	9	8	5	8*	8*
SLI-3	3	3	6*	5	8*	7
SLI-4	12	8	12	6	6	6
SLI-5	7	7	8	6	7	5
SLI-6	3	1	4	6	5	5
SLI-7	7	7	6	6	6	7
SLI-8	8	8	4	6	7	6
LWMI-1	5	4	5	6	8	6
LWMI-2	11	6	4	7	6	7

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which translated to 3 scaled score points.

Working memory measures showed gains for 6 participants (see Table 3.9). Of these, one showed improvement both post-intervention and at follow-up (SLI-1). Three participants scored significantly higher at post-intervention testing only (SLI-2, SLI-6, SLI-8) and 2 showed increases at follow-up only (SLI-3, LWMI-2). Notably, most of the increases were seen in tasks requiring both storage and processing of information; only one participant improved on the verbal short term memory span task, with a second participant approaching significant gains.

Performance on reading measures showed treatment effects for three participants (SLI-1, SLI-7, SLI-8; see Table 3.10). Scores of 2 of these participants (SLI-1, SLI-7) showed an upward trajectory throughout all three testing sessions, reaching a significant effect size at follow-up testing. The third (SLI-8) demonstrated large improvements already at both post-intervention and follow-up testing. Performance on math measures showed treatment effects for only one participant (SLI-2; see Table 3.11).

Table 3.9

Standardized Measures of Short Term Memory and Working Memory

	Digit Recall			Counting Recall			Spatial Recall		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SLI-1	97	86	82	78	114*	99*	77	118*	110*
SLI-2	97	90	82	78	103*	86	116	129*	94
SLI-3	88.7	85.8	101*	101	101	76.6	90.2	83.7	116*
SLI-4	92	92	88.7	107	101	98.1	99.9	103	103
SLI-5	79	84	80	120	119	113	129	128	135
SLI-6	108	103.4	100.5	83	95*	76.6	87	87	90.2
SLI-7	75	82	86	83	70	75	99	110	99
SLI-8	88.7	85.8	94.6	88.8	88.8	79.6	93.5	113.1*	100.1
LWMI-1	99.9	100.5	97.6	83	76.6	70.4	87	93.5	64.1
LWMI-2	92	94	90	91	89	86	92	88	107*

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.

Table 3.10

Standardized Measures of Reading

	Sight Word Efficiency			Phonemic Decoding Efficiency			Reading Fluency		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SLI-1	87	87	87	68	76	82*	90	90	92
SLI-2	77	84	84	82	83	78	81	86	80
SLI-3	94	94	91	92	98	95	94	103	105
SLI-4	116	122	118	127	136	107	115	126	125
SLI-5	92	87	90	90	83	82	84	89	92
SLI-6	93	91	92	98	88	91	88	81	86
SLI-7	90	97	97	76	86	98*	85	82	94
SLI-8	116	117	109	111	124*	71	127	146*	148*
LWMI-1	103	102	96	107	113	95	96	101	100
LWMI-2	72	61	70	84	73	86	72	66	68

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.

Table 3.11

Standardized Measures of Math

	Math Fluency			Calculations		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SLI-1	113	110	106	106	107	98
SLI-2	77	89*	87	97	95	103
SLI-3	79	85	85	75	77	64
SLI-4	100	100	108	78	76	70
SLI-5	80	80	81	80	62	86
SLI-6	72	69	—	65	58	68
SLI-7	79	79	82	86	76	76
SLI-8	125	121	120	101	97	94
LWMI-1	75	80	73	63	62	60
LWMI-2	78	77	81	78	76	74

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.
— Data not interpretable due to administration error.

A summary of improvements on standardized measures is found in Table 3.5. In total, 7 participants improved on some measure of language (3), working memory (6), reading (3), or math (1). Of these, 3 participants (SLI-1, SLI-2, SLI-3) earned higher scores on both language and working memory measures post-intervention, at follow-up, or both. SLI-1 made additional gains in nonword reading and SLI-2 in math fluency. Two other participants (SLI-6, LWMI-2) improved on working memory measures only, SLI-7 improved on reading only, and SLI-8 improved on both working memory and reading measures.

Overall Results

A summary of results is presented in Table 3.5. Nine of 10 participants improved on some aspect of narrative retell. Agreement across measurements was found for some cases. Specifically, increases in sentence complexity in the context of narrative retell (Microstructure) were congruent with improvements on the Sentence Combining probe for 4 participants (SLI-1, SLI-2, SLI-4, and LWMI-2), 2 of which also made gains on subtests of the CELF-4. The fifth participant to improve on the Sentence Combining probe (SLI-6) did not show increases in grammatical complexity elsewhere, but did improve on narrative macrostructure and verbal working memory. The remainder of participants improved on language measures despite showing no improvements on the language probes. Of these, 4 participants showed improvements on narrative microstructure (SLI-7, SLI-8, and LWMI-1), including 2 participants who showed increases in reading (SLI-7, SLI-8). The final participant (SLI-5) improved solely on the narrative retell task. Of note was one participant (SLI-3) who improved on both standardized measures of language despite showing no gains on other measures of linguistic ability.

With respect to working memory gains, all but one participant improved on at least one measure of working memory. Six participants improved on the visuospatial working memory probe (Puzzle Completion; SLI-1, SLI-4, SLI-7, SLI-8, LWMI-1, SLI-3), 3 of whom also improved on one or more standardized measures of working memory (SLI-1, SLI-8, SLI-3). Three others (SLI-2, SLI-6, LWMI-2) showed increases on standardized measures of working memory alone despite showing no gains on Puzzle Completion. Notably, improvement on the verbal short term memory probe (Nonword Repetition) was always accompanied by improvement in verbal working memory (Counting Recall; SLI-1, SLI-2, SLI-6).

Combined results reveal various degrees of treatment effect across participants. For instance, one group of participants showed convincing language gains through improvement in both the language probe (Sentence Combining) and another measure of language (SLI-1, SLI-2, SLI-6, SLI-4, LWMI-2). Similarly, 5 participants showed convincing working memory gains by demonstrating improvement in one of the memory probes (Nonword Repetition, Puzzle Completion) and another measure of working memory (SLI-1, SLI-2, SLI-3, SLI-6, SLI-8). Four participants showed transfer to either reading or math (SLI-1, SLI-2, SLI-7, SLI-8), whereas one participants showed no improvement on any task beyond the narrative retell measures (SLI-5).

Responder Analysis

A follow-up analysis was conducted to examine which characteristics might influence the effect of a narrative-based language intervention. To examine which factors might influence improvement in language, participants were grouped as Language Responders or Language Nonresponders. Language Responders consisted of children who showed convincing gains in language as demonstrated by improvement on the language probe (Sentence Combining) and at least one additional language measure (n = 5). Remaining participants were grouped as Language Nonresponders (n = 5). Table 3.12 presents baseline scores for all participants grouped by responder type. Using t-tests, groups were compared on all baseline language and working memory measures (Table 3.13). No group comparisons reach statistical significance; however, some comparisons resulted in large effect sizes. Specifically, Language Responders had higher Digit Recall scores (d = 1.13), and higher scores on Concepts and Following Directions (d = 0.90). It is also noteworthy that at baseline, 4 of 5 Language Responders had higher receptive language skills than expressive language skills (as measured by Concepts and Following Directions and Recalling Sentences). Importantly, the one Language Responder without a receptive language advantage at baseline (SLI-6) presented with learning difficulties in addition to language impairment. In contrast, Language Nonresponders appear to have had a more even profile of language abilities at baseline. Additionally, among the Language Nonresponders are the two oldest participants in the study (SLI-8, SLI-3), one of whom was the only participant to be exposed to a language other than English in the home (SLI-8). As well, LWMI-1 completed the intervention sessions distributed over a longer time span than the other participants. These observations suggest that the effectiveness of the intervention may be affected by age, language exposure, or intervention intensity.

Additional analyses examined factors contributing to intervention effects on domains beyond language. To investigate influences on working memory gains, participants were grouped again based on demonstrated intervention effect. Working Memory Responders included participants who improved on at least one memory probe (Nonword Repetition or Puzzle Completion) and on some other working memory

Table 3.12

Baseline Scores for Measures of Working Memory, Language, Reading, and Math

		Working Memory Measures			Language Measures		Reading Measures			Math Measures	
	Responder Type	DR	CR	SR	CFD	RS	SWE	PDE	RF	MF	Calc
SLI-4	LR	92	107	99.9	12	6	116	127	115	100	78
LWMI-2	LR	92	91	92*	11	7	72	84	72	78	78
SLI-6	LR +WM	108	83*	87	3	6	93	98	88	72	65
SLI-2	LR +WM,Ma	97	78*	116*	10	5*	77	82	81	77*	97
SLI-1	LR +WM,Re	97	78*	77*	8*	4	87	68*	90	113	106
SLI-8	LN +WM,Re	88.7	88.8	93.5*	8	6	116	111*	127*	125	101
SLI-3	LN +WM	88.7*	101	90.2*	3*	5*	94	92	94	79	75
SLI-7	LN +Re	75	83	99	7	6	90	76*	85	79	86
SLI-5	LN	79	120	129	7	6	92	90	84	80	80
LWMI-1	LN	99.9	83	87	5	6	103	107	96	75	63

Note. LR = Responder, LN = Language Nonresponder, +WM = Working Memory Responder, improved on at least one memory probe and at least one working memory measure, +Ma = improved on math measure, +Re = improved on reading measure, DR = Digit Recall, CR = Counting Recall, SR = Spatial Recall, CFD = Concepts and Following Directions, RS = Recalling Sentences, SWE = Sight Word Efficiency, PDE = Phonemic Decoding Efficiency, RF = Reading Fluency, MF = Math Fluency, Calc = Calculations.
* Improvements seen on measure at post-intervention or follow-up.

Table 3.13

Comparison of Baseline Linguistic and Working Memory Ability for Language Responders and Nonresponders

	Language Responders		Language Nonresponders				
	M	*SD*	*M*	*SD*	*t*	*p*	Cohen's *d*
CFD	8.8	3.56	6.0	2.0	1.53	.16	0.90
RS	5.6	1.14	5.8	0.45	0.37	.72	-0.24
DR	97.20	6.53	86.26	9.71	2.09	.07	1.13
CR	87.40	12.18	95.18	15.72	0.87	.41	-0.56
SR	94.38	14.66	99.74	16.95	0.53	.61	-0.35

Note. CFD = Concepts and Following Directions, RS = Recalling Sentences, DR = Digit Recall, CR = Counting Recall, SR = Spatial Recall.

Measure (*n* = 5; +WM; see Table 3.12). Remaining participants were grouped as Working Memory Nonresponders (*n* = 5). Using t-tests, groups were compared on all baseline working memory and language measures (Table 3.14). One significant comparison revealed lower Recalling Sentences scores for Working Memory Responders with a large effect (d = -1.21). Two other comparisons resulted in large but nonsignificant differences. Specifically, Working Memory Responders showed higher Digit Recall baseline scores (d = 0.86) but lower Counting Recall baseline scores (*d* = -0.80). These results suggest that carry over from language intervention to working memory performance may be affected by baseline abilities in language and working memory. Notably, 3 participants were grouped as both Language Responders and Working Memory Responders (SLI-1, SLI-2, SLI-6). These are the same 3 participants who improved on both measures of verbal memory: the Nonword Repetition probe and Counting Recall.

Table 3.14

Comparison of Baseline Linguistic and Working Memory Ability for Working Memory Responders and Nonresponders

	Working Memory Responders		Working Memory Nonresponders				
	M	*SD*	*M*	*SD*	*t*	*p*	Cohen's *d*
CFD	6.4	3.21	8.4	2.97	1.02	.34	-0.65
RS	5.2	0.84	6.2	0.45	2.36	.05	-1.21
DR	95.88	7.95	87.58	10.28	1.43	.19	0.86
CR	85.76	9.61	96.80	16.25	1.31	.23	-0.80
SR	92.74	14.39	101.38	16.32	0.89	.40	-0.57

Note. CFD = Concepts and Following Directions, RS = Recalling Sentences, DR = Digit Recall, CR = Counting Recall, SR = Spatial Recall.

Lastly, 4 participants showed improvement on reading or math measures. The 2 participants who improved on only Phonemic Decoding (SLI-1, SLI-7) were similar in that their baseline Phonemic Decoding scores appeared to be a weakness relative to their other reading scores. At follow-up, both of these participants showed less of a jagged reading profile. This pattern did not hold true for SLI-8, who also improved on reading measures. SLI-2 was the only participant to improve on either measure of math, and was also the only participant to demonstrate such a low Math Fluency score relative to Calculations.

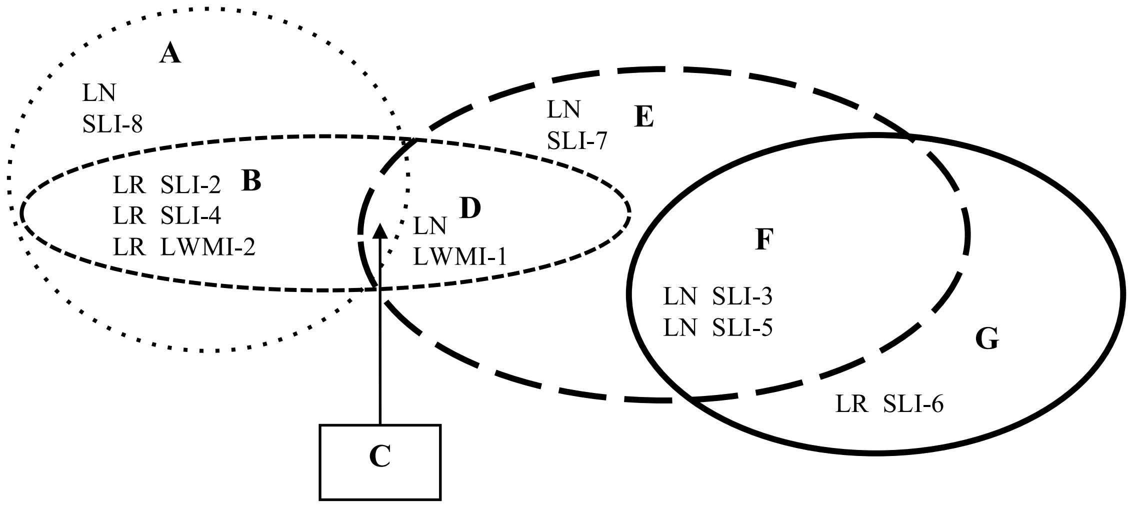
In summary, it appeared that baseline ability in both language and working memory influenced language gains and working memory gains following the narrative-based language intervention. First, language gains seemed to be associated with higher baseline scores in verbal short term memory and receptive language, as well as a language profile showing relative strength in receptive language. Second, working memory gains seemed to be associated with higher verbal short term memory at baseline but lower verbal working memory and expressive language abilities at baseline. Both reading gains and math gains appeared to be more likely among participants with markedly low nonword reading and math fluency relative to other abilities in these areas.

Responders, Simplifiers, and Risk Takers

The final analysis examined the relation between responsiveness to the narrative-based language intervention and participant speaking style as determined in a previous study of narrative retell ability (see Chapter 2). Figure 3.10 presents a map of the speaking style clusters from Chapter 2, with the language intervention participants included. The participant labels denote responder type and the location of the label indicates speaking style. Simplifiers are located toward the left side of the figure whereas Risk Takers are located toward the right. Note that SLI-1 (a Language Responder) does not appear on the figure because none of the descriptors from the figure were assigned to the participant's narrative. Although exploratory only, two broad observations can be made from this comparison. First, Language Responders and Language Nonresponders appear in mutually exclusive locations on the cluster map. Four of the 5 Language Nonresponders had 'Clumsy Links' with or without some other feature, and one (SLI-8) had 'Short Sentences.' Recall that 'Clumsy Links' indicated awkward wording associated with attempts to connect ideas in a sentence through subordination or other means. In contrast, 3 of the 5 Language Responders had both 'Missing Content' and 'Short Sentences' and the fourth (SLI-6) had 'Verbal Mazing.' Notably, the two participants who deviate from this pattern (SLI-8, SLI-6) are special cases to some degree. SLI-8 was exposed to Vietnamese at home in addition to English, and SLI-6 presented with learning difficulties beyond language impairment. Second, participants who improved in working memory (SLI-1, SLI-2, SLI-3, SLI-6, SLI-8), reading (SLI-1, SLI-7, SLI-8), or math (SLI-2) do not appear to be grouped together on the cluster map in any obvious pattern. In other words, carry over gains in working memory, reading, or math do not appear to be associated with speaking style.

Discussion

The primary purpose of this study was to evaluate the effectiveness of a narrative-based language intervention that targeted both story grammar and complex syntax for school aged children. Additionally, carry over effects were tested in related domains, including working memory, reading, and math. Results from the narrative retell task were favourable, showing improvements for 9 of 10 participants, with the majority of those improving on more than one measure of narrative retell. Language gains beyond the narrative retell context were evident for 5 participants, who made improvements on both the Sentence Combining probe and an additional measure of language. In addition, 5 participants made working memory gains, as demonstrated by improvement on both a memory probe and an additional measure of working memory. Carry over to other domains was noted in 3 participants for reading and 1 for math.



	Short Sentences	Based on subjective appraisal of average sentence length.
	Missing Content	Lacking some significant story event.
	Clumsy Links	Difficulty joining ideas via subordination or other means.
	Verbal Mazing	Hesitations (uhs, ums), false starts (repetitions at beginning of utterance), or revisions (changing what was said).

Figure 3.10. Responder analysis cross-referenced with narrative speaking style. LR = Language Responder, LN = Language Nonresponder

Quantitative and qualitative responder analyses revealed that improvement in language may be associated with higher verbal short term memory and receptive language at baseline, and a primarily expressive language impairment. Other factors that may have limited the intervention effect on language were older age and lower intervention intensity. In contrast, carry over to working memory performance may be more likely among higher baseline verbal short term memory but lower verbal working memory and expressive language ability. Improvements in reading and math appeared to be more likely for children with disproportionately low performance in only nonword reading or math fluency. Finally, possible associations were identified between intervention response and speaking style (Simplifiers, Risk Takers). Children who showed improvements in language were more likely to be characterized as Simplifiers, whereas those who showed limited improvements in language were more likely to produce narratives with 'Clumsy Links', that is, narratives containing awkward wording with attempts to connect ideas.

The high response rate on the narrative retell task suggests that narrative-based language intervention is an effective tool for improving the narrative abilities of children ages 8 to 11 with language impairment. In addition, the intervention effects seen on other language measures suggests that for half of the participants, a narrative-based language intervention can lead to broader language gains. A positive response to narrative intervention is in line with previous research on younger school age populations (e.g., Fey et al., 2010; Petersen et al., 2010). Existing literature has demonstrated overall that improvement in story grammar, or narrative macrostructure, is more likely than improvement in syntax use, or narrative microstructure (Davies et al., 2004; Fey et al., 2010; Green & Klecan-Aker, 2012; Petersen et al., 2010; Swanson et al., 2005). However, in the present study, improvements were found for both macrostructure and microstructure. It is possible that the difference is related to differences in outcome measures used. Relying entirely on standardized measures, such as Recalling Sentences from the CELF-4 or scores from the Developmental Sentence Score may have been insufficient to capture the improvements in earlier studies (e.g., Fey et al., 2010; Swanson et al., 2005). In contrast, microstructure measures were employed in the current study in addition to standardized tests. Moreover, these microstructure measures were designed for the study and were closely matched to the goals of the intervention, which may have increased the likelihood of detecting improvements. As well, two of the microstructure measures in the current study were designed to give credit for any type of embedded verb structure, even if they were not directly targeted in the intervention. In comparison, previously used bespoke measures may have been narrower, for example, tallying the number of utterances with conjunctions other than “and” or “then” (Fey et al., 2010).

The variation in responses to language intervention highlight the heterogeneity among children with language impairment and point to the influence of baseline abilities on intervention effect. Stronger baseline abilities were associated with better outcomes in some respects. For instance, language gains were associated with higher verbal short term memory and receptive language abilities. These findings are similar to others showing greater linguistic treatment effects for children with higher baseline abilities in the targeted domain (Johanson, et al., 2016; Penno et al., 2002). As well, the importance of verbal short term memory in language development has been documented elsewhere, in reference to vocabulary acquisition (e.g., Baddeley, Gathercole, Papagno, 1998; Majerus & Boukebza, 2013) and language ability in general (e.g., Archibald & Gathercole, 2006; Baddeley, 2003). Specific associations between verbal short term memory span and comprehension of complex syntax have been documented in a number of populations (e.g., Papagno, Cecchetto, Reati, & Bello, 2007; Robertson & Joanisse, 2010), suggesting that verbal short term memory may support learning of complex syntax.

Other possible moderating factors included participant age and intervention intensity. The intervention was designed around five children’s picture books. Although the language levels were appropriate for the participants, the genre or content of the stories may have seemed immature to some of the older participants, resulting in lower motivation and less engagement from the participant. It is possible that using stories with more mature content or expository content would have better engaged the older participants. Finally, the intervention was extended over 7 weeks instead of the intended 5 weeks to accommodate frequent school absences of one participant. It is possible that the lower intensity reduced the effectiveness of the intervention.

The second aim of this study was to examine the effects of a narrative-based language intervention on the related domains, including working memory, reading, and math. This is the first study to document working memory improvements following a narrative-based language intervention. Notably, gains in working memory performance were seen on measures of verbal short term memory, verbal working memory, and visuospatial working memory. The exploratory responder analyses offered some insight into the nuanced association between baseline abilities and intervention effects. Specifically, the profile of Working Memory Responders, higher verbal short term memory but lower verbal working memory and expressive language, paints a picture of a child who has the cognitive capacity for learning (higher verbal short term memory) but who for unknown reasons has not developed age appropriate abilities in linguistic expression or processing (poor expressive language and verbal working memory). If this is the case, an effective language intervention might not only increase language specific knowledge but also general language processing abilities, such as those required for verbal working memory tasks. In fact, this is the response seen for a number of the Working Memory Responders. This logic, however, only holds true for a certain profile, specifically those who were both Language Responders and Working Memory

Responders. The remaining Working Memory Responders showed increases in measures of only spatial working memory. It is possible that language and working memory are interacting differently for these children; however, that interaction is unclear given the present data set.

The effect of the language intervention on reading and math ability was minimal, showing clinically significant improvement for only 3 participants in reading and 1 participant in math. The reading results place this study in contrast with the positive results of Clarke and colleagues (2010), but more in line with Westerveld and Gillon (2008), who also found a limited intervention effect on reading ability. It is possible that the difference in findings is a simple discrepancy in criteria for significance. Clarke et al. (2010) report an average reading comprehension improvement of 7 standard score points, a difference that was statistically significant given the study design. In contrast, the criterion for significant improvement in the present study was more conservative (12 standard score points). Alternatively, it could be a difference in reading measures. Whereas Clark et al. (2010) employed a paragraph-level reading comprehension measures, the measures in the present study tested word-level and sentence-level reading. The limited improvement in math may seem surprising given the strength of research supporting an association between performance in language in math. However, the results from the present study suggest instead that this association may be more complex, and potentially mediated by other factors. For 3 of 4 participants, improvements in reading or math were characterized by gains on a single task that had a strikingly low baseline score relative to the child's performance on other tasks in the same domain. It is possible that retesting was enough to lead to score increases for children who scored low initially.

However, this is not a likely explanation for SLI-8, who improved on 2 measures of reading despite scoring high on all reading measures at baseline.

Comparing responder type to speaking style revealed that children who told narratives with short sentences and missing information were more likely to show improvements in linguistic ability following language intervention. In contrast, children whose narratives were characterized by clumsy attempts to link ideas were less likely to show language gains. Two possible explanations arise from these results. One possible explanation is that children who struggle with linking ideas are attempting longer structures already, therefore leaving less room for improvement. A closer look at baseline language scores suggests, however, that this is not the case; expressive language ability did not differentiate Language Responders from Nonresponders, indicating that other factors may influence speaking style. Alternatively, it may be that speaking styles are related to self-monitoring or awareness of ability. If so, clumsy links would be indicative of low monitoring, and simplified stories and syntax would be the result of high monitoring. It follows that children with simplified stories may be more likely to respond to intervention because they are already keenly aware of their verbal output. This latter explanation is partially supported by the tendency of Language Responders (who are also Simplifiers) to present with relatively spared receptive language abilities despite impaired expressive language. This imbalance between understanding and producing language may be why some children display higher levels of self-monitoring.

Conclusion

In summary, this study demonstrates that narrative-based language intervention can be an effective tool for improving the narrative abilities of school age children with language impairment with or without concurrent working memory impairment. Second, narrative intervention may lead to improved working memory performance or broader syntactic gains outside the context of narratives for some children. Finally, the likelihood of experiencing improvements in syntax or working memory is influenced by a number of interacting factors, including participant age, baseline cognitive and linguistic abilities, and speaking style. These findings serve as a reminder of the heterogeneity among children with language impairment and highlight the importance of accounting for that heterogeneity in research studies to facilitate selection of appropriate interventions for children with impairments. Future research should examine the extent that intervention response is affected by baseline cognitive ability, and verbal short term memory in particular, and explore alternate interventions to suit the needs of those children with lower baseline abilities.

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Appendix 3A

Developmental Progression of Complex Sentences

Level	Descriptor	Example
1	Simple infinitive	I want to go. Let's try to go.
2	Unmarked infinitive (make, let, help, watch without a 'to' marker)	Watch me swim!
	Simple conjoining (uses and, but, or, because, after, etc. to join two phrases)	I want lunch because I am hungry.
	Conjoined noun phrases	Jack and Jill went up the hill.
	Conjoined verb phrases	He chewed and swallowed his sandwich.
3	Gerund (-ing noun form, used as a verb)	Running is good exercise.
	Infinitive clause with a different subject	She wants her babysitter to make dinner.
	Simple wh- clause (uses who, what, where, when, why, how but not with an infinitive "to")	Let's see what she wants.
	Relative clause modifying the object of a main verb	The man scolded the boy who stole the bicycle.
	Nominalization in object position	Why can't you understand his rejection of the offer?
	Finite clause as object of main verb	Remember where it is?
	Subject extraposition	It was surprising for John to have left Mary
	Raising	John seems to Mary to be happy.

4	Full propositional complement/object noun phrase complement (uses think, guess, wish, know, hope, wonder, show, remember pretend, mean, forget, say, tell; may or may not contain the word that)	I hope (that) we go to lunch soon.
	Wh- infinitive (uses who, what, where, when, why, how with an infinitive "to")	I don't know what to wear.
	-ing form in complement position	He loves visiting his grandfather.
	Complements other than object noun phrase or finite clause	Remember where to go? I consider John a friend.
	Comparative with object of comparison	John is older than Mary.
5	Participle (contains an –ing modifying a noun or pronoun)	I see a man driving down the street.
	Sentences joined by a subordinating conjunction	They will play today if it does not rain.
	Nonfinite clauses in adjunct (not complement) positions	Cookie Monster touches Grover after jumping over the fence.
6	Relative clause (contains an embedded phrase that functions as an adjective; modifies an object or subject noun phrase; may be marked by who, which, that)	The man who is running fast.
	Embedded clause as the subject of the main verb	For John to have left Mary was surprising.
	Nominalization serving as subject of main verb	John's refusal of the drink angered Mary.
7	Embedded and conjoined (contains both an embedded and conjoined clause; will have 3 or more verbs)	Swimming is fun because I like to get wet. I want to stay here, but my mummy says no.
	Multiple embedding (contains more than one embedded clause, will have 3 or more verbs)	I know that we have to eat soon.

(Covington et al., 2006; Steffani, 2007)

Appendix 3B

Dynamic Assessment of Complex Sentences

Provide prompts only as necessary to elicit a form similar to the target. The task is to elicit the target grammatical form. The content of the sentence may vary. Write down the child's answers verbatim.

Target
I want to eat supper.

Prompt 1. Make a sentence with the words 'to eat'.
Prompt 2. You could start your sentence with 'I want …'
Prompt 3. You could say something like 'Bob wants to eat lunch'.

Target
She has to go.

Prompt 1. Make a sentence with the words 'to go'.
Prompt 2. You could start your sentence with 'She has …'
Prompt 3. You could say something like 'Bob has to go to the store'.

Target
Let me do it.

Prompt 1. Make a sentence with the word 'let'.
Prompt 2. You could start your sentence with 'Let me …'
Prompt 3. You could say something like 'Let her go now'.

Target
Call me tomorrow.

Prompt 1. Make a sentence with the words ‘call’.
Prompt 2. You could start your sentence with ‘Call me …’
Prompt 3. You could say something like ‘Call your mom now’.

Target
The boy and girl are jumping.
Or The boy is jumping and running.

Prompt 1. Make a sentence with the words ‘and’.
Prompt 2. You could start your sentence with ‘The boy …’
Prompt 3. You could say something like ‘The dog and cat …’

Target
Making noise is fun sometimes.

Prompt 1. Make a sentence with the words ‘making noise’.
Prompt 2. You could start your sentence with ‘Making noise is …’
Prompt 3. You could say something like ‘Being quiet isn’t always fun’.

Target
Running.

Prompt 1. Make a sentence with the word ‘running’.
Prompt 2. You could start your sentence with ‘Running is …’
Prompt 3. You could say something like ‘Riding your bike is fun’.

Target
I want you to go.

Prompt 1. Make a sentence with the words ‘you to go’.
Prompt 2. You could start your sentence with ‘I want …’
Prompt 3. You could say something like ‘I need Bob to move it’.

Target
The mom wants the baby to eat.

Prompt 1. Make a sentence with the words ‘baby to eat’.
Prompt 2. You could start your sentence with ‘The mom (wants) …’
Prompt 3. You could say something like ‘Bob needs the man to open it’.

Target
I think we’re going to leave now.

Prompt 1. Make a sentence with the word ‘think’.
Prompt 2. You could start your sentence with ‘I think …’
Prompt 3. You could say something like ‘He knows she’s playing the game’.

Target
I don’t know what to wear.

Prompt 1. Make a sentence with the words ‘what to wear’.
Prompt 2. You could start your sentence with ‘I don’t know …’
Prompt 3. You could say something like ‘She’s not sure who to ask’.

Target
He’ll tell you where to go.

Prompt 1. Make a sentence with the words ‘where to go’.
Prompt 2. You could start your sentence with ‘He’ll tell …’
Prompt 3. You could say something like ‘I told Sue how to make it’.

Target
That one is smaller.

Prompt 1. Make a sentence with the word ‘smaller’.
Prompt 2. You could start your sentence with ‘That one (is) …’
Prompt 3. You could say something like ‘The blue ball is bigger’.

Target
I hear the dog barking over there.

Prompt 1. Make a sentence with the words ‘the dog barking’.
Prompt 2. You could start your sentence with ‘I hear …’
Prompt 3. You could say something like ‘Bob sees the man driving’.

Target
The girl listens to the mom reading a story.

Prompt 1. Make a sentence with the words 'the mom reading'.
Prompt 2. You could start your sentence with 'The girl listens …'
Prompt 3. You could say something like 'Bob sees the man driving'.

Target
I ate a snack after school.

Prompt 1. Make a sentence with the words 'after school'.
Prompt 2. You could start your sentence with 'I ate …'
Prompt 3. You could say something like 'Bob washes his hands before supper'.

Target
I will go if I can.

Prompt 1. Make a sentence with the words 'if I can'.
Prompt 2. You could start your sentence with 'I will …'
Prompt 3. You could say something like 'Bob will buy it if he has enough money'.

Target
Mom asked who was knocking.

Prompt 1. Make a sentence with the words 'who was knocking'.
Prompt 2. You could start your sentence with 'Mom asked …'
Prompt 3. You could say something like 'Bob wondered when it was happening'.

Target
I don't know <u>who did it</u>.

Prompt 1. Make a sentence with the words 'who did it'.
Prompt 2. You could start your sentence with 'I don't know …'
Prompt 3. You could say something like 'I don't know how to make it'.

Target
I like to make sandwiches so I can eat them.

Prompt 1. Make a sentence with the words 'like', 'make', and 'eat' but you don't have to keep them together.
Prompt 2. You could start your sentence with 'I like …'

Target
I want to start writing a story.

Prompt 1. Make a sentence with the words 'want', 'start', and 'writing' but you don't have to keep them together.
Prompt 2. You could start your sentence with 'I want …'

Appendix 3C

Correspondence Regarding Permission to use Story Materials from Kids Can Press

January 25, 2012	Initial email sent to Kids Can Press requesting permission to use colour photocopies of pages from Willow's Whispers, Small Saul, The Boy Who Love Bananas, and Stanley's Party in a research study.
February 17, 2012	Reply from Alison Van Ginkel at Kids Can Press, directing us to seek permission from Access Copyright.
February 17, 2012	Email sent to Access Copyright requesting permission to use colour photocopies of pages from Willow's Whispers, Small Saul, The Boy Who Love Bananas, and Stanley's Party.
February 21, 2012	Reply from Access Copyright requesting further details.
February 26, 2012	Email sent to Access Copyright with ISBNs of requested books and list of pages of interest for the study.
February 27, 2012	Reply from Access Copyright indicating that reprinting 20% or less of each book would be permitted.
February 27, 2012	Email sent to Access Copyright stating we would reduce the number of pages copied to less than 20% of each book.
February 27, 2012	Reply from Access Copyright granting permission.

Note. Permission was not obtained to reprint the contents of the emails from Access Copyright; therefore, only brief summaries are presented here. Original emails are retained by Lisa Archibald.

Appendix 3D

Correspondence Regarding Permission to use Story Materials from Annick Press

January 23, 2012	Initial email sent to Annick Press requesting permission to use colour photocopies of Purple, Green, and Yellow in a research study.
February 27, 2012	Reply from Annick Press granting permission on the condition that there is no charge for the intervention and the photocopied images will not be sold (see below).

From: Lisa Archibald larchiba@uwo.ca
Subject: Re: permissions
Date: February 17, 2012 at 5:53 PM
To: Gayna Theophilus gaynat@annickpress.com

LA

Dear Gayna
Thank you very much for this message. It's wonderful.
I can provide the assurances that there is no fees involved with our intervention program, and the manipulatives will not be available outside of the research project or sold in any way.
Thank you for your confirmation.
Lisa

Lisa Archibald, PhD
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Language and Working Memory Lab
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Language, Memory and Academic Achievement Project
screening09@gmail.com

The LWM lab blog can be found at www.canadianSLP.blogspot.com

On 2012-02-17, at 4:52 PM, Gayna Theophilus wrote:

> Hello Lisa,
>
> Thank you for your request. Annick Press is pleased to grant permission for the use you have described below, provided that there is no charge for your program and that the material used as "manipulatives" will not be for sale or otherwise made available outside of this research project. Please consider this email formal confirmation.
>
> With best wishes,
> Gayna
>
> ______________
> Gayna Theophilus
> Sales & Rights Manager
> Annick Press Ltd.
> gaynat@annickpress.com

Appendix 3E

Fidelity Checklist

Fidelity Checklist – Language and Working Memory Intervention									
Date									
Person doing check									
Participant filecode									
	Check if present:								
Session 1									
Preparation of theme									
Prompts to elicit knowledge									
Reinforce semantic connections									
Reinforce phonological structures									
Share Story									
Clarification of vocabulary									
Questions									
Computer retelling									
Model linguistic forms									
Model complex sentence structures									
Reviews story aspects (character, setting, problem, plan, resolution, ending)									
Silly riddles									
Retell									
Session 2									
Preparation of theme									
Prompts for elicit knowledge									
Reinforce semantic connections									
Reinforce phonological structures									
Interactive story retelling									
Prompts for elaboration and detail									
Encourages perspective taking									
Character-based retells									
Review characters									
Identify story perspective									
Choose new perpsective									
Review story aspects from this perspective									
Before-or-after									
Retell									
Session 3									
Preparation of theme									
Prompts for elicit knowledge									
Reinforce semantic connections									

Reinforce phonological structures									
Interactive story retelling									
Provides starter									
Model complex sentences									
Prompt for details									
Conflict									
Prompts to identify problems									
Encourages consideration of alternatives									
Following directions									
Retell									
OVERALL									
Uses appropriate language level for individual child's goal									
Uses scaffolding strategies at the child's level to encourage responses									

Chapter 4

Cognitive and Linguistic Effects of Working Memory Training in Children with Specific Working Memory Impairment or Language and Working Memory Impairment

Introduction

Working memory is the domain-general cognitive process responsible for manipulation and storage of material held in the current focus of attention (Baddeley & Hitch, 1974). Working memory has been linked to other cognitive abilities, such as language (Baddeley, 2003) and intelligence (Engle, Tuholski, Laughlin, & Conway, 1999), and academic abilities, such reading (Cain, Oakhill, & Bryant, 2004) and math (Swanson, 2011; Zheng, Swanson & Marcoulides, 2011). In addition, working memory capacity in school age children has been linked with learning potential (Alloway, 2009), making it a significant predictor of academic achievements later on. This association between working memory and academic ability holds true for children with learning disabilities and impairments in reading (Dawes, Leitão, Claessen, & Nayton, 2015; Swanson, Zheng, & Jerman, 2009) and math (Swanson & Jerman, 2006). With such strong associations between working memory and academic performance, it is not surprising that much recent research has been focused on developing and testing programs designed to improve working memory capacity and functioning. Effects of working memory training are seen commonly on tasks bearing a strong resemblance to those employed in training, but effects on related abilities, such as language, reading, and math, are inconsistent (Melby-Lerväg, Redick, & Hulme, 2016; Schwaighofer, Fischer, & Bühner, 2015). Two possible reasons for these inconsistent findings are the complexities of cognitive impairments and the limitations of the large-group study designs that make up the majority of studies in this literature. Children with cognitive impairments present with a variety of profiles that may be lost in large group comparisons. The present study addresses these limitations by testing working memory training on children with isolated working memory impairment in a single subject design. It is important to note that the intervention study reported here was run in conjunction with the language intervention reported in Chapter 2.

Working Memory

Working memory is a limited-capacity processing system responsible for manipulation of material in the current focus of attention. According to Baddeley and Hitch's model (1974), working memory can be conceptualized as a three-component system consisting of two domain-specific storage systems and a central executive responsible for control of attention. One storage system is verbal short term memory, also known as the phonological loop, and is comprised of a phonological store and a subvocal rehearsal mechanism (Baddeley, 1986). Stored verbal information is subject to rapid decay unless it is maintained through either vocal or subvocal rehearsal. The second storage system is visuospatial short term memory, termed the visuospatial sketchpad, and functions parallel to verbal short term memory by storing visual and spatial information. As with verbal short term memory, memory traces of visuospatial information experience rapid decay. However, retention of such information can be supported by encoding the images verbally and storing the labels in verbal short term memory (e.g., Colle & Welsh, 1976; Conrad & Hull, 1964).

The central executive was originally conceptualized as a mechanism for attentional control. Later attempts to further understand the role of the central executive lead to the proposal of four main functions (Baddeley, 1996). Central executive was thought to be responsible for focusing attention, dividing attention between two stimulus streams, switching between tasks, and interfacing with long term memory. In a later version of the model, the episodic buffer was added to account for the ability to combine phonological and visual information into an integrated episode or chunk (Baddeley, 2000). The episodic buffer is a limited capacity buffer store thought to bind, manipulate, and retain information from both visual and phonological sources.

Working memory and language. The relation between working memory and language has been explored extensively in many contexts (see Baddeley 2003 for review). One particularly robust finding is the role of the verbal short term memory in the acquisition of new vocabulary, whether in the context of native language acquisition (Baddeley, Gathercole, & Papagno, 1998; Gathercole, Hitch, Service, & Martin, 1997), learning a foreign language (Baddeley, Papagno, & Vallar, 1988) or learning nonwords (Majerus & Boukebza, 2013). This association between the verbal short term memory and language ability has been supported by consistent findings of poor verbal short term memory ability among children with language impairment (Archibald & Gathercole, 2006; Graf Estes, Evans, & Else-Quest, 2007). Other research has demonstrated an association between verbal working memory ability and comprehension of complex syntax in both children (Montgomery, Magimairay, & O'Malley, 2008) and adults (Roberts & Gibson, 2002), suggesting that processing complex language relies on adequate support from the central executive.

Working memory may also connect to language ability by supporting language production in more demanding linguistic tasks, such as narrative retell, as was explored in Chapter 2. Based on findings that working memory impairment was associated with low quality narratives regardless of language ability, it was suggested that working memory impairment functioned as a limiting factor in narrative skill. An additional finding in

Chapter 2 was that children could be grouped according to their linguistic style, namely whether their output consisted largely of short simple sentences and minimal story content, or attempts at longer constructions with awkward wording and verbal mazes. These groups were named Simplifiers and Risk Takers, respectively. It is possible that the speaking styles of these two groups, Simplifiers and Risk Takers may have some relation to cognitive ability, a question explored in the current study. Taken together, the findings from existing literature suggest a close association between working memory and language ability.

Working memory and academic abilities. Studies have shown strong associations between working memory ability and academic abilities in reading and math (Alloway, 2009; Alloway & Alloway, 2010; Gathercole, Pickering, Kinght & Stegmann, 2004; Nouwens, Groen, & Verhoeven, 2017). For example, correlational studies have shown an association between verbal working memory and reading comprehension in university students (Daneman & Carpenter, 1980) and children (Engel de Abreu, Gathercole, & Martin, 2011). Working memory performance has also predicted accuracy on math word problems (Swanson & Beebe-Frankenberger, 2004) and various other math tasks including comparing and ordering quantities and completing arithmetic problems (Alloway & Passolunghi, 2011). Further support for the connection between working memory and academic achievement comes from research monitoring the relationship over time. For instance, growth in working memory ability has been associated with growth in accuracy of solving word problems (Swanson, 2011). In addition, working memory ability has been shown to predict reading and math skills 6 years later, even to a greater degree than nonverbal intelligence at baseline (Alloway & Alloway, 2010). Taken together, these findings suggest that working memory performance has a significant influence on academic success.

Working Memory Impairment

Deficits in working memory are not uncommon; they have been noted in a number of populations, including children with Attention-Deficit/Hyperactivity Disorder (ADHD; e.g., Martinussen, Hayden, Hogg-Johnson & Tannock, 2005), Autism Spectrum Disorder (ASD; e.g., Macizo, Soriano, & Paredes, 2016; Steele, Minshew, Luna, & Sweeney, 2007; Williams, Goldstein, Carpenter, & Minshew, 2005), and traumatic brain injury (e.g., Chapman et al., 2006; Cicerone et al., 2011; McDowell, Whyte, & D'Esposito, 1997). Working memory deficits have also been found among children with arithmetic difficulties (Swanson & Jerman, 2006) and children with low language and reading abilities (Dawes et al., 2015; Ellis Weismer, Evans, & Hesketh, 1999; Swanson et al., 2009). Such evidence suggests that working memory deficits are associated with poor performance in many other domains. One domain that has been thought to share a particularly close association with working memory is language (e.g., Baddeley et al., 1998; Leonard et al., 2007; Montgomery et al., 2008; Van der Linden et al., 1999)

In contrast, recent research has found that children may demonstrate working memory deficits despite otherwise typical neurodevelopment (Archibald & Joanisse, 2009). Using standardized tests, Archibald and Joanisse identified a group children with specific working memory impairment (SWMI), an impairment characterized by working memory scores in the impaired range but age-appropriate scores in language and nonverbal intelligence. These findings suggest that working memory and language may not be as closely associated as was proposed earlier. Instead, working memory and language may operate somewhat independently.

The presentation of working memory impairment can be difficult to pinpoint due to the concomitant impairments in many populations and the close associations between working memory and other cognitive abilities. Nevertheless, converging findings indicate that the effects of working memory impairment in children can be far-reaching.

An observational study found that children with SWMI were rated by classroom teachers as demonstrating language-related difficulties such as poor pragmatic skills and problematic behaviours such as difficulty staying on task (Archibald, Joanisse, & Edmunds, 2011). Children with low working memory have been described by teachers as inattentive (Holmes et al., 2014), highly distractible, and forgetful (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Gathercole, Alloway, et al., 2008). Teachers have also reported that students with low working memory frequently forget material already learned, leave tasks incomplete, struggle with monitoring their work, and lack creativity in problem solving (Alloway et al., 2009; Gathercole, Durling, Evans, Jeffcock, & Stone, 2008). Behavioural measures have shown that children with poor working memory have difficulty carrying out verbal instructions (Gathercole, Durling, et al., 2008), develop numeracy skills slower than typical peers (Toll & Van Luit, 2013), and have difficulty planning and executing tasks with multiple steps (St Clair-Thompson, 2011). Given these difficulties with behaviour and learning, it is not surprising that the majority of children with low working memory perform poorly on measures of reading and math (Alloway et al., 2009; Gathercole, Durling, et al., 2008). Taken together, these findings provide compelling evidence that children with poor working memory will likely demonstrate both social and academic difficulties.

Working Memory Training

Associations between working memory deficits and negative social and academic outcomes have lead to the development of many programs designed to improved working memory performance. Two such examples are Jungle Memory™ (2008) and *Cogmed* (2005). These training programs are typically comprised of a variety of activities designed to target isolated components of working memory using discrete drill-based trials. The design of the majority of these programs is in line with capacity theory (Engle & Kane, 2004), which conceptualizes working memory as a mental space that can be increased through repeated practice. Increasing working memory capacity is believed to be driven by repeated practice at the upper limits of working memory capacity. Targeting the limits of working memory is achieved by adjusting the difficulty level of each trial according to performance on the previous trial (e.g., Klingberg et al., 2005). Specifically, the level of difficulty increases with successful trials and decreases with failed trials. Training programs incorporating this approach are called adaptive. Importantly, this type of training is designed to be implicit, meaning that participants are offered no explicit instruction of meta-cognitive strategies such as chunking or rehearsal.

A major area of interest surrounding working memory training is the degree to which training gains in working memory can transfer to other tasks. Improvement in domains beyond working memory is known as far transfer, and is predicated on the assumption that increases in these domains are due to increases in working memory (Melby-Lerväg et al., 2016; von Bastian & Oberauer, 2014). Unfortunately, far transfer has been difficult to demonstrate (Melby-Lerväg et al., 2016; Schwaighofer et al., 2015), spurring much debate on the mechanisms of transfer and what might influence the extent of transfer. It has been suggested that transfer will be limited to only those untrained tasks that share a high degree of overlap in task demands or that rely on the same underlying neural networks as the training task (Dahlin, Nyberg, Bäckman, & Stigsdottir Neely, 2008; Dahlin, Stigsdotter Neely, Larsson, Backman, & Nyberg, 2008). In other words, the likelihood of transfer decreases as the difference between training and transfer tasks increases. Other influences on far transfer have included participant specific characteristics such as age, cognitive abilities, personality traits, and level of engagement in the training task (Jaeggi, Buschkuehl, Jonides, & Shah, 2011; von Bastien & Oberauer, 2014). In addition, features of the training program, such as intensity, have also influenced far transfer (Schwaighofer et al., 2015; von Bastian & Oberauer, 2014).

Evidence Base for Working Memory Training

Near transfer. Working memory training has been shown to improve performance on working memory tasks that are similar or identical to those used in the training program (Melby-Lerväg & Hulme, 2013; Melby-Lerväg et al., 2016). This type of improvement is known as near transfer. Among children with reported low working memory, studies have shown improvements on multiple components of working memory following training compared to control groups completing nonadaptive training (Dunning, Holmes, & Gathercole, 2013; Holmes, Gathercole, & Dunning, 2009) or active treatment (Gray et al., 2012). Maintenance of near transfer effects has been demonstrated at both 6 months (Holmes et al., 2009) and 12 months following training (Dunning et al., 2013). These near transfer effects are similar to those seen in children with other impairments and in healthy controls, although the effect appears to be larger for healthy controls (see Melby-Lerväg et al., 2016 for review). Despite the promising tone of these results, the effects are not likely to be noticed in functional settings because the skills showing transfer effects may not be relevant to school performance.

Far transfer. Despite successful replication of near transfer effects and close associations between working memory and academic abilities, far transfer effects following working memory training have been unsupported by research. One limitation of the current research, however, is that few studies include children with measured working memory impairment. It may be that working memory training would be more beneficial for children with specific working memory impairment than for children with average working memory capacity. Because so few studies have examined the effects of working memory training with children with low working memory, the literature reviewed here includes studies with participants who are suspected to have low working memory, such as children with learning disabilities, low language, and ADHD. Of particular interest to the present study are findings regarding transfer to language, reading, and math among children with low working memory ability.

At this point, there is limited research on the effects of working memory training on language ability. In one study (Peng & Fuchs, 2015), grade one students at risk of learning disability were trained on four verbal working memory tasks. One group received additional instruction on rehearsal strategies. Following 10 daily sessions of training, all participants were re-tested on baseline measures, including a passage listening task. For this task, children listened to a short passage and were required to retell the passage (listening retell) and answer comprehension questions (listening comprehension). At post-test the rehearsal strategy group outperformed passive controls on a verbal working memory task and both listening tasks, whereas the non-instruction group outperformed passive controls on listening comprehension alone. However, none of these differences remained significant after controlling for multiple comparisons.

More promising results were found in a second study (Holmes et al., 2015), where school age children with low language abilities and an IQ-matched typical language group completed Cogmed, the same computerized working memory training program used in the present study. Along with gains on visuospatial short term memory tasks and measures of nonverbal intelligence, improvements were seen on some nonword repetition tasks and verbal intelligence for all participants. However, no improvements were seen on the other language measures, which assessed receptive vocabulary, sentence repetition, and comprehension of spoken paragraphs.

Computerized working memory training has also lead to gains in verbal abilities for children with learning disabilities (Alloway, Bibile, & Lau, 2013) and in following instructions for children with low working memory (Holmes et al., 2009). However, in other cases this type of training was not effective at improving verbal abilities in children with ADHD (Holmes et al., 2010) or improving rhyme detection, verbal abilities, or following instructions in children with low working memory (Dunning et al., 2013).

Research examining training effects on reading performance have shown mixed results. On one hand, reading gains following working memory training have been shown for children with special needs (Dahlin, 2011), low academic performance (Holmes & Gathercole, 2014), and ADHD (Egeland, Aarlien, & Saunes, 2013). In one case (Holmes & Gathercole, 2014), training effects were seen in improved performance in school testing of reading, suggesting that working memory gains lead to improved learning potential in the classroom. In contrast, other research has shown limited effect of working memory training on reading. For instance, Gray et al. (2012) showed computerized working memory training to be no better than math training at improving reading ability among adolescents with ADHD. Similar null effects on reading have been shown for children with ADHD (van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van der Leij, & Lindauer, 2015) or those with poor reading and verbal working memory abilities (Banales, Kohnen, & McArthur, 2015).

As with gains in reading, working memory training effects on math performance are inconsistent. One study by Holmes et al. (2009) showed far transfer among school age children (mean age 10;1) with low working memory abilities. Following training with Cogmed, children showed improvement on math measures completed 6 months after the completion of the program. However, children in the control group were not reassessed at 6 months; therefore, it is impossible to rule out the effects of maturation on the increases in math scores. In another study (Dahlin, 2013), transfer to math abilities was seen in children (9–12 years) with ADHD. The effect was particularly pronounced for boys, who maintained the elevated math scores at follow-up. However, these far transfer effects also must be interpreted with caution because participants were compared with passive controls only. A third study compared the effects of two working memory training programs on children (7 years old) with poor working memory and math skills (Ang, Lee, Cheam, Poon, & Koh 2015). The group who received updating training showed slight improvements immediately following training but the difference was significant 6 months later. In contrast, the group who completed Cogmed made significant immediate gains that were not maintained at follow-up. These results are difficult to interpret in light of the Holmes et al. (2009) study, which showed the opposite trajectory for math scores following Cogmed. Other studies reported elevated math performance on classroom testing following computerized working memory training in children with low academic abilities (Holmes & Gathercole, 2014). Still other research has shown that math ability may not respond to working memory training. For instance, gains in math following working memory training were no greater than improvements following from math training (Gray et al., 2012) or even a nonadaptive version of the computerized working memory training (Karbach, Strobach, & Schubert, 2015). In addition, research has also demonstrated no transfer to math in children with learning disabilities (Alloway et al., 2013) or low working memory (Dunning et al., 2013).

Taken together, existing research offers limited evidence to support far transfer effects of working memory training among children with confirmed or possible low working memory. One possible reason for the inconsistent effects is insufficient attention to individual participant characteristics such as baseline cognitive abilities. For instance, Holmes et al. (2015) found that higher or lower baseline verbal abilities were associated with gains in different components of working memory ability. As well, Dahlin (2011) found that lower reading scores at baseline were associated with greater gains in reading comprehension. The present study aims to investigate this question by employing a single subject design, which allows for closer examination of individual progress and individual differences that may affect responsiveness to working memory training.

Study Purpose

The purpose of this study was to test the effectiveness of a working memory training program among children with working memory impairment. Of particular interest were the near and far transfer effects of working memory training to tasks tapping working memory or other skills (language, reading, math), respectively. To address these questions, a working memory training program, Cogmed, was offered to children with specific impairment in working memory (SWMI) and children with impairments in both language and working memory (LWMI). Effects of the training on both near and far transfer tasks were measured using probes, which were collected throughout baseline, intervention, and follow-up phases, and standardized measures, which were administered before, immediately after, and 3 months after the training was completed. Improvement on working memory measures only would be consistent with near transfer, whereas improvement on measures of language, reading, or math would be indicative of far transfer. In order to examine possible factors affecting transfer, response to the working memory training was compared to participant characteristics, including speaking style, baseline abilities in working memory, language, and math, and improvement on training tasks.

Methods

Participants

Participants were 7 children, 6 of whom were recruited from a database of children involved in an earlier study (Archibald, Oram Cardy, Joanisse, & Ansari, 2013), and were included in the participant group for the study reported in Chapter 2. For the previous study (Archibald et al., 2013), all children were assessed twice approximately one year apart with a battery of standardized measures of working memory, language, and nonverbal intelligence. See Chapter 2 for a description of the measures. Children also completed the standardized measures of reading and math described in Chapter 3. The parent and teacher reports described in Chapter 2 were collected in the current study as well.

For the present study, children were considered to have a working memory impairment if, at the second assessment, they scored 87 or lower on the working memory composite and the teacher reported concern in any area. As well, participants were required to present with some degree of impairment at the first time point, as demonstrated by two or more of the following: a low score (≤ 87) on the working memory composite, reported concern from a teacher or parent, a low score (≤ 87) on one or more measures of reading or math. Children were required to score in the normal range (≥ 85) on a measure of nonverbal intelligence at both time points.

In addition, children recruited to the present study were categorized based on linguistic ability at the second time point of the previous study (Archibald et al., 2013). To meet criteria for specific working memory impairment (SWMI) in the absence of language impairment, children were required to demonstrate age appropriate language skills as indicated by a *Composite Language Score* (CLS) in the normal range (≥ 86), and a discrepancy between working memory and language ability as indicated by at least a 9-point advantage for the *CLS* over the working memory composite. To meet criteria for a combined language and working memory impairment (LWMI), children were required to earn a *CLS* that was in the impaired range (≤ 85) and no more than 7 points higher than the working memory composite. The CLS was obtained from the *Clinical Evaluations of Language Fundamentals – Fourth edition* (CELF-4; Semel, Wiig, Secord, 2003), and the working memory composite was an average of 3 subtests from the *Automated Working Memory Assessment* (AWMA; Alloway, 2007; see Chapter 2 for details).

A total of 7 participants met criteria for SWMI, and 10 met criteria for LWMI. Of these, 14 could be contacted and invited to participate in the study. Ten children agreed to participate: 5 with SWMI and 5 with LWMI. Two of the children with LWMI were randomly assigned to receive the working memory training in the current study, and the remaining 3 participants with LWMI were invited to receive the language intervention outlined in Chapter 3. The descriptive statistics for all participants in the present study are presented in Table 4.1. One additional participant with SWMI was self-recruited to the study based on parent report and performance on standardized measures of working memory, language, and nonverbal intelligence (see Chapter 2).

Table 4.1

Participant Age, Sex, Language, Working Memory, and Nonverbal Intelligence

Group	*n*	male	Age[a] (yrs)	CLS	WMComp[b]	PIQ[b]
SWMI	5	3	9.65 (0.98)	98.5 (4.12)	84.25 (3.30)	103.60 (4.28)
LWMI	2	1	11.34 (1.65)	77.00 (2.82)	81.67 (1.89)	100.5 (0.71)
All participants	7	4	10.13 (1.33)	91.33 (11.62)	83.51 (3.07)	102.71 (3.82)

Note. [a] Age at point of data collection for current study. [b] Includes scores from the self-recruited participant.

General Procedure

The study timeline followed the same course as outlined in Chapter 3. In the present study, children completed a computerized working memory training program that was comprised of 20 to 25 sessions over 5 weeks. Each 40-minute session was conducted in a quiet room in the child's school or home.

Intervention Materials

Working memory training was completed on a laptop in a quiet room in the child's home or school. All participants completed the Cogmed RM program (Klingberg et al., 2005), which was designed for school age children. As per the requirements for administration, participants were provided with a set of head phones to reduce auditory distractions and a computer mouse to select responses in the program.

Intervention Procedure

The Cogmed training program required the completion of 20 to 25 sessions of approximately 40 minutes. In each session, participants completed 8 of 11 possible games, each with 15 trials. Participants could decide the order in which they completed the games. The number of items increased with the child's successes and decreased after failed trials so that the child was always working at capacity. Of the 11 games, 3 targeted visuospatial short term memory. In *Data Room*, participants saw 20 lights lining the inside walls of a box. A sequence of lights lit up in random order and the child responded by clicking on the lights in order of presentation. *Visual Data Link* followed the same procedure as Data Room, but the lights were presented in a grid of 16 lights. In *Space Whack*, participants saw space creatures pop out of a random array of craters and responded by clicking on the craters in order. Four games targeted visuospatial working memory. In *3D Cube*, panels of a 3-dimensional cube lit up as the cube rotated slightly and the participants responded by clicking on the panels in order. In *Rotating Data Link*, a grid of 16 lights rotated 90 degrees clockwise before a series of lights lit up. The grid rotated back to its home position before participants clicked on the lights in order. In *Rotating Dots*, a circle of lights constantly rotated clockwise as they lit up and as participants recalled the targets. *Asteroids* was similar to *Rotating Dots* except that the target items (asteroids) were moving randomly around the screen.

Two games targeted verbal short term memory. In *Decoder*, participants recalled sequences of spoken letters by selecting the target letter from an array of three letters for each item. In *Input Module*, participants heard sequences of numbers as the numbers lit up on a grid similar to a phone pad, and responded by clicking on the numbers in order. The final two games targeted verbal working memory. *Input Module with Lid* was similarly to *Input Module*, except that the sequences of numbers were heard while the number pad was covered, and participants were required to recall the numbers in reverse order. Finally, in *Sorter*, numbers were briefly revealed in random places on a grid and participants recalled the items in numerical order.

Throughout the training sessions, participants were accompanied by a training aide who sat with the participant during the sessions and offered encouragement. Training aides also reminded participants to take breaks or stay on task as needed. This role was filled primarily by research assistants, except for one child, who was supported by a family member.

Motivational rewards were included as part of the training program. At the end of each session, participants could play a racing game that accompanied the training program. At the end of each week, children received a small prize. These prizes had been chosen in collaboration with research assistant at the beginning of the intervention. Examples include time engaging in favourite activities in the classroom, a favourite snack, or a small gift such as a pencil and notepad. At the end of the training program, children received a larger prize, such as a movie night with family.

Study Timeline and Outcome Measures

The effect of the working memory training was assessed following the same timeline and outcome measures as were employed in Chapter 3. Briefly, probe measures were completed repeatedly during baseline, intervention, and follow-up phases. The four probe measures were designed to place demands on language (Sentence Combining), visuospatial working memory (Puzzle Completion), both language and working memory (Nonword Repetition), and neither domain (Number Comparison). An assessment battery of standardized measures was completed in an initial assessment (Time 1), immediately following completion of the training program (Time 2), and 6 months following the initial assessment (Time 3). The battery included measures of working memory (*Digit Recall,* *Counting Recall,* and *Spatial Recall* from the AWMA; Alloway, 2007), language (*Concepts and Following Directions,* and *Recalling Sentences* from the CELF-4; Semel et al., 2003), single word reading (*Sight Word Efficiency* and *Phonemic Decoding Efficiency* from the *Test of Word Reading Efficiency*; Torgesen, Wagner, & Rashotte, 1999), reading fluency (*Reading Fluency* from the *Woodcock Johnson III*; WJ-III; Woodcock, McGrew, & Mather, 2001), and math measures (*Math Fluency,* and *Calculations* from the WJ-III). From these outcome measures, near transfer was assessed with the Puzzle Completion and Nonword Repetition probes and the three AWMA subtests. Far transfer was assessed with the Sentence Combining probe and standardized measures of language, reading, and math.

Analysis

Probe measures were analyzed as in Chapter 3. Specifically, the proportion/frequency approach (Bloom, Fischer, & Orme, 2006) was employed to determine statistical significance and Busk and Serlin's (1992) standard mean difference was used to calculate effect size. Based on Cohen's (1988) guidelines and previous research (Ebert, Rentmeester-Disher, & Kohnert, 2012; Gillam, Crofford, Gale, & Hoffman, 2001), improvement of 0.8 *SD* in the probe effect sizes or standardized measures was deemed to be a meaningful change. This translated to a minimum increase of 12 standard points on measures standardized around a mean of 100 and an increase of 3 points on scaled measures standardized around a mean of 10.

Following analysis of probe measures and standardized tests, additional analyses were conducted to examine possible factors affecting response to training. First, participants were grouped according to their response to the training and the extent of far transfer effects found. Factors examined were age, comments from training coaches, concurrent improvements on training tasks and other assessment measures, as well as baseline performance on measures of working memory, language, reading, and math. Due to the small sample size and potential for multiple groups, this responder analysis was conducted qualitatively.

Second, response to working memory training was compared to each child's speaking style as determined by a narrative retell task. The speaking styles, Risk Takers and Simplifiers, are described in Chapter 2. Of relevance to this analysis was the finding (in Chapter 2) that narrative retell performance was shown to be influenced by working memory ability; therefore, it is possible that narrative retell and response to working memory training may be related. In the present study, response to the working memory training was examined in light of each participant's speaking style (Risk Taker or Simplifier, as reported in Chapter 2). Patterns among responder groups were analyzed qualitatively due to the small sample size and potential for multiple groups.

Treatment Fidelity

All participants were required to complete a minimum of 20 sessions of working memory training to complete the program with the additional requirement that each session be completed in a single sitting. A second compliance measure was the Improvement Index provided by Cogmed. It is calculated by subtracting the Start Index (based on performance of days 2 and 3 of training) from the Max Index (based on performance from 2 best training days). Some studies have set 24 as the minimum Improvement Index for indicating successful improvement (Bennett, Holmes, & Buckley, 2013; Holmes & Gathercole, 2014; Holmes et al., 2009, 2010); however, others have employed a more lenient score of 17 (Chacko et al., 2014; Gray et al., 2012). Finally, a trajectory of progress score was determined by calculating the slope of the daily index scores was for each participant. A negative slope would indicate an overall decrease in training performance, whereas a positive slope would indicate an overall increase in performance on the training tasks.

Results

Treatment Fidelity

All participants completed the required 20 sessions of working memory training (*M* = 23.9 days, range = 22 – 25 days). One participant (SWMI-5), however, was reported to show fatigue and low levels of interest in the training tasks. Therefore, the training aide for this participant decided to permit the child to complete the training tasks in two sittings each day. All other participants completed the required number of sessions in the customary timeframe.

Progress scores are reported in Table 4.2. Review of the Improvement Index Scores reveals that none of the participants met the criteria employed by Holmes and colleagues (Improvement Index of 24; Bennett et al., 2013; Holmes & Gathercole, 2014; Holmes et al., 2009, 2010) and only 3 of 7 participants met the lower criteria of 17 (Chacko et al., 2014; Gray et al., 2012). Review of the Slope scores indicates that 3 participants had an overall positive trajectory to their performance, whereas 4 showed a negative slope. Notably, one participant (SWMI-5) demonstrated a particularly steep negative slope despite earning one of the higher Improvement Index scores. This was also the same participant who reportedly demonstrated fatigue and low levels of interested in the training tasks.

Table 4.2

Cogmed Compliance and Progress Scores

	Cogmed scores			
	Start Index	Max Index	Improvement Index	Slope
SWMI-1	59	69	11	-0.19
SWMI-2	71	82	11	-0.18
SWMI-3	71	88	16	0.49
SWMI-4	68	76	8	-0.09
SWMI-5	59	75	17	-2.21
LWMI-3	53	70	17	0.63
LWMI-4	67	87	21	0.86

Probe Measures

Figures 4.1 through 4.4 present the results from the probes across baseline, intervention, and follow-up phases, indicating improvement according to the proportion/frequency approach and effect size calculations (where $d \geq 0.8$). All effect sizes (d) for probe measures are reported in Table 4.3. Studying the results of the Puzzle Completion probe (Figure 4.1) reveals intervention effects for six of seven participants as measured by both effect size and the proportion/frequency approach (SWMI-1, SWMI-2, SWMI-3, SWMI-4, SWMI-5, LWMI-3). Of these, three participants (SWMI-1, SWMI-5, LWMI-3) showed large significant effects at both intervention and follow-up phases. The remaining three (SWMI-2, SWMI-3, SWMI-4) showed large effects at both intervention and follow-up but only significant results at follow-up. Visual inspection reveals possible upward trajectories over the baseline for two of these six participants (SWMI-2, SWMI-4); however, baselines for the other four participants appear to be relatively level.

Results of the Nonword Repetition probe (Figure 4.2) showed improvements for two of seven participants. SWMI-1 demonstrated significant gains during intervention with a large effect, and LWMI-4 showed large significant effects for both intervention and follow-up phases. A remarkable feature of SWMI-1's performance is the seemingly immediate improvement even at the beginning of the intervention. Moreover, only a minimal number of data points in the intervention phase overlapped with those of the baseline phase, which contrasts with the performance of the other participants. Like SWMI-1, LWMI-4 also demonstrated consistently higher scores in intervention relative to baseline, but, unlike SWMI-1, showed treatment effects into the follow-up phase. The baseline of LWMI-4 appears to have a slight upward slope; however, the drop in performance after intervention suggests that improvement on this probe was not due to practice alone.

On the Sentence Combining probe (Figure 4.3), four participants showed treatment effects (SWMI-1, SWMI-3, SWMI-4, LWMI-4). SWMI-1 showed large significant effects for words and propositions per sentence in intervention and follow-up and a large effect for propositional density (PDensity) at follow-up. SWMI-3 showed large significant effects for words and propositions per sentence at follow-up and significantly fewer shorter sentences in intervention. Both SWMI-1 and SWMI-3 showed improvement according to multiple measures in both intervention and follow-up phases; however, a positive slope at baseline suggests that at least some of the improvement seen in later phases may be due in part to practice effects. SWMI-4 demonstrated significant gains in intervention only for PDensity and propositions with moderate effect sizes (d = 0.63, 0.64, respectively). LWMI-4 showed increases in words during the intervention and increases in PDensity during the follow-up phases with moderate effect sizes ($d = 0.56$, 0.52 respectively).

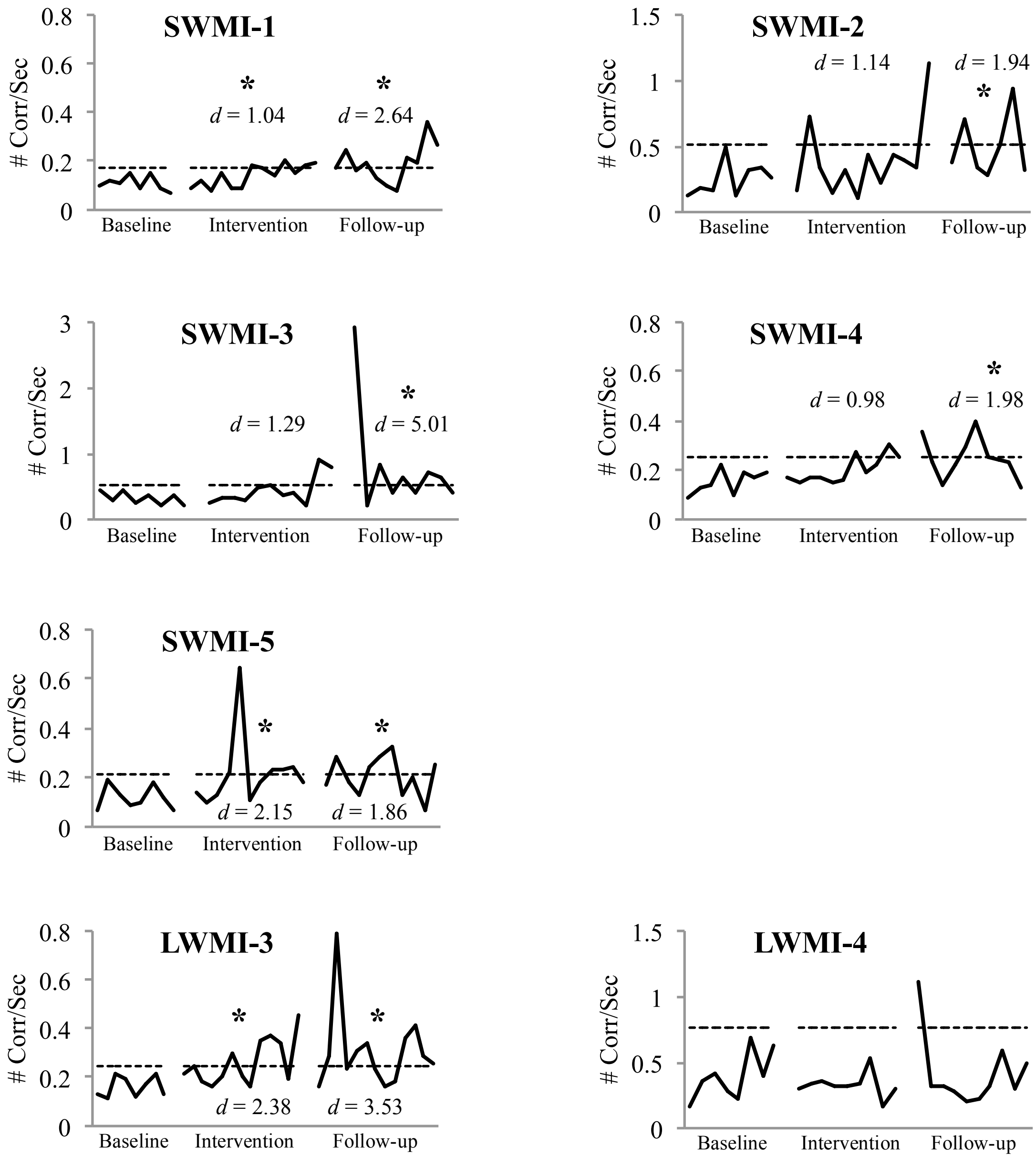


Figure 4.1. Puzzle completion probe. Graphs present the correct number of shapes selected per second averaged over all three trials for each session. Dashed line represents 2 *SD* above mean score at baseline. Asterisks indicate significant improvement using 2 *SD* limit. All unmarked effect sizes $d < 0.8$.

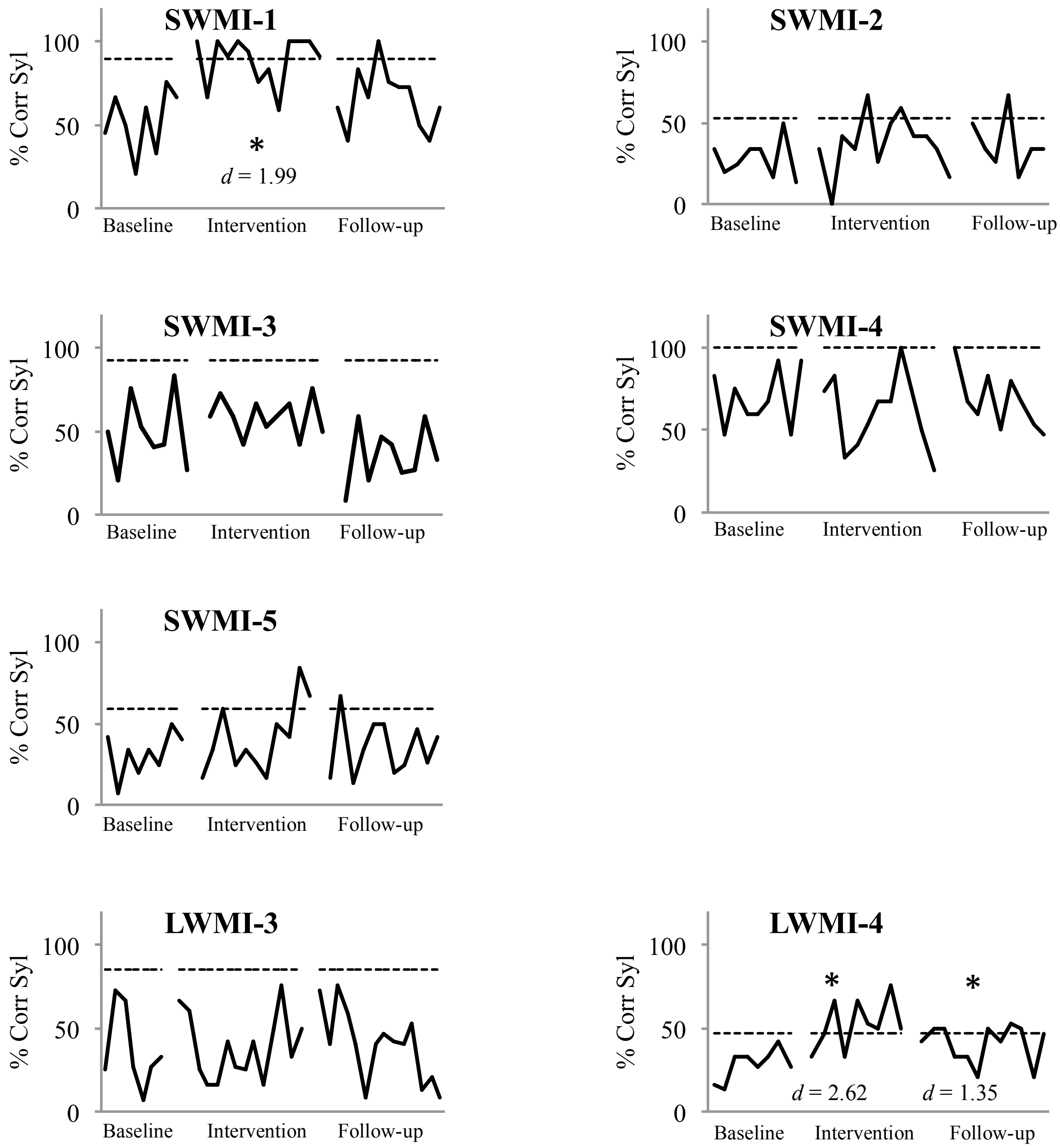


Figure 4.2. Nonword repetition probe. Dashed line represents 2 *SD* above mean baseline score. Asterisks indicate significant improvement from baseline using 2 *SD* limit. All unmarked effect sizes $d < 0.8$.

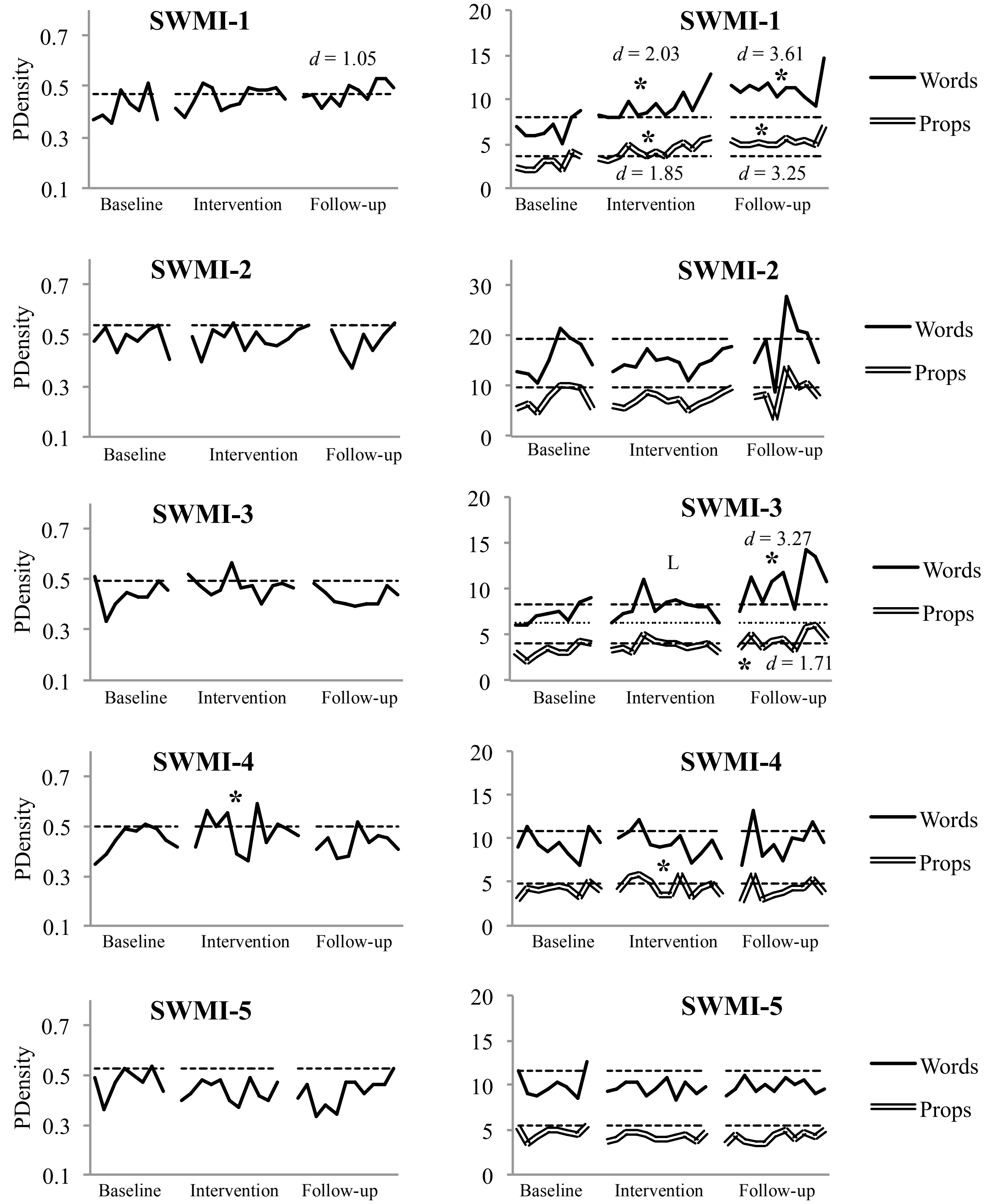


Figure 4.3. Sentence Combining probe. Graphs represent three scores averaged over each session: the ratio of propositions to words (PDensity; left column), words per trial, and propositions per trial (right column). Dashed line represents 1 *SD* above mean baseline performance (+1 *SD*). Where included, dotted line represents 1 *SD* below mean baseline performance (-1 *SD*). Asterisks indicate significance according to +1 *SD* limit. L indicates significance according to *-1 SD* limit. All unmarked effect sizes $d < 0.8$.

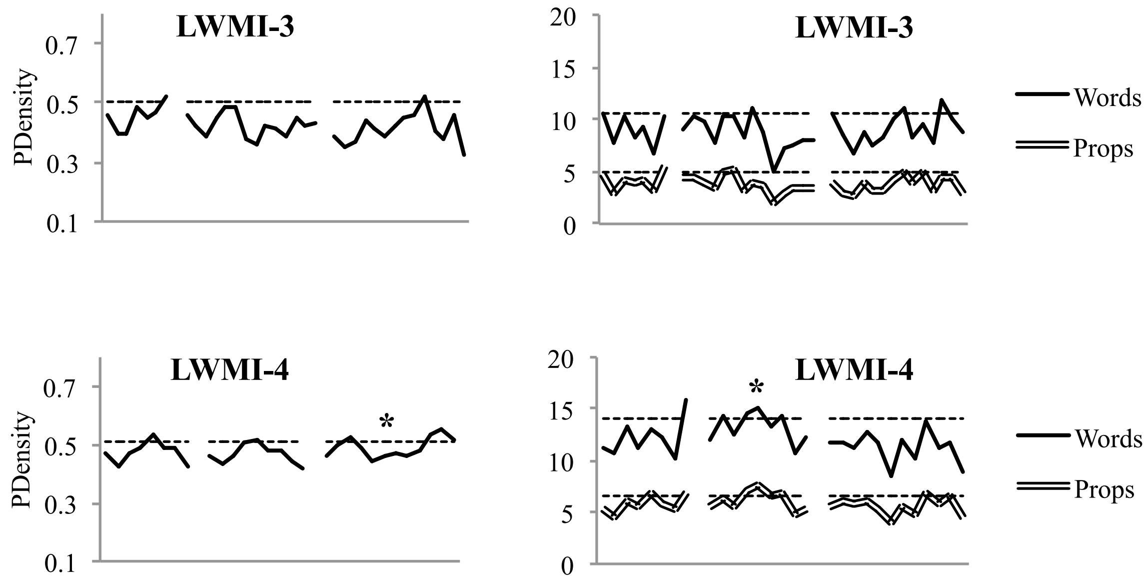


Figure 4.3 cont'd. Sentence Combining probe.

On the Number Comparison probe (Figure 4.4), all participants achieved relatively high accuracy, which resulted in the 2 *SD* cut-off exceeding the limits of the task. Therefore, the 2 *SD* limit was set to 100% for all participants. Despite high accuracy and a lenient cut-off, no participant demonstrated ceiling effects or improvement on this probe according to either the proportion/frequency method or effect size calculations.

Taken together, results of the probe measures show treatment effects for all participants (see Table 4.4). Most of the participants improved on the Puzzle Completion probe, and four participants improved on more than one probe. The one participant who did not improve on the Puzzle Completion probe (LWMI-4) showed improvements on both the language probe (Sentence Completion) and the verbal working memory probe (Nonword Repetition). Although there were some cases where participants seemed to show practice effects, none of the participants improved on the control probe (Number Comparison).

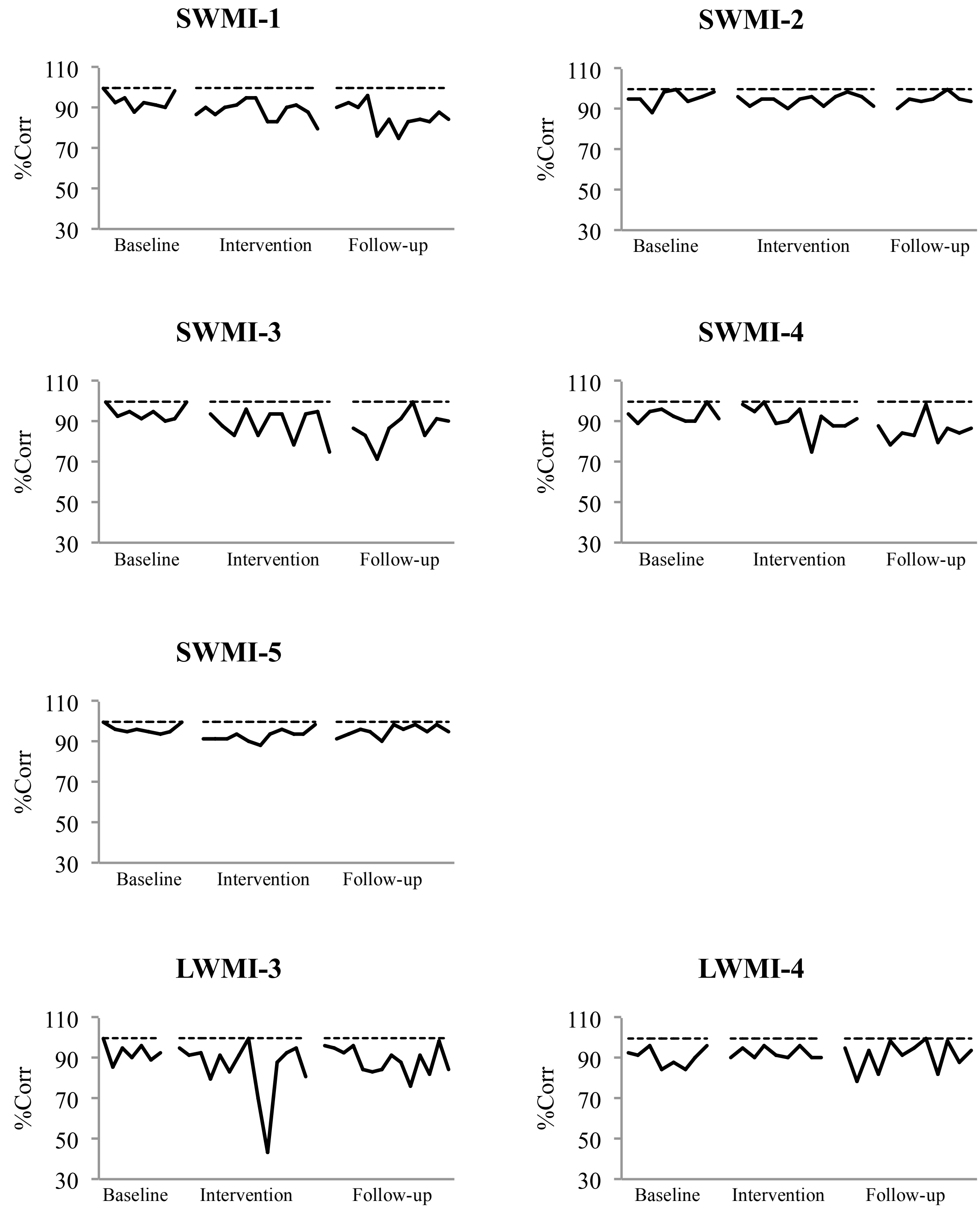


Figure 4.4. Number Comparison probe. Graphs present percent items correct from each session. Dashed line indicates 100% items correct in place of 2 *SD* limit.

Table 4.3

Effect Sizes of Probe Measures

	Sentence Combining						Nonword Repetition		Puzzle Completion		Number Comparison	
	Density		Words		Props							
Participant	I	F	I	F	I	F	I	F	I	F	I	F
SWMI-1	0.73	**1.05**	**2.03**	**3.61**	**1.85**	**3.25**	**1.99**	0.72	**1.04**	**2.64**	-1.25	-1.91
SWMI-2	0.08	-0.21	-0.18	0.65	-0.10	0.56	0.74	0.76	**1.14**	**1.94**	-0.29	-0.31
SWMI-3	0.66	-0.21	0.72	**3.27**	0.68	**1.71**	0.45	-0.61	**1.29**	**5.01**	-1.57	-1.90
SWMI-4	0.63	-0.25	0.05	0.15	0.64	0.02	-0.48	-0.10	**0.98**	**1.98**	-0.02	-0.08
SWMI-5	-0.70	-0.79	-0.25	-0.15	-0.75	-0.78	0.72	0.31	**2.15**	**1.86**	-1.42	-0.44
LWMI-3	-0.64	-0.94	-0.26	0.06	-0.43	-0.41	0.08	0.12	**2.38**	**3.53**	-1.55	-0.80
LWMI-4	-0.22	0.52	0.56	-0.52	0.53	-0.27	**2.62**	**1.35**	-0.35	0.13	-0.15	0.12

Note. I = Intervention phase, F = Follow-up phase, Large effect sizes ($d \geq 0.8$) in bold.

Table 4.4

Summary of Results from Probes and Standardized Measures of Working Memory, Language, Reading, and Math

	Probes				Standardized Measures			
	Puzz Comp	Nwd Rep	Sent Comb	Num Comp	WM	Language	Reading	Math
LWMI-3	✔[IF]							
SWMI-5	✔[IF]				SR[I]			
SWMI-1	✔[IF]	✔[I]	✔[IF]		SR[I]			
SWMI-4	✔[IF]		✔[I]			CFD[F]		
SWMI-2	✔[IF]				DR[F], CR[F], SR[I]			Calc[F]
SWMI-3	✔[IF]		✔[IF]		DR[I], CR[I]	CFD[F]		MF[F]
LWMI-4		✔[IF]	✔[IF]		SR[F]		PDE[IF], RF[IF]	

Note. ✔ Improvement in probes according to either 2 *SD* bandwidth or effect size calculations. [I] Improvement during or post-intervention. [F] Improvement during or at follow-up. Sent Comb = Sentence Combining probe, Nwd Rep = Nonword Repetition probe, Puzz Comp = Puzzle Completion probe, Num Comp = Number Comparison probe, CFD = Concepts and Following Directions, RS = Recalling Sentences, CR = Counting Recall, DR = Digit Recall, SR = Spatial Recall, PDE = Phonemic Decoding Efficiency, RF = Reading Fluency, MF = Math Fluency.

Standardized Measures

Results of standardized measures of working memory, language, reading, and math are presented in Tables 4.5 through 4.8. Standardized measures of working memory (Table 4.5) showed improvement for five participants (SWMI-1, SWMI-2, SWMI-3, SWMI-5, LWMI-4). Three participants showed increases on Spatial Recall only with two improving immediately after the intervention (SWMI-1, SWMI-5) and the third improving at follow-up (LWMI-4). One participant (SWMI-2) improved on all measures, showing gains on Spatial Recall immediately after the intervention and gains and on both verbal tasks at follow-up. One final participant (SWMI-3) demonstrated increases on the verbal measures immediately following intervention only.

Testing on standardized language measures revealed improvements for only two participants (SWMI-3, SWMI-4; Table 4.6). In both cases, gains were seen at follow-up testing only. Follow-up scores on Concepts and Following Directions for one participant (LWMI-4) could not be converted to scaled scores because the age of the participant at that point in the study exceeded the age limits of the test. The raw score, however, gives no indication of treatment effect (Scores at Time 1, 2, and 3 for Concepts & Following Directions were 47, 48, and 48). Results of standardized tests in reading (Table 4.7) and math (Table 4.8) showed limited treatment effects. Only LWMI-4 improved on reading measures (Phonemic Decoding Efficiency, Reading Fluency), but in both cases, gains were achieved post-training and at follow-up. Improvements on math measures were seen at follow-up only for two participants (SWMI-2, SWMI-3).

Table 4.5

Standardized Measures of Short Term Memory and Working Memory

	Digit Recall			Counting Recall			Spatial Recall		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SWMI-1	90	101	97	81	89	81	83	99*	94
SWMI-2	80	84	92*	86	77	98*	78	94*	75
SWMI-3	108	120*	101	89	110*	91.9	122	132	110
SWMI-4	92	88	84	83	80	80	97	97	81
SWMI-5	104	113	113	115	118	97	81	110*	87
LWMI-3	69	69	65	95	77	80	84	81	72
LWMI-4	82.9	85.8	93	107.3	107.3	96.1	77.2	87	99.5*

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.

Table 4.6

Standardized Measures of Language

	Concepts & Following Directions			Recalling Sentences		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SWMI-1	9	10	8	6	7	7
SWMI-2	9	8	8	8	9	10
SWMI-3	8	9	12*	—[a]	11	10
SWMI-4	3	5	8*	9	9	9
SWMI-5	13	12	10	10	10	12
LWMI-3	3	3	2	7	5	5
LWMI-4	6	7	—[b]	12	10	10

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was closest to 3 scaled score points. [a]Data missing due to administration error. [b]Raw scores could not be converted to scaled scores because child's age exceeded the age limits of the test.

Table 4.7

Standardized Measures of Reading

	Sight Word Efficiency			Phonemic Decoding Efficiency			Reading Fluency		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SWMI-1	93	93	97	93	95	95	93	98	100
SWMI-2	93	95	96	90	90	97	100	105	100
SWMI-3	109	107	108	104	114	105	109	105	98
SWMI-4	91	89	90	84	90	80	90	89	91
SWMI-5	119	129	122	109	108	101	110	117	115
LWMI-3	84	83	87	78	70	74	75	77	81
LWMI-4	92	96	94	77	90*	95*	81	93*	101*

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.

Table 4.8

Standardized Measures of Math

	Math Fluency			Calculations		
	Pre	Post	Follow-Up	Pre	Post	Follow-Up
SWMI-1	84	85	82	86	76	76
SWMI-2	73	71	77	83	89	97*
SWMI-3	95	98	111*	100	102	109
SWMI-4	77	78	74	74	79	73
SWMI-5	100	100	93	110	107	96
LWMI-3	74	70	67	65	72	69
LWMI-4	72	73	71	62	71	60

Note. *Clinically significant improvement over baseline performance; minimum requirement was 0.8 *SD*, which was equivalent to 12 standard points.

Overall Results

A summary of results from probe measures and standardized measures is presented in Table 4.4. Agreement between probe measures and standardized measures was seen for some participants but not others. For instance, four participants improved on both the spatial working memory probe (Puzzle Completion) and some standardized measure of working memory (SWMI-1, SWMI-2, SWMI-3, SWMI-5), but the remaining three participants improved on either the probe or standardized measures of working memory (SWMI-4, LWMI-3, LWMI-4). One of these three (LWMI-4) improved on the verbal working memory probe (Nonword Repetition) as well as the standardized measure of visuospatial working memory (Spatial Recall). With respect to language gains, of the four participants (SWMI-1, SWMI-3, SWMI-4, LWMI-4) who improved on either verbal probe (Nonword Repetition, Sentence Combining), only two made gains on a standardized measure of language (SWMI-3, SWMI-4).

Combined results reveal minimal treatment effects for some participants, but greater effects for others. For instance, two participants (LWMI-3, SWMI-5) improved on working memory measures only, but the remaining participants demonstrated evidence of treatment effect on domains beyond working memory. Two participants (SWMI-1, SWMI-4) showed improvements on language measures in addition to the improvements seen on working memory measures. One participant (SWMI-2) showed gains in arithmetic and working memory. Two other participants (SWMI-3, LWMI-4) showed increases on standardized measures of either reading or math in addition to those on working memory and language measures.

Responder Analysis

The variation in degree of response to the working memory training program warrants some investigation of what differentiates those participants who improved in working memory alone from those who showed improvement across multiple domains. Scores for all baseline measures are presented in Table 4.9. Consider first the participants who improved on only working memory measures, the working memory only group (WMO; LWMI-3, SWMI-5). In other words, these participants showed only near transfer effects. LWMI-3 was differentiated by a markedly low Digit Recall score at baseline, scoring 2 *SD* below average for a child this age. This score was low according to standardized norms and relative to the scores of the other participants in the present study. On the other hand, SWMI-5 was set apart from other participants by age, training intensity, and overall baseline abilities. Having enrolled in the study at 8.1 years old, SWMI-5 was the youngest child to participate in this study; the other participants were between 1 and 4 years older. In addition, SWMI-5 was the only participant to complete the daily training in two shorter sessions rather than one longer session, and the only participant to demonstrate a steep downward trajectory in training performance (see Table 4.10). Findings from the WMO group suggest that response to working memory training may be associated with age, training intensity, and baseline working memory ability.

Consider next the participants who improved on language probes or standardized language measures in addition to working memory measures. This includes the two participants who improved on language but not academic measures (SWMI-1, SWMI-4), those who improved on both language and academic measures (LWMI-4, SWMI-3), and one who improved on only academic measures (SWMI-2). Review of baseline scores for these 5 participants revealed a possible effect of baseline working memory on far transfer. The 2 participants who made gains in multiple domains outside of working memory (LWMI-4, SWMI-3) also had some of the highest working memory scores at baseline (Table 4.9). These participants additionally showed the greatest progress on the training tasks, as demonstrated by higher scores in Max Index and Improvement Index along with a positive slope (Table 4.10). In comparison, those participants who improved on only one domain outside of working memory showed more modest Improvement Index scores and even negative slopes.

Table 4.9

Baseline Scores for Measures of Working Memory, Language, Reading, and Math

		Working Memory Measures			Language Measures		Reading Measures			Math Measures	
	Responder Type	DR	CR	SR	CFD	RS	SWE	PDE	RF	MF	Calc
LWMI-3	WMO	69	95	84	3	7	84	78	75	74	65
SWMI-5	WMO	104	115	81*	13	10	119	109	110	100	110
SWMI-1	+La	90	81	83*	9	6	93	93	93	84	86
SWMI-4	+La	92	83	97*	3*	9	91	84	90	77	74
LWMI-4	+La,Re	82.9	107.3	77.2*	6	12	92	77*	81*	72	62
SWMI-3	+La,Ma	108*	89*	122	8*	—	109	104	109	95*	100
SWMI-2	+Ma	80*	86*	78*	9	8	93	90	100	73	83*

Note. WMO = improved on working memory measures only, +La = improved on working memory and language measures, +La,Re = improved on working memory, language, and reading measures, +La,Ma = improved on working memory, language, and math measures, +Ma = improved on working memory and math measures, DR = Digit Recall, CR = Counting Recall, SR = Spatial Recall, CFD = Concepts and Following Directions, RS = Recalling Sentences, SWE = Sight Word Efficiency, PDE = Phonemic Decoding Efficiency, RF = Reading Fluency, MF = Math Fluency, Calc = Calculations. *Improvements seen on measure at post-intervention or follow-up. — Data not interpretable due to administration error.

Table 4.10

Progress Scores from Working Memory Training Performance

	Group	Start Index	Max Index	Improvement Index	Slope
LWMI-3	WMO	53	70	17	0.63
SWMI-5	WMO	59	75	17	-2.21
SWMI-1	+La	59	69	11	-0.19
SWMI-4	+La	68	76	8	-0.09
LWMI-4	+La,Re	67	87	21	0.86
SWMI-3	+La,Ma	71	88	16	0.49
SWMI-2	+Ma	71	82	11	-0.18

Lastly, three participants showed transfer effects on academic measures (LWMI-4, SWMI-3, SWMI-2; Table 4.9). LWMI-4 was the only participant to improve on reading scores, and earned some of the lowest reading scores at baseline. Notably, compared with LWMI-3, LWMI-4 earned similar baseline reading scores, but substantially higher verbal short term memory scores. Both SWMI-2 and SWMI-3 showed gains in math at follow-up. They were also the only participants to improve on multiple standardized measures of working memory, suggesting an association between broad working memory growth and improvement in math. Interestingly, baseline math scores did not appear to differentiate SWMI-2 and SWMI-3 from other participants.

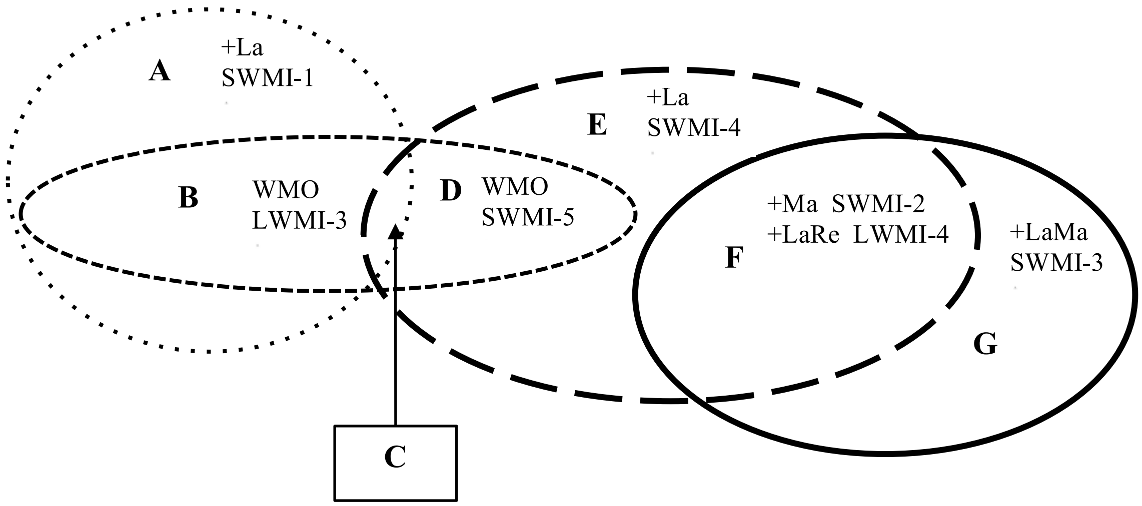
In summary, it appears that far transfer is more likely among participants with some minimum short term memory span and for those who completed the training program with the required intensity. Working memory ability seems to be linked to far transfer in that transfer to multiple domains outside of working memory was associated with higher working memory scores at baseline and greater gains on training tasks. Reading gains appeared to be associated with lower baseline reading scores whereas math gains seemed to be associated with broad working memory improvement but not baseline math scores.

Responders, Simplifiers, and Risk Takers

The final analysis compared participants' response to working memory training with the speaking style as determined in a previous study of narrative retell ability (see Chapter 2). Figure 4.5 presents a recreation of the speaking style clusters from Chapter 2, with working memory training participants included. The label of the participants indicates responder type and location of the label indicates speaking style. Simplifiers are located toward the left side of the figure whereas Risk Takers would be located toward the right side. It should be noted that these comparisons are exploratory. Nevertheless, a number of observations can be made from these data. First, both participants in the WMO group are located toward the left side of the figure, which aligns them to some degree with Simplifiers. Second, all participants who improved on reading or math are located toward the right of the figure, which suggests they are likely to be Risk Takers. Likewise 3 of 4 children who improved on language are also more closely aligned with Risk Takers. These results, termed here the Risk Taker effect, suggest there may be an association between speaking style and potential for response to working memory training, at least for these two groups.

Discussion

The purpose of this study was first to test the effectiveness of working memory training on children with working memory impairment, and second, to examine the effect of working memory training on related domains including language, reading, and math. Results of this single subject design showed near transfer effects for all participants according to improved performance on either the visuospatial working memory probe or a standardized measure of working memory. As well, over half of the participants showed far transfer effects, that is, improvements in language, reading, or math performance. In addition to making working memory gains, two participants improved on language measures, one improved on a math measure, and two others improved on both language and academic measures. A qualitative responder analysis revealed that likelihood of any kind of far transfer may be influenced by age, training intensity, and baseline verbal short term memory span. In addition, transfer to reading appeared to be more likely for children with lower reading abilities at baseline, provided verbal short term memory abilities were not severely impaired. In contrast, transfer to math appeared to be associated with broad gains in working memory rather than to baseline math abilities.



Short Sentences	Based on subjective appraisal of average sentence length.
Missing Content	Lacking some significant story event.
Clumsy Links	Difficulty joining ideas via subordination or other means.
Verbal Mazing	Hesitations (uhs, ums), false starts (repetitions at beginning of utterance), or revisions (changing what was said).

Figure 4.5. Responder analysis cross-referenced with narrative speaking style. WMO = Improved on working memory measures only, +La = Improved on working memory and language measures, +La,Re = Improved on working memory, language, and reading measures, +La,Ma = Improved on working memory, language, and math measures, +Ma = Improved on working memory and math measures.

Finally, qualitative comparison of speaking style (Simplifier, Risk Taker) with responder type revealed possible associations. It appeared those who showed limited improvements following working memory training were more likely to be characterized as Simplifiers in a narrative retell task. That is, they were likely to speak with short sentences and minimal story content. In contrast, those who made greater gains were more likely to be characterized as Risk Takers. That is, they were likely to speak with longer sentences with some awkward wording and instances of verbal mazing.

Near transfer effects found in the present study replicate those seen elsewhere both among children with low working memory ability (Dunning et al., 2013; Gray et al., 2012; Holmes et al., 2009) and among children with other ability levels (Karbach et al., 2015; Peng & Fuchs, 2015). These results were not surprising because, as in previous studies, outcome measures of working memory measured skills similar to those targeted in the training tasks. The training games and working memory measures placed similar demands on the participants, facilitating transfer.

The second aim of this study was to test the effect of working memory training on related domains, including language. The influence on language was examined by including participants with language impairment, and by measuring language gains on probes and standardized testing. Considering the results from all these methods of assessment, the influence of working memory on language ability appears to be complex. On one hand, approximately half of the participants made language gains following the working memory training. These results are in line with the divide in existing literature between those studies showing language gains (e.g., Holmes et al., 2009; Peng & Fuchs, 2015) and those that show no effect on language (Dunning et al., 2013; Holmes et al., 2010). Examining notable cases further highlights the complex association. Specifically, the particularly low baseline verbal short term memory score of one participant (LWMI-3) appeared to limit this participant’s response to the training, suggesting that adequate verbal short term memory capacity may be a prerequisite for language gains. This effect is similar to one reported in the previous chapter (Chapter 3), where lower verbal short term memory at baseline was associated with null language gains following a language intervention. In contrast, a second participant (SWMI-2) demonstrated ample evidence of working memory gains yet did not improve on any of the language measures. On one hand, the restricting factor of low working memory capacity seems to suggest that other cognitive abilities depend on working memory. On the other hand, improvement on many working memory measures without improvement on any of the language measures indicates some degree of separation between working memory and language. Instead these results suggest that while working memory is a necessary prerequisite for language gains, there are other factors influencing a child's potential for language growth.

Far transfer effects to reading and math were not widespread in this study, falling in line with findings from a recent meta-analysis showing no reliable far transfer to either reading or math (Melby-Lerväg et al., 2016). Nevertheless, the limited far transfer in the present study replicates patterns seen in other research. First, the participant who improved on reading performance had some of the lowest readings cores at baseline. This negative association between baseline reading ability and gains in reading has been found elsewhere (Dahlin, 2011; Karbach et al., 2015), suggesting that those children with weakest reading skills have the most to gain from working memory training. Findings from the current study would add that some minimum level of working memory capacity also may be required for maximum gains in reading. Second, far transfer to math performance was seen only at follow-up testing. This finding is consistent with other studies of children with confirmed or possible low working memory abilities (Dahlin, 2013; Holmes et al., 2009; Holmes et al., 2014), adding support to the notion that increases in working memory capacity set the stage for later improvements in math. This hypothesis is further supported by the finding that participants who improved in math also made the most widespread gains in working memory performance. Responder analysis did not find an effect of baseline math scores on math gains following working memory training, which is in line with the findings of other studies (e.g., Dahlin, 2013; Schwaighofer et al., 2015).

The comparison of speaking style to responder type revealed that children who attempted longer sentences and made verbal mazes in a spontaneous language sample were more likely to demonstrate far transfer to reading and math following working memory training. The exploratory nature of this comparison prompts more questions than answers. At this point the connection between language production and far transfer effects of working memory training is unclear. The simplest explanation is that some underlying factor relates to both language production and readiness to improve on scholastic tasks. In the present study however, no single baseline cognitive ability could identify participants who improved on reading or math measures. Similarly, Risk Takers and Simplifiers were not differentiated by cognitive ability in Chapter 2. Therefore, it is likely that this association is being driven by some factor not measured in this study.

Collectively, the results presented here bring to light the complexities of far transfer from working memory training and the many factors that influence it. Results of the present study have raised the possibility that far transfer may be associated to some degree with baseline ability in working memory and, for some outcome measures, baseline academic ability. However, the degree of influence these factors have on far transfer seems to vary with the domain of interest. For instance, language gains were associated with typical or moderately impaired baseline working memory performance, while reading gains were associated with low baseline reading scores. In contrast, math gains showed no obvious association with baseline scores in any domain. All of these associations, however, were overpowered by low engagement levels in one participant and particularly low verbal short term memory abilities in another, both of which seemed to constrain improvements in any domain. Along with baseline cognitive ability and engagement, some other factor appears to be associated with potential for far transfer, as was found in the comparison of responders to speaking style, revealing the Risk Taker effect. Whatever factor underlies this effect is likely to be separate from cognitive ability because no measure of language or working memory was sufficient to characterize either the Risk Takers (Chapter 2) or those who showed far transfer in the current study.

Notably, all of the possible moderating factors investigated here are specific to participants, and many overlap with findings from previous research (Jaeggi et al., 2011; von Bastian & Oberauer, 2014). These individual differences, in combination with other known influences on far transfer such as intensity of training and similarity of training and transfer task demands, are indicative of the complex nature of cognitive development and the connections between domains. Although working memory capacity is associated with performance in other cognitively demanding tasks, the large number of moderating factors shown in this study alone serves as a reminder that working memory is only one aspect of what may be driving learning deficits in children. Therefore, improvement in working memory may be only one part of what some children with learning deficits require before they are able to make functional gains in related domains.

Conclusion

In summary, a number of findings can be concluded from this study. First, working memory training can lead to immediate and long term near transfer gains among children with working memory impairment. Second, working memory training can lead to far transfer effects for some children with working memory impairment. Finally, whether or not a participant is likely to exhibit far transfer effects is heavily influenced by a number of participant-specific characteristics including baseline working memory and academic abilities. These participant-specific characteristics are not consistent across outcome measures and appear to be most informative in combination. This points to the complex interaction between working memory ability and other higher level cognitive processes and scholarly tasks. Moreover, this complex interaction speaks to the inconsistent effects of working memory training in the literature. It may be that working memory training is better suited for participants with particular profiles. Future research is needed to examine in more detail the interaction of participant characteristics that are likely to predict response to working memory training.

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Chapter 5

General Discussion

Many children with an unexplained delay in language development, known as specific language impairment (SLI), present with deficits in working memory in addition to their language impairment. Comorbid deficits in language and working memory have led to debate about the relation between thee two domains in children with impairment. Exploring the nature of this relationship informs both the understanding of the interaction between cognitive processes supporting language, as well as best practices for assessing and remediating impairments in language or working memory. The studies in this thesis examined working memory and language in children with impairments in one or both domains in the contexts of naturalistic language sampling and domain-specific intervention.

Working Memory and Language Ability in Narrative Retell

Narrative language samples offer clinicians and researchers a wealth of information about the speaker's linguistic abilities and are often used by speech-language pathologists as a naturalistic measure of communication ability. Previous research has examined the narrative abilities of children with SLI by comparing their performance to that of children without SLI and attributing any differences in performance to linguistic deficits (e.g., Gillam & Johnston, 1992; MacLachlan & Chapman, 1988; Scott & Windsor, 2000). It is possible, however, that other cognitive processes, such as working memory, support narrative ability. It may be that working memory is involved in encoding the narrative, integrating the details of the story, and generally forming a mental representation of the story (Botting, 2002; Montgomery, Polunenko, & Marinellie, 2009). Working memory may also support the formulation of syntactically complex sentences (Kemper, Herman,

& Lian, 2003), which are important for connecting elements of the narrative to form a cohesive story.

It is well documented that many children with SLI have concurrent working memory impairment (e.g., Archibald & Gathercole, 2006, 2007; Archibald & Joanisse, 2009; Ellis Weismer, Evans, & Hesketh, 1999). Considering the cognitive demands of narrative tasks and the likelihood of working memory impairment, it is possible that some narrative retell performance indicators formerly attributed to linguistic deficits may be linked to working memory ability. Three categories of performance indicators were examined in study 1: productivity, grammaticality, and fluency. Productivity refers to the amount of verbal output offered by a child. Grammaticality measures capture the grammatical complexity and accuracy within a language sample. Measures of fluency describe the flow of verbal output, and typically include rates of pausing and mazing. Working memory may influence a number of outcome measures in these categories, including narrative length (Dodwell & Bavin, 2008; Tsimpli, Peristeri & Andreou, 2016), grammatical complexity (Mills, 2005; Tsimpli et al., 2016), mazing (Levelt, 1989; Marini, Gentili, Molteni, & Fabbro 2014), and pausing (Eichorn, Marton, Schwartz, Melara, & Pirutisnky, 2016). The likely involvement of working memory in narrative retell suggests that this tool may not be a pure measure of linguistic ability, and calls for a closer investigation of the cognitive processes tested by narrative retell. The results of such an investigation could reveal which performance indicators are better markers of working memory impairment or language impairment and could inform the use of narrative retell in identifying impairment in these domains.

The goal of study 1 was to examine the contributions of working memory and language to performance on narrative retell performance, and to examine whether performance on narrative retell could point to either language or working memory impairment. A quantitative analysis tested logistic regression models to determine which outcome measures better predicted language or working memory impairment. An exploratory qualitative analysis investigated whether qualitative descriptors could distinguish narratives from children with and without impairment.

Summary of Results

The quantitative analysis revealed that language impairment was best predicted by a model that included mean length of utterance in words, percent grammatical utterances, age, and the interactions between them. Specifically, the interactions indicated that, in younger children longer utterances were associated with lower grammatical accuracy. On the other hand, in older children with typical language, longer utterances were associated with better grammatical accuracy. In older children with language impairment, however, narratives with longer utterances were associated with higher rates of grammatical error and a greater percentage of grammatically correct utterances. In other words, most of the utterances were grammatically accurate, but the few that were inaccurate contained many errors.

Further model testing revealed that working memory could not be predicted using the variables employed as predictors in the language impairment model. Instead, working memory impairment was better predicted by number of events recalled, subordinate clauses per C-unit, and their interaction. Specifically, in children with typical working memory ability, a higher number of story events was associated with lower rates of subordination. In contrast, the opposite was true for children with working memory impairment.

The exploratory qualitative analysis resulted in 22 descriptors based on linguistic features of the narratives. Comparisons of features between samples showed that some features were associated with samples from children with only language impairment, and others with samples from children with either impairment type. Further analysis revealed clusters of characteristics that pointed to contrasting speaking styles: Simplifiers, who used short, simple sentences and minimal story content; and Risk Takers, who were more likely to attempt longer sentences but also exhibit mazing and awkward attempts to link ideas. Finally, a decision tree was formulated using the descriptors to identify impairment in participants. This decision tree could correctly classify 92% of participants as impaired or typical, but could not distinguish between those with language impairment and those with working memory impairment.

Implications of Findings

Overall, children with impairment in language or working memory were differentiated from controls based on narrative retell measures. This finding replicates extensive literature demonstrating poor narrative retell abilities of children with language impairment (e.g., Duinmeijer, de Jong, & Scheper, 2012; Greenhalgh & Strong, 2001; Scott & Windsor, 2000; Thordardottir, 2008) and adds evidence to the research demonstrating an association between working memory and narrative skill (Dodwell & Bavin, 2008; Kuijper, Hartman, Bogaerds-Hazenberg, & Hendriks, 2016; Mills, 2005; Tsimpli et al., 2016). Results of model testing demonstrated that different measures of narrative performance were associated with language impairment and working memory impairment, suggesting distinct constraints based on the nature of the impairment. It follows from this that working memory capacity and language ability may contribute uniquely to narrative retell performance, a finding that has not been demonstrated elsewhere. These findings lend evidence to the argument that working memory and language are separable domains (e.g., Archibald & Joanisse, 2009). However, the results of this study also reinforce involvement of working memory in a linguistic task such as narrative retell, particularly as recall of linguistic content relates to the formulation of complex sentences. This study provides sufficient evidence to argue that impairment in working memory with or without language impairment affects how children encode and recall linguistic information, and motivates further studies examining the relationship between working memory and syntax in more detail.

Although the quantitative findings provide clear support for the separability of working memory and language, results from the exploratory qualitative analysis painted a slightly different picture. Qualitative findings showed that narratives of children with either language or working memory impairment could not easily be differentiated from each other based on readily observable features. Instead, it may be that a deeper level of analysis is required to distinguish narratives from these groups. Distinction between the influence of working memory and language was also blurred in the broad speaking style groups of Risk Takers and Simplifiers. These groups, based largely on the presence or absence of verbal mazing and attempts to construct longer utterances, did not appear to be associated with either working memory or language impairment. Instead, it seemed that some other factor was contributing to speaking style.

Clinically, these findings indicate that narrative retell performance is affected by both linguistic ability and working memory capacity as well as other factors not measured here. Although narrative tasks are useful for assessing a child's functional communication ability, poor performance should not be an assumed indicator of a primary linguistic impairment. Other measures should be administered alongside narrative retell to determine the nature of the underlying impairment constraining language performance.

Narrative-Based Language Intervention

The second and third chapters of this thesis presented the results of a second study testing the effectiveness of language intervention or working memory training with children with specific or combined impairments in language and working memory. This intervention study was designed to investigate the separability of working memory and language by examining the degree of change in the targeted and non-targeted domains following intervention. To address this question, two well-researched interventions were selected: narrative-based language intervention (e.g., Swanson, Fey, Mills, & Hood, 2005) and *Cogmed*, a working memory training program (Klingberg et al., 2005). This section will outline the results and implications of the language intervention.

Narrative-based language interventions can be designed to target both the macrostructure of a story, such as the characters, setting, and plot, and the microstructure of a story, such as syntax and vocabulary (e.g., Gillam, Gillam, & Reece, 2012; Gillam, Olszewski, Fargo, & Gillam, 2014; Klecan-Aker, Flahive, & Fleming, 1997; Petersen, Gillam, Spencer, & Gillam, 2010; Swanson et al., 2005). This type of intervention is well-suited to the purpose of the present study for a number of reasons. First, narrative ability is highly relevant to the social and academic worlds of school age children; narrative skill plays an important role in forming and maintaining peer relationships (e.g., Davidson, Walton, Kansal, Cohen, 2017; Preece, 1987), learning in the classroom (e.g., Fazio, Naremore, & Connell, 1996), and building a foundation for reading skill (e.g., Botting, Simkin, & Conti-Ramsden, 2006; Griffin, Hemphill, Camp, & Wolf, 2004).

Second, narratives provide a meaningful context in which to target complex syntax, which is a primary area of weakness for children with SLI. The story provides contextual support for the comprehension of complex sentences; and the use of complex sentences within the narratives allows the speaker to enrich the narrative by expressing temporal relations, causal relations, and character intentions.

Third, narrative ability appears to be associated with working memory capacity, as indicated by studies finding correlations between various working memory measures and narrative outcome measures (Chapman et al., 2006; Dodwell & Bavin, 2008; Kuijper et al., 2017; Tsimpli et al., 2016; Youse & Coelho, 2005). Such associations make narrative intervention an ideal medium for testing cross-domain effects of language intervention on working memory.

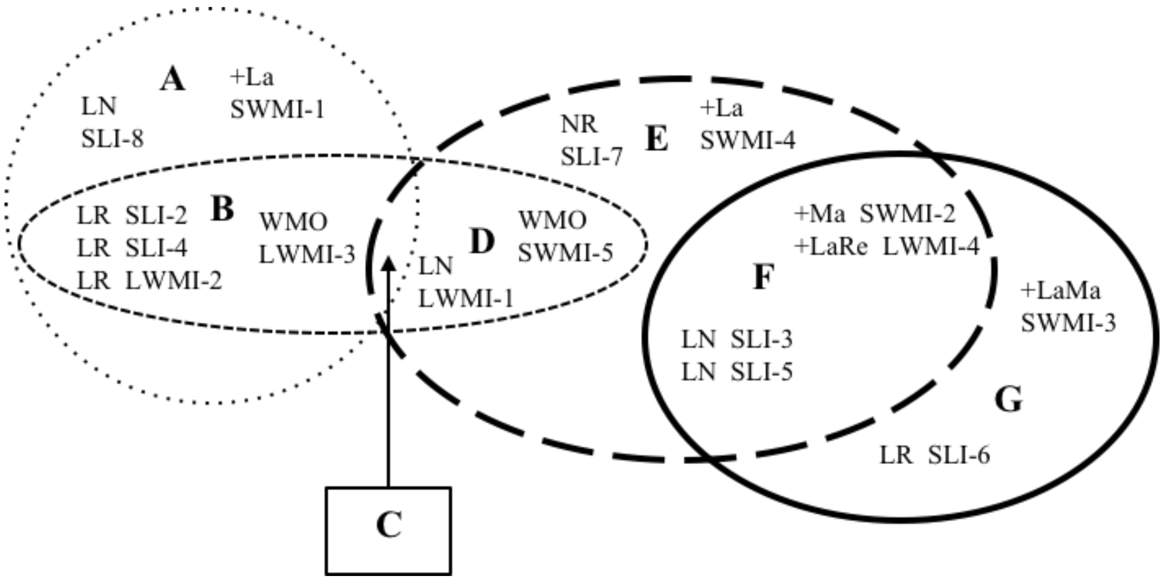
The language intervention component of this study was conducted by offering narrative-based language intervention to 8 children with SLI and 2 children with language and working memory impairment using a multiple-probe single subject design. Intervention effects were measured with probes targeting language and working memory ability, and an assessment battery of language, working memory, and academic measures. A responder analysis compared the baseline abilities of participants who did or did not show broad language gains.

Summary of Results

Effectiveness of the language intervention was evident from the improvement of at least one narrative retell measure for 9 of 10 participants. Broader linguistic effects of the intervention were seen for 5 participants according to significant improvements on both the language probe and one other measure of language. Domain-general effects of the language intervention were indicated by significant gains on the working memory probe for 5 participants, 3 of whom also improved on the language probe. In addition, carry over effects to academic abilities were limited, with 3 participants showing reading gains, and 1 showing math gains.

To examine participant-specific factors affecting intervention effectiveness, participants were grouped into Language Responders (those who improved on both the language probe and at least one additional measure of language; $n = 5$) and Language Nonresponders (the remainder of participants; $n = 5$). Responder analysis revealed a few patterns. Relative to Language Nonresponders, Language Responders had substantially higher verbal short term memory scores and receptive language scores at baseline. Other factors that appeared to restrict response to intervention were older age and lower intervention intensity. Next, Language Responders and Nonresponders were compared against the results of the qualitative narrative analysis from study 1 to explore the link between speaking style and responsiveness to language intervention (see Figure 5.1, reprinted below from Chapters 3 and 4). The main finding from this comparison was that 4 of 5 Language Nonresponders spoke in a style that was characterized by clumsy attempts to link ideas. In contrast, the majority of Language Responders (3 of 5) produced narratives with missing content and short sentences. Whereas Language Nonresponders tended to align with Risk Takers, Responders tended to align with Simplifiers.

Overall, the results of the language intervention provide strong evidence that narrative intervention improves narrative ability and syntactic skill, but equivocal evidence that narrative intervention improves working memory functioning. Limited support was found for intervention effects on reading and math.



Short Sentences	Based on subjective appraisal of average sentence length.
Missing Content	Lacking some significant story event.
Clumsy Links	Difficulty joining ideas via subordination or other means.
Verbal Mazing	Hesitations (uhs, ums), false starts (repetitions at beginning of utterance), or revisions (changing what was said).

Figure 5.1. Responder analysis cross-referenced with narrative speaking style. Participants who completed the language intervention are placed to the left of the cluster letters, and participants who completed the working memory training are placed to the right of the cluster letters. LR= Language Responder, LN = Language Nonresponder, +La = Improved on working memory and language measures following working memory training, +Ma = Improved on working memory and math measures following working memory training, +Re = Improved on working memory and reading measures following working memory training, WMO = Improved on only working memory measures following working memory training.
Note. The narrative of one participant (SLI-1) was not assigned any of these descriptors, and is therefore absent from this figure.

Implications of Findings

The findings from the narrative-based language intervention are in line with extant research in three respects: that story grammar ability is sensitive to intervention (e.g., Fey, Finestack, Gajewski, Popescu, & Lewine, 2010; Petersen et al., 2010; Swanson et al., 2005), that complex syntax can improve following narrative intervention in some cases (e.g., Davies, Shanks, & Davies, 2004; Gillam et al., 2012; Klecan-Aker et al., 1997; Petersen et al., 2010; but see Green & Klecan-Aker, 2012; Swanson et al., 2005), and that working memory function may improve following language-based intervention (Gillam & van Kleeck, 1996; Park, Ritter, Lombardino, Wisehart, & Sherman, 2014; van Kleeck, Gillam, & Hoffman, 2006). The greater sensitivity of story grammar than syntax to intervention may be related to scope. Whereas story grammar is comprised of a discrete set of concepts, complex syntax is a much broader construct to target.

Findings from the responder analysis pointed to a positive association between adequate baseline verbal short term memory and likelihood of responding to intervention targeting complex syntax. Research has shown the importance of verbal short term memory in learning novel words (Baddeley, Gathercole, & Papagno, 1998; Gupta & MacWhinney, 1997; Majerus & Boukebza, 2013); perhaps verbal short term memory also plays a key role in learning new syntactical structures. In addition, the positive association between baseline receptive language and response to intervention are in line with other research showing greater treatment effects for children with higher language abilities at baseline (e.g., Penno, Wilkinson, & Moore, 2002). Finally better language outcomes were associated with a baseline narrative speaking style characterized by short, simple sentences and minimal content. Though exploratory, these combined associations offer some insight into possible underlying influences on speaking style and response to intervention. It may be that a discrepancy between poor expressive language and relatively spared receptive language leads to greater awareness of linguistic deficits and self-monitoring. According to this view, children with greater awareness of their linguistic deficits may simplify their verbal output to avoid difficult syntactic structures, whereas children with lower awareness may either have less capacity for such linguistic planning or be less self-conscious about making revisions as the speak. This heightened linguistic awareness among Simplifiers may be a key factor in facilitating a positive response to intervention because children are already accustomed to monitoring their verbal output.

Improvements for some children on the working memory probe lends support to the view of a close association between language ability and working memory functioning among children with SLI (e.g., Ellis Weismer 1996; Montgomery & Evans, 2009). One problem with this conclusion, however, is that some of the working memory gains were achieved in the absence of language gains. Improving in one domain without showing positive effects in the other seems to support the view that working memory and language are separable domains.

Working Memory Training

The limited capacity theory of SLI suggests that limited working memory capacity can result in language deficits (Ellis Weismer, 1996). It follows from this that increases in working memory capacity should lead to improvements in linguistic ability. One well-researched approach to increasing working memory capacity is through adaptive, drill-based training programs, such as Cogmed (Klingberg et al., 2005). So far, research has shown effects of working memory training on tasks that are similar to the trained tasks, but limited transfer to performance on tasks such as language, reading, or math (Dahlin, 2011, 2013; Dunning, Holmes, & Gathercole, 2013; Gray et al., 2012; Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2015).

Despite extensive research on working memory training, there are significant gaps in the literature. First, very few studies include participants with confirmed low working memory capacity. Second, the large group designs commonly implemented in this line of research have tended to leave out investigation of participant characteristics that might influence responsiveness to working memory training. This step in the research process is particularly important when studying children with language or working memory impairment because of the inherent heterogeneity within these populations. The intervention study presented here addressed these two questions by employing a single subject design to test the effectiveness of working memory training in children with working memory impairment with or without language impairment.

Summary of Results

Two participants improved on working memory measures only. The remaining 5 participants showed treatment effects on measures of language, reading, or math. Of these, evidence of working memory and language gains were seen for 4 participants, 2 of which also improved in reading or math. The final participant improved on working memory and math measures. To examine factors affecting intervention effectiveness, qualitative responder analyses considered the effect of participant-specific factors on the type of far transfer demonstrated. These analyses revealed a possible effect of baseline cognitive ability. First, the participant demonstrating improvement on the fewest outcome measures had a markedly low baseline verbal short term memory score. Second, participants who improved in two domains beyond working memory had higher overall working memory scores at baseline. Third, low reading skills at baseline appeared to be associated with reading gains, provided baseline verbal short term memory was not severely impaired. In addition, responder analyses revealed a possible effect of working memory gains on far transfer. For one, the participants who demonstrated the greatest improvement on the training tasks showed transfer effects to multiple domains. As well, the participants who made math gains were the only ones to also improve on multiple measures of working memory. Notably, math gains did not appear to be associated with baseline math skills. Transfer to language ability appeared to be more complex: language gains were not clearly associated with baseline language scores, baseline working memory ability, or working memory gains.

Finally, comparison of intervention response with speaking style revealed possible associations between a Risk Taker speaking style and improvements in language, reading, and math (see Figure 1). Also, the children who improved only on working memory tasks produced narratives that were characterized by missing content, aligning them more with the Simplifier speaking style.

Implications of Findings

Improvement on working memory tasks replicates findings that working memory training can lead to improvement on tasks similar to those targeted in training (e.g., Dunning et al., 2013; Holmes et al., 2009). Transfer to academic measures for only some cases replicates the limited far transfer seen in the literature (e.g., Dahlin, 2011, 2013; Karbach, Strobach, & Schubert, 2015; Holmes et al., 2009, 2015; but see Melby-Lervåg, Redick, & Hulme, 2016). Associations between reading gains and low reading ability at baseline are consistent with other findings (Dahlin, 2011; Karbach et al., 2015) and suggest that children with low reading ability may have the most to gain from working memory training. Improvements in math at follow-up testing only is consistent with other studies of children with low working memory (Holmes et al., 2009), suggesting that working memory gains may set the stage for better math learning. This notion is supported by the finding that math scores increased for only those children who improved on multiple measures of working memory.

The results presented here highlight that the effect of working memory training is moderated by a complex interaction of participant-specific variables. The number of moderating variables is a reminder that many factors outside of working memory capacity contribute to each child's learning profile. Adaptive training programs may lead to functional changes for some individuals, but further research is needed in order to determine who exactly those individuals are.

General Discussion

The nature of the relationship between working memory and language in children with impairments affects both the understanding of cognitive processes and how to assess and remediate these impairments. Therefore, the studies presented in this manuscript were designed to address questions pertinent to both theoretical research and clinical work. The following discussion outlines the theoretical, clinical, and research implications from these studies.

Theoretical Implications: Working Memory and Language

One question addressed by the studies presented here was the nature of the relationship between working memory and language. If working memory and language were inseparable, then intervention gains in one domain would have been matched by gains in the other. However, this was not the case in the present study, adding evidence to the view that working memory and language are distinct cognitive processes. Additional evidence for separation was seen in the unique contributions of each domain to narrative retell performance. On the other hand, many participants did make cross-domain gains following intervention, suggesting that working memory and language may work closely together. Further support for cross-domain interaction comes from performance on the narrative retell task, where working memory ability was found to be associated with production of complex syntax. Taken together, these findings are consistent with the suggestion that working memory and language are separable but symbiotic cognitive resources (Archibald, 2017).

Clinical Implications

Heterogeneity. Findings from the intervention study suggest that narrative based language intervention and working memory training may be beneficial for children with impairments in one or both domains. However, the effect of these interventions appears to be influenced by a number of participant-specific characteristics. Such variability of intervention response is not surprising considering the heterogeneity among children with impairments, which was evident in both studies presented in this dissertation. First, the different speaking styles, as described by the qualitative analysis of the narrative retell language samples, suggest that the expressive language of children with SLI cannot be characterized by one particular set of features. Instead, some children may simplify their output using short and simple sentences with relatively few verbal mazes (i.e., Simplifiers), while others may attempt longer more complex utterances but make many revisions in the process (i.e., Risk Takers). Second, findings from the responder analyses for the intervention study demonstrated that individual differences are likely to affect how well children respond to intervention. For example, verbal short term memory span appeared to be positively associated with greater intervention effects for both working memory and language interventions. As well, higher baseline ability in the targeted domain was generally associated with better outcome. Specifically, higher receptive language scores were associated with greater effects from the language intervention, and higher working memory scores were associated with better far transfer following working memory training. Finally, the association between speaking style and responder type further highlights the influence of individual differences on treatment outcome (see Figure 1). Notably, contrasting speaking styles appeared to be associated with different responses to the two interventions: language intervention responders tended to align with the Simplifier speaking style, whereas far transfer from working memory training was more common among children with the Risk Taker speaking style.

The clear influence of individual differences in this study suggests that clinicians should carefully consider the whole profile of each child when selecting and developing interventions. For instance, children with poor verbal short term memory may benefit from adaptations that limit the short term memory requirements during intervention sessions.

Far transfer. Far transfer is considered by some to be the litmus test for the effectiveness of working memory training (e.g., Melby-Lerväg et al., 2016). Similarly, associations between language and reading seem to suggest that language intervention may lead to reading gains (e.g., Snowling & Hulme, 2012). The findings from this study suggest, however, that neither language intervention nor working memory training are likely to have far transfer effects in reading or math. Such findings are consistent with previous studies on working memory training (e.g., Gray et al., 2012; Holmes et al., 2009; Melby-Lerväg et al., 2016) and language (Bowyer-Crane et al., 2008; Westerveld & Gillon, 2008) and seem to indicate that interventions may not have immediate effects on associated domains or abilities, even if the targeted domain is thought to the be underlying problem. Instead, the results of these studies suggest that additional interventions targeting the associated domains may be required before a functional improvement is evident. For example, a child with low math ability that has been attributed to poor working memory may require intervention in both working memory and math skill. Likewise, a child with low reading ability thought to be the result of an underlying language impairment may require remediation in both language and reading.

Research Implications: Responder Analyses

The findings in the present studies highlight the importance of incorporating into research designs the investigation of participant-specific features that influence the effectiveness of the intervention in question. This is particularly vital for research directed toward clinical audiences. In the clinical context, the effectiveness of an intervention is only one factor in determining the appropriateness of an intervention; a second key factor is determining which clients will best benefit from the intervention. Although randomized controlled trials are considered the best design for testing causal relationships between interventions and outcome, averaging results from such large group designs washes out the characteristics of each individual. This lost information may reduce the generalizability of large group designs to an individual (Hersen & Barlow, 1976). Instead, future intervention studies of children with impairments should conduct either single subject designs, responder analyses, or both in order to offer more information for clinicians seeking to incorporate the tested intervention into clinical practice.

Conclusions

The studies in this manuscript examined the relationship between working memory and language in the context of naturalistic assessment and domain-specific intervention of children with impairments in one or both of those domains. Results revealed that impairment in either language or working memory can negatively affect narrative retell performance. Although differences in the effect of working memory and language impairment on narrative ability could not be detected by qualitative analysis, quantitative offline analysis revealed that language ability and working memory capacity contribute uniquely to narrative retell. The intervention study showed domain-specific effects of intervention targeting language or working memory ability with cross-domain effects in some cases. Responder analyses revealed that intervention effectiveness was inhibited by low verbal short term memory, low engagement, or reduced intervention intensity. In addition, better outcomes were seen for those participants who had better baseline scores in the targeted domain. Taken together, the findings from these studies suggest that working memory and language are separate but related cognitive processes that are mutually supportive. Responder analyses underscore the heterogeneity among children with SLI and highlight the importance of such analyses in clinical research. Overall, the findings in this thesis point to the importance of considering individual characteristics and responses to intervention to better inform clinical application of research findings.

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Appendix A

Ethics Approval

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Amendment Approval Notice

Principal Investigator: Lisa Archibald
Department & Institution: Health Sciences\Communication Sciences & Disorders,Western University

NMREB File Number: 101971
Study Title: Investigating strategies for improving outcomes for children with specific delays in language or working memory. 18622S
Sponsor: Ontario Research and Innovation Early Researcher Award

NMREB Revision Approval Date: November 21, 2014
NMREB Expiry Date: December 31, 2015

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Letter of Information	LOI - new for typically developing group	2014/10/24
Revised Western University Protocol		2014/11/17

The Western University Non-Medical Science Research Ethics Board (NMREB) has reviewed and approved the amendment to the above named study, as of the NMREB Amendment Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Et[redacted]nson, NMREB Chair

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Pauls, L. J., & Archibald, L. M. D. (2016). Executive functions in children with Specific Language Impairment: A meta-analysis. *Journal of Speech, Language, and Hearing Research*, *59*(5), 1074–1086.

Peer-Reviewed Poster Presentations:

Pauls, L., & Archibald, L. (2017). Exploring the linguistic and cognitive processes supporting narrative retell in school age children with diverse impairments. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Pauls, L., Davidson, D., & Archibald, L. (2015). Examining memory span and implicit rule knowledge across language and music abilities in children. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Pauls, L., & Archibald, L. (2015). Inhibitory control and cognitive flexibility in children with specific language impairment: A meta-analysis. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Pauls, L., & Archibald, L. (2014). Language sample analysis for language or working memory impairment: Using the right measuring stick. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Pauls, L., & Archibald, L. (2013). Outcomes for language and related domains following narrative or working memory intervention. Poster presented at American Speech-Language-Hearing Association Convention, Chicago, IL.

Pauls, L., & Archibald, L. (2013). Domain-specific intervention for children with specific or mixed impairment in language and working memory. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Pauls, L., & Archibald, L. (2013). Language and working memory: Domain specificity in intervention. Poster presented at Canada-Israel Symposium on Brain Plasticity, Learning, & Education, London, ON.

Pauls, L., & Archibald, L. (2012). Parental and teacher validation of language impairment status based on standardized tests in school age children. Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.