Predictors of Reading Comprehension: A Model-Based Meta-analytic Review

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PREDICTORS OF READING COMPREHENSION:
A MODEL-BASED META-ANALYTIC REVIEW

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For my mother Barb, my grandmother Irene, and my God father Andy.
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ABSTRACT

The present study investigated the meta-relations among common components of reading comprehension. The Simple View of Reading (SVR, Hoover & Gough, 1990) posits that reading comprehension is the sum or product of linguistic comprehension and decoding. The meta-analysis presented here investigated extending the SVR using a two-stage correlational meta-analytic structural equation modeling (SEM) approach with added additional components of working memory, background knowledge, and reasoning and inference. A comprehensive literature search using terms related to reading comprehension and the hypothesized predictors produced a total of $k = 155$ included studies. Results of an expanded SVR model run on the full sample ($n = 1,205,581$) showed that none of the hypothesized added predictors accounted for additional variance beyond that accounted for by the SVR components of decoding and linguistic comprehension. Age was then considered as a moderator in these analyses. The correlation matrices were dichotomized into a younger (age < 11 years) and older cohort (age $\geq 11$ years). The SVR model fit the data well for both the younger cohort and the older cohort. Whereby both decoding and linguistic comprehension were important in earlier grades, once decoding was fluent, only linguistic comprehension was a significant predictor of reading comprehension for later grades. Neither working memory, background knowledge, nor reasoning and inference made significant contributions to reading comprehension in the older cohort. For the younger cohort, reasoning and inference was a statistically significant predictor of individual differences in reading comprehension but the additional variance accounted for was trivial. The models accounted for approximately 60% of the variance in reading comprehension. Results are presented in the context of the development of reading ability in the early elementary years and implications for policy and practice are discussed.
CHAPTER 1
INTRODUCTION

1.1 Rationale

Successful reading is the foundation of educational attainment and for securing economic and social opportunities beyond school. The latest release of the Nation’s Report Card indicates that only 35 percent of children in grade 4 and 36 percent of children in grade 8 have proficient reading skills (National Assessment of Educational Progress [NAEP], 2013). Proficient reading includes reading comprehension, “the process of simultaneously extracting and constructing meaning through interaction and involvement with written language.” (Snow, 2002, p. 11). Comprehension of a written task involves bottom-up word recognition processes and top-down comprehension processes supported by numerous component skills (e.g., Perfetti, 1999), and the development of reading comprehension depends upon the development of these underlying component skills (Tunmer & Hoover, 1993; Perfetti, Landi, & Oakhill, 2005). When there are deficits in one of these component skills, the ability to read and comprehend may fail. For example, deficits in word and non-word decoding, a hallmark of reading disability, result in impaired comprehension.

Identifying the key component skills for successful reading comprehension has implications in the diagnosis of specific learning disabilities. According to the Florida Department of Education, (FLDOE, 2014), when learning experiences are appropriate and adequate, yet the student fails to achieve or make adequate progress, the student may be referred for evaluation and identification of a learning disability. As adopted in FLDOE Rule 6A-1.09401, F. A. C, inadequate achievement relative to chronological age in oral expression, listening comprehension, basic reading skills, reading fluency, and/or reading comprehension can be used to determine if further evaluation is necessary.

The purpose of this meta-analysis was to expand on a previous meta-analysis that investigated the relations between decoding, linguistic comprehension and reading comprehension (Quinn, 2015) through including additional component skills of reading comprehension and through using a state-of-the-art approach for model-based meta-analysis.
1.2 Identifying Component Skills of Reading Comprehension

The Simple View of Reading (SVR, Gough & Tunmer, 1986; Hoover & Gough, 1990) is an established model of reading comprehension that posits that the sum and/or interaction of decoding and listening comprehension leads to successful reading comprehension. Decoding and listening comprehension are both necessary but neither are sufficient for successful reading comprehension: If there is decoding, but there is no translation to language, then a text is not understood. Accordingly, if there is no decoding, then written text cannot be translated and mapped on to the lexicon. This introduction is organized by way of this theory. First, decoding and related word reading constructs are introduced followed by the discussion of listening comprehension and other relevant oral language skills. Then, additional important cognitive components are considered.

1.2.1 Decoding

1.2.1.1 Word decoding. Decoding, also called word recognition, is the ability to interpret printed letters and words into their respective phonetic code (Perfetti, 1985). According to the verbal efficiency theory (Perfetti), word identification is a limiting factor in comprehension of written text. Knowledge of a word’s phonological and orthographic characteristics relies heavily on using the alphabetic principle, or the ability to represent a letter or a combination of letters by their phonemes (Adams, 1990; Rozin & Gleitman, 1977; Stanovich, 1986). Quickly identifying written words and activating associated relevant information, such as pronunciation, meaning, and sentence structures in which the word appear, aid in comprehending a text (Seidenberg & McClelland, 1989).

Accurate word recognition is a necessary but not sufficient condition of successful reading comprehension. Models of reading comprehension posit that decoding and language comprehension interact to result in successful reading comprehension. Oakhill, Cain, and Bryant (2003) argue each skill makes independent contributions to learning to read, even after controlling for IQ, age, and vocabulary. In earlier work studying poor comprehenders (e.g., Cain & Oakhill, 1996, 1999; Yuill & Oakhill, 1991), skilled comprehenders and poor comprehenders had adequate decoding skills, yet differed on text representations, such that skilled comprehenders developed more informative mental representations during reading.
A recent meta-analysis of 110 studies examining the relations between decoding and comprehension reported a high correlation (\( r = 0.74 \), Garcia & Cain, 2014). Further, they determined that age and listening comprehension ability significantly moderate these relations. Listening comprehension accounted for as much as 40% of the variance in the relations between decoding and listening comprehension. This relation was negative (\( \beta = -0.63 \)): increasing levels of listening comprehension ability were associated with decreasing correlations between decoding and reading comprehension. Additionally, as age of the readers increased, the strength of the decoding-reading comprehension relationship decreased, similar to the results of numerous studies and consistent with the SVR (e.g., Hoover & Gough 1990; Gough, Hoover, & Peterson, 1996; Keenan, Betjemann, & Olson, 2008).

1.2.1.2 Reading fluency. Efficient word recognition is an important aspect of reading fluency (Adams, 1990). Text reading fluency is the ability to accurately and efficiently read connected text (Fuchs, Fuchs, Hosp, & Jenkins, 2001; Kim & Wagner, 2015; National Institute of Child Health and Human Development [NICHD], 2000). Theories of reading fluency have been greatly influenced by the automaticity view of reading, such that a reader has limited attention capacities to give to cognitive tasks. The more attention given to word decoding, the less that is available to construct meaning from written text. Therefore, fast and accurate word reading facilitates reading comprehension (LaBerge & Samuels, 1974; Logan, 1988). Relatedly, Perfetti’s verbal efficiency theory also clarifies the relations between fluency and comprehension (Perfetti, 1985, 1992; Perfetti & Hart, 2001). According to this theory, efficient and fluent word reading increases the amount of attention resources available for higher order construction of meaning (Chall, 1983; Kim, 2015).

Correlations between measures of text reading fluency and reading comprehension range from moderate to high, with studies showing correlations as high as 0.91 (Fuchs et al., 2001; Fuchs, Fuchs, & Maxwell, 1988; Good, Simmons, & Kaméenui, 2001; Kim, Petscher, Schatschneider, & Foorman; 2010; Petscher & Kim, 2011; Roberts, Good, & Corcoran, 2005; Roehrig, Petscher, Nettles, Hudson, & Torgesen, 2008; Schatschneider, Harrell, & Buck, 2007). Further, text reading fluency explains additional variance in reading comprehension above and beyond language comprehension (Kim et al., 2012; Klauda & Guthrie, 2008).
There also exists evidence for longitudinal prediction. For example, oral reading fluency measured at the end of first grade was significantly related to reading comprehension at the end of second grade (Ridel, 2007). In an attempt to account for additional information on the relations between ORF and comprehension, Schatschneider, Wagner, and Crawford (2008) used end-of-year status on oral reading fluency and rate of growth to predict reading comprehension ability and growth. Results indicated that end-of-year status of oral reading fluency in first grade was positively related to reading comprehension at the end of first and second grades, but rate of growth in oral reading fluency did not provide any additional predictive information. Kim et al. (2010) observed different results, such that individual differences in oral reading fluency growth rate in first grade explained significant variance in reading comprehension at the end of first and third grades.

Although most of the research on the relations between oral reading fluency and comprehension have considered unidirectional relations in the direction that fluency affects comprehension, there is also evidence that improving comprehension skills can lead to more efficient and fluent reading (e.g., Jenkins, Fuchs, Van den Broek, Espin, & Deno, 2003; Smith, 2012). Further, the influence of contextual cues in efficient comprehension improves word reading speed and accuracy (Perfetti, Goldman, & Hogaboam, 1979; Perfetti & Roth, 1980). Additionally, longitudinal modeling of the relations between fluency and reading comprehension show bidirectional effects, such that fluency affects reading comprehension growth more strongly than the converse relation (Little, Hart, Quinn, Tucker-Drob, Taylor, & Schatschneider, in press).

Previous research on reading fluency has considered two types of fluency: fluency for reading connected text (text reading fluency) and fluency for reading isolated words (word reading fluency). These highly related yet separable constructs largely overlap in early reading development, such that word reading fluency is the primary contributor to individual differences in reading comprehension (Kim et al., 2012, 2014; Kim & Wagner, 2015). This is a result of primarily bottom-up processes accounting for reading at that time: Students are more dependent on decoding and have not yet mastered fluent reading recognition (Ehri, 2005). Text reading fluency begins to account for additional variance in reading comprehension as early as second grade (Kim et al., 2012) but normally by fourth grade (Jenkins et al., 2003; Kim & Wagner,
This reflects a switch from learning to read to reading to learn (Chall, 1983), whereby a child begins to engage in more top-down processing such as fluent reading, inference generation, and online comprehension monitoring (Cain & Oakhill, 2006; Kim & Wagner; Perfetti, 1982). For the purposes of this meta-analysis, word reading fluency and text reading fluency are treated as separate constructs, as previous research has shown that text reading fluency predicts reading comprehension above and beyond word reading fluency (e.g., Jenkins et al., 2003; Kim, 2015; Kim, Wagner, & Lopez, 2012).

1.2.2 Oral Language

As mentioned above, the SVR posits that reading comprehension is comprised of decoding and listening comprehension. This interplay between written and spoken components of language has been widely accepted as a model for reading comprehension, yet there is still doubt on how to define these specific components of listening comprehension. Important conceptualizations of relevant oral language skills are discussed in turn.

1.2.2.1 Listening comprehension. Listening comprehension is the ability to take lexical information and to interpret its meaning (Gough & Tunmer, 1986). This ability is vital to literacy skills. In a study of Korean kindergarten students, Kim (2015) found that listening comprehension made a significant contribution to reading comprehension ability above word reading after controlling for cognitive abilities and language skills such as vocabulary knowledge, working memory and theory of mind. Kendeou, van den Broek, White, and Lynch (2009) found that the ability to comprehend audio and televised stories significantly predicted future reading comprehension ability.

Much like reading comprehension, listening comprehension is supported by numerous important component skills. Not only is vocabulary knowledge important in predicting individual differences in listening comprehension (e.g., Florit, Roch, & Levorato, 2011), but higher-order cognitive skills such as inference ability (e.g., Tompkins, Guo, & Justice, 2013), theory of mind (Kim, 2015; Slade & Ruffman, 2005), and comprehension monitoring (Cain & Oakhill, 2006; Kim, 2015; Oakhill, Hartt, & Samols, 2005; Slade & Ruffman, 2005) have all been found to support listening comprehension skills.
In addition to direct causal relations from listening comprehension skills to reading comprehension, reciprocal relations exist between listening comprehension and reading comprehension. Specifically, in the early elementary years, these reciprocal relations have been found in a representative sample of Dutch students (Verhoeven & van Leeuwe, 2008). Verhoeven and van Leeuwe argued that “…listening comprehension and later reading comprehension are so intricately intertwined that progress on one variable more or less automatically promotes progress on the other” (p. 419).

1.2.2.2 Vocabulary knowledge. Vocabulary knowledge is directly implicated in the acquisition of and growth in pre-reading skills, word identification, and reading comprehension. Vocabulary size in particular is significantly related to listening comprehension (Florit et al., 2009; Kendeou, Bohn-Gettler, White, & van den Broek, 2008). Additionally, expressive and receptive word knowledge accounts for a large proportion of variance in listening comprehension ability at kindergarten (Florit, Roch, & Levorato, 2013; 2014). According to the lexical restructuring model (LRM, Metsala & Walley, 1998), vocabulary growth affects ones’ ability to notice phonetic units in streams of speech. Additionally, vocabulary knowledge is important for word recognition (Chiappe, Chiappe, & Gottardo, 2004; Lindsey et al., 2003). Levelt, Roelofs, and Meyer (1999) posited that children with larger and deeper vocabularies are at a distinct advantage over children with smaller and shallower vocabularies due to superior phonological and semantic representations, which allow for more efficient and accurate word identification.

Vocabulary knowledge is one of the most important predictors of reading comprehension (Anderson & Freebody, 1981; Beck & McKeown, 1991; McKeown, Beck, Omanson, & Perfetti, 1983; National Institute for Child and Human Development [NICHD, 2000], Ouellette, 2006). Muter, Hulme, Snowling, and Stevenson (2004) found that vocabulary knowledge was the most important predictor of reading comprehension, even after controlling for word recognition, phonemic awareness, and letter knowledge. This unique additional variance has also been found in struggling readers, as adding measures of depth and breadth of vocabulary accounted for additional variance in reading comprehension above and beyond decoding and listening comprehension measures (Braze et al., 2007). Breadth and depth of vocabulary measure how many words one knows and how well one knows those words, respectively (Ouellette, 2006). Both Ouellette (2006) and Tannenbaum, Torgesen, and Wagner (2006) have shown that
measures of breadth and depth individually account for unique variance in reading comprehension in third- and fourth-grade students.

Recent advances in longitudinal modeling have enabled the simultaneous examination of growth both within and across domains of development. For instance, the co-development of vocabulary knowledge and reading comprehension has been modeled using latent change score modeling (McArdle, 2009). In two studies using this method, vocabulary knowledge was found to be a significant predictor of change in reading comprehension, but the converse relation was not found (e.g., Reynolds & Turek, 2012; Quinn, Wagner, Petscher, & Lopez, 2015). However, separate studies found bidirectional relations between vocabulary and reading comprehension (Ferrer et al., 2007, 2010; Quinn, Wagner, Menzel, Petscher, Schatschneider, & McArdle, 2016), although the influence of vocabulary on reading comprehension was larger than that of reading comprehension on vocabulary.

Morphological awareness, or the ability to recognize and manipulate morphemes (Carlisle, 1995), is highly related to vocabulary knowledge (e.g., McBride-Change, Wagner, Muse, Chow, & Shu, 2005; Wagner, Muse, & Tannenbaum, 2007). A number of studies show the two are indistinguishable over time (e.g., Kirby et al., 2012; Nagy, Berninger, Abbott, Vaughn, & Vermeulen, 2003; Spencer et al., 2015), yet others show these skills become more distinct over time (Deacon, Kieffer, Laroche, 2014; Kieffer & Lesaux, 2012). For instance, Kieffer and Lesaux (2012) found that vocabulary breadth, contextual sensitivity, and morphological awareness were separable factors, but Spencer et al. (2015) found that vocabulary knowledge and morphological awareness were best described by a single underlying dimension.

Due to its highly correlated nature with vocabulary knowledge, morphological awareness is also a significant direct predictor of reading comprehension performance (e.g., Carlisle, 2000; 2003; Deacon et al., 2014; Kirby et al., 2012), and has been shown to be a unique predictor of reading comprehension above vocabulary knowledge (e.g., Deacon & Kirby, 2004; Nagy, Berninger, & Abbott, 2006). These findings may be due in part to morphological awareness being helpful in inferring the meanings of unknown words (Nagy & Anderson, 1984). In the present study, morphological awareness and vocabulary knowledge were combined in to a single factor for the analyses.
1.2.3 Potentially Important Predictors Missing from the Simple View

Dissociation and independent contributions of word reading and listening comprehension have been examined with typically developing children as well as children with dyslexia (e.g., Kendeou et al., 2009; Tunmer & Greaney, 2010). The SVR, then, assumes a complete mediation model such that the influences of language and cognitive skills on reading comprehension is indirect via listening comprehension and word reading. Support for this comes from research simultaneously investigating the relations between decoding and linguistic comprehension on reading comprehension (e.g., Hart & Quinn, 2015; Quinn, 2015). In contrast, the multicomponent view of reading (Cain, 2009; Cain et al., 2004) posits that multiple component skills, such as background knowledge, working memory, and inference or reasoning, make distinct contributions to RC. Therefore, an alternative model is that these language and cognitive skills might be related to reading comprehension over and above listening comprehension and word reading.

1.2.3.1 Background knowledge. Background knowledge affects comprehension. The research on background knowledge is largely based on schema theory: A schema is an abstract structure of knowledge that assists in summarizing what is known about a subject (Hirsch, 2003). These schemas of prior knowledge are useful for (a) making inferences about what is being read, (b) directing attention to important information in a domain of knowledge, and (c) providing a plan for information recall (Anderson & Pearson, 1984).

In support of this schematic theory view, students with high amounts of domain knowledge comprehend a text better than their low-domain knowledge peers. For instance, Adams, Bell, and Perfetti (1995) found that high-skilled readers in fourth through seventh grades with little domain knowledge compensate for this lack of knowledge by relying on their general reading skill. Conversely, low-skilled readers with high domain knowledge compensate for poorer reading skills by relying on their specific domain knowledge. Domain knowledge and vocabulary knowledge make significant but distinct impacts on comprehension (Stahl, Chou Hare, Sinatra, & Gregory, 1991) and domain knowledge facilitates inference and processing of whole texts (Fincher-Kiefer, 1992). Background knowledge more strongly facilitates reading comprehension as a reader ages (Evans, Floyd, McGrew, & Leforgee, 2001), and in addition to
domain-specific knowledge, knowledge of written and spoken language devices such as irony or metaphors is important for understanding ambiguous texts (Hirsch, 2003).

A vital component of comprehension skill is identifying semantic relations between the information in the text and between this information and a reader’s background knowledge (van den Broek, 2005), and research has supported both memory-based and constructionist processes as the source for making these connections. The memory-based view of text processing states that information in the text activates a reader’s background knowledge as the reader engages with the text, triggering a spread of activation through the knowledge base to related information (Gerrig & McKoon, 1998; Gerrig & O’Brien, 2005; McKoon, Gerrig, & Greene, 1996; Myers & O’Brien, 1998). This activation is passive, occurring in a reader’s episodic memory of the text already read and through semantic memory of related background knowledge (McKoon & Ratcliff, 1992). The more similar the concepts are to previously encountered (and subsequently stored) information, the more readily these processes occur (e.g., Myers & O’Brien, 1998). The constructionist view evolved in direct contrast to this minimalist view in that it proposes there are active and strategic processes a reader uses to accomplish explicit and implicit goals during text reading (van den Broek, 2005). Readers employ their background knowledge and generate inferences during active text reading to satisfy these goals (Graesser, Singer, & Trabasso, 1994; Singer, Graesser, & Trabasso, 1994).

Background knowledge has directs effects on the comprehension of written text (e.g., Dole, Valencia, Greer, & Wardrop, 1991; Lee, 1995; Spires & Donley, 1998). It is also indirectly implicated through mediating factors such as strategy usage (e.g., Miyake & Norman, 1979; O’Donnell, 1993) and inference generation (e.g., Vidal-Abarca, Martinez, & Gilabert, 2000) or both processes (e.g., Cromley & Azvedo, 2007), and is highly correlated with both word reading and vocabulary knowledge (e.g., Cunningham & Stanovich, 1991, 1997).

1.2.3.2 Working memory. Working memory is a cognitive system important for temporarily storing, manipulating, and processing actively held information (Baddeley, 1992; Baddeley & Hitch, 1974). Working memory involves simultaneous storage and active manipulation of information (see Baddeley, Eysenck, & Anderson, 2009, for a review), and has been hypothesized as a foundational cognitive skill that supports higher level cognitive skills such as comprehension monitoring and inference making (e.g., Oakhill, Hartt, & Samols, 2005;
Slade & Ruffman, 2005). Working memory has been found to be an important predictor of reading comprehension across a wide range of grades and reader ability levels even after controlling for word reading ability, vocabulary, and verbal skills (Cain, Oakhill, & Bryant, 2004; Perfetti, Landi, & Oakhill, 2005; Seigneuric & Ehrlich, 2005; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000; Swanson & Berninger, 1995). Presumably, during reading comprehension, working memory serves as a means of storing relevant information about the text as a means of facilitating the comprehension process (Gernsbacher, Varner, & Faust, 1990), and thus, is a critical component to understanding written text.

Stronger working memory capacity allows a reader to retain recently processed information and make connections with previously processed text to generate an overall representation and subsequent understanding of the text (Cain, Oakhill, Bryant, 2004; Swanson & O’Connor, 2009; Swanson, 1999). There is substantial evidence that working memory has a direct impact on individual differences in reading comprehension for young children (i.e., 7-through 11-year-olds; Cain, Oakhill, & Bryant; Seigneuric & Ehrlich, 2005; Seigneuric et al, 2000). Working memory also makes a unique contribution to listening comprehension (Florit et al., 2009; Was & Woltz, 2007) and reading comprehension for children in middle elementary grades and upper grades and adults. Additionally, poor comprehenders have lower working memory capacity than good comprehenders (Oakhill et al., 2005).

Although there has been cross-sectional and longitudinal evidence for the importance of working memory to reading comprehension across development, some studies have found that working memory does not account for unique reading comprehension variance after accounting for several component skills (Oakhill & Cain, 2012; Tighe & Schatschneider, 2014; Tighe, Wagner, & Schatschneider, 2015). For example, Tighe et al. (2015) found that working memory was not uniquely predictive of reading comprehension for third, seventh, or tenth graders after controlling for decoding, verbal reasoning, and nonverbal reasoning. In a longitudinal investigation, Oakhill and Cain (2012) found that working memory did not contribute unique variance to reading comprehension at any of the four time points (7 through 11-year-olds) independent of word reading ability, verbal skills, vocabulary knowledge, discourse skills, and the autoregressive effect of comprehension.
Working memory may have an indirect effect on reading comprehension through other literacy-based mediators, such as fluency and decoding (Daneman, 1991; Daneman & Merikle, 1996; Swanson & O’Connor, 2009), verbal and semantic skills (Nation et al., 1999), and/or attentional control or mind wandering (McVay & Kane, 2012). The *compensatory hypothesis* suggests that fluency (i.e., the automaticity and speed of reading) underpins the relationship between working memory and reading comprehension. Thus, according to this hypothesis, increasing fluency skills may result in an improvement in reading comprehension because demands on working memory capacity will be reduced (Swanson & O’Connor). Decoding also acts as mediator of the relation between working memory and reading comprehension. Studies have demonstrated that working memory only plays a minor role in explaining variance in reading comprehension after accounting for decoding skills (Goff, Pratt, & Ong, 2005; Shankweiler & Crain, 1986), but conflicting evidence shows that working memory remains a significant predictor of growth in reading comprehension when accounting for both decoding skills and vocabulary knowledge (e.g., Quinn, Tighe, Spencer, & Wagner, 2016).

**1.2.3.3 Reasoning and inference.** Working memory is highly related to intelligence, such that demands placed on one construct reduces capacity for the other construct (Au, Sheehan, Tsai, Duncan, Buschkuehl, & Jaeggi, 2015; Gray, Chabris, & Braver, 2003; Halford, Cowan, & Andrews, 2007; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; van der Sluis, de Jong, & van der Leij, 2007). Reasoning skills are important for understanding not only spoken language around us, but in understanding and making connections in our own knowledge.

Measures of verbal reasoning usually involve verbal analogies tasks using word puzzles or pictures, and measures of nonverbal reasoning usually involve mental rotation tasks or replacing missing pieces to match abstract patterns. Verbal and non-verbal reasoning tasks are significantly correlated with word reading and non-word reading (Pammer & Kevan, 2007). Additionally, before response-to-intervention became the research standard, IQ-discrepancy models of dyslexia were popular (for a review, see Stuebing et al., 2002; see also Quinn & Wagner, 2015). Given the measurement error inherent to diagnosing based on a pre-specified cut-off value of a single criterion, this method has been criticized. Newer models of identification include using RTI on a variety of variables and using hybrid models to identify reading disabilities (see Spencer et al., 2014; Schatschneider, Wagner, Hart, & Tighe, 2016).
Inference generation from written text involves using available information and background knowledge to interpolate or extrapolate missing information. It is important for constructing a situation model (Kintsch, 1988) and constructing semantic representations (Kintsch & Kintsch, 2005; van den Broek, 1994). Information from long-term memory and contextual clues help to establish a coherent interpretation of missing information. The use of context is particularly important, in that this ability involves identifying semantically related sentences (Kintsch).

Inference is important for listening comprehension (Lepola et al., 2007; Lynch & van den Broek, 2007; Tompkins et al., 2013) and for reading comprehension (Cain et al., 2004; Kendeou et al., 2008). Training and longitudinal studies provided converging evidence that inferential skills make a unique contribution to reading and listening comprehension (Lepola et al., 2012; Oakhill & Cain, 2012; Yuill & Joscelyne, 1988; Yuill & Oakhill, 1988; see also McGee & Johnson, 2003). Moreover, there is evidence that inferential skills directly predicted reading and listening comprehension over and above the autoregressor effect of prior comprehension and lower-level components (Lepola et al., 2012; Oakhill & Cain, 2012). Additionally, children who have normal vocabulary and decoding skills but poor comprehension ability have been shown to have poor inference making ability (e.g., Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001).

1.3 The Present Study

The present study was conducted to examine meta-analytic relations between reading comprehension and these additional important constructs and to answer the following questions:

1. What are the meta-analytic correlations between decoding accuracy, decoding fluency, text reading fluency, listening comprehension, vocabulary knowledge, background knowledge, working memory, reasoning and inference, and reading comprehension?
2. How much variance is accounted for in reading comprehension through the Simple View of Reading?
3. How much additional variance is accounted for in reading comprehension when adding working memory, background knowledge, or reasoning and inference to the meta-SEM?
4. Does the addition of moderators (e.g., grade, reader ability) affect the meta-SEM results?
CHAPTER 2

METHODS

2.1 Literature Base

2.1.1 Search Criteria

Using PsycINFO, ProQuest (Dissertations and Theses, PQTD), and ERIC, a primary search of the literature was conducted to identify studies that included one of the following phrases in the title of the document: *reading comprehension* OR *text comprehension* OR *simple view of reading* OR *simple view*. To ensure retrieval of empirical studies, the abstract must have also contained *predict* OR *develop* OR *assoc* OR *relat* OR *depend* OR *connect* OR *occur* (the asterisk is to denote all extensions of the word are acceptable, e.g., prediction, development). All studies must have been published from 1990 on, as methods for teaching reading and measuring reading ability differed substantially prior to this time. Additionally, included studies must have had one or more of the following key words as a subject: *reading* (or *reading comprehension* or *text comprehension*), *working memory* (or *short term memory* or *verbal memory*), *intelligence* (or *IQ* or *verbal aptitude*), *reasoning* (or *inference*), and *background knowledge* (or *print knowledge* or *letter knowledge* or *schema theory* or *prior knowledge* or *domain knowledge*) (see Appendix A for all related search terms).

A complete search of the literature resulted in 4,258 studies being identified using the criteria outlined above and given in detail in Appendix A. After removing duplicate sources, a total of 2,404 studies were identified (1,350 from PsycINFO and ProQuest and 1,054 from ERIC). Due to issues with retrieval of manuscripts from the databases, the total number of studies subjected to exclusionary criteria was reduced to 1,815.

2.1.1.1 Exclusion criteria. Due to the large number of studies identified as potentially important to the meta-analysis, exclusionary criteria were applied in two steps. Within the first step, the titles of the articles were screened for studies that included special populations (individuals with an intellectual disability [ID] or Down’s Syndrome, individuals with brain injuries, lesions, aphasia or other abnormalities, or individuals with vision or hearing...
impairments, deafness, or cochlear implants) or children with extreme or specific behavioral problems (i.e., individuals with Autism Spectrum Disorder [ASD], individuals with attention deficit/hyperactivity disorder [ADHD] or other severe behavioral problems). A total of 71 studies conducted on special populations were excluded, and an additional 47 studies including individuals with behavior problems were excluded. Studies including students with reading impairments or disabilities were not excluded in order to include covariates and a full range of reading ability. Additionally, studies unrelated to text reading, non-empirical studies, single-case studies, corrigendum, and commentaries were excluded, resulting in an additional 110 studies excluded. Lastly, studies conducted on English language learning (ELL) individuals and studies not conducted in English were excluded, resulting in an additional 300 studies excluded. This was to remove the possibility of different writing systems having effects on the relations between the predictors of interest and reading comprehension ability, as it has been shown that the SVR theory applies differently to transparent and opaque orthographies (Florit & Cain, 2011; Tobia & Bonifacci, 2015). Applying these four exclusionary criteria to the titles resulted in the exclusion of 528 total studies.

The full texts of the remaining 1,287 studies were then consulted to determine if the study was eligible to be included in analyses. Studies must have measured individual constructs (i.e., no composite scores that combine multiple target constructs will be included) and measures must have been collected within the same year (i.e., only concurrent correlations were included, with the exception of adult learners [older than 16 years old]). Studies must have had a correlation coefficient between a measure of reading comprehension and at least one predictor variable, and studies must have been related to text reading. Two hundred and twelve studies were excluded due to issues with retrieval, 514 studies were excluded because they were not relevant to text reading, 181 were excluded because they were conducted on non-English populations, 43 studies were discarded because they were duplicates, and an additional 182 studies were excluded due to insufficient data to be included in the analyses. The authors of 19 of these 182 studies could be contacted, but 15 could no longer provide the data. In total, $k = 155$ studies, denoted with asterisks within the References, were included in the present analyses.
2.2 Moderator Variables

In an effort to account for possible heterogeneity in estimates of correlations, important moderators were considered. The average age of the participants in each study was coded to determine if the relations held in younger versus older students. Additionally, if the study reported separate correlation matrices for students with and without a reading problem, these matrices were coded separately. This was to allow for the analysis of reader ability on the meta-analytic correlation matrices to determine if these models were different in students with and without reading problems. Where possible, these status groups were coded separately for reading impairment (i.e., word-level reading problems), comprehension impairment (i.e., comprehension-level problems), and learning disability not otherwise specified.

2.3 Univariate vs. Multivariate Meta-Analytic Approaches

The primary studies included in this meta-analysis were, for the most part, conducted by different researchers at different universities with different samples and procedures. The number of effect sizes reported in each study varied greatly. Traditionally, a univariate approach has been taken to construct a composite correlation matrix in which separate meta-analyses are carried out for each cell of the matrix. There are problems with this approach, including the practical problem of determining the appropriate number of studies and sample sizes to be used in analyses based on the composite correlation matrix. Newer and more preferred approaches for constructing a composite correlation matrix take a multivariate approach.

2.3.1 Multivariate Approach

Meta-SEM models use a multivariate approach to estimate the composite correlation matrix by considering homogeneity among the included studies and estimating the asymptotic sampling covariance matrix. For example, Becker (1992; 1995; 2000; 2009) proposed a model-based meta-analysis approach by fitting a generalized least square model to correlational data. An average correlation matrix among relevant variables is estimated under a random effects model, and variation relevant to studies is included in the estimation of confidence intervals around the estimated correlations. Through standardized multiple regression models, the relations among variables that takes their covariances into account can be estimated (Becker, 2000; 2009).
Cheung and Chan (2005) extended this GLS method to a two-stage structural equation modeling (TSSEM) approach that uses multiple-group SEM to pool correlation matrices in the first stage of the analysis, and then using weighted least squares (WLS) estimation to weigh the precision of the pooled correlation matrix in fitting the proposed SEM(s). Through the second stage, the weighing of the correlational elements allows for the sampling covariance matrix to assign different weights to the cells depending on their precisions. Thus, there is no need to decide on one sample size to use for the estimation of model effects across the included variables (Cheung, 2015). The present study used the two-staged multivariate approach to estimate the pooled correlation matrix and to analyze the relations among the included variables.

2.4 Coding Scheme

Each study was coded for the following information and recorded in a spreadsheet using Microsoft Excel: Study name and year, sample of students, age(s) or grade(s) of the sample, reader status of the sample (e.g., reading disability, typical readers), and available correlations between reading comprehension and the eight predictor variables. Additionally, the types of measures used in the study were included below the matrix for moderator analyses. Where correlations were missing from a study, the cell was left blank. If a cell had more than one correlation, the method used by the National Reading Panel (NRP, 2000) was adopted by averaging the effect sizes together.

2.4.1 Reliability of Coding

To assess reliability, an independent coder coded 20 of the identified studies to establish acceptable inter-rater reliability of the scheme. The mean kappa was .94 (.82-1.0) for the correlative matrices, and was 1 for age, .95 for reader ability designation, and 1 for sample size.

2.5 Correlational Meta-Analyses

2.5.1 Fixed Versus Random Effects Models

It is reasonable to expect that there were study-specific correlations due to differences in samples, measures, and study designs. As such, a random-effects model was adopted. Additionally, a random effects model allows for the generalization of findings to be outside of the studies used in a meta-analysis. The R package metaSEM (Cheung, 2014) provides a two-
stage structural equation modeling (TSSEM) method to first calculate the sampling covariance matrix of the correlations and to estimate a pooled correlation matrix. The second stage of the TSSEM analyzes the pooled correlation matrix according to the user’s hypothesized models.

Using metaSEM, the $I^2$ statistic was estimated to quantify the heterogeneity of the correlations in a random effects multivariate approach. This was defined as:

$$I^2_{Q(Mul)} = 1 - \frac{df_{Mul}}{Q_{Mul}}$$

Where $Q_{Mul}$ and $df_{Mul}$ are the $Q$ statistic and its dfs in testing the homogeneity of effect sizes using the following equation:

$$Q = (y - X\beta)^T V^{-1} (y - X\beta)$$

where $y$ is a $p_i \times 1$ stacked vector of effect sizes, $X$ is $p_i \times p$ design matrix with 0 and 1 to select the observed effect sizes, and $V$ is a block diagonal (symmetric) matrix of the conditional sampling covariances.

2.6 Meta-Analytic Structural Equation Models

After creating the pooled correlations using the first step of the TSSEM approach, the pooled correlation matrix was analyzed using the second stage of the TSSEM approach in R. For this approach, the estimated values of the stage 1 results were treated as sample statistics in the stage 2 analysis. Similar to a structural equation modeling (SEM) framework, latent variables were conceptualized as true effect sizes in this meta-analysis. Residual variances and disturbance terms in these models can be considered the amount of variance unaccounted for in the data from these studies that may be attributable to heterogeneity in sampling, measured variables, or similar sources of variance.

Cheung (2015) identified a potential problem with pooling correlation matrices: It is difficult to choose one sample size to use for the second stage of the analysis. Instead, the author proposed a weighted-least squares (WLS) estimation method, where different weights are applied to the elements in the estimated common correlation matrix depending on their precisions. In fitting a structural model on the population correlation matrix $P(\theta)$, the discrepancy function for the proposed structural model $\rho(\theta) = vech\{P(\theta)\}$ is
\[ F_{WLS}(\theta) = (r_R - \rho_R(\theta))^T V_R^{-1} (r_R - \rho_R(\theta)). \]

This approach weights the elements of the correlation tables by the inverse of their sampling covariance matrix. The first stage of the TSSEM approach used different weights to take account of the precision of the estimates. The sample size of a study was not involved in the function defined above; it was only involved indirectly by affecting the estimation of \( V_R \) from the first stage of the analysis in metaSEM.

2.6.1 Hypothesized a Priori Models

A series of structural equation models were fit to the composite correlation matrix created in the first step of the TSSEM. Using metaSEM, the structural models fit to the data differed from traditional SEMs in important ways. First, the latent variables specified below represented the common variance across related constructs, unlike traditional SEM that considers this a reflection of the common variance across measures of the same construct. Secondly, residual variances and disturbance terms in these models can be considered the amount of variance unaccounted for that may be attributable to heterogeneity in sampling and measurement.

2.6.1.1 Model 1. In the first model, the Simple View of Reading was fit using separate higher-order factors accounting for shared variance between the five variables (word reading fluency, text reading fluency, decoding accuracy, vocabulary/morphological knowledge, and listening comprehension). This model was similar to the original SVR models from Gough and Tunmer (1986) and Hoover and Gough (1990); however, the present study only utilized the additive model due to the use of correlational data. A multiplicative model in which reading comprehension was posited to be the result of the interaction between decoding and linguistic comprehension could not be estimated.

In this model, a higher order linguistic comprehension factor with two indicators (vocabulary/morphological knowledge and listening comprehension) and a higher order decoding factor with three indicators (decoding accuracy, word reading fluency, and text reading fluency) were defined. The use of higher order factors accounted for the shared variance across decoding accuracy, text reading fluency, and word reading fluency and across vocabulary knowledge and listening comprehension.
Additionally, pathways from working memory, reasoning and inference, and background knowledge were included in this model, thereby expanding on the SVR in important ways to include constructs that have been extensively studied and supported as important contributors to individual differences in reading comprehension.

2.6.1.2 Model 2. In this model, the structural equation model from Model 1 was fit; however, text reading fluency was also cross-identified by both the linguistic comprehension factor and the decoding factor to create a complex indicator. There is reason to believe that at older ages, text reading fluency is predicted by not only bottom up processes such as decoding fluency and accuracy, but also by top-down processes related to language comprehension (LaBerge & Samuels, 1974; Perfetti, 1992). A nested-model comparison test was conducted between Model 1 and Model 2 to determine the significance of including the cross-loading parameter.

2.6.1.3 Moderator analyses. The first stage of the TSSEM estimates the amount of heterogeneity due to cluster effects in the form of a \( Q \) statistic (see above). A significant \( Q \) statistic provides information on conducting relevant moderator analyses. During the coding procedure, both average age of the sample and reader ability status were coded to be included as moderators. While there was enough information to group the correlation matrices according to average age, there was not enough information to create the full composite correlation matrix for both the typical sample of readers and for readers with learning or reading disabilities. As such, only moderator analyses using age were conducted on the above models.

2.6.2 Model Fit

Model fit was assessed using the chi-square test of model fit and its degrees of freedom, the confirmatory fit index (CFI), the Tucker-Lewis index (TLI), and the root mean-squared error of approximation (RMSEA). Maximized CFI and TLI values (> .95), minimized RMSEA values (< .08), and a low ratio of the chi-square value to its degrees of freedom (<= 2) were preferred (Kline, 2011). Nested models were compared using chi-square difference testing, and non-nested models were compared using the Bayesian Information Criteria (BIC), where models with lower values (towards negative infinity) were preferred (Raftery, 1995).
CHAPTER 3

RESULTS

3.1 First Stage Results

3.1.1 Descriptive Statistics

Results of the first stage of the TSSEM approach are presented in Table 1. Correlations between the nine predictor variables ranged from low to moderate (0.271 – 0.699), but all were significantly different from zero. The strongest correlation was between measures of word reading fluency and text reading fluency, and the weakest correlation was between measures of reasoning and inference and word reading fluency. The average sample size across all included studies was \( n = 5,530 \). The harmonic mean, which considers both large and small sample sizes by bringing them more towards the central tendency of the distribution, was \( n = 114 \). In sum, \( n = 1,205,581 \) participants from \( k = 155 \) studies were included in the present meta-analysis.

3.2 Second Stage Results

Stage 2 of the TSSEM approach tested Model 1 and Model 2 by using the correlation matrix estimated in stage 1. This approach was beneficial because it was a multivariate approach that considered each study’s sample size instead of relying on using one single sample size (e.g., the average sample size or harmonic mean), thereby increasing the precision of the parameter estimates. Results for each model are presented in turn.

3.2.1 Full Sample: Model 1

The hypothesized expanded SVR model was fit to the stage 1 results of the TSSEM approach. This model provided excellent fit to the data, \( \chi^2 [16] = 43.5206, \text{CFI} = 0.9953, \text{TLI} = 0.9979, \text{RMSEA} = 0.0012, \text{BIC} = -180.5189 \). The results of this model are presented in Figure 1. The loadings of word reading fluency \( \lambda = 0.710, p < .001 \), decoding accuracy \( \lambda = 0.784, p < .001 \), and text reading fluency \( \lambda = 0.869, p < .001 \) were all significant and positive, indicating that the latent construct of decoding captured significant common variance across the included studies. A similar pattern of loadings for vocabulary and morphological knowledge \( \lambda \)
= 0.759, p < .001) and listening comprehension (λ = 0.637, p < .001) were seen, indicating that the construct of linguistic comprehension was also capturing significant common variance between these two indicators. The loading for listening comprehension onto the higher order factor for linguistic comprehension was lower than the other four indicators, signifying that there was a significant portion of variance unexplained by the linguistic comprehension factor (e = 0.594).

The regression pathways from the higher order factors of linguistic comprehension (β = .578, p < .001) and decoding (β = .265, p < .001) were significant and positive. Additionally, these parameters were significantly different, as constraining them to equality resulted in significant degradation of model fit (χ²[1] = 4.134, p < .05). There was a stronger contribution of linguistic comprehension to individual differences in reading comprehension than decoding.

Further, the regression pathways for working memory (β = -0.029, p = 0.274), background knowledge (β = -0.091, p = 0.185), and reasoning and inference (β = 0.065, p = 0.068) were all non-significant. After accounting for individual differences in decoding and linguistic comprehension skills, these three additional constructs did not predict significant additional variance in reading comprehension.

3.2.2 Full Sample: Model 2

Model 2 estimated the same general structure of the SEM from Model 1, but with an additional cross-loading from linguistic comprehension onto the indicator of text reading fluency to create a complex indicator. This model also provided good fit to the data (χ²[15] = 40.6121, CFI = 0.9953, TLI = 0.9981, RMSEA = 0.0012, BIC = -169.425). The path estimates for this model are presented in Figure 2. The cross-loading from the linguistic comprehension factor to text reading fluency was not significant (λ = 0.157, p = 0.0537). Additionally, the parameter estimates are mostly unchanged from Model 1, such that only linguistic comprehension (β = .597, p < .001) and decoding (β = .257, p < .001) account for significant variance in reading comprehension after accounting for the other variables in the model. The difference in BIC (+11.094) and a non-significant difference in chi-square values (Δχ²[1] = 2.9085, p < .05) did not justify the addition of this cross-loaded pathway for the full sample of correlation matrices.
3.3 Moderator Analyses

Before conducting the second stage of the TSSEM on the studies for younger versus older children, the first stage of the TSSEM approach was used to create separate composite correlation matrices for these two groups. Both Model 1 and Model 2 were then fit separately to these matrices. In order to ensure there were enough data to estimate separate models for younger and older children, the age variable was dichotomized at 11 years. This dichotomization represents children in grades 5 and below for the younger cohort and grades 6 and above for the older cohort.

3.3.1 Younger Cohort

The composite correlation matrix and heterogeneity estimates for the younger children are contained in Table 2. Correlations ranged from low to moderately high (0.278 – 0.740). The correlations between listening comprehension and word reading fluency (r = 0.311), between word reading fluency and working memory (r = 0.312), and between working memory and text reading fluency (r = 0.318) were all homogenous, indicating that the way studies measured these constructs for younger children was consistent. During model fitting in the first stage of the TSSEM approach, it was discovered that there was not enough information across the included studies in the young cohort (k = 79) to estimate the meta-correlations for background knowledge. For the purposes of this portion of the meta-analysis, background knowledge was removed from the models for the younger cohort.

3.3.1.1 Younger Cohort: Model 1. The expanded SVR was fit to the composite correlation matrix for the younger cohort. This model provided excellent fit to the data, ($\chi^2 [13] = 24.551$, CFI = 0.9972, TLI = 0.9987, RMSEA = 0.0013, BIC = -146.7995). The results of this model are presented in Figure 3. The loadings of word reading fluency ($\lambda = 0.787$, $p < .001$), decoding accuracy ($\lambda = 0.800$, $p < .001$), and text reading fluency ($\lambda = 0.877$, $p < .001$) were all significant and positive, indicating that the latent construct of decoding was capturing significant common variance across the included studies. A similar pattern of loadings for vocabulary and morphological knowledge ($\lambda = 0.747$, $p < .001$) and listening comprehension ($\lambda = 0.662$, $p < .001$) were estimated, indicating that the construct of linguistic comprehension was also capturing significant common variance. The loading for listening comprehension onto
the higher order factor for listening comprehension was lower than the other four indicators, signifying that there was a significant portion of variance unexplained by the linguistic comprehension factor ($e = 0.562$).

The regression pathways from the higher order factors of linguistic comprehension ($\beta = 0.578$, $p < .001$) and decoding ($\beta = 0.265$, $p < .001$) were both significant and positive, indicating that after accounting for all other predictors in the model, both decoding skills and linguistic comprehension predict unique, significant variance in reading comprehension. In addition to these two SVR components, reasoning and inference emerged as a unique, significant predictor of variance in reading comprehension ($\beta = 0.101$, $p = .031$). Working memory did not emerge as a significant predictor after accounting for the other predictors in this model ($\beta = -0.036$, $p = .407$).

### 3.3.1.2 Younger Cohort: Model 2.

Model 2 was then fit to the younger composite cohort correlation matrix. This model also provided good fit to the data ($\chi^2 [12] = 20.125$, CFI = 0.9978, TLI = 0.9991, RMSEA = 0.0011, BIC = -138.0442). The path estimates for this model are presented in Figure 4. The cross-loading from the linguistic comprehension factor to text reading fluency was significant in this model ($\lambda = 0.207$, $p = .0154$). Additionally, the parameter estimates were mostly unchanged from Model 1, such that linguistic comprehension ($\beta = 0.597$, $p < .001$), decoding ($\beta = 0.257$, $p < .001$), and reasoning and inference ($\beta = 0.106$, $p = .0150$) accounted for unique variance in reading comprehension. A non-significant difference in BIC values (+8.7553) and a significant improvement in chi-square values ($\Delta \chi^2 [1] = 4.4260$, $p < .05$) justified the inclusion of the significant cross-loading from linguistic comprehension to text reading fluency.

### 3.3.2 Older Cohort

The first stage of the TSSEM was conducted in R on the studies with cohorts of older children ($k = 86$). The composite correlation matrix and associated heterogeneity statistics for this sample are presented in Table 3. The correlations ranged from low to moderate ($r = 0.243 – 0.596$). Additionally, the correlations between listening comprehension and word reading fluency ($r = 0.313$), between word reading fluency and reasoning and inference ($r = 0.243$), between background knowledge and word reading fluency ($r = 0.302$), and between listening
comprehension and background knowledge (r = 0.517) were all homogenous, indicating the way these four constructs were measured in the older cohort was consistent across the included studies.

3.3.2.1 Older Cohort: Model 1. The expanded SVR was fit to the composite correlation matrix for the older cohort. This model provided excellent fit to the data, ($\chi^2 [16] = 26.1206$, CFI = 0.9965, TLI = 0.9984, RMSEA = 0.0010, BIC = -188.5714). The results of this model are presented in Figure 5. The loadings of word reading fluency ($\lambda = 0.648, p < .001$), decoding accuracy ($\lambda = 0.756, p < .001$), and text reading fluency ($\lambda = 0.841, p < .001$) were all significant and positive, indicating that the latent construct of decoding captured significant common variance across the included studies. A similar pattern of loadings for vocabulary and morphological knowledge ($\lambda = 0.758, p < .001$) and listening comprehension ($\lambda = 0.629, p < .001$) were estimated, indicating that the construct of linguistic comprehension also captured significant common variance. Similar to the younger cohort, the loading for listening comprehension onto the higher order factor for listening comprehension was lower than the other four indicators, signifying that there was a significant portion of variance unexplained by the linguistic comprehension factor ($e = 0.604$).

The regression pathway from the higher order factors of linguistic comprehension ($\beta = 0.882, p < .001$) was significant and positive, indicating that after accounting for all other predictors in the model, linguistic comprehension predicts unique, significant variance in reading comprehension. However, decoding was not a significant, unique predictor of reading comprehension once linguistic comprehension was accounted for ($\beta = 0.004, p = .979$). This supports the SVR, whereby it was posited that once decoding is automatic and fluent, linguistic comprehension begins to account for most of the variance in reading comprehension. Background knowledge ($\beta = -0.214, p = .177$), working memory ($\beta = -0.001, p = .979$), and reasoning and inference ($\beta = 0.034, p = .628$) all were not unique predictors after accounting for the other predictors in this model.

3.3.2.2 Older Cohort: Model 2. Model 2 was then fit to the older composite cohort correlation matrix. This model also provided good fit to the data ($\chi^2 [15] = 21.1661$, CFI = 0.9977, TLI = 0.9991, RMSEA = 0.0008, BIC = -180.1076). The path estimates for this model
are presented in Figure 6. The cross-loading from the linguistic comprehension factor to text reading fluency was significant in this model ($\lambda = 0.327, p = .0028$). The addition of this cross-loading changed the loading of text reading fluency on to the decoding factor ($\lambda = 0.482, p = .0003$), reflecting the shared variance between these two higher order constructs in accounting for variance in text reading fluency. Additionally, the regression estimates are mostly unchanged from Model 1, such that linguistic comprehension ($\beta = 0.952, p < .001$) is the only construct to account for unique variance in reading comprehension. A non-significant difference in BIC values (+8.4638) and a significant improvement in chi-square values ($\Delta \chi^2 [1] = 4.9545, p < .05$) justifies the inclusion of the significant cross-loading from linguistic comprehension to text reading fluency for the older cohort of children.
CHAPTER 4

DISCUSSION

The present study used a relatively new and advanced meta-analytic structural equation modeling approach to analyzing a composite correlation matrix of important predictors of reading comprehension over 155 studies and over 1 million subjects. The results of the two-stage modeling approach supported the Simple View of Reading: once decoding and linguistic comprehension skills were accounted for, working memory, background knowledge, and reasoning and inference making abilities did not account for additional variance in explaining individual differences in reading comprehension.

4.1 The Simple View of Reading

4.1.1 Decoding

The higher order construct of decoding included three indicators that have been shown to individually predict variance in reading comprehension across a wide range of ages (Jenkins et al., 2003; Kim et al., 2014). The decision to separate word reading into both a decoding accuracy and decoding fluency component occurred due to the imperfect correlation between timed and untimed measures of word level reading. Additionally, text reading fluency was considered separately because it has been showed that reading words in context can improve the accuracy and efficiency with which they are read (Kim et al., 2011; Kim et al., 2012). Further, once decoding skills become fluent, there was reason to believe that reading words in context for fluency would be influenced by language and linguistic skills. This hypothesis was supported, as the fitting of Model 2 for the older cohort resulted in a significant cross-loading of text reading fluency onto both the decoding and linguistic comprehension higher order factors. The cross-loading of linguistic comprehension on to text reading fluency was also significant for the younger cohort; however, the magnitude of the loadings were significantly different, indicating that decoding skills were still more vital to text reading fluency than linguistic comprehension for younger children.

Once linguistic comprehension was accounted for, decoding was no longer a unique predictor of reading comprehension for the older sample. This was not unsurprising, given the shift from learning to read to reading to learn that occurs in the late elementary years (Chall, 1986). That decoding would not predict any variance in reading comprehension, however, was
surprising, as these skills should still be necessary for understanding a written text. For the younger sample, both decoding and linguistic comprehension made similar, unique contributions to the comprehension of written text.

4.1.2 Linguistic Comprehension

Linguistic comprehension was an important, unique predictor of reading comprehension for the full sample and for both the younger and older cohorts. Linguistic comprehension made the largest contribution to comprehension of written text for the older students, such that no other predictor in the model was significant (see Figures 5 and 6).

The estimated residual variances for some constructs were high (e.g., residual variance for listening comprehension). As mentioned previously, the residual variances estimates can be considered the amount of variance unaccounted for in these models. Differences in how these constructs are measured can have a large impact on the parameter estimates, because correlations may change depending on how they are measured. Particularly, the construct of listening comprehension included not only receptive measures of language, but also expressive measures of language. Future studies should consider oral expression as a separate, unique construct in an effort to provide more stable, valid indicators of a linguistic comprehension higher order factor. Additionally, the study-specific correlations can also differ when samples vary widely in sampling characteristics such as SES, ethnicities, and reader ability. For the most part, the latent constructs accounted for significant amounts of variance in the individual indicators included in the meta-analysis.

4.2 The Impact of the Additional Predictors

4.2.1 Working Memory

Previous studies have found that working memory has an important role in reading comprehension (e.g., Cain et al., 2004; Quinn et al., 2016; Seigneuric et al., 2005), yet the present study did not find evidence of working memory as a significant, independent predictor. It is important to note that particularly for Quinn et al. (2016), the measure of working memory was a listening span task that tapped into the language abilities of the children. Additionally, other studies have used reading span tasks to measure working memory in children, presenting with the issue of common method variance between a predictor skill and criterion skill. This confound may bias the results of the present study and should be considered a limitation. Future studies should consider non-verbal working memory, such as digit span tasks, as a purer measure
of working memory that can account for variance outside of the criterion skill of reading comprehension, or consider verbal and nonverbal working memory separate in SEMs of reading comprehension.

While a direct relation between working memory and reading comprehension was not supported in the current study, previous studies have found that working memory may act on reading comprehension through mediators such as fluency and decoding (Daneman, 1991; Daneman & Merikle, 1996; Swanson & O’Connor, 2009), verbal and semantic skills (Cunningham & Stanovich, 1991, 1997; Nation et al., 1999), and attentional control or mind wandering (McVay & Kane, 2012). It is possible that the working memory variable included in this meta-analysis had an indirect effect on reading comprehension through the decoding or linguistic comprehension higher order factors.

4.2.2 Background Knowledge

Background knowledge did not emerge as a unique predictor in any of the meta-SEMs. This was a surprising finding, due to evidence suggesting its importance in schema development and in the application of this knowledge to content areas such as science (e.g., Evans et al., 2001; McKoon et al., 1996; Myers & O’Brien, 1998). However, background knowledge is indirectly important to reading comprehension through mediating factors such as strategy usage (e.g., Miyake & Norman, 1979; O’Donnell, 1993), inference generation (e.g., Vidal-Abarca, Martinez, & Gilabert, 2000), and both strategy use and inferences skills (e.g., Cromley & Azvedo, 2007). Like working memory, background knowledge may act indirectly in these models.

Background knowledge was highly correlated with linguistic comprehension for both the older cohort \( r = 0.718 \) and for the full sample \( r = 0.698 \), yet the regression pathway from background knowledge to reading comprehension in the older sample was non-significant and negative for Model 1 \( \beta = -0.214 \) and for Model 2 \( \beta = -0.233 \). Given that background knowledge and linguistic comprehension were positively correlated, and both background knowledge and linguistic comprehension were both positively correlated with reading comprehension, there is reason to believe that this multicollinearity caused net suppression to occur in this model (Cohen & Cohen, 1983, Cohen, West, Aiken, & Cohen, 2003). Future models could consider background knowledge as an indicator or mediator of linguistic comprehension in its relation to reading comprehension.
4.2.3 Reasoning and Inference

Reasoning and inference was a unique predictor of reading comprehension, but only for the younger cohort of children. This could be due to having fewer predictors in the model for the younger cohort than for the older cohort due to issues with the missing data for background knowledge. Additionally, though this predictor was significant, it accounted for only a small amount of the variance in reading comprehension. However, it is surprising that this construct was not a unique predictor of reading comprehension for the older sample, as it has been shown that inference skills are particularly important for reading comprehension in later grades after controlling for lower-level skills (e.g., Cain et al., 2004; Kendeou et al., 2008; Lepola et al., 2012). The coding for this variable combined non-verbal reasoning ability and inference-making skills into one latent construct, which may have had an effect on either construct’s ability to predict unique variance in the outcome variable. Future studies should consider coding these as separate abilities in order to determine their importance in explaining individual differences in reading comprehension.

4.3 Limitations

The results of this study need to be considered in the context of several important limitations, discussed in turn below.

4.3.1 Missing Components

4.3.1.1 Missing bottom-up processes. First, this analysis only included predictor variables for comprehension to test the original SVR model. However, additional cognitive components have been implicated in the simple view (e.g., Johnston & Kirby, 2006; Kirby & Savage, 2008; Ouellette & Beers, 2010; Savage, 2001; Stuart, Stainthorp, & Snowling, 2008; Tunmer & Chapman, 2012). Phonological awareness (PA) has been identified as a significant source of variance in reading abilities (Quinn, Spencer, & Wagner, 2015; Wagner & Torgesen, 1987) and is important in the early identification of reading disability (Brady, Braze, & Fowler, 2011). A highly related skill, rapid automatized naming (RAN), is also strongly related to concurrent and longitudinal measurement of reading ability (Badian, 1993; Bowers, 1995; Denckla & Rudel, 1976; Wolf, Bally, & Morris, 1996), even after controlling for phonological awareness (Bowers, 1995; Kirby et al., 2003; Manis, Doi, & Bhadha, 2000). Slow naming speed ability is a characteristic common to children with reading disabilities (e.g., Denckla & Rudel, 1976; Wolf, 1991), and a double-deficit in naming speed and phonological awareness is
associated with more severe reading problems (Bowers & Wolf, 1993; Swanson & Berninger, 1995; Swanson, Trainin, Necoechea, & Hammill, 2003). Future meta-analyses or studies should consider the important contributions of phonological awareness and RAN in learning to read, particularly by way of the development of accurate and fluent decoding skills.

4.3.1.2 **Missing top-down processes.** There exist additional high-order cognitive constructs that account for variance in reading comprehension, such as comprehension monitoring (e.g., Cain & Oakhill, 2012; Oakhill, Hartt, & Samols, 2005) and executive functioning (e.g., shifting, inhibitory control; Christopher et al., 2012). This meta-analysis was comprised of studies that, for the most part, included widely-used measures of the predictor constructs that are standardized and/or well-established. Most measures of metacognition and other higher-order processes are limited in their scope, are researcher-based, and are not standardized (with the exception of well-established reasoning tasks). Future research including these important predictors in the estimation of a larger correlation matrix is needed.

4.3.2 Methodological Concerns

4.3.2.1 **Range restriction.** The date range of studies was limited to the past 26 years. This reduces the amount of studies that would meet criteria had studies been accepted from years prior to 1990. Future meta-analyses should include studies from before 1990 and use year or range of years as a moderator to test for the effect of differences in measures, educational standards, and methodologies over time.

4.3.2.2 **Dichotomization.** Age was dichotomized to produce a matrix for a younger sample of children who were younger than age 11 and an older sample of children who were aged 11 and older. Dichotomizing continuous variables has been heavily criticized (e.g., MacCallum, Zhang, Preacher, & Rucker, 2002; Maxwell & Delaney, 2004), as it produces a loss of effect size and power, loss of information regarding individual differences, and loss of measurement reliability. However, most of these criticisms are directed at dichotomizing scales that are normally distributed (e.g., using cut-points on a continuous scale of ability or skill). While the use of age as a continuous moderator would have been ideal, the solution in this study is justified in that there are reasons to believe children younger children will have different patterns of predictor importance than older children. The results of the meta-SEM presented here supported this, however; the model for the younger cohort and older cohort cannot be directly compared due to inability to analyze the same covariance structure across these cohorts.
4.3.2.3 Reader ability status. Reader status was coded for all studies but was not able to be included as a moderator in the meta-SEM analyses. This limits the ability to investigate whether the parameter estimates and model structure are different across separable groups of impairment, which is an important distinction. An additional study on the differences between these groups is warranted and necessary.

4.3.2.4 Bidirectional relations. The expanded SVR posited a unidirectional, multivariate model such that the SVR components, linguistic comprehension and decoding, additively lead to successful reading comprehension, but it ignored the fact that reading comprehension may also cause changes in these constructs. In a large-scale study of at-risk readers, Quinn et al. (2016b) investigated the longitudinal relations between reading comprehension and vocabulary and found that there are bidirectional coupled relations. Reading comprehension is a significant predictor in gains in vocabulary knowledge, an important component of linguistic comprehension. Additionally, Hart and Quinn (2016) used latent change score modeling to examine the development of the simple view in a sample of students measured in kindergarten, second, fourth, and sixth grades. Reading comprehension is a significant and negative predictor of reading recognition (a measure of word decoding), such that those with better comprehension tend to change less in decoding ability. Additionally, there are positive bidirectional relations between vocabulary knowledge and reading recognition. These important cross-construct causal relations are ignored in this review (as posited by the SVR) but should be included in future studies.

There is also reason to believe that reading comprehension may affect the other three important predictors included in the meta-analysis. Reading comprehension may have a significant impact on expanding one’s background knowledge and ability to generate inferences due to exposure alone. Further, reading comprehension may impact working memory, though this bidirectional relationship was not supported in a recent paper using latent change score modeling that used listening span to measure working memory (Quinn et al., 2016a).

4.3.2.5 Reliability of measurement. One final limitation of the current study was that the reliability of the measures was not controlled for at the individual study level. While some studies had information about measurement reliability, the included studies did not consistently provide this information. Additionally, the estimation of decoding and linguistic comprehension higher order latent factors privileged these variables in the predictor model, since these variables
had their reliability adjusted in the estimation of the latent variable structure. Future studies should consider multiple indicators of working memory, background knowledge, and reasoning and inference to create stable latent variables that consider measurement reliability at the study level.

4.4 Implications and Future Directions

Given the limitations of the present meta-analysis, the results still provide implications for education policy and practice.

4.4.1 Implications for Education Policy and Practice

Decoding and linguistic comprehension are important for reading comprehension. Individual differences in fluency, accuracy, vocabulary, and listening comprehension have implications in comprehension of written text. While the additional variables in the expanded SVR model did not significantly and directly predict individual differences in reading comprehension, there is evidence that these variables are indirectly related to reading comprehension. For example, improvements in fluency skills may result in an improvement in reading comprehension by reducing the workload required by a child’s working memory (Swanson & O’Connor, 2009). Improvements in the mediating factors may result in increased impacts of background knowledge, working memory, and reasoning and inference on reading comprehension due to decreased demands placed upon these higher order skills.

The results of the meta-SEMs indicated that the original SVR model is sufficient in explaining individual differences in reading comprehension for older students; however, for younger students, it is apparent that reasoning and inferences skills provide an additional source of individual differences in the comprehension of written text. While non-verbal reasoning skills tend to be crystallized, the inclusion of inferencing skills as a target for early intervention may prove beneficial in the long term. Inferencing skills help a reader to generate ideas regarding the text that may be missing or vague, allowing for the reader to create a situation model of the text and thereby facilitating other higher order skills such as comprehension monitoring (Cain & Oakhill, 2006; Oakhill, Hartt, & Samols, 2005).

Establishing a valid and reliable model of reading comprehension is important for educational research and policy, particularly in the identification of impaired readers. Previous studies using constellation or hybrid models to identify students with reading disability have had
promising results (e.g., Spencer et al., 2014) and highlight the importance of including multiple sources of information in the estimation and prediction of reading ability.

4.4.2 Future Directions

These results presented supported the SVR, particularly the expanded SVR for younger children, but there remain additional sources of variance outside of these models. At best, the meta-SEM models accounted for a little over 60% of the variance in reading comprehension skills. The remaining 40% of variance unaccounted for has vital implications for how we define and measure reading comprehension. Future meta-analyses on the development of reading comprehension should include more sources of information to account for additional variance that the present study did not, and should explore indirect models that consider mediating relations between original variables of the SVR and the added components.

4.5 Concluding Remarks

The meta-SEM results presented here were provided by the first multivariate, large-scale meta-analysis to be conducted on individual differences in reading comprehension. This promising statistical approach can benefit researchers of any field, but is particularly beneficial for the education sciences, where curricula, measures, and samples can vary extremely. The two stage approach to combining correlation matrices across multiple studies and considering the covariances between correlations provides a unique way to account for this stochastic dependence. In sum, the meta-SEM approach provided a composite correlation matrix of the nine included variables and fit multiple models to the data that supported both the original and expanded versions of the SVR.
APPENDIX A

LITERATURE SEARCH CRITERIA

Reading Comprehension alone:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su(reading comprehension OR text comprehension)

Reading Comprehension and Vocabulary/Morphology terms:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su(vocabulary OR "word knowledge" OR lexic* OR "morpholog* knowledge" OR "morpholog* awareness")

Reading Comprehension and Fluency terms:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su("reading fluency" OR "oral reading fluency" OR "text reading fluency" OR "fluency" OR
"word reading fluency")

Reading Comprehension and Decoding terms:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su("decoding" OR "word recognition" OR "alphabetic principle" OR "word identification" OR
"word reading")

Reading Comprehension and Oral Language terms:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su("oral comprehension" OR "language comprehension" OR "listening comprehension" OR
"linguistic comprehension" OR grammar OR synta* OR semantic*)

Reading Comprehension and Reasoning/Inference terms:

"reading comprehension" OR "text comprehension" OR "simple view of reading") AND
ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND
su("inference" OR "reasoning" OR "inference generation" OR "inference making" OR
"intelligence" OR "verbal reasoning" OR "nonverbal reasoning")
**Reading Comprehension and Working Memory terms:**

```
ti("reading comprehension" OR "text comprehension" OR "simple view of reading") AND ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND su("working memory" OR "short term memory" OR "memory" OR "verbal memory" OR "listening span" OR "digit span" OR "reading span")
```

**Reading Comprehension and Background Knowledge:**

```
ti("reading comprehension" OR "text comprehension" OR "simple view of reading") AND ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND su("background knowledge" OR "schema knowledge" OR "schema theory" OR "domain knowledge" OR "prior knowledge" OR "print knowledge" OR "letter knowledge" OR "print awareness")
```

**Reading Comprehension and all search terms:**

```
ti("reading comprehension" OR "text comprehension" OR "simple view of reading") AND ab(predict* OR develop* OR assoc* OR relat* OR depend* OR connect* OR occur*) AND su("background knowledge" OR "schema knowledge" OR "schema theory" OR "domain knowledge" OR "prior knowledge" OR "print knowledge" OR "letter knowledge" OR "print awareness" OR "reading comprehension" OR "text comprehension" OR vocabulary OR "word knowledge" OR lexic* OR "morpholog* knowledge" OR "morpholog* awareness" OR "reading fluency" OR "oral reading fluency" OR "text reading fluency" OR "fluency" OR "word reading fluency" OR "decoding" OR "word recognition" OR "alphabetic principle" OR "word identification" OR "word reading" OR "oral comprehension" OR "language comprehension" OR "listening comprehension" OR "linguistic comprehension" OR grammar OR synta* OR semantic* OR "inferenc*" OR "reasoning" OR "inference generation" OR "inference making" OR "intelligence" OR "verbal reasoning" OR "nonverbal reasoning" OR "inference*" OR "reasoning" OR "inference generation" OR "inference making" OR "intelligence" OR "verbal reasoning" OR "nonverbal reasoning" OR "working memory" OR "short term memory" OR "memory" OR "verbal memory" OR "listening span" OR "digit span" OR "reading span")
```
### APPENDIX B

**COMPOSITE CORRELATION MATRICES**

**Table 1.** Correlations and heterogeneity statistics for the nine included constructs.

<table>
<thead>
<tr>
<th>Construct</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
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<td>.988</td>
<td>.988</td>
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<td>.869</td>
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<td>.983</td>
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<td>.977</td>
<td>.969</td>
<td>.988</td>
<td>.972</td>
<td>.977</td>
</tr>
<tr>
<td>5. V/M</td>
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<td>.413</td>
<td>.520</td>
<td>.480</td>
<td>--</td>
<td>.987</td>
<td>.986</td>
<td>.979</td>
<td>.992</td>
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<tr>
<td>6. LC</td>
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<td>.401</td>
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<td>.482</td>
<td>--</td>
<td>.960</td>
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<td>--</td>
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<td>.990</td>
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<td>.344</td>
<td>.321</td>
<td>.331</td>
<td>.327</td>
<td>.342</td>
<td>--</td>
<td>.976</td>
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<tr>
<td>9. BGK</td>
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<td>.381</td>
<td>.423</td>
<td>.423</td>
<td>.535</td>
<td>.431</td>
<td>.378</td>
<td>.328</td>
<td>--</td>
</tr>
</tbody>
</table>

*Note.* Correlations are below the diagonal; heterogeneity statistics are above the diagonal. RC = reading comprehension; WRF = word reading fluency; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. R/I = reasoning and inference; BGK = background knowledge. Bolded values indicate homogenous correlations.
<table>
<thead>
<tr>
<th>Construct</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>.987</td>
<td>.983</td>
<td>.976</td>
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<tr>
<td>6. LC</td>
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</tbody>
</table>

Note. Correlations are below the diagonal; heterogeneity statistics are above the diagonal. RC = reading comprehension; WRF = word reading fluency; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension; R/I = reasoning and inference; BGK = background knowledge. Bolded values indicate homogenous correlations. Background knowledge was excluded from the analyses for the younger cohort due to insufficient data.
## Table 3. Correlations and heterogeneity statistics for the older cohort.

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<td>.865</td>
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</table>

*Note.* Correlations are below the diagonal; heterogeneity statistics are above the diagonal. RC = reading comprehension; WRF = word reading fluency; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension; R/I = reasoning and inference; BGK = background knowledge. Bolded values indicate homogenous correlations.
Figure 1. Meta-SEM path diagram of Model 1 for the full sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; BGK = background knowledge; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
Figure 2. Meta-SEM path diagram of Model 2 for the full sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; BGK = background knowledge; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
Figure 3. Meta-SEM path diagram of Model 1 for the younger sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
Figure 4. Meta-SEM path diagram of Model 2 for the younger sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
Figure 5. Meta-SEM path diagram of Model 1 for the older sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; BGK = background knowledge; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
Figure 6. Meta-SEM path diagram of Model 2 for the older sample. * = p < .001. Dashed, grey pathways are not significant. WM = working memory; R/I = reasoning and inference; BGK = background knowledge; WRF = word reading fluency; DEC = decoding accuracy; TRF = text reading fluency; V/M = vocabulary/morphological knowledge; LC = listening comprehension. e = residual variance error terms, d = disturbance term.
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BIOGRAPHICAL SKETCH

Jamie Quinn attended Florida State University for her undergraduate studies, where she majored in psychology and minored in statistics. She worked as an undergraduate research assistant with Dr. Paul Ward in cognitive psychology and was active in the Psi Chi chapter in the Department of Psychology. In addition, she completed an Honors Thesis project that received the Bess Ward Honors Thesis Ward and the Howard D. Baker Undergraduate Research Award under the direction of Dr. Richard Wagner, which is now published in the Journal of Learning Disabilities. She was a member of the Marching Chiefs and Seminole Sound pep band, and was an active sister of the Beta Alpha chapter of Sigma Alpha Iota. She graduated Magna Cum Laude, With Honors, and Phi Beta Kappa in May of 2010.

She is currently a doctoral student in the developmental area of the Department of Psychology at Florida State University and is advised by Dr. Richard Wagner. She works in conjunction with the Florida Center for Reading Research and Florida Learning Disabilities Research Center as a graduate research assistant. She received her Master of Science degree in Developmental Psychology in December of 2012 and completed an IES Pre-doctoral Interdisciplinary Research Training Fellowship in August of 2015. She was awarded the Russell and Eugenia Morcom Career Development Award in 2014 and the Jane M. West Fellowship in 2015. She is active in multiple professional societies for education research and child development and is a manuscript peer reviewer for multiple interdisciplinary journals. Jamie’s main research interests lie in identifying important predictors of reading ability and failure from a methodological and statistical angle and in evaluating the effectiveness of large-scale education intervention studies. Upon the receipt of her doctoral degree, Jamie will continue these lines of research as she pursues a postdoctoral research fellow position at the Meadows Center for Preventing Educational Risk at the University of Texas at Austin with Drs. Greg Roberts and Sharon Vaughn.