ANSWERING THE QUESTIONS OF "WHICH, HOW, AND WHEN": A COMPREHENSIVE INVESTIGATION OF THE RELATION BETWEEN SYNTACTIC SKILLS AND READING COMPREHENSION

by

Elizabeth J. MacKay

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

at

Dalhousie University

Halifax, Nova Scotia

June 2023

Table of Contents

List of Tables

List of Figures

Abstract

Reading comprehension, or the understanding of written texts, is a vital skill for full engagement in school and society, and, as such, is among the most important skills children learn in elementary school. One skill reliably implicated in theories of reading comprehension is syntax: the organization of words and phrases into sentences. However, there remain many open questions regarding the relation between syntactic skills and reading comprehension, including which aspect of syntactic skills matters most for reading comprehension, how syntactic skills contribute to reading comprehension, and if these relations change throughout elementary school. Thus, the overarching goal of this dissertation was to comprehensively explore the relation between syntactic skills and reading comprehension in English-speaking elementary students. This goal was accomplished through three studies, including a meta-analysis and two studies of original data collection. The results from all studies suggest that two aspects of syntactic skills — those of comprehension and awareness — are both important for reading comprehension, challenging current theories that suggest only comprehension or awareness contributes to reading comprehension. These findings also illuminate just *how* syntactic skills contribute to reading comprehension: both word reading and vocabulary mediate the relation between syntactic skills and reading comprehension. Interestingly, these relations are influenced by the aspect of syntactic skill and developmental period. Results also offer preliminary evidence of mediation for the more novel mechanism of syntactic parsing. Finally, these results indicate that these direct and mediated relations between syntactic skills and reading comprehension shift through reading development, providing further clarity as to the timeline of these relations. Together, the findings of this dissertation push the boundaries of current theoretical predictions, offer clear targets for intervention design, and, in turn, suggest potential practices for education.

Keywords: reading comprehension, syntactic skills, elementary students, meta-analysis, longitudinal design

Acknowledgements

I would like to acknowledge and give my sincerest thanks to my supervisor, Dr. Hélène Deacon, for her support over the last 10 years that we have worked together. This research and degree would not have been possible without her continued instruction, guidance, support, and understanding. In addition, these manuscripts would not have been possible without the support of the lab managers in the Language and Literacy Lab, Annie Laroche and Steph Hartlin, as well as the many research assistants and volunteers who supported in collecting and scoring the data in these chapters.

I would also like to thank my committee, Dr. Aaron Newman and Dr. Shannon Johnson, my external examiner, Dr. Mads Poulsen, as well as my comprehensive supervisors, Dr. Nicole Conrad, Dr. Sherry Stewart, and Dr. Becky Chen, for their support throughout this process. Likewise, I am very grateful for the professors who made a lasting impact on me throughout my undergraduate and doctoral training at Dalhousie University, especially Dr. Tim Juckes. Finally, I am indebted to all my clinical supervisors who supported both the academic and clinical aspects of this degree, especially Dr. Joanne Gillespie, Dr. Julie Wershler, Dr. Ena Vukatana, and Dr. Chelsea da Estrela.

And, of course, I am incredibly thankful for my family and friends, who have shown unending patience and kindness as I worked to complete this dissertation and degree. I am especially thankful for my mother and husband, both of whom I could not have done this degree without.

Chapter 1: General Introduction

Reading comprehension, the end goal of reading development (Oakhill et al., 2014; Snow, 2002), is the single most transferable skill children learn in elementary. It lays the groundwork for successful engagement in school and society (Colenutt & Toye, 2012; Petch et al., 2004). Reading comprehension is defined as the process of constructing a mental representation of written text through understanding meaning at the word and sentence levels (Perfetti et al., 2005). Reflecting its categorical importance, understanding which skills matter for reading comprehension is critical; here, we focus on syntax. Syntax is defined as how words and phrases are organized into larger phrases and sentences. Syntactic skills, then, are individuals' abilities to understand and be aware of the ways in which words and phrases are organized. Syntactic skills are likely to be highly relevant to reading comprehension: the sentences in children's texts are far more complex than those in oral language (e.g., Uccelli et al., 2015) and the complexity of syntax has been identified as the single strongest determinant of text difficulty (e.g., Graesser et al., 2011; Stenner & Swartz, 2012). These facts underscore the likelihood that children need support to best understand the sentences they read, which should then facilitate their text comprehension. This assertion is reflected by recent advocacy that children be taught how to tackle complex sentences to support text comprehension (Common Core State Standards, 2021). This practical relevance adds to theories of reading comprehension that broadly agree on the importance of syntactic skills in developing reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). Yet, despite this educational and theoretical consensus that syntactic skills matter for reading comprehension, there remain several open and theoretically contentious questions. In particular, it is unclear which aspect(s) of syntactic skills matter most for reading comprehension, how syntactic skills contribute to reading comprehension, and the ages at which

each of these relations occur. Answering such questions would respond to unresolved theoretical contention and offer data that could inform intervention designs and educational practices.

The need to answer these questions is highlighted by the fact that the Common Core State Standards (2021), a set of evidence-based curriculum benchmarks, recently recommended that children be taught how to tackle complex sentences to support reading comprehension. To keep pace with these recommendations, we need studies that clarify the relation between syntactic skills and reading comprehension; as of now, we are lacking the data to best inform classroom instruction. Despite this, educators report teaching syntactic skills in the classroom to some degree (e.g., Barnes et al., 2019; Shanahan, 2020) and literacy-focused professional development programs include modules on the importance of sentence structure (Sedita, 2007). However, the effectiveness of this instruction is largely unknown, with minimal intervention data on the success of teaching syntactic skills for reading comprehension (see Silverman et al., 2020 for a review of rare exceptions). This lack of specific guidance aligns with educators' concerns that teaching such skills is harder than other aspects of language (Barnes, 2019). These challenges are reflected in Shanahan (2020)'s comments on the misalignment between the science of reading and the science of reading instruction: he states that the questions studied in basic research are not readily applicable to reading instruction. A first step toward aligning the science of reading and science of reading instruction, then, is to produce data that indicate how to capitalize on the effectiveness of syntactic skills in the classroom. For instance, should children be taught to understand sentences as well as reflect on their structure, or is training in only one of these aspects sufficient to improve reading comprehension? Are there other skills that may benefit from training in syntax, such as word reading, which will then have knock-on effects to reading comprehension? These are the types of questions that would informing effective intervention,

which can then direct educational practices. Thus, the overarching goal of this dissertation is to offer data that respond to the open questions of which aspects, how, and when syntactic skills contribute to reading comprehension.

Theories of Reading Comprehension and the Role of Syntactic Skills

Across multiple theories, reading comprehension is considered a dynamic skill that develops from both bottom-up and top-down processes. For example, in their theory of text comprehension, van Dijk and Kintsch (1983; Kintsch, 1992) hypothesize that successful comprehension arises from creation of a textbase and a situation model. A textbase is a process wherein the reader integrates the words, phrases, and semantics of a text to understand its meaning; this represents bottom-up processing. A situation model reflects top-down processing: the situation model is a process during which a reader engages in a deeper understanding of the text by integrating the textbase with their prior knowledge. Building on these models, the Reading Systems Framework (Perfetti & Stafura, 2014) views reading comprehension as the output of the interaction between word identification – or bottom-up – processes, which include phonological, orthographic, morphological, and syntactic skills, and text comprehension – or top-down – processes, such as parsing sentences and texts, inference making, and creating a situation model.

Importantly, there is a place for syntactic skills in both bottom-up and top-down processes. In terms of bottom-up processes, such as word identification, syntactic skills may help a reader sound out a novel word by providing clues about the category to which the word belongs (Tunmer, 1989; Browne Rego, 1993). Further, according to the Lexical Quality Hypothesis (Perfetti & Hart, 2002), knowledge of syntax will help form strong word representations in one's lexicon, leading to more efficient word retrieval. Both decoding novel

words and faster word retrieval will support stronger reading comprehension. In terms of top-down processes, syntactic skills could facilitate parsing of sentences into more manageable chunks. In this case, syntactic skills may help a reader recognize where and how to divide sentences into smaller units (Gaux & Gombert, 1999; Kintsch, 1992; Perfetti & Stafura, 2014; Browne Rego, 1993), easing overall processing load and increasing availability of cognitive resources. Thus, parsing may allow for creation of more elaborate mental models of the text and thus stronger reading comprehension.

Overall, then, theories of reading comprehension identify a role of syntax, in both bottom-up and top-down processes. Yet, in the face of this universal inclusion of syntactic skills in theories of reading comprehension, several open questions remain, including which aspect of syntactic skills matters most for reading comprehension, how syntactic skills contribute to reading comprehension, and if these relations change across development.

Which Aspect of Syntactic Skills Matters Most for Reading Comprehension?

The first key question lies in which aspect(s) of syntactic skills are most important for reading comprehension. There are two most commonly described aspects of syntactic skills: syntactic comprehension and syntactic awareness. These are described in both theory and research studies. Syntactic comprehension (also referred to syntactic knowledge in the literature, see Gottardo et al., 2018; Brimo et al., 2017) is the ability to understand meanings conveyed in sentences through different syntactic constructs (Cutting & Scarborough, 2006). One way this skill is measured is through children hearing sentences of varying complexity and subsequently selecting a picture that best represents the sentence (e.g., Poulsen & Gravgaard, 2016; Sorenson Duncan et al., 2021). Syntactic awareness is the ability to reflect on and manipulate word order in sentences (Cain, 2007). Syntactic awareness is commonly measured by children hearing a

sentence with words in the incorrect order and then being asked to re-arrange the words into a proper sentence (e.g., Cain, 2007; Deacon & Kieffer, 2017). The key difference between these two aspects of syntactic skills, then, is that syntactic comprehension is a linguistic skill, whereas syntactic awareness is a metalinguistic one. Indeed, Gombert (1992) describes linguistic skills as more tacit and procedural than metalinguistic skills, which involve more explicit awareness of the rules of language. Certainly, establishing separability of these two aspects is key and something that we take on throughout these studies.

Despite the theoretical consensus that syntactic skills, broadly construed, should matter in the development of reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), there exists contention among theories as to which aspect of syntactic skills is most important. On the one hand, the Simple View of Reading (Gough & Tunmer, 1986) purport that linguistic skills – including syntactic comprehension (e.g., Melby-Lervåg & Lervåg, 2014) – are sufficient to develop reading comprehension skills. Specific to sentences, understanding a variety of syntactic structures may offer key linguistic information about the events described and help a reader keep track of a sentence's events (Kintsch, 1994). Such comprehension at the sentence level should help the reader create a mental representation of the event, which could have knock-on effects to comprehension of the sentence and, therefore, of the text (Kintsch, 1994; Perfetti & Stafura, 2014; Sorenson-Duncan et al., 2020).

On the other hand, other theories suggest that because of the explicit nature of metalinguistic skills, these skills – including syntactic awareness – should be more related to reading comprehension than linguistic skills. In Gombert's (1992) view, the ability to manipulate components of language facilitates a reader's ability to break apart complex sentences and texts, easing the process of reading comprehension. Perfetti and Stafura (2014) make similar

predictions: awareness of syntactic structure may help a reader determine the placement of clause boundaries, providing insight into the division of sentences that could make them more accessible (Perfetti & Stafura, 2014). Gaux and Gombert (1999) argue that this more explicit awareness of sentence structure allows syntactic awareness to contribute to within-sentence comprehension monitoring more than syntactic comprehension, resulting in a stronger relation of reading comprehension with syntactic awareness than syntactic comprehension.

And, of course, it is possible that both syntactic comprehension and awareness are important for reading comprehension. Syntactic comprehension might support identification of event structures, and syntactic awareness parsing of complex sentences, each with influences on reading comprehension. Further, building on the idea that syntactic comprehension develops prior to syntactic awareness (Bowey & Patel, 1988; Gombert, 1992), it may be that a positive feedback loop exists between syntactic comprehension and syntactic awareness. Understanding a variety of syntactic structures may pave the way for being able to reflect on and manipulate these structures; this explicit awareness may, in turn, support readers in understanding more complex sentence structure, and so on. While testing the relation between syntactic comprehension and syntactic awareness is beyond the scope of this dissertation, determining if each is related to reading comprehension will allow us to generate clearer predications on the ways in which these aspects may interact to bolster text comprehension. We thus test the contributions of each of syntactic comprehension and awareness to reading comprehension in each of the three studies of this dissertation.

Critically, responding to this contention also helps us advise what will offer the biggest "bang-for-our-buck" in classroom instruction. Aligning with different conceptualizations and measurements for syntactic comprehension versus awareness, the way in which these aspects are

taught may differ. For instance, to teach syntactic comprehension, an educator may focus on ensuring children understand a variety of syntactic constructs, while, for syntactic awareness, they may encourage children to rearrange the words in a sentence while maintaining the same meaning. These ideas are inspired by the only intervention study we were able to identify that targeted each of syntactic comprehension and awareness. Phillips (2014) taught syntactic comprehension by asking children to read sentences of varying syntactic structures and then asking follow-up questions to ensure comprehension; syntactic awareness was taught by asking children to create their own sentences using specific syntactic structures. This training was found to be effective in improving syntactic skills but was not linked to reading comprehension development.

As we endeavour to untangle the relation between syntactic skills and reading comprehension, we acknowledge the various developmental trajectories within the broad domain of syntax. With regard to expressive syntax, it has long been demonstrated that children are able to produce sentences of varying complexity by the time they enter school (e.g., Barako Ardnt & Schuele, 2013; Bloom et al.,1984; Paul, 1981; Tyack & Gottsleben, 1986), with children as young as three completing tasks of syntactic production (Bloom et al., 1984; Hadley et al., 2018; Limber, 1973). Relatedly, even very young children demonstrate the ability to understand basic sentences. Studies using preferential looking paradigms show that children as young as 18 months can distinguish between different syntactic order, such as “the cat watches the dog” versus “the dog watches the cat” (see Golinkoff et al., 2013, for a review). However, this level of competency does not seem to be matched for more challenging sentences: research shows that late-elementary school-aged children (e.g., Montgomery et al., 2016) and even adults (e.g., Traxler et al., 2022) struggle to understand complex sentences. In a similar vein, theories argue

that the explicit awareness of language does not develop until the elementary years, when children have had sufficient practice with complex language as well as educational exposure (e.g., Donaldson, 1978; Gombert, 1992; Herriman, 1986). These ideas are echoed by educators (see e.g., Sedita, 2007) and supported by data that shows an increase in awareness of syntactic structure throughout elementary (e.g., Oakhill et al., 2003). Thus, children seem to be able to produce sentences of various complexity and understand basic sentences, but likely have emerging abilities in their comprehension of complex sentences and awareness of all sentence types. Given that sentences are far more complex in the written than oral domain (e.g., Dąbrowska & Street, 2006; Uccelli et al., 2015) and syntactic structure is the strongest predictor of text readability (e.g., Graesser, et al., 2011; Sedita, 2007), the role of understanding and being aware of sentences in reading comprehension needs additional attention. Here, we respond to the ensuing questions of which aspects of syntactic skills relate to reading comprehension and how and when they do so.

How Do Syntactic Skills Contribute to Reading Comprehension?

A second key question lies in how syntactic skills contribute to reading comprehension. To contextualize this question, we return to our discussion of theories of reading comprehension that describe both a bottom-up and top-down role of syntactic skills in reading comprehension. As a bottom-up process, syntactic skills may contribute to reading comprehension through a skill at the lexical level, such as word reading or vocabulary. In terms of top-down processes, theories suggest that syntactic parsing – the ability to break sentences down into their respective clauses, or "chunks" – may help explain the relation between syntactic skills and reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014).

With the respect to bottom-up skills that act as a mediator in the relation between syntactic skills and reading comprehension, the most contentious possibility is word reading. Tunmer (1989) makes clear predictions that word reading should mediate the relation between syntactic skills and reading comprehension. He suggests that syntactic skills may help a reader sound out a novel word by providing clues about the category to which the word belongs. This aligns with predictions from the Lexical Quality Hypothesis (Perfetti & Hart, 2002) that ascertain that knowledge of syntax will help form strong word representations in one's lexicon, leading to more efficient word retrieval. Yet, not all theories describe such a role for word reading. For instance, Ehri (2005) argues that automatic decoding is key for successful word reading, with no input, or perhaps even a negative one, from syntactic skills. She suggests that sentence structure is more likely to slow a reader down than help them decode a novel word, which would ultimately lead to less efficient reading. This contention is further intensified because the current empirical base is mixed and small, despite many studies having the required data to explore these mediated relations. Tunmer et al. (1988) and Tunmer (1989) found that word reading mediated the relation between syntactic skills and reading comprehension in a sample of first and second grade students, findings that contrast sharply with no evidence of mediation in Deacon and Kieffer's (2017) sample of third and fourth grade students. Certainly, it is possible that developmental period played a role in these differential results; this conclusion is hard to evaluate with such a limited evidence base. Here, in our first chapter, we explore word reading as a mechanism by which syntactic skills contribute to reading comprehension in a large, meta-analytic sample.

Another potential skill that acts as a mechanism in this relation is vocabulary. Children may leverage syntactic structure to help them determine the meaning of a novel word, as

syntactic structure can help provide clues to the syntactic category (e.g., noun, verb. adjective) the new word belongs; this process is called syntactic bootstrapping. Importantly, syntactic bootstrapping is well documented to support word learning in oral language acquisition (e.g., Babineau et al., 2020; Kamil et al., 2000; Naigles, 1990). It is plausible that this benefit would extend to word learning in written language, particularly given the substantial evidence of vocabulary's unique role in reading comprehension development (e.g., Cain & Oakhill, 2014). Further, in their sample of English-speaking adults, Guo et al. (2011) found that vocabulary had a significant mediated effect on the relation between syntactic skills and reading comprehension. To our knowledge, no studies with children have addressed the mediated role of vocabulary in this relation, although many available studies have the data to explore such a relation. Thus, in our first chapter, we address whether these bottom-up processes help explain the relation between syntactic skills and reading comprehension by conducting mediated meta-analyses.

In terms of top-down processes, one explanation that arises in theories is syntactic parsing (e.g., Perfetti & Stafura, 2014); to our knowledge, this mechanism has not been empirically linked to reading comprehension. In terms of parsing, a reader is hypothesized to use their knowledge and awareness of a sentence's structure to divide the sentence into manageable chunks, thus easing cognitive load and bolstering comprehension of the sentence's meaning (see also Deacon & Kieffer, 2017). Take, for instance, the following sentence: "The boy talked to the girl who was wearing a black shirt while his parents waited". Dividing this long and complex sentence into its relevant pieces of "The boy talked to the girl", "who was wearing a black shirt", and "while his parents waited" should make the meaning of the sentence more accessible than if the reader tries to gain the meaning from a string of 16 words. Even young children have been shown to parse complex sentences in oral language (e.g., Weighall & Altmann, 2011), with no

evidence on how this ability impacts reading comprehension. In our fourth chapter, we take the novel steps of exploring the role of syntactic parsing as an explanation for how syntactic skills contribute to reading comprehension in a longitudinal, autoregressive design, following students from first to fourth grade.

Do Relations between Syntactic Skills and Reading Comprehension Change with Age?

Given that reading skills develop across elementary school years, a final query is whether developmental period affects the relations between syntactic skills and reading comprehension. Indeed, some suggest that the relation between syntactic skills and reading comprehension should be larger in older than younger elementary students, due, in part, to the greater sentence complexity in texts that older students read as compared younger students (e.g., Curran, 2020; Jagaiah et al., 2020). Such longer and more complex sentence structures might allow older children to leverage their syntactic skills to best understand such structures; these skills may not be as necessary for the comparatively basic sentences younger children read.

This shift might be particularly relevant for syntactic awareness: the longer and more complex sentences in texts for older children may require greater metalinguistic awareness of sentence structure. Gombert (1992; see also Gaux & Gombert, 1999) makes clear predictions that this should be the case; as he explains, syntactic awareness, and not comprehension, is what allows readers to break down sentences into units, which works to ease overall processing load and improve comprehension. This skill is crucial for understanding long and complex sentences. Several theories have also argued that young children (i.e., ages 6-7; Donaldson, 1978; Gombert, 1992; Herriman, 1986) have emerging syntactic awareness skills, thus restricting their ability draw on such skills to support their text comprehension in the same way older children might. Again, then, we may find that syntactic awareness is more related to reading comprehension in

older than younger children. Yet, there is evidence of improvements in both aspects of children's syntactic skills across the elementary school years (e.g., Oakhill et al., 2003), presenting the possibility that, even if not fully developed, younger children may still utilize their syntactic awareness skills to some degree to support text comprehension. Critically, these improvements might match the increased syntactic complexity of the texts that children read, leading to consistency in the magnitude of the relation between syntactic awareness and reading comprehension in younger and older children.

Developmental effects may also exist for the questions of *how* syntactic skills relate to reading comprehension. For instance, children may pull on sentence-level skills to support their word reading and vocabulary development when these skills are in a period of intense development, typically in the younger elementary years (Phythian-Sence & Wagner, 2007; Whitehurst & Lonigan, 1998). Indeed, Tunmer (1989) predicted that understanding and awareness of a sentence's structure should help a child decode novel words by placing constraints on the type of word the unknown word could be. It may be that children are more likely to need this extra support when their decoding skills are still emerging, as compared to when such skills are more fluent. One could make parallel predictions for vocabulary: children may need the additional support of sentence structure to determine the meaning of novel words when many words in a text are new, which tends to be the case for younger as compared to older elementary children. We may see the developmental shift in the role of vocabulary as children progress through the vocabulary "boom" of middle elementary (Merritt, 2016). Yet, readers are consistently encountering new words in text (Hulme et al., 2018; Hulme et al., 2022; Nagy et al., 1987), so we may find that younger and older elementary students leverage sentence-level skills

to a similar magnitude to uncover the meaning of novel words. Certainly, these ideas require empirical testing.

Combining results across the three available empirical studies that investigate the mediated effect of word reading on syntactic skills and reading comprehension support the possibility of developmental effects. In two studies of first and second grade students, Tunmer (1988; 1989) found that word reading mediated the relation between syntactic skills and reading comprehension, but in their study of third and fourth grade students, Deacon and Kieffer (2017) did not find a mediated effect. To our knowledge, no studies with younger and older elementary students exploring the mediated effect of vocabulary exist. In our second chapter, we address these potential developmental shifts in the mediated effects of word reading and vocabulary on the relations between syntactic skills and reading comprehension by conducting moderated, mediated meta-analyses.

Present Study

To clarify the role of syntactic skills in the development of reading comprehension abilities, we ask three theoretically and educationally important questions: (1) which aspects of syntactic skills matter most for reading comprehension; (2) how syntactic skills contribute to reading comprehension; and (3) whether the relations between syntactic skills and reading comprehension change with age. These three questions are addressed across three studies with English-speaking elementary-aged students.

Our first question of which aspects of syntactic skills – syntactic comprehension and/or awareness – matter most for reading comprehension responds to unresolved theoretical contention (e.g., Gombert, 1992; Gough & Tunmer, 1986) regarding what kind of sentence-level skills children need to support their text comprehension. We address this question in three ways.

We report on a meta-analysis that explores the magnitude of the relations between each of syntactic comprehension and awareness to reading comprehension in elementary-aged children (Chapter 2). We then conduct two separate studies that explore the relative contributions of each of syntactic comprehension and awareness to reading comprehension, one with a cross-sectional design with children in third to fifth grade children (Chapter 3) and the other with a longitudinal, autoregressive design of students from first to fourth grade (Chapter 4). Together, these three studies test the size of the contribution of each of syntactic comprehension and awareness to reading comprehension across the elementary years.

Our next question addresses the mechanism by which the relation between syntactic skills and reading comprehension functions. This question is well-informed by theories of reading comprehension (e.g., van Dijk & Kintsch 1983; Perfetti & Stafura, 2014) that conceptualize reading comprehension as a skill characterized by bottom-up and top-down processes. Specifically, such theories highlight that lexical skills, such as word reading and vocabulary, contribute to reading comprehension through bottom-up processes. Conversely, broader language skills, such as syntactic parsing, support reading comprehension via top-down processes. This question is also supported by models that explicitly describe a role of mediators in the relation between syntactic skills and reading comprehension (e.g., Tunmer, 1989). We explore the possibility of bottom-up mechanisms – specifically, word reading and vocabulary - using a mediated meta-analytic design (Chapter 2). We examine whether the top-down process of syntactic parsing helps explain the relation between syntactic skills and reading comprehension in an autoregressive, longitudinal design following children from first to fourth grade (Chapter 4).

Finally, we explore developmental shifts in the relations between syntactic skills and reading comprehension, including in the mechanisms that may enable these relations. Doing so helps delineate when each aspect matters and if how they relate to reading comprehension changes throughout development. Answering these questions will likely go some way in providing guidance as to what educators should be doing in the classroom: for example, given that younger readers are reading less complex texts, should their instruction focus on syntactic comprehension? On the other hand, should older students, who read more complex texts, learn about syntactic awareness? With respect to mechanisms, given young reader's novice word reading skills, would it be more effective to target syntactic skills to support word reading in younger instead of older readers? We investigate these important developmental effects in moderated meta-analytic designs (Chapter 2) and by comparing results from a cross-sectional study of older students (Chapter 3) with a separate longitudinal study of younger students (Chapter 4). Thus, we are well positioned to respond to this question of developmental shift, both within and across the papers included in this dissertation.

Chapter 2: A Meta-Analysis on the Contribution of Syntactic Skills to Reading Comprehension

Abstract

The ability to understand what one reads, or reading comprehension, sets the stage for successful academic learning and full societal participation. Here we present a meta-analysis focusing on syntactic, or sentence-level, skills. In the face of widespread theoretical predictions of their relevance to reading comprehension, the questions of which aspects of syntactic skills matter most and whether there is mediation and/or developmental change in these relations are unanswered. We conducted a meta-analysis of available empirical studies with English speaking elementary school-aged children to address these questions. After abstract and full-text screening, we identified 40 studies on the relation between reading comprehension and syntactic skills—assessed with syntactic comprehension and/or awareness tasks. Correlational meta-analyses show that syntactic skills are significantly related to reading comprehension in first to sixth grade English speaking children. This relation holds across both syntactic comprehension and awareness and both younger and older elementary-school aged children. Mediation meta-analyses reveal that syntactic skills are related to reading comprehension through each of word reading and vocabulary, with some indications of greater mediation for younger children. We discuss implications of these results for theory, including highlighting key avenues for future research.

Keywords: syntactic skills, syntactic comprehension, syntactic awareness, reading comprehension, elementary-aged children

Introduction

The ability to understand what one reads, or reading comprehension, is a critical skill for success in school and society (e.g., Colenutt & Toye, 2012). Reading comprehension is defined as the process of constructing a mental representation of written text through understanding at the word and sentence levels (Perfetti et al., 2005). Substantial research has been directed to understanding contributions to reading comprehension at the word level (e.g., Bowers et al., 2010; Hjetland et al., 2017), with far less attention to the sentence level. The term syntax refers to this sentence level, defined as the organization of words and phrases into sentences (e.g., Dawson & Phelan, 2016). Syntax is likely to be highly relevant to reading comprehension because the sentences in children's texts are far more complex than those in oral language (e.g., Uccelli et al., 2015). Indeed, the complexity of syntax has been identified as the single strongest determinant of text difficulty (e.g., Graesser et al., 2011; Stenner & Swartz, 2012). In line with this applicability, theories of reading comprehension widely include sentence level skills as important to reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), because a barrier at the sentence-level will certainly hinder an ability to gain meaning from the text. Further, educational policies advocate teaching children to tackle complex sentences to support text comprehension (Common Core State Standards, 2021).

In the face of this conceptual, theoretical, and educational enthusiasm, the empirical evidence to date is equivocal as to the relation of syntactic skills to reading comprehension. Key differences in studies to date - such as specific aspects of syntactic skills measured, mediators tested, and the age range investigated (e.g., Cain, 2007; Deacon & Kieffer, 2017) - are likely relevant (see MacKay et al., 2021, for a discussion). Meta-analytic approaches are powerful in such a case. For instance, there is contention among theories regarding which aspect of syntactic

skills – syntactic comprehension or awareness – should matter more for reading comprehension, with the further possibility that their relative importance shifts across development (e.g., Biemiller, 2014; Curran, 2020; Gombert, 1992). These questions have been difficult to resolve, with very few studies including both aspects in analyses (see Bowey & Patel, 1988; Brimo, Apel, et al., 2017; Cain, 2007, for exceptions). Yet, there are adequate data when collated across studies, making meta-analytic techniques particularly useful to address such questions. Similarly, there are contentious predictions regarding mediators in the relation between syntactic skills and reading comprehension, including the age at which these mediated relations likely occur (e.g., Tunmer, 1989). Again, there are limited published analyses testing these predictions (see Deacon & Kieffer, 2017; Tunmer et al., 1988; Tunmer, 1989 for exceptions), even though many studies have the required data to conduct such analyses. We conduct a meta-analysis designed to leverage the impact of this statistical technique by analysing existing data to answer the questions of which aspect(s) of syntactic skills matter most for reading comprehension, whether mediators are present in this relation, and if these direct and mediated relations shift across reading development.

This empirical evidence is also valuable in delivering on the educational potential of syntax; meta-analytic data can help inform which aspects of syntactic skills should be taught and when this teaching may be most fruitful. Despite the lack of detailed evidence-based advice, teachers seem to be teaching syntactic skills (e.g., Barnes et al., 2019; Shanahan, 2020); the feasibility and effectiveness of such interventions to support their students' text comprehension are unknown. Accordingly, educators have noted that teaching children about syntax is harder than other parts of language, such as academic vocabulary (Barnes et al., 2019). This underscores the importance of implementing guidelines that advise on teaching children how to tackle

complex sentences to support text comprehension (e.g., Common Core State Standards, 2021). It is recommended that language skills are taught with "direct, systematic, explicit structured" methods to enhance reading outcomes (Moats, 2010, pg. 16; see also Moats, 2020; Wolf, 2018); doing so indeed requires specific guidance. For instance, is it enough that children are taught to understand sentences, as captured in syntactic comprehension (e.g., Gough & Tunmer, 1986), or do they need to be taught to manipulate them, as captured in syntactic awareness (e.g., Gombert, 1992)? Similarly, should this instruction connect sentences to word reading and/or vocabulary? Should such teaching be targeted at younger readers, who might need most support with word reading and vocabulary, or to older readers who are tackling more challenging texts? Overall, we are left with a set of skills that educators are told to teach with little associated data for the most effective way to do so. One steppingstone toward bridging this gap between evidence and practice is by leveraging meta-analytic data to investigate which syntactic skills matter most for reading comprehension and how and when they do so.

Aspects of Syntactic Skills and Their Relations with Reading Comprehension

Our first question lies in the aspects of syntactic skills that matter for reading comprehension. While theories of reading comprehension widely advocate for the role of sentence-level skills, there is discord concerning what *type* of sentence-level skill should contribute to reading comprehension. To date, the aspects of syntactic skills that have received the most theoretical and empirical attention are syntactic comprehension and syntactic awareness. Syntactic comprehension is a linguistic skill that reflects the ability to understand spoken sentences (Poulsen & Gravgaard, 2016). To assess this skill, children may hear a sentence and are asked to select a picture that best matches the sentence. Syntactic awareness is the metalinguistic skill of reflecting on or manipulating spoken sentences (Cain, 2007). Syntactic

awareness may be assessed with a word-order correction task, on which children hear a sentence with words in an incorrect order and are asked the make the sentence “sound right”.

In terms of syntactic comprehension, the idea that understanding sentences supports reading comprehension aligns with the Simple View of Reading (Gough & Tunmer, 1986). According to the Simple View of Reading, reading comprehension is the product of decoding and linguistic comprehension. The Simple View of Reading describes linguistic comprehension as the skills required to comprehend written texts; these include phonology, morphology, syntax, semantics, and pragmatics (Apel, 2022; Bloom & Lahey, 1978). Thus, syntactic comprehension falls under the umbrella of linguistic comprehension, with empirical confirmation of this relation (e.g., Kim, 2020). The Simple View of Reading does not explicitly include metalinguistic skills, which extends to syntactic awareness (but see Apel, 2022). Instead, syntactic comprehension, as a part of linguistic comprehension, is suggested to contribute to reading comprehension.

In contrast, in his theory of metalinguistic development, Gombert (1992) argues that the metalinguistic demands of syntactic awareness are the active ingredient that bolsters reading comprehension; simply understanding sentences is not adequate to develop reading comprehension skills. This makes sense in terms of the demands of the sentences that children encounter in texts, with far more complex sentences in texts than in oral language (Fang, 2006; Uccelli et al., 2015). As such, in comparison to syntactic comprehension, syntactic awareness is predicted to be more related to reading comprehension.

Very few studies include both aspects of syntactic skills in their investigations of reading comprehension (see Brimo, Apel, et al., 2017, for a rare exception), leaving us unable to distinguish between these theoretical predictions or apply these ideas to education. Syntactic comprehension and awareness are conceptualized differently, and so they would also be taught

differently. For instance, educators might teach children about syntactic comprehension by asking them to read sentences with different syntactic constructs - such as active or passive voices - and then checking that the children understood the sentences written in these different ways (e.g., Phillips, 2014). Syntactic awareness, as a metalinguistic skill, likely requires more explicit instruction that supports the child's own manipulation. An educator could teach word order for different sentence types - e.g., subject-verb-object for active voice - and ask children to create their own sentences using these constructs (e.g., Phillips, 2014). Available individual differences studies do little to inform which of these approaches might be most effective in supporting reading comprehension. Conducting a meta-analysis is a powerful way to use existing data to address these contentious theoretical predictions. Here, we include studies with data for either, or both, syntactic comprehension and awareness to determine which (if either) of syntactic comprehension or syntactic awareness has a stronger relation to reading comprehension.

The value of collating results for studies of individual differences is heightened by the dearth of intervention studies focused specifically on syntax. A recent meta-analysis identified several interventions showing effectiveness of teaching syntactic skills along with other oral language skills, although many of these did not include reading comprehension as an outcome (Silverman et al., 2020). Focusing solely on syntax, Phillips (2014) demonstrated feasibility of training in each of syntactic comprehension and awareness and the effectiveness on these two syntactic skills. However, again, this study did not test effects of this training on reading comprehension. We identified a single intervention study in which children were taught specifically syntactic skills with effects tested on reading comprehension. Balthazar and Scott (2018) taught 10- to 14-year-olds with Specific Language Impairment about complex sentences through teaching of the components of complex sentences and explicit instruction about and

practice with complex sentences. There were pre- to post-test improvements on measures of syntactic skills, but not on reading comprehension. It is not clear whether the absence of transfer to reading comprehension was due to the ineffectiveness of instruction in syntax on reading comprehension or to the demonstrated challenges that children with specific language impairment have with processing oral language, including syntax. This thin base of empirical studies then leaves it unclear as to whether and how either or both aspects of syntactic skills may bolster reading comprehension.

Mediators in the Relation Between Syntactic Skills and Reading Comprehension

Beyond these predicted direct relations between syntactic skills and reading comprehension, another theoretically driven question lies in how syntactic skills support reading comprehension; that is, if (a) mediator(s) exists in this relation. The most contentious mediator is word reading. Some decades ago, Tunmer (1989) advocated that children could leverage their knowledge of the structure of sentences to help decode unknown words, with the prediction that syntactic skills would contribute indirectly to reading comprehension via word reading. Take the sentence "After her best friend starred in the play, she felt jealous" and imagine that the child is not able to fully decode the word *jealous,* even if they are familiar with the meaning of the word. Given that *jealous* comes after a linking verb, the sentence structure could allow the reader to determine that the unknown word is likely to be an adjective, limiting the set of possible words that could conclude this sentence. Perfetti, Landi, and Oakhill (2005) make similar predictions: in addition to a direct pathway between syntactic skills and reading comprehension, syntactic skills are predicted to impact word reading because syntax is a part of high-quality lexical representations. On the other hand, some theories argue that automatic decoding is key for successful word reading, with no role, or perhaps even a negative one (e.g., Ehri, 2005) for

syntactic skills. The idea here is that sentence structure will not support decoding skills, and may, in fact, slow a reader down, ultimately leading to less efficient reading. If this is the case, we would not expect word reading to mediate the relation between syntactic skills and reading comprehension, as syntactic skills should not contribute to word reading.

This theoretical discord is amplified by the limited and conflicting available analyses. To date, a mediating effect by word reading has been reported in two studies of first and second grade students (e.g., Tunmer et al., 1988; Tunmer, 1989), with no evidence of mediation in a study of third and fourth grade children (Deacon & Kieffer, 2017). And yet, other studies have the appropriate data (e.g., Kieffer et al., 2016) that have not yet been analysed to examine mediated relations. Thus, a meta-analysis of available data will go some way towards resolving this theoretical debate.

Another plausible prediction is that syntactic skills support reading comprehension through vocabulary. Syntactic structure can help children learn the meaning of new words in oral language in a process known as syntactic bootstrapping (e.g., Kamil et al., 2000). Syntactic bootstrapping is purported to help children learn word meanings through the recognition of syntactic categories (e.g., verbs, nouns, adjectives), with strong empirical support in the literature on oral language acquisition (e.g., Babineau et al., 2020; Kamil et al., 2000; Naigles, 1990). Given its utility in oral language, syntactic bootstrapping may also support learning of word meanings in written texts, which could improve overall text comprehension. This is particularly plausible given the substantial evidence of the unique contribution of vocabulary to reading comprehension development (e.g., Cain & Oakhill, 2014).

A single study with English-speaking adults showed a mediated effect of vocabulary in the relation between syntactic awareness and reading comprehension (Guo et al., 2011), with few

other empirical tests of these relations to our knowledge. As with mediation by word reading, there are studies with available data on vocabulary that have not been analysed in this way (e.g., Deacon & Kieffer, 2017). As such, more comprehensive testing of these relations can be done in a meta-analysis. Here, we test whether either (or both) of word reading and vocabulary mediate the relation between syntactic skills (i.e., both syntactic comprehension and awareness) and reading comprehension in a meta-analytic sample of elementary-aged children.

Changes in the Relations between Syntactic Skills and Reading Comprehension Across Elementary Grades

Given that reading skill develops across the elementary school years, there are likely shifts in the relations between syntactic skills and reading comprehension as children progress through elementary grades. It is well demonstrated that the contribution of oral language in reading comprehension is larger in older than younger readers (Biemiller, 2014; Hoover & Gough, 1990). This could be in part because the texts that older students read have far greater sentence complexity than do those for younger students (e.g., Curran, 2020; Jagaiah et al., 2020). Such longer and more complex sentence structures may give older children a greater opportunity to draw on syntactic skills than is afforded to younger children. This shift may be clearer for syntactic awareness than comprehension: the longer and more complex sentences in texts for older children may require greater metalinguistic awareness of sentence structure. For instance, Gombert (1992; see also Gaux & Gombert, 1999) argues that explicit awareness of sentence structure allows readers to break down sentences into units, which works to ease overall processing load and improve comprehension; he suggests this skill is particularly important to understand longer and more complex sentences. Gombert (1992) also argued that young children may not have adequate syntactic awareness skills on which to draw to support their text

comprehension, suggesting we may see stronger relations between syntactic awareness and reading comprehension in older than younger children. Yet, there is evidence of improvements in both aspects of children's syntactic skills across the elementary school years (e.g., Oakhill et al., 2003). Importantly, these improvements might keep pace with the increased syntactic complexity of the texts that children read, leading to consistency in the magnitude of the relation of each aspect of syntactic skills to reading comprehension. We test whether the relation between reading comprehension and syntactic skills, captured as both or either of syntactic comprehension and/or awareness, shift across elementary grades in our meta-analytic sample of elementary-aged students.

Mediated relations between syntactic skills and reading comprehension might also change across the elementary grades. Early in reading development, when children's word reading skills are still developing and they are encountering many new words, syntactic skills may offer sentence-level support that is needed in these beginning readers but not more skilled readers (Tunmer, 1989). This is one interpretation in the pattern in the few available studies to date; mediation by word reading has emerged in the relation between syntactic awareness and reading comprehension in the studies of younger (Tunmer et al., 1988; Tunmer, 1989) but not older readers (Deacon & Kieffer, 2017). That said, this interpretation would be stronger if supported by more than three studies. Such shifts might occur in mediation via vocabulary as children progress through the vocabulary 'boom' in the middle elementary years (Merritt, 2016). For children with smaller vocabularies, as is the case for children in early elementary, syntactic skills may provide additional support for learning word meanings. Later in elementary, when children have larger vocabularies, syntactic skills may be less needed in determining word meaning. In this case, as with word reading, we would expect a stronger mediated effect of

vocabulary in younger than older elementary students. And yet, readers encounter new words in text throughout the lifespan (e.g., Hulme et al., 2018; Hulme et al., 2022; Nagy et al., 1987), and so we might see relative consistency in mediated effects of vocabulary on the relation between syntactic skills and reading comprehension in younger and older elementary students. Here, we apply available data to explore mediated pathways via word reading and vocabulary meta-analytically in younger and older elementary students.

Available Meta-Analyses on Syntactic Skills and Reading Comprehension

To date, two meta-analyses have examined the relation between syntactic skills and reading comprehension. Tong et al. (in press) reviewed studies on the relation between syntactic skills and reading comprehension conducted with children who spoke either English or Chinese as a first language. Across the 59 identified studies, there were strong meta-analytic correlations between syntactic skills and reading comprehension, associations that were of a similar size for English and Chinese. These similarly sized correlations between English and Chinese held where there were adequate data to contrast correlations at specific age groups (i.e., younger and older elementary students), task modalities (i.e., oral), and specific task types (i.e., error detection/correction and word-order correction, but not oral cloze). The authors interpret these results as suggesting that syntactic skills are a universal predictor of reading comprehension. Brimo, Lund, and Sapp (2017) conducted the other available meta-analysis, this one contrasting syntactic comprehension with awareness in studies of 7- to 15-year-old children with average versus poor reading comprehension. In the studies reviewed, poor comprehenders had substantially impaired reading comprehension skills with intact word level reading skills, with some variation in the specific methods for selecting poor comprehenders. Across the 14 identified studies, average comprehenders had higher levels of syntactic comprehension than

poor comprehenders, with no differences in syntactic awareness. Brimo et al.'s findings point to the possibility that, in line with Gough and Tunmer's (1986) predictions, syntactic comprehension, but not awareness, is related to reading comprehension. Together, these meta-analyses support the existence of a relation between syntactic skills and reading comprehension, with some suggestion of differences in this relation for syntactic comprehension versus awareness.

We build on these meta-analyses to examine several key open questions. A first lies in the relative contributions of syntactic comprehension and awareness in typical readers. While the two available meta-analyses touch on this question, the contribution of individual differences in both aspects of syntactic skills to reading comprehension in typically developing readers is not yet fully described. For instance, in their English-speaking sample, Tong et al. (in press) found stronger correlations with reading comprehension for syntactic tasks of recalling sentences and error detection/correction tasks as compared to sentence-picture matching and oral cloze tasks. Yet, these groups of tasks do not clearly match onto syntactic comprehension or awareness, leaving it unclear as to which aspect has a stronger relation with reading comprehension. It would be useful to collate data across studies to build on these analyses to specifically contrast sets of tasks examining syntactic comprehension versus awareness. Brimo and colleagues' (2017) study contrasted effects for syntactic comprehension with awareness with a small set of studies with poor comprehenders. These need to be extended to capture effects on individual differences for typical readers. A second question lies in examining the role of mediators in the relations between syntactic skills and reading comprehension, a question with substantive theoretical contention (e.g., Ehri, 2005; Tunmer, 1989); this was not investigated in either meta-analysis. Finally, we investigate potential developmental shifts in direct and mediated relations

between syntactic skills and reading comprehension. Tong et al. (in press) found some evidence of developmental differences in the English-speaking sample, where there was adequate data: the size of the correlation between syntactic skills and reading comprehension was smaller in the kindergarten sample than in younger and older elementary samples. Investigating these developmental effects when examining syntactic comprehension and awareness separately and in mediated relations is a key next step.

Present Study

Our overarching goal is to determine which aspects of syntactic skills matter most for reading comprehension, as well as mediated and developmental changes in these relations. We do so with a meta-analysis collating across studies that included either or both of syntactic comprehension and syntactic awareness. Our meta-analysis builds on the two available meta-analyses to answer key remaining and theoretically driven questions.

Our first objective is to analyze the relation between syntactic skills and reading comprehension in English first-language elementary-school aged students from kindergarten to sixth grade, as well as to contrast the magnitude of this relation for tasks assessing syntactic comprehension versus awareness. We focus on English-speaking children as theories describing the role of syntactic skills and reading comprehension, including the contention of syntactic comprehension vs. awareness (e.g., Gombert, 1992; Gough & Tunmer, 1986) and the role of mediators (e.g., Tunmer, 1989), focus on English reading development.

We first confirm the relation between syntactic skills and reading comprehension, by combining data for syntactic comprehension and syntactic awareness. Based on theory (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), we expect to find that a significant relation between syntactic skills and reading comprehension in our meta-analytic sample. We then compare the

magnitude of the relations between reading comprehension and each of syntactic comprehension and syntactic awareness. Doing so allows us to test diverging theoretical predictions, with the Simple View of Reading (Gough & Tunmer, 1986) suggesting stronger contributions of syntactic comprehension as part of the linguistic comprehension system, and Gombert (1992) advocating for stronger contributions for syntactic awareness, given its status as a metalinguistic skill. Comparing the magnitude of the relation between each aspect of syntactic skills with reading comprehension allows us to inform such theoretical predictions.

Our second objective is to determine if the relation between syntactic skills and reading comprehension is mediated via word reading (e.g., Tunmer, 1989) and/or vocabulary (e.g., Naigles, 1990; Guo et al., 2011). This objective is theoretically driven: some theories suggest Some theories suggest that a mediator, such as word reading or vocabulary, exists between syntactic skills and reading comprehension, while others point solely to a direct relation between syntactic skills and reading comprehension (e.g., Ehri, 2005). We use the existing body of data -- much of which has not yet been analysed in this way -- to determine if either or both skills mediate the relation between syntactic skills and reading comprehension. Given the theoretical contention of word reading as a mediator and the disparate results in a limited number of studies, it is not clear whether word reading mediates the relation between the two aspects of syntactic skills and reading comprehension. Based on theoretical predictions and empirical evidence, we hypothesize that vocabulary will mediate the relation between the two aspects of syntactic skills and reading comprehension.

Our third objective is to examine the influence of development on the direct and mediated relations between syntactic skills and reading comprehension by including age group as a moderator and conducting cross-age analyses. Such cross-age analyses not only respond to

theoretical contentions regarding which aspects of syntactic skills matter most (e.g., Gombert, 1992; Gough & Tunmer, 1986) and whether mediators exist across development (e.g., Tunmer, 1989); they also go some way in informing when children should be taught about sentences, and to what end. For instance, when children begin to read texts with more complex sentences (e.g., Curran, 2020), should the focus of instruction be on syntactic awareness instead of comprehension? Similarly, should we teach children about sentences to help read words and learn word meanings? Might this type of teaching only be important when children are still developing their decoding skills and learning many word meanings? Indeed, having guidelines for when to teach which skills is crucial: instruction time in school is limited, as evidenced by calls from educators for support in optimizing this time (see e.g., Froese-Germain, 2014; Hunter & Sonnemann, 2022; The Pennsylvania State University, 2017). Thus**,** extending prior analyses (Tong et al., in press), we examine the influence of development on relations between reading comprehension and each of syntactic comprehension and syntactic awareness, as well as on key mediated relations.

We focus on elementary-school aged children in our examination of the influence of development on these direct and mediated relations. Text complexity increases rapidly during the elementary school years largely due to increased complexity at the sentence level (e.g., Curran, 2020; Fang, 2006). Thus, this period is the one in which we are most likely to capture the emerging and potentially shifting relations between syntactic skills and reading comprehension. We divide our meta-analytic sample into kindergarten students, younger elementary students, (Grades 1 and 2) and older elementary students (Grades 3 to 6). Following on other work (Tong et al., in press), kindergarten students are their own group because their word reading and reading comprehension skills are highly intertwined (e.g., Haft et al., 2019), more so than other

elementary children. The divide between younger and older elementary students is based on theoretical and empirical evidence that third grade is dubbed the point in transition from "learning to read" to "reading to learn" (Chall, 1983), highlighting the amplified focus of instruction on reading to understand as compared to a focus on decoding words (e.g., Snow & Matthews, 2016). Further, during the transition to upper elementary, children read, hear, and produce increasingly complex sentence structures as compared to the simpler sentence structures typical of early elementary (e.g., Gombert, 1992; Koutsoftas, 2013). Because of these shifts, upper elementary is often conceptualized as distinct from earlier elementary grades (e.g., IDEA, 2004; Tilanus et al., 2019), during which time such skills are less developed, texts are less complex (Curran, 2020), and instruction is primarily focused on decoding.

In exploring the developmental shifts of direct relations, we expect to find that syntactic skills are more strongly related to reading comprehension in older than in younger elementary students, with potential differences in developmental patterns for syntactic comprehension and awareness. Considering syntactic skills as a whole, older students are likely to have more developed syntactic skills and read longer and more complex texts than younger students (e.g., Curran, 2020; Oakhill et al., 2003). Yet, contrasting syntactic comprehension versus awareness, syntactic awareness may be more related to reading comprehension in older children, with their more developed metalinguistic skills and reading of more complex texts (e.g., Curran, 2020; Gombert, 1992).

In terms of the developmental shifts for the mediated relations of word reading and vocabulary on syntactic skills and reading comprehension, we make separate predictions for each of these models. We hypothesize that the mediated effect of word reading will be stronger in the younger than older elementary sample, with word reading skills becoming more automatic from

early to later elementary. As children's knowledge of word meanings also grows from early to later elementary, we may see a similar developmental trend for vocabulary; however, effects of similar magnitudes may emerge for younger versus older children given children are continuously encountering new words in text.

Method

Literature Searches and Inclusion Criteria

Searches were conducted in four major databases: PsycInfo, ERIC, Medline, and Embase. These searches included the following search terms: reading OR text*; comprehension OR ability; AND syntax OR syntact* OR sentence OR gramm*; awareness OR comprehend* OR knowledge. Search terms were limited to the title and abstract. These terms and guidelines were developed with the help of a librarian specialized in systematic literature searches. The search was last updated on September 2nd, 2022. It includes all studies published up to this date. Table 1 shows a comprehensive list of dissertations and studies included in this meta-analysis as well as their sample sizes, the age group, and the included tasks. Selected studies needed to include a sample of typically developing elementary-school children between the ages of 5 and 12 years who spoke English as a first language.

We included studies in this meta-analysis that reported on measures of syntactic skills as well as reading comprehension. We identified studies with measures of syntactic skill that test sentence-related skills in the oral domain. We focus on oral measures to reduce the possible confound between syntax and word reading, a known predictor of reading comprehension (e.g., Gough & Tunmer, 1986) and considered as a possible mediator in this study. We further divided the measures of syntactic skill into syntactic comprehension and syntactic awareness. Syntactic comprehension measures were those that assessed a child's understanding of sentence-level

information without having to manipulate the given information (Brimo, Lund, et al., 2017). Syntactic awareness measures involved changing, manipulating, or creating information given in order to produce syntactically plausible sentences (Brimo, Lund, et al., 2017). Following Melby-Lervåg and Lervåg (2014), measures of reading comprehension were those in which children were asked to read a passage or sentence and then answer questions, either orally or written, that assessed their understanding of the text. Examples of measures of reading comprehension include Passage Comprehension from the Woodcock Johnson, on which children read short passages and orally answer literal and inferential follow-up questions, and the Gates-MacGinitie Reading Test, on which children read passages of varying length and answer questions about the passages on paper. All studies had to be peer-reviewed (n = 35) or published dissertations (n = 6) (e.g., Sorenson Duncan et al., 2021).

Studies had to meet the requirement of containing measures of syntactic skills and reading comprehension. If these requirements were met, we then recorded if these studies included measures of word reading and/or vocabulary. We did not exclude studies that did not include these measures. This allowed us to investigate our research question concerning the mediated relations between syntactic skills and reading comprehension. Word reading measures were those that assessed children's ability to accurately identify words, including tests of both fluency and accuracy. Vocabulary measures evaluated children's receptive or expression skills with individual lexical items (e.g., Sorenson Duncan et al., 2021).

Selection of Studies and Study Coding

Our searches from all databases yielded a total of 3472 studies (PsycInfo n = 2,406; ERIC n = 577; Medline n = 228; Embase n = 261). We used Mendeley (Mendeley Inc., 2019) to search for and remove duplicates. After duplicates were removed, 1598 results were uploaded to

Rayyan QCRI (Ouzzani et al., 2016). We then used Rayyan QRCI as the platform to support our independent screening of studies for inclusion and exclusion. The first and second author independently screened the titles and abstracts of each study, with an agreement of .95. Any disagreement was resolved by consensus.

After title and abstract screening, we excluded 1493 studies, leaving 105 for full-text screening. The same two authors completed full-text screening. As with the initial round of screening, disagreement was resolved through consensus. After full-text screening, we excluded an additional 51 studies. We identified 10 additional studies through the references of selected studies, four of which met criteria, resulting in a final included sample of 58. Figure 1 shows a flow diagram of the inclusion and exclusion of studies (Moher et al., 2010).

Of these 58 papers, 37 reported the necessary correlations. The remaining 21 authors were contacted to request data. Four authors responded with data. Thus, our meta-analysis is based on 41 unique studies. Details of the included studies are provided in Table 1. Data extraction from these studies was done independently by first and second authors and the results were compared to ensure accuracy.

Prior to title, abstract, and full-text screening, we developed a coding scheme that the first and second author used independently to decide whether each study should be included or excluded. These codes reflected our exclusion criteria and were as follows: age, defined as younger or older than our target population (n = 295); specialized population, defined as a study in which the population was not typically developing (n = 236); language, defined as a study conducted only in (a) language(s) other than English and/or only including participants who spoke English as a second language (n = 267); no reading comprehension, defined as the study not having a measure of reading comprehension (n = 234); no syntax, defined as the study not

including (a) measure(s) of syntax or only having written measures of syntax (n = 509); incorrect method type, defined as not including original data, being a meta-analysis, a systematic review, and/or a report (n = 63); and incorrect study type, defined as not being a peer-reviewed or published dissertation (n = 23).

All codes were made as labels on Rayyan, and each study was categorized according to the reason(s) for exclusion. We coded 10 percent of the studies and then discussed coding decisions to ensure that our coding system was functioning as intended and captured the variability across studies. The inter-rater agreement was .97 at this time. The authors were then blinded to the other's coding decisions until all studies were coded.

Meta-Analytic Procedures

All meta-analyses were conducted in R (R Core Team, 2017; see below for specific packages). We used Pearson's *r* as our measure of effect size. We also report Cohen's *d,* which represents the strength of the bivariate relations.

To examine the direct relations between syntactic skills and reading comprehension across the entire sample, we followed a correlated-effects Robust Variance Estimation (RVE) paradigm (Hedges et al., 2010; Tipton & Pustejovsky, 2015). Robust variance estimation methods generate a working model of the dependence (see e.g., Tipton & Pustejovsky, 2015; Pustejovsky & Tipton, 2022); this allows one to account for a dependent structure, without knowing the exact structure of this dependence. We had several dependent effect sizes because several studies included in this meta-analysis administered multiple measures of the same construct to the same sample of children. Robust variance estimation methods have been shown to generate specific and accurate effect size estimates (Moeyaert et al., 2017).

To contrast whether the direct relations between syntactic skills and reading comprehension differed by aspect of syntactic skill and age range, we first coded each study based on aspect of syntactic skill (comprehension and/or awareness) as well as age range (kindergarten, younger, and older elementary students). Our kindergarten sample was children in kindergarten or grade primary, or approximately 5 years old. Our younger elementary school sample included children in grades 1 and 2, or between 6 and 7 years roughly. Our older elementary school sample included children in grades 3 to 6, or between 8 and 12 years roughly.

We then used the subgroup correlated effects RVE paradigm (Pustejovsky & Tipton, 2022). This paradigm facilitates comparing the average effect sizes from different subgroups because the working model for the entire dataset assumes that there are separate meta-regressions within this dataset. This means that the independent effect size estimates generated for each subgroup are directly comparable because they are all part of one model. This can be compared to other subgroup analysis techniques, in which the pooled effect sizes from each subgroup are dependent upon each other and thus are not directly comparable. For all models, we used the 'metafor' and 'clubSandwich' packages and the 'rma.mv' and 'robust.rma.mv' functions to generate effect sizes with robust variance estimation. For the moderator analyses, we also used additional code published by Pustejovsky and Tipton (2022).

To test the mediated meta-analytic relations, we followed correlation-based, meta-analytic structural equational modeling (c-MASEM) procedures described by Cheung and colleagues (e.g., Cheung & Chan, 2005; Cheung & Cheung, 2016) and used by others in the field (Hjetland et al., 2017; Harrer et al., 2019) To summarize, the c-MASEM is completed in a two-stage structural equation modeling approach (TSSEM, see Cheung & Chan, 2005; Cheung & Cheung, 2016). The first stage requires pooling correlation matrices for each study; these

matrices were imported into R from Excel. We combined our correlation matrices using random-effects model, as this allows for between-study heterogeneity (Harrer et al., 2019). In the second stage, we used this pooled correlation matrix to specify our mediation pathways. Importantly, this method inherently deals with dependent correlations (Cheung & Cheung, 2016), limiting the concerns associated with dependent correlations present in our sample.

To test whether the mediated relations between syntactic skills and reading comprehension differed by aspect of syntactic skill and age range, we selected only the aspect and/or population in which we were interested from the entire sample. This allowed us to compare the size of relations across subgroups while minimizing concerns about dependent effect sizes across groups. We then followed the above c-MASEM procedures. For all these analyses, the 'OpenMx' and 'lavaan' packages and 'metaSEM' functions were used.

To assess publication bias, Begg and Mazumadar's (1994) rank correlation and funnel plots were conducted using the 'metafor' package and 'ranktest' function. Begg and Mazumadar's rank correlation represents the relation between the standardized form of an effect size and its associated variance, with a positive relation demonstrating that the effect size is larger when variance is larger, which typically happens with smaller sample sizes. The stronger the magnitude of the correlation, the more likely it is that there is publication bias. Thus, a strong positive correlation could indicate that the studies with small sample sizes are biased, resulting in an overestimation of effect. In funnel plots, sample size is plotted against effect size. Because smaller-sampled studies typically have greater variation among effect sizes than do larger-sampled studies, this plot should form an inverted funnel. If there is minimal publication bias present in the meta-analysis, the plot will be symmetric; however, if publication bias exists, the plot will be asymmetric.

Results

The correlations and their 95% confidence intervals among syntactic skills with reading comprehension are presented in Table 2. Heterogeneity statistics were generated using the 'metafor' package and 'rma.mv' function. Both between effect size (σ = .005) and between study variability (σ = .007) were significant (p's < .001). Further, our tests generated a significant Q statistic, $Q(128) = 343.176$, $p < .001$, suggesting significant between effect size variability, even while accounting for the clustering nature of the data. Upon examination of the variance within the model, we found that 25% was attributable to within-study variance while 40% was attributable to between study variance.

Based on statistical soundness and established practice (e.g., Fu et al., 2011; Melby-Lervåg et al., 2012), for all moderator analyses, we conduct by-group analyses (e.g., by age group) only if there are 4 or more independent samples in one group.

Relation between Syntactic Skills and Reading Comprehension

We begin by quantifying the relation between syntactic skills and reading comprehension in elementary school aged children. There were 41 unique studies included in this analysis, with a total sample size of 10738 (*mean* = 195.24, *SD* = 196.59, *range* = 19 – 884). The mean correlation between syntactic skills and reading comprehension in elementary students, across all grades, was r = .480 (.441 - .510), d = 1.07. The distribution of correlations across studies is illustrated in Figure 2, wherein we see that most studies report positive correlations; of the 133 correlations, the confidence intervals of 11 correlations include 0. Accordingly, there appeared to be minimal publication bias, reflected by a nonsignificant rank correlation value of -0.11 (p > .05) and a symmetric funnel plot. Our results then suggest that syntactic skills and reading comprehension are strongly related in an elementary-aged sample.

Relations between Syntactic Comprehension, Syntactic Awareness, and Reading Comprehension

We then evaluated the relative direct relations between each of syntactic comprehension and awareness with reading comprehension in the same sample. There were 22 unique studies with measures of syntactic comprehension, with a sample of 4528 children (*mean* = 141.50, *SD* = 94.71, *range* = 19 – 368). The average correlation between syntactic comprehension and reading comprehension was r = .472 (.433 - .511), d = 1.07. The distribution of correlations across studies is illustrated in Figure 3. Again, we see that most of the correlations are positive: of the 72 correlations reported, only 3 have confidence intervals that include 0. A degree of publication bias may have been present, as demonstrated by a rank correlation value of -.155 (p = .053); however, the funnel plot was relatively symmetrical suggesting limited publication bias.

There were 25 unique studies reporting on the relation between measures of syntactic awareness and reading comprehension, with a sample of 6362 children (*mean* = 227.21, *SD* = 213.78, and *range* = 32 – 884). The average correlation between syntactic awareness and reading comprehension was r = .482 (.423 - .430), d = 1.10. The distribution of correlations across studies is illustrated in Figure 4, wherein we see only 9 correlations out of 61 with a confidence interval that includes 0. Publication bias was minimal, as demonstrated by a small Begg and Mazumadar's rank correlation of r = .002, a non-significant p-value (p = .987), and a relatively symmetric funnel plot.

To statistically compare the effects of syntactic comprehension and awareness on reading comprehension, we conducted t-tests using the 'anova' function. These results suggest that the magnitude of the relations between syntactic comprehension or awareness and reading comprehension are not significantly different, $F(1, 24.27) = .089$, p = .768. Thus, across both

analyses, we see that syntactic comprehension and awareness are significantly related to reading comprehension in elementary-aged, English-speaking participants, and that these correlations are numerically and statistically similar in size.

Cross-Grade Comparisons of the Direct Models

To determine whether the relative strength of the correlations differed by developmental period, we explored each of the direct relations between syntactic skills, syntactic comprehension, or syntactic awareness and reading comprehension while including age as a(n additional) moderator. We were unable to include the kindergarten sample in these cross-age comparisons, as we only identified two studies with children in kindergarten that met our criteria, which is below the recommended sample of four independent studies (e.g., Fu et al., 2011).

We used the *t*-test function to compare the effect of developmental period on each of the relations. The number of effect sizes used in each analysis are presented in Table 2; notably, there were substantially fewer studies reporting on younger than older elementary samples. Results of our cross-age comparisons suggest that correlation between syntactic skills and reading comprehension was numerically similar between younger and older elementary students ($F(1, 14.5) = 0.673$; $p = .426$), a result that held for both syntactic comprehension ($F(1, 7.45) = 1.232$; $p = .302$) and awareness ($F(1,7.75) = .040$; $p = .847$).

Mediated Relations between Syntactic Skills and Reading Comprehension

Our second objective was to investigate the mediated effects of word reading and vocabulary on the relations among syntactic skills, its aspects, and reading comprehension. As the first stage of the TSSEM, we created pooled correlation matrices for each study. We checked the correlation matrices for positive definiteness, as this a requirement for the second stage (Harrer et al., 2019). A matrix is considered positive definite if all eigenvalues are positive

(Wothke, 1993). All studies included in the mediation analyses met the positive definite criterion. Thus, all studies were included in the pooled correlation matrices.

We then specified the word reading mediation models as part of the TSSEM for the relations among syntactic skills and reading comprehension. For each analysis, the model fit the data adequately or well. Model fit statistics for the word reading mediation models are reported in Table 3 and the model coefficients are reported in Table 5. Figure 5 is provided as a visual example of the mediated pathways with word reading. The model containing syntactic skills, word reading, and reading comprehension had a sample size of 8331. Word reading had a significant mediated effect on the relation between syntactic skills and reading comprehension, *b* = .352 [.325, .380] (Figure 5). We then conducted the same analysis again, this time with the studies including specifically measures of syntactic comprehension. This analysis had a sample size of 4164. Again, word reading had a significant mediated effect, *b* = .348 [.311, .386]. Finally, we conducted a parallel analysis with the studies including specifically syntactic awareness tasks, which had a sample size of 4167. Word reading had a significant mediated effect, *b* = .349 [.309, .389]. Thus, word reading emerged as a significant mediator among the relations between syntactic skills generally and each of syntactic comprehension and awareness and reading comprehension.

Next, we identified the mediation models with vocabulary. For each analysis, the model fit the data adequately or well (Table 4). All model coefficients are reported in Table 6. Figure 6 is provided as an example of the mediated pathways with vocabulary. The model containing syntactic skills, vocabulary, and reading comprehension had a sample size of 7922. A significant mediated effect of vocabulary emerged, *b* = .373 [.359, .396] (Figure 6). Nearly identical results emerged for the model with syntactic comprehension (n = 4188), with a significant mediated

effect of vocabulary, *b* = .379 [.354, .404]. The results of the model with syntactic awareness (n = 3734) were similar: again, a significant mediated effect of vocabulary emerged, *b* = .346 [.308, .384]. As with word reading, then, vocabulary emerged as a significant mediator in each analysis.

Across each of the above analyses, the overall pattern that emerges is that both word reading and vocabulary mediate the relation between syntactic skills, measured as either syntactic comprehension or syntactic awareness, and reading comprehension.

Cross-Grade Comparisons of the Mediated Models

To determine if the mediated relations differed between younger and older elementary students, we then conducted each of the mediated analyses of word reading or vocabulary described above by developmental period. As with the cross-age comparisons of the direct models, we did not have the required sample of 4 or more to include a kindergarten group in these analyses (e.g., Fu et al., 2011).

We first examined mediation by word reading in the younger and older elementary groups on the relation between syntactic skills and reading comprehension. There was a significant mediated effect of word reading on the relation between syntactic skills and reading comprehension for the younger elementary students (n = 1844, *b* = .321 [.281, .361]) that was numerically similar in size to that for the older elementary students (n = 6487, *b* = .335 [.299, .370]). We next conducted identical analyses with studies that specifically investigated syntactic comprehension in the younger (n = 1161) and older (n = 3003) elementary students. A significant mediated effect of word reading emerged for the younger and older elementary groups (*b* = .285 [.237, .335] and *b* = .331 [.286, .376], respectively), with effects that were quite similar in size. In parallel analyses with syntactic awareness, there were significant mediated effects of word reading for the younger (n = 683, *b* = .426 [.389, .462]) and older elementary students (n = 3484,

b = .334 [.281, .389]), with numerically larger effects for the younger children. Together, these findings suggest consistency across age groups in the magnitude of the mediated paths via word reading for syntactic comprehension, but potentially larger mediated effects via word reading for syntactic awareness for the younger than older group.

We then examined mediation by vocabulary in the younger and older elementary groups on the relation between syntactic skills and reading comprehension. The model with syntactic skills, vocabulary, and reading comprehension had a sample size of n = 3091 in the younger and n = 4831 in the older elementary students. In both cases, there was a significant mediated effect, with a larger effect size for the younger, *b* = .430 [.400, .460] than older elementary students, *b* = .346 [.318, .373]. Similar results emerged for the model with syntactic comprehension, with significant mediated effects via vocabulary for both younger (n = 1188) and older (n = 3000) elementary students and numerically larger effects in the younger than older elementary students, *b* = .426 [.383, .697] and *b* = .342 [.316, .369], respectively. For the model with syntactic awareness, there was a significant mediated effect of vocabulary for both the younger (n = 1903) and older elementary students (n = 1831); again, this effect was numerically larger in the younger than older elementary sample, *b* = .432 [.393, .470] and *b* = .329 [.279, .381], respectively. These findings suggest that the mediated effects of vocabulary on the relations between both syntactic comprehension or syntactic awareness and reading comprehension are stronger for younger than older readers.

To recap, our mediated models clearly point to both word reading and vocabulary acting as mediators in relations between syntactic skills and reading comprehension. The results of the these models suggest mediation via word reading that is of a similar size for younger and older elementary-school readers. Mediation via vocabulary was stronger in the younger than older

students. Comparing models with syntactic comprehension and syntactic awareness, we found that mediation via word reading was of a similar size across age groups for syntactic comprehension, with some evidence of larger effects for younger than older children for syntactic awareness. For vocabulary, we found mediation from both syntactic comprehension and awareness to reading comprehension via vocabulary was stronger in the younger than older sample.

Discussion

The overarching goal of this meta-analysis was to determine which aspects of syntactic skills matter most for reading comprehension and to explore mediated and grade-level changes in these relations. Certainly, theories widely predict a direct role for sentence-level skills in reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), with disagreement as to whether these effects come from syntactic comprehension (Gough & Tunmer, 1986) or awareness (e.g., Gombert, 1992). There is further debate as to how these effects function, specifically as to whether word reading and/or vocabulary mediate these relations (e.g., Tunmer, 1989), and when in reading development these potential direct and mediated relations emerge. We addressed these questions in a meta-analytic sample of English-speaking elementary school aged students. Addressing such questions with a meta-analytic sample allowed us to leverage existing data that, for the most part, has not been used to explore these ideas. The results of this meta-analysis reveal strong direct relations between syntactic skills and reading comprehension that remain remarkably stable across syntactic comprehension and awareness. The magnitude of these effects also remains stable across developmental period. Finally, our results point to mediated relations between syntactic skills and reading comprehension; interestingly, these relations are influenced by the aspect of syntactic skill, mediation by word reading or vocabulary, and developmental

period. Collectively, our findings push the bounds of current theory and offer some practical implications.

Aspects of Syntactic Skills and Their Relations with Reading Comprehension

Our meta-analysis demonstrates that syntactic skills are significantly related to reading comprehension in English-speaking elementary school-aged participants, converging with predictions of theories for a role for syntactic skills in reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014) and the one other meta-analysis to date (Tong et al., in press). Our meta-analytic findings clarify the apparent ambiguity of results reported in prior empirical work on the relation between syntactic skills and reading comprehension (e.g., Cain & Oakhill, 2006; Deacon & Kieffer, 2017). In fact, the relation between syntactic skills and reading comprehension appears quite consistently, with 90% of correlations demonstrating a positive relation between syntactic skills and reading comprehension (see also Tong et al., in press). Perhaps most notably, these correlations are larger than meta-analytic correlations of other predictors of reading comprehension, including vocabulary (e.g., Hjetland et al., 2017; Stahl & Fairbanks, 1986), albeit smaller than those of word reading (García & Cain, 2014). As such, these findings identify a need to maintain, and potentially amplify, the role of syntactic skills in theories of reading comprehension.

We then tested competing theoretical predictions (Gombert, 1992; Gough & Tunmer, 1986) regarding which aspect of syntactic skills has a stronger relation with reading comprehension. Our results revealed correlations between reading comprehension and each of syntactic comprehension and awareness that were similar in size, both in the moderate to strong range. These results directly respond to theoretical contention as to which of syntactic comprehension or syntactic awareness contributes to reading comprehension: while theories such

as the Simple View of Reading highlight the importance of linguistic skills, including syntactic comprehension (e.g., Gough & Tunmer, 1986), others underscore the unique relevance of metalinguistic awareness, such as syntactic awareness (e.g., Gombert, 1992). Our results suggest that tasks assessing each of these aspects are relevant, and potentially neither primary, in capturing the relation between syntactic skills and reading comprehension. Critically, then, in response to this theoretical contention, our results accentuate that both syntactic comprehension and awareness should likely be included in models of reading comprehension. These analyses also integrate two literatures that were largely separate (but see Brimo, Apel, et al., 2017 for an exception). We think that the next key step is to examine mechanisms by which these aspects of syntactic skills contribute to reading comprehension (Kintsch, 1994; Perfetti & Stafura, 2014), as each may have a distinct mechanism by which it relates to reading comprehension. For example, understanding complex sentence structures may allow readers to integrate different events in a complex sentence (Kintsch, 1994), while awareness of syntactic structure may heighten a reader's ability to identify clause or phrase boundaries, easing parsing of complex sentences (Perfetti & Stafura, 2014). Both these mechanisms could increase accessibility of the entire text and are possibilities are worthy of empirical testing.

Mediators in the Relation Between Syntactic Skills and Reading Comprehension

Beyond these direct effects, our analyses also respond to contentious predictions regarding mediators by revealing significant mediated effects of both word reading and vocabulary on the relation between syntactic skills and reading comprehension. Indeed, both skills reliably emerge as mediators in the relation between reading comprehension and syntactic skills, effects that held for both syntactic comprehension and awareness. These meta-analytic results converge with theories that predict a mediated relation between syntactic skills and

reading comprehension (e.g., Tunmer, 1989) and stress the need for other theories and empirical studies to specify mediated effects in fully understanding this relation. Relatedly, our results extend the literature on syntactic skills and reading comprehension: many studies on this relation included measures of word reading and/or vocabulary (e.g., Michener et al., 2018; Muter et al., 2004), yet do not report on tests of possible mediation pathways. Undoubtedly, the power of a meta-analytic sample is especially potent for these mediated analyses: while many studies had the appropriate data to analyze mediated relations, remarkably few do (see Deacon & Kieffer, 2017; Tunmer et al., 1988; Tunmer, 1989 for exceptions), making the current results novel and particularly valuable. Certainly, we acknowledge that our results need to be replicated in individual studies, as there are so few of these to which to compare our mediated results.

One implication of these mediated analyses is that targeting syntactic skills could lead to improvements in word reading and vocabulary, which could have the downstream effect of stronger reading comprehension. For instance, imagine that a child encounters an unknown word. Syntactic comprehension could allow the child to understand the rest of the sentence and therefore give context for the unknown word, while syntactic awareness could help narrow the type of word the novel word should be. Decoding and learning the word's pronunciation would then support overall text comprehension. If the meaning of the word was also unknown to the child, they could again use their comprehension of the rest of the sentence and ability to reflect on syntactic structure to suss out the word's meaning. Equipped with both the pronunciation and definition of the novel word, the sentence and therefore entire text may become more accessible to the child.

Changes in the Relations between Syntactic Skills and Reading Comprehension Across Elementary Grades

With an eye to guiding precise theories of reading development with direct implications for instruction, we then explored whether the magnitude of our direct and mediated relations changed across the elementary school years. To summarise the results, there was remarkable parity between younger and older readers in the direct relations between reading comprehension and syntactic skills, captured as either or both of syntactic comprehension and awareness, with clear shifts across our two grade groups in mediated effects. Mediation by word reading and vocabulary tended to be stronger in the younger than older elementary sample, with some influence of aspect of syntactic skill. Overall, then, it seems that providing elementary children of all ages explicit instruction about syntactic comprehension and awareness may benefit their reading comprehension. Yet, it appears that instruction about sentences to bolster word reading and vocabulary is more important for younger elementary students, when these skills are in period of intense development (e.g., Phythian-Sence & Wagner, 2007; Whitehurst & Lonigan, 1998). We interpret each of these key findings below.

In terms of direct relations, our analyses suggest that syntactic skills are consistently important for reading comprehension across the elementary grades (see also Tong et al., in press). Indeed, there were remarkably similarly sized direct correlations between syntactic skills and reading comprehension for younger and older elementary students, findings that held true for both syntactic comprehension and syntactic awareness. These findings are perhaps surprising because of widespread evidence that texts increase in complexity across the elementary school years, leading to predictions of a stronger role of syntactic skills in older than younger children (e.g., Gombert, 1992; Oakhill & Cain, 2007). Yet, the complexity in the texts to which children

are exposed may be matched by development in their syntactic skills, leading children to continuously apply emerging syntactic skills to new sentence types to master the variety of sentences they read. There is some support for this speculation: just as studies document the increasingly complex sentences in written text as children progress through elementary (e.g., Curran, 2020), children are also better able to complete syntactic tasks with complex sentences in later than early elementary (Montgomery et al., 2016; Oakhill et al., 2003; Sorenson Duncan et al., 2020). Overall, these results can be taken to support the relevance of both aspects of syntactic skills in reading comprehension in first to sixth grade students.

In the mediated effect of word reading on the relation between syntactic skills and reading comprehension, key differences emerged for younger versus older readers, with further influence of aspect of syntactic skill. For syntactic comprehension, mediated effects via word reading were of similar size for our two age groups, but for syntactic awareness, mediated effects were stronger in the younger than older elementary group. Thus, our results suggest that, across development, children levy their understanding of a sentence's events to support decoding a word, likely one that already exists in their mental lexicon. Awareness of and ability to use syntactic structure, however, seems to especially optimise the utility of novice phonological decoding skills typically characteristic of younger as compared to older readers. Syntactic awareness may bolster emerging decoding skills by, for example, providing explicit constraints on the type of word an unknown word could be (Tunmer, 1989; Deacon & Kieffer, 2017).

Turning to our mediated models with vocabulary, cross-age analyses revealed that the mediated effect of vocabulary was stronger for both syntactic comprehension and awareness in younger than older elementary school children. Syntactic comprehension may be beneficial in supporting learning of word meanings because it provides the child with the sentence context in

which the novel word needs to fit, narrowing the potential definitions that the unknown word could have. Such a process is likely more relevant for younger children because of their more limited vocabularies (Merritt, 2016). That awareness of syntactic structure supports younger readers' learning of word meanings aligns with evidence of syntactic bootstrapping in young children, showing the use of sentence-level information to learn new word meanings (Babineau et al., 2020; Naigles, 1990). Our results provide a novel application of ideas from word leaning research (e.g., Naigles, 1990) and converge with the few studies that show vocabulary mediates this relation in adulthood (Guo et al., 2011). Together, these mediated results highlight that if the meaning of a word is unknown to a child, they may use their comprehension of the rest of the sentence and ability to reflect on syntactic structure to suss out the word's meaning; these processes appear to be particularly important for younger children.

Theoretical and Educational Implications

Collectively, our findings solidify the role of syntactic skills in theories of reading comprehension and suggest detail as to how to best include them. We found similarly sized correlations between reading comprehension and each of syntactic comprehension and syntactic awareness. These findings clearly answer theoretical contention: both aspects are relevant to reading comprehension and to a similar extent and so both should be included in theoretical models to comprehensively conceptualize the relation between syntactic skills and reading comprehension. Extending beyond these core findings, we suggest that the mechanisms described in theories as to how syntactic skills broadly contribute to reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014) might differ for syntactic comprehension and syntactic awareness. In particular, we think that understanding complex sentence structures may allow readers to integrate different events in a complex sentence (Kintsch, 1994), while

awareness of syntactic structure may heighten a reader's ability to identify clause or phrase boundaries, making parsing complex sentences easier (Perfetti & Stafura, 2014). In both cases, children could leverage these mechanisms to increase accessibility of the entire text. Building on these suggested mechanisms, our findings that both word reading and vocabulary mediate the relations between syntactic skills and reading comprehension also encourage updating of theories. Certainly, explicitly including word reading and vocabulary as mediators would allow for more precise predictions of how syntactic skills contribute to reading comprehension. In this vein, our results suggest that the mediated effects of word reading and vocabulary on the relation between syntactic skills, its aspects, and reading comprehension may be especially prominent for younger children, for whom word reading and vocabulary are in a period of intense development (e.g., Phythian-Sence & Wagner, 2007; Whitehurst & Lonigan, 1998). One possible explanation is that younger children may use their understanding of either events within a sentence or awareness of its structure to decode a novel word or grasp its meaning (see Tunmer, 1989; Deacon & Kieffer, 2017). Collectively, our meta-analytic results offer key areas of elaboration for theories of reading comprehension.

Indeed, our findings bring new theoretical precision, as well as suggestions for the design of instruction of syntactic skills that is likely to be effective in improving reading comprehension. The Common Core State Standards (Common Core State Standards, 2021) stress the importance of teaching syntax in preparing children to tackle the increasingly complex texts they read. The Common Core State Standards do not, however, offer specific guidance in terms of how educators might do so, likely in part because of an absence of empirical basis for such recommendations. Our results provide a starting point for just such an evidence base: our findings of similarly sized correlations between reading comprehension and each of syntactic

comprehension and syntactic awareness point to the likely need to teach both or either aspects in the classroom. We found a single intervention study that might offer ideas as to how one might go about doing so. Phillips (2014) taught pre-kindergarten to first grade children syntactic comprehension by asking them to read sentences of different syntactic constructs and followed by comprehension questions. She taught syntactic awareness by asking children to create their own sentences using specific syntactic structures. Following on this instruction, children improved in both aspects of syntactic skills. The effects of this training method have yet to be linked to the loftier goal of improving reading comprehension. Yet, Phillip's intervention lays the groundwork for how to teach syntactic skills. We add to these ideas here by suggesting that teachers may bolster understanding and awareness of syntax by asking children to provide the meaning of the whole sentence – a focus on syntactic comprehension – and asking children to isolate a subordinate clause from the main clause – a focus on syntactic awareness. Designing and testing interventions is critical to guide educational practices.

Several limitations need to be addressed as we consider these implications. First, we focused exclusively on studies with English-speaking children. We did so to accomplish our goal of testing competing predictions from prominent theories of reading comprehension (e.g., Gombert, 1992; Gough & Tunmer; 1986; Perfetti & Stafura, 2014), majority of which focus on English. Emerging literature suggests that awareness of sentence structure may be important for reading comprehension in other languages, such as Chinese (e.g., Tong & McBride, 2017), pointing to the need to investigate these effects across languages with different sentence structures (see Tong et al., in press, for a recent meta-analysis with Chinese speaking students). Relatedly, we restricted our age range to elementary-aged children to best respond to the theoretical contention that exists primarily for this population; however, other research may find

that middle and high school students employ syntactic skills in different ways than elementary children (see Tong et al., in press, for an example of such analyses). Relatedly, we endeavoured to include a kindergarten sample in our cross-age comparisons, but we identified two studies for the kindergarten sample that met our inclusion criteria, fewer than the 4 required to be included in analyses (e.g., Fu et al., 2011; Melby-Lervåg et al., 2012). While Tong and colleagues identified 5 studies, our study identification and inclusion criteria differed from theirs, thus impacting the number of studies each meta-analysis included. For example, we were only interested in studies wherein the first language and language of instruction was English to decisively test theoretical predictions of English reading development. Thus, as compared to Tong and colleagues, we excluded French Immersion samples (e.g., Jared et al., 2011). Overall, the results of this study spur several possible empirical avenues towards more precisely conceptualizing the relation between syntactic skills and reading comprehension.

To summarise, our meta-analysis demonstrated that syntactic skills, including both syntactic comprehension and syntactic awareness, have strong direct relations that remain consistent for English-speaking elementary school aged children. Further, we uncovered that word reading and vocabulary each mediate the relation between syntactic skills and reading comprehension, with generally stronger relations in the younger than older sample. Overall, these results offer answers to theoretical contentions and ambiguities, as well as pave the way toward the development of effective interventions. Moving forward, it would be imperative to expand on the findings of this study through longitudinal and intervention work in English and other languages. Doing so will directly respond to the Common Core State Standards' (2021) recommendation to teach children to tackle complex sentences and provide clarity and guidance on how to teach syntactic skills. Indeed, only longitudinal and intervention designs provide

evidence that ultimately leads to concrete avenues for improving children's reading comprehension skills; however, here, we help set the stage for the future work that needs to be done.

References

Apel, K. (2022). A different view on the Simple View of Reading. *Remedial and Special Education*, *43*(6), 434-447. https://doi.org/10.1177/07419325211063487

Babineau, M., Carvalho, A., Trueswell, J., & Christophe, A. (2020). Familiar words can serve as a semantic seed for syntactic bootstrapping. *Developmental Science, 24*(1). https://doi.org/10.1111/desc.13010

Balthazar, C. H., & Scott, C. M. (2018). Targeting complex sentences in older school children with specific language impairment: Results from an early-phase treatment study. *Journal of Speech, Language, and Hearing Research*, *61*(3), 713–728. https://doi.org/10.1044/2017_JSLHR-L-17-0105

Barnes, E. M., Oliveira, A. W., & Dickinson, D. K. (2019). Teacher accommodation of academic language during Head Start pre-kindergarten read-alouds. *Journal of Education for Students Placed at Risk*, *24*(4), 369–393. https://doi.org/10.1080/10824669.2019.1657868

Begg, C.B., & Mazumdar, M. (1994) Operating characteristics of a rank correlation test for publication bias. *Biometrics*, *50*, 1088-1101. http://dx.doi.org/10.2307/2533446

Biemiller, A. (2014). Oral comprehension sets the ceiling on reading comprehension. *Literacy Ladder: Increasing Young Children's Language, Knowledge and Reading Comprehension*, 52–53.

Bloom, L. & Lahey, M. (1978). *Language development and language disorders*. New York: Wiley.

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The effects of morphological instruction on literacy skills: A systematic review of the literature. *Review of Educational Research*, *80*(2), 144–179. https://doi.org/10.3102%2F0034654309359353

Bowey, J. A., & Patel, R. K. (1988). Metalinguistic ability and early reading achievement. *Applied Psycholinguistics*, *9*(4), 367–383. https://doi.org/10.1017/S0142716400008067

Brimo, D., Apel, K., & Fountain, T. (2017). The effects of syntactic awareness and syntactic knowledge on reading comprehension among 9th and 10th grade students. *Journal of Reading Research, 40*(1), 57-74. https://doi.org/10.1111/1467-9817.12050

Brimo, D., Lund, E., & Sapp, A. (2017). Syntax and reading comprehension: A meta-analysis of different spoken-syntax assessments. *International Journal of Language and Communication Disorders*, *53*(3), 431-445. https://doi.org/10.1111/1460-6984.12362

Cain, K. (2007). Syntactic awareness and reading ability: Is there any evidence for a special relationship? *Applied Psycholinguistics, 28*(4), 679-694. https://doi.org/10.1017/S0142716407070361

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. *British Journal of Educational Psychology, 76*(4), 683-696. https://doi.org/10.1348/000709905X67610

Cain, K., & Oakhill, J. (2014). Reading comprehension and vocabulary: Is vocabulary more important for some aspects of comprehension? *L'Année Psychologique*, *114*(4), 647–662. https://doi.org/10.4074/S0003503314004035

Chall, J. S. (1983). *Stages of reading development*. New York, NY: McGraw-Hill.

Cheung, M. W.-L., & Chan, W. (2005). Meta-analytic structural equation modeling: A two-stage approach. *Psychological Methods*, *10*(1), 40–64. https://doi-org/10.1037/1082-989X.10.1.40.supp (Supplemental)

Cheung, M. W. L. & Cheung, S. F. (2016). Random-effects models for meta-analytic structural equation modeling: review, issues, and illustrations. *Research Synthesis Methods*, *7*(2), 140-155. https://doi.org/10.1002/jrsm.1166

Common Core State Standards (2021). *Key shifts in English language arts*. Retrieved from http://www.corestandards.org/other-resources/key-shifts-in-english-language-arts/

Colenutt, A., & Toye, M. A. (2012). Critical crossroads: Youth, criminal justice and literacy Discussion Paper. Retrieved March 9, 2021, from http://en.copian.ca/library/research/frontier/critical_crossroads/critical_crossroads.pdf

Curran, M. (2020). Complex sentences in an elementary science curriculum: A research note. *Language, Speech, and Hearing Services in Schools, 51*(2), 329-335. https://doi.org/10.1044/2019_LSHSS-19-00064

Dawson, H. & Phelan, M. (2016). *Language files: Materials for an introduction to language and linguistics* (12th ed.). The Ohio State University Press.

Deacon, S. H., & Kieffer, M. (2017). Unraveling the relations between syntactic awareness and reading comprehension: Evidence from mediation and longitudinal models. *Journal of Educational Psychology*, *110*(1), 72-86. https://doi.org/10.1037/edu0000198

Ehri, L. C. (2005). Development of sight word reading: Phases and findings. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 135–154). Blackwell Publishing. https://doi.org/10.1002/9780470757642.ch8

Fang, Z. (2006). The language demands of science reading in middle school. International *Journal of Science Education*, *28*, 491–520. https://doi.org/10.1080/09500690500339092

Froese-Germain, B. (2014). *Work-life balance and the Canadian teaching profession*. Retrieved from https://files.eric.ed.gov/fulltext/ED546884.pdf

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., ... & Trikalinos, T. A. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology, 64*(11), 1187-1197. https://doi.org/10.1016/j.jclinepi.2010.08.010

García, J. R., & Cain, K. (2014). Decoding and reading comprehension: A meta-analysis to identify which reader and assessment characteristics influence the strength of the relationship in English. *Review of Educational Research*, *84*(1), 74–111. https://doi-org/10.3102/0034654313499616

Gaux, C., & Gombert, J. É. (1999). Implicit and explicit syntactic knowledge and reading in pre-adolescents. *British Journal of Developmental Psychology*, *17*(2), 169–188. https://doi.org/10.1348/026151099165212

Gombert, J. E. (1992). *Metalinguistic development*. Hertfordshire, GB: Harvester Wheatsheaf

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education, 7*(1), 6-10. https://doi.org/10.1177/074193258600700104

Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2011). Coh-metrix providing multilevel analyses of text characteristics. *Educational Researcher*, *40*(5), 223-234. https://doi.org/10.3102/0013189X11413260

Guo, Y., Roehrig, A. D., & Williams, R. S. (2011). The relation of morphological awareness and syntactic awareness to adults' reading comprehension: Is vocabulary knowledge a

mediating variable? *Journal of Literacy Research*, *43*(2), 159–183. https://doi.org/10.1177/1086296X11403086

Haft, S. L., Caballero, J. N., Tanaka, H., Zekelman, L., Cutting, L. E., Uchikoshi, Y., & Hoeft, F. (2019). Direct and indirect contributions of executive function to word decoding and reading comprehension in kindergarten. *Learning and Individual Differences*, *76*, 101783. https://doi.org/10.1016/j.lindif.2019.101783

Harrer, M., Cuijpers, P., Furukawa, T.A, & Ebert, D. D. (2019). *Doing meta-analysis in R: A hands-on guide*. http://doi.org/10.5281/zenodo.2551803

Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods*, *1*(1), 39–65. https://doi.org/10.1002/jrsm.5

Hjetland, H. N., Brinchmann, E. I., Scherer, R., & Melby-Lervåg, M. (2017). Preschool predictors of later reading comprehension ability: A systematic review. *Campbell Systematic Reviews*, *13*(1), 1-155. https://doi.org/10.4073/csr.2017.14

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *2*(2), 127–160. https://doi.org/10.1007/BF00401799

Hulme, R. C., Barsky, D., & Rodd, J. M. (2018). Incidental learning and long-term retention of new word meanings from stories: The effect of number of exposures. *Language Learning: A Journal of Research in Language Studies*, *69*(1), 18-43. https://doi.org/10.1111/lang.12313

Hulme, R. C., Shapiro, L. R., & Taylor, J. S. H. (2022). Learning new words through reading: Do robust spelling–sound mappings boost learning of word forms and meanings?. *Royal Society Open Science.* https://doi.org/10.1098/rsos.210555

Hunter, J., & Sonnemann, J. (2022). *Making time for great teaching: How better government policy can help*. Grattan Institute. Retrieved from https://grattan.edu.au/wp-content/uploads/2022/01/Making-time-for-great-teaching-how-better-government-policy-can-help-Grattan-Report.pdf

Individuals with Disabilities Education Act [IDEA], 20 U.S.C. § 1400 (2004).

Jagaiah, T., Olinghouse, N. G., & Kearns, D. M. (2020). Syntactic complexity measures: Variation by genre, grade-level, students' writing abilities, and writing quality. *Reading and Writing: An interdisciplinary Journal, 33*, 2577–2638. https://doi.org/10.1007/s11145-020-10057-x

Jared, D., Cormier, P., Levy, B. A., & Wade-Woolley, L. (2011). Early predictors of biliteracy development in children in French immersion: A 4-year longitudinal study. *Journal of Educational Psychology*, *103*(1), 119-139. https://doi.org/10.1037/a0021284

Kamil, M., Mosenthal, P., Pearson, P. D., & Barr, R. (Eds.). (2000). *Handbook of reading research* (Vol. 3). Erlbaum.

Kieffer, M. J., Petscher, Y., Proctor, C. P., & Silverman, R. D. (2016). Is the whole greater than the sum of its parts? Modeling the contributions of language comprehension skills to reading comprehension in the upper elementary grades. *Scientific Studies of Reading*, *20*(6), 436–454. https://doi.org/10.1080/10888438.2016.1214591

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303. http://dx.doi.org/10.1037/0003-066X.49.4.294

Koutsoftas, A. D. (2013). School–age language development: Application of the five domains of language across four modalities. In N. Capone-Singleton & B. B. Shulman (Eds.),

Language development: Foundations, processes, and clinical applications (pp. 215-229). Jones & Bartlett Learning.

MacKay, E., Lynch, E., Sorenson Duncan, T., & Deacon, S. H. (2021). Informing the science of reading: Students' awareness of sentence-level information is important for reading comprehension. *Reading Research Quarterly*. https://doi-org /10.1002/rrq.397

Melby-Lervåg, M., & Lervåg, A. (2014). Reading comprehension and its underlying components in second-language learners: A meta-analysis of studies comparing first- and second-language learners. *Psychological Bulletin*, *140*(2), 409-433. http://doi.org/10.1037/a0033890

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*(2), 322–352. https://doi.org/10.1037/a0026744

Merritt, D. D. (2016, February). Typical speech and language development for school-age children: A checklist for school nurses. Retrieved from: http://ctserc.org/component/k2/item/130-typical-speech-and-language-development-for-school-age-children

Michener, C. J., Proctor, C. P., & Silverman, R. D. (2018). Features of instructional talk predictive of reading comprehension. *Reading and Writing: An Interdisciplinary Journa*l, *31*(3), 725–756. http://dx.doi.org/10.1007/s11145-017-9807-4

Moats, L. C. (2010). *Speech to print: Language essentials for teachers*. Baltimore, MD: Brookes Publishing.

Moats, L. C. (2020). Teaching reading is rocket science: What expert teachers of reading know and should be able to do [excerpt]. *American Educator.* Retrieved from https://files.eric.ed.gov/fulltext/EJ1260264.pdf

Moeyaert, M., Ugille, M., Beretvas, N. S., Ferron, J., Bunuan, R., & Van den Noortgate, W. (2017). Methods for dealing with multiple outcomes in meta-analysis: a comparison between averaging effect sizes, robust variance estimation and multilevel meta-analysis. *International Journal of Social Research Methodology*, *20*(6), 559–572. https://doi.org/10.1080/13645579.2016.1252189

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2010). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery*, *8*(5). 336-341.

Montgomery, J. W., Evans, J. L., Gillam, R. B., Sergeev, A. V., & Finney, M. C. (2016). "Whatdunit?" Developmental changes in children's syn- tactically based sentence interpretation abilities and sensitivity to word order. *Applied Psycholinguistics*, *37*, 1281–1309. http://dx.doi.org/10 .1017/S0142716415000570

Muter, V., Hulme, C., Snowling, M. J., Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology*, *40*(5), 665–681.

Nagy, W. E., Anderson, R. C., & Herman, P. A. (1987). Learning word meanings from context during normal reading. *American Educational Research Journal*, *24*(2), 237-270. https://doi.org/10.3102/00028312024002237

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, *17*(2), 357–374. https://doi.org/10.1017/S0305000900013817

Oakhill, J., & Cain, K. (2007). Introduction to comprehension development. In J. Oakhill and K. Cain (Eds.), *Children's comprehension problems in oral and written language*. (pp. 1-40). Guilford Press.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes*, *18*(4), 443–468. https://doi.org/10.1080/01690960344000008

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan — a web and mobile app for systematic reviews. *Systematic Reviews*, *5*(210). http://doi.org/10.1186/s13643-016-0384-4

The Pennsylvania State University (2017). *Teacher stress and health: Effects on students, teachers, and schools.* Retrieved from https://www.rwjf.org/en/insights/our-research/2016/07/teacher-stress-and-health.html

Perfetti, C. A., Landi, N., & Oakhill, J. (2005). The acquisition of reading comprehension skill. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 227–247). Blackwell Publishing. https://doi.org/10.1002/9780470757642.ch13

Perfetti, C. A., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*, 22-37. https://doi.org/10.1080/10888438.2013.827687

Phillips, B. M. (2014). Promotion of syntactical development and oral comprehension: Development and initial evaluation of a small-group intervention. *Child Language Teaching and Therapy*, *30*, 63–77. https://doi.org/10.1177/026565901348774

Phythian-Sence, C., & Wagner, R. K. (2007). Vocabulary acquisition: A primer. In R. K. Wagner, A. E. Muse, & K. R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (p. 1–14). Guilford Press.

Poulsen, M., & Gravgaard, A. K. (2016). Who did what to whom? The relationship between syntactic aspects of sentence comprehension and text comprehension. *Scientific Studies of Reading*, *20*(4), 1-14. https://doi.org/10.1080/10888438.2016.1180695

Proctor, C. P., Silverman, R. D., Harring, J. R., Jones, R. L., & Hartranft, A. M. (2020). Teaching bilingual learners: Effects of a language based reading intervention on academic language and reading comprehension in grades 4 and 5. *Reading Research Quarterly*, 55(1), 95–122. https://doi.org/10.1002/rrq.258

Pustejovsky, J. E., & Tipton, E. (2022). Meta-analysis with Robust Variance Estimation: Expanding the range of working models. *Prevention Science*, 23, 425–438. https://doi.org/10.1007/s11121-021-01246-3

R Core Team. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna (AU).

Shanahan, T. (2020). Why we need to teach sentence comprehension. Retrieved from https://www.readingrockets.org/blogs/shanahan-literacy/why-we-need-teach-sentencecomprehension

Silverman, R. D., Johnson, E., Keane, K., & Khanna, S. (2020). Beyond decoding: A meta-analysis of the effects of language comprehension interventions on k–5 students' language and literacy outcomes. *Reading Research Quarterly*, *55*(51), S207-S233. https://doi.org/10.1002/rrq.346

Snow, C. E., & Matthews, T. J. (2016). Reading and language in the early grades. *Future of Children*, *26*(2), 57-74. Retrieved from https://files.eric.ed.gov/fulltext/EJ1118540.pdf

Snowling, M. J., & Hulme, C. (2011). Evidence-based interventions for reading and language difficulties: Creating a virtuous circle. *British Journal of Educational Psychology*, *81*(1), 1–23. https://doi.org/10.1111/j.2044-8279.2010.02014.x

Sorenson Duncan, T., Karkada, M., Deacon, S. H., & Smith, I. M. (2021). Building meaning: Meta-analysis of component skills supporting reading comprehension in children with autism spectrum disorder. *Autism Research*. https://doi-org/10.1002/aur.2483

Sorenson Duncan, T., Mimeau, C., Crowell, N., & Deacon, S. H. (2020). Not all sentences are created equal: Evaluating the relation between children's understanding of basic and difficult sentences and their reading comprehension. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000545

Stahl, S. A., & Fairbanks, M. M. (1986). The effects of vocabulary instruction: A model-based meta-analysis. *Review of Educational Research*, *56*(1), 72–110. https://doi-org/10.2307/1170287

Stenner, A. J., & Swartz, C. (2012, April). *A causal Rasch model for understanding comprehension in the context of reader-text-task*. Paper presented at the annual meeting of the National Council on Measurement in Education, Vancouver, Canada.

Tilanus, E. A. T., Segers, E., & Verhoeven, L. (2019). Responsiveness to intervention after second versus third grade diagnosis of dyslexia. *Reading & Writing Quarterly*: *Overcoming Learning Difficulties,* 521-541. https://doi.org/10.1080/10573569.2019.1667929

Tipton, E., & Pustejovsky, J. E. (2015). Small-sample adjustments for tests of moderators and model fit using robust variance estimation in meta-regression. *Journal of Educational and Behavioral Statistics*, *40*, 604–634. https://doi.org/10.3102/1076998615606099

Tong, X., & McBride, C. (2017). A reciprocal relationship between syntactic awareness and reading comprehension. *Learning and Individual Differences*, *57*, 33–44. https://doi.org/10.1016/j.lindif.2017.05.005

Tong, X., Yu, L., & Deacon, S. H. (in press). A meta-analysis on the relation between syntactic skills and reading comprehension: A cross-linguistic and developmental investigation. *Review of Educational Research*. Advanced online publication.

Tunmer, W. E. (1989). The role of language-related factors in reading disability. In D. Shankweiler & I.Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 91-131). University of Michigan Press.

Tunmer, W., Herriman, M., & Nesdale, A. (1988). Metalinguistic abilities and beginning reading. *Reading Research Quarterly*, *23*(2), 134-158. https://doi.org/10.2307/747799

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. Child Development, 69(3), 848–872. https://doi.org/10.2307/1132208

Wolf, M. (2018). The science and poetry in learning (and teaching) to read. Phi Delta Kappan, 100(4), 13–17. https://doi.org/10.1177/0031721718815667

Wothke, W. (1993). Nonpositive definite matrices in structural modeling. *Sage Focus Editions*, *154*, 256-256.

Uccelli, P., Galloway, E. P., Barr, C. D., Meneses, A., & Dobbs, C. L. (2015). Beyond vocabulary: Exploring cross-disciplinary academic-language proficiency and its association with reading comprehension. *Reading Research Quarterly, 50*(3), 337–356. https://doi.org/10.1002/rrq.104

Table 1

Descriptives of the Studies Reported on in this Meta-Analysis

Author	N	Age Group	Syntactic Skills Measures	Reading Comprehension Measures
Alsdorf (1998)	48	Older elementary	Sentence Completion Naming from TOWF	PC from WJ
Blackmore & Pratt (1997)	40	Younger elementary	Grammatical Correction and Oral Close	IRAS
Bowey (1986)	48	Older elementary	Error Imitation and Error Correction	PAT and GAP
Bowey & Patel (1988)	60	Younger elementary	Error Correction and Sentence Imitation from TOLD-P	PC from WJ
Cain (2007)	99	Older elementary	Word-order Correction, Grammatical Correction, and Grammatical Knowledge from TROG	NARA -II
Cain & Oakhill (2006)	23	Older elementary	Grammatical Knowledge from TROG	NARA -II
Caravolas et al. (2019)	179	Younger elementary	Grammatical Knowledge from TROG	GMRT
Carter (1997)	35	Older elementary	Sentence Correction, Oral Cloze Task, and Sentence Repetition	QR-II
Connor et al. (2018)	345	Older elementary	Syntax Construction from CASL	TOSREC and GMRT

Davidson (2016)	25	Older elementary	Grammatical Comprehension from TOLD	PC from WRMT-III
Deacon & Kieffer (2017)	100	Older elementary	Sentence Correction	PC from WJ
DeNigris & Brooks (2018)	62	Younger elementary	Grammatical Knowledge from TROG	Reading Comprehension composite from Woodcock Reading Mastery Tests
Farnia & Geva (2013)	153	Older elementary	Grammatical Judgment Task	GMRT and experimental
Foorman, Herrera, et al. (2015)	287	Younger elementary	Sentence Structure and Recalling Sentences from CELF	GMRT
Foorman, Koon, et al. (2015)	901	Older elementary	Recalling Sentences from CELF and Grammatical Judgment from CASL	GMRT and FCAT
Foorman, Petscher, & Herrera (2018)	2,047	Younger and older elementary	Sentence Structure, Formulating Sentences, and Recalling Sentences from CELF; Grammatical Judgment from CASL	GMRT and FCAT
Foorman, Wu, Quinn, & Petscher (2020)	321	Older elementary	Recalling Sentences from CELF and Grammatical Judgment from CASL	GMRT and FCAT
Glass & Perna (1986)	95	Older elementary	Sentence Comprehension	SDRT-4
Gottardo, Stanovich, & Siegel (1996)	112	Older elementary	Sentence Correction and Sentence Judgment	SDRT-4

Kieffer, Petscher, Proctor, & Silverman (2016)	311	Older elementary	Formulated Sentences CELF-4	GMRT and PC from WJ
Kim (2017)	350	Younger elementary	Grammatical Judgment from CASL	PC from WJ and Reading Comprehension subtest from WIAT
Kim & Graham (2022)	350	Younger elementary	Grammatical Judgment from CASL	PC from WJ and Reading Comprehension subtest from WIAT
Kim, Otaiba, Sidler, Gruelich (2013)	527	Younger elementary	Grammatical Completion from TOLD-I	PC from WJ
Kim & Petscher (2020)	529	Younger elementary	Grammatical Judgment from CASL	PC from WJ and Reading Comprehension subtest from WIAT
Kim et al. (2011)	242	Kindergarten	Sentence Imitation and Grammatical Completion from TOLD	PC from WJ
Lee, Yeatman, Luna, & Feldman (2011)	24	Older elementary	TROG-2	PC from WJ
Lesaux, Lipka, & Siegel (2006)	395	Kindergarten	Oral Cloze	SDRT-4
Lesaux, Rupp, & Siegel (2007)	689	Older elementary	Oral Cloze	SDRT-4

Low & Siegel (2005)	884	Older elementary	Oral Cloze	SDRT-4 and experimental measure
Michener, Proctor, & Silverman (2018)	236	Older elementary	Formulated Sentences CELF-4	Woodcock-Munos Language Survey-Revised Passage Comprehension
Mokhtari & Thompson (2006)	32	Older elementary	Sentence Combining, Word Ordering, and Grammatical Competence from TOLD	GMRT and Oklahoma Criterion-Referenced Reading Test
Mokhtari & Niederhauser (2013)	32	Older elementary	Sentence Combining, Word Ordering, and Grammatical Competence from TOLD	GMRT
Muter, Hulme, Snowling, & Stevenson (2004)	90	Younger elementary	Word-order Correction	NARA -II
Oakhill, Cain, & Bryant (2003)	102	Younger and elementary older	TROG-III	NARA-R and GMRT
Russell (2002)	98	Older elementary	Grammatical Comprehension from TOLD	Qualitative Reading Inventory-III Passage Comprehension
Santoro (2013)	619	Older elementary	CELF Formulated Sentences	GMRT and Maze
Sorenson Duncan, Mimeau, Crowell, & Deacon (2020)	104	Older elementary	Whatdunnit	GMRT

Tong, Deacon, & Cain (2014)	100	Older elementary	Sentence Correction	GMRT and PC from WRMT
Torrey (1983)	27	Younger elementary	Sentence Comprehension	Metropolitan Achievement Test
Tunmer (1989)	184	Younger elementary	Sentence Correction	Reading Comprehension subtest from Informal Reading Inventory
Yoon (2011)	26	Older elementary	Sentence Verification	PC from WRMT-R

Table 2

The Number of Effect Sizes (k), Effect Size Statistics, and the F-Statistic for Group Comparisons of the Direct Relations

	Effect Sizes			
Relationship	*k*	*r*	95% CI	*F*
Syntactic Skills and RC				
Full Sample	133	.473	.441 - .510	
Younger Elementary	35	.495	.447 - .543	
Older Elementary	98	.471	.423 - .513	F(1, 14.5) = .673; *p* = .426
SC and RC				
Full Sample	72	.472	.433 - .511	
Younger Elementary	16	.506	.423 - .584	
Older Elementary	56	.465	.419 - .511	F(1,7.45) = 1.232; *p* = .302
SA and RC				
Full Sample	61	.482	.423 - .430	
Younger Elementary	19	.488	.404 – .572	
Older Elementary	42	.479	.394 – .564	F(1,7.75) = .040; *p* = 0.847

Table 3

The Model Fit Statistics for the Mediation Model with Word Reading for the Full Sample and Younger and Older Elementary Groups

	Model Fit Statistics							
	$\chi 2$	*p*	RMSEA	SRMR	CFI	TLI	AIC	BIC
Syntactic Skills								
Full Sample	144.960	<.001	.104	.136	.903	.708	142.960	135.467
Younger Elementary	69.340	<.001	.161	.106	.940	.820	67.340	61.463
Older Elementary	99.604	<.001	.099	.144	.886	.657	97.604	90.386
SC								
Full Sample	88.486	<.001	.119	.153	.886	.657	86.486	79.752
Younger Elementary	45.136	<.001	.199	.137	.949	.847	43.136	38.122
Older Elementary	62.735	<.001	.110	.155	.875	.626	60.735	54.198
SA								
Full Sample	58.214	<.001	.090	.114	.929	.787	56.214	49.352
Younger Elementary	33.618	<.001	.146	.122	.962	.885	31.618	26.289
Older Elementary	38.797	<.001	.088	.131	.913	.738	36.797	30.304

Table 4

The Model Fit Statistics for the Mediation Model with Vocabulary for the Full Sample and Younger and Older Elementary Groups

	Model Fit Statistics							
	$\chi 2$	*p*	RMSEA	SRMR	CFI	TLI	AIC	BIC
Syntactic Skills								
Full Sample	150.891	<.001	.099	.107	.942	.826	148.891	141.248
Younger Elementary	104.982	<.001	.149	.127	.786	.929	102.982	96.530
Older Elementary	95.269	<.001	.093	.103	.946	.837	93.260	85.956
SC								
Full Sample	102.379	<.001	.102	.100	.961	.883	100.379	93.197
Younger Elementary	47.840	<.001	.125	.096	.951	.854	45.840	39.833
Older Elementary	93.101	<.001	.117	.095	.962	.887	91.101	84.288
SA								
Full Sample	62.149	<.001	.099	.115	.926	.778	60.149	53.413
Younger Elementary	49.223	<.001	.185	.149	.930	.791	47.223	41.792
Older Elementary	28.891	<.001	.076	.112	.938	.815	26.891	20.414

Table 5

The Coefficients and Error Variances for All Variables in the Mediated Effect Models with Word Reading

Group	Coefficients	Estimate	95% CI
Full Sample	Syntax - WR	.50	.47 - .53
	WR - RC	.70	.66 - .74
	SC - WR	.49	.45 - .53
	WR - RC	.71	.65 - .77
	SA - WR	.51	.47 - .56
	WR - RC	.68	.63 - .73
Younger Elementary	Syntax - WR	.46	.41 - .50
	WR - RC	.70	.66 - .74
	SC - WR	.42	.36 - .48
	WR - RC	.67	.63 - .72
	SA - WR	.56	.51 - .61
	WR - RC	.76	.71 - .82
Older Elementary	Syntax - WR	.51	.47 - .55
	WR - RC	.66	.61 - .71
	SC - WR	.49	.44 - .54
	WR - RC	.67	.61 - .74
	SA - WR	.54	.47 - .60
	WR - RC	.62	.56 - .69

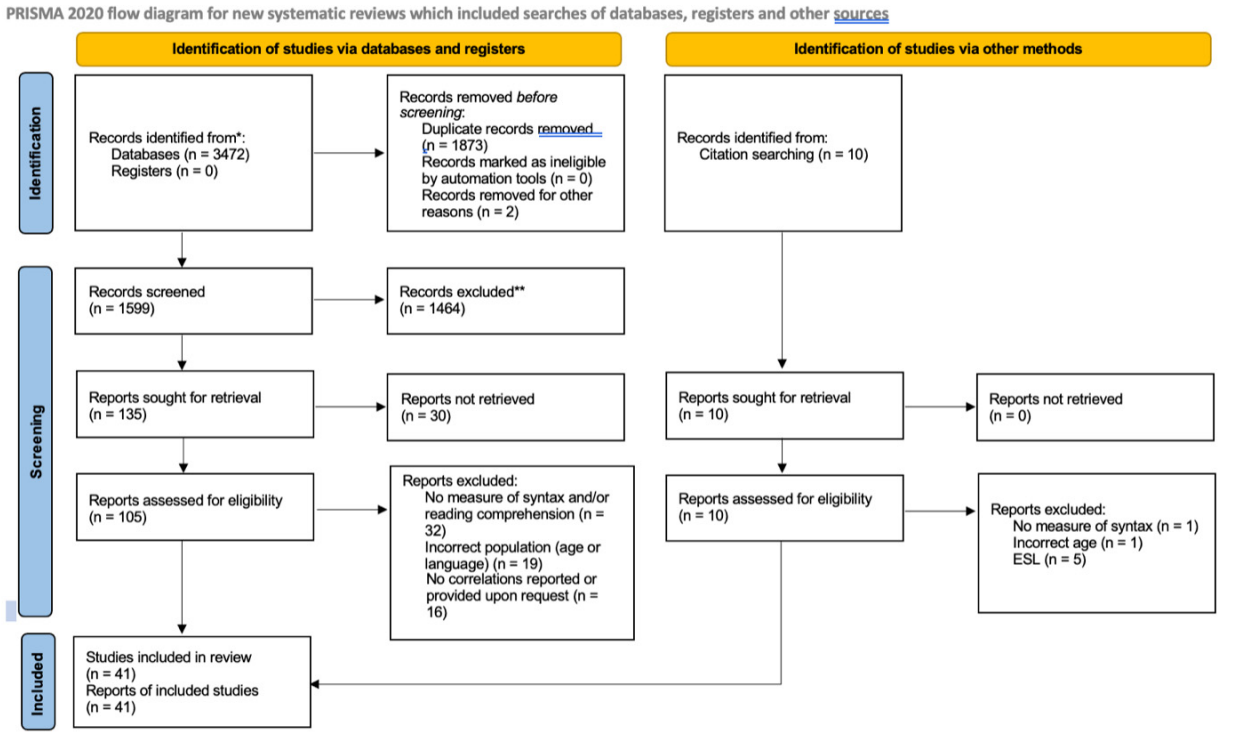
Table 6

The Coefficients and Error Variances for All Variables in the Mediated Effect Models with Vocabulary

Group	Coefficients	Estimate	95% CI
Full Sample	Syntax - Vocab	.61	.58 - .64
	Vocab - RC	.61	.58 - .63
	SC - Vocab	.62	.58 - .65
	Vocab - RC	.61	.59 - .64
	SA - Vocab	.61	.56 - .66
	Vocab - RC	.57	.52 - .61
Younger Elementary	Syntax - Vocab	.72	.68 - .76
	Vocab - RC	.59	.56 - .63
	SC - Vocab	.74	.69 - .79
	Vocab - RC	.58	.53 - .62
	SA - Vocab	.67	.62 - .72
	Vocab - RC	.64	.59 - .70
Older Elementary	Syntax - Vocab	.56	.53 - .60
	Vocab - RC	.61	.58 - .65
	SC - Vocab	.55	.51 - .58
	Vocab - RC	.62	.60 - .65
	SA - Vocab	.58	.52 - .65
	Vocab - RC	.56	.50 - .62

Figure 1

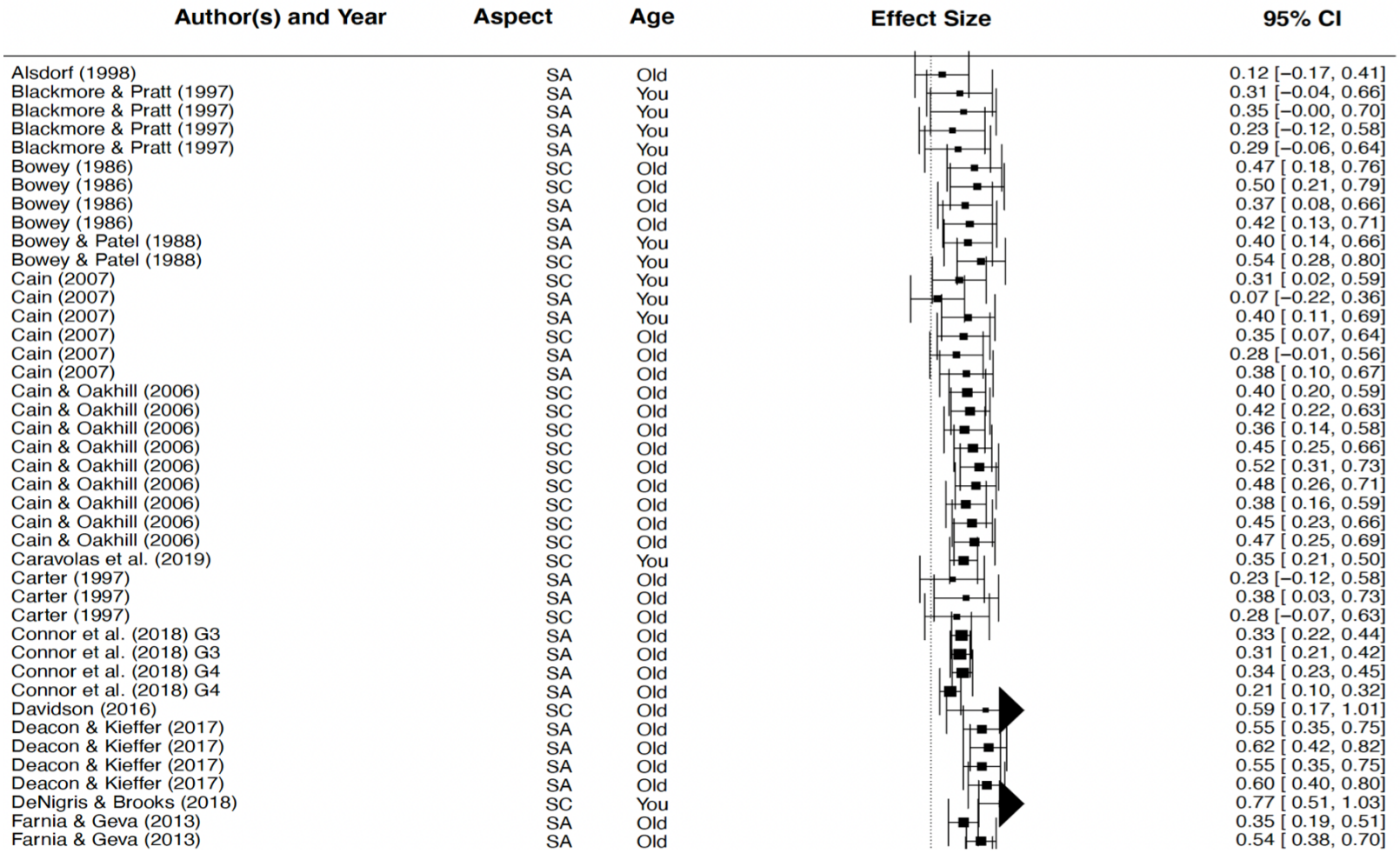
The PRISMA Flow Diagram for the Inclusion and Exclusion of Studies

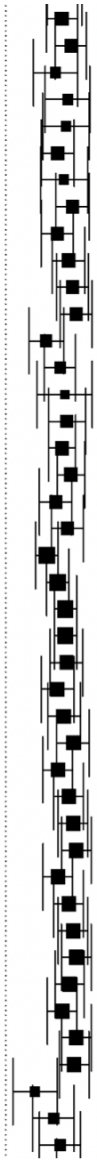


From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

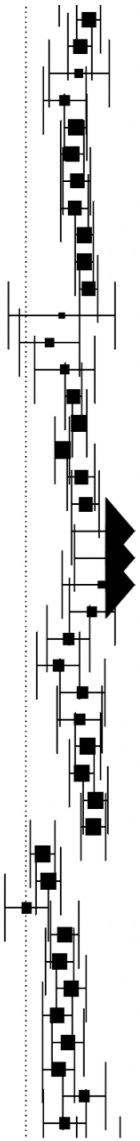
Figure 2

The Effect Sizes from Studies Investigating the Relationship between Syntactic Skills and Reading Comprehension





Foorman, Herrera, et al. (2015) G1	SC	You	0.52 [0.38, 0.66]
Foorman, Herrera, et al. (2015) G1	SC	You	0.60 [0.46, 0.74]
Foorman, Herrera, et al. (2015) G2	SC	You	0.46 [0.26, 0.66]
Foorman, Herrera, et al. (2015) G2	SC	You	0.57 [0.37, 0.77]
Foorman, Koon,et al. (2015) G4	SC	Old	0.56 [0.34, 0.77]
Foorman, Koon, et al. (2015) G4	SC	Old	0.48 [0.33, 0.63]
Foorman, Koon, et al .(2015) G5	SA	Old	0.54 [0.32, 0.75]
Foorman, Koon, et al. (2015) G5	SA	Old	0.62 [0.46, 0.77]
Foorman, Koon, et al. (2015) G4	SC	Old	0.48 [0.33, 0.63]
Foorman, Koon, et al. (2015) G4	SC	Old	0.58 [0.43, 0.73]
Foorman, Koon, et al. (2015) G6	SA	Old	0.62 [0.47, 0.76]
Foorman, Koon, et al. (2015) G6	SA	Old	0.65 [0.50, 0.80]
Foorman, Koon, et al. (2015) G5	SC	Old	0.38 [0.21, 0.54]
Foorman, Koon, et al. (2015) G5	SC	Old	0.50 [0.36, 0.64]
Foorman, Koon, et al. (2015) G6	SA	Old	0.54 [0.29, 0.80]
Foorman, Koon, et al. (2015) G6	SA	Old	0.56 [0.39, 0.73]
Foorman, Petscher, & Herrera (2018) G1	SC	You	0.52 [0.39, 0.65]
Foorman, Petscher, & Herrera (2018) G1	SC	You	0.60 [0.47, 0.73]
Foorman, Petscher, & Herrera (2018) G2	SC	You	0.46 [0.31, 0.61]
Foorman, Petscher, & Herrera (2018) G2	SC	You	0.57 [0.42, 0.72]
Foorman, Petscher, & Herrera (2018) G3	SC	Old	0.38 [0.28, 0.48]
Foorman, Petscher, & Herrera (2018) G3	SC	Old	0.48 [0.38, 0.58]
Foorman, Petscher, & Herrera (2018) G3	SC	Old	0.55 [0.45, 0.65]
Foorman, Petscher, & Herrera (2018) G3	SC	Old	0.55 [0.45, 0.65]
Foorman, Petscher, & Herrera (2018) G4	SC	Old	0.56 [0.41, 0.71]
Foorman, Petscher, & Herrera (2018) G4	SC	Old	0.48 [0.33, 0.63]
Foorman, Petscher, & Herrera (2018) G5	SA	Old	0.54 [0.39, 0.69]
Foorman, Petscher, & Herrera (2018) G5	SA	Old	0.62 [0.47, 0.77]
Foorman, Petscher, & Herrera (2018) G4	SC	Old	0.48 [0.34, 0.62]
Foorman, Petscher, & Herrera (2018) G4	SC	Old	0.58 [0.44, 0.72]
Foorman, Petscher, & Herrera (2018) G6	SA	Old	0.62 [0.48, 0.76]
Foorman, Petscher, & Herrera (2018) G6	SA	Old	0.65 [0.51, 0.79]
Foorman, Petscher, & Herrera (2018) G5	SC	Old	0.48 [0.34, 0.62]
Foorman, Petscher, & Herrera (2018) G5	SC	Old	0.58 [0.44, 0.72]
Foorman, Petscher, & Herrera (2018) G6	SA	Old	0.62 [0.48, 0.76]
Foorman, Petscher, & Herrera (2018) G6	SA	Old	0.65 [0.51, 0.79]
Foorman, Wu, Quinn, & Petscher (2020)	SC	Old	0.59 [0.45, 0.73]
Foorman, Wu, Quinn, & Petscher (2020)	SC	Old	0.52 [0.38, 0.66]
Foorman, Wu, Quinn, & Petscher (2020)	SA	Old	0.65 [0.51, 0.79]
Foorman, Wu, Quinn, & Petscher (2020)	SA	Old	0.63 [0.49, 0.77]
Glass & Perna (1986)	SC	Old	0.27 [0.07, 0.47]
Gottardo, Stanovuch, & Siegel (1996)	SA	Old	0.44 [0.25, 0.63]
Gottardo, Stanovuch, & Siegel (1996)	SA	Old	0.50 [0.31, 0.69]



Kieffer, Petscher, Proctor, & Silverman (2016)	SC	Old	0.58 [0.47, 0.69]
Kieffer, Petscher, Proctor, & Silverman (2016)	SC	Old	0.50 [0.39, 0.61]
Kim et al. (2011)	SC	Kin	0.49 [0.21, 0.77]
Kim et al. (2011)	SA	Kin	0.36 [0.16, 0.56]
Kim (2017)	SA	You	0.46 [0.35, 0.57]
Kim (2017)	SA	You	0.43 [0.32, 0.54]
Kim & Graham (2021)	SA	You	0.47 [0.35, 0.59]
Kim & Graham (2021)	SA	You	0.45 [0.33, 0.57]
Kim & Petscher (2021)	SA	You	0.54 [0.45, 0.63]
Kim & Petscher (2021)	SA	You	0.54 [0.45, 0.63]
Kim, Otaiba, Sidler, Gruelich (2013)	SA	You	0.58 [0.49, 0.67]
Lee, Yeatman, Luna, & Feldman (2011)	SC	Old	0.33 [−0.16, 0.82]
Lesaux, Lipka, & Siegel (2006)	SA	Kin	0.22 [−0.06, 0.50]
Lesaux, Lipka, & Siegel (2006)	SA	Old	0.36 [0.08, 0.64]
Lesaux, Rupp, & Siegel (2007)	SA	Old	0.44 [0.37, 0.51]
Low & Siegel (2005)	SA	Old	0.49 [0.43, 0.56]
Low & Siegel (2005)	SA	Old	0.34 [0.27, 0.40]
Michener, Proctor, & Silverman (2018)	SC	Old	0.51 [0.38, 0.64]
Michener, Proctor, & Silverman (2018)	SC	Old	0.55 [0.42, 0.68]
Mokhtari & Thompson (2006)	SA	Old	0.79 [0.42, 1.15]
Mokhtari & Thompson (2006)	SA	Old	0.82 [0.45, 1.18]
Mokhtari & Niederhauser (2013)	SA	Old	0.70 [0.34, 1.06]
Muter, Hulme, Snowling, & Stevenson (2004)	SA	You	0.61 [0.40, 0.82]
Oakhill, Cain, & Bryant (2003)	SC	You	0.40 [0.20, 0.59]
Oakhill, Cain, & Bryant (2003)	SC	You	0.30 [0.11, 0.50]
Oakhill, Cain, & Bryant (2003)	SC	Old	0.52 [0.31, 0.73]
Oakhill, Cain, & Bryant (2003)	SC	Old	0.50 [0.29, 0.70]
Proctor, Silverman, & Harring (2012)	SC	Old	0.57 [0.46, 0.69]
Proctor, Silverman, & Harring (2012)	SC	Old	0.52 [0.40, 0.63]
Proctor, Silverman, & Harring (2012)	SC	Old	0.64 [0.53, 0.76]
Proctor, Silverman, & Harring (2012)	SC	Old	0.62 [0.51, 0.74]
Proctor, Silverman, & Harring (2012)	SC	Old	0.16 [0.04, 0.27]
Proctor, Silverman, & Harring (2012)	SC	Old	0.21 [0.09, 0.32]
Russell (2002)	SC	Old	0.01 [−0.19, 0.21]
Santoro (2013)	SC	Old	0.36 [0.23, 0.49]
Santoro (2013)	SC	Old	0.31 [0.18, 0.44]
Santoro (2013)	SC	Old	0.42 [0.28, 0.56]
Santoro (2013)	SC	Old	0.29 [0.15, 0.43]
Santoro (2013)	SC	Old	0.39 [0.24, 0.54]
Santoro (2013)	SC	Old	0.30 [0.15, 0.45]
Sorenson–Duncan, Mimeau, Crowell, & Deacon (2020)	SC	Old	0.54 [0.34, 0.74]
Sorenson–Duncan, Mimeau, Crowell, & Deacon (2020)	SC	Old	0.36 [0.16, 0.56]

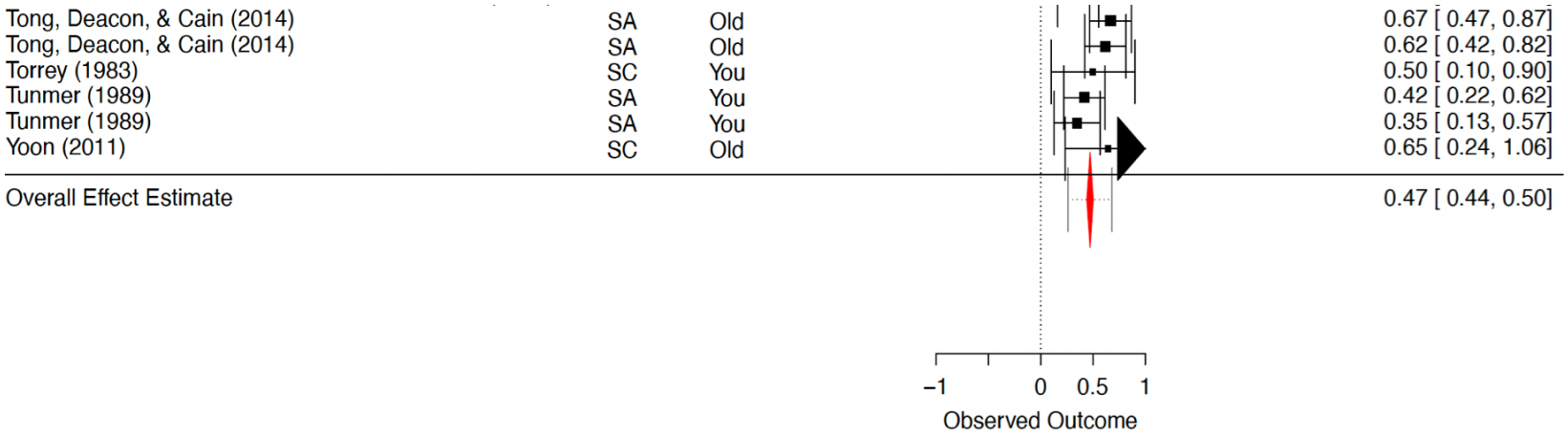
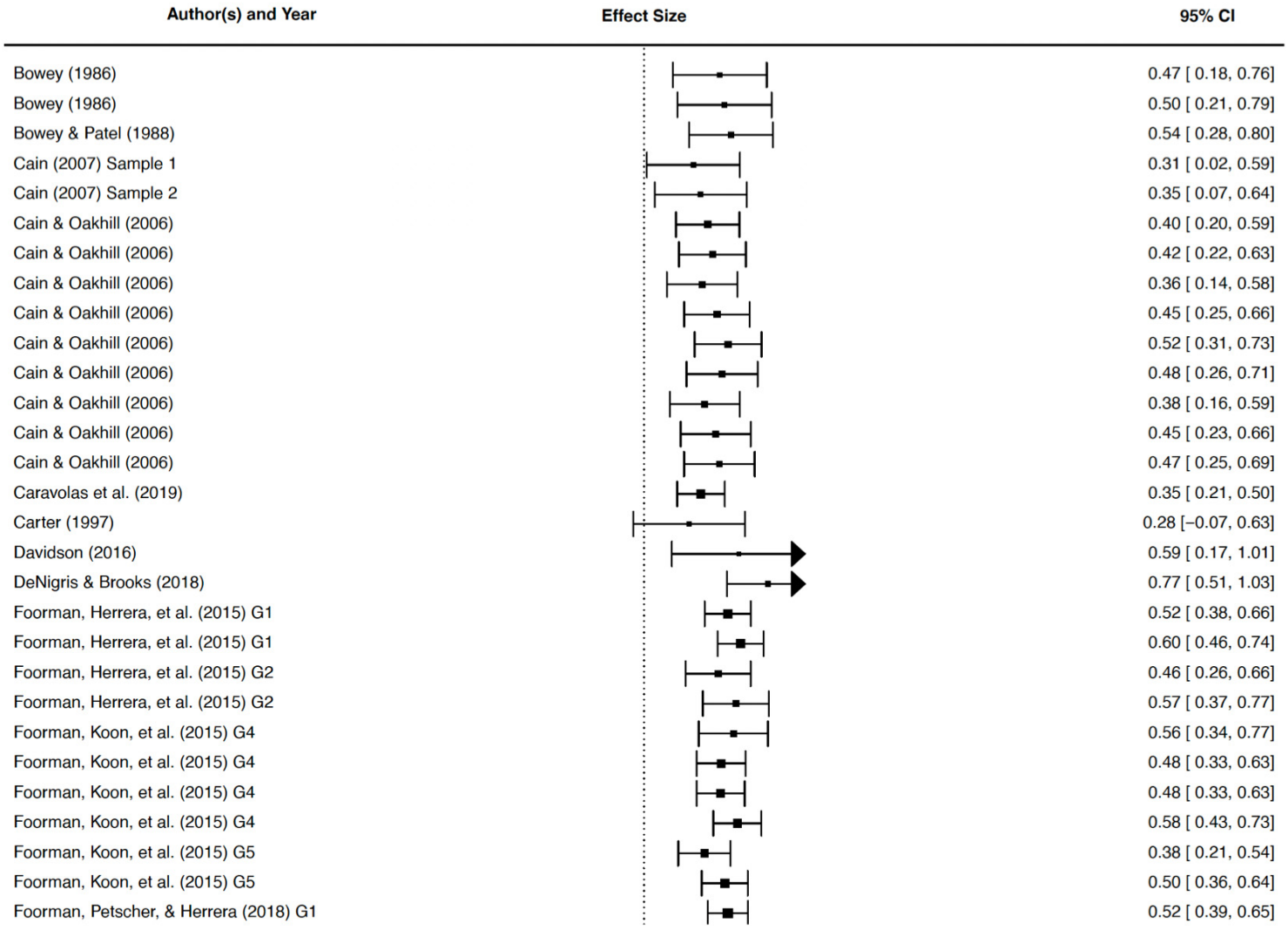
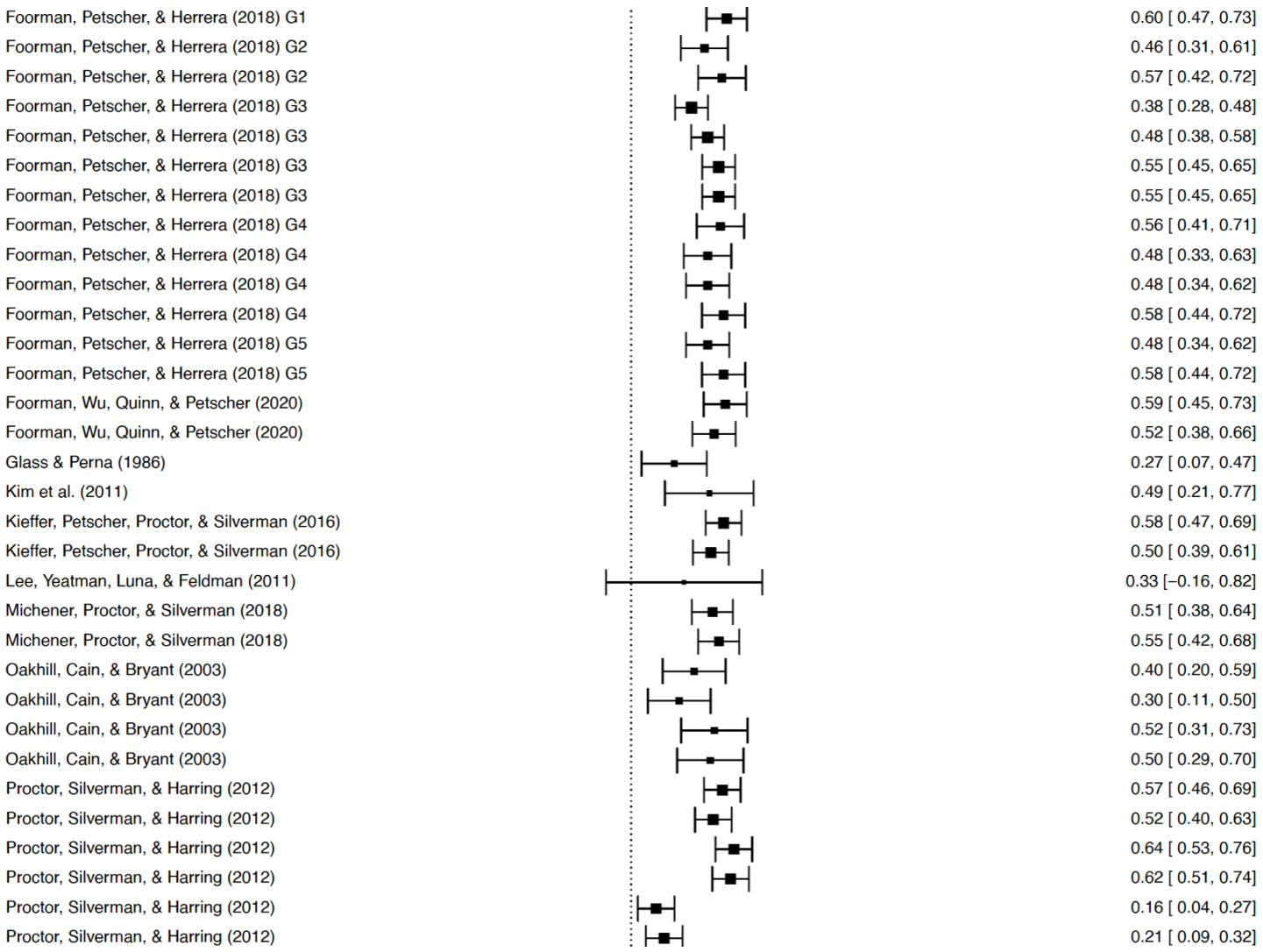

Tong, Deacon, & Cain (2014) SA Old 0.67 [0.47, 0.87]
Tong, Deacon, & Cain (2014) SA Old 0.62 [0.42, 0.82]
Torrey (1983) SC You 0.50 [0.10, 0.90]
Tunmer (1989) SA You 0.42 [0.22, 0.62]
Tunmer (1989) SA You 0.35 [0.13, 0.57]
Yoon (2011) SC Old 0.65 [0.24, 1.06]
Overall Effect Estimate 0.47 [0.44, 0.50]
−1
0
0.5
1
Observed Outcome

Figure 3

The Effect Sizes from Studies Investigating the Relationship between Syntactic Comprehension and Reading Comprehension




Foorman, Petscher, & Herrera (2018) G1 0.60 [0.47, 0.73]
Foorman, Petscher, & Herrera (2018) G2 0.46 [0.31, 0.61]
Foorman, Petscher, & Herrera (2018) G2 0.57 [0.42, 0.72]
Foorman, Petscher, & Herrera (2018) G3 0.38 [0.28, 0.48]
Foorman, Petscher, & Herrera (2018) G3 0.48 [0.38, 0.58]
Foorman, Petscher, & Herrera (2018) G3 0.55 [0.45, 0.65]
Foorman, Petscher, & Herrera (2018) G3 0.55 [0.45, 0.65]
Foorman, Petscher, & Herrera (2018) G4 0.56 [0.41, 0.71]
Foorman, Petscher, & Herrera (2018) G4 0.48 [0.33, 0.63]
Foorman, Petscher, & Herrera (2018) G4 0.48 [0.34, 0.62]
Foorman, Petscher, & Herrera (2018) G4 0.58 [0.44, 0.72]
Foorman, Petscher, & Herrera (2018) G5 0.48 [0.34, 0.62]
Foorman, Petscher, & Herrera (2018) G5 0.58 [0.44, 0.72]
Foorman, Wu, Quinn, & Petscher (2020) 0.59 [0.45, 0.73]
Foorman, Wu, Quinn, & Petscher (2020) 0.52 [0.38, 0.66]
Glass & Perna (1986) 0.27 [0.07, 0.47]
Kim et al. (2011) 0.49 [0.21, 0.77]
Kieffer, Petscher, Proctor, & Silverman (2016) 0.58 [0.47, 0.69]
Kieffer, Petscher, Proctor, & Silverman (2016) 0.50 [0.39, 0.61]
Lee, Yeatman, Luna, & Feldman (2011) 0.33 [−0.16, 0.82]
Michener, Proctor, & Silverman (2018) 0.51 [0.38, 0.64]
Michener, Proctor, & Silverman (2018) 0.55 [0.42, 0.68]
Oakhill, Cain, & Bryant (2003) 0.40 [0.20, 0.59]
Oakhill, Cain, & Bryant (2003) 0.30 [0.11, 0.50]
Oakhill, Cain, & Bryant (2003) 0.52 [0.31, 0.73]
Oakhill, Cain, & Bryant (2003) 0.50 [0.29, 0.70]
Proctor, Silverman, & Harring (2012) 0.57 [0.46, 0.69]
Proctor, Silverman, & Harring (2012) 0.52 [0.40, 0.63]
Proctor, Silverman, & Harring (2012) 0.64 [0.53, 0.76]
Proctor, Silverman, & Harring (2012) 0.62 [0.51, 0.74]
Proctor, Silverman, & Harring (2012) 0.16 [0.04, 0.27]
Proctor, Silverman, & Harring (2012) 0.21 [0.09, 0.32]

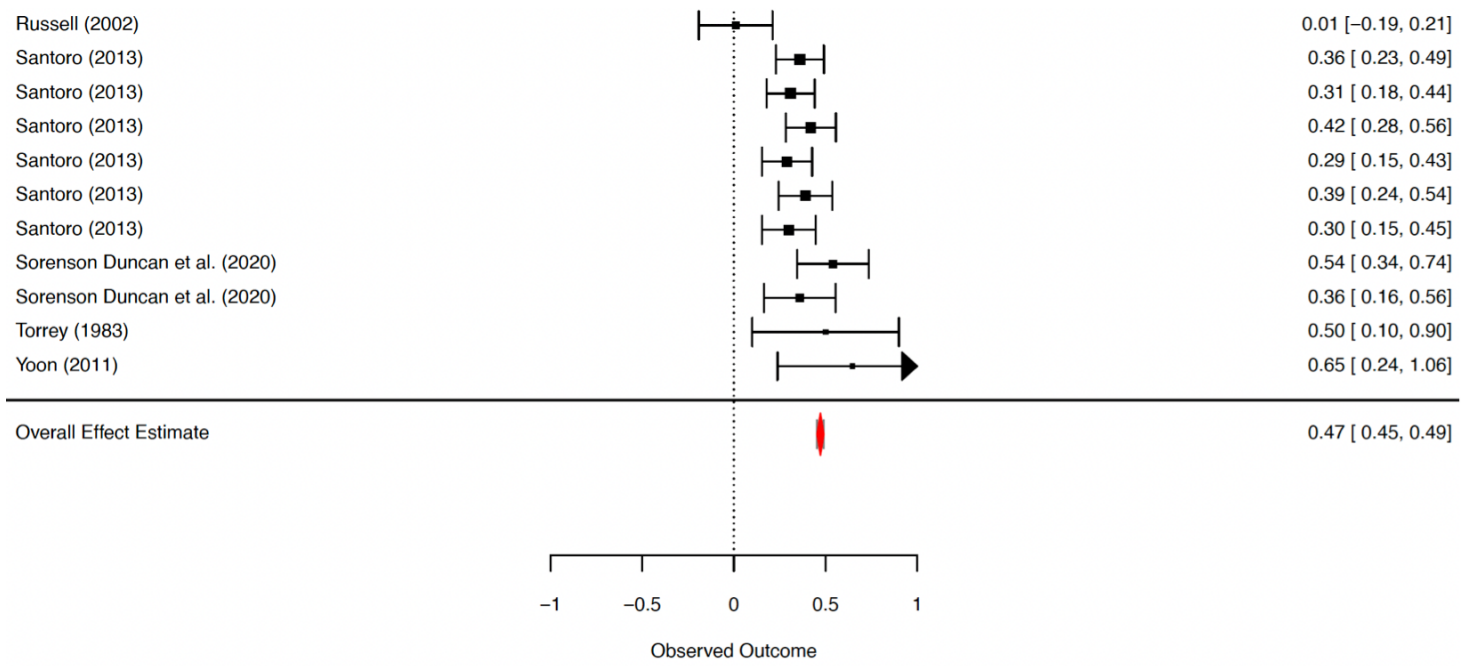
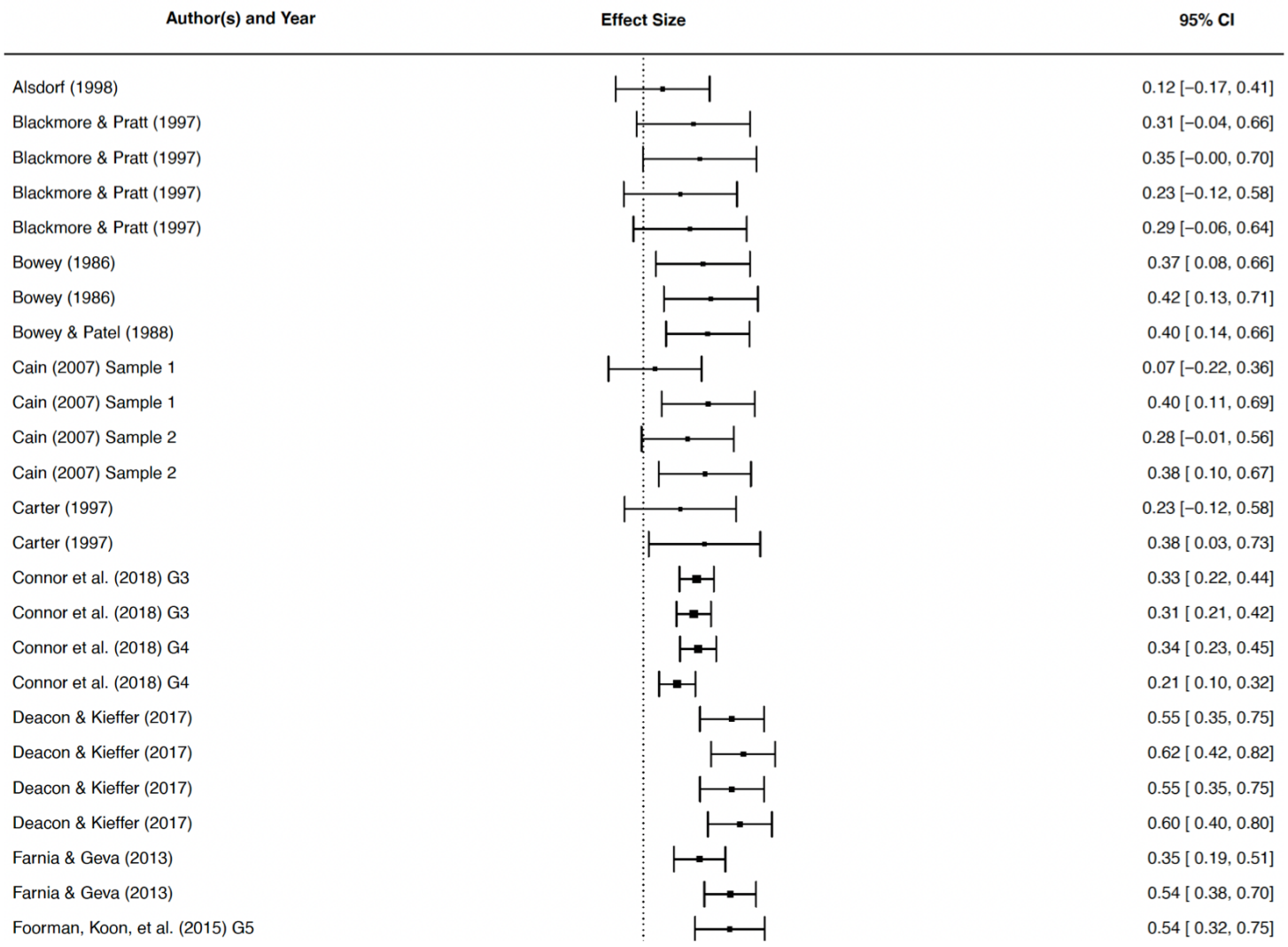
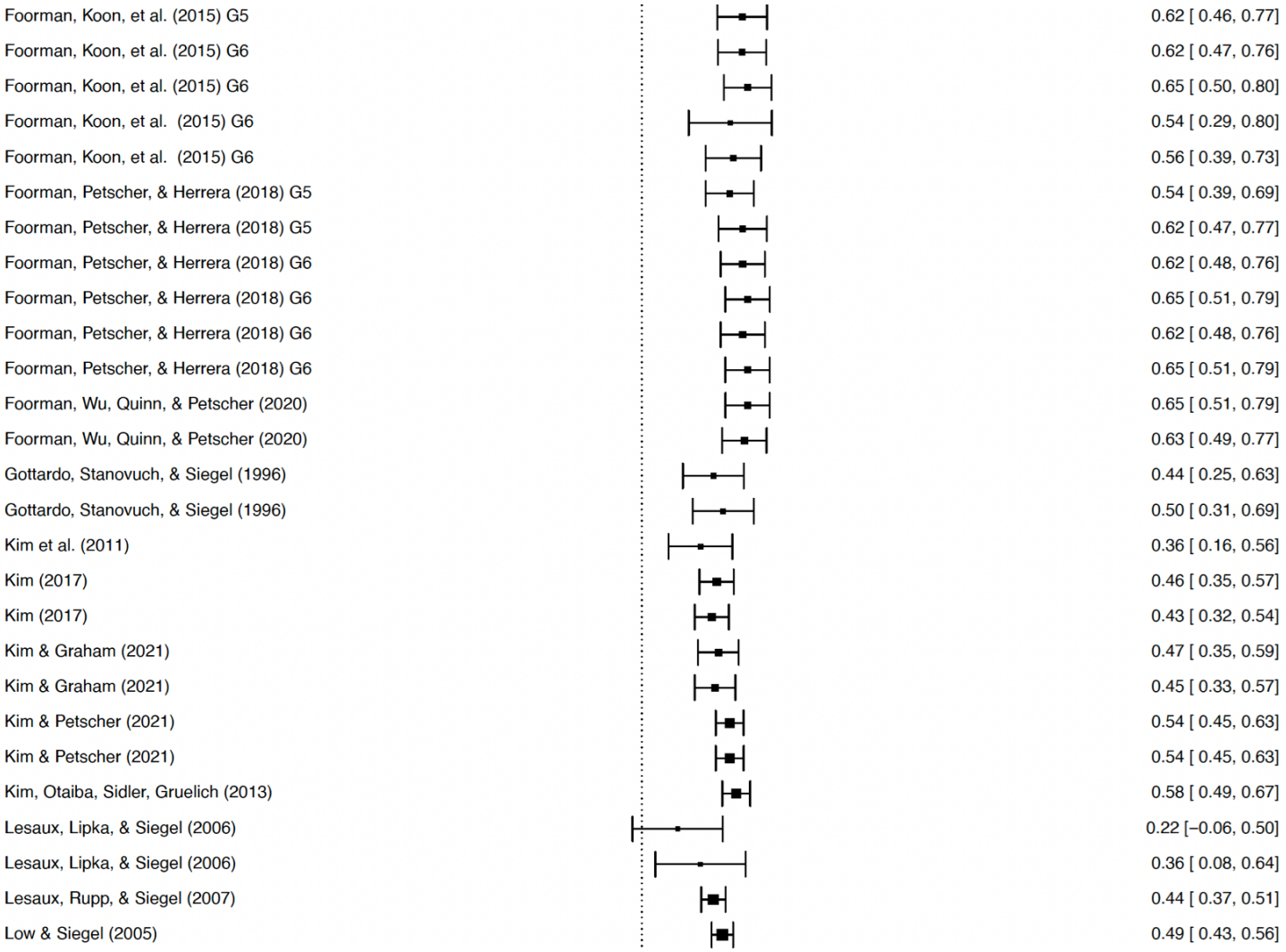

Russell (2002)
Santoro (2013)
Santoro (2013)
Santoro (2013)
Santoro (2013)
Santoro (2013)
Santoro (2013)
Sorenson Duncan et al. (2020)
Sorenson Duncan et al. (2020)
Torrey (1983)
Yoon (2011)
Overall Effect Estimate
0.01 [−0.19, 0.21]
0.36 [0.23, 0.49]
0.31 [0.18, 0.44]
0.42 [0.28, 0.56]
0.29 [0.15, 0.43]
0.39 [0.24, 0.54]
0.30 [0.15, 0.45]
0.54 [0.34, 0.74]
0.36 [0.16, 0.56]
0.50 [0.10, 0.90]
0.65 [0.24, 1.06]
0.47 [0.45, 0.49]
−1
−0.5
0
0.5
1
Observed Outcome

Figure 4

The Effect Sizes from Studies Investigating the Relationship between Syntactic Awareness and Reading Comprehension




Foorman, Koon, et al. (2015) G5 0.62 [0.46, 0.77]
Foorman, Koon, et al. (2015) G6 0.62 [0.47, 0.76]
Foorman, Koon, et al. (2015) G6 0.65 [0.50, 0.80]
Foorman, Koon, et al. (2015) G6 0.54 [0.29, 0.80]
Foorman, Koon, et al. (2015) G6 0.56 [0.39, 0.73]
Foorman, Petscher, & Herrera (2018) G5 0.54 [0.39, 0.69]
Foorman, Petscher, & Herrera (2018) G5 0.62 [0.47, 0.77]
Foorman, Petscher, & Herrera (2018) G6 0.62 [0.48, 0.76]
Foorman, Petscher, & Herrera (2018) G6 0.65 [0.51, 0.79]
Foorman, Petscher, & Herrera (2018) G6 0.62 [0.48, 0.76]
Foorman, Petscher, & Herrera (2018) G6 0.65 [0.51, 0.79]
Foorman, Wu, Quinn, & Petscher (2020) 0.65 [0.51, 0.79]
Foorman, Wu, Quinn, & Petscher (2020) 0.63 [0.49, 0.77]
Gottardo, Stanovuch, & Siegel (1996) 0.44 [0.25, 0.63]
Gottardo, Stanovuch, & Siegel (1996) 0.50 [0.31, 0.69]
Kim et al. (2011) 0.36 [0.16, 0.56]
Kim (2017) 0.46 [0.35, 0.57]
Kim (2017) 0.43 [0.32, 0.54]
Kim & Graham (2021) 0.47 [0.35, 0.59]
Kim & Graham (2021) 0.45 [0.33, 0.57]
Kim & Petscher (2021) 0.54 [0.45, 0.63]
Kim & Petscher (2021) 0.54 [0.45, 0.63]
Kim, Otaiba, Sidler, Gruelich (2013) 0.58 [0.49, 0.67]
Lesaux, Lipka, & Siegel (2006) 0.22 [−0.06, 0.50]
Lesaux, Lipka, & Siegel (2006) 0.36 [0.08, 0.64]
Lesaux, Rupp, & Siegel (2007) 0.44 [0.37, 0.51]
Low & Siegel (2005) 0.49 [0.43, 0.56]

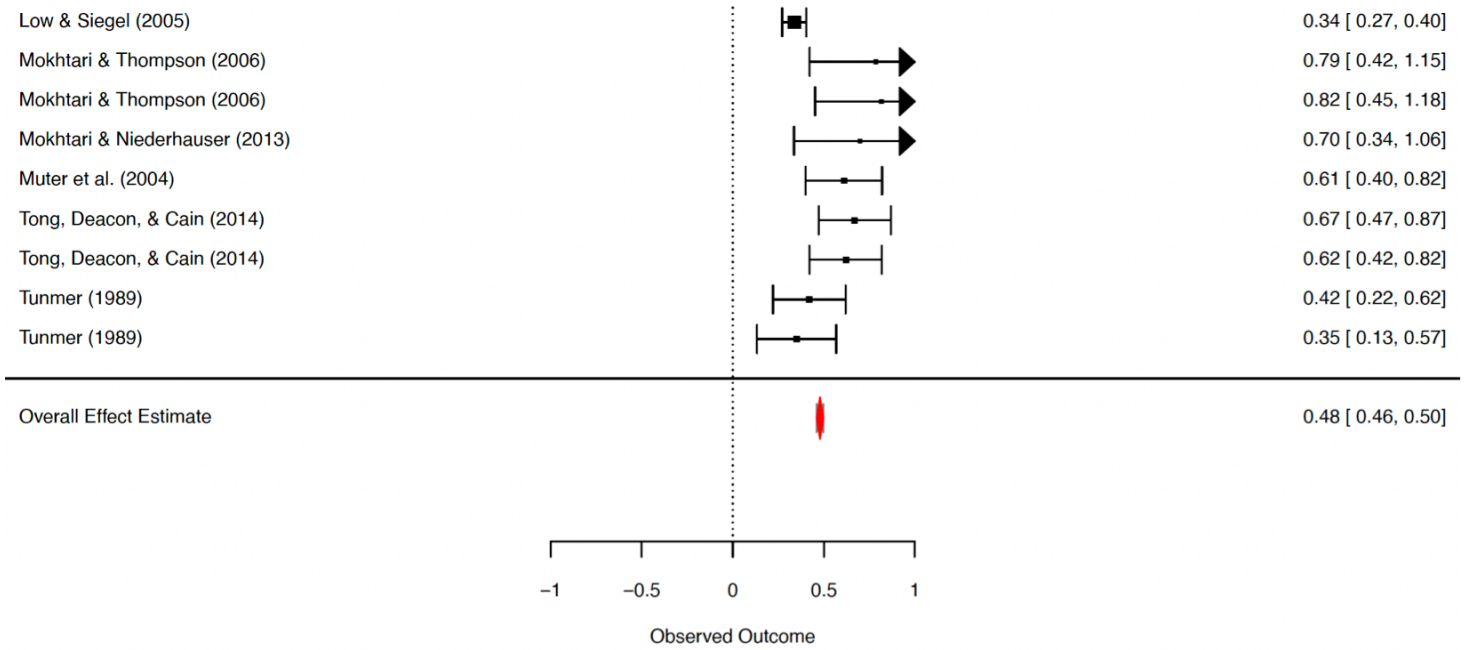

Low & Siegel (2005)
0.34 [0.27, 0.40]
Mokhtari & Thompson (2006)
0.79 [0.42, 1.15]
Mokhtari & Thompson (2006)
0.82 [0.45, 1.18]
Mokhtari & Niederhauser (2013)
0.70 [0.34, 1.06]
Muter et al. (2004)
0.61 [0.40, 0.82]
Tong, Deacon, & Cain (2014)
0.67 [0.47, 0.87]
Tong, Deacon, & Cain (2014)
0.62 [0.42, 0.82]
Tunmer (1989)
0.42 [0.22, 0.62]
Tunmer (1989)
0.35 [0.13, 0.57]
Overall Effect Estimate
0.48 [0.46, 0.50]
−1
−0.5
0
0.5
1
Observed Outcome

Figure 5

The Mediation Effect of Word Reading on the Relation between Syntatcic Skills and Reading Comprehension

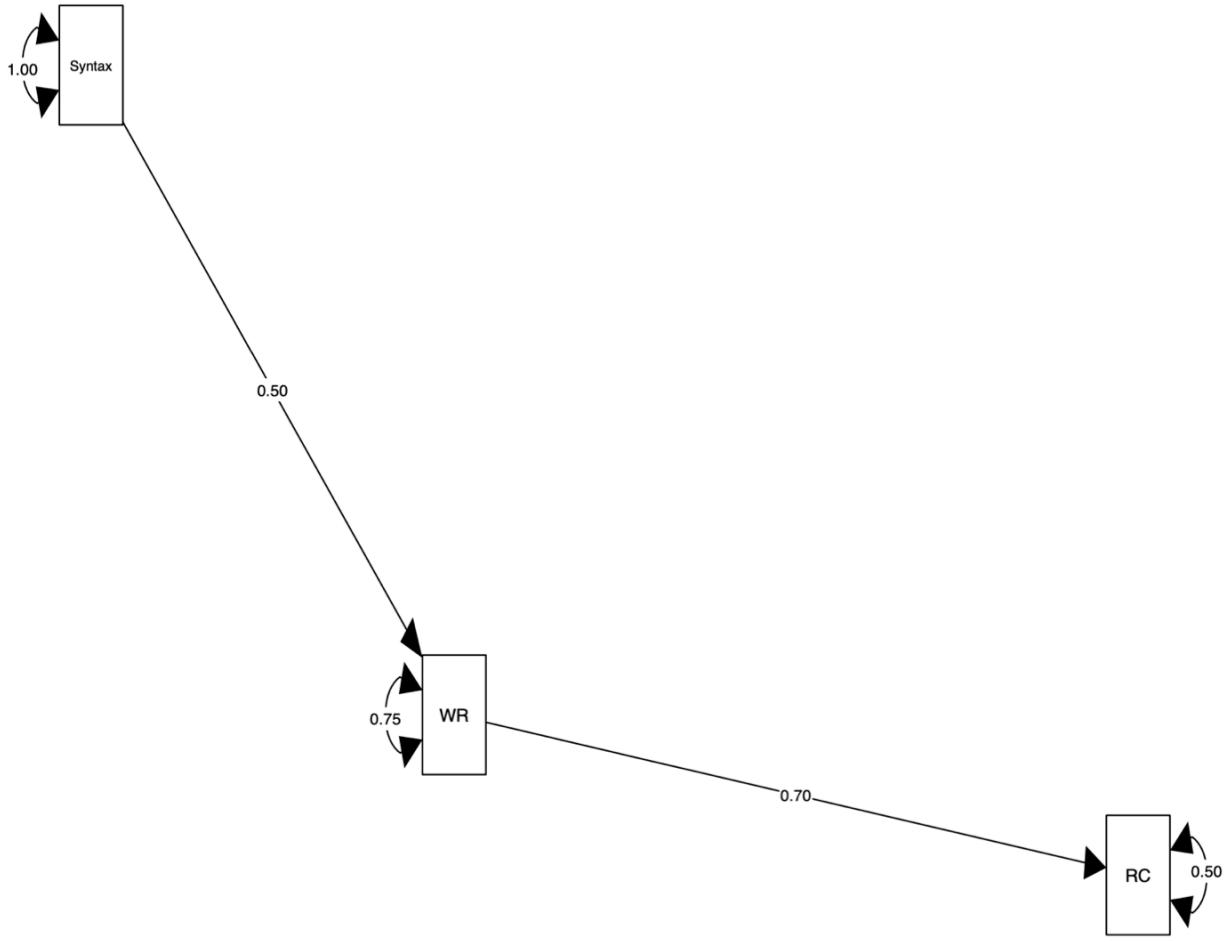
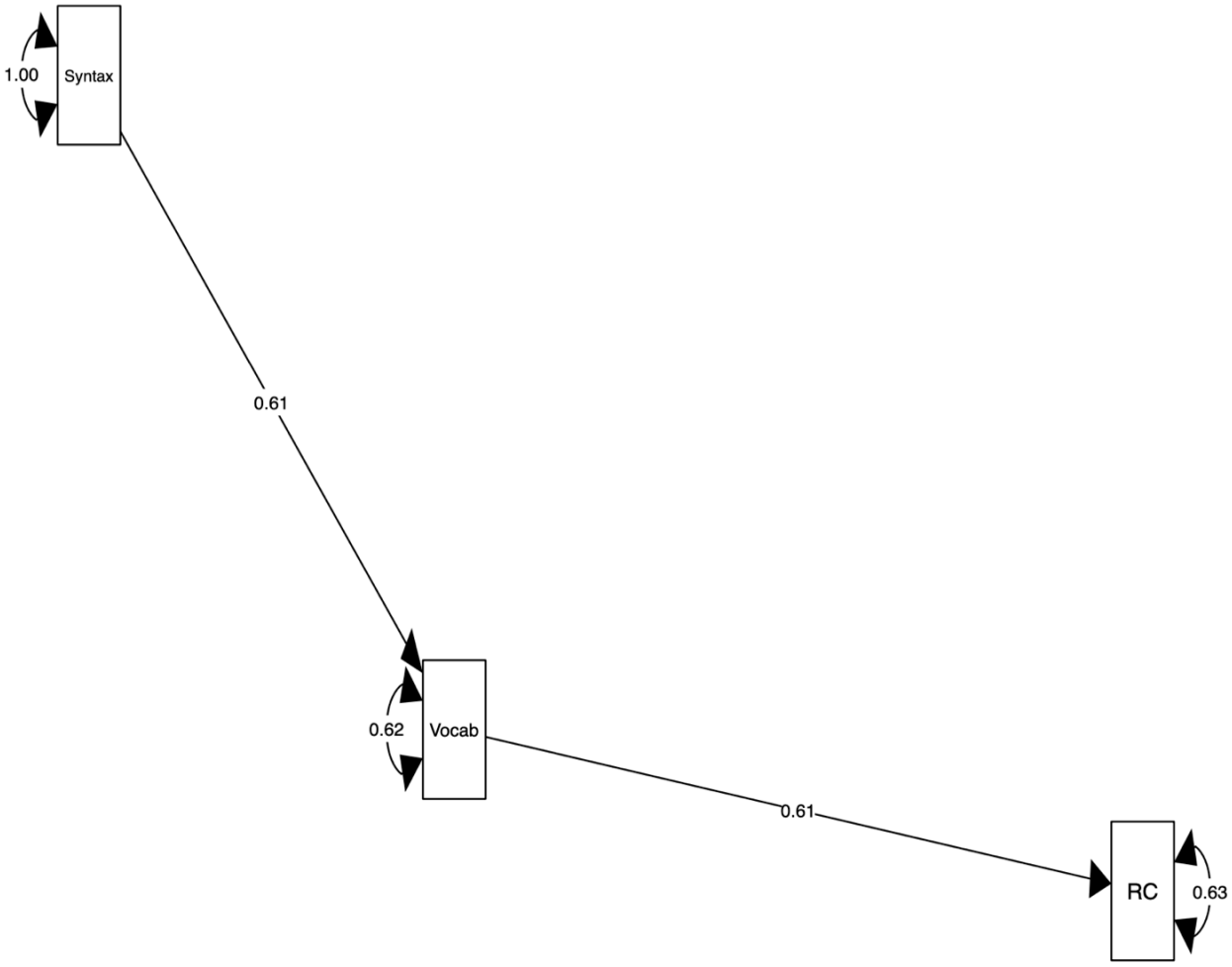


Figure 6

The Mediation Effect of Vocabulary on the Relation between Syntatcic Skills and Reading Comprehension



Chapter 3: Identifying the Syntactic Skills Relevant to Children's Reading Comprehension

Abstract

Reading comprehension is among the most important skills children learn in elementary school. One skill reliably implicated in theories of reading comprehension is syntax: the organization of words and phrases into sentences. A growing body of work demonstrates the contribution of syntactic skills to reading comprehension, but it remains unclear which aspects of syntactic skills are important for reading comprehension. Research has often assessed one of two aspects: syntactic comprehension -- the understanding of spoken sentences -- or syntactic awareness -- the ability to reflection on and manipulate spoken sentences. We jointly examine these aspects, with the goal of testing their relative contributions to reading comprehension. We administered measures of reading comprehension and syntactic skills to 148 third to fifth grade English-speaking students. Measurement models suggest distinctiveness between syntactic comprehension and awareness. Hierarchical linear regressions reveal that each of syntactic comprehension and awareness make unique and similar-sized contributions to reading comprehension beyond control variables. Our results extend reading theories that specify a role for syntactic skills by reinforcing the need to delineate potentially separate roles for syntactic comprehension and awareness. This demarcation can guide the development of interventions aimed at training syntactic skills, with the broader goal of improving reading comprehension.

Keywords: syntactic skills, syntactic comprehension, syntactic awareness, reading comprehension, elementary-school children, English

Introduction

Reading comprehension is the ability to understand written texts (e.g., Kamil, 2003). It is the single-most transferable skill that children learn in elementary school, laying the groundwork for successful learning across school years and enabling full societal engagement in adulthood (e.g., Colenutt & Toye, 2012; Petch et al., 2004). In an effort to uncover the skills fundamental to understanding texts, we focus on the role of skills in syntax, or the way words and phrases are organized to form larger phrases and sentences (Dawson & Phelan, 2016). There is strong theoretical consensus as to the importance of syntactic skills to reading comprehension (e.g., Perfetti & Stafura, 2014). This makes sense given that syntactic structure is the strongest predictor of text readability (Graesser, et al., 2011) and sentences are far more complex in written than spoken language (e.g., Uccelli et al., 2015). There is now a relatively robust literature showing that children's syntactic skills are related to their ability to understand what they read (e.g., Cutting & Scarborough, 2006; Author et al., 2017; Low & Siegel, 2005; Sorenson Duncan et al., 2021). Accordingly, the Common Core State Standards (Common Core State Standards, 2021) explicitly recommend that teachers instruct children how to tackle complex sentences to support reading comprehension. Yet, we are lacking key information regarding which aspects of these skills are most relevant for reading comprehension. Not knowing this directly impacts our ability to advise on how to teach syntactic skills, as there are likely differences in the way these aspects are taught. As such, our recommendations for specifying such instruction would be, largely, a shot in the dark. Thus, we build on current research to examine which aspects of syntactic skills are relevant to reading comprehension, responding to calls to explore the nature of this relationship (e.g., Author et al., 2021; Scott, 2009), with the hope of providing data that can inform intervention studies and, ultimately, classroom instruction.

At the outset, we feel it is important to clearly delineate syntactic skills from other aspects of oral language. Broadly, syntactic skills allow individuals to understand and manipulate the way words and phrases are organized together to create sentences. There are several constructs related to syntactic skills within the domain of oral language (e.g., Apel, 2022; Metsala et al., 2021; Perfetti & Stafura, 2014); one such construct is listening comprehension. To distinguish between syntactic skills and listening comprehension, we highlight that syntax refers to sentences in particular; listening comprehension includes "all of verbal ability, including vocabulary, syntax, inferencing and the construction of mental schemas" (Kirby & Savage, 2008, p. 76). In terms of assessment, passages within listening comprehension tasks typically assess comprehension of larger chunks of language, such as passages, and often require inferencing and integration (e.g., Wechsler, 2009). These ideas are further supported by research that shows empirical distinctions between syntactic skills and listening comprehension among elementary-aged students (e.g., Foorman et al., 2015), and other studies that find such a distinction matters for explaining reading comprehension development (e.g., Metsala et al., 2021). In line with this, there is some indication that children with language-based disorders struggle specifically with syntax (e.g., Montgomery et al., 2016). Thus, while we acknowledge that syntactic skills are related to other aspects of oral language, we argue that it is important to understand how syntactic skills, on their own, relate to reading comprehension.

Within this broader construct of syntactic skills, research to date captures two aspects: syntactic comprehension and syntactic awareness. Syntactic comprehension is considered the ability to understand syntactic structures in a spoken sentence (e.g., Cutting & Scarborough, 2006); it is a linguistic skill that does not require explicit awareness of language. Syntactic awareness, on the other hand, is the ability to reflect on and/or manipulate spoken sentences

(Cain, 2007); this ability to reflect and manipulate classifies it as a metalinguistic skill, or a skill that requires individuals to think about language (e.g., Gombert, 1992; see Myhill, 2020 for an example of her work on this distinction with respect to writing). Syntactic comprehension is often assessed by asking children to listen to sentences of varying complexity and indicate which picture of several captures each sentence's meaning (e.g., Poulsen & Gravgaard, 2016; Sorenson Duncan et al., 2021). These types of tasks tap children's ability to understand sentences, but not necessarily do anything with those sentences. Syntactic awareness is frequently assessed by asking children to listen to words in an incorrect order and to re-order them to produce a syntactically correct sentence. In this case, children are asked to "fix up the sentence so it sounds right" (e.g., Cain, 2007; Deacon & Kieffer, 2017). Essentially, tasks assessing syntactic comprehension focus on understanding while those of syntactic awareness tend to include a manipulation component.

Research to date supports the idea that each of these two aspects of syntactic skills is related to reading comprehension (e.g., Deacon & Kieffer, 2017; Sorenson Duncan et al., 2020). For instance, Sorenson Duncan and colleagues demonstrated that syntactic comprehension is related to reading comprehension beyond word reading, vocabulary, and memory in fifth grade students (see Poulsen & Gravgaard, 2016, for similar results in Danish). In a longitudinal design, Deacon and Kieffer (2017) demonstrated that syntactic awareness predicted gains in children's reading comprehension between third and fourth grades beyond controls of nonverbal ability, vocabulary, and phonological and morphological awareness (see Low & Siegel, 2005, for similar results with sixth grade students). It seems, then, that each of these aspects of syntactic skills is related to reading comprehension, at least in studies in which one of the two are measured.

And yet, research on these two potential aspects of syntactic skills has proceeded largely separate from one another (MacKay et al., 2021), leaving it unclear as to their relative contributions to reading comprehension. One key value in answering this question lies in informing the design of instruction. The relevance of sentences to text readability (Graesser et al., 2011; Stenner & Swartz, 2012; Écalle et al., 2014) and the inclusion of syntax is theories of reading comprehension (e.g., Gombert, 1992; Perfetti & Stafura, 2014) has led to widespread encouragement to include syntax in instruction (e.g., Barnes, 2019; Common Core State Standards, 2021; Shanahan, 2020). Perhaps the most compelling example is the Common Core State Standards, which has called for educators to teach children to tackle complex sentences to facilitate reading in the language arts and in other subjects. However, we know very little about how to design and deliver effective instruction in syntax, leaving us unable to guide the specific design of effective instruction of syntactic skills in the classroom. As a key example, aligning with the differences in measurement, the best ways to teach syntactic comprehension and awareness may differ. For instance, to teach syntactic comprehension, an educator may focus on ensuring children understand a variety of syntactic constructs. To teach syntactic awareness, however, a teacher may encourage children to rearrange the words in a sentence while maintaining the same meaning. These possibilities accentuate the need to better understand the relations between syntactic skills and reading comprehension: as of now, we are quite limited in our ability to design effective interventions and comment on possible classroom instruction.

To date, the evidence of effectiveness of instruction in syntactic skills on reading comprehension (e.g., Morris et al., 2012; Proctor et al., 2020) is challenging to interpret because most interventions have taught syntax along with other aspects of oral language (see Silverman et al., 2020, for a meta-analysis). Balthazar and Scott's (2018) study is an exception: they taught

10- to 14-year-olds with Specific Language Impairment about complex sentences. Training included exposure to the components of complex sentences and explicit instruction about and practice with complex sentences. Participants demonstrated pre- to post-test improvements on measures of syntactic skills, but not on reading comprehension. Similar results emerge in the one available study to test the effectiveness of training both syntactic comprehension and awareness (Phillips, 2014). Phillips taught syntactic comprehension by explaining different syntactic constructs and then asking children to complete requests using these structures. She trained syntactic awareness by asking children to produce sentences that followed certain syntactic rules (e.g., answer a question with a sentence with a passive structure). Following on training in both aspects, children demonstrated pre-to post-test improvement on a researcher-created measure assessing syntactic comprehension and awareness. This study did not test transfer to reading comprehension. These two studies suggest that syntactic skills can be effectively taught, but neither demonstrates effects on reading comprehension of training in syntactic skills in general or on one aspect of syntactic skills in particular.

One way to gain insight into the most likely answer to this question lies in leveraging correlational data, which is far less resource intensive than intervention studies. We report here on a research study that delineates the relations between each of syntactic comprehension and syntactic awareness and reading comprehension. We do so in part to provide insight into which aspects of syntactic skills are likely to have the most ‘bang for the buck’ of valuable instruction time – that is, to improve reading comprehension skills, should educators focus on syntactic comprehension, syntactic awareness, or both? While cross-sectional data cannot directly inform educational practices, our goal is to provide data that can begin to inform intervention studies;

given the time and resource intensive nature of intervention studies, basic data is a critical first step.

Providing an empirical answer to this question has further value because, from a theoretical point of view, both syntactic comprehension and awareness are plausibly related to reading comprehension. On the one hand, the likely importance of syntactic comprehension to reading comprehension aligns with the highly cited Simple View of Reading, whose theorists name two key contributors to reading comprehension: word reading and linguistic comprehension, a term that they use to refer, broadly, to oral language skills (Gough & Tunmer, 1986; see Apel, 2021). Syntactic comprehension has been placed squarely within the linguistic comprehension domain (e.g., Melby-Lervåg & Lervåg, 2014). Understanding a variety of syntactic structures offers key linguistic information about the events described, which is then predicted to have effects on reading comprehension. Take, for example, this sentence from a science textbook (see Fang, 2006, pg. 496): “Satellite images can also detect increases in ocean temperatures, which may put an area at risk for red tide.”. A reader with strong syntactic comprehension would likely understand different syntactic structures, such as the clause that starts with relative pronoun “which” (e.g., Brimo et al., 2017; Catts et al., 2005), helping the reader to work out that “which” in this sentence indicates the clause about increasing ocean temperatures (and not e.g., satellite images). This comprehension should help the reader create a mental representation of the event, which could facilitate comprehension of the sentence and of the text (Kintsch, 1994; Perfetti & Stafura, 2014; Sorenson-Duncan et al., 2020).

Others argue that the metalinguistic awareness characteristic of syntactic awareness is the active ingredient that supports reading comprehension. Gombert (1992) makes a clear prediction that syntactic awareness should be more related to reading comprehension than syntactic

comprehension, as the former allows for explicit use of language structure, whereas the latter is predicted to be too implicit to apply to reading comprehension. In much of his work, he uses this rationale to explain the differential contributions of syntactic comprehension and awareness to reading comprehension (e.g., Gombert, 1992; Gaux & Gombert, 1996). Indeed, the ability to reflect on and manipulate syntactic structure could allow the reader to parse complex sentences into their multiple parts (Perfetti & Stafura, 2014), which should lead to more efficient processing (Gaux & Gombert, 1996). For instance, a reader with strong syntactic awareness skills could parse this sentence "I kept my eye on my swimming tree, the tall pine I always kept in sight, ever since I was little and first learned to swim across the lake" into its four constituent parts; even this simple parsing would enable more efficient cognitive processing than as a single stream of 29 words. And this parsing could also identify the primary meaning (i.e., that of swimming across a lake) from supplemental pieces of information (e.g., that the swimming tree is a pine, and the subject has been since a young age). Using syntactic awareness to parse this sentence is likely to decrease cognitive demands and increase access to the meaning of the sentence, with likely effects on understanding the entire text.

Certainly, these theoretical predictions are not mutually exclusive. Syntactic comprehension might support identification of the events that happen within a sentence – termed event structures (e.g., Kintsch, 1994) - and syntactic awareness may bolster parsing of complex sentences, each with influences on reading comprehension. As we explore these ideas, we remain open to the prospect that syntactic comprehension and syntactic awareness are not distinct aspects of syntactic skills. For instance, Bowey and Patel (1988) argued that syntactic awareness does not necessarily develop independently of syntactic comprehension, as children who have stronger general language skills will go on to have stronger metalinguistic skills. If this is the

case, then syntactic comprehension and awareness might in fact load on a single syntactic skill factor and make overlapping contributions to reading comprehension. Although there is some evidence that they are separable, with correlations between measures of the two ranging from .2 to .7 (Brimo et al., 2015; Cain, 2007), this remains to be confirmed empirically. Given this possibility, we first determine if syntactic comprehension and awareness are separable constructs by comparing measurement models of uni- and multidimensional factor structures. We then investigate their relation(s) with reading comprehension.

Our study will build on the three studies to date that have investigated the contributions of both syntactic comprehension and awareness to reading comprehension, with some evidence of differential relations between each and reading comprehension (Bowey & Patel, 1988; Brimo et al., 2017; Cain, 2007). All three studies assessed syntactic comprehension by asking children to listen to a sentence and select the picture that best represented the sentence and all three assessed syntactic awareness with a word-order correction task. In Brimo and colleagues' (2017) study with students in grades 9 and 10, syntactic comprehension made a unique, direct contribution to reading comprehension beyond key controls of working memory, vocabulary, and word reading. Syntactic awareness had an indirect relation to reading comprehension through syntactic comprehension, but no direct contribution, in models with the same controls. Together, these results point to stronger contributions of syntactic comprehension than of syntactic awareness to reading comprehension. Findings of full mediation also emphasise the need to test the separability of syntactic comprehension and syntactic awareness. Results from the other two studies (Cain, 2007; Bowey & Patel, 1988) are more challenging to interpret because performance on either syntactic comprehension and/or awareness was entered into regression equations together with other predictors. For instance, in Cain's (2007) study with children in

grades 3 and 5, when entered along with vocabulary and working memory, syntactic comprehension predicted reading comprehension after controlling for syntactic awareness. Syntactic awareness entered on its own did not predict reading comprehension, after controlling for syntactic comprehension, vocabulary, and working memory (see also Bowey & Patel, 1988). And yet, we do not know if unique effects would have emerged for syntactic comprehension if it was entered alone. In sum, there is some evidence that syntactic comprehension has a stronger relation with reading comprehension than syntactic awareness, although interpreting the pattern of results from this small set of studies is somewhat challenging. There is clearly room for greater clarity in understanding of the relative contributions of syntactic comprehension and awareness to reading comprehension.

Present Study

The overarching goal of this study was to investigate the relative contributions of syntactic comprehension and syntactic awareness to reading comprehension in third to fifth grade students. This investigation advances theoretical and empirical work by simultaneously investigating syntactic comprehension and syntactic awareness, which have largely been considered separately (e.g., Deacon & Kieffer, 2017; Sorenson Duncan et al., 2020). Towards this primary goal, we statistically verified that syntactic comprehension and syntactic awareness are distinct aspects of syntactic skills.

We recruited third- to fifth- grade children for this study for several reasons. Children in this age range are likely to have developed metalinguistic skills (e.g., Gombert, 1992) and therefore could reasonably be expected to complete measures of syntactic awareness. Sentences in text are also becoming increasingly complex during this grade range (Graesser et al., 2011), pointing to the utility of syntactic skills in understanding sentences, and therefore texts, during

this period. Further still, this range marks a time in which the expectation that children can learn from the texts they read is increasing (e.g., Chall, 1983), and the texts they read are becoming more complex (e.g., Curran, 2020).

Our assessment of both aspects of syntactic skills followed on previous literature. We use the Whatdunnit task to measure syntactic comprehension (e.g., Montgomery et al., 2016; Sorenson Duncan et al., 2020). This task has good reliability and range of performance for upper elementary students (e.g., Sorenson Duncan et al., 2020). In this task, children hear sentences about one object doing an action to another object; they are then asked to select an image of the object that did the action (Montgomery et al., 2016). The use of objects rather than people or animals in this task reduces the availability of semantic cues, focusing measurement more closely on children's syntactic skills (Lesgold, 1974). To assess syntactic awareness, we use two versions of the widely used word-order correction task, in which children hear words in an incorrect order and are asked to "fix the sentence so it sounds right". Such tasks have demonstrated good reliability for this age range (e.g., Cain, 2007; Deacon & Kieffer, 2017).

In terms of predictions, first and foremost, we suspect both syntactic comprehension and awareness to contribute to reading comprehension in this grade range. There are strong theoretical reasons for each of these aspects to be related to reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). Importantly, most theoretical rationales for one aspect do not discredit the other; that is, the theoretical accounts for why syntactic comprehension should contribute to reading comprehension does not disqualify syntactic awareness's contribution, and vice versa (see Gombert, 1992, for an exception). This prediction also aligns with empirical work investigating either one of two aspects of syntactic skills (e.g., Deacon & Kieffer, 2017 Sorenson Duncan et al., 2021) and with the fact that age range of our sample is

expected to have both linguistic and metalinguistic skills (Gombert, 1992), highlighting that they could be expected to pull on both to support their reading comprehension.

We remain open to two other possible patterns of results. Based on the view that linguistic comprehension, of which syntactic comprehension is a part, is a key predictor of reading comprehension, syntactic comprehension may be more strongly related to reading comprehension than syntactic awareness. This would converge with the limited empirical work that has explored the effects of both aspects on reading comprehension (e.g., Brimo et al., 2017). Alternatively, based on Gombert's (1992) predictions that metalinguistic skills should be more important for reading development than linguistic skills, we may find that syntactic awareness makes a stronger relative contribution to reading comprehension than syntactic comprehension.

Method

Participants

The participants in this study were recruited as part of a larger project on metalinguistic skills and reading development. They were from four schools in a small city on the east coast of North America. We tested 148 children (53% female) in grades 3 to 5, with a mean age of 9.32 (0.97) years. By grade, there were 48 children in Grade 3 (M*age* = 8.27 years; SD = 0.45), 49 in Grade 4 (M*age* = 9.22 years; SD = 0.22), and 54 in Grade 5 (M*age* = 10.36 years; SD = 0.48). Scores on our predictor, outcomes, and controls measures did not significantly differ across schools. Further, Table 1 shows that our participants scored in the average range for both means and standard deviations scores on our measures of nonverbal intelligence, phonological awareness, vocabulary, word reading, and reading comprehension, suggesting they represent typically developing third to fifth grade readers.

All children were enrolled in standard English programs and spoke English fluently. All children in these programs were invited to participate. 87% of children who participated spoke English as a first language. Other L1s included Korean (2%), Arabic, Bengali, and Mandarin (each 1.3% of the sample), as well as Croatian, Hebrew, Hindi, Igbo, Malayalam, Polish, Spanish, Tagalog, and Urdu (all less than 1% of the sample). We did not collect socioeconomic status data; however, based on the postal codes of the associated neighborhoods of schools where we tested, most participants would fall in the average to high-average range of socio-economic status.

Measures

Predictor and Outcome Measure.

Syntactic Comprehension. To assess syntactic comprehension, we administered a shortened version of the Whatdunnit task from Montgomery et al. (2016). In this task, children heard a sentence with three objects in which one object was doing an action to another object (e.g., the dress had washed the boot near the very hot new glove). After hearing the sentence, children saw the three objects appear on a computer screen. Children were asked to indicate which object completed the action by pressing one of three marked dots on keys on the keyboard, each positioned below one of the three pictures.

This task included active, passive, subject-relative, and object-relative clauses. There were 7 of each sentence type, for a total of 28 items. All sentences were matched for length. This reduced the possibility that sentence constructs that are typically longer than others (e.g., sentences containing relative clauses) were harder because of length rather than syntactic complexity. To reduce the confound of vocabulary, we ensured all sentences contained an average word frequency great than 50 words/million. The task began with four practice items on

which participants received feedback. This task was scored based on accuracy of identifying the object that completed the action. Cronbach's alpha of this measure for our sample was .82.

Syntactic Awareness. To assess syntactic awareness, we administered two word-order correction measures: syntactic correction and dative sentence correction. In the syntactic correction task (Cain, 2007), children heard a jumbled sentence (e.g., the girl opened door the) and were asked to "fix up the sentence so that it sounds right" (the girl opened the door). Children were instructed to not change, add, or remove any words. All errors that children were asked to correct were specifically syntactic, in that they were of word order (see e.g., Deacon & Kieffer, 2017). For this task, we created items to include a wider variety of sentence types than is the original Cain (2007) task; we did this to more closely parallel the items used in the Whatdunnit task. Sentence types included: active, passive, reflexive anaphora, subject-relative clause, and object-relative clause. We modeled the new items after the items used in Cain (2007). There were two practice items on which children received feedback and 30 test items, as well as a stop rule of four consecutive errors. This task was scored dichotomously based on a child's ability to produce the correct target sentence. Split-half reliability for this measure was .71 for our sample.

The dative sentence correction task was developed by Nation and Snowling (2000). As with syntactic correction, children heard a sentence with an incorrect word order, and they were asked to change the order of the words to produce a "sentence that makes sense". In this task, half of the items were semantically reversible (e.g., to the monkey gave the elephant the rabbit; the monkey gave the rabbit to the elephant is one possible answer), while half were semantically irreversible (e.g., put the picture on the tiger the wall; the tiger put the picture on the wall is the only semantically correct answer). All sentences were balanced for length and word frequency

across conditions (p = .878). Given the results of our confirmatory factor analysis (see below), the two forms were combined in most analyses. However, we report descriptive information for each item type. There were two practice items and 20 test items, as well as a stop rule of four consecutive errors. This task was scored dichotomously based on a child's ability to produce the correct target sentence. Split-half reliability for this measure was .81 for our sample.

Reading Comprehension. We administered the Passage Comprehension subtest from the Woodcock Reading Mastery Test (WRMT) as per the manual (Woodcock, 2011). Each child read sentences and passages of increasing length and difficulty and is asked to provide the missing word based on the context of what they read. Testing was discontinued after four consecutive scores of 0. We followed manual scoring, wherein children received one point for each correct answer. Split-half manual reliability ranged from .85 to .87 for the grades in our sample.

Control Measures

Nonverbal Ability. To estimate nonverbal ability, we administered the Matrix Reasoning subtest from the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011). As per the manual, each child saw an incomplete pattern and was asked to select the best option to complete the pattern. Children received one point for each correct answer. Testing was discontinued when children answered three in a row incorrectly. Split-half manual reliability ranges from .85 to .88 for the ages in our sample.

Phonological Awareness. Our measure of phonological awareness was the Elision subtest from the Comprehension Test of Phonological Processing-2 (CTOPP-2; Wagner et al., 2013). As per the manual, children removed individual or sets of sounds from a larger word to produce a smaller word. Children received one point for correct answers. Testing was

discontinued when children answered three in a row incorrectly. Raw scores were verified with an audio recording. Cronbach's alpha ranged from .87 to .93 for the ages in our sample.

Receptive Vocabulary. Children's receptive vocabulary was assessed with a modified version of the Peabody Picture Vocabulary Test – 4 (M-PPVT-4; Dunn & Dunn, 2006). To reduce testing time, we administered every fourth item on the original task. Scores from the shortened version are highly correlated with those from the full version (Deacon et al., 2013). The administration and scoring of the modified version paralleled that of the full version: children hear a word and select the most appropriate picture from an array of four pictures. There was a stop rule of 6 incorrect in a row. Children receive one point for correct answers. Cronbach's alpha for our sample was .91.

Word Reading. To assess word reading, we administered Form A of the Sight Word Efficiency subtest from Test of Word Reading Efficiency 2 (Torgesen et al., 2012). As per the manual, children read as many of 104 words as they could in 45 seconds. Scoring is based on number of words read correctly in 45 seconds. Test-retest reliability is .90 for this age group.

Procedure

All children were tested individually in a quiet room in their school. The tasks used in this study come from a larger battery focusing on the contribution of metalinguistic awareness to reading comprehension. The complete battery was typically divided into two sessions in order to accommodate the schools' schedules and to reduce participants' fatigue. No more than 3 days elapsed between the sessions. Total battery time was approximately two hours. The order in which children completed the tasks on which we report here was: PPVT-M, Syntactic Correction, Matrix Reasoning, Elision, Dative Sentence Correction, Passage Comprehension, Whatdunnit, and TOWRE. The appropriate ethics boards approved all procedures.

Data Analysis

We first determined whether syntactic comprehension and syntactic awareness were distinct in our sample of third to fifth grade children. To do so, we conducted and compared several measurement models using the whole sample of participants in MPlus (Muthén & Muthén, 2017). In these models we included the total means for each of the active, passive, subject-relative, and object-relative items from the Whatdunnit task, as well as the means for the reversible and irreversible items of the dative sentence task. We included the overall mean from the grammatical correction task, as this task was not divided into smaller forms and we employed a stop rule; thus, parallel forms were difficult to create after administration.

Because the separability of syntactic comprehension and syntactic awareness is not empirically confirmed, we conducted and compared three plausible model specifications to determine the best way to represent these two aspects of syntactic skills. In particular, we tested two versions of a two-factor model specification as well as a unidimensional factor model. Figure 1a shows a two-factor correlated solution, with syntactic comprehension and awareness loading onto separate, but correlated, factors. We then tested a bi-factor model extension of this correlated factor model: a two-factor + general factor model (Figure 1b). This model includes a general syntactic skills factor that accounts for the potential shared variance among syntactic comprehension and awareness. Finally, we tested a unidimensional factor model that tested if the items from the syntactic comprehension and awareness tasks were best explained as one construct (Figure 1c). Following on recommendations for language research, we considered factor loadings of .3 or above as acceptable (Kline, 2005). Model fit was evaluated using multiple fit indices, including the chi-square value, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and the Standardized Root

Mean Square Residual (SRMR) (Kline, 2011). Excellent model fit is characterized by a non-significant chi-square value, CFI and TLI values above .90, and RMSEA and SRMR below .08.

We then conducted hierarchical linear regressions to determine the relative contributions of syntactic comprehension and awareness to reading comprehension. In these analyses, we controlled for three socio-demographic variables: gender, grade, and language status. We also control for cognitive and language skills, including an estimate of nonverbal ability, phonological awareness, receptive vocabulary, and word reading. Where possible, we use standardized scores for these measures, as our sample spanned three grades. These cognitive and language controls were selected as they are related to syntactic skills and reading comprehension in third to fifth grade students (e.g., Gough & Tunmer, 1986; National Institute of Literacy, 2008; Melby-Lervåg & Lervåg, 2014). In particular, phonological awareness is the strongest predictor of word reading (e.g., Melby- Lervåg et al., 2012), which in turn is a reliable predictor of reading comprehension (e.g., Melby- Lervåg & Lervåg, 2014). Nonverbal ability, word reading, and vocabulary have robust relations with both syntactic skills and reading comprehension (e.g., Dethorne et al., 2012; Tilstra et al., 2009). Including vocabulary as a control increased confidence that effects of syntactic skills were not attributable to oral language more broadly (e.g., Lervåg et al., 2018).

For both sets of analyses, we combine data combined across our sample of third to fifth grade students based on the likelihood that they are in a similar phase of reading development (Chall, 1983; Tilanus et al., 2020) and comparability in text complexity in this grade range (e.g., Curran, 2020). However, in our linear regressions, we also explore the possibility of an interaction between grade and aspects of syntactic skills on reading comprehension.

Results

We inspected our data to ensure it met the assumptions of factor analysis and linear regression. No violations to these assumptions were found (Tabachnick & Fidell, 2013). The overall and subtest means for the experimental measures for the full sample are presented in Table 1. The correlations among all measures are presented in Table 2.

We first present the results of our measurement models. Results from the one-factor model yielded a poor fit for the data [[$\chi^2(14) = 107.314$, $p < .001$], CFI = .736, TLI = .605, RMSEA = .211 [.175, .249], SRMR = .150]. The two-factor, bifactor model was an acceptable fit for the data based on some, but not all metrics ([$\chi^2(10) = 39.582$, $p < .001$], CFI = .916, TLI = .825, RMSEA = .140 [.096, .188], SRMR = .093). The two-factor, correlated specification was a good fit for data the based on most metrics ([$\chi^2(13) = 37.827$, $p < .001$], CFI = .930, TLI = .883, RMSEA = .025 [.010, .052], SRMR = .065). The two-factor, correlated model was superior to the one-factor model ($\Delta\chi^2 = 69.847$, $\Delta df = 1$, $p < .001$). There was no significant difference between the two-factor, correlated model and the two-factor, bifactor model ($\Delta\chi^2 = 1.755$, $\Delta df = 3$, $p > .100$). However, based on the principle of parsimony, we chose the two-factor, correlated model as the most appropriate fit for our data (see Figure 2).

Given that our factor analysis demonstrated separability of syntactic comprehension and syntactic awareness, we proceeded with including both aspects of syntactic skills in our linear regression. Because we first analyzed the three grade groups together, we checked that the variance matrices were equal across these groups and therefore appropriate to combine. The Box's M value of 14.936 was associated with a p value of .275, which was interpreted as non-significant based on Huberty and Petoskey's (2000) guideline (i.e., $p < .005$). This suggests the three grade groups had similar variance matrices and therefore could be combined into one

group. This was important, as a power analysis suggested we were underpowered to examine each group separately.

To analyze the relative contributions of syntactic comprehension and syntactic awareness to reading comprehension, we conducted one hierarchical linear regression in SPSS (IBM Corps, 2020). Syntactic comprehension and awareness were the predictor variables and reading comprehension was the outcome. In the first step, we entered the socio-demographic controls of gender, grade, language status. In the second step, we entered the language controls of nonverbal ability, phonological awareness, receptive vocabulary, and word reading. In the third step, we entered our predictor variables of syntactic comprehension and syntactic awareness. We entered the factor scores generated from the CFA.

The results of our hierarchical linear regression are presented in Table 5. These show that the control variables accounted for a significant 55.5% of variance in reading comprehension. Beyond these controls, syntactic comprehension and syntactic awareness together accounted for a unique 5.0% of variance in reading comprehension. Inspection of the individual beta weights revealed that each construct accounted for significant variance in reading comprehension (β's = .214 and .343; *p*'s = .002 and < .001, respectively), with the relative contributions remarkably similar in size. These similarly sized contributions were confirmed by conducting separate linear regressions for each of syntactic comprehension and awareness, while accounting for the same controls of nonverbal ability, phonological awareness, receptive vocabulary, and word reading.

We then conducted follow-up analyses to explore the effect of grade on the relation between each aspect of syntactic skills and reading comprehension, given that grade emerged as significant as a control in our regression analyses. As we were underpowered to conduct these analyses, we present this as a preliminary analysis designed to begin to understand how grade

level may impact this relation. Further, as these analyses are exploratory, we do not include controls.

To examine the influence of grade on the relation between syntactic comprehension and awareness and reading comprehension, we included interaction terms between grade and each aspect of syntactic skills in a regression model with reading comprehension as the outcome (Table 6). Results from these preliminary analyses reveal an effect of grade: in third grade, syntactic comprehension, but not awareness, was significantly related to reading comprehension. In fourth and fifth grade, syntactic awareness, but not syntactic comprehension, was related to reading comprehension.

Discussion

The goal of this study was to examine the relative contributions of two aspects of syntactic skills – syntactic comprehension and syntactic awareness – to reading comprehension in English-speaking children in Grades 3 to 5. Our interest in syntactic skills is driven by their theoretical, conceptual, and empirical value for reading comprehension (e.g., MacKay et al., 2021). Converging with Scott's (2009, pg. 185) statement that syntax is the "vehicle, even 'workhorse' of meaning", sentences become increasingly complex as children advance through school (e.g., Curran, 2020; Jagaiah et al., 2020) and syntactic complexity is the strongest predictor of text difficulty (e.g., Graessar et al., 2012). We are further motivated in providing a detailed understanding of the contribution of two aspects of syntactic skills to reading comprehension to move toward developing more precise theory and effective instruction (e.g., Scott, 2009). Our results confirm the separability of syntactic comprehension and awareness. Most importantly, syntactic comprehension and syntactic awareness each show unique contributions to reading comprehension — both medium in size — after accounting for each

other, nonverbal ability, phonological awareness, vocabulary, and word reading. Together, these findings point to the need to include both aspects of syntactic skills in theories and to explore how to teach both in classrooms.

Our finding that both syntactic comprehension and awareness contributed significantly, and at a similar magnitude, to reading comprehension in third to fifth grade children extends past work demonstrating a relation between either syntactic comprehension or awareness with reading comprehension (e.g., Deacon & Kieffer, 2017; Sorenson Duncan et al., 2020). These findings also extend the limited research that has considered syntactic comprehension and syntactic awareness in tandem (Bowey & Patel, 1988; Brimo et al., 2017; Cain 2007) by demonstrating their relative and independent contributions to reading comprehension. Our finding that each contributes to reading comprehension at a unique and similar magnitude suggests that including only one of syntactic comprehension or awareness may underestimate the contribution of syntactic skills to reading comprehension. These findings encourage theorizing and empirical work to consider the roles of both aspects of syntactic skills in reading comprehension.

We also conducted preliminary analyses to determine if the relative contributions of syntactic comprehension and awareness to reading comprehension shifted with grade; we found that they did. Syntactic comprehension, but not syntactic awareness, predicted reading comprehension in third grade students; however, the reverse was true for fourth and fifth grade students. This suggests that younger students rely more on their syntactic comprehension skills to support reading comprehension, while older students draw on their syntactic awareness skills more than their syntactic comprehension skills. This could be because older children have more developed metalinguistic skills (Gombert, 1992), and thus are able to pull on syntactic awareness

skills more readily. It is also possible that the texts older children read require more explicit awareness of sentence structure than texts that younger children read; this possibility is supported by the fact that syntactic complexity increases throughout elementary (e.g., Curran, 2020). In interpreting these results we highlight that we were underpowered to conduct these analyses; thus, the findings should be interpreted cautiously. Nonetheless, we think these findings underscore the importance of further examining the developmental shifts that may occur in the relations among syntactic comprehension, awareness, and reading comprehension.

Our finding that each of syntactic comprehension and syntactic awareness contribute to reading comprehension aligns with the results of our measurement models, which demonstrated statistical separability between these aspects. Here, we provide empirical validation of a distinction assumed in some prior work (e.g., Cain, 2007; Brimo et al., 2017). Theoretically, our finding that syntactic comprehension and awareness are separable supports Gombert's (1992) distinction between linguistic and metalinguistic skills. Gombert argued that a key distinction between the two is that syntactic comprehension emerges earlier than, and serves as a prerequisite to, syntactic awareness. While our cross-sectional data cannot speak to this hypothesis, developmental data, particularly beginning with younger children, could inform these ideas. Developmental data could also illuminate if there is reciprocity in the relation between syntactic skills and reading comprehension; indeed, it is possible that reading comprehension supports syntactic skills (but see Deacon & Kieffer, 2017).

Evidence of the distinctiveness between these two aspects of syntactic skills and their respective and similarly sized contributions to reading comprehension encourages the specification of distinct roles for each in theories of reading development. Indeed, the underlying mechanism through which each contributes to reading comprehension may differ. For example,

understanding various syntactic structures may help a reader keep track of a sentence's referents and events, even in longer and more complex sentences (e.g., Kintsch, 1994). Awareness of syntactic structure may help a reader determine the placement of clause boundaries, providing insight into the division of sentences that could make them more accessible (Perfetti & Stafura, 2014). In both cases, the cognitive load of the text may be decreased, making the text more comprehensible. The importance of including both aspects of syntactic skills in theoretical accounts is further stressed by the fact that they each made similar sized contributions, with similar percent variance, to reading comprehension. Incorporating both syntactic comprehension and awareness in theoretical predictions will enable comprehensive modeling of the relation between syntactic skills and reading comprehension.

Relatedly, the finding that syntactic comprehension and syntactic awareness together explained significant variance in reading comprehension after stringent controls highlights the need to understand how these aspects work together. Following on Gombert's (1992) prediction that syntactic comprehension develops prior to syntactic awareness, we hypothesize a positive feedback loop between syntactic comprehension and syntactic awareness. Understanding different syntactic constructs should expose children to how sentences are structured, which in turn likely familiarizes children with this structure. This familiarity could then aid children in developing the higher order metalinguistic skill of using and manipulating this structure. For example, if a child encounters the sentence *The girl pets the dog*, understanding the meaning of this sentence — that the girl is the actor and the dog is the recipient — might help to solidify the subject – verb – object structure of an active sentence. This increased metalinguistic awareness may then support the understanding of more complex sentence constructs and structures, thus restarting the loop. A robust answer to these developmental questions requires longitudinal data;

mediation and path analyses are critical next steps to deepen our understanding of how these constructs interact to improve reading comprehension in elementary students (see Brimo et al., 2017 for such analyses with high school students).

In terms of education, our findings of similarly sized contributions of each of syntactic comprehension and awareness to reading comprehension in the whole sample suggest that both aspects of syntactic skills may be useful to target in intervention studies, and, subsequently, the classroom. As an extension of this, our preliminary findings of a developmental effect highlight hat syntactic comprehension may be more useful to teach for younger students' reading comprehension skills, while syntactic awareness may be more impactful for older students' reading comprehension. Interestingly, there is a good deal of evidence that teachers explicitly teach sentence structure (e.g., Candler, n.d.; Shanahan, 2020), with the end goal of improving children's reading and writing skills. And yet, to date, only a few studies have tested the effects of such training on reading comprehension. A recent meta-analysis (Silverman et al., 2020) identified four studies that tested the effects of teaching of syntactic skills; all of these did so along with other language skills, a context that might be similar to what is already happening in some classrooms. Two of these studies reported that training syntactic skills along with other language skills led to significant improvements in reading comprehension (Morris et al., 2012; Proctor et al., 2020) and the other two studies found no significant effects (Connor et al., 2018; Proctor et al., 2011). It would be useful to build on this mixed pattern of results to test the effectiveness of instruction that focuses exclusively on syntactic skills. New research could further build on this base by contrasting the effectiveness of teaching focused on either or both syntactic comprehension and awareness on reading comprehension. Indeed, Phillips (2014) trained each of syntactic comprehension and awareness, resulting in improvements in both

aspects of syntactic skills. The question of whether and when such skills should be taught together or separately for maximum impact on reading comprehension remains unanswered and is an important avenue for future research.

Our study is not without limitations. Most pressing is that our data is cross-sectional; longitudinal or interventional data are needed to begin to explore causal claims about the relations among syntactic skills and reading comprehension. To our knowledge, all available studies of syntactic comprehension are cross-sectional. The limited longitudinal research to date has been done with syntactic awareness and shows a bidirectional relation with reading comprehension (e.g., Deacon & Kieffer, 2017; Tong & McBride, 2017). Clearly, we need to test the temporal order of these relations separately for each of syntactic comprehension and awareness. Testing these effects may require task development; reliable and valid syntactic measures across elementary and beyond will be crucial to targeting developmental questions. Relatedly, we recognize that our measures of syntactic comprehension and syntactic awareness were not completely parallel; the measure of syntactic comprehension was completed on the paper and had more potential responses than did the measure of syntactic awareness. We recognize that this may have impacted the results of the measurement models, and as such, we encourage the use of more parallel measures in the future. Nonetheless, theories (e.g., Gombert, 1992) and previous empirical work (e.g., Brimo et al., 2017) do advocate for distinction between these aspects; thus, our finding of their separability fit with existing literature. Further, future research could consider additional controls, including working memory given its known relations to performance on syntactic tasks (Siegel & Ryan, 1988). Even in the absence of this control, we remain confident in our results in part because we demonstrate unique contributions beyond the other measure of syntactic skill, which would capture some contributions of working memory.

Further, recent evidence suggests performance on syntactic tasks is not solely explained by working memory (Poulsen et al., 2021) and the inclusion of non-verbal ability goes some distance in removing contributions of general cognitive skills. Future research could build on this base to build a richer picture of contributions of syntactic skill to reading comprehension.

To summarise, our study demonstrates unique contributions of each of syntactic comprehension and syntactic awareness, and of the same magnitude, to reading comprehension in English-speaking children in Grades 3 to 5, after substantive controls. These findings bridge two bodies of work on these aspects of syntactic skills that have been conducted largely in isolation from one another (but see Brimo et al., 2017 for an exception). We think that these findings go some distance in responding to calls for future research, including Scott's (2009) statement that "It is relatively easy to establish an association between syntactic ability and reading. By way of contrast, it is exceedingly difficult to understand the true nature of this relationship". Here we identify that two aspects of syntactic skills are separable and make unique contributions to reading comprehension, findings that provide insight into the mechanisms that might be responsible for the association between syntactic skills and reading comprehension. These findings stress the importance of uncovering how these two aspects work together to support reading comprehension and encourage theories to specify a distinct role for each in models of reading development. Such specification could springboard development of evidence-based teaching approaches, which would align directly with the Common Core State Standard recommendations. Such evidence-based teaching approaches also propel us toward the end goal of strong reading comprehension (e.g., Oakhill et al., 2014; Snow, 2002), which is key to both academic and societal success (e.g., Kamil, 2003).

References

Apel, K. (2022). A different view on the simple view of reading. *Remedial and Special Education*, *43*(6), 434–447. https://doi-org/10.1177/07419325211063487

Barnes, E. M., Oliveira, A. W., & Dickinson, D. K. (2019). Teacher accommodation of academic language during Head Start pre-kindergarten read-alouds. *Journal of Education for Students Placed at Risk, 24*(4), 369–393. https://doi.org/10.1080/10824669.2019.1657868

Balthazar, C. H., & Scott, C. M. (2018). Targeting complex sentences in older school children with specific language impairment: Results from an early-phase treatment study. *Journal of Speech, Language, and Hearing Research*, *61*(3), 713–728. https://doi.org/10.1044/2017_JSLHR-L-17-0105

Bowey, J. A., & Patel, R. K. (1988). Metalinguistic ability and early reading achievement. *Applied Psycholinguistics*, *9*(4), 367–383. https://doi.org/10.1017/S0142716400008067

Brimo, D., Apel, K., & Fountain, T. (2017). The effects of syntactic awareness and syntactic knowledge on reading comprehension among 9th and 10th grade students. *Journal of Research in Reading, 40*(1), 57-74. https://doi.org/10.1111/1467-9817.12050

Cain, K. (2007). Syntactic awareness and reading ability: Is there any evidence for a special relationship? *Applied Psycholinguistics, 28*(4), 679-694. https://doi.org/10.1017/S0142716407070361

Candler, L. (n.d.). Teaching kids how to write super sentences. Retrieved from https://www.lauracandler.com/super-sentences/

Chall, J. S. (1983). *Stages of reading development*. McGraw-Hill.

Colenutt, A., & Toye, M. A. (2012). Critical crossroads: Youth, criminal justice and literacy Discussion Paper. Retrieved March 9, 2021, from http://en.copian.ca/library/research/frontier/critical_crossroads/critical_crossroads.pdf

Connor, C. M., Phillips, B. M., Kim, Y.-S. G., Lonigan, C. J., Kaschak, M. P., Crowe, E., Dombek, J., & Al Otaiba, S. (2018). Examining the efficacy of targeted component interventions on language and literacy for third and fourth graders who are at risk of comprehension difficulties. *Scientific Studies of Reading*, *22*(6), 462–484. https://doi.org/10.1080/10888438.2018.1481409

Curran, M. (2020). Complex sentences in an elementary science curriculum: A research note. *Language, Speech, and Hearing Services in Schools, 51*(2), 329-335. https://doi.org/10.1044/2019_LSHSS-19-00064

Cutting, L. E., & Scarborough, H. S. (2006). Prediction of reading comprehension: Relative contributions of word recognition, language proficiency, and other cognitive skills can depend on how comprehension is measured. *Scientific Studies of Reading*, *10*(3), 277–299. https://doi.org/10.1207/s1532799xssr1003_5

Dawson, H. & Phelan, M. (2016). *Language files: Materials for an introduction to language and linguistics* (12th ed.). The Ohio State University Press.

Deacon, S. H., Benere, J., & Pasquarella, A. (2013). Reciprocal relationship: Children's morphological awareness and their reading accuracy across grades 2 to 3. *Developmental Psychology*, *49*(6), 1113-1126. https://doi.org/10.1037/a0029474

Deacon, S. H., & Kieffer, M. (2017). Unraveling the relations between syntactic awareness and reading comprehension: Evidence from mediation and longitudinal models. *Journal of Educational Psychology*, *110*(1), 72-86. https://doi.org/10.1037/edu0000198

DeThorne, L. S., Harlaar, N., Petrill, S. A., & Deater-Deckard, K. (2012). Longitudinal stability in genetic effects on children's conversational language productivity. *Journal of Speech, Language, and Hearing Research*, *55*, 739–753. https://doi.org/10.1044/1092-4388(2011/11-0014)

Dunn, L. M., & Dunn, D. M. (2006). *The Peabody picture vocabulary test – fourth edition* (PPVT-IV). Pearson.

Écalle, J., Bouchafa, H., Potocki, A., & Magnan, A. (2013). Comprehension of written sentences as a core component of children's reading comprehension. *Journal of Research in Reading, 36*(2), 117-131. https://doi.org/10.1111/j.1467-9817.2011.01491.x

Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.). SAGE Publications.

Gombert, J. E. (1992). *Metalinguistic development*. Harvester Wheatsheaf

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education*, *7*(1), 6-10. https://doi.org/10.1177/074193258600700104

Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2011). Coh-metrix providing multilevel analyses of text characteristics. *Educational Researcher*, *40*(5), 223-234. https://doi.org/10.3102/0013189X11413260

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Prentice Hall.

Huberty, C. J, & Petoskey, M. D. (2000). Multivariate analysis of variance and covariance. In H. E. A. Tinsley & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 183–208). Academic Press. https://doi.org/10.1016/B978-012691360-6/50008-2

IBM Corp. (2020). IBM SPSS Statistics for Windows, Version 27.0. IBM Corp.

Kamil, M. L. (2003). *Adolescents and literacy: Reading for the 21st century*. Alliance for Excellent Education.

Kazak, A. E. (2018). Editorial: Journal article reporting standards. *American Psychologist*, *73*(1), 1-2. http://dx.doi.org/10.1037/amp0000263

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review*, *95*(2), 163–182. https://doi.org/10.1037/0033-295X.95.2.163

Kintsch, W. (1992). A cognitive architecture for comprehension. In H. L. Pick, Jr., P. W. van den Broek, & D. C. Knill (Eds.), *Cognition: Conceptual and methodological issues* (pp. 143–163). American Psychological Association. https://doi.org/10.1037/10564-006

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303. http://dx.doi.org/10.1037/0003-066X.49.4.294

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). Guilford Press.

Kline, R. B. (2011). *Principles and practice of structural equation mod*eling (3rd ed.). Guilford Press.

Lervåg, A., Hulme, C. & Melby-Lervåg, M. (2018). Unpicking the developmental relationships between oral language skills and reading comprehension: It's simple, but complex. *Child Development, 89*(5), 1821-1838. https://doi.org/10.1111/cdev.12861

Lesgold, M. (1974). Variability in children's comprehension of syntactic structures. *Journal of Educational Psychology*, *66*, 333–338. http://dx.doi.org/10.1037/h0036427

MacKay, E., Lynch, E., Sorenson Duncan, T., & Deacon, S. H. (2021). Informing the science of reading: Children's awareness of sentence-level information is important for reading comprehension. *Reading Research Quarterly*. https://doi.org/10.1002/rrq.397

Melby-Lervåg, M., & Lervåg, A. (2014). Reading comprehension and its underlying components in second-language learners: A meta-analysis of studies comparing first- and second-language learners. *Psychological Bulletin*, *140*(2), 409-433. https://doi.org/10.1037/a0033890

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*(2), 322–352. https://doi-org/10.1037/a0026744.supp (Supplemental)

Montgomery, J. W., Evans, J. L., Gillam, R. B., Sergeev, A. V., & Finney, M. C. (2016). "Whatdunit?" Developmental changes in children's syn- tactically based sentence interpretation abilities and sensitivity to word order. *Applied Psycholinguistics*, *37*, 1281–1309. http://dx.doi.org/10 .1017/S0142716415000570

Morris, R. D., Lovett, M. W., Wolf, M., Sevcik, R. A., Steinbach, K. A., Frijters, J. C., & Shapiro, M. B. (2012). Multiple component remediation for developmental reading disabilities: IQ, socioeconomic status, and race as factors in remedial outcome. *Journal of Learning Disabilities, 45*(2), 99–127. https://doi.org/10.1177/0022219409355472

Muthén, L.K. & Muthén, B.O. (1998-2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén

Nation, K., & Snowling, M. (2000). Factors influencing syntactic awareness skills in normal readers and poor comprehenders. *Applied Psycholinguistics*, *21*(2), 229-241. https://doi.org/10.1017/S0142716400002046

National Institute for Literacy. (2008). Developing early literacy: A scientific analysis of early literacy development and implications for intervention. Retrieved from http://www.nifl.gov/publications/pdf/NELPReport09.pdf

Oakhill, J., Cain, K., & Elbro, C. (2014). *Understanding and teaching reading comprehension: A handbook*. Routledge.

Perfetti, C. A., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*, 22-37. https://doi.org/10.1080/10888438.2013.827687

Petch, E., Ronson, B., & Rootman, I. (2004). Literacy and health in Canada: What we have learned and what can help in the future? A Research Report. Clear Language Edition. Canadian Institute of Health Research.

Phillips, B. M. (2014). Promotion of syntactical development and oral comprehension: Development and initial evaluation of a small-group intervention. *Child Language Teaching and Therapy*, *30*, 63–77. https://doi.org/10.1177/026565901348774

Poulsen, M., & Gravgaard, A. K. (2016). Who did what to whom? The relationship between syntactic aspects of sentence comprehension and text comprehension. *Scientific Studies of Reading*, *20*(4), 1-14. https://doi.org/10.1080/10888438.2016.1180695

Poulsen, M., Nielsen, J. L., & Vang Christensen, R. (2021). Remembering sentences is not all about memory: Convergent and discriminant validity of syntactic knowledge and its relationship with reading comprehension. *Journal of Child Language*, 1-17. https://doi.org/10.1017/S0305000921000210

Proctor, C. P., Dalton, B., Uccelli, P., Biancarosa, G., Mo, E., Snow, C., & Neugebauer, S. (2011). Improving comprehension online: Effects of deep vocabulary instruction with

bilingual and monolingual fifth graders. *Reading and Writing*, *24*(5), 517–544. https://doi.org/10.10 07/s11145-009-9218-2

Proctor, C. P., Silverman, R. D., Harring, J. R., Jones, R. L., & Hartranft, A. M. (2020). Teaching bilingual learners: Effects of a language-based reading intervention on academic language and reading comprehension in grades 4 and 5. *Reading Research Quarterly*, 55(1), 95–122. https://doi.org/10.1002/rrq.258

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/.

Scott, C. M. (2009). A case for the sentence in reading comprehension. *Language, Speech, and Hearing Services in Schools*, *40*(2), 184–191. https://doi.org/10.1044/0161-1461(2008/08-0042)

Shanahan, T. (2020). Why we need to teach sentence comprehension. Retrieved from https://www.readingrockets.org/blogs/shanahan-literacy/why-we-need-teachsentencecomprehension

Siegel, L. S., & Ryan, E. B. (1988). Development of grammatical-sensitivity, phonological, and short-term memory skills in normally achieving and learning disabled children. *Developmental Psychology*, *24*, 28–37. https://doi.org/10.1037/0012-1649.24.1.28

Silverman, R. D., Johnson, E., Keane, K., & Khanna, S. (2020). Beyond decoding: A meta-analysis of the effects of language comprehension interventions on k–5 students' language and literacy outcomes. *Reading Research Quarterly, 55*(51), S207-S233. https://doi.org/10.1002/rrq.346

Snow, C. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. Rand Corporation.

Snowling, M. J., & Hulme, C. (2011). Evidence-based interventions for reading and language difficulties: Creating a virtuous circle. *British Journal of Educational Psychology*, *81*(1), 1–23. https://doi.org/10.1111/j.2044-8279.2010.02014.x

Sorenson Duncan, T., Mimeau, C., Crowell, N., & Deacon, S. H. (2020). Not all sentences are created equal: Evaluating the relation between children's understanding of basic and difficult sentences and their reading comprehension. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000545

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson.

Tilanus, E. A. T., Segers, E., & Verhoeven, L. (2019). Responsiveness to intervention after second versus third grade diagnosis of dyslexia. *Reading & Writing Quarterly: Overcoming Learning Difficulties*. https://doi-org/10.1080/10573569.2019.1667929

Thornton, R. (2016). Children's acquisition of syntactic knowledge. *Oxford Research Encyclopedias.* https://doi.org/10.1093/acrefore/9780199384655.013.72

Tilstra, J., McMaster, K., Van den Broek, P., Rapp, D. (2009). Simple but complex: Components of the simple view of reading across grade levels. *Journal of Research in Reading*, *32*, 383–401. https://doi.org/10.1111/j.1467-9817.2009.01401.x

Tong, X., & McBride, C. (2017). A reciprocal relationship between syntactic awareness and reading comprehension. *Learning and Individual Differences*, *57*, 33–44. https://doi.org/10.1016/j.lindif.2017.05.005

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2012). *Test of word reading efficiency – second edition* (TOWRE-2). Pro-Ed.

Uccelli, P., Galloway, E. P., Barr, C. D., Meneses, A., & Dobbs, C. L. (2015). Beyond vocabulary: Exploring cross-disciplinary academic-language proficiency and its

association with reading comprehension. *Reading Research Quarterly*, *50*(3), 337–356. https://doi.org/10.1002/rrq.104

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2013). *Comprehensive test of phonological processing – second edition*. (CTOPP-2). Pro-Ed

Wechsler, D. (2011). *Wechsler abbreviated scale of intelligence–second edition* (WASI-II). NCS Pearson.

Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models: An evaluation of power, bias, and solution propriety. *Educational and Psychological Measurement*, *76(*6), 913–934. https://doi.org/10.1177/0013164413495237

Woodcock, R. W. (2011). *Woodcock reading mastery tests – third edition (*WRMT-III). Pearson.

Table 1

The Reliabilities, Means (Raw and Standardized Scores), and Standard Deviations for the Control, Outcome, and Experimental Measures for the Whole Sample and by Grade

Task (Max Score)	Reliability	Range	Mean	Grade		
				3	4	5
Nonverbal Reasoning (30)		3.00-26.00	15.59 (4.80)	13.33 (4.87)	16.67 (4.68)	16.64 (4.19)
Nonverbal Reasoning (SS)	.85-.88[a]	24.00-99.00	49.78 (11.65)	47.21 (10.75)	51.90 (12.30)	50.15 (11.60)
Phono. Awareness (34)		8.00-34.00	25.62 (5.69)	23.71 (6.45)	27.15 (4.81)	25.96 (5.30)
Phono. Awareness (SS)	.87-.93[a]	4.00-16.00	9.75 (2.91)	9.63 (2.86)	10.52 (2.98)	9.17 (2.78)
Vocabulary (51)	.91[b]	7.00-49.00	37.05 (5.58)	34.19 (6.47)	36.92 (4.70)	39.72 (4.02)
Word Reading (SS)	.90[a]	55.00-131.00	98.65 (13.30)	97.44 (15.30)	99.45 (11.62)	99.04 (12.91)
Reading Comp. (38)		2.00-34.00	20.55 (5.75)	16.90 (4.03)	21.32 (5.39)	23.17 (5.75)
Reading Comp. (SS)	.85-.87[a]	55.00-140.00	104.79 (16.62)	101.35 (13.74)	107.68 (17.49)	105.33 (17.89)
Syn. Comp (28)	.82[b]	2.00-27.00	16.94 (5.52)	15.13 (4.90)	16.59 (5.80)	18.66 (5.30)
Active		0.00-7.00	4.69 (1.67)	4.51 (1.78)	4.57 (1.66)	4.94 (1.60)
SR		0.00-7.00	5.26 (1.68)	4.95 (1.69)	5.16 (1.78)	5.58 (1.55)
Passive		0.00-7.00	4.03 (2.30)	3.23 (2.38)	3.91 (2.13)	4.78 (2.18)

OR		0.00-7.00	2.95 (1.77)	2.44 (1.37)	2.95 (1.87)	3.36 (1.89)
Syn. Awareness (Syntactic Correction; 30)	.71[c]	1.00-27.00	14.81 (6.57)	11.36 (6.37)	16.31 (5.48)	16.49 (6.57)
Syn. Awareness (Dative Sentence; 20)	.81[c]	0.00-20.00	12.03 (5.30)	9.20 (5.30)	13.16 (4.36)	13.52 (5.16)
Reversible		0.00-10.00	5.63 (2.99)	4.11 (2.99)	6.35 (2.48)	6.26 (3.01)
Irreversible		0.00-10.00	6.54 (2.67)	5.35 (2.76)	6.82 (2.35)	7.26 (2.56)

Note: [a] = manual reliability; [b] = Cronbach's alpha based on our sample; [c] = split-half reliability based on our sample. The estimate of nonverbal reasoning was measured with WASI-II Matrix Reasoning; Phonological awareness was measured with CTOPP-2 Elision; Vocabulary was measured with a modified version of the PPVT; Word reading was measured with TOWRE Sight Word Efficiency; and Reading comprehension was measured with WRMT Passage Comprehension.

Table 2

The Correlations Among our Predictor, Outcome, and Control Measures

	MR	CTOPP	PPVT	TOWRE	WD	SC	DS	RC
Nonverbal Reasoning	**1**							
Phonological Awareness	.390	**1**						
Vocabulary	.224	.181	**1**					
Word Reading	.300	.406	.164	**1**				
Syntactic Comp.	.446	.274	.233	.328	**1**			
Syntactic Awareness (SC)	.418	.496	.393	.304	.368	**1**		
Syntactic Awareness (DS)	.227	.396	.353	.305	.407	.696	**1**	
Reading Comprehension	.507	.503	.307	.457	.430	.574	.445	**1**

Note: The estimate of nonverbal reasoning was measured with WASI-II Matrix Reasoning; Phonological awareness was measured with CTOPP-2 Elision; Vocabulary was measured with a modified version of the PPVT; and word reading was measured with TOWRE Sight Word Efficiency. Syntactic awareness (SC) represents the syntactic correction task. Syntactic awareness (DS) represents the dative sentence task.

7Table 3

The Fit Indices for Each of the Three Measurement Models Tested

Model	χ^2	df	*p*	Comparative Fit Index	Tucker-Lewis Index	Root Mean Square Error of Approximation	Standardized Root Mean Square Residual
Uni	107.31	14	>.001	.74	.61	.21	.15
2F-C	37.83	13	>.001	.93	.88	.03	.07
2F-B	39.58	10	>.001	.92	.83	.14	.09

Note: Uni = unidimensional model; 2F-C = 2-factor, correlated model; 2F-B = 2-factor, bifactor model

Table 4

The Factor Loadings for the Two-Factor Model Explaining the Syntactic Comprehension and Awareness Measures in the Sample of Third to Fifth Grade Children. Values less than .3 are Excluded

	Factor	
	Syntactic Comprehension	Syntactic Awareness
Whatdunnit Active	.795	
Whatdunnit SR	.800	
Whatdunnit Passive	.516	
Whatdunnit OR	.394	
Syntactical Correction		.772
Dative Sentence Reversible		.833
Dative Sentence Irreversible		.840

Table 5

The Hierarchical Linear Regression Statistics Predicting Reading Comprehension from Syntactic Comprehension and Awareness and Controls in the Whole Sample

	Unstandardized Coefficients		Standardized Coefficients			
	B	Std. Err	Beta	t	*p*	**R^2 Change**
Controls						**8.3**
Gender	.040	.747	.003	.053	.958	
Grade	2.309	.409	.323	4.709	<.001	
Language Status	.476	1.128	.028	.422	.674	
NV Reasoning	.168	.041	.297	4.109	<.001	**47.2**
PA	.347	.146	.177	2.370	.019	
Vocabulary	.328	.068	.320	4.815	<.001	
Word Reading	.103	.031	.238	3.312	.001	
Syntactic Skills						**5.0**
Comprehension	1.415	.440	.214	3.217	.002	
Awareness	2.202	.492	.343	4.475	<.001	

Note: NV Reasoning = Estimate of nonverbal reasoning, measured with Matrix Reasoning; PA = phonological awareness, measured with CTOPP Elision; Vocabulary was measured with a modified version of the PPVT; and word reading was measured with TOWRE Sight Word Efficiency.

Table 6

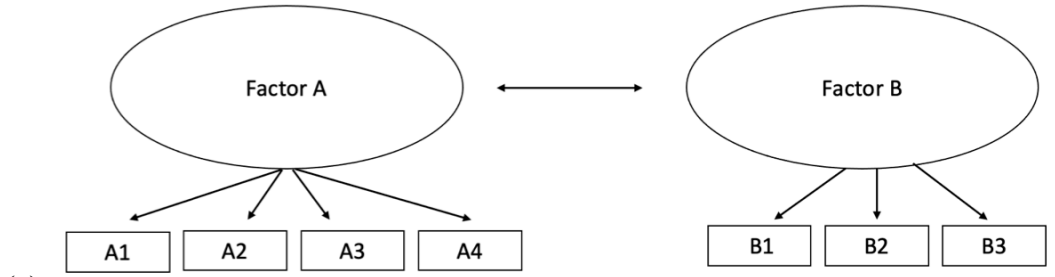
The Hierarchical Linear Regression Statistics Predicting Reading Comprehension from Syntactic Comprehension and Awareness by Grade

	Unstandardized Coefficients		Standardized Coefficients			
	B	Std. Err	Beta	t	*p*	**R^2 Change**
Interaction Effects						**51.3**
Grade 3 x SC	2.127	.906	.174	2.348	.020	
Grade 3 x SA	1.374	.826	.129	1.663	.099	
Grade 4 x SC	.171	.814	.016	.210	.834	
Grade 4 x SA	4.979	.975	.379	5.106	<.001	
Grade 5 x SC	1.428	.888	.134	1.608	.110	
Grade 5 x SA	3.215	.850	.316	3.784	<.001	

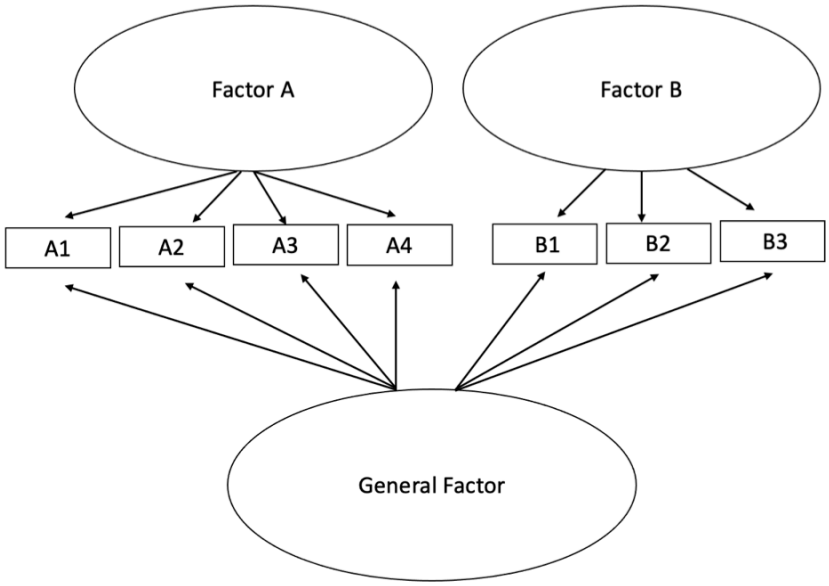
Note: Following on the procedure for investigating interaction effects, main effects were also entered in the linear regression but are not interpreted due to the presence of interaction effects.

Figure 1

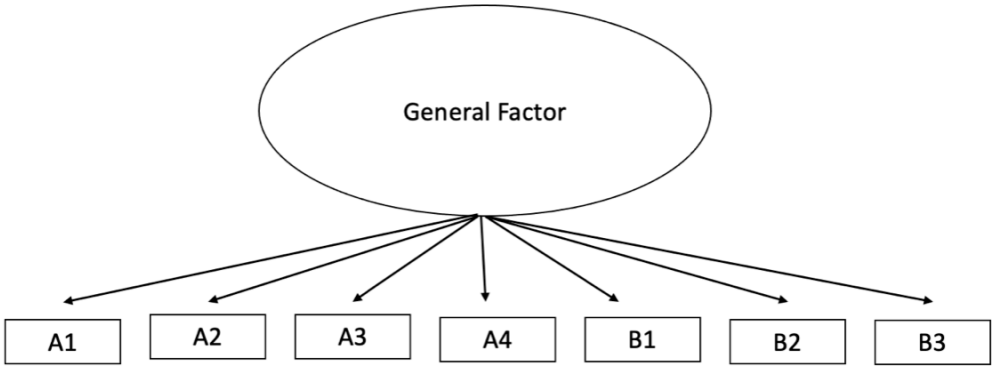
Representations of the Three Possible Measurement Models for our Two Aspects of Syntactic Skills: A Multidimensional, Correlated Model (a), a Multidimensional, Bifactor model (b), and a Unidimensional Model (c)



(a)



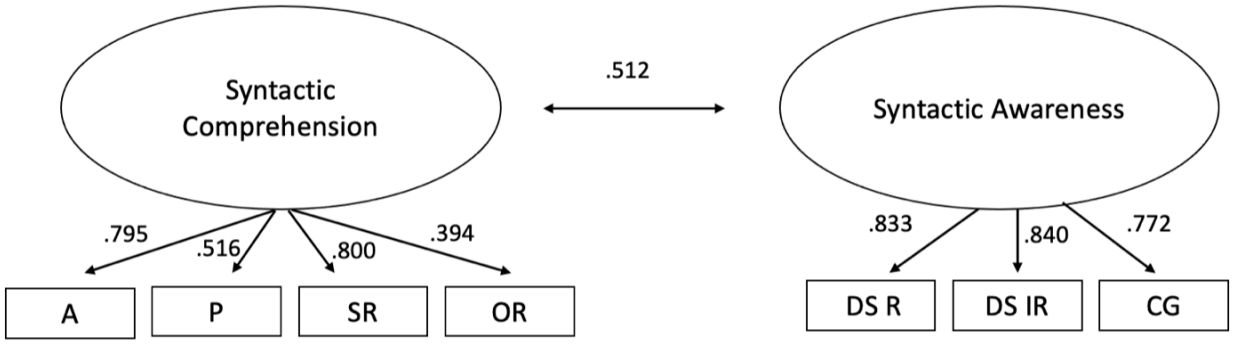
(b)



(c)

Figure 2

The Final 2-Factor, Correlated Measurement Model for our Data



Chapter 4:

Identifying Which Sentence Skills Enable the Development of Reading Comprehension and How They Do So

Abstract

Theories of reading comprehension predict that syntax, or the way words and phrases are organized into sentences, supports the development of reading comprehension. Here we test this prediction, with an eye to resolving key theoretical debates. The first is which of two aspects of syntactic skills – syntactic comprehension or syntactic awareness – is most important for the development of reading comprehension. The second lies in whether syntactic parsing, which is the ability to chunk sentences into more manageable pieces, is a mechanism by which syntactic skills may contribute to reading comprehension. We respond to each of these open theoretical questions in our longitudinal, autoregressive design. In a study tracking development from Grade 1 to 4, 257 English-speaking children completed measures of syntactic comprehension, syntactic awareness, syntactic parsing, and reading comprehension, as well as relevant controls. Measurement models confirmed distinctiveness between syntactic comprehension and syntactic awareness. Path analyses showed that Grade 1 syntactic comprehension and Grade 2 syntactic awareness predicted gains in reading comprehension between Grades 1 and 4 beyond controls. These analyses also revealed that early syntactic comprehension predicted later syntactic parsing skill, although there was less evidence of a relation between syntactic parsing and gains in reading comprehension. Overall, these results encourage theories to include roles for both aspects of syntactic skills when describing reading comprehension development. Our findings also point to the potential efficacy of teaching syntax in the classroom, emphasising syntactic comprehension for younger children and syntactic awareness for older children.

Keywords: Syntactic comprehension, syntactic awareness, reading comprehension, elementary-aged students, longitudinal

Introduction

The end goal of reading development is for readers to understand the content of the texts that they read – what is referred to as reading comprehension (e.g., Oakhill et al., 2014). It is widely argued that reading comprehension involves skill in syntax, a term referring to the way words and phrases are organized into larger phrases and sentences (Dawson & Phelan, 2016). Syntactic skills are widely included in theories of reading comprehension (e.g., Gombert, 1992; Kintsch, 1994; Perfetti & Stafura, 2014). Accordingly, the Common Core State Standards (2021) argue that children should be taught to tackle complex sentences to optimize their reading comprehension. This inclusion of syntactic skills in reading theories and educational guidelines makes sense given that syntactic complexity is the strongest predictor of text readability (e.g., Graesser et al., 2011; Stenner & Swartz, 2012). Aligning with this theoretical and practical relevance, empirical work has identified syntactic skills to be important for reading comprehension; yet we lack critical data to inform effective intervention (see MacKay et al., 2021; Moats, 2020; Scott, 2009). Here we report on a study that provides key information on two open questions. The first is which aspect of syntactic skills is most relevant to reading comprehension—whether this is in skill in understanding or manipulating sentences, known as syntactic comprehension and awareness, respectively. The second lies in just how either of these syntactic skills enable reading comprehension. We test a mechanism — that of syntactic parsing — that has been described in theories as enabling reading comprehension but not yet tested empirically. We report on a longitudinal study of English-speaking children from first to fourth grade designed to answer these questions.

There is unequivocal educational value in investigating each of these open questions (see e.g., Elleman & Oslund, 2019). The Common Core State Standards (2021) advises that children

should be taught to tackle complex sentences, and yet also provides minimal guidance on how to teach syntactic skills. This lack of guidance means that teachers who are forging ahead in designing and offering classroom instruction about syntax (e.g., Barnes, 2019; Shanahan, 2020) are doing so without clear guidance as to which approaches are most likely to support children's reading comprehension. This is an unfortunate situation; classroom time is precious and teaching syntax is hard, more so than other aspects of language, such as academic vocabulary (Barnes et al., 2019). Shanahan (2020) describes the dissonance between the evidence base and what is happening in the classroom by suggesting that the science of reading – the findings from basic research investigating the skills important for reading comprehension – is not readily applicable to reading instruction. Thus, it is essential to create data that can inform the most effective way to teach syntactic skills, given that such skills are already being implemented in the classroom. Robust studies of individual differences are one way to inform the design of interventions. Here, we take steps toward informing intervention and classroom instruction; to do so, we determine whether and how two potentially distinctive syntactic skills predict gains in reading comprehension three years later.

Which Aspect of Syntactic Skills is Most Important for Reading Comprehension?

The first theoretically driven question that we tackle is which of syntactic comprehension or awareness matters most for reading comprehension. Syntactic comprehension is defined as a linguistic skill that reflects the ability to understand spoken sentences (Poulsen & Gravgaard, 2016). Syntactic awareness is defined as the metalinguistic skill of reflecting on or manipulating spoken sentences (Cain, 2007). While multiple theories make clear predictions about the role of syntactic skills in reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), there is

a lack of clarity regarding which aspect of syntactic skill is most important, specifically whether this is syntactic comprehension or awareness.

The Simple View of Reading (Gough & Tunmer, 1986) advocates for a role for syntactic comprehension in reading comprehension. According to this theory, linguistic comprehension, within which syntactic comprehension sits (e.g., Apel, 2022; Gough & Tunmer, 1986; Kim, 2020), is one of two key contributors to reading comprehension. Gough and Tunmer (1986) argue that linguistic skills allow a reader to understand and synthesize a text, which then leads to overall text comprehension. Within this explanation, there is no specific place for metalinguistic skills, including syntactic awareness (but see Apel, 2022). Based on this theoretical standpoint, we would expect that understanding sentences is enough to support reading comprehension.

On the other hand, Gombert (1992) predicts that reading comprehension is more likely to be supported by syntactic awareness than syntactic comprehension. He argues that, as a metalinguistic skill, syntactic awareness is more likely to enable improvements in reading comprehension. There is practical merit to this view; understanding sentences is likely to be more supported by oral language and the sentences that children encounter in text are shown to be far more complex than those that children hear in oral language (Fang, 2006; Uccelli et al., 2015).

That said, it is possible that both syntactic comprehension and awareness are important for reading comprehension development. This aligns with theories that include syntactic skills broadly without describing the specific role of either aspect (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). All these theoretical predictions are currently open questions, in that they lack clear empirical data resolving them.

Answering the question of which of syntactic comprehension or syntactic awareness has the strongest impacts on the development of reading comprehension also has downstream educational implications. Teaching these two aspects of syntactic skills would look different in the classroom. This difference is captured just by reviewing the two constructs; syntactic comprehension emphasises understanding sentences and syntactic awareness on manipulating them. Critically, these characteristics may impact how each aspect is taught. Phillips (2014) made these different instructional approaches concrete in an innovative study with pre-kindergarten to first grade children. In this study, her instruction for syntactic comprehension exposed children to sentence structures of varying complexity and she followed up with comprehension questions. A different group of children learned about syntactic awareness by writing sentences following certain syntactic rules. Both types of training were found to improve children's syntactic comprehension and awareness skills, although effects on reading comprehension were not assessed. Yet, this study demonstrates that there can be separate instruction on each aspect with evidence that this instruction can enable children's syntactic skills.

Turning to studies of individual differences, to our knowledge, two studies have investigated the relations between both syntactic comprehension and awareness with reading comprehension in elementary students, although neither test unique relations from these two aspects of syntactic skills. Bowey and Patel (1988) report on first grade students and Cain (2007) a cross-sectional sample of third to fifth grade students. Both studies assessed syntactic comprehension by asking children to select a picture that best represents a spoken sentence and syntactic awareness by administering a word-order correction task. In both studies, hierarchical linear regression analyses showed that syntactic comprehension, when entered with vocabulary

(Bowey & Patel, 1988) or working memory (Cain, 2007), predicted reading comprehension beyond syntactic awareness. Similarly, both studies report non-significant contributions of syntactic awareness to reading comprehension after controlling for syntactic comprehension; effects of syntactic awareness on reading comprehension without this control were not assessed. These findings have been interpreted to suggest that syntactic comprehension is more related to reading comprehension than syntactic awareness in elementary-aged children. However, neither study tested the effects of syntactic comprehension independently, reporting only on effects assessed along with either vocabulary or working memory, both known predictors of reading comprehension (e.g., Lervåg et al., 2018). Further, in both studies, syntactic awareness was entered into the regressions after syntactic comprehension and, again, either vocabulary or working memory, and so the null effects of syntactic awareness on reading comprehension assessed quite differently than those of syntactic comprehension. Here, we extend current research by investigating the unique relations between each of syntactic comprehension and awareness with reading comprehension.

We extend this cross-sectional evidence base further by testing which of syntactic comprehension and awareness contributes to children's development of reading comprehension over time. To do so, we analyse longitudinal data with autoregressive controls for earlier levels of reading comprehension in analyses (e.g., Kenny, 1975; Levesque et al., 2019). This is a critical advancement for both theoretical and educational purposes. Many theories that detail a role of syntactic skills in reading comprehension make directional predictions, suggesting that either the ability to understand (e.g., Gough & Tunmer, 1986) or manipulate (e.g., Gombert, 1992) sentences should lead to the development of stronger reading comprehension. Cross-sectional studies, such as those to date (Bowey & Patel, 1988; Cain, 2007) do not inform us as to

directionality of effects. In these studies, it may have been that as children developed stronger reading comprehension, their ability to understand and/or manipulate sentences improved. Indeed, texts have more complex sentences than oral language (e.g., Uccelli et al., 2015) and children who are stronger readers are likely to read more (e.g., van Bergen et al., 2018). This leads to more exposure to and practice with complex sentences, which may improve their understanding and/or awareness of sentence structure. Longitudinal analyses are thus ideally suited to respond to current open theoretical questions. From an educational perspective, identifying the skills that lead to improvements in reading comprehension is essential to optimising the use of limited classroom time and resources (e.g., Froese-Germain, 2014; Hunter & Sonnemann, 2022) and analyses focusing on gains in reading comprehension can provide valuable insight into how to support student learning. While intervention data is ultimately the most robust way to advise on which skills lead to change in reading comprehension, an autoregressive, longitudinal design is the most efficient and powerful step in the short-term to inform what needs to be targeted in intervention studies.

How Do Syntactic Skills Contribute to the Development of Reading Comprehension?

A second theoretically driven question is just *how* syntactic skills contribute to reading comprehension; this question applies regardless of which aspect we consider. Several theories have suggested syntactic parsing as a mechanism through which this relation functions. Syntactic parsing is described as the ability to divide sentences into constituent clauses, or "chunks"; such chunking should make the whole sentence, and therefore text, more accessible (Kintsch, 1994; Perfetti & Stafura, 2014). For example, Perfetti and Stafura (2014) describe that syntactic skills allow readers to create boundaries between different parts of the sentences, effectively dividing one, long sentence into more manageable pieces. Take, for instance, the following sentence: "The

boy talked to the girl who was wearing a black shirt while his parents waited". This could be processed as a string of 16 words or as three chunks, such as "The boy talked to the girl", "who was wearing a black shirt", and "while his parents waited"; the latter would likely be far more efficient. We report here on analyses that explore if syntactic skills are related to later syntactic parsing, and if syntactic parsing, in turn, is related to later reading comprehension.

While there is theoretical consensus that parsing is a mechanism by which syntactic skills contribute to reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014), there is ambiguity as to which aspect of syntactic skills supports this mechanism. For instance, Gombert (1992) argues that a reader's ability to parse a sentence into its relevant pieces is more accessible when one has developed syntactic awareness skills. This is because the explicit awareness of language that is characteristic of syntactic awareness is what allows the parsing mechanism to occur. Thus, in Gombert's view, understanding sentences is not sufficient to evoke a reader's ability to divide a sentence into its constituent clauses. Corroborating this prediction, Deacon and Kieffer (2017) hypothesize that syntactic awareness allows a reader to parse sentences into meaningful "chunks", which in turn contributes to the creation of text level representations, the foundations of reading comprehension (e.g., Farnia & Geva, 2013; Willows & Ryan, 1986). Yet, others argue that understanding the events that happen within a sentence will allow the reader to chunk the sentence into its meaningful parts, facilitating processing and reducing cognitive load. This should lead to improved reading comprehension (Kintsch, 1994).

To our knowledge, syntactic parsing has not been empirically connected to syntactic skills nor reading comprehension, although psycholinguistic research certainly demonstrates that parsing is possible. Indeed, researchers have demonstrated that children can parse sentences to enhance their comprehension at the sentence-level. For example, Weighall and Altmann (2011)

asked 6- to 8-year-old children to listen to relative-clause sentences (e.g., The cow will hug the cat that bumped the bear) and then answer questions to demonstrate understanding of the main clause (the cow will hug the cat) and the relative clause (the cat bumped the bear). Children were better able to identify and answer questions about the main and relative clauses when they heard right-branching relative clauses (e.g., The cow will hug the cat that bumped the bear) as compared to centre-embedded relative clauses (e.g., The cat that bumped the bear will hug the cow). Weighall and Altmann argue that this is evidence that better ability to parse sentences into their constituent clauses led to stronger comprehension. They explained that children were better able to parse and subsequently understand the clauses when presented in right-branching as compared to centre-embedded format, as centre-embedded sentences are more challenging for children of this age. Thus, there is some evidence that early elementary students can parse sentences into meaningful units; whether this ability is related to syntactic skills and/or reading comprehension is unknown. Indeed, key theoretical predictions regarding the relations among syntactic skills, syntactic parsing, and reading comprehension have not been tested empirically. Here, we fill this gap.

Present Study

The overarching goal of the present study is to investigate which aspect of syntactic skills is most important for reading comprehension and a potential mechanism by which this relation functions. We did so by working with children in Grade 1 and following them to Grade 4 in an autoregressive, longitudinal design. Children completed measures of syntactic comprehension, syntactic awareness, and related controls in first grade, syntactic awareness and syntactic parsing in second grade, and reading comprehension in fourth grade. Studying skills in first and second grade lets us explore the early skills that predict gains in reading comprehension and whether

there are changes over time in the relative importance of these skills. This then allows us to offer suggestions as to which skills might be most effective to target early in reading development to facilitate improvements in reading comprehension skill. Assessing fourth grade reading comprehension enables us to capture a period when students have likely developed reading comprehension skills and, as such, when they are expected to use these reading comprehension skills to learn other subjects (e.g., Chall, 1983).

We used well-established measures for each of syntactic comprehension and awareness. We use the Whatdunnit task to measure syntactic comprehension (e.g., Montgomery et al., 2016; Sorenson Duncan et al., 2020). On this task, children hear sentences about one object doing an action to another object; they are then asked to select an image of the object that did the action (Montgomery et al., 2016). Following on recent studies (e.g., Montgomery et al., 2016; Sorenson Duncan et al., 2020), we use objects rather than people or animals to reduces the availability of semantic cues, focusing measurement more closely on children's syntactic skills (Lesgold, 1974). To assess syntactic awareness, we use a version of the widely used word-order correction task (e.g., Cain, 2007; Deacon & Kieffer, 2017). To measure syntactic parsing, we administer a research-created task, informed by educational resources (e.g., Sedita, 2007). In this task, children read sentences and are asked to "draw lines underneath the groups of words that go together". We chose to measure syntactic parsing in this way because it reflects how theories describe syntactic parsing as the ability to divide sentences into their constituent clauses (e.g., Deacon & Kieffer, 2017; Perfetti & Stafura, 2014).

Responding to open theoretical questions, our first objective is to determine the direct contributions of first grade syntactic comprehension and awareness to gains in fourth grade reading comprehension. We do so with an autoregressive, longitudinal design, which tests

whether syntactic comprehension and/or awareness explains development in reading comprehension skills over time (e.g., Deacon et al., 2013; Kenny, 1975; Levesque et al., 2019). This design enables stronger conclusions about which skills promote change in reading comprehension.

In line with the Simple View of Reading (Gough & Tunmer, 1986), we may find that syntactic comprehension is more predictive of reading comprehension development than syntactic awareness. Conversely, based on Gombert's (1992) predictions regarding the importance of metalinguistic skills to reading comprehension, we may expect a stronger relation between reading comprehension and syntactic awareness than syntactic comprehension. And, finally, it is possible that both aspects of syntactic skills emerge as important for later reading comprehension skill (e.g., Perfetti & Stafura, 2014). In modeling these relations, we address potential developmental effects by exploring if the contributions of syntactic awareness to gains in reading comprehension emerge from Grade 1 or 2. This is a key question for metalinguistic skills: while children are expected to have linguistic skills, including syntactic comprehension, upon entering school (e.g., Chomsky, 2002; de Marneffe et al., 2012; Oberecker et al., 2005), several theories state that metalinguistic skills begin emerging between 6 and 7 years of age (e.g., Donaldson, 1978; Gombert, 1992; Herriman, 1986). Therefore, in first grade (around age 6 years), children's emergent syntactic awareness skills may not yet be strong enough to support reading comprehension development, with these relations emerging instead from second grade syntactic awareness to predict gains in reading comprehension. Thus, we explore whether early syntactic comprehension or awareness is more important to reading comprehension development, acknowledging the possibility that the role of syntactic awareness in reading comprehension might shift in early elementary.

In order to establish which of syntactic comprehension and syntactic awareness predicts gains in reading comprehension, we test the separability of syntactic comprehension and syntactic awareness. Our models explore tested three theoretically plausible possibilities. Based on theoretical distinction between syntactic comprehension and syntactic awareness (Gombert, 1992), a correlated-factor model may be the best fit, in which syntactic comprehension and awareness emerge as separate but related constructs (Figure 1a). However, given that both aspects tap skills at the sentence level, a bifactor model may best explain our data: in this case, syntactic comprehension and awareness would emerge as separate constructs that also share common properties, represented by a general, syntactic skills construct (Figure 1b). Each of these two possibilities would support the use of each aspect of syntactic skills in subsequent analyses; the key difference is that the bifactor model would also support the inclusion of a general syntactic skills construct. Yet, following on suggestions made by Bowey and Patel (1988) that linguistic and metalinguistic skills do not develop separately, we acknowledge the possibility that syntactic comprehension and awareness are best explained as one construct (Figure 1c).

Our second objective is to explore whether syntactic parsing, which is the ability to chunk sentences into more manageable pieces, is a mechanism by which syntactic skills may contribute to reading comprehension. For this to be the case, several relations would need to be in place. First, based on theoretical accounts that suggest that syntactic skills, broadly speaking, help readers break sentences into their constituent chunks (e.g., Perfetti & Stafura, 2014), we would expect syntactic skills to be related to later syntactic parsing, which in turn may be related to reading comprehension. Given theoretical debate as to whether syntactic comprehension (Kintsch, 1994) or syntactic awareness (Gombert, 1992) supports the parsing mechanism, it is an open question as to which might do so. Second, based on the idea that syntactic parsing allows a

reader to break sentences into more manageable pieces, we would expect parsing to be related to later reading comprehension (e.g., Perfetti & Stafura, 2014). Finally, as the strongest evidence of syntactic parsing as a mechanism by which syntactic skills may contribute to reading comprehension, we test whether syntactic parsing mediates the relation between syntactic skills and reading comprehension. Our autoregressive, longitudinal design is critical to testing mediation (Selig & Little, 2012; Maxwell & Cole, 2007), as at its core, mediation is meant to explain how causal relations unfold over time; a cross-sectional study is ill-equipped to address relations over time.

In modeling our first and second objectives, we include multiple controls. We control for an estimate of nonverbal ability, phonological awareness, receptive vocabulary, and word reading at Grade 1, all of which have been shown to be related to syntactic skills and reading comprehension in early elementary students (e.g., Gough & Tunmer, 1986; National Institute of Literacy, 2008). Phonological awareness is the strongest predictor of word reading (e.g., Melby-Lervåg et al., 2012), which in turn is a reliable predictor of reading comprehension (e.g., Melby-Lervåg & Lervåg, 2014). Nonverbal ability, word reading, and vocabulary have robust relations with both syntactic skills and reading comprehension (e.g., Dethorne et al., 2012; Tilstra et al., 2009). Including vocabulary as a control increased confidence that effects of syntactic skills were not attributable to oral language more broadly (e.g., Lervåg et al., 2018). Further, we also control for the autoregressor of reading comprehension, which allows us to take the critical step of identifying variables that lead to improvements in reading comprehension (e.g., Kenny, 1975).

Method

Participants

Participants were recruited from 18 urban and rural schools in and around a small city on the east coast of North America as part of a larger longitudinal project on reading development. Three hundred and thirty-three children were first tested in winter and spring of Grade 1. Eighty two children were tested again in Grade 2; these children were all from the first set of 18 schools, as testing in this year was cut short because all schools in the province closed for the remainder of the academic year due the COVID-19 pandemic. Two hundred and fifty-seven children were then tested again two years later in Grade 4; Grade 4 was the first year that testing was permitted to resume following the COVID-19 pandemic closures. Participant demographics are included in Table 1.

Measures

Syntactic comprehension was administered in first grade and syntactic awareness was administered in first and second grade. Syntactic parsing was administered in second grade. The outcome of reading comprehension was administered in fourth grade. Our control measures of nonverbal ability, phonological awareness, receptive vocabulary, and word reading and the autoregressor for reading comprehension were administered in first grade.

Predictor Measures

Syntactic Awareness. In both first and second grade, we administered a syntactic correction task, based on the grammatical correction task used in Cain (2007). On this task, children heard a sentence with words in the incorrect order (e.g., the girl opened door the) and were asked “fix up the sentence so it sounds right”. Children received one point for each correct answer on the test items.

This task had two practice items and 28 test items in grade one and two practice items and 20 test items in grade two. Children received corrective feedback on the practice items and testing stopped after four consecutive errors. We modified items used in previous versions of this task (e.g., Cain, 2007) such that there were only syntactic, and no morphological, errors. We removed items that were low accuracy with an older sample of third to fifth children (MacKay & Deacon, submitted) and added items of sentence types that are more accessible to first grade children (i.e., active and subject-relative clauses). The sentence types included on this task were active, passive, reflexive anaphora, subject-relative clause, and object-relative clause. Split-half reliability was .937 for our first-grade sample and .946 for our second-grade sample.

Syntactic Comprehension. To assess syntactic comprehension, we administered a shortened version of the Whatdunnit task (Montgomery et al., 2016). In this task, children heard a sentence with three objects in which one object was doing an action to another object (e.g., the key that saw the bed near the car was cold). As hearing the sentence, the three objects in the sentence appeared on a computer screen. Children were asked to indicate which object completed the action by pressing one of three coloured dots on keys on the keyboard underneath each of the three pictures. Children received one point for correctly identifying the object that did the action.

This task included four practice items and 28 test items. Participants were given corrective feedback on all practice items. The sentences on this task included active, passive, subject-relative, and object-relative clauses. There were 7 of each sentence type. The task was further divided into two forms: the basic sentences (active and subject-relative clauses) and the difficult sentences (passive and object-relative clauses). Sentences were matched for length, an important step given that active sentences are typically shorter than passive sentences, and both

are shorter than sentences containing a relative clause. Cronbach's alpha of this measure for our sample was .632; the reliabilities for the basic and difficult sentences were .755 and .509, respectively.

Syntactic Parsing. In this measure, children read sentences of varying types and lengths and were instructed that sentences that have "groups of words that go together". The participants were asked to "draw lines underneath the groups of words that go together". Thus, the children identified the clauses in each sentence as well as the boundaries between the clauses. To avoid inadvertently giving the children prosodic cues to clause boundaries (e.g., Schafer et al., 2000), children read the sentences silently to themselves. This also likely increased the role of word reading in performance on the task. To reduce this, the examiner was allowed to provide a single word if a child was unable to decode a word in a sentence (although not two or more in a row, again to reduce the influence of prosodic cues).

All sentences had 1 to 4 boundaries and 2 to 5 clauses. As an example of boundaries and clauses, in the sentence "The dog chased the cat that had a green bow", children would place one line under "The dog chased the cat" and one under "that had a green bow", creating one boundary and two clauses. We ensured that each sentence contained frequent words for first grade students (i.e., >50 words/million, Zeno, 2005) to increase the likelihood our sample would be able to read the sentences independently. Further, in order to minimize the possibility that children could rely on punctuation to guide their parsing decisions, none of our sentences included punctuation.

In terms of scoring, children received one point for each correctly identified clause in the sentence and one point for indicating the correct number of boundaries. For example, in the sentence "The dog chased the cat that had a green bow", the maximum score is 3: one point

awarded for correctly indicating there was only one boundary in the sentence (The dog chased the cat that had a green bow) and two points awarded for correctly identifying each group of words. If the child incorrectly indicated the "groups of words that go together" (e.g., The dog chased the cat that had a green bow), they would receive 1 point for the boundary score, as they correctly indicated there was one boundary in the sentence, but 0 points for the clause score, as they did not correctly identify either clause. This would result in a score of 1/3. The total score was calculated by summing the boundary and clause scores for all items. All items were scored by two researchers. Inter-rater reliability was .902.

This task had one example item, three practice items, and 16 test items. For the teaching item, children received explicit instruction from the examiner in how to complete the task; this was accompanied by an example sentence that the examiner completed. Corrective feedback was provided for each of the practice items. Cronbach's alpha was .888 for this sample.

Outcome Measure

Reading Comprehension. Level 4, Form T from the Gates-MacGinitie Reading Tests – 2nd Edition (GMRT-2; MacGinitie & MacGinitie, 1992) was used to assess fourth grade reading comprehension. The GMRT-2 consists of several passages of varying length and content that children were asked to read silently and independently. Children were instructed to select one of three pictures that best represented the passage after they finished reading each passage. As per the manual, two practice items were administered. Children had 35 minutes to complete as many test passages as possible. This was administered in a group setting with pencil and paper. Manual reliability is 940.

Control Measures

Nonverbal Ability. We administered the Matrix Reasoning subtest from the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 2011) to estimate the participants' nonverbal abilities. Children saw increasingly complex incomplete visual patterns and were asked to select the best option to complete the pattern. As per the manual, children received one point for each correct answer and testing was discontinued after three incorrect answers in a row. Manual reliability is .927 for the ages in our sample.

Working Memory. To assess participants' working memory, we administered the Backwards Digit Span from Wechsler Intelligence Scale for Children – 4th Edition (WISC-IV; Wechsler, 2003). Following on the manual, children heard strings of numbers increasing in length and had to repeat the numbers backward to the examiners. Each correct answer received one point. As per the manual, a discontinue rule of 2 consecutive errors in a block was applied. Split-half reliability for our sample was .740.

Phonological Awareness. Children's phonological awareness was tested using the Blending and Deletion subtests from Woodcock Reading Mastery Tests – 3rd Edition (WRMT-III; Woodcock, 2011). On the Blending subtest, children were told they would hear a word one part at a time (e.g., pop / corn) and were asked to put the parts together to form one word (e.g., popcorn). Children were asked to blend both whole words (pop / corn) and letters (c / a / t). For the Deletion subtest, children were asked to removed groups of sounds (e.g., cowgirl without girl) or individual sounds (e.g., slack without /l/) from a word. As per the manual, children received one point per correct answer and testing was discontinued after four consecutive errors. As we did not use the full phonological awareness battery from the WRMT-III, we could not

obtain standard scores nor manual reliabilities for this measure. Split-half reliabilities for our sample are .693, .772, and .814 for blending, deletion, and the total score, respectively.

Word Reading. Word reading was tested using the Word ID subtest from WRMT-III (Woodcock, 2011), on which children read increasingly difficult rows of word, one word at a time. Following on the manual, each correctly read word is awarded one point and testing was discontinued after 4 consecutive errors. Manual reliability for our aged sample is .927.

Vocabulary. The Peabody Picture Vocabulary Test-5th Edition (PPVT-5; Dunn, 2018) was used to assess receptive vocabulary. Children heard a word and selected the picture that best represented the word from an array of four pictures. Items were administered in blocks, with 12 items in a block. As per the manual, each correct answer received one point and testing was discontinued after 8 or more errors in one block. Manual reliability for our sample is .970.

Reading Comprehension. First grade reading comprehension was assessed using the Passage Comprehension subtest from the WRMT-III (Woodcock, 2011). Children read passages of increasing length and complexity, each of which had one word missing. Participants were asked to indicate the missing word to verify their comprehension of the text. Following manual rules, each correct answer was awarded one point and testing was discontinued after four consecutive incorrect responses. For this age, manual split-half reliability is .930.

Procedure

All children were tested in a quiet room in their school. Children completed the tasks across two or three sessions designed to accommodate the schools' schedules and to avoid participant fatigue. In grades 1 and 2, all sessions were completed individually; in grade 4, Gates was administered in a group setting session. In grade 1, children completed the tasks in the following order: Matrix Reasoning, Blending and Deletion, Backward Digit Span, Passage

Comprehension, Whatdunnit, Grammatical Correction, Word ID, and PPVT. In grade 2, the order was Grammatical Correction and Syntactic Parsing. The appropriate ethics boards approved all procedures. All children provided assent before testing began and were thanked with a small token, such as a pencil or an eraser.

Data Analysis

To address our research questions, measurement modeling and structural equation modeling (SEM) were conducted in MPlus (Muthén & Muthén, 2017) . Specifically, to model the factor structure of the syntactic skills measures, we conducted and compared correlated-factor (Figure 1a), bifactor (Figure 1b), and unidimensional models (Figure 1c). A bifactor model not only allows the items to load onto specific factors (i.e., syntactic comprehension and awareness, as with the traditional unidimensional and correlated-factor approaches), but it also accounts for a general, global factor that includes all items (i.e., syntactic skills). Further, the specific factors are assumed to be uncorrelated and unique because what is shared among them is represented by the general factor. Thus, in subsequent structural analyses, we could control for the general factor and better isolate the unique contributions of the specific factors.

Model fit was evaluated using multiple fit indices, including the chi-square value, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR) (Kline, 2011). Excellent model fit is characterized by a non-significant chi-square value, CFI and TLI values above .90, and RMSEA and SRMR below .08. To compare nested models, we additionally investigated AIC and BIC values, with smaller values suggesting a stronger fit for the data. Informed by the evaluation of our data's structure, structural analyses were conducted and compared to determine the relative contributions of the latent variable(s) to reading

comprehension and explore if syntactic parsing and syntactic awareness at second grade mediated these relations.

Results

The means and standard deviations for all variables are reported in Table 2 and correlations are reported in Table 3. These tables demonstrate that the children in our sample are typically developing, as they are within the expected range on each of the controls as well as the outcome of reading comprehension. Yet, as shown in these tables, the difficult items on the syntactic comprehension task have approximately 32% accuracy, restricted variability, and are negatively correlated with most other measures. The reliability of these items is also low: Cronbach's alpha is .509. Given these metrics, we omitted the difficult items from analyses. They do not appear to be an appropriate measure of syntactic comprehension in early elementary students.

Separability of Syntactic Comprehension and Syntactic Awareness

To respond to our first objective most convincingly, we determine the factor structure of syntactic comprehension and awareness in first grade, we conducted and compared several measurement models. In these models we included the means for the active and subject-relative items from the Whatdunnit task as well as the means from two parallel sets of items from the syntactic correction task. The two sets of items from this task were divided based on even and odd-numbered items. We considered three model specifications for our data. We tested two versions of a two-factor model specification. Figure 1a shows a two-factor correlated solution, with syntactic comprehension and awareness loading onto separate, but correlated, factors. This specification is informed by theories (e.g., Gombert, 1992) and empirical work (e.g., Brimo et al., 2017) that treat syntactic comprehension and syntactic awareness as distinct constructs. We

then tested a bi-factor model extension of this correlated factor model: a two-factor + general factor model (Figure 1b). This model includes a general syntactic skills factor that accounts for the potential shared variance among syntactic comprehension and awareness. Finally, we tested a unidimensional factor model that tested if the items from the syntactic comprehension and awareness tasks were best explained as one construct (Figure 1c). Following on recommendations for language research, we considered factor loadings of .3 or above as acceptable (Kline, 2005).

Results from the one-factor model yielded a poor fit for the data [[$\chi^2(2) = 174.465$, $p < .001$], CFI = .745, TLI = .236, RMSEA = .517 [.453, .583], SRMR = .150]. The two-factor, bifactor model was an acceptable fit for the data based on some, but not all metrics ([$\chi^2(3) = 23.187$, $p < .001$], CFI = .962, TLI = .924, RMSEA = .144 [.093, .202], SRMR = .089). The two-factor, correlated specification was a strong fit for data the based on all metrics ([$\chi^2(1) = 1.198$ $p = .273$], CFI = 1.00, TLI = .998, RMSEA = .025 [.010, .052], SRMR = .003). The two-factor, correlated model was also superior to both the one-factor model ($\Delta\chi^2 = 173.267$, $\Delta df = 1$, $p < .001$) and the two-factor, bifactor model ($\Delta\chi^2 = 21.989$, $\Delta df = 2$, $p < .001$). As such, we chose the two-factor, correlated model as the most appropriate fit for our data (see Figure 2).

Path Analysis

Building an Autoregressive Model

Given our modest sample size relative to the large number of paths in a conservative autoregressive framework, we began by building a parsimonious control model (Agresti & Finlay, 2009; Kline, 2016). To do so, fourth grade reading comprehension and second grade syntactic awareness and parsing were regressed on our first-grade controls of nonverbal reasoning, working memory, phonological awareness, and vocabulary. At this stage, the key

paths of interest – those that address our questions of direct and mediated effects – were omitted from analyses.

We then removed individual control pathways with a *p*-value greater than .3. Removing pathways with a *p*-value greater than .3 is considered a conservative approach and increases confidence that we are only removing those pathways that do not help to explain the data (Agresti & Finlay, 2009). This process suggested that phonological awareness and vocabulary could be removed from final analyses, as they both had *p*-values greater than .3. We then conducted chi-square difference testing to determine if removal of such pathways reduced model fit. Results of this testing revealed no significant difference between the full models (i.e., all control pathways included) and the nested model (i.e., phonological awareness and vocabulary removed), confirming that removing phonological awareness and vocabulary does not impact model fit. We are thus justified in removing these controls from our final models, particularly in light of our modest sample size in comparison to our stringent analyses (Kline, 2016). Indeed, keeping the most parsimonious models is especially important in models with small to modest sample sizes that employ conservative approaches (Kline, 2016).

Testing and Comparing an Autoregressive Model

We tested a series of theoretically driven models that each evaluated the longitudinal relations between syntactic comprehension and awareness with reading comprehension, including the presence of mediators, from grades 1 to 4. We began with Model 1 (Figure 3), or the full model, as this model contained all potential pathways in one model. The standardized regression coefficients in Figure 3 offer a preliminary idea of the strength of each pathway. Further, all mediated effects were included in this model, although none reached significance (*p*'s > .100). Based on several fit indices, this model was a good fit for the data.

We then went on to test Models 2 to 9, each of which was nested within the full model. Importantly, for each nested model, we tested a-priori alternate predictions to best explain our data. In particular, we systematically removed direct and indirect paths to determine if these paths added substantial meaning to our data. We compared each of the nested models to the full model (Model 1) using the Satorra-Bentler chi-square difference test (see Table 4). In this test, a significant chi-square value suggests a meaningful reduction in model fit, highlighting that the removed pathway is important to best explain the data. In line with our primary research question, we first tested the direct pathways between each of syntactic comprehension and awareness and reading comprehension.

Objective 1: Which Aspect of Syntactic Skills is Most Important for Reading Comprehension?

In Models 2 though 4, we removed the direct pathways from first grade syntactic comprehension (Model 2; Mod 2 in Figure 3), first grade syntactic awareness (Model 3; Mod 3 in Figure 3), and second grade syntactic awareness (Model 4; Mod 4 in Figure 3) to reading comprehension. This allowed us to test the importance of each pathway in the model. Results of the Satorra-Bentler chi-square difference tests suggest that removing the pathways of each of first grade syntactic comprehension and second grade syntactic awareness significantly reduces model fit (p = .004 and p = .030, respectively), highlighting that these paths play an important role in the model. We are thus justified in retaining these paths in the final model.

However, removing the direct path between first syntactic grade syntactic awareness and reading comprehension yielded no change to model fit. Indeed, the Satorra-Bentler chi-square difference test revealed a clearly non-significant difference between this model and the full model (p = .878), suggesting this pathway does not add substantial meaning to the data. This

means that first grade syntactic awareness does not predict gains in fourth grade reading comprehension.

Objective 2: How Do Syntactic Skills Contribute to Reading Comprehension?

Focusing on our second objective, Models 5 to 7 tested the relations that would help us understand whether syntactic parsing is a way in which syntactic skills contribute to reading comprehension. For this to be the case, we would need three pathways to be in place: the pathways between syntactic parsing and each of syntactic comprehension (Model 5; Mod 5 in Figure 3) and syntactic awareness (Model 6; Mod 6 in Figure 3), as well as the pathway from syntactic parsing to reading comprehension (Model 7; Mod 7 in Figure 3). We then systemically removed these pathways to determine their importance in the model. Doing so revealed that the pathway from syntactic comprehension to syntactic parsing is important, as removal of this pathway resulted in significantly worse model fit for Model 5 as compared to the full model (p = .020). This justifies the retention of this path in the final model.

Interestingly, Satorra-Bentler chi-square difference test revealed non-significant differences between the full model and both Models 6 (p = .769) and 7 (p = .547), implying that syntactic awareness does not contribute to later syntactic parsing skills, and syntactic parsing does not contribute to later reading comprehension skills. We thus remove these paths from the final model.

Post-Hoc Model Comparisons

We then conducted two additional model comparisons of pathways included in our full model: the path between first grade syntactic comprehension and second grade syntactic awareness (Model 8; Mod 8 in Figure 3) and second grade syntactic awareness and second grade syntactic parsing (Model 9; Mod 9 in Figure 3). The purpose of testing Model 8 was to explore

another potential path by which syntactic comprehension may be related to reading comprehension. The goal of testing Model 9 was to determine if syntactic awareness and syntactic parsing were related when children's syntactic awareness abilities had increased, potentially pointing to an emerging relation among these variables. In both cases, Satorra-Bentler chi-square difference test results suggested that the fits of these models were statistically equivalent to that of the full model ($p = .341$ and $p = .237$, respectively), suggesting that neither path added meaningful information to the full model. Both pathways were thus excluded from the final model.

Final Model

We tested a final nested model (Model 10; Figure 4), which was informed by the model-testing process described above as well as our original predictions. In particular, we removed the following pathways that were found to be nonessential to model fit: first grade syntactic awareness to fourth grade reading comprehension and second grade syntactic parsing; first grade syntactic comprehension to second grade syntactic awareness; second grade syntactic parsing to fourth grade reading comprehension; and second grade syntactic awareness to second grade syntactic parsing. Mediated pathways related to these nonessential direct pathways were also removed, including both mediated pathways with syntactic parsing, as well as the mediated pathway of second grade syntactic awareness on first grade syntactic comprehension and reading comprehension.

In keeping with the results of our control model, nonverbal ability, working memory, word reading, and the autoregressor of reading comprehension were also included in this model. We created a latent variable for grade 4 reading comprehension. To do so, we divided the 48-item reading comprehension form into two parcels with 24 items each. To divide the form, we split

the items into even and odd-numbered items. The factor loadings for each of these forms was .945 and .976, respectively.

Model fit statistics suggest that the data fit the model well (Table 4). Our final model tested the following predictions: first grade syntactic comprehension predicts gains in fourth reading comprehension; first grade syntactic comprehension predicts second grade syntactic parsing; first grade syntactic awareness predicts second grade syntactic awareness; second grade syntactic awareness predicts fourth grade reading comprehension; and second grade syntactic awareness mediates the relation between first grade syntactic awareness and fourth grade reading comprehension. As shown in Figure 4, each of the retained pathways emerged as significant. Further, there was a significant indirect effect of second grade syntactic awareness on the relation between first grade syntactic awareness and reading comprehension, $\beta = 0.088$, 95% CI [0.045, 0.196], $p = .029$.

Exploration of Syntactic Parsing and Reading Comprehension

Our second objective focused on investigating the pathways that would support syntactic parsing as a mechanism by which syntactic skills contribute to reading comprehension. While the first pathway in this question – that of syntactic skills to syntactic parsing – emerged in the full model, the second piece of this puzzle – the relation between syntactic parsing and reading comprehension – did not. However, the full model was incredibly stringent, with several controls, the autoregressor of reading comprehension, and two other syntactic variables that predicted gains in reading comprehension. Indeed, it seems that these other syntactic variables dominated the space for syntactic effects in the model, leaving little space for syntactic parsing to contribute anything to reading comprehension. Further, the relation between syntactic parsing and reading comprehension is theoretically driven; it is thus conceptually important to see if this

relation emerges in less stringent models. As such, we specifically explored the effect of syntactic parsing on reading comprehension in an isolated model (Figure 5).

We conducted a path analysis with second grade syntactic parsing as the predictor, fourth grade reading comprehension as the outcome, and the first-grade controls of nonverbal ability, working memory, word reading, and vocabulary. The results of this analysis show that second grade syntactic parsing is significantly related to fourth grade reading comprehension ($\beta = 0.102$, 95% CI [0.070, 0.143], $p = .045$) beyond the controls of nonverbal ability, working memory, word reading, and vocabulary.

Discussion

There were two objectives of the current study. The first was to examine which of two aspects of syntactic skills – syntactic comprehension or syntactic awareness - predicted gains in reading comprehension over time. In a key first step toward answering this question, we confirmed the separability of syntactic comprehension and syntactic awareness in early elementary students. We found that first grade syntactic comprehension and second grade syntactic awareness predicted gains in reading comprehension between Grades 1 and 4 beyond several relevant controls. Our second objective was to investigate just how syntactic skills contribute to reading comprehension; here, we explored the theoretically supported mechanism of syntactic parsing. We found that syntactic comprehension, but not syntactic awareness, predicted syntactic parsing one year later; intriguingly, syntactic parsing did not predict gains in later reading comprehension, although it was related to later reading comprehension. Together, these findings offer precision to theoretical accounts of the role of syntax in reading comprehension and guidance for effective classroom instruction.

Which Aspect of Syntactic Skills is Most Important for Reading Comprehension?

Responding directly to open theoretical questions, our longitudinal analyses suggest that each of syntactic comprehension and syntactic awareness predict gains in fourth grade reading comprehension; effects from syntactic comprehension were from Grade 1 and those from awareness were from Grade 2. These results provide much needed empirical information, both for theories and educational practices. We extend cross-sectional studies that investigate both aspects of syntactic skills (Bowey & Patel, 1988; Cain, 2007) by examining each aspects effect on its own, and not combined with other predictors of reading comprehension. Further, with respect to an autoregressive design, very few studies employ this method with one aspect of syntactic skill and reading comprehension (see Deacon & Kieffer, 2017 for such analyses with syntactic awareness); to our knowledge, no studies have employed a longitudinal, autoregressive design with both aspects of syntactic skills. As far as we can tell, we are the first to undertake this critical step.

These findings offer avenues for elaboration in current theories of reading comprehension. First and foremost, our findings underscore that both syntactic comprehension and syntactic awareness need to be included in models of reading development; only including syntactic comprehension (Gough & Tunmer, 1986) or syntactic awareness (Gombert, 1992) is insufficient. As an example of this constraint, including only one aspect of syntactic skills does not promote speculation on *how* these aspects may work together to foster progress in reading comprehension. It may be that syntactic comprehension and awareness in a positive feedback loop: understanding basic sentence types may allow a reader to develop explicit awareness of sentence structure; such awareness may then beget understanding of more complex sentences, and so on. Further, by including only one aspect of syntactic skills, theories lack clarity as to

when each aspect should support reading comprehension; this is a specification that our results suggest is necessary. Indeed, we found that first grade syntactic comprehension, but second grade syntactic awareness, matter for reading comprehension development. Theoretical precision with respect to these developmental timelines is another advancement toward fully explicating the relation between syntactic skills and reading comprehension. Overall, then, our results encourage theories that detail a role of only one aspect of syntactic skills to expand their frameworks. Such expansion will hopefully lead to more comprehensive empirical investigations and, eventually, educational designs.

That first grade syntactic comprehension predicts reading comprehension fits with suggestions that children have developed adequate linguistic comprehension skills by the time they enter school and thus can pull on these skills to support reading comprehension development (e.g., Chomsky, 2002; de Marneffe et al., 2012). This contrasts with the more complex skill of syntactic awareness, which showed a clear developmental trend: second grade, but not first grade, syntactic awareness supported gains in reading comprehension. Our findings emphasize that the importance of syntactic awareness to reading comprehension increases as children progress through elementary school. In our view, the most likely reason for this developmental shift is that children advanced in their syntactic awareness skills between first and second grades (e.g., Donaldson, 1978; Gombert, 1992; Herriman, 1986). As children gain more mastery with the nuances of language and accumulate more educational experiences, such as reading more texts, their ability to reflect on the structure of language, including at the sentence level, should improve.

The results of this study also statistically confirm the separability of syntactic comprehension and syntactic awareness, responding empirically to the theoretical contention

concerning the separability of these aspects of syntactic skills. While Gombert (1992) advocates that syntactic comprehension and awareness are separable aspects, Bowey and Patel (1988) argued that, for early elementary students, these aspects are too entwined to be meaningfully distinct. Our results validate theories and empirical work that have assumed and advocated for this distinction (e.g., Cain, 2007; Brimo et al., 2017; Gombert, 1992). Further, our findings underscore the possibility that educators need to teach these aspects separately (e.g., Phillips, 2014). Although both aspects tap sentence level skills, our results suggest that syntactic comprehension and awareness also have distinctive features that likely warrant unique teaching methods. Phillips (2014) took the first steps to demonstrate feasibility of teaching each aspect: she taught young children either syntactic comprehension or awareness using aspect-specific methods and found pre- to post-test improvements on the aspects that children were trained on. Connecting such teaching methods to reading comprehension is a critical next step.

How Do Syntactic Skills Contribute to Reading Comprehension?

Turning to our question of *how* syntactic skills contribute to reading comprehension, we explicitly test theoretical predictions that syntactic parsing is a mechanism by which readers use syntactic skills to support their reading comprehension. These analyses are innovative: to our knowledge, syntactic parsing has not yet been empirically linked to syntactic skills, nor has syntactic parsing been explored in relation to reading comprehension. In doing so, we developed a reliable measure of syntactic parsing that can be administered in a group setting, thus offering a practical method for assessing syntactic parsing moving forward. We think that our findings provide a jumping-off point for future studies towards understanding how syntactic skills predict gains in reading comprehension.

From our path analyses, we found that Grade 1 syntactic comprehension, but not awareness predicted syntactic parsing in Grade 2, a key step toward testing syntactic parsing as a mechanism by which syntactic skills contribute to reading comprehension. This finding suggests that understanding of sentences, rather than the ability to reflect on them, contributed to students' abilities to break sentences into more manageable chunks. Interestingly, this is also consistent with our finding that syntactic comprehension and not awareness at Grade 1 predicted gains in reading comprehension over time. Aligning with select theories' views on early metalinguistic skills (e.g., Donaldson, 1978; Gombert, 1992; Herriman, 1986), one interpretation is that young children are not yet adequately skilled at reflecting on sentence structure to help them to use it to break sentences into their constituent clauses. This might shift over time, with later developed syntactic awareness skills allowing readers to parse sentence into their meaningful pieces. This interpretation is supported by the stronger correlation between syntactic parsing and syntactic awareness at Grade 2 than 1. These ideas warrant future study.

The other piece of this puzzle was determining if syntactic parsing is related to later reading comprehension. Providing novel empirical support for theoretical predictions (e.g., Perfetti & Stafura, 2014), our results suggest that second grade syntactic parsing is related to fourth grade reading comprehension, even beyond the controls of nonverbal ability, working memory, word reading, and vocabulary. These findings begin to elucidate how readers may tackle complex texts: indeed, our results suggest that the ability to divide sentences into smaller chunks is related to reading comprehension ability. However, given that syntactic parsing did not predict gains in reading comprehension, we remain open to the possibility that syntactic parsing and reading comprehension are best contextualized as a bidirectional relationship. It could be that more experience with complex texts affords readers the opportunity to hone their ability to

break sentences apart, which, in turn, could then support children in understanding even more complex texts, and so on. In our view, it is likely that this process will be especially palpable for children who read more, and thus have more practice with complex texts and chances to develop strategies to tackle them. Overall, our novel finding goes some way in elucidating just how children are using syntactic skills, which can help guide precision in intervention designs. We encourage others to continue untangling the exact nature of this relation.

Theoretical and Educational Implications

Our findings have implications for theories. As a first implication, our results underscore that both syntactic comprehension and syntactic awareness need to be included in theories of reading comprehension. Indeed, our findings encourage theories that advocate that only one aspect of syntactic skills matters for reading comprehension (e.g., Gombert, 1992) to revisit their ideas and explicitly include both aspects. Further, our findings suggest that while syntactic comprehension and awareness are both foundational skills for later reading comprehension, their contributions follow unique trajectories: the ability to understand a variety of sentences contributes to gains in reading comprehension earlier than the ability to explicitly reflect on and manipulate sentence structure does. Interestingly, such trajectories seem to extend to which of these aspects enable parsing: syntactic comprehension, but not awareness at Grade 1 predicted syntactic parsing at Grade 2. Syntactic parsing, in turn, was related to later reading comprehension, suggesting that children may divide sentences into their respective chunks to facilitate text comprehension. However, the absence of a unique relation of syntactic parsing to gains in reading comprehension over time encourages theories to explore if this relation is best understood as bidirectional. Indeed, reading may embolden children's ability to break sentences down into chunks, which could then support comprehension of more complex sentences and

texts. Overall, our findings encourage theories to further lay out the relation between each aspect of syntactic skills and syntactic parsing, including if and when this relation exists.

In terms of education, our results underscore recent recommendations from the Common Core State Standards (2021) that syntactic skills should be a focus of classroom instruction as a way to improve reading comprehension. Our findings extend this by guiding how to do so. Specifically, our findings suggest that teaching young children to understand and be explicitly aware of a variety of sentence types could be most effective in text comprehension development. Phillips (2014) has taken steps to illuminate what this training could look like. She taught pre-kindergarten to first grade children syntactic comprehension and awareness using unique methods for each. Results suggest improvements pre- to post-test on the aspect on which children were trained; effects of such training on reading comprehension were not tested. Our results also help to clarify while both aspects are likely useful to target, an emphasis on syntactic comprehension for younger children and syntactic awareness for older children may be the most fruitful for reading comprehension development. Finally, given that we found syntactic parsing is related to later reading comprehension, explicitly teaching children to break sentences down into their constituent clauses may also bolster reading comprehension skills. Taken together, our results go some way in responding to recommendations that language skills are taught with "direct, systematic, explicit structured" methods in order for them to enhance reading outcomes (Moats, 2010, pg. 16; see also Wolf, 2018). Indeed, we offer data that suggests targeting both syntactic comprehension and awareness should lead to improvements in reading comprehension, with further evidence to target comprehension before awareness. We also offer preliminary evidence that training in syntactic parsing may support text comprehension, with the possibility that exposure to texts will, in turn, support parsing ability. Of course, continuing intervention

studies will be critical, particularly considering educators' concerns that syntax is more challenging to teach than other parts of language, such as academic vocabulary (Barnes et al., 2019); however, here, we provide data that offer a steppingstone toward effective interventions.

As with all studies, there are limitations that must be born in mind while interpreting our findings. The first is the stringency of an autoregressive design. While this design is powerful in informing us which skills will predict improvements in reading comprehension, such a stringent design does not leave much space for other variables to predict variance in reading comprehension (see e.g., Huslander, 2010). Further, there was a large percentage of missing data, particularly for the grade 2 variables. We acknowledge that this may have impacted our power to find certain effects; yet, this data was missing at random and thus, we still have confidence that our results are a reasonable estimation of what we would have found with our full data set. Finally, some issues of measurement require attention. While we made good progress in the measurement of syntactic comprehension and awareness, and therefore in teasing apart the relative contributions of each, we did not have a measure of syntactic comprehension in grade 2. As such, we were unable to determine the relative importance of second grade syntactic comprehension and awareness, as we did with these variables in first grade. Similarly, our measures of syntactic comprehension and awareness were not completely parallel, as the measure of comprehension was divided based on basic and difficult sentences and the measure of awareness was not. Relatedly, the difficult sentences of the syntactic comprehension appear to be too challenging for first grade students; this will be important to consider and investigate moving forward. Finally, we took the novel step of creating a short, easily administered measure of syntactic parsing, allowing us to jump start the investigation of the relation among syntactic skills, syntactic parsing, and reading comprehension. That said, we also acknowledge that there

are other ways syntactic parsing may be assessed. For example, children may chunk sentences based on events in the sentence, which could then help them integrate the meaning of the entire sentence into an overall event structure (Kintsch, 1994). This idea could be explored with tasks that explicitly assess children's organization and understanding of the events within a sentence.

To recap, we reported here on a longitudinal study testing which syntactic skills contribute to reading comprehension and how they do so. There are two key findings. First, syntactic comprehension and awareness skills both matter for growth in reading comprehension, with these contributions coming from first grade syntactic comprehension but second grade syntactic awareness. These findings respond directly to theoretical contention regarding which aspect of syntactic skills is most important: both warrant inclusion in theories of reading comprehension, with unique developmental trajectories. Secondly, we found pieces of evidence that syntactic parsing is a mechanism by which syntactic skills contribute to reading comprehension. In particular, syntactic comprehension, but not awareness, is related to children's later skill in parsing sentences, while syntactic parsing was related to later reading comprehension ability. We have yet to determine how syntactic parsing is related to gains in reading comprehension. These results are a novel empirical test of theories that discuss syntactic parsing as a mechanism in the relation between syntactic skills and reading comprehension (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). Practically, our findings suggest that instruction in both syntactic comprehension and awareness is likely to strengthen children's reading comprehension, with emphasis on syntactic comprehension in first grade and a focus on syntactic awareness in second grade. Targeting syntactic parsing may be another approach to strengthen reading comprehension skills. Overall, our results bridge the gap between the science of reading and the

science of reading instruction, a critical advancement toward designing the most effective classroom instruction (e.g., Common Core State Standards, 2021; Shanahan, 2020).

References

Agresti, A., & Finlay, B. (2009). Model building with multiple regression. In A. Agresti & B. Finlay (Eds.), *Statistical Methods for the Social Sciences* (4th ed., pp. 441–474). Prentice Hall.

Apel, K. (2022). A different view on the simple view of reading. *Remedial and Special Education*, *43*(6), 434–447. https://doi-org/10.1177/07419325211063487

Barnes, E. M., Oliveira, A. W., & Dickinson, D. K. (2019). Teacher accommodation of academic language during Head Start pre-kindergarten read-alouds. *Journal of Education for Students Placed at Risk, 24*(4), 369–393. https://doi.org/10.1080/10824669.2019.1657868

Bowey, J. A., & Patel, R. K. (1988). Metalinguistic ability and early reading achievement. *Applied Psycholinguistics*, *9*(4), 367–383. https://doi.org/10.1017/S0142716400008067

Brimo, D., Apel, K., & Fountain, T. (2017). The effects of syntactic awareness and syntactic knowledge on reading comprehension among 9th and 10th grade students. *Journal of Research in Reading, 40*(1), 57-74. https://doi.org/10.1111/1467-9817.12050

Cain, K. (2007). Syntactic awareness and reading ability: Is there any evidence for a special relationship? *Applied Psycholinguistics, 28*(4), 679-694. https://doi.org/10.1017/S0142716407070361

Chall, J. S. (1983*). Stages of reading development*. McGraw-Hill.

Chomsky, N. (2002). *Syntactic structures*. Martino Publishing.

Common Core State Standards (2021). *Key shifts in English language arts*. Retrieved from http://www.corestandards.org/other-resources/key-shifts-in-english-language-arts/

Dawson, H. & Phelan, M. (2016). *Language files: Materials for an introduction to language and linguistics* (12th ed.). The Ohio State University Press.

de Marneffe, M.-C., Grimm, S., Arnon, I., Kirby, S., & Bresnan, J. (2012). A statistical model of the grammatical choices in child production of dative sentences. *Language and Cognitive Processes*, *27*(1), 25–61. https://doi-org/10.1080/01690965.2010.542651

Deacon, S. H., Benere, J., & Pasquarella, A. (2013). Reciprocal relationship: Children's morphological awareness and their reading accuracy across grades 2 to 3. *Developmental Psychology*, *49*(6), 1113-1126. https://doi.org/10.1037/a0029474

Deacon, S. H., & Kieffer, M. (2017). Unraveling the relations between syntactic awareness and reading comprehension: Evidence from mediation and longitudinal models. *Journal of Educational Psychology*, *110*(1), 72-86. https://doi.org/10.1037/edu0000198

DeThorne, L. S., Harlaar, N., Petrill, S. A., & Deater-Deckard, K. (2012). Longitudinal stability in genetic effects on children's conversational language productivity. *Journal of Speech, Language, and Hearing Research*, *55*, 739–753. https://doi.org/10.1044/1092-4388(2011/11-0014)

Donaldson, M. (1978). *Children's minds*. Collins.

Dunn, D. M. (2018). *The Peabody picture vocabulary test – fifth edition* (PPVT 5). Pearson.

Elleman, A. M., & Oslund, E. L. (2019). Reading comprehension research: Implications for practice and policy. *Behavioural and Brain Sciences*, *6*, 3-11. https://doi.org/10.1177/2372732218816339

Fang, Z. (2006). The language demands of science reading in middle school. *International Journal of Science Education*, *28*, 491–520. https://doi.org/10.1080/09500690500339092

Farnia, F., & Geva, E. (2013). Growth and predictors of change in English language learners' reading comprehension. *Journal of Research in Reading*, 36(4), 389–421.

Froese-German, B. (2014). *Work-life balance and the Canadian teaching profession*. Canadian Teachers' Federation.

Gombert, J. E. (1992). *Metalinguistic development*. Harvester Wheatsheaf

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education*, *7*(1), 6-10. https://doi.org/10.1177/074193258600700104

Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2011). Coh-metrix providing multilevel analyses of text characteristics. *Educational Researcher*, *40*(5), 223-234. https://doi.org/10.3102/0013189X11413260

Hunter, J., & Sonnemann, J. (2022). *Making time for great teaching: How better government policy can help*. Grattan Institute. https://grattan.edu.au/wp-content/uploads/2022/01/Making-time-for-great-teaching-how-better-government-policy-can-help-Grattan-Report.pdf

Huslander, J., Olson, R. K., Willcutt, E. G., & Wadsworth, S. J. (2010). Longitudinal stability of reading-related skills and their prediction of reading development. *Scientific Studies of Reading*, *14*(2), 111–136. https://doi.org/10.1080/10888431003604058

Kazak, A. E. (2018). Editorial: Journal article reporting standards. *American Psychologist*, *73*(1), 1–2. https://doi.org/10.1037/amp0000263

Kenny, D. (1975). Cross-lagged panel correlation: A test for spuriousness. *Psychological Bulletin*, *82*, 887–903. http://dx.doi.org/10.1037/0033-2909.82.6.887

Kim, Y.-S. G. (2020). Toward integrative reading science: The direct and indirect effects model of reading. *Journal of Learning Disabilities*, *53*(6), 469–491. https://doi-org/10.1177/0022219420908239

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303. http://dx.doi.org/10.1037/0003-066X.49.4.294

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). Guilford Press.

Kline, R. B. (2011). *Principles and practice of structural equation mod*eling (3rd ed.). Guilford Press.

Kline, R. B. (2016). *Principles and practice of structural equation modeling* (4th ed.). Guilford Press.

Lervåg, A., Hulme, C. & Melby-Lervåg, M. (2018). Unpicking the developmental relationships between oral language skills and reading comprehension: It's simple, but complex. *Child Development, 89*(5), 1821-1838. https://doi.org/10.1111/cdev.12861

Lesgold, M. (1974). Variability in children's comprehension of syntactic structures. *Journal of Educational Psychology*, *66*, 333–338. http://dx.doi.org/10.1037/h0036427

Levesque, K. C., Kieffer, M. J., & Deacon, S. H. (2019). Inferring meaning from meaningful parts: The contributions of morphological skills to the development of children's reading comprehension. *Reading Research Quarterly*, *54*(1), 63–80. https://doi-org/10.1002/rrq.219

MacGinitie, W. H., & MacGinitie, R. K. (1992). *Gates-MacGinitie reading tests – second edition*. The Riverside Publishing Company.

MacKay, E., Lynch, E., Sorenson Duncan, T., & Deacon, S. H. (2021). Informing the science of reading: Children's awareness of sentence-level information is important for reading comprehension. *Reading Research Quarterly*. https://doi.org/10.1002/rrq.397

Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods*, *12*(1), 23–44. https://doi.org/10.1037/1082-989X.12.1.23

Melby-Lervåg, M., & Lervåg, A. (2014). Reading comprehension and its underlying components in second-language learners: A meta-analysis of studies comparing first- and second-language learners. *Psychological Bulletin*, *140*(2), 409-433. https://doi.org/10.1037/a0033890

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*(2), 322–352. https://doi-org/10.1037/a0026744.supp (Supplemental)

Moats, L. C. (2020). *Teaching reading is rocket science: What expert teachers of reading should know and be able to do*. American Federation of Teachers.

Montgomery, J. W., Evans, J. L., Gillam, R. B., Sergeev, A. V., & Finney, M. C. (2016). "Whatdunit?" Developmental changes in children's syn- tactically based sentence interpretation abilities and sensitivity to word order. *Applied Psycholinguistics*, *37*, 1281–1309. http://dx.doi.org/10 .1017/S0142716415000570

Muthén, L. K.., & Muthén, B. O. (2017). MPlus User's Guide (Eighth Edition). Muthén & Muthén.

National Institute for Literacy. (2008). Developing early literacy: A scientific analysis of early literacy development and implications for intervention. Retrieved from http://www.nifl.gov/publications/pdf/NELPReport09.pdf

Oakhill, J., Cain, K., & Elbro, C. (2014). *Understanding and teaching reading comprehension: A handbook*. Routledge.

Oberecker, R., Friedrich, M., & Friederici, A. D. (2005). Neural correlates of syntactic processing in two-year-olds. *Journal of Cognitive Neuroscience*, *17*(10), 1667–1678. https://doi-org/10.1162/089892905774597236

Perfetti, C. A., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*, 22-37. https://doi.org/10.1080/10888438.2013.827687

Phillips, B. M. (2014). Promotion of syntactical development and oral comprehension: Development and initial evaluation of a small-group intervention. *Child Language Teaching and Therapy*, *30*, 63–77. https://doi.org/10.1177/026565901348774

Poulsen, M., & Gravgaard, A. K. (2016). Who did what to whom? The relationship between syntactic aspects of sentence comprehension and text comprehension. *Scientific Studies of Reading*, *20*(4), 1-14. https://doi.org/10.1080/10888438.2016.1180695

Schafer, A. J., Speer, S. R., Warren, P., & White, S. D. (2000). Intonational disambiguation in sentence production and comprehension. *Journal of Psycholinguistic Research*, *29*(2), 169–182. https://doi-org/10.1023/A:1005192911512

Scott, C. M. (2009). A case for the sentence in reading comprehension. *Language, Speech, and Hearing Services in Schools*, *40*(2), 184–191. https://doi.org/10.1044/0161-1461(2008/08-0042)

Sedita, J. (2007). *Syntactic awareness: Teaching sentence structure* (Excerpt from Module 7). Keys to Beginning Reading Professional Development Program.

Selig, J. P., & Little, T. D. (2012). Autoregressive and cross-lagged panel analysis for longitudinal data. In B. Laursen, T.D. Little, & N.A. Card (Eds.), *Handbook of developmental research methods* (pp. 265–278). Guilford.

Shanahan, T. (2020). Why we need to teach sentence comprehension. Retrieved from https://www.readingrockets.org/blogs/shanahan-literacy/why-we-need-teachsentencecomprehension

Sorenson Duncan, T., Mimeau, C., Crowell, N., & Deacon, S. H. (2020). Not all sentences are created equal: Evaluating the relation between children's understanding of basic and difficult sentences and their reading comprehension. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000545

Stenner, A. J., & Swartz, C. (2012, April). *A causal Rasch model for understanding comprehension in the context of reader-text-task*. Paper presented at the annual meeting of the National Council on Measurement in Education, Vancouver, Canada.

Tilstra, J., McMaster, K., Van den Broek, P., Rapp, D. (2009). Simple but complex: Components of the simple view of reading across grade levels. *Journal of Research in Reading*, *32*, 383–401. https://doi.org/10.1111/j.1467-9817.2009.01401.x

Tong, X., & McBride, C. (2017). A reciprocal relationship between syntactic awareness and reading comprehension. *Learning and Individual Differences*, *57*, 33–44. https://doi.org/10.1016/j.lindif.2017.05.005

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2012). *Test of word reading efficiency – second edition* (TOWRE-2). Pro-Ed.

Uccelli, P., Galloway, E. P., Barr, C. D., Meneses, A., & Dobbs, C. L. (2015). Beyond vocabulary: Exploring cross-disciplinary academic-language proficiency and its

association with reading comprehension. *Reading Research Quarterly*, *50*(3), 337–356. https://doi.org/10.1002/rrq.104

van Bergen, E., Snowling, M. J., de Zeeuw, E. L., van Beijsterveldt, C. E. M., Dolan, C. V., & Boomsma, D. I. (2018). Why do children read more? The influence of reading ability on voluntary reading practices. *Journal of Child Psychology and Psychiatry*, *59*(11), 1205–1214. https://doi-org/10.1111/jcpp.12910

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2013). *Comprehensive test of phonological processing – second edition*. (CTOPP-2). Pro-Ed

Wechsler, D. (2003). *Wechsler intelligence scale for children, fourth edition* (WISC-IV). APA PsycTests.

Wechsler, D. (2011). *Wechsler abbreviated scale of intelligence–second edition* (WASI-II). NCS Pearson.

Weighall, A. R., & Altmann, G. T. M. (2011). The role of working memory and contextual constraints in children's processing of relative clauses. *Journal of Child Language*, *38*(3), 579–605. https://doi-org/10.1017/S0305000910000267

Willows, D. M., & Ryan, E. B. (1986). The development of grammatical sensitivity and its relation to early reading achievement. *Reading Research Quarterly*, *21*, 253-266.

Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models: An evaluation of power, bias, and solution propriety. *Educational and Psychological Measurement*, *76(*6), 913–934. https://doi.org/10.1177/0013164413495237

Woodcock, R. W. (2011). *Woodcock reading mastery tests – third edition (*WRMT-III). Pearson

Zeno, S. (2005). *The educator's word frequency guide*. Touchstone Applied Science Associates.

Table 1

Participant Demographics

Demographic Measure	**Mean (SD)**
Age	
Grade 1	6.82 (0.31)
Grade 2	NA
Grade 4	9.85 (0.30)
Gender (% of sample)	
Male	54.20
Female	45.80
SES (% of sample)	
First Quartile	17.90
Second Quartile	29.10
Third Quartile	40.50
Fourth Quartile	12.50
Ancestry (% of sample)	
European	55.00
Aboriginal	
Acadian	
African NS	
African	
Asian	
East Asian	

Middle Eastern	
Did not report	18.00

Note: To protect participants' anonymity, we cannot provide exact numbers for certain ethnicities in our sample, as there are too few participants who fall into these groups. As such, for ethnicities other than *White* and *Did Not Report*, we only list the ethnicities that were present in our sample, without providing numbers.

Table 2

The Mean and Standard Deviations for all Measures (N = 333 for Grade 1 measures; N= 82 for Grade 2 measures; N = 257 for Grade 4 measures)

Measure	Mean (SD)	Range
First Grade		
Nonverbal ability raw (30)	8.68 (3.61)	0.00-20.00
Nonverbal ability SS (50)	48.36 (7.44)	26.00-70.00
Working memory (16)	4.85 (1.78)	0.00-8.00
Phonological awareness: Blending (9)	5.90 (1.60)	0.00-8.00
Phonological awareness: Deletion (8)	5.00 (1.94)	0.00-8.00
Phonological awareness: Total (17)	10.90 (2.99)	0.00-16.00
Word reading raw (46)	15.39 (6.40)	0.00-33.00
Word reading SS (100)	104.34 (14.39)	64.00-145.00
Vocabulary raw (240)	136.28 (18.23)	73.00-192.00
Vocabulary SS (100)	105.64 (15.22)	66.00-160.00
Reading comprehension raw (38)	9.67 (4.37)	0.00-23.00

Reading comprehension SS (100)	103.27 (13.40)	65.6500-140.00
Syntactic comprehension: Basic (14)	7.30 (3.37)	0.00-14.00
Syntactic comprehension: Difficult (14)	4.43 (2.37)	0.00-12.00
Syntactic comprehension: Total (28)	11.85 (4.54)	0.00-24.00
Syntactic awareness (28)	7.81 (5.50)	0.00-26.00
Second Grade		
Syntactic awareness (16)	5.92 (3.28)	0.00-12.00
Syntactic parsing (84)	52.89 (17.37)	0.00-82.00
Fourth Grade		
Reading comprehension raw (48)	30.35 (10.32)	0.00-48.00
Reading comprehension stanine score	4.87 (1.76)	1.00-9.00

Note: Stanine scores are a measure of children's achievement relative to others their age. They range from 1-9, with scores of 1-3 representing below average scores, 4-6 representing average scores, and 7-9 representing above average scores.

Table 3

Bivariate Correlations Between All Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
G1 (*N* = 333)													
1. Nonverbal	**1**												
2. Working Mem	**.274**	**1**											
3. PA	**.309**	**.311**	**1**										
4. Vocabulary	**.281**	**.329**	**.319**	**1**									
5. Word Reading	**.300**	**.338**	**.579**	**.350**	**1**								
6. Reading Comp.	**.307**	**.393**	**.559**	**.493**	**.809**	**1**							
7. Syn. Comp	**.218**	**.231**	**.204**	**.364**	**.305**	**.373**	**1**						
8. SC Basic	**.162**	**.275**	**.238**	**.307**	**.280**	**.344**	**.854**	**1**					
9. SC Difficult	**.168**	.019	.025	**.226**	**.154**	**.187**	**.602**	.089	**1**				
10. Syn. Awar.	**.351**	**.368**	**.504**	**.581**	**.491**	**.555**	**.356**	**.323**	**.186**	**1**			
G2 (*N* = 82)													
11. Syn. Awar.	-.005	-.147	**.399**	**.281**	.160	**.238**	.099	**.237**	-.186	**.377**	**1**		
12. Syn. Parsing	.179	**.265**	.121	-.064	**.331**	**.352**	.189	**.251**	-.037	.070	**.204**	**1**	
G4 (*N* = 257)													
13. Reading Comp.	**.379**	**-.441**	**.546**	**.423**	**.546**	**.669**	**.333**	**.376**	.057	**.518**	**.405**	**.355**	**1**

Note: Significant correlations are bolded.

Table 4

Model Fit Indices and Model Comparisons

Model	χ^2	df	*p*	AIC	BIC	Comparative Fit Index	Tucker-Lewis Index	Root Mean Square Error of Approximation	Standardized Root Mean Square Residual	SB χ^2 difference test
1	64.32	34	>.001	14864.30	14900.59	.98	.97	.05	.07	---
2	71.01	35	>.001	14868.53	14904.16	.98	.96	.06	.07	8.07*
3	64.17	35	.002	14862.34	14897.98	.98	.97	.05	.07	0.04
4	69.93	35	>.001	14866.79	14902.43	.98	.96	.05	.08	5.61*
5	69.63	35	>.001	14866.99	14902.63	.98	.96	.05	.08	6.82*
6	63.10	35	.003	14862.50	14898.23	.98	.97	.05	.08	0.16
7	64.46	35	>.001	14863.45	14901.94	.98	.97	.05	.07	0.79
8	65.15	35	.002	14862.94	14898.58	.98	.97	.05	.07	0.71
9	64.98	35	.002	14862.50	14898.14	.98	.97	.05	.07	0.26
10	64.23	38	.005	14857.28	14890.98	.98	.97	.04	.08	0.89

Note: Models are depicted in Figures 3 (Full Model) and 4 (Final Model). The Satorra–Bentler scaled χ2 difference test compared the fit of each model with that of model 1. A significant p-value (*$p < .05$, $^2p < .07$) indicates a significant reduction in model fit compared with model 1.

Figure 1

Representations of the Three Possible Measurement Models for our Two Aspects of Syntactic Skills: A Multidimensional, Correlated Model (a), a Multidimensional, Bifactor model (b), and a Unidimensional Model (c)

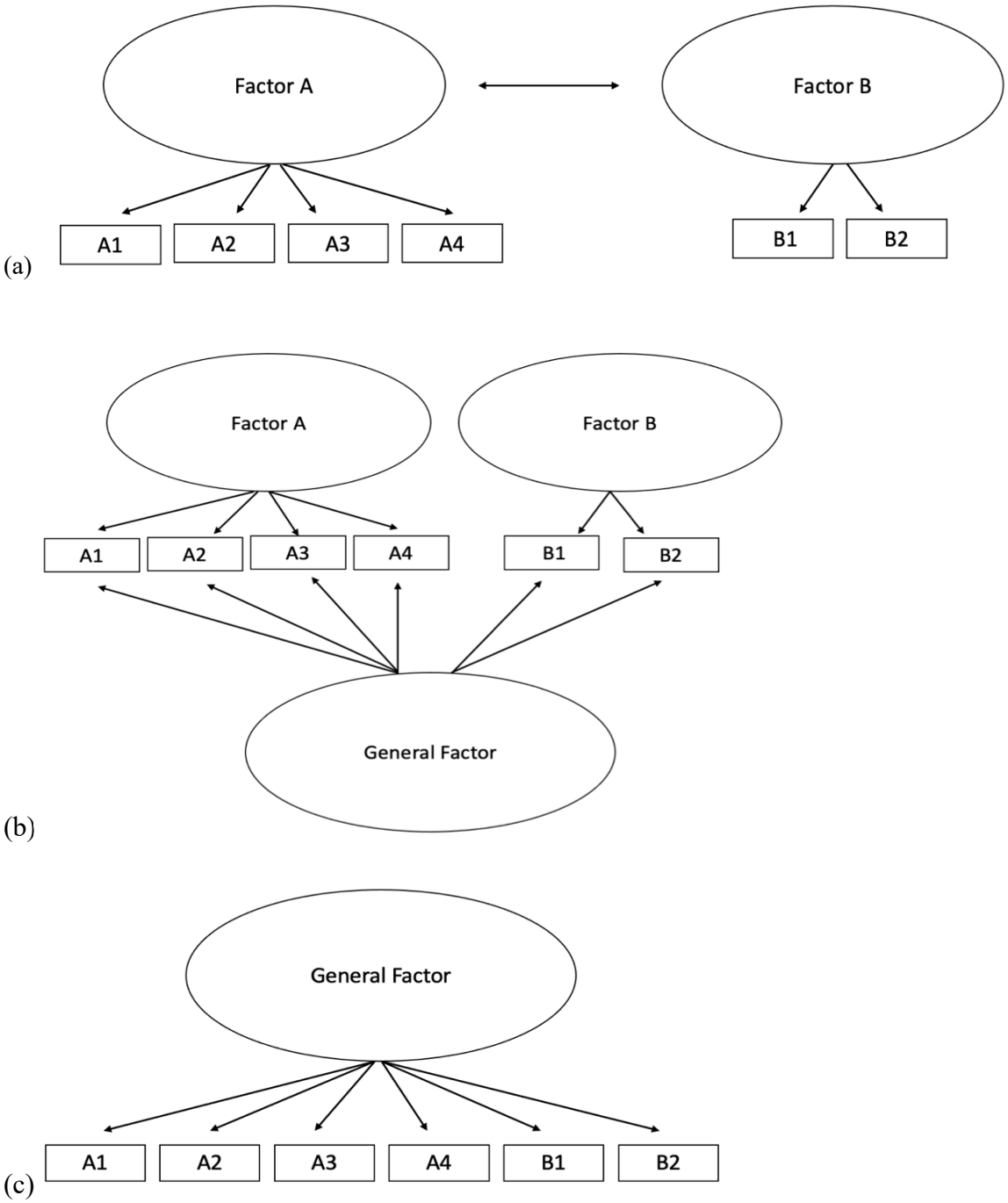


Figure 2

The Two-Factor, Correlated Measurement Model of our Data with the Standardized Factor Loadings and Correlation between the Latent Variables of Syntactic Comprehension and Syntactic Awareness. All Factor Loadings are Significant.

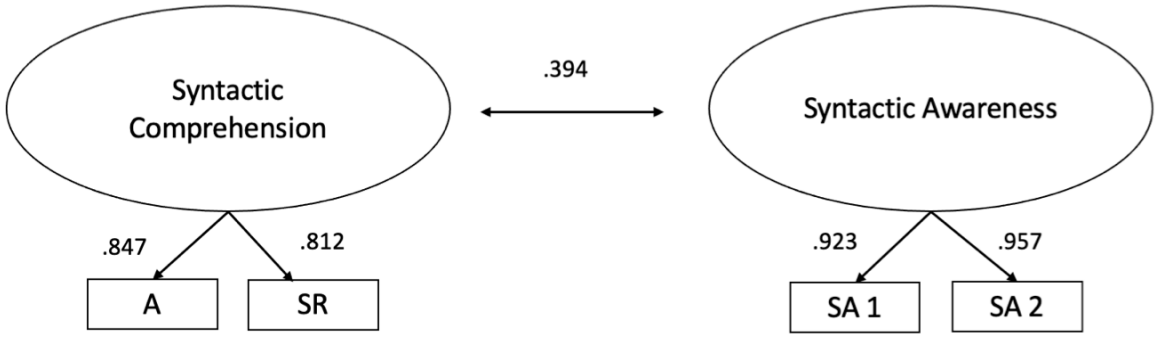
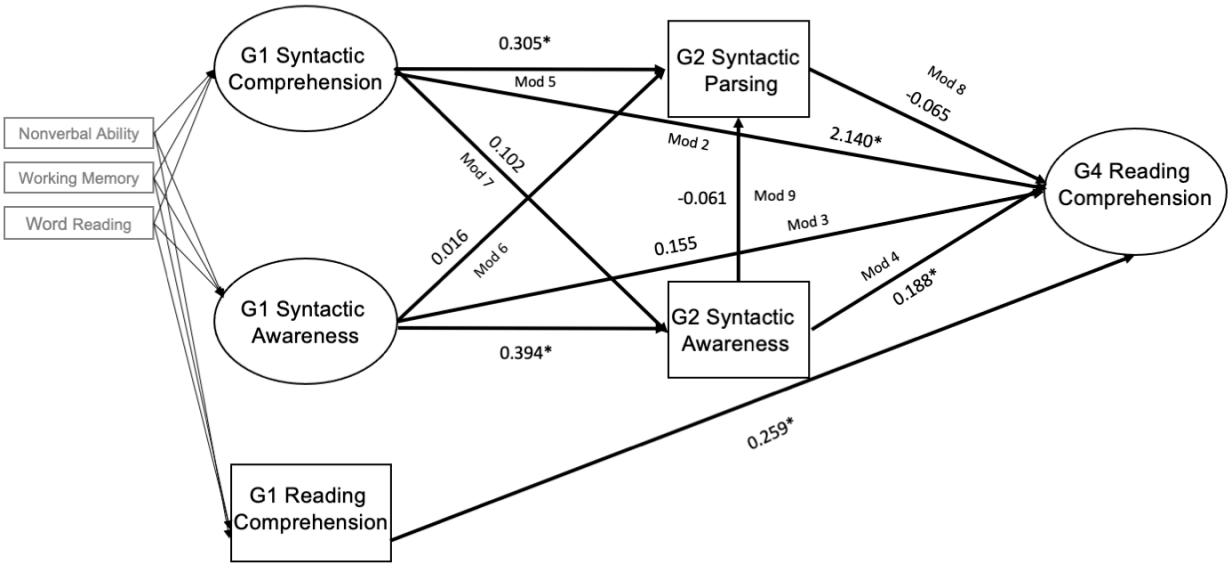


Figure 3

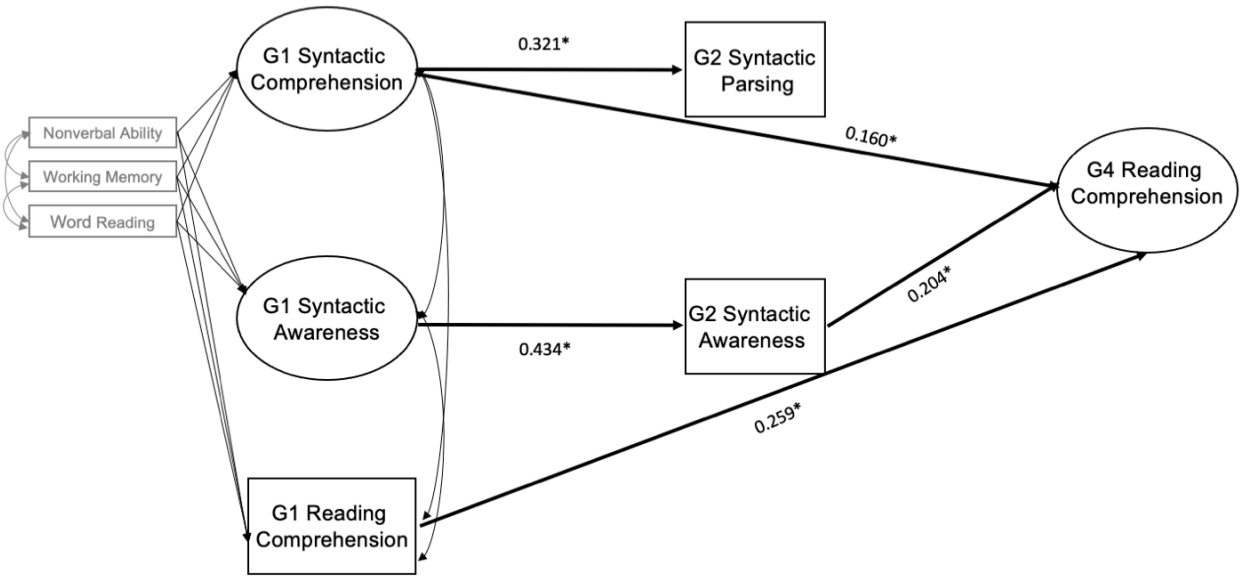
The Full Model with Standardized Coefficients Included



Note: Mod 2-Mod 9 paths represent the paths that were individually removed to test model fit. Model fit statistics and chi-square comparison results are included in Table 3.
* = $p < .05$

Figure 4

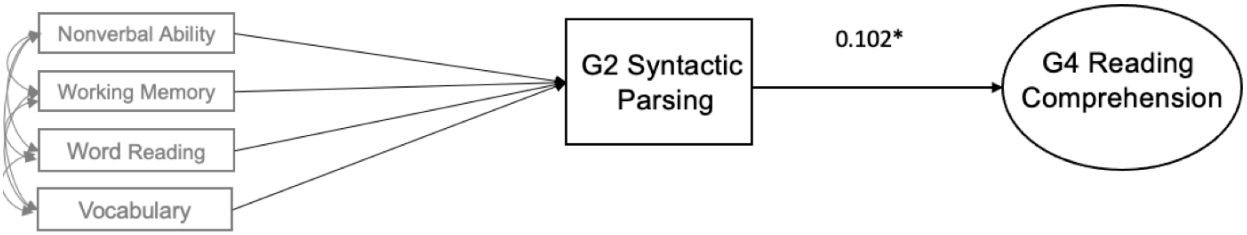
The Final Model (Model 10) with Standardized Coefficients for Key Paths



Note: * = $p < .05$

Figure 5

The Isolated Effect of Syntactic Parsing on Reading Comprehension



Chapter 5: General Discussion

The overarching goal of this dissertation was to respond to theoretically driven and educationally relevant questions concerning the relation between syntactic skills and reading comprehension. First, across all studies, we evaluated which aspect of syntactic skills – either syntactic comprehension or awareness – is most relevant for reading comprehension. The emergent answer is that both matter, with some indication that developmental period affects their relative importance. Second, we investigated just *how* syntactic skills contribute to reading comprehension. In this pursuit, we explored the effects of three theoretically implicated mediators on the relation between syntactic skills and reading comprehension: word reading, vocabulary, and syntactic parsing. Our results show that both word reading and vocabulary mediate the relation between syntactic skills and reading comprehension, but these relations are influenced by the aspect of syntactic skill and developmental period. We also found preliminary evidence of mediation for the more novel mechanism of syntactic parsing. Finally, findings within and across each of the three studies highlight that age and grade impact the relation between syntactic skills and reading comprehension. Together, our results expand the boundaries of current theoretical predictions, offer clear targets for intervention design, and, in turn, suggest potential practices for education.

Which Aspect of Syntactic Skills Matters Most for Reading Comprehension?

In all three studies, we responded to theoretical contention regarding which aspect of syntactic skills matters most for reading comprehension with a clear answer: both syntactic comprehension and awareness are important. The implication is that both deserve a place in theories of reading comprehension. Our results come from three robust sets of analyses: meta-analytic correlations with reading comprehension were similar in magnitude for each of syntactic comprehension and awareness (Chapter 2); tightly controlled linear regressions demonstrated

that syntactic comprehension and awareness made contributions of a similar magnitude to reading comprehension (Chapter 3); and longitudinal, autoregressive analyses show that both aspects predict gains in reading comprehension, again to a similar magnitude (Chapter 4). As such, we are confident in suggesting that a comprehensive theory of reading comprehension needs to include both syntactic comprehension and awareness. This suggestion is further underscored by the fact that both aspects are related to reading comprehension in younger and older readers, indicating both are important across reading development. We think that explicitly including syntactic comprehension and awareness in theories will encourage empirical work on these aspects in tandem. Such inclusion in both theoretical and empirical work may pave the way to a more explicit description of how these two aspects interact, a discussion that is scant at present (e.g., MacKay et al., 2021). Indeed, understanding the relation between syntactic comprehension and awareness in supporting reading comprehension is a potential step for future research.

In terms of our question of developmental shifts in the importance of each aspect of syntactic skills to reading comprehension, we found that both aspects of syntactic skills matter for younger and older elementary school readers. In particular, meta-analytic correlations between reading comprehension and each of syntactic comprehension and awareness were remarkably similar for younger and older readers (Chapter 2). Additionally, comparing the results from our studies of first and second grade (Chapter 4) and third to fifth grade (Chapter 3) readers suggests that both aspects matter across the elementary years, both before and after the shift from “learning to read” to “reading to learn” (Chall, 1983).

Although both aspects of syntactic skills are important for reading comprehension across the elementary years, we found developmental differences with respect to when each predicts

gains in reading comprehension. Results from our longitudinal, autoregressive design (Chapter 4) show that gains in reading comprehension are predicted by first grade syntactic comprehension and second grade syntactic awareness, but not first grade syntactic awareness. It is possible that syntactic awareness, as a metalinguistic skill, requires additional time to develop as compared to syntactic comprehension. This explanation is supported by evidence that children enter school understanding spoken sentences (e.g., Chomsky, 2002; de Marneffe et al., 2012), yet their awareness of sentence structure is still emerging (e.g., Oakhill et al., 2014). Further, several theories make clear predictions that children's metalinguistic awareness will develop as they gain more exposure to complex language and obtain more academic experiences (Donaldson, 1978; Gombert, 1992; Herriman, 1986), all of which is expected to happen around second grade. Thus, it seems that children are well set-up to rely on their syntactic comprehension skills even in the very early stages of their academic careers to build the foundation for reading comprehension; however, syntactic awareness needs more time to develop before it can be reliably used to support reading comprehension improvement.

We empirically confirmed the separability of syntactic comprehension and syntactic awareness, further propelling our advocacy to include both in theories of reading comprehension and empirical studies. Indeed, in both studies with original data collection (Chapters 3 and 4), we use measurement models to show that these aspects are empirically distinct. This finding represents what has been assumed in some theories (e.g., Gombert, 1992) as well as in some empirical work (e.g., Brimo et al., 2017; Cain, 2007). It also supports the use of distinct task types for syntactic comprehension versus awareness: tasks of comprehension focus on understanding a variety of sentence types, those of awareness focus on awareness and manipulation of sentence structure. Further, this distinction emerged for both younger and older

readers, again highlighting the importance of including both aspects when exploring how syntactic skills contribute to reading comprehension. Overall, our results from each of Chapters 2, 3, and 4 allow us to decisively respond to theoretical contention regarding which aspect of syntactic skills matters most for reading comprehension.

How Do Syntactic Skills Contribute to Reading Comprehension?

Our second theoretically driven question was just *how* syntactic skills contribute to reading comprehension. To this end, we followed on theories that describe a role for both bottom-up and top-down processes in reading comprehension development (e.g., Perfetti & Stafura, 2014; Tunmer, 1989). We first turn to results from Chapter 2, our meta-analysis, to address the mediated role of bottom-up skills. Our mediated meta-analytic results imply that both word reading and vocabulary are mechanisms in the relation between syntactic skills and reading comprehension, effects that held for both syntactic comprehension and awareness. These findings converge with theories that predict a mediated relation via word reading (e.g., Tunmer, 1989) and/or vocabulary (e.g., Naigles, 1990) between syntactic skills and reading comprehension. They also point to the need for other theories and empirical work to include mediators in the relation between syntactic skills and reading comprehension to represent this relation most comprehensively. Practically, our results suggest that children leverage both their understanding and awareness of sentence structure to support word reading and vocabulary knowledge, skills that then support reading comprehension (e.g., Lervåg & Melby-Lervåg, 2018). This finding opens the possibility that instruction in both syntactic comprehension and awareness could lead to improvements in word reading and vocabulary, which may then have downstream effects of improving reading comprehension.

Responding to our goal of investigating changes across grades, results from Chapter 2 suggest that targeted training in syntactic comprehension and awareness may be particularly impactful for novice readers. Our moderated, mediated meta-analyses revealed developmental differences for the mediated effects of word reading and vocabulary, effects that were further impacted by aspect of syntactic skill. For the models with word reading, we found that this skill mediated the relation between syntactic comprehension and reading comprehension for both younger and older readers; however, word reading was particularly important for the relation between syntactic awareness and reading comprehension in the younger versus older readers. This suggests that, throughout elementary school, children leverage their understanding of sentences to support their word reading skills. However, it appears that younger readers rely more heavily on awareness of syntactic structure to support word reading. In line with Tunmer (1989)'s prediction, novice readers, who are expected to have emerging phonological decoding skills, may use their awareness of sentence structure to support these emerging decoding skills by, for example, placing constraints on the type of word an unknown word could be (see also Deacon & Kieffer, 2017). These ideas are speculative and merit explicit empirical testing.

For the meta-analytic mediated models with vocabulary, we found stronger mediated effects of vocabulary on the relations between reading comprehension and both of syntactic comprehension and awareness for younger than older elementary students. This suggests that novice readers, in particular, use their understanding and awareness of sentence structure to help them figure out the meaning of an unknown word. Understanding a sentence may help a child by providing context into which the meaning of the novel word may fit. Similarly, and aligning with the literature on syntactic bootstrapping (e.g., Babineau et al., 2020; Kamil et al., 2000; Naigles, 1990) being aware of a sentence's structure can help provide clues to the syntactic category (e.g.,

noun, verb. adjective) the new word belongs. Narrowing the category could help a reader determine the word's meaning. These processes may be particularly important for younger readers due to their more limited vocabulary knowledge (Merritt, 2016). Again, these ideas are speculative and require empirical testing with tasks that assess whether sentence structure gives children an indication of a novel word's category; we strongly encourage this type of work moving forward.

Turning to top-down processes, we took the novel step of investigating the theoretically described mechanism of syntactic parsing (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). In our fourth chapter, in a model that included second grade syntactic parsing as a predictor of reading comprehension, we found that syntactic parsing was related to fourth grade reading comprehension skill beyond first-grade nonverbal ability, working memory, word reading, and vocabulary. This finding provides some empirical support to theories that hypothesize the ability to break sentences down into their constituent clauses helps readers understand the texts they read. Interestingly, syntactic parsing did not predict gains in reading comprehension in the full model, which included other syntactic measures as well as stringent controls and the autoregressor of reading comprehension. In our view, one reason for this is that the relation between syntactic parsing and reading comprehension is best understood as bidirectional, such that they each work to improve the other. Certainly, it is conceivable that experience with reading a variety of sentence types gives readers the chance to develop strategies to tackle complex sentences, including learning how to break these sentences into chunks.

Interestingly, our results revealed that one aspect of syntactic skills – syntactic comprehension – predicted later syntactic parsing. This suggests that understanding a sentence's meaning helps a reader break down the sentence into its chunks. This interpretation can be seen

as aligning with theories that describe that understanding a sentence's content supports a reader in breaking down the sentence into its chunks (e.g., Kintsch, 1994); in particular, according to these theories, such chunks correspond to events within the sentence. Breaking the sentence down in this way should help a reader create an event structure of the sentence, which can then be integrated with event structures from other sentences to understand the text. Syntactic awareness, on the other hand, did not predict later syntactic parsing. This suggests that the ability to reflect on sentence structure did not contribute to students' abilities to break sentences into their respective parts. Aligning with select theories' views on early metalinguistic skills (e.g., Donaldson, 1978; Gombert, 1992; Herriman, 1986), one interpretation is that young children are not yet good enough at reflecting on sentence structure to help break sentences into their constituent clauses. Indeed, future researchers might find that more developed syntactic awareness skills allow readers to parse sentence into their meaningful pieces. Yet, we also acknowledge the possibility that it is syntactic comprehension, and not syntactic awareness, that evokes the parsing mechanism throughout reading development. These ideas are worthy of future study.

Taken together, our results provide empirical support for both bottom-up and top-down skills that mediate the relation between syntactic skills and reading comprehension. We found that word reading and vocabulary acted as mediators in the relation between reading comprehension and syntactic skills, measured as either syntactic comprehension or awareness. Interestingly, there were key developmental effects for these relations; broadly speaking, the mediated effects were stronger in younger than older readers. We also found evidence that children's syntactic skills – particularly, their ability to understand sentences – predicted later parsing skill, which, in turn, predicted reading comprehension. The complete relation among

syntactic skills, syntactic parsing, and reading comprehension has yet to be uncovered and is an important area for future work.

Theoretical Implications and Proposed Framework

Our findings point to the need for a comprehensive framework describing how syntactic skills contribute to the development of reading comprehension. To succinctly depict what we see as the most likely explanation for the relation between syntactic skills and reading comprehension based on the results of the current studies, we have created such a framework (Figure 1). Given that we find some divergent effects across younger and older readers, we also have specifications for this framework with these two groups (Figures 2a and b). In these frameworks, relations that may change in strength as children age are bolded, with a bolder line suggesting a stronger relation. We go through each part of this framework in turn.

First, the results from each of the three studies respond decisively to theoretical contention regarding the importance of syntactic comprehension versus awareness for reading comprehension: both matter across reading development and thus deserve inclusion in theories of reading comprehension. This is represented by the arrows from each of syntactic comprehension and awareness to reading comprehension in Figure 1. As of now, in our reading, no theory explicitly includes both; theories either include one of the two aspects (e.g., Gombert, 1992; Gough & Tunmer, 1986) or describe the role of syntactic skills broadly (e.g., Perfetti & Stafura, 2014). One consequence of this is that we do not have a strong model for how these two aspects work together. Here, we start the ball rolling by suggesting that syntactic comprehension and awareness engage in a positive feedback loop. Understanding sentences with varying syntactic structures likely affords a reader the opportunity to be aware and reflect on this structure. For example, if a reader understands the sentence “The dog chased the cat”, this gives them a

foundation to explicitly learn the subject-verb-object sentence structure. The development of such metalinguistic awareness may then allow a reader to understand more complex sentences, thus restarting the loop. Look at an expanded version of the first sentence: “The dog who was black with white spots chased the cat that the neighbour hates because it chases their bird”. If a reader can use their explicit awareness of where the subject (dog), verb (chased), and object (cat) should be in this sentence, this provides a skeleton within which the rest of the details can fit, leading to better understanding of the sentence.

There are likely developmental shifts in how syntactic comprehension and awareness interact to lead to improvements in reading comprehension. It seems that younger children rely on their linguistic skills – in this case, syntactic comprehension – more than their metalinguistic skills, such as syntactic awareness, to support their reading comprehension. While these syntactic comprehension skills work to improve children’s reading comprehension, they may also be setting the foundation for emerging syntactic awareness skills. Thus, for younger children, instead of a balanced feedback loop between syntactic comprehension and awareness, we may find that syntactic comprehension contributes to growth in syntactic awareness. This idea is depicted by a bolder arrow from syntactic comprehension to awareness than vice versa in Figure 2a. For older children, when syntactic awareness has more solidly developed, we may then see the feedback loop emerge, where the two aspects can work together in an equitable way to support each other as well as reading comprehension (Figure 2b). We encourage others to build on these ideas.

Within this framework, we follow on theories of reading comprehension and include both top-down and bottom-up skills that may mediate the relation between syntactic skills and reading comprehension (e.g., Perfetti & Stafura, 2014). We first discuss the role of syntactic parsing, a

top-down skill (e.g., Kintsch, 1994; Perfetti & Stafura, 2014). As shown in Figure 1, our results suggest that an ability to understand sentences helps readers break sentences down into their constituent parts. Building on ideas put forward by Kintsch (1994), this could be because understanding what happened in a sentence allows a reader to put boundaries between the different events in a sentence, thus making it easier to create a mental picture of the events of the sentence. This would ease integration of events within and across sentences.

While we did not find evidence of a relation between syntactic awareness and syntactic parsing in the current study, we believe this relation warrants consideration, particularly for older children (Figure 2b). As children develop more metalinguistic ability, they could then pull on their syntactic awareness skill to enable syntactic parsing. We suggest a similar mechanism as that for syntactic comprehension (see also Deacon & Kieffer, 2017; Perfetti & Stafura, 2014): awareness of sentence structure may allow a reader to break sentences down based on their syntactic boundaries, thus creating clauses. Therefore, for both syntactic comprehension and awareness, the idea of "chunking" the sentence applies; what may differ is the content of those chunks. And, given that the end goal of reading is *understanding*, we are open to the possibility that as children develop syntactic awareness skills, they use these skills to help divide a sentence into clauses; these clauses then support syntactic comprehension and the creation of a mental picture of what is happening in the sentence. This process, ultimately, could support integration of events within and across sentences, leading to stronger text comprehension.

We believe that the relation between syntactic parsing and reading comprehension is also worth discussing. We found some evidence that syntactic parsing is related to later reading comprehension. Conceptually, this makes sense: an ability to break sentences down into chunks, whether these chunks are enabled by syntactic comprehension, awareness, or both, should ease

processing and free up cognitive resources to facilitate text comprehension. Yet, we also suggest that reading comprehension likely leads to stronger syntactic parsing skills. Indeed, experience reading complex sentences should facilitate the development of skills to make these sentences easier to read. This effect may be particularly apparent in children who are frequent readers, as they will have more opportunities to learn how to tackle complex sentences; such opportunities are more limited for children who do not read. Building on this idea, it is possible that the relation between syntactic parsing and reading comprehension strengthens as children progress through school and gain more exposure to various types of sentences and texts (Figure 2b).

With respect to bottom-up skills, our findings point to the fact that theories should explicitly include word reading and vocabulary in the relation between syntactic skills and reading comprehension. For word reading, it may be that syntactic skills – whether it be understanding sentences or being able to reflect on sentence structure – eases the process of decoding a novel word by providing syntactic boundaries on the type of word the novel word could be (see also Tunmer, 1989 and Deacon & Kieffer, 2017, for a discussion of how word reading may mediate these relations). Following on psycholinguistic research (Babineau et al., 2020; Kamil et al., 2000; Naigles, 1990), we suggest a similar process by which vocabulary may act as a mechanism between syntactic skills and reading comprehension: an ability to understand and reflect on sentence structure likely helps a reader restrict the possibilities for what the novel could mean. A reader could, for example, use their understanding of a sentence's events to narrow the potential definitions of an unknown word. Similarly, awareness of sentence structure may assist a reader in determining if the unknown word is a noun, verb, or adjective, again limiting the possible meanings of the word. Overall, it will be important to integrate these ideas

of how word reading and vocabulary act as mediators in the relation between syntactic skills and reading comprehension into one, comprehensive theory of reading comprehension.

We found that the effects of word reading and vocabulary on the relation between syntactic skills and reading comprehension are especially prominent for younger children. Here, we provide a starting point for why this may be: we suggest that, for children whose word reading and vocabulary skills are in a period of intense development (e.g., Phythian-Sence & Wagner, 2007; Whitehurst & Lonigan, 1998), syntactic skills are particularly important to provide clues about pronunciations and word meanings. Younger children encounter many new words in every new text they read. Successfully decoding and learning the meaning of this onslaught of new words is a dauting task, one that likely requires several support skills - our results indicate that syntactic skills are one such set of skills. For older children, however, decoding is likely to be more automatic, and their vocabulary banks have expanded; their increased word reading fluidity and vocabulary knowledge may decrease their need to rely on support skills. We encourage theories to build on our data and ideas; doing so could spur further empirical investigation and intervention designs, ultimately leading to the most effective classroom instruction.

Educational and Clinical Implications

Our results go some way in responding to calls for educators to teach children to tackle complex sentences to bolster reading comprehension (Common Core State Standards, 2021). Indeed, our data offer opportunities for critical advancements in the design of interventions, with the downstream impacts on education. In particular, we suggest that both syntactic comprehension and awareness be targeted throughout elementary in order to improve reading comprehension skill. Further, we offer suggestions for the optimal time to target each of these

aspects: children could begin to learn about syntactic comprehension early in their elementary education, while they may need to be older for syntactic awareness training to be meaningful. Such developmental effects also arise in terms of syntactic skills training to bolster other skills - i.e., word reading and vocabulary - that lead to stronger reading comprehension. It seems that targeting syntactic comprehension will help all elementary-aged children decode new words; however, to support learning of new word meanings, young children may benefit from syntactic comprehension instruction more than older children. Similarly, targeting syntactic awareness with the goal of improving word reading and vocabulary skills is likely most impactful in younger as compared to older readers. These precise, empirically guided ideas will support educators in maximizing already limited classroom time, something that educators have requested help with (see e.g., Froese-Germain, 2014; Hunter & Sonnemann, 2022; The Pennsylvania State University, 2017).

Importantly, some ideas already exist as to *how* we can target each of syntactic comprehension and syntactic awareness; we use these ideas as a springboard to further elaborate on how our results connect to education. In her widely implemented Keys to Early Literacy professional development program, Sedita (2007) tells educators that to improve reading comprehension, syntactic awareness should be targeted. In line with this goal, she instructs educators to, for example, have children complete sentence anagrams and combine two or more sentences into one sentence. To our reading, there is not an explicit place in this program for syntactic comprehension; our results indicate that it should be included. For example, educators may expose children to a variety of sentence structures and ask them to indicate which scenes depict the events in different sentences. There is some indication that this type of training would bolster syntactic skills: in an empirical study, Phillips (2014) targeted syntactic comprehension

by asking pre-kindergarten to first grade children to read sentences of different syntactic constructs and followed by comprehension questions. Such training improved syntactic comprehension skills. She also taught a different group of same-aged children syntactic awareness by asking them to create their own sentences using specific syntactic structures. Pre-to post-test results demonstrate that these methods improved syntactic awareness. Neither Sedita's (2007) nor Phillips's (2014) training methods have been explicitly linked to reading comprehension improvement; studying the impact of such training on reading comprehension is a vital next step.

The finding that syntactic awareness predicts reading comprehension to a similar magnitude as syntactic comprehension points to ideas for clinical practice, the most notable of which is the inclusion of tests of metalinguistic skills in psychoeducational assessments. There are standardized tests of linguistic skills (e.g., CELF-5; Wiig et al., 2013) that can be used to inform why reading comprehension deficits emerge; the extent to which this is done, however, is unclear. Unfortunately, there exists very few standardised tests of metalinguistic skills, limiting their use in psychoeducational assessments. As both syntactic comprehension and awareness are important for reading comprehension development, explicitly including syntactic awareness measures in assessments of reading comprehension will provide more comprehensive results. As an example, it is possible for a child to perform in the Average range on measures of linguistic skills (syntactic comprehension, vocabulary) and basic reading skills (word reading, pseudoword decoding), yet below average on reading comprehension. In this case, it may be that the child lacks explicit awareness of syntax, and this is impairing their ability to gain meaning from text. Yet, without testing syntactic awareness, we would be in the dark with respect to *why* these reading comprehension deficits emerge, impacting our ability to make precise and useful

recommendations. This is problematic, considering the centrality of reading comprehension to success in both school and society (e.g., Colenutt & Toye, 2012). In terms of developing these tests, we suggest that the syntactic awareness measures often used in research (e.g., word-order correction tasks) offer a solid foundation from which to build standardized clinical tests, as such measures have demonstrated reliability in a variety of languages and populations.

Future Directions for Empirical Studies

The results of this dissertation encourage several next steps; we highlight what we perceive as the most critical ones here. First, the results from each of the three studies indicate the importance of both syntactic comprehension and syntactic awareness to reading comprehension across the elementary years. The next stage, in our view, is to explore how and when these aspects may interact to lead to reading comprehension improvements. We provide such ideas in our hypothesized framework (Figure 1). In terms of empirical tests of these predictions, designs that include both syntactic comprehension and syntactic awareness will be of paramount importance.

Building on this, it will also be important to explore *how* syntactic skills contribute to reading comprehension. In particular, we suggest that researchers continue to explore the bottom-up and top-down processes that act as mediators in the relation between syntactic skills and reading comprehension. We think that this will be particularly important for top-down processes. Certainly, theories name several other top-down processes that may allow a reader to understand texts. For example, they document the importance of inference making, creating a text representation, and comprehension monitoring (e.g., Kintsch, 1994; Perfetti & Stafura, 2014); each of these processes has empirical support (see e.g., Elleman & Oslund, 2019 and Oakhill, 2020 for reviews). It may be that top-down processes are best modeled as several,

integrated constructs (see Perfetti & Stafura, 2014). Further delving into these relations will not only allow more precision in theories, but also provide further direction on the best way to teach syntactic skills. And, now that intervention designs can be armed with more precise empirical data, they will be integral in continuing to bridge the science of reading and the science of reading instruction.

Here, we only explored the relation among syntactic skills and reading comprehension in elementary-aged children. Some work has demonstrated a relation among syntactic skills and reading comprehension in older students (e.g., Brimo et al., 2017) and adults (Guo et al., 2011). Given that syntactic complexity in texts continues to increase through grade school and university (e.g., Curran, 2020), and these complex sentences are critical in understanding various subjects (e.g., e.g., Karasinski, 2016; Reynolds, 2021), further research on if, how, and when syntactic skills relate to reading comprehension in these older populations will be important.

Similarly, all participants in these studies' samples were English-speaking; however, investigating the relation between syntactic skills and reading comprehension in other languages will illuminate if syntactic skills are a language-specific or universal predictor of reading comprehension. Interestingly, some studies suggest that latter possibility may be the case. For instance, Tong et al. (2023) reported on a meta-analysis on the relation between syntactic skills and reading comprehension with children who spoke either English or Chinese as a first language. Across the 59 identified studies, there were strong meta-analytic correlations between syntactic skills and reading comprehension, associations that were of a similar size for English and Chinese. These similarly sized correlations between English and Chinese held where there were adequate data to contrast correlations at specific age groups (i.e., younger and older elementary students), task modalities (i.e., oral), and specific task types (i.e., error

detection/correction and word-order correction). The authors interpret these results as suggesting that syntactic skills are a universal predictor of reading comprehension. We advocate for others to build on this work in other languages to continuing addressing if syntactic skills are, in fact, a global indicator of reading comprehension. Further, building on the questions in this dissertation, research with other languages can examine if syntactic comprehension and awareness are separable, what their relative contributions to reading comprehension are, and how and when each of these relations functions. Certainly, there is some way to go before we have fully elucidated the relation between syntactic skills and reading comprehension; nonetheless, we argue that we have taken significant steps to advance our knowledge and understanding of this relation.

Conclusion

The studies of this dissertation were designed to answer theoretically driven and educationally important questions about the relation between syntactic skills and reading comprehension. In service of this, we provide a comprehensive set of data that clearly guides theories and intervention designs. First, we are confident in concluding that both aspects of syntactic skills matter for reading comprehension across the elementary years, with developmental effects emerging for when each will predict gains in reading comprehension. Secondly, mediators such as word reading, vocabulary, and syntactic parsing help us understand how syntactic skills contribute to reading comprehension, with further precision concerning the age at which each of these mediators is most prominent. By providing this data, we hope to help bridge the gap between the science of reading and the science of reading instruction (Shanahan, 2020), a gap that desperately needs to be filled to best support students and teachers. Indeed, the advancements made in these studies can be used to inform the design of interventions, which,

then, can be translated to classroom practices. Evidence-based educational practices are fundamental to improving children's reading comprehension skill, a skill that is uniquely important for success in school and society (e.g., Colenutt & Toye, 2012).

References

Babineau, M., Carvalho, A., Trueswell, J., & Christophe, A. (2020). Familiar words can serve as a semantic seed for syntactic bootstrapping. *Developmental Science, 24*(1). https://doi.org/10.1111/desc.13010

Brimo, D., Apel, K., & Fountain, T. (2017). The effects of syntactic awareness and syntactic knowledge on reading comprehension among 9th and 10th grade students. *Journal of Reading Research, 40*(1), 57-74. https://doi.org/10.1111/1467-9817.12050

Cain, K. (2007). Syntactic awareness and reading ability: Is there any evidence for a special relationship? *Applied Psycholinguistics, 28*(4), 679-694. https://doi.org/10.1017/S0142716407070361

Chall, J. S. (1983). *Stages of reading development*. New York, NY: McGraw-Hill.

Chomsky, N. (2002). *Syntactic structures*. Martino Publishing.

Colenutt, A., & Toye, M. A. (2012). Critical crossroads: Youth, criminal justice and literacy Discussion Paper. Retrieved March 9, 2021, from http://en.copian.ca/library/research/frontier/critical_crossroads/critical_crossroads.pdf

Common Core State Standards (2021). *Key shifts in English language arts*. Retrieved from http://www.corestandards.org/other-resources/key-shifts-in-english-language-arts/

Curran, M. (2020). Complex sentences in an elementary science curriculum: A research note. *Language, Speech, and Hearing Services in Schools, 51*(2), 329-335. https://doi.org/10.1044/2019_LSHSS-19-00064

Deacon, S. H., & Kieffer, M. (2017). Unraveling the relations between syntactic awareness and reading comprehension: Evidence from mediation and longitudinal models. *Journal of Educational Psychology*, *110*(1), 72-86. https://doi.org/10.1037/edu0000198

de Marneffe, M.-C., Grimm, S., Arnon, I., Kirby, S., & Bresnan, J. (2012). A statistical model of the grammatical choices in child production of dative sentences. *Language and Cognitive Processes*, *27*(1), 25–61. https://doi-org/10.1080/01690965.2010.542651

Donaldson, M. (1978). *Children's minds*. Collins.

Elleman, A. M., & Oslund, E. L. (2019). Reading comprehension research: Implications for practice and policy. *Behavioural and Brain Sciences*, *6*, 3-11. https://doi.org/10.1177/2372732218816339

Froese-German, B. (2014). *Work-life balance and the Canadian teaching profession*. Canadian Teachers' Federation.

Gombert, J. E. (1992). *Metalinguistic development*. Hertfordshire, GB: Harvester Wheatsheaf

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education, 7*(1), 6-10. https://doi.org/10.1177/074193258600700104

Guo, Y., Roehrig, A. D., & Williams, R. S. (2011). The relation of morphological awareness and syntactic awareness to adults' reading comprehension: Is vocabulary knowledge a mediating variable? *Journal of Literacy Research*, *43*(2), 159–183. https://doi.org/10.1177/1086296X11403086

Hunter, J., & Sonnemann, J. (2022). *Making time for great teaching: How better government policy can help*. Grattan Institute. https://grattan.edu.au/wp-content/uploads/2022/01/Making-time-for-great-teaching-how-better-government-policy-can-help-Grattan-Report.pdf

Kamil, M., Mosenthal, P., Pearson, P. D., & Barr, R. (Eds.). (2000). *Handbook of reading research* (Vol. 3). Erlbaum.

Karasinski, C. (2016). Comprehension of narratives, non-fiction, and complex syntax as predictors of science achievement. *Speech, Language and Hearing, 19*(4), 203–210. https://doi.org/10.1080/2050571X.2016.1187465

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303. http://dx.doi.org/10.1037/0003-066X.49.4.294

Lervåg, A., Hulme, C. & Melby-Lervåg, M. (2018). Unpicking the developmental relationships between oral language skills and reading comprehension: It's simple, but complex. *Child Development, 89*(5), 1821-1838. https://doi.org/10.1111/cdev.12861

MacKay, E., Lynch, E., Sorenson Duncan, T., & Deacon, S. H. (2021). Informing the science of reading: Children's awareness of sentence-level information is important for reading comprehension. *Reading Research Quarterly*. https://doi.org/10.1002/rrq.397

Merritt, D. D. (2016, February). Typical speech and language development for school-age children: A checklist for school nurses. Retrieved from: http://ctserc.org/component/k2/item/130-typical-speech-and-language-development-for-school-age-children

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, *17*(2), 357–374. https://doi.org/10.1017/S0305000900013817

Oakhill, J. (2020). Four decades of research into children's reading comprehension: A personal review. *Discourse Processes*, *57*, 402-419. https://doi.org/10.1080/0163853X.2020.1740875

Oakhill, J., Cain, K., & Elbro, C. (2014). *Understanding and teaching reading comprehension: A handbook*. Routledge.

The Pennsylvania State University (2017). *Teacher stress and health: Effects on students, teachers, and schools.* Retrieved from https://www.rwjf.org/en/insights/our-research/2016/07/teacher-stress-and-health.html

Perfetti, C. A., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*, 22-37. https://doi.org/10.1080/10888438.2013.827687

Phillips, B. M. (2014). Promotion of syntactical development and oral comprehension: Development and initial evaluation of a small-group intervention. *Child Language Teaching and Therapy*, *30*, 63–77. https://doi.org/10.1177/026565901348774

Phythian-Sence, C., & Wagner, R. K. (2007). Vocabulary acquisition: A primer. In R. K. Wagner, A. E. Muse, & K. R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (p. 1–14). Guilford Press.

Reynolds, D. (2021). Scaffolding the academic language of complex text: An intervention for late secondary students. *Journal of Research in Reading,* 1-21. https://doi.org/10.1111/1467-9817.12353

Sedita, J. (2007). *Syntactic awareness: Teaching sentence structure* (Excerpt from Module 7). Keys to Beginning Reading Professional Development Program.

Shanahan, T. (2020). Why we need to teach sentence comprehension. Retrieved from https://www.readingrockets.org/blogs/shanahan-literacy/why-we-need-teach-sentencecomprehension

Tong, X., Yu, L., & Deacon, S. H. (2023). A meta-analysis on the relation between syntactic skills and reading comprehension: A cross-linguistic and developmental investigation. *Review of Educational Research*. Advanced online publication.

Tunmer, W. E. (1989). The role of language-related factors in reading disability. In D. Shankweiler & I.Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 91-131). University of Michigan Press.

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. Child Development, 69(3), 848–872. https://doi.org/10.2307/1132208

Wiig, E. H., Semel, E., & Secord, W. A. (2013). Clinical evaluation of language fundamentals–fifth edition (CELF-5). *Journal of Psychoeducational Assessment*, *33*(5), 495–500.

Figure 1

A Theoretical Framework for How Syntactic Skills and Mechanisms Interact to Improve Reading Comprehension

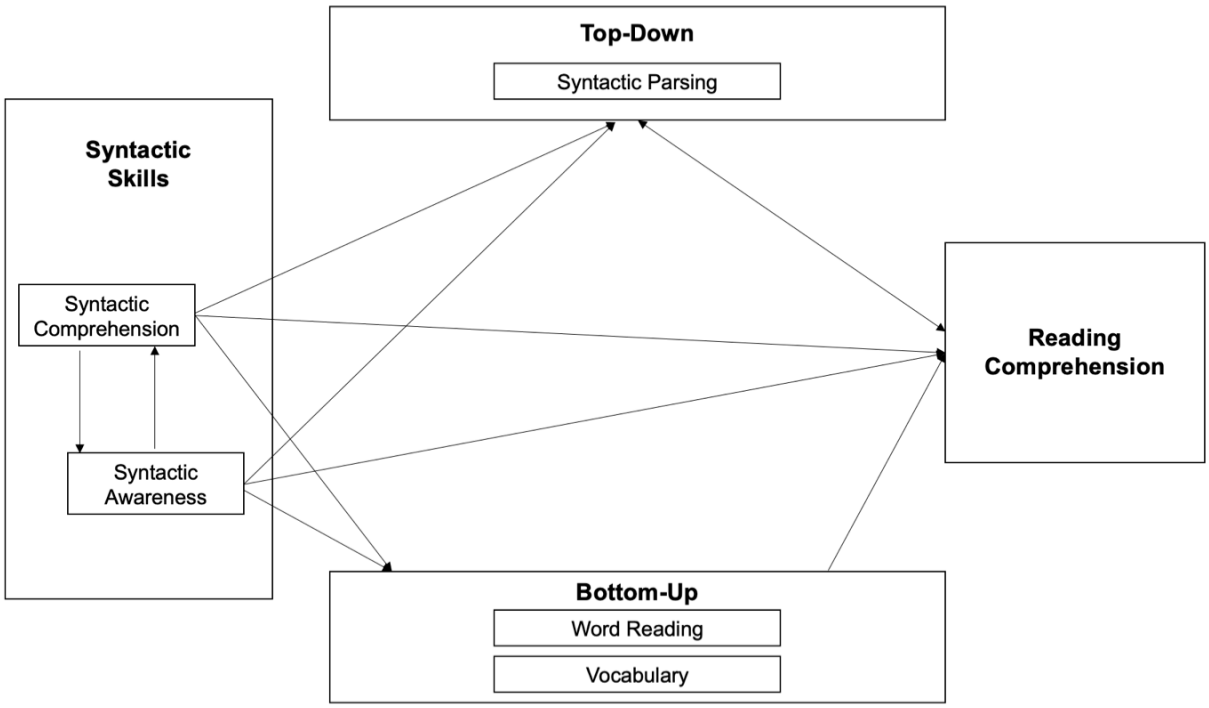
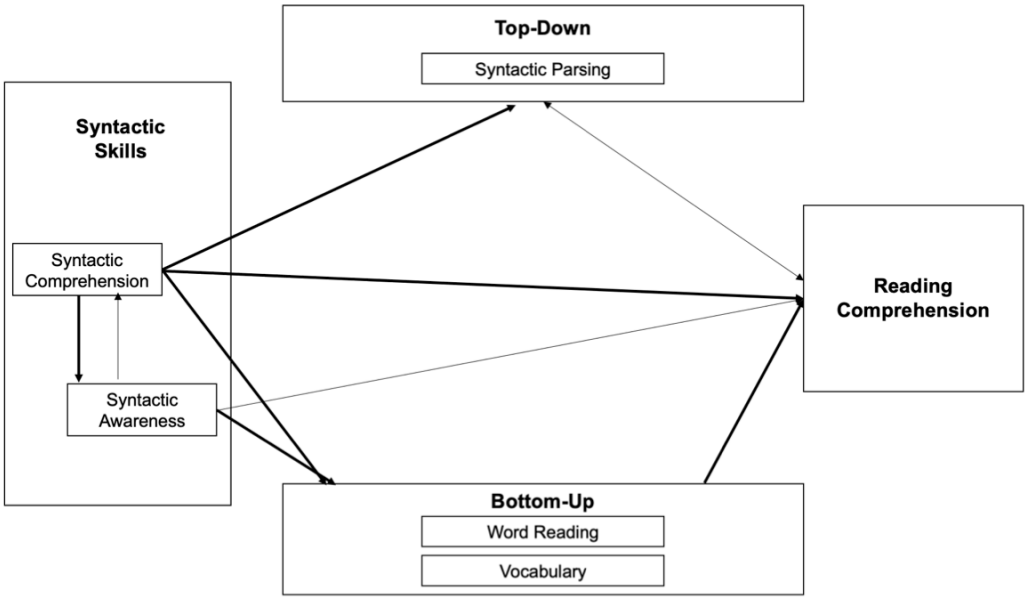


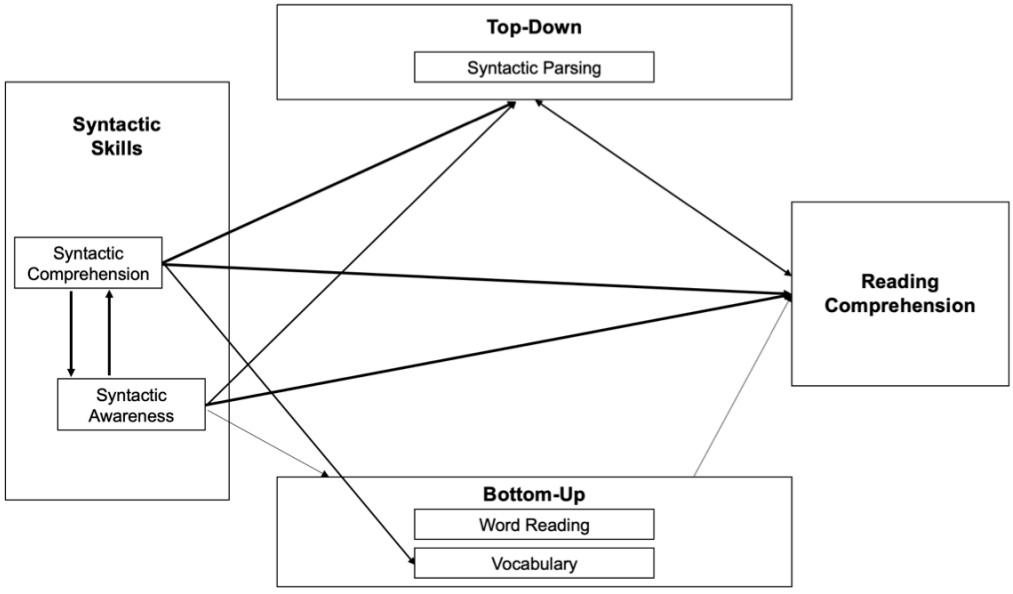
Figure 2

The Above Framework Specified for Younger (2a) and Older (2b) Readers

(a)



(b)



Note: Bold lines indicate relations that may increase in strength as children age. Bolder lines indicate a stronger relationship. Syntactic comprehension is to the left of syntactic awareness, as the former develops earlier than the latter.

References

Agresti, A., & Finlay, B. (2009). Model building with multiple regression. In A. Agresti & B. Finlay (Eds.), *Statistical Methods for the Social Sciences* (4th ed., pp. 441–474). Prentice Hall.

Apel, K. (2022). A different view on the Simple View of Reading. *Remedial and Special Education*, *43*(6), 434-447. https://doi.org/10.1177/07419325211063487

Babineau, M., Carvalho, A., Trueswell, J., & Christophe, A. (2020). Familiar words can serve as a semantic seed for syntactic bootstrapping. *Developmental Science, 24*(1). https://doi.org/10.1111/desc.13010

Balthazar, C. H., & Scott, C. M. (2018). Targeting complex sentences in older school children with specific language impairment: Results from an early-phase treatment study. *Journal of Speech, Language, and Hearing Research*, *61*(3), 713–728. https://doi.org/10.1044/2017_JSLHR-L-17-0105

Barnes, E. M., Oliveira, A. W., & Dickinson, D. K. (2019). Teacher accommodation of academic language during Head Start pre-kindergarten read-alouds. *Journal of Education for Students Placed at Risk*, *24*(4), 369–393. https://doi.org/10.1080/10824669.2019.1657868

Begg, C.B., & Mazumdar, M. (1994) Operating characteristics of a rank correlation test for publication bias. *Biometrics*, *50*, 1088-1101. http://dx.doi.org/10.2307/2533446

Biemiller, A. (2014). Oral comprehension sets the ceiling on reading comprehension. *Literacy Ladder: Increasing Young Children's Language, Knowledge and Reading Comprehension*, 52–53.

Bloom, L. & Lahey, M. (1978). *Language development and language disorders*. New York: Wiley.

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The effects of morphological instruction on literacy skills: A systematic review of the literature. *Review of Educational Research*, *80*(2), 144–179. https://doi.org/10.3102%2F0034654309359353

Bowey, J. A., & Patel, R. K. (1988). Metalinguistic ability and early reading achievement. *Applied Psycholinguistics*, *9*(4), 367–383. https://doi.org/10.1017/S0142716400008067

Brimo, D., Apel, K., & Fountain, T. (2017). The effects of syntactic awareness and syntactic knowledge on reading comprehension among 9th and 10th grade students. *Journal of Reading Research, 40*(1), 57-74. https://doi.org/10.1111/1467-9817.12050

Brimo, D., Lund, E., & Sapp, A. (2017). Syntax and reading comprehension: A meta-analysis of different spoken-syntax assessments. *International Journal of Language and Communication Disorders*, *53*(3), 431-445. https://doi.org/10.1111/1460-6984.12362

Cain, K. (2007). Syntactic awareness and reading ability: Is there any evidence for a special relationship? *Applied Psycholinguistics, 28*(4), 679-694. https://doi.org/10.1017/S0142716407070361

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. *British Journal of Educational Psychology, 76*(4), 683-696. https://doi.org/10.1348/000709905X67610

Cain, K., & Oakhill, J. (2014). Reading comprehension and vocabulary: Is vocabulary more important for some aspects of comprehension? *L'Année Psychologique*, *114*(4), 647–662. https://doi.org/10.4074/S0003503314004035

Candler, L. (n.d.). Teaching kids how to write super sentences. Retrieved from https://www.lauracandler.com/super-sentences/

Chall, J. S. (1983). *Stages of reading development*. McGraw-Hill.

Cheung, M. W.-L., & Chan, W. (2005). Meta-analytic structural equation modeling: A two-stage approach. *Psychological Methods*, *10*(1), 40–64. https://doi-org/10.1037/1082-989X.10.1.40.supp (Supplemental)

Cheung, M. W. L. & Cheung, S. F. (2016). Random-effects models for meta-analytic structural equation modeling: review, issues, and illustrations. *Research Synthesis Methods*, *7*(2), 140-155. https://doi.org/10.1002/jrsm.1166

Chomsky, N. (2002). *Syntactic structures*. Martino Publishing.

Common Core State Standards (2021). *Key shifts in English language arts*. Retrieved from http://www.corestandards.org/other-resources/key-shifts-in-english-language-arts/

Connor, C. M., Phillips, B. M., Kim, Y.-S. G., Lonigan, C. J., Kaschak, M. P., Crowe, E., Dombek, J., & Al Otaiba, S. (2018). Examining the efficacy of targeted component interventions on language and literacy for third and fourth graders who are at risk of comprehension difficulties. *Scientific Studies of Reading*, *22*(6), 462–484. https://doi.org/10.1080/10888438.2018.1481409

Colenutt, A., & Toye, M. A. (2012). Critical crossroads: Youth, criminal justice and literacy Discussion Paper. Retrieved March 9, 2021, from http://en.copian.ca/library/research/frontier/critical_crossroads/critical_crossroads.pdf

Curran, M. (2020). Complex sentences in an elementary science curriculum: A research note. *Language, Speech, and Hearing Services in Schools, 51*(2), 329-335. https://doi.org/10.1044/2019_LSHSS-19-00064

Cutting, L. E., & Scarborough, H. S. (2006). Prediction of reading comprehension: Relative contributions of word recognition, language proficiency, and other cognitive skills can depend on how comprehension is measured. *Scientific Studies of Reading*, *10*(3), 277–299. https://doi.org/10.1207/s1532799xssr1003_5

Dawson, H. & Phelan, M. (2016). *Language files: Materials for an introduction to language and linguistics* (12th ed.). The Ohio State University Press.

de Marneffe, M.-C., Grimm, S., Arnon, I., Kirby, S., & Bresnan, J. (2012). A statistical model of the grammatical choices in child production of dative sentences. *Language and Cognitive Processes*, *27*(1), 25–61. https://doi-org/10.1080/01690965.2010.542651

Deacon, S. H., Benere, J., & Pasquarella, A. (2013). Reciprocal relationship: Children's morphological awareness and their reading accuracy across grades 2 to 3. *Developmental Psychology*, *49*(6), 1113-1126. https://doi.org/10.1037/a0029474

Deacon, S. H., & Kieffer, M. (2017). Unraveling the relations between syntactic awareness and reading comprehension: Evidence from mediation and longitudinal models. *Journal of Educational Psychology*, *110*(1), 72-86. https://doi.org/10.1037/edu0000198

DeThorne, L. S., Harlaar, N., Petrill, S. A., & Deater-Deckard, K. (2012). Longitudinal stability in genetic effects on children's conversational language productivity. *Journal of Speech, Language, and Hearing Research*, *55*, 739–753. https://doi.org/10.1044/1092-4388(2011/11-0014)

Donaldson, M. (1978). *Children's minds*. Collins.

Dunn, D. M. (2018). *The Peabody picture vocabulary test – fifth edition* (PPVT 5). Pearson.

Dunn, L. M., & Dunn, D. M. (2006). *The Peabody picture vocabulary test – fourth edition* (PPVT-IV). Pearson.

Écalle, J., Bouchafa, H., Potocki, A., & Magnan, A. (2013). Comprehension of written sentences as a core component of children's reading comprehension. *Journal of Research in Reading, 36*(2), 117-131. https://doi.org/10.1111/j.1467-9817.2011.01491.x

Ehri, L. C. (2005). Development of sight word reading: Phases and findings. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 135–154). Blackwell Publishing. https://doi.org/10.1002/9780470757642.ch8

Elleman, A. M., & Oslund, E. L. (2019). Reading comprehension research: Implications for practice and policy. *Behavioural and Brain Sciences*, *6*, 3-11. https://doi.org/10.1177/2372732218816339

Fang, Z. (2006). The language demands of science reading in middle school. International *Journal of Science Education*, *28*, 491–520. https://doi.org/10.1080/09500690500339092

Farnia, F., & Geva, E. (2013). Growth and predictors of change in English language learners' reading comprehension. *Journal of Research in Reading*, 36(4), 389–421.

Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.). SAGE Publications.

Froese-Germain, B. (2014). *Work-life balance and the Canadian teaching profession*. Retrieved from https://files.eric.ed.gov/fulltext/ED546884.pdf

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., ... & Trikalinos, T. A. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology, 64*(11), 1187-1197. https://doi.org/10.1016/j.jclinepi.2010.08.010

García, J. R., & Cain, K. (2014). Decoding and reading comprehension: A meta-analysis to identify which reader and assessment characteristics influence the strength of the

relationship in English. *Review of Educational Research*, *84*(1), 74–111. https://doi-org/10.3102/0034654313499616

Gaux, C., & Gombert, J. É. (1999). Implicit and explicit syntactic knowledge and reading in pre-adolescents. *British Journal of Developmental Psychology*, *17*(2), 169–188. https://doi.org/10.1348/026151099165212

Gombert, J. E. (1992). *Metalinguistic development*. Hertfordshire, GB: Harvester Wheatsheaf

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *RASE: Remedial & Special Education, 7*(1), 6-10. https://doi.org/10.1177/074193258600700104

Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2011). Coh-metrix providing multilevel analyses of text characteristics. *Educational Researcher*, *40*(5), 223-234. https://doi.org/10.3102/0013189X11413260

Guo, Y., Roehrig, A. D., & Williams, R. S. (2011). The relation of morphological awareness and syntactic awareness to adults' reading comprehension: Is vocabulary knowledge a mediating variable? *Journal of Literacy Research*, *43*(2), 159–183. https://doi.org/10.1177/1086296X11403086

Haft, S. L., Caballero, J. N., Tanaka, H., Zekelman, L., Cutting, L. E., Uchikoshi, Y., & Hoeft, F. (2019). Direct and indirect contributions of executive function to word decoding and reading comprehension in kindergarten. *Learning and Individual Differences*, *76*, 101783. https://doi.org/10.1016/j.lindif.2019.101783

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Prentice Hall.

Harrer, M., Cuijpers, P., Furukawa, T.A, & Ebert, D. D. (2019). *Doing meta-analysis in R: A hands-on guide*. http://doi.org/10.5281/zenodo.2551803

Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods*, *1*(1), 39–65. https://doi.org/10.1002/jrsm.5

Hjetland, H. N., Brinchmann, E. I., Scherer, R., & Melby-Lervåg, M. (2017). Preschool predictors of later reading comprehension ability: A systematic review. *Campbell Systematic Reviews*, *13*(1), 1-155. https://doi.org/10.4073/csr.2017.14

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *2*(2), 127–160. https://doi.org/10.1007/BF00401799

Huberty, C. J, & Petoskey, M. D. (2000). Multivariate analysis of variance and covariance. In H. E. A. Tinsley & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 183–208). Academic Press. https://doi.org/10.1016/B978-012691360-6/50008-2

Hulme, R. C., Barsky, D., & Rodd, J. M. (2018). Incidental learning and long-term retention of new word meanings from stories: The effect of number of exposures. *Language Learning: A Journal of Research in Language Studies*, *69*(1), 18-43. https://doi.org/10.1111/lang.12313

Hulme, R. C., Shapiro, L. R., & Taylor, J. S. H. (2022). Learning new words through reading: Do robust spelling–sound mappings boost learning of word forms and meanings?. *Royal Society Open Science.* https://doi.org/10.1098/rsos.210555

Hunter, J., & Sonnemann, J. (2022). *Making time for great teaching: How better government policy can help*. Grattan Institute. Retrieved from https://grattan.edu.au/wp-content/uploads/2022/01/Making-time-for-great-teaching-how-better-government-policy-can-help-Grattan-Report.pdf

Huslander, J., Olson, R. K., Willcutt, E. G., & Wadsworth, S. J. (2010). Longitudinal stability of reading-related skills and their prediction of reading development. *Scientific Studies of Reading*, *14*(2), 111–136. https://doi.org/10.1080/10888431003604058

IBM Corp. (2020). IBM SPSS Statistics for Windows, Version 27.0. IBM Corp.

Individuals with Disabilities Education Act [IDEA], 20 U.S.C. § 1400 (2004).

Jagaiah, T., Olinghouse, N. G., & Kearns, D. M. (2020). Syntactic complexity measures: Variation by genre, grade-level, students' writing abilities, and writing quality. *Reading and Writing: An interdisciplinary Journal, 33*, 2577–2638. https://doi.org/10.1007/s11145-020-10057-x

Jared, D., Cormier, P., Levy, B. A., & Wade-Woolley, L. (2011). Early predictors of biliteracy development in children in French immersion: A 4-year longitudinal study. *Journal of Educational Psychology*, *103*(1), 119-139. https://doi.org/10.1037/a0021284

Kamil, M. L. (2003). *Adolescents and literacy: Reading for the 21st century*. Alliance for Excellent Education.

Kamil, M., Mosenthal, P., Pearson, P. D., & Barr, R. (Eds.). (2000). *Handbook of reading research* (Vol. 3). Erlbaum.

Kazak, A. E. (2018). Editorial: Journal article reporting standards. *American Psychologist*, *73*(1), 1-2. http://dx.doi.org/10.1037/amp0000263

Kenny, D. (1975). Cross-lagged panel correlation: A test for spuriousness. *Psychological Bulletin*, *82*, 887–903. http://dx.doi.org/10.1037/0033-2909.82.6.887

Kieffer, M. J., Petscher, Y., Proctor, C. P., & Silverman, R. D. (2016). Is the whole greater than the sum of its parts? Modeling the contributions of language comprehension skills to reading comprehension in the upper elementary grades. *Scientific Studies of Reading*,

20(6), 436–454. https://doi.org/10.1080/10888438.2016.1214591

Kim, Y.-S. G. (2020). Toward integrative reading science: The direct and indirect effects model of reading. *Journal of Learning Disabilities*, *53*(6), 469–491. https://doi-org/10.1177/0022219420908239

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review*, *95*(2), 163–182. https://doi.org/10.1037/0033-295X.95.2.163

Kintsch, W. (1992). A cognitive architecture for comprehension. In H. L. Pick, Jr., P. W. van den Broek, & D. C. Knill (Eds.), *Cognition: Conceptual and methodological issues* (pp. 143–163). American Psychological Association. https://doi.org/10.1037/10564-006

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303. http://dx.doi.org/10.1037/0003-066X.49.4.294

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). Guilford Press.

Kline, R. B. (2011). *Principles and practice of structural equation mod*eling (3rd ed.). Guilford Press.

Kline, R. B. (2016). *Principles and practice of structural equation modeling* (4th ed.). Guilford Press.

Koutsoftas, A. D. (2013). School–age language development: Application of the five domains of language across four modalities. In N. Capone-Singleton & B. B. Shulman (Eds.), *Language development: Foundations, processes, and clinical applications* (pp. 215-229). Jones & Bartlett Learning.

Lervåg, A., Hulme, C. & Melby-Lervåg, M. (2018). Unpicking the developmental relationships between oral language skills and reading comprehension: It's simple, but complex. *Child Development, 89*(5), 1821-1838. https://doi.org/10.1111/cdev.12861

Lesgold, M. (1974). Variability in children's comprehension of syntactic structures. *Journal of Educational Psychology*, *66*, 333–338. http://dx.doi.org/10.1037/h0036427

Levesque, K. C., Kieffer, M. J., & Deacon, S. H. (2019). Inferring meaning from meaningful parts: The contributions of morphological skills to the development of children's reading comprehension. *Reading Research Quarterly*, *54*(1), 63–80. https://doi-org/10.1002/rrq.219

MacGinitie, W. H., & MacGinitie, R. K. (1992). *Gates-MacGinitie reading tests – second edition*. The Riverside Publishing Company.

MacKay, E., Lynch, E., Sorenson Duncan, T., & Deacon, S. H. (2021). Informing the science of reading: Students' awareness of sentence-level information is important for reading comprehension. *Reading Research Quarterly*. https://doi-org /10.1002/rrq.397

Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods*, *12*(1), 23–44. https://doi.org/10.1037/1082-989X.12.1.23

Melby-Lervåg, M., & Lervåg, A. (2014). Reading comprehension and its underlying components in second-language learners: A meta-analysis of studies comparing first- and second-language learners. *Psychological Bulletin*, *140*(2), 409-433. http://doi.org/10.1037/a0033890

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*(2), 322–352. https://doi.org/10.1037/a0026744

Merritt, D. D. (2016, February). Typical speech and language development for school-age children: A checklist for school nurses. Retrieved from: http://ctserc.org/component/k2/item/130-typical-speech-and-language-development-for-school-age-children

Michener, C. J., Proctor, C. P., & Silverman, R. D. (2018). Features of instructional talk predictive of reading comprehension. *Reading and Writing: An Interdisciplinary Journa*l, *31*(3), 725–756. http://dx.doi.org/10.1007/s11145-017-9807-4

Moats, L. C. (2010). *Speech to print: Language essentials for teachers*. Baltimore, MD: Brookes Publishing.

Moats, L. C. (2020). Teaching reading is rocket science: What expert teachers of reading know and should be able to do [excerpt]. *American Educator.* Retrieved from https://files.eric.ed.gov/fulltext/EJ1260264.pdf

Moeyaert, M., Ugille, M., Beretvas, N. S., Ferron, J., Bunuan, R., & Van den Noortgate, W. (2017). Methods for dealing with multiple outcomes in meta-analysis: a comparison between averaging effect sizes, robust variance estimation and multilevel meta-analysis. *International Journal of Social Research Methodology*, *20*(6), 559–572. https://doi.org/10.1080/13645579.2016.1252189

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2010). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery*, *8*(5). 336-341.

Montgomery, J. W., Evans, J. L., Gillam, R. B., Sergeev, A. V., & Finney, M. C. (2016). “Whatdunit?” Developmental changes in children’s syn- tactically based sentence

interpretation abilities and sensitivity to word order. *Applied Psycholinguistics*, *37*, 1281–1309. http://dx.doi.org/10 .1017/S0142716415000570

Morris, R. D., Lovett, M. W., Wolf, M., Sevcik, R. A., Steinbach, K. A., Frijters, J. C., & Shapiro, M. B. (2012). Multiple component remediation for developmental reading disabilities: IQ, socioeconomic status, and race as factors in remedial outcome. *Journal of Learning Disabilities, 45*(2), 99–127. https://doi.org/10.1177/0022219409355472

Muter, V., Hulme, C., Snowling, M. J., Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology*, *40*(5), 665–681.

Muthén, L. K. & Muthén, B. O. (1998-2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén

Nagy, W. E., Anderson, R. C., & Herman, P. A. (1987). Learning word meanings from context during normal reading. *American Educational Research Journal*, *24*(2), 237-270. https://doi.org/10.3102/00028312024002237

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, *17*(2), 357–374. https://doi.org/10.1017/S0305000900013817

Nation, K., & Snowling, M. (2000). Factors influencing syntactic awareness skills in normal readers and poor comprehenders. *Applied Psycholinguistics*, *21*(2), 229-241. https://doi.org/10.1017/S0142716400002046

National Institute for Literacy. (2008). Developing early literacy: A scientific analysis of early literacy development and implications for intervention. Retrieved from http://www.nifl.gov/publications/pdf/NELPReport09.pdf

Oakhill, J., & Cain, K. (2007). Introduction to comprehension development. In J. Oakhill and K. Cain (Eds.), *Children's comprehension problems in oral and written language*. (pp. 1-40). Guilford Press.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes*, *18*(4), 443–468. https://doi.org/10.1080/01690960344000008

Oakhill, J., Cain, K., & Elbro, C. (2014). *Understanding and teaching reading comprehension: A handbook*. Routledge.

Oberecker, R., Friedrich, M., & Friederici, A. D. (2005). Neural correlates of syntactic processing in two-year-olds. *Journal of Cognitive Neuroscience*, *17*(10), 1667–1678. https://doi-org/10.1162/089892905774597236

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan — a web and mobile app for systematic reviews. *Systematic Reviews*, *5*(210). http://doi.org/10.1186/s13643-016-0384-4

The Pennsylvania State University (2017). *Teacher stress and health: Effects on students, teachers, and schools.* Retrieved from https://www.rwjf.org/en/insights/our-research/2016/07/teacher-stress-and-health.html

Perfetti, C. A., Landi, N., & Oakhill, J. (2005). The acquisition of reading comprehension skill. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 227–247). Blackwell Publishing. https://doi.org/10.1002/9780470757642.ch13

Perfetti, C. A., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*, 22-37. https://doi.org/10.1080/10888438.2013.827687

Petch, E., Ronson, B., & Rootman, I. (2004). Literacy and health in Canada: What we have learned and what can help in the future? A Research Report. Clear Language Edition. Canadian Institute of Health Research.

Phillips, B. M. (2014). Promotion of syntactical development and oral comprehension: Development and initial evaluation of a small-group intervention. *Child Language Teaching and Therapy*, *30*, 63–77. https://doi.org/10.1177/026565901348774

Phythian-Sence, C., & Wagner, R. K. (2007). Vocabulary acquisition: A primer. In R. K. Wagner, A. E. Muse, & K. R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (p. 1–14). Guilford Press.

Poulsen, M., & Gravgaard, A. K. (2016). Who did what to whom? The relationship between syntactic aspects of sentence comprehension and text comprehension. *Scientific Studies of Reading*, *20*(4), 1-14. https://doi.org/10.1080/10888438.2016.1180695

Poulsen, M., Nielsen, J. L., & Vang Christensen, R. (2021). Remembering sentences is not all about memory: Convergent and discriminant validity of syntactic knowledge and its relationship with reading comprehension. *Journal of Child Language*, 1-17. https://doi.org/10.1017/S0305000921000210

Proctor, C. P., Dalton, B., Uccelli, P., Biancarosa, G., Mo, E., Snow, C., & Neugebauer, S. (2011). Improving comprehension online: Effects of deep vocabulary instruction with bilingual and monolingual fifth graders. *Reading and Writing*, *24*(5), 517–544. https://doi.org/10.10 07/s11145-009-9218-2

Proctor, C. P., Silverman, R. D., Harring, J. R., Jones, R. L., & Hartranft, A. M. (2020). Teaching bilingual learners: Effects of a language based reading intervention on academic language

and reading comprehension in grades 4 and 5. *Reading Research Quarterly*, 55(1), 95–122. https://doi.org/10.1002/rrq.258

Pustejovsky, J. E., & Tipton, E. (2022). Meta-analysis with Robust Variance Estimation: Expanding the range of working models. *Prevention Science*, 23, 425–438. https://doi.org/10.1007/s11121-021-01246-3

R Core Team. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna (AU).

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/.

Schafer, A. J., Speer, S. R., Warren, P., & White, S. D. (2000). Intonational disambiguation in sentence production and comprehension. *Journal of Psycholinguistic Research*, *29*(2), 169–182. https://doi-org/10.1023/A:1005192911512

Scott, C. M. (2009). A case for the sentence in reading comprehension. *Language, Speech, and Hearing Services in Schools*, *40*(2), 184–191. https://doi.org/10.1044/0161-1461(2008/08-0042)

Sedita, J. (2007). *Syntactic awareness: Teaching sentence structure* (Excerpt from Module 7). Keys to Beginning Reading Professional Development Program.

Selig, J. P., & Little, T. D. (2012). Autoregressive and cross-lagged panel analysis for longitudinal data. In B. Laursen, T.D. Little, & N.A. Card (Eds.), *Handbook of developmental research methods* (pp. 265–278). Guilford.

Shanahan, T. (2020). Why we need to teach sentence comprehension. Retrieved from https://www.readingrockets.org/blogs/shanahan-literacy/why-we-need-teach-sentencecomprehension

Siegel, L. S., & Ryan, E. B. (1988). Development of grammatical-sensitivity, phonological, and short-term memory skills in normally achieving and learning disabled children. *Developmental Psychology*, *24*, 28–37. https://doi.org/10.1037/0012-1649.24.1.28

Silverman, R. D., Johnson, E., Keane, K., & Khanna, S. (2020). Beyond decoding: A meta-analysis of the effects of language comprehension interventions on k–5 students' language and literacy outcomes. *Reading Research Quarterly*, *55*(51), S207-S233. https://doi.org/10.1002/rrq.346

Snow, C. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. Rand Corporation.

Snow, C. E., & Matthews, T. J. (2016). Reading and language in the early grades. *Future of Children*, *26*(2), 57-74. Retrieved from https://files.eric.ed.gov/fulltext/EJ1118540.pdf

Snowling, M. J., & Hulme, C. (2011). Evidence-based interventions for reading and language difficulties: Creating a virtuous circle. *British Journal of Educational Psychology*, *81*(1), 1–23. https://doi.org/10.1111/j.2044-8279.2010.02014.x

Sorenson Duncan, T., Karkada, M., Deacon, S. H., & Smith, I. M. (2021). Building meaning: Meta-analysis of component skills supporting reading comprehension in children with autism spectrum disorder. *Autism Research*. https://doi-org/10.1002/aur.2483

Sorenson Duncan, T., Mimeau, C., Crowell, N., & Deacon, S. H. (2020). Not all sentences are created equal: Evaluating the relation between children's understanding of basic and difficult sentences and their reading comprehension. *Journal of Educational Psychology*. https://doi.org/10.1037/edu0000545

Stahl, S. A., & Fairbanks, M. M. (1986). The effects of vocabulary instruction: A model-based meta-analysis. *Review of Educational Research*, *56*(1), 72–110. https://doi-org/10.2307/1170287

Stenner, A. J., & Swartz, C. (2012, April). *A causal Rasch model for understanding comprehension in the context of reader-text-task*. Paper presented at the annual meeting of the National Council on Measurement in Education, Vancouver, Canada.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson.

Thornton, R. (2016). Children's acquisition of syntactic knowledge. *Oxford Research Encyclopedias*. https://doi.org/10.1093/acrefore/9780199384655.013.72

Tilanus, E. A. T., Segers, E., & Verhoeven, L. (2019). Responsiveness to intervention after second versus third grade diagnosis of dyslexia. *Reading & Writing Quarterly*: *Overcoming Learning Difficulties,* 521-541. https://doi.org/10.1080/10573569.2019.1667929

Tilstra, J., McMaster, K., Van den Broek, P., Rapp, D. (2009). Simple but complex: Components of the simple view of reading across grade levels. *Journal of Research in Reading*, *32*, 383–401. https://doi.org/10.1111/j.1467-9817.2009.01401.x

Tipton, E., & Pustejovsky, J. E. (2015). Small-sample adjustments for tests of moderators and model fit using robust variance estimation in meta-regression. *Journal of Educational and Behavioral Statistics*, *40*, 604–634. https://doi.org/10.3102/1076998615606099

Tong, X., & McBride, C. (2017). A reciprocal relationship between syntactic awareness and reading comprehension. *Learning and Individual Differences*, *57*, 33–44. https://doi.org/10.1016/j.lindif.2017.05.005

Tong, X., Yu, L., & Deacon, S. H. (in press). A meta-analysis on the relation between syntactic skills and reading comprehension: A cross-linguistic and developmental investigation. *Review of Educational Research*. Advanced online publication.

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2012). *Test of word reading efficiency – second edition* (TOWRE-2). Pro-Ed.

Tunmer, W. E. (1989). The role of language-related factors in reading disability. In D. Shankweiler & I.Y. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 91-131). University of Michigan Press.

Tunmer, W., Herriman, M., & Nesdale, A. (1988). Metalinguistic abilities and beginning reading. *Reading Research Quarterly*, *23*(2), 134-158. https://doi.org/10.2307/747799

Uccelli, P., Galloway, E. P., Barr, C. D., Meneses, A., & Dobbs, C. L. (2015). Beyond vocabulary: Exploring cross-disciplinary academic-language proficiency and its association with reading comprehension. *Reading Research Quarterly, 50*(3), 337–356. https://doi.org/10.1002/rrq.104

van Bergen, E., Snowling, M. J., de Zeeuw, E. L., van Beijsterveldt, C. E. M., Dolan, C. V., & Boomsma, D. I. (2018). Why do children read more? The influence of reading ability on voluntary reading practices. *Journal of Child Psychology and Psychiatry*, *59*(11), 1205–1214. https://doi-org/10.1111/jcpp.12910

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2013). *Comprehensive test of phonological processing – second edition*. (CTOPP-2). Pro-Ed

Wechsler, D. (2003). *Wechsler intelligence scale for children, fourth edition* (WISC-IV). APA PsycTests.

Wechsler, D. (2011). *Wechsler abbreviated scale of intelligence–second edition* (WASI-II). NCS Pearson.

Weighall, A. R., & Altmann, G. T. M. (2011). The role of working memory and contextual constraints in children's processing of relative clauses. *Journal of Child Language*, *38*(3), 579–605. https://doi-org/10.1017/S0305000910000267

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. Child Development, 69(3), 848–872. https://doi.org/10.2307/1132208

Willows, D. M., & Ryan, E. B. (1986). The development of grammatical sensitivity and its relation to early reading achievement. *Reading Research Quarterly*, *21*, 253-266.

Wolf, M. (2018). The science and poetry in learning (and teaching) to read. Phi Delta Kappan, 100(4), 13–17. https://doi.org/10.1177/0031721718815667

Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models: An evaluation of power, bias, and solution propriety. *Educational and Psychological Measurement*, *76(*6), 913–934. https://doi.org/10.1177/0013164413495237

Woodcock, R. W. (2011). *Woodcock reading mastery tests – third edition (*WRMT-III). Pearson.

Wothke, W. (1993). Nonpositive definite matrices in structural modeling. *Sage Focus Editions*, *154*, 256-256.

Zeno, S. (2005). *The educator's word frequency guide*. Touchstone Applied Science Associates.