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The Relation among Phonological Processing, Oral and Silent Reading Fluency, and Reading Comprehension for Students with Dyslexia: A Longitudinal Investigation

Melissa Fetterer Robinson

THE RELATION AMONG PHONOLOGICAL PROCESSING, ORAL AND SILENT READING FLUENCY, AND READING COMPREHENSION FOR STUDENTS WITH DYSLEXIA: A LONGITUDINAL INVESTIGATION

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Melissa Fetterer Robinson

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Abstract

The purpose of this study was to examine the relations among phonological skills, oral and silent reading fluency, and reading comprehension for a longitudinal sample of students who have been diagnosed with dyslexia. Only two studies to date have modeled the relation between oral and silent reading fluency and comprehension, of which only one addressed phonological processing. No studies to date have modeled these relations in students with dyslexia. Participants in this study were 104 students in grades 2-5 with dyslexia, who were administered oral and silent reading fluency and comprehension assessments and selected phonological processing measures at the beginning and end of the school year. A cross-lagged path analysis was used to examine the relations among the phonological processing and text-level reading skills. A developmental model was also examined, but the inclusion of age as a covariate resulted in poor fit. Among the phonological skills included in the model, RAN showed the most robust and consistent relations to text-level reading skills across both modalities. In terms of reading fluency, oral accuracy made the strongest contribution to comprehension across both modalities. Ultimately, the results followed a pattern of progression from lower to higher reading skills, and indicated that oral reading supports silent skills.

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Introduction

Reading fluency is an important skill that contributes to a reader's comprehension of text and has been constructively referred to as the "bridge" to comprehension (e.g., Pikulski & Chard, 2005). Fluency impacts comprehension because it consists of a conglomeration of skills (i.e., accuracy, automaticity, and oral reading prosody) which facilitate the construction of meaning from written text (Kuhn, Schwanenflugel, & Meisinger, 2010). Fluency is an essential factor in both oral and silent reading modalities that can either support or limit comprehension (Kuhn et al., 2010). Strong correlations (between .50 and .85) are typically found between reading comprehension and reading fluency during the time when early reading skills are burgeoning (Schwanenflugel & Knapp, 2016). Furthermore, students' growth in oral reading fluency rates have been found to predict later comprehension performance (Kim, Petscher, Schatschneider, & Foorman, 2010). Although reading fluency has been examined at various levels of the reading process (i.e., sub-lexical, lexical, phrase), for the sake of parsimony we will use this term to denote reading at the connected text level.

Oral reading fluency deficits are common for those individuals who have been identified as having a specific learning disability (SLD) in reading. Lyon, Shaywitz, & Shaywitz (2003) label dysfluency, the inability to read fluently, as a hallmark characteristic of individuals who have dyslexia. It is important to note that the current version of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) does not include a diagnostic code for dyslexia; it is subsumed under specific learning disorder in reading and states that dyslexia is an alternative term used to refer to problems with poor decoding and spelling abilities and difficulties with accurate or fluent word recognition (American Psychiatric Association, 2013).

The International Dyslexia Association (2002) defines the diagnosis of dyslexia as,

> ..a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (p. 1).

These definitions highlight deficits in phonological skills that can lead to the dysfluency and subsequent difficulties with comprehension. Additionally, Torgesen (2005) purports that the word reading difficulties experienced by these students who have dyslexia is the primary barrier to good reading comprehension performance and also impedes the development of fluent reading. In regard to remediation, many studies have found that improvement in oral reading fluency has been harder to obtain than word reading skills (Lyon et al., 2004; Meyer & Felton, 1999; Torgesen et al., 2001; Torgesen, 2005). According to Lefly and Pennington (1991) and Shaywitz (2003), issues with dysfluency often continue even after readers have become more accurate in their reading. Emerging research even supports the existence of a subgroup of dyslexic readers with specific deficits in text oral fluency (who may also experience deficits in rapid naming speed and comprehension) (Meisinger, Bloom, & Hynd, 2010).

The purpose of this research was to further elucidate relations between two modalities (e.g. silent and oral) of reading fluency and comprehension for students with dyslexia. In addition, this research aimed to add extra elements (i.e., areas of phonological processing deficits) that have been identified as core deficits for students identified with dyslexia. These are important skills for children to master in regard to reading achievement in order to successfully navigate through the educational realm, and research in this area is needed to inform assessment practices and intervention efforts. In order to understand how these variables (i.e., phonological processing, oral and silent reading fluency, comprehension) relate to one another, core theoretical frameworks, areas of phonological processing deficits, and the role of reading modality is reviewed in subsequent sections.

Theoretical Frameworks

LaBerge and Samuels' (1974) automaticity theory offers a compelling framework for how reading fluency influences comprehension. Automatic processes occur with speed, without conscious awareness or even intent, and are obligatory in nature (Logan, 1997). Samuels (2006) summarizes three assumptions made by automaticity theory: (1) the brain has a limited capacity when it comes to performing difficult tasks, (2) the mental effort it takes to perform these difficult tasks (e.g., recognizing words in the text) consumes part of that limited capacity, and (3) practicing lessens the amount of effort required to performs these tasks. Thus, when the amount of effort it takes to perform a difficult task lessens substantially (e.g., decoding and identifying words), one can then take on a new task (e.g., comprehending text) simultaneously (Samuels, 2006). Once the process of reading becomes automatic, words can be read as fast as digits, because they are being processed as a single unit in a process termed unitization (LaBerge & Samuels, 1974). Furthermore, LaBerge and Samuels (1974) distinguish between automaticity and accuracy by proposing that attention is necessary for processing when it comes to the accuracy level; however, attention is not necessary once the process has become automatic as reading becomes fluent. In sum, reading fluency is often perceived as the bridge between decoding and comprehension (Pikulski & Chard, 2005).

Automaticity theory (LaBerge & Samuels, 1974) is a way of explaining how a beginning reader transforms into an expert, skilled reader; but it is a general, overarching theory of automatic information processing in reading. Other theoretical frameworks such as Perfetti's verbal efficiency theory (1977, 1984) and Ehri's theory of sight word reading (1998, 1999, 2002) extend the automaticity theory by addressing how phonological skills contribute to the reading process and to the development of automatic word decoding. Verbal efficiency theory postulates that there are three skills that support lexical access (i.e., vocabulary, orthographic, and phonological skills), and that these skills are necessary for the process of reading and comprehending text. Similar to LaBerge and Samuels' (1974) model, verbal efficiency theory proposes that when lower-level processes that support access to lexical information are executed efficiently, cognitive resources are freed for higher-order processes such as comprehension (Perfetti & Hart, 2001). When the system is inefficient, reading difficulties arise and this can impede the reader's comprehension. The slow rate at which the text is read and processed interferes with the reader's capacity to hold large units of text in their working memory, further limiting the reader's capacity to manipulate and organize the information from text (Perfetti, 1977, 1984).

Ehri's (1998, 1999, 2002) sight word reading theory emphasizes a visual-phonological connection between the written word and its other identities in memory. Ehri (1998) proposed a four-phase alphabetic model of reading that describes the progression a reader takes to become an automatic decoder of words. The importance of this model lies in its focus on automatic decoding at the word-level (i.e., sight word reading), which tends to be an area of weakness for those who have dyslexia. Ehri's model describes the process of unitization in the third phase, referred to as the full alphabetic phase, where readers can decode and blend unfamiliar words together as single units with the use of storing and retrieving words from long term memory to aid in faster decoding (Ehri, 1998). Ehri's theory describes how automatic sight word reading develops, but does not address its relation to comprehension, text fluency, or other reading skills. However, informational processing theories such as those offered by LaBerge & Samuels (1974) and Perfetti (1977, 1984) bridge that gap by emphasizing that issues with cognitive processing of low-level skills (e.g., phonological processing) impact one's performance on higher-order reading skills (e.g., comprehension, inference-making).

Areas of Phonological Processing Deficits

Consensus exists that weaknesses in phonological processing represent a core area of deficit for students with dyslexia. Meta-analytic findings point to deficits in the areas of phonological awareness, rapid automatized naming (RAN), and phonological memory (Johnson, Humphrey, Mellara, Woods, & Swanson, 2010; Melby-Lervåg, Lyster, & Hulme, 2012). Wagner, Torgesen, Rashotte, & Pearson (2013) purport a model of reading-related phonological processing that emphasizes these three core phonological skills as distinct constructs whose relations vary across development. Research suggests that phonological memory and phonological awareness are highly correlated with one another, while RAN is only moderately correlated with other skills (Wagner et al., 2013). However, the strength of the relations among the three aspects of phonological skills weakens as children grow older and gain abilities in reading (Wagner et al., 1987; Wagner et al., 1993).

Phonological awareness, a core phonological skill, refers to one's ability to recognize and manipulate the sound structure of spoken words (Wagner et al., 2013). Research suggests that the development of phonological awareness in children follows a hierarchical pattern, advancing from the ability to isolate sound units (i.e., syllables or words) to intermediate units (onsets versus rimes) to the smallest units in our language (phonemes; Stanovich, 1992; Treiman & Zukowski, 1991). Melby-Lervåg et al. (2012) conducted a meta-analysis that examined phonological skills and its relation to reading development. They found 37 studies that investigated phonemic awareness among students with dyslexia and that had a comparison group of reading-level controls (i.e., group of students without reading difficulties). Meta-analytic results indicated that students with dyslexia tend to perform less well on phonemic awareness tasks than compared to reading-level controls. Across the longitudinal studies examined in their meta-analysis, a mean correlation of .43 was found between phonemic awareness measured in preschool–kindergarten and later decoding skills (Melby-Lervåg et al., 2012). Similar results were also supported by longitudinal meta-analytic findings of the National Institute for Literacy (2008), with a mean correlation of .42 between phonemic awareness in early childhood and later decoding skills across studies. The link between deficits in phonological awareness and difficulty in decoding words helps to explain why learning to read is especially difficulty for children who have dyslexia (Szenkovits & Ramus, 2005; Hulme & Snowling, 2009). As students begin learning to read, they start to process small words in a system where one sound corresponds to one letter (Ehri 1999, 2002, 2005). As they go through the various reading phases of development, these students can process two syllable words and compound words, and even get to processing multi-syllabic words (Ehri 1999, 2002, 2005). For those students with weakness in phonological awareness, there are targeted interventions (e.g., Bowyer-Crane et al., 2008) that can help build up this basic, foundational, lower-level reading skill that is essential for supporting the development of decoding, sight-word reading, and reading fluency skills (Gray & McCutchen, 2006; Kibby et al., 2014; Wagner et al., 1997; Wolf and Bowers, 1999). Indeed, early interventions in phonological awareness have been shown to greatly decrease the incidence of later reading difficulties (National Institute for Literacy, 2008).

A second subcomponent of phonological processing is phonological memory, which refers to the coding of phonological information for temporary storage in one's short-term (i.e., a proposed intermediary memory system that holds information as it travels from sensory memory to long-term memory) or working memory (i.e., the information that is currently available in one's memory for working on a problem) (Wagner et al., 2013). Deficits in phonological processing have been linked to issues with working memory's role in supporting comprehension (Rayner, Pollatsek, Ashby, & Clifton, 2011). The phonological loop is the part the working memory model and is involved with briefly storing phonological information and holding auditory information in the phonological store (Baddeley, 1986, 1992; Torgesen, 1996). The phonological loop consists of the phonological store (i.e., tape-recording loop that can hold up to 2 seconds of auditory information) and an articulatory control process (i.e., this second piece can provide input and refresh information to the phonological loop so that it can be stored for longer than the initial 2 seconds). Past research has shown that impairments in phonological memory can constrain the ability to learn new vocabulary in both spoken and written forms (Gathercole & Baddeley, 1990; Gathercole, Willis, & Baddeley, 1991). Phonological memory has also been found to support comprehension; however, the research regarding its influence is mixed perhaps due to methodological issues with some studies defining phonological memory as short-term memory and others examining working memory. In addition to varying definitions of the construct itself, Melby-Lervåg et al. (2012)'s meta-analysis suggested that verbal short-term memory may play a minimal role in predicting reading skills. Verbal short-term memory did not significantly contribute any unique variance in word reading skills by itself; but together with phonemic and rime awareness 43.2% of the variance in word reading skills were explained. Kibby et al. (2014) also found similar results, where phonological memory, defined as "short-term memory for phonetically coded material" (p. 1), explained a small but significant portion of the variance in decoding and word identification skills after RAN and phonological awareness were taken into account. Past research that has examined phonological memory has found that it may play a greater role in basic reading (e.g., decoding; Gathercole et al., 1991; Kibby, 2009) than in comprehension (Kibby & Cohen, 2008) or in fluency (Puolakanaho et al., 2008).

Rapid automatized naming (RAN) refers to the speed with which an individual can pronounce the names of a presented set of limited stimuli, such as letters or numbers. It is considered a third subcomponent of the phonological processing model and requires the retrieval of phonological information from long-term memory (Torgesen et al., 2013). Torgesen and Wagner (1987) conceptualized RAN under the phonological processing umbrella and referred to it as "phonological recording in lexical access" (p. 192); they advocated that this subskill is predictive of reading because it requires access to and retrieval of phonological representations that is inherent in the process of reading (i.e., verbal production of what is retrieved). Measures of RAN (e.g., naming numbers or letters that are presented on a page as quickly as one can) require processing of visual and phonological information and require speed as it is usually a timed task. Many researchers have found a strong relation between RAN and oral reading fluency with varying types of reading material (e.g., single word lists, nonword/pseudoword lists, connected texts) (Kirby et al., 2010; Manolitsis, Georgiou, & Parrila, 2011; Swanson et al., 2003). A deficit in RAN has been linked to the dysfluency apparent in struggling readers; however, readers who have deficits in both rapid naming and phonological awareness typically experience the most severe reading difficulties (e.g., Kirby, Parrila, & Pfeiffer, 2003; McBride-

Chang & Ho, 2000; Torppa, Georgiou, Salmi, Eklund. & Lyytinen, 2012; Wolf & Katzir-Cohen, 2001). Research has shown that RAN becomes an increasingly more important predictor of decoding, single-word identification, and passage comprehension from grade 1 to grade 5 (Kirby et al., 2003). Further, RAN demonstrates strong positive relations with many aspects of reading, such as pseudoword reading speed, pseudoword reading accuracy, word reading speed, word reading accuracy, text-reading speed, fluency, and reading comprehension (Kirby et al., 2010). In addition, research has demonstrated that RAN accounts for unique variance across a wide array of reading skills even after taking into account the effects of phonological short-term memory (e.g., Moll et al., 2014; Parrila et al., 2004; Xue, Shu, Li, Li, & Tian, 2013) and phonological awareness (e.g., Lepola et al., 2005; Liao et al., 2015; Parrila, Kirby, & McQuarrie, 2004).

Overall, deficits in one or more of these three components of phonological processing can make it difficult for readers to gain skill in utilizing the alphabetic principle (i.e., understanding letter sounds and the ability to name letters and their corresponding sounds both accurately and quickly); therefore, individuals struggle to decode unknown words and develop their sight word reading skills (Share & Stanovich, 1995). These deficits make the word learning process much harder and prohibits successful fluent reading; additionally, it is this word-level difficulty that presents itself as a barrier to the achievement of adequate comprehension (Ehri, 2002; Vellutino, Fletcher, Snowling, & Scanlon, 2004). To tie this back to automaticity theory and the other information processing theories that affect their reading ability - deficits in the areas of phonological processing hinders the development of automaticity at the letter, letter pattern, and word level, draining cognitive and attentional resources that could be allocated to higher-order skills such as comprehension. Even after improvement in word reading accuracy have been obtained, the slow rate when reading connected text often is a persistent issue for students with reading disabilities (Torgesen, 2005).

Reading Modality

Oral reading fluency and phonological processing deficits are prominent characteristics of a learning disability in reading. Indeed, the literature is replete with accounts of the importance of phonological processing and oral reading fluency (e.g., Kuhn & Schwanenflugel, 2007). Oral reading allows for the reinforcement of letter-sound correspondence, permits students and their teachers to monitor progress and shape interventions accordingly, facilitates corrective feedback, and allows the reader to utilize listening comprehension skills to better understand the text (Kuhn & Schwanenflugel, 2007). The literature places more emphasis on oral reading, despite the fact that independent silent reading is the desired outcome of literacy instruction (Kim, Wagner, & Foster, 2011; Share, 2008). This gap in the literature may be due to the fact that silent reading is not an observable behavior and may be a more difficult construct to measure (Denton et al., 2011).

Even though silent reading with comprehension is the end goal for being an accomplished reader, there is still much to uncover about the shift from oral to silent reading. Schwanenflugel & Knapp (2016) posit that oral reading supports the internalization of cognitive processes involved in reading, and facilitates the eventual shift from oral to silent modes. The transition from oral to silent reading with equivalent comprehension is thought to occur around fourth-grade (Chall, 1983; 1996), but the exact timing of this transition is still uncertain. Research suggests that the strong correlations between oral reading fluency and comprehension weaken by late elementary school, and that oral fluency growth has largely slowed down by the middle school years for fluent readers (Schwanenflugel & Knapp, 2016). As students move through elementary schools and upwards, reading becomes silent and the text that is required in the classroom becomes more complex, requiring the student to utilize higher-level cognitive skills (e.g., inferences, summarization) and prior background knowledge (Sweet & Snow, 2003). Additionally, it is important to highlight that rate plays a different role in oral versus silent reading, as oral reading speed is determined by the speech with which an individual can talk (Hiebert, Wilson, & Trainin, 2010). Schmidt and Flege (1995) discovered that the typical rate of speech production in adults is 150 words per minute. Furthermore, Hausbrouck and Tindal (2006) found that this cap on the rate of oral reading, 150 words per minute, has usually been reached by the sixth and seventh grade, while silent reading rates continue to improve through college. Thus, silent reading rates increase far longer than oral reading rates do because silent reading is not constrained by the oral production required for oral reading.

When it comes to typical readers, studies that examined the effect of reading modality (i.e., silent versus oral reading) on comprehension for this population generally indicate that young readers comprehend text better after oral reading compared to listening or silent reading (Elgart, 1978; Fletcher & Pumfrey, 1988; Kragler, 1995). When comparing readers with varying skill (i.e., typical versus struggling readers), results on the relation between comprehension and reading modality are somewhat mixed, but generally find that both student groups comprehend text better after oral reading when compared to listening or silent reading (Burge, 1983; Dickens & Meisinger, 2015; McCallum, Sharp, Bell, & George, 2004; Miller & Smith, 1985). Robinson, Meisinger, & Waters (2018) investigated the impact of reading modality on reading comprehension for a clinical sample of students with dyslexia. Oral reading was found to facilitate higher reading comprehension scores than silent reading for early elementary students (i.e., second- and third-graders) whereas equivalent comprehension was found across these modalities for late elementary students (i.e., fourth- and fifth-graders), which is consistent with the literature on typical readers.

Various researchers have discussed the relation between oral reading fluency and phonological processing and the influence of phonological processing variables in the reading process (e.g., Fuchs et al., 2001; Hudson et al., 2009; Kame'enui & Simmons, 2001; Samuels & Farstrup, 2006). Fuchs et al. (2001) and Kame'enui and Simmons (2001) agree that the oral reading fluency should be examined and defined as a direct measure of phonological segmentation, recoding skill, and rapid word recognition and that comprehension is a correlate of oral reading. Hudson et al. (2009) and Samuels and Farstrup (2006) summarized the literature by highlighting the research that has found support for a reciprocal relation between oral reading rate and comprehension; and found a direct relation between oral reading rate and rapid naming. It is important to note that these studies used a global measure of text reading fluency that combined rate and accuracy; however, a few studies have parsed reading fluency apart into oral reading accuracy and rate.

Several researchers have studied the relation between accuracy, prosody, rate, and reading comprehension (Daane et al., 2005; Schwanenflugel, Hamilton, Kuhn, Wisenbaker, & Stahl, 2004) whereas others have considered the relation between reading comprehension and text reading fluency (Berninger et al., 2006; Jenkins et al., 2003; Schwanenflugel, Meisinger, Wisenbaker, Kuhn, Strauss, & Morris, 2006). Some have approached this research area with a developmental perspective and have examined the development of sub-lexical and lexical reading skills and their role to text reading fluency in beginning readers (Burke, Crowder, Hagan-Burke, & Zou, 2009);others have studied the predictive validity of decoding fluency to text reading fluency in young readers (Good, Simmons, & Kame'enui, 2001; Speece et al., 2003;

Speece & Ritchey, 2005). Hudson et al. (2012) utilized structural equation modeling using 198 second-grade students to examine the relations of word reading rate and accuracy to a variety of components (e.g., reading comprehension, decoding, letter sounds, phonemic blending, text reading fluency). Hudson et al. (2012) found that the effects from letter sound fluency and phonemic blending fluency to decoding were mediated by decoding fluency, single-word reading fluency, phonogram fluency, and reading comprehension had direct effects on the text reading fluency of second-grade students. Furthermore, Hudson et al. (2012) did not address silent reading fluency or other phonological components (i.e., phonological memory).

Only two studies to date have modeled the relation between oral and silent reading fluency and reading comprehension (Kim et al., 2011; Price, Meisinger, D'Mello, & Louwerse, 2016), and of those only one included some components of phonological processing. Kim et al. (2011) examined the relation of both silent and oral reading fluency to comprehension, also taking into account skills in word reading fluency and listening comprehension. Kim et al. (2011) utilized structural equation modeling techniques with a large sample of 316 first-grade students. Oral reading fluency was assessed using three passages from the Dynamic Indicators of Basic Early Literacy Skills assessments of Oral Reading Fluency (5th ed.; Good, Kaminski, Smith, Laimon, & Dill, 2001). Students read the passages aloud for one minute and the number of words read accurately during each reading of the passage was recorded for analysis. Silent reading fluency was assessed using two forms (Forms A & O) of the Test of Silent Reading Efficiency and Comprehension (TOSREC; Wagner, Torgesen, Rashotte, & Pearson, 2010). Students had to read sentences and indicate whether each statement was true or false by circling yes or no via a sentence verification task. Kim et al. (2011) found oral reading fluency made a strong contribution to the prediction of reading comprehension independently of silent reading fluency and silent reading fluency did not uniquely contribute to comprehension; additionally, oral reading fluency had a stronger relation to reading comprehension for average than for skilled readers. Interestingly, the relation between reading comprehension and silent reading fluency had differing effects on skilled and average readers: silent reading fluency had no relation to reading comprehension for average readers. Lastly, both oral and silent reading fluency were more strongly related to one another for skilled readers than average readers.

Price et al. (2016) examined the relation between oral and silent reading fluency and reading comprehension, as well as the contributions of lower-level reading skills (i.e., word reading, rapid automatic naming) and vocabulary on reading fluency and comprehension, using a normative sample of 106 fourth-grade students. Price et al. (2016) used an experimental underlining technique that was validated in a previous study (i.e., Price, Meisinger, D'Mello, & Louwerse, 2012) as one indicator of silent reading fluency. As students read a passage silently from a tablet computer, they underlined the text word-by-word with a stylus and their underlining time, regressions, and pauses were recorded. Students also answered reading comprehensions that were tied to the passage. The Test of Silent Contextual Reading Fluency (TOSCRF; Hammill, Wiederholt, & Allen, 2006) served as a second indicator of students' silent reading fluency. Students were presented with passages of increasing length and complexity where all the spaces and punctuation had been removed and the words were printed in all uppercase letters. Students had three minutes to draw lines or slashes between as many words as possible. Price et al. (2016) found that oral reading fluency and vocabulary, but not silent reading fluency, contributed significantly to reading comprehension. Additionally, Price et al. (2016) found that RAN contributed significantly to oral reading fluency but not to silent reading fluency. Despite the variety of methods of measuring silent reading fluency, both Kim et al.

(2011) and Price et al. (2016) found that oral and silent reading fluency represent distinct but related constructs. After reviewing the limited literature on silent reading fluency, it became apparent that no studies to date have examined these relations for students with dyslexia.

There is still much to be learned about the relation between phonological processing skills (i.e., rapid naming, phonological memory, phonological awareness) and both oral and silent reading fluency. The empirical literature lends support to the notion that phonological awareness is a foundational literacy skill and that deficits in these key skills serve as an indicator for students who are at-risk for later reading difficulties (Johnson et al., 2010; Melby-Lervåg, et al., 2012). Furthermore, when it comes to the remediation of reading disabilities, interventions focused on remediating phonological awareness and decoding bring about gains in both word reading accuracy and comprehension but gains in oral reading fluency are far more difficult to obtain (Lyon et al., 2004; Meyer & Felton, 1999; Torgesen et al., 2001; Torgesen, 2005; Share, 2008). If oral reading fluency is parsed into rate and accuracy, an emerging literature suggests that the observed difficulties in remediating text reading fluency may be due to the slow reading rate that persists even after a reader's accuracy has improved (Torgesen, 2005). Share (2008) argues that silent reading involves less phonological processing (i.e., omitting the phonological loop in the silent modality) than oral reading, which explains why oral reading rates are typically slower than silent reading rates. Price et al. (2016) posits that phonological decoding is more important for the oral rendering of text than for silent reading and argues that silent reading does not necessary require the ability to fully pronounce words. In addition, some studies have shown that RAN is a stronger predictor of oral reading fluency than silent reading fluency (Georgiou et al., 2014; Price et al., 2016; van den Boer, van Bergen, & de Jong, 2014).

Purpose

The purpose of this study was to examine the relations among phonological skills, oral and silent reading fluency, and reading comprehension for a longitudinal sample of students who have been diagnosed with dyslexia. Only a handful of studies have modeled the relation between reading comprehension and reading fluency in both modalities (e.g., Price et al., 2016; Kim et al., 2001), and only Price et al. (2016) incorporated some aspects phonological processing skills (e.g. RAN). Using Wagner et al. (2013)'s model as a framework for phonological processing, this study contributes to the literature by incorporating all three aspects of phonological processing variables that are implicated in the literature as important for supporting the acquisition of proficient reading skills (Johnson et al., 2010; Melby-Lervåg et al., 2012). No studies to date have examined these relations in a clinical sample of students with dyslexia. Yet dysfluent reading is a hallmark of dyslexia, and slow reading rate in particular has been proven to be an intractable deficit for students with more severe reading difficulties (Torgesen, 2005). Therefore, this study will parse oral reading fluency into accuracy and rate to shed light on how phonological processing skills influence these components of reading fluency and later comprehension. Given that silent reading fluency cannot yield accuracy data per se, parsing rate and accuracy for oral reading will also allow for more direct comparisons between oral and silent reading rate.

Another important consideration for the relation between reading fluency in both modalities and comprehension is the developmental level of the reader. Students are thought to transition from oral to silent reading with equivalent comprehension around fourth-grade (Chall, 1983; 1996), and results from recent research conducted with elementary school students identified with dyslexia were consistent with this timeline (Robinson et al., 2018). Further, developmental trends have also been observed in terms of the relative contributions of phonological processing skills to reading skills (Johnson et al., 2010; Melby-Lervåg, et al., 2012). In this study it was important to investigate the relations between these variables from a developmental perspective by examining students in early (second to third-grade) and late elementary school (fourth to fifth-grade) developmental groups. A cross-lagged multi-group analysis was used to examine the relations between phonological processing, reading fluency in both modalities, and reading comprehension to determine whether the relations among these variables vary across the two developmental reading groups (see Figure 1).

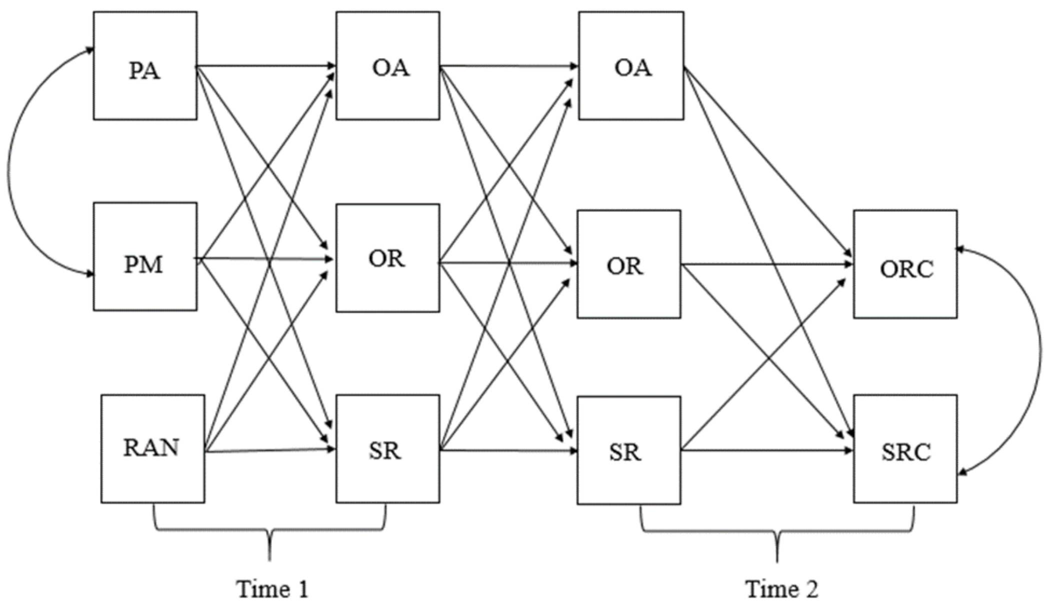

Figure 1. Hypothesized multi-group cross-lagged model of reading. Time 1 = Fall, Time 2 = Spring, PA = phonological awareness, PM = phonological memory, RAN = rapid automatized naming, OA = oral accuracy, OR = oral rate, SR = silent rate, ORC = oral reading comprehension, SRC = silent reading comprehension.

The following questions guided this research: (a) Do phonological processing skills (i.e., phonological awareness, phonological memory, rapid automatized naming) contribute to oral and silent reading fluency and reading comprehension skills?, (b) Is there a reciprocal (cross-lagged) relation between oral and silent reading fluency across the school year (fall to spring)?, (c)

Across reading modality, to what extent does reading fluency contribute to reading comprehension?, and (d) do the relations among these phonological processing and text-level reading skills vary across the two developmental groups (early versus late elementary)? Based on the prior research, it was hypothesized that phonological memory would covary with phonological awareness, but that it would not contribute directly to reading fluency or comprehension. Phonological awareness was expected to contribute directly to oral reading accuracy, and RAN is also expected to predict oral reading fluency (rate and accuracy) and silent reading rate. A reciprocal (cross-lagged) relation among the oral and silent reading fluency variables from fall to spring was expected. In regard to the developmental groups under investigation, it was hypothesized that a stronger relation would be observed between some of the phonological processing and reading skill variables in the early as compared to the late elementary students. Specifically, phonological awareness will be more important for the younger readers and as reading ability develops this will be less important in the older reading group. However, RAN is expected to be important an important player in both groups of readers. It was further hypothesized that a stronger relation between the oral and silent reading variables will be observed in the late elementary students. Lastly, the oral and silent reading fluency variables are expected to contribute to reading comprehension in late elementary school students, whereas only oral reading fluency is expected to emerge as important for comprehension in early elementary students.

Method

Participants

This study employed a subsample of students who participated in a longitudinal study investigating the development of reading fluency and accompanying readings skills. Participants were 102 students enrolled in second- (*n* = 25), third- (*n* = 26), fourth- (*n* = 25), and fifth- grade (*n* = 26) attending a private school in the Mid-South region of the United States that delivers a rigorous remedial day treatment program for students diagnosed with a SLD in reading. Prior to school admission, all students were diagnosed with an SLD in reading using the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition criteria (DSM-5; American Psychiatric Association, 2013). Students were 89.2% European American, 5.9 % African American, 1.0% Asian American, 1.0% Hispanic, and 2.9% other; approximately 61.8% of the students were boys. Available school records were used to calculate the average full-scale IQ (*M* = 102.82; *SD* = 13.14) for the sample as well as the percentage of students with an educationally relevant comorbid diagnosis (i.e., attention-deficit/hyperactivity disorder (ADHD): 45%, SLD in written expression: 35%, SLD in mathematics: 15% , and speech and/or language impairment:19%). Longitudinal data from across three academic years (2015-2016; 2016-2017; 2017-2018) were utilized in this study. If multiple years of data were available for a given student, data from the grade with the lowest number of participants were retained to create a more even distribution across grade-levels.

Measures

AIMSweb Standard Reading Assessment Passages (RAPs). The AIMSweb passages (AIMSweb Technical Manual, 2012) were used as a measure of both oral and silent reading fluency. Each participant read two grade-level passages, one was read orally and the other was read silently. The two grade-level AIMSweb passages were shortened to prevent frustration and fatigue effects, in light of the low skill level of the students. The Grade 2 passages were 129 words and 132 words (containing 24 and 22 idea units, respectively), the Grade 3 passages were 137 and 141 words (containing 23 units each), the Grade 4 passages were 170 and 179 words (containing 29 idea units each), and the Grade 5 passages were 236 and 242 words (containing 33 and 40 idea units, respectively). To avoid frustrating readers who were unable to read the passage, the passage reading was discontinued under the following circumstances: 4 or more errors were made in the first line during the oral reading passage, after 5 minutes the student was not close to the end of the passage, or if it was apparent that the entire passage would not be completed under 5 minutes. The directions used for the oral and silent reading conditions are as follows:

Oral Reading Directions

> I am going to give you a reading passage. When I say “begin”, I want you to read the passage out loud as carefully and as quickly as you can. If you come to a word that you don't know, do your best and keep going. When you have finished reading, I will take up the passage and ask you questions about what you just read. I cannot give you any hints or help. Do you have any questions? Ok, here is the passage (*examiner places the passage in front of the student*). Remember to read the passage out loud. Begin reading here (*examiner points to the first word of the passage*). *If the child begins reading silently, provide prompt*, "Remember to read out loud," *and restart timer.*

Silent Reading Directions

> I am going to give you a reading passage. When I say begin, I want you to read the passage silently, or in your head, as carefully and as quickly as you can. If you come to a

word that you don't know, do your best and keep going. Only read the passage through once. When you have finished reading the passage, look up at me, and say, "Done." I will take up the passage and ask you questions about what you just read. I cannot give you any hints or help. Do you have any questions? Ok, here is the passage (*examiner places the passage in front of the student*). Remember to read the passage silently. Begin reading here (*examiner points to the first word of the passage and starts the timer*).

For passages read aloud or read silently, the time in seconds taken to read the passage was recorded. For passages read orally, the number of words read incorrectly (i.e., omissions and substitutions) were recorded. Oral reading accuracy was assessed by calculating the percentage of words read correctly in the passage (number of words read correctly/total number of words). Reading rate was assessed by calculating the number of words read per minute (WPM) for each passage by dividing the number of words in the passage by the reading time in seconds and then multiplying by 60, resulting in a score for oral reading rate and silent reading rate. When used as a measure of oral reading fluency, the AIMSweb probes have demonstrated test-retest reliability of .94 (Christ & Silberglitt, 2007) and alternate-form reliability of .94 (Howe & Shinn, 2002). In addition, scores were found to correlate strongly (.70) with state reading tests from third to fifth grade (AIMSweb Technical Manual, 2012). A recent study that examined the validity of silent reading fluency measures found that paper and pencil measures, using procedures similar to those in this study, correlated moderately with other commonly used measures of silent reading fluency (.52-.62) and reading comprehension (.44-.47) (Price et al., 2012). Importantly, the concurrent validity estimates reported for paper-and-pencil were comparable to other measures of silent reading fluency.

Passage Retell. Examinees were asked to retell the grade-level AIMSweb passage they read as a measure of both oral and silent reading comprehension. The retell method of assessing reading comprehension and coding for idea units of the main points of each passage read by the student has been outlined in the literature (Fuchs & Maxwell, 1988; Leslie & Caldwell, 2011). For each passage, the key ideas, phrases, and words used in the story were identified by researchers using an example from the QRI-5 (Leslie & Caldwell, 2011). An idea unit was identified as any information relevant to the story. Researchers marked every mention of an idea unit in student transcriptions. No points were awarded to repetitive idea units unrelated to the passage (e.g., “I didn’t like that story” or “That’s all I remember”). A half point was given to each idea unit that was partly correct but inadequate in detail to be a full idea unit. One point was given to each idea unit of a passage that was synonymous or completely matched the idea unit for a passage. For example, if the idea unit was about a rabbit hopping, one point was given if both the hopping action and the rabbit were mentioned in the response. Only a half point was given if the retell included mention of only the hopping but not the rabbit. No points were given to a response that did not mention hopping or a rabbit. Audio recordings of the retells were transcribed for scoring purposes. After a retell transcription of the oral passage was scored and summed, the percentage correct was calculated by dividing the number of points received by the total number of idea units in the passage). The research literature shows moderate to high (.52-.82) correlations between retell scores and other standardized measures of reading comprehension (Reed & Vaughn, 2012).

The Gray Oral Reading Tests, Fifth Edition (GORT-5). The GORT-5 (Wiederholt & Bryant, 2012) is an individually administered, norm-referenced test of oral reading fluency and reading comprehension. For this study, Form A was used in the fall and Form B was used in the spring semester. The test consists of a series of passages that increase in difficulty level with each successive passage. Entry points are based on an individual's grade or ability level. In addition, basal and ceiling rules ensure that the reader is exposed to text that measures the appropriate level of difficulty. Passages are read orally and the reading time as well as the number of reading errors (i.e., any deviation from print; such as, insertions, substitutions, repetitions, self-corrections, and skipping a line of text). After reading each passage aloud, respondents answer five open-ended comprehension questions tied to that passage. Raw scores for Rate, Accuracy, Fluency (comprised of rate and accuracy scores), and Comprehension are summed across passages to produce scaled scores ($M = 10$, $SD = 3$), and the Fluency and Comprehension scores combine to yield the Oral Reading Index ($M = 100$, $SD = 15$). The Rate, Accuracy, and Comprehension scores will be used in this study. Internal consistency coefficients range from .91 to .97; the alternate form reliability correlation coefficient between Form A and Form B is .93 for immediate administration, while the delayed administration alternate form reliability correlation coefficient range from .77 to .88; test-retest reliability range from .82 to .90; and the validity estimates relating results from the GORT-5 with other measures of reading had a median correlation of .72 (Wiederholt & Bryant, 2012).

IOWA Assessments. The Reading subtest from Form E of the IOWA Assessments (Dunbar, Welch, Hoover, & Frisbie, 2011) was used to measure silent reading comprehension and is a standardized, norm-referenced measure. Level 8, 9, 10, and 11 were administered to the second-, third-, fourth-, and fifth- grade students, respectively. The students silently read a series of passages, literary and informational, and answered multiple-choice questions corresponding to each passage. The Reading subtest assesses one's understanding of the author's craft, implicit and explicit meaning, key ideas of the passage, and vocabulary. The Iowa Assessments provide means, standard deviations, and standard scores that vary based on the grade-level and the test form that is administered. Dunbar, Welch, Hoover, and Frisbie (2014) reported reliability estimates exceeding .90 for the Reading test and strong correlations with other measures of reading achievement (.75 to .85).

Comprehensive Test of Phonological Processing, Second Edition (CTOPP-2). Three subtests from the CTOPP-2 were administered.

Elision. This subset from the CTOPP-2 (Wagner et al., 2013) is used as a measure of phonological awareness and consists of 34 items. The Elision subtest is designed to measure the ability to remove phonological segments from spoken words to form other words. For example, the examinee is instructed to say “cat”. After repeating the word “cat” aloud, the examinee is instructed to say “cat” without saying /c/. The correct response would be “at”. The examiner’s manual reports test-retest reliability coefficients ranging from .77 to .93, internal consistency of .91, and concurrent validity estimates with similar measures ranging from .59 to .85 (Wagner et al., 2013).

Memory for Digits. This subtest is used as a measure of phonological memory and is designed to measure the ability to repeat numbers accurately. The examinee is asked to repeat the sequence of numbers of increasing length, ranging from two to eight digits, in the same order in which they were heard. The examiner’s manual reports an internal consistency of .81 and test-retest reliability coefficients ranging from .74 to .94; concurrent validity estimates with similar measures ranged from .41 to .74 (Wagner et al., 2013).

Rapid Symbolic Naming. This composite is comprised of the Rapid Digit Naming and Rapid Letter Naming subtests from the CTOPP-2 and measures retrieval of phonological and visual information from long-term memory. On the Rapid Digit Naming subtest, examinees are asked to name numbers presented on one page, which has four rows and nine columns of six randomly arranged numbers. The total number of seconds it takes to name all the numbers on the page is the individual's score for this subtest. The Rapid Letter Naming subtest uses the same format but requires the examinees to name all the letters presented on the page as fast as possible. The total number of seconds it takes to name all the letters on the page is the individual's score for this subtest. The Rapid Symbolic Naming composite yields standard scores (M = 100; SD = 15). The examiner's manual reports test-retest reliability coefficients ranging from .81 to .89 and internal consistency of .92; concurrent validity estimates with similar measures ranged from .53 to .91 (Wagner et al., 2013).

Procedure

Written parental consent and student assent were required for participation in the study. Three waves of data were collected in the 2015-2016, 2016-2017, and 2017-2018 school year, following the approval from the University of Memphis Institutional Review Board (IRB#3814). The oral and silent reading fluency passages, passage retell, selected subtests form the CTOPP-2, and GORT-5 were administered within a two-week period in both the fall (August) and spring (May) of each academic year. The Iowa Assessments were only administered in the spring (May) by school personnel. All the measures, except for the Iowa Assessments, were administered to participants as part of a larger test battery by examiners with previous training in psychoeducational assessment. Prior to data collection, examiners practiced coding the assessments utilizing audio recordings of students' reading until a minimum of 95% agreement was achieved.

Measures were administered across two sessions to guard against fatigue effects. The administration order of the assessments was further counterbalanced within and across sessions.

The two grade-level AIMSweb passages were also counterbalanced across reading modality (oral and silent) and time point (fall and spring). This ensured that passages read silently in the fall were read orally in the spring and vice versa. The assessments were individually administered in a quiet location (i.e., an empty classroom or office) during regular school hours. At the end of each session, students received a prize, such as a small toy car or sticker, in appreciation for completing the assessments. All testing sessions were audio recorded for later scoring and review. Twenty-five percent of these data were randomly selected for blind review using an online randomizer (Urbaniak & Plous, 2013) by an independent reviewer to ensure inter-rater agreement using the audio recordings. Discrepancies were rare (< 1%) and resolved via discussion for the data collected in wave 1, 2, and 3.

Two raters transcribed each passage retell using audio recordings of the sessions. Each rater transcribed half of the retells, which was then reviewed by the other rater for accuracy. There was 100% agreement between raters (no discrepancies within the transcriptions). A retell scoring manual was used to ensure clear guidelines, and the retell transcriptions were then scored for the number of idea units recalled. Fifty percent of transcriptions were then randomly selected to be independently scored by both raters using the coding manual. Both raters scored the remaining transcriptions. Data from wave 1, wave 2, and wave 3 resulted in strong agreement between raters ($\kappa = .93$, $p < .001$ and $\kappa = .95$, $p < .001$, $\kappa = .92$, $p < .001$, respectively).

Results

Data Processing and Screening

Data were screened for accuracy of input, out-of-range values, implausible means and standard deviations, skewness, kurtosis, univariate and multivariate outliers, missing data points, and normality. No univariate outliers were identified in the data set (i.e., *z*-scores > 3.29; Tabachnick & Fidell, 2013). Missing data were relatively rare (>1%) and were distributed across variables and time points. Instances of missing data were due to administration error and a recording malfunction; as such the data were assumed to be missing at random.. With regard to the AIMSweb passages, the use of the discontinue rule during oral reading or implausible (i.e., very fast) silent reading times indicated that the student could not read the passage and may have faked reading during the silent passage. Therefore, if the discontinue rule was met for the AIMSweb passage then the reading time and retell data for both the oral and silent passages were treated as missing data ($n = 3$). Data were screened for implausible silent reading times (i.e., less than 45 seconds); if criteria was met, then both the time and idea units for the silent passage were treated as missing data ($n = 6$). Little's MCAR test was not significant, χ^2 (56, $N = 120$) = 49.73, $p = .71$, suggesting that these data were missing completely at random. Skewness and kurtosis statistics fell within acceptable limits (i.e., < |2.0|; Tabachnick & Fidell, 2013). Pairwise plots were visually inspected for nonlinearity and heteroscedasticity, and appeared to be normally distributed. Tolerance values were all <.10 and did not indicate issues with multicollinearity (Kline, 2016).

An independent samples t-test was used to check for administration order effects (i.e., whether the first passage was read silently or aloud) on reading comprehension. No effect on reading comprehension was detected for administration order for passages read orally, $t(54)$ = -

1.274, p = .206, or silently, $t(54)$ = .759, p = .449 in the fall. Similarly, no effect on reading comprehension was detected for administration order for passages read orally, $t(54)$ = -.374, p = .709, or silently, $t(54)$ = .197, p = .844 in the spring. Passage effects are common in the literature (Christ & Ardoin, 2009; Francis et al., 2008). Therefore, a series of independent samples t-tests were used to check for passage effects (i.e., each student read two grade level passages) on reading comprehension across the orally and silently read conditions, separately by grade, but none were found. For grade 2, passage effects were not found for oral, $t(14)$ = -1.287, p = .210, and silent reading, $t(14)$ =1.244, p = .225 in the fall; and oral, $t(14)$ = -.388, p = .702 and silent reading, $t(14)$ = 1.039, p = .309, in the spring. For grade 3, passage effects were not found for either oral, $t(12)$ = .447, p = .659, and silent reading, $t(12)$ =-1.190, p = .246 in the fall; and oral, $t(12)$ = 1.097, p = .284 and silent reading, $t(12)$ = -1.016, p = .320 in the spring. For grade 4, passage effects were not found for both oral, $t(12)$ = -.829, p = .416, and silent reading, $t(12)$ = .996, p = .330 in the fall; and oral, $t(12)$ = -.346, p = .733 and silent reading, $t(12)$ = 1.121, p = .275 in the spring. Lastly, passages effects for grade 5 were not found for either oral, $t(14)$ = -.331, p = .774, and silent reading, $t(14)$ = 1.127, p = .271 in the fall; and oral, $t(14)$ = -1.283, p = .212 and silent reading, $t(14)$ = -1.136, p = .268 in the spring.

Next, composites for oral accuracy, oral rate, silent rate, oral reading comprehension, and silent reading comprehension were created for each time point. Because measures used in this study produced a variety of score types (percentages, scaled scores, wcpm, etc.), the data had to be converted to z-scores before the composites based on their averages could be created. Z-scores from the GORT-5 Accuracy subtest and the percentage of words read correctly from the oral reading AIMSweb passage were averaged to create the oral accuracy composite. The number of words read per minute (WPM) from the oral reading AIMSweb passage and the

GORT-5 Rate subtest comprised the oral rate composite. The GORT-5 Reading Comprehension and percentage of idea units correctly recalled from the oral reading AIMSweb passage formed the oral reading comprehension composite. Lastly, the silent reading comprehension composite consisted of the IOWA Reading Comprehension and percentage of ideas unit correctly recalled from the silent reading AIMSweb passage.

Cross-Lagged Path Analysis

This study utilized Mplus 8 (Muthen & Muthen, 2014) to conduct a cross-lagged path analysis to address the first three research questions (i.e., the contribution of phonological processing to reading fluency and comprehension and the relations among fluency and comprehension across the year) (see Figure 1).

Robust maximum likelihood (MLR) estimation was used to estimate the model because it is preferred when dealing with continuous variables, and because it adjusts for any potential issues with nonnormality and data assumed to be missing at random (Kline, 2016). Using this model, the direct contributions of the phonological processing variables to the reading fluency variables, as well as any indirect contributions made to reading comprehension through the reading fluency variables, were examined. Further, the reciprocal relations among the reading fluency variables across two-time points (beginning and end of the school year) were explored. The autoregressive paths examined the relation between the same variable at two points of time (e.g., oral accuracy at time 1 and time 2) and the cross-lagged paths examined the reciprocal relations from one variable to a different variable from time 1 to time 2 (e.g., oral reading rate at time 1 to silent reading rate at time 2). Further, the relative contribution of the reading fluency variables to oral and silent reading comprehension was examined. After addressing these relations in an initial baseline model, the fourth research question (focused on developmental differences) was attempted using a multi-group cross-lagged path analysis to test for differences in the path coefficients between the early and late elementary groups.

Model Evaluation Criterion. Four indices including the Model chi-square (Bollen & Long, 1993), Steiger-Lind root mean square error of approximation (RMSEA; Steiger, 1998) with its 90% confidence interval, Bentler comparative fit index (CFI; Bentler, 1990), and the Standardized root mean square residual (SRMR; Hu & Bentler, 1999) were used to evaluate the model fit as recommended by Kline (2016). The model chi-square is used to measure "badness-of-fit" and a *p*-value less than 0.5 indicates a bad fit when comparing the model to sample data. The RMSEA is a "badness-of-fit" index that takes into account sample size, where values less than or equal to .05 indicate good model fit or close approximate fit, values between .05 and .08 suggest reasonable error of approximation, and values greater than or equal to .10 suggest poor model fit (Browne & Cudeck, 1993). The CFI is a "goodness-of-fit" index that reflects how much better a model fits the data compared to a baseline model with uncorrelated variables. For the CFI, values above .90 indicates reasonably good model fit and a CFI of .95 indicates excellent model fit (Hu & Bentler, 1999). The SRMR is the standardized difference between the observed correlation and the predicted correlation. Furthermore, SRMR values less than .10 are considered favorable, whereas values less than .08 are considered a good fit (Hu & Bentler, 1999).

Baseline model. To address the first three research questions, the baseline model was conducted with the entire sample without dividing students into developmental groups. Modification indices suggested that including a path from oral accuracy (in the fall) to silent reading comprehension (in the spring) and allowing oral and silent rate (in the fall) and oral rate and oral accuracy (in the fall) to covary would improve model fit. Because these modifications made sense conceptually, they were implemented in the baseline model (see Figure 2).

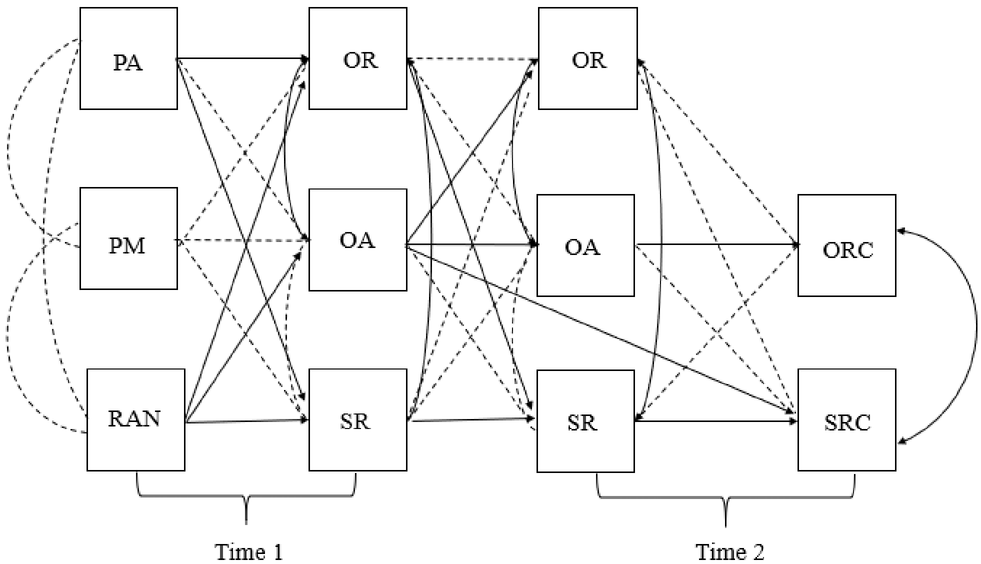

Figure 2. Cross-lagged baseline model of reading. Significant paths are solid lines; insignificant paths are dotted lines. PA = phonological awareness, PM = phonological memory, RAN = rapid automatized naming, OA = oral accuracy, OR = oral rate, SR = silent rate, ORC = oral reading comprehension, SRC = silent reading comprehension.

Refer to Table 1 for correlations, means, and standard deviations for the baseline model and to Figure 2 for significant and non-significant paths.

Table 1. *Correlation Matrix for Baseline Model*

	PA	PM	RAN	OR1	OA1	SR1	OR2	OA2	SR2	ORC	SRC	*M* (*SD*)
PA	1.00	--	--	--	--	--	--	--	--	--	--	.00 (1.00)
PM	.03	1.00	--	--	--	--	--	--	--	--	--	.00 (1.00)
RAN	.12	-.08	1.00	--	--	--	--	--	--	--	--	.00 (1.00)
OR1	-.10	.04	.44	1.00	--	--	--	--	--	--	--	-.55 (.75)
OA1	.159	.11	.28	.61	1.00	--	--	--	--	--	--	-.71 (.67)
SR1	-.32	-.09	.17	.64	.20	1.00	--	--	--	--	--	.00(1.00)

OR2	.02	.14	.35	.58	.44	.43	1.00	--	--	--	--	-.43 (.70)

Table 1 (Continued)

	PA	PM	RAN	OR1	OA1	SR1	OR2	OA2	SR2	ORC	SRC	*M* (*SD*)
OA2	.35	.09	.30	.45	.76	.01	.45	1.00	--	--	--	-.60 (.75)
SR2	-.16	-.02	.23	.72	.43	.63	.56	.23	1.00	--	--	.00(1.00)
ORC	.16	.13	.14	.25	.33	.02	.32	.48	.19	1.00	--	-.47 (.70)
SRC	.05	.16	.11	.51	.58	.20	.38	.47	.52	.57	1.00	.23(.83)

Note. PA = phonological awareness, PM = phonological memory, RAN = rapid automatized naming, OR1 = oral rate at time 1, OA1 = oral accuracy at time 1, SR1 = silent rate at time 1, OR2 = oral rate at time 2, OA2 = oral accuracy at time 2, SR2 = silent rate at time 2, ORC = oral reading comprehension, SRC = silent reading comprehension.

Fit indices indicated that the baseline model fit well (see Table 2).

Table 2. *Fit Indices for Multigroup Invariance Testing*

Model	χ^2	*df*	*p*	RMSEA (90% CI)	SRMR	CFI
Baseline	18.477	18	0.425	0.016 (0.000 – 0.090)	0.034	0.998
Age	109.953	29	<0.001	0.165 (0.133 – 0.199)	0.093	0.789

Note. χ^2 = chi square goodness of fit statistic; *df* = degrees of freedom; RMSEA = Root-Mean-Square Error of Approximation; CFI= Comparative Fit Index; SRMR= Standardized Square Root Mean Residual.

Standardized direct, indirect, and total effects from the baseline model are portrayed in Table 3.

Table 3. *Standardized Direct and Indirect Effects for the Baseline Model*

	Fall			Spring				
	OA	OR	SR	OA	OR	SR	ORC	SRC
Fall								
PA								
Direct	.124	-.160*	-.343***					
Indirect				.112	-.093	-.176*	.031	.002
Total	.124	-.160*	-.343***	.112	-.093	-.176*	.031	.002
PM								
Direct	.126	.080	-.062					

Indirect				.110	.043	.027	.052	.068
Total	.126	.080	-.062	.110	.043	.027	.052	.068

Table 3 (continued)

	Fall			Spring				
	OA	OR	SR	OA	OR	SR	ORC	SRC
RAN								
Direct	.279**	.353***	.200*					
Indirect				.238***	.256***	.302***	.138**	.229***
Total	.126**	.353***	.200*	.238***	.256***	.302***	.138**	.229***
OA								
Direct				.657***	.177***	.077		.399***
Indirect							.297***	.080
Total				.657***	.177***	.007	.297***	.479***
OR								
Direct				.194	.376	.462**		
Indirect							.138	.166*
Total				.194	.376	.462**	.138	.166*
SR								
Direct				-.181	.159	.324**		
Indirect							-.048	.091
Total				-.181	.159	.324**	-.048	.091
Spring								
OA								
Direct							.417***	.089
Total							.417***	.089
OR								
Direct							.117	-.029
Total							.117	-.029
SR								
Direct							.029	.345***
Total							.029	.345***

Note. PA = phonological awareness, PM = phonological memory, RAN = rapid automatized naming, OA = oral accuracy, OR = oral rate, SR = silent rate, ORC = oral reading comprehension, SRC = silent reading comprehension. ***p< .001** p < .01, *p < .05.

Akin to beta weights from regression analyses, these coefficients specify the proportion of the standard deviation unit that the dependent variable changes as a function of a one standard deviation change in the independent variable (Kline, 2016). According to Kline (2010), standard coefficient effect sizes above 0.05 are considered “small”, effect sizes above 0.15 are considered “moderate”, and effect sizes above 0.25 are considered “large”.

The phonological processing variables displayed varying patterns of direct and indirect effects on the fluency and comprehension variables. RAN showed the most robust and consistent relations to these text-level reading skills. RAN had a direct effect on all of the reading fluency variables at time 1, including oral rate (.35), oral accuracy (.28), and silent rate (.20). Notably, RAN continued to influence these same variables indirectly at time 2: oral rate (.26), oral accuracy (.24), and silent rate (.30). Furthermore, RAN was the only phonological variable that impacted reading comprehension outcomes at the end of the school year, with results supporting an indirect effect on silent reading comprehension (.23) and oral reading comprehension (.14). Phonological awareness contributed directly to both oral rate (-.16) and silent rate (.34) at time 1, and indirectly to silent rate (-.18) at time 2. However, verbal short-term memory (i.e., phonological memory) did not contribute directly or indirectly to any of the text-level variables across the year.

As would be expected, the autoregressive relations (i.e., direct contributions from a variable to itself at the second time point) among the fluency variables were generally significant (i.e., oral accuracy time 1 and to oral accuracy time 2 (.66); and silent rate time 1 and silent rate time 2 (.32)), except for oral rate time 1 and oral rate time 2. With regard to the cross-lagged relations, oral rate at time 1 contributed significantly to silent rate at time 2 (.46), and oral accuracy at time 1 contributed significantly to oral rate at time 2 (.18).

The third research question addressed the relation between reading fluency and comprehension across reading modalities. Results indicated that oral accuracy played a major role both indirectly and indirectly in supporting both oral and silent reading comprehension. Oral accuracy in the fall indirectly contributed to oral reading comprehension (.30) and directly contributed to silent reading comprehension (.40). Additionally, oral accuracy in the spring contributed directly to oral reading comprehension (.42). Oral and silent rate played significant but less pronounced roles in the model when compared to oral accuracy. Oral rate in the fall was found to indirectly contribute to silent (but not oral) reading comprehension at the end of the year; however, no direct effects for oral rate on reading comprehension in the spring were found. Lastly, silent rate had no indirect effect to either silent or oral reading comprehension in the fall, although it was found to contribute directly to silent reading comprehension in the spring (.35). It is notable that the baseline model explained nearly twice as much variance in silent reading comprehension (R^2 = .45) than in oral reading comprehension (R^2 = .24). This baseline model later served as a comparison to the developmental model.

Developmental model. The proposed analyses included a multi-group cross-lagged path analysis; however, attempts to incorporate the early versus late elementary group as a variable resulted in poor fit. The unconstrained multi-group model, where all the parameters estimates were allowed to freely vary across the subgroups, was to serve as the initial model against which subsequent models would be compared. However, the unconstrained multi-group model resulted in poor fit as there were more parameters than participants in the model. Several attempts were made at partially constraining the multi-group model (i.e., first – examined model with partial constraints and silenced a path that had a “parameter nonpositive negative matrix”; second- constrained everything in the model but the means; and lastly- variances were freed), but all resulted in ill-fitting models. Therefore, age in months was added to the baseline model as a covariate allowing development to be considered as a continuous variable. However, the developmental model resulted in poor model fit (see Table 2).

Discussion

The purpose of this study was to analyze the relations among phonological skills, oral and silent reading fluency, and oral and silent reading comprehension for a longitudinal sample of students who were diagnosed with dyslexia. Relations among the reading skills were largely consistent with the literature, with a few exceptions (e.g., phonological awareness and oral accuracy). Model results indicated that RAN was the most noteworthy phonological processing variable and had consistent relations to the text-level reading skills. Additionally, oral accuracy was the most prominent subcomponent of fluency that had indirectly and directly influenced text-level reading across both modalities of comprehension. The baseline model where students were not divided into developmental groups was found to fit the data best, and fit only worsened when the covariate of age was added to the proposed developmental model. These results suggest that this clinical sample of readers may not exhibit pronounced developmental differences in the phonological processing and reading fluency skills that are required for adequate comprehension of text; however, methodological limitations may have influenced these results.

One aim of this research was to examine the contribution of phonological processing skills to oral and silent reading fluency and reading comprehension skills across the school year. Based on the literature, it was hypothesized that phonological memory would covary with phonological awareness, but that it would not contribute directly to reading fluency or comprehension. Results revealed that phonological memory appeared to play no role in supporting text-level reading, as it did not significantly contribute either directly or indirectly to any of the skills depicted in the model. This finding was generally consistent with the literature (Kibby et al., 2014; Melby-Lervåg et al., 2012) which indicates that phonological memory (i.e., verbal short-term memory) may play a minimal role in predicting fluency and comprehension. Additionally, methodological issues surrounding working versus short-term memory may have placed a role in no results seen. The literature on short-term memory and its relation to reading development is mixed, with some meta-analytic findings pointing to a negligible role in predicting reading skills (Melby-Lervåg et al., 2012), whereas others have found significant differences in performance on verbal short-term memory tasks between typical readers and those with reading deficits (Kudo, Lussier, Swanson; 2015). Also, phonological memory may not as important for older students (2nd through 5th grade) as past research has found that it may play a stronger role in word reading and decoding skills (Gathercole et al., 1991; Kibby, 2009). Despite the weak support for the role of short-term memory, it was an important variable to examine in this study given the dearth of research on text-level reading skills and silent reading.

It is well established that weaknesses in phonological awareness represents the primary cognitive deficit for students with dyslexia, and that this skill is essential to supporting the acquisition of word reading and decoding skills (Fletcher, Lyon, Fuchs & Barnes, 2019). Yet, phonological awareness was found to play a somewhat unexpected role (i.e., did not contribute to accuracy) in the baseline model. Phonological awareness contributed directly to oral rate and silent rate in the fall and continued to influence silent rate indirectly into the spring. It is important to note that this relation was negative, indicating that students who were more sensitive to the structure of sounds within the words tended to read more slowly. On the surface this finding seems counterintuitive. Although phonological skills did not impact the accuracy of the text read, it could be inferred that these students read at a slower rate because they attended more closely to each word. For example, these students may have made attempts to decode rather than skipping or guessing unknown words in the passage. Data regarding miscues (omissions, substitution types, etc.) are be needed to further examine this explanation. Additionally, phonological awareness was expected to contribute directly to oral reading accuracy, but this prediction was not borne out in the model results. Phonological awareness is known to be vital for early reading acquisition. Although this finding again seems counterintuitive, it may indicate that phonological awareness is more important for younger, beginning readers and is less influential for older readers (Melby-Lervåg et al., 2012). It should be noted that studies showing robust effects for phonological awareness also typically examined word-level skills (e.g., word and non-word lists) whereas, this study focused on text-level reading with comparatively older students.

RAN was the strongest phonological processing variable represented in the baseline model. RAN contributed directly to all the oral and silent reading fluency variables in the fall and indirectly to all the fluency and comprehension variables in the spring. These findings are consistent with the extant literature indicating that RAN is an important predictor of many reading skills from grade 1 to grade 5 (Kirby et al., 2003; Kirby et al., 2010). Furthermore, most prior studies that investigated the relation between RAN and reading skills did not examine text-level skills. Price et al. (2016) found that RAN did not contribute to silent reading fluency, but contributed significantly to oral reading fluency. This study extends the RAN literature by addressing fluency and comprehension across reading modalities and by examining a clinical sample. These results provide strong support for the notion that RAN is an essential skill to both oral and silent reading development.

Another important aim of this study was to better understand the nature of the relations among the subcomponents of oral and silent reading fluency (i.e., rate and accuracy) across the school year. Autoregressive (same skill across time 1 and 2) and reciprocal (cross-lagged) relations among the oral and silent reading fluency variables from fall to spring were expected. For accuracy during oral reading and silent reading rate, initial skill in the fall was found to predict performance on that the same skill in the spring (i.e., the autoregressive paths). It is notable that oral reading rate in the fall did not explain additional variance in oral reading rate in the spring, instead initial skill in oral reading accuracy was found to support oral reading rate at the end of the year. Accuracy during oral reading explained additional variance either directly and/or indirectly in all the other oral and silent reading fluency and comprehension skills. Additionally, oral reading rate in the fall contributed to silent reading rate in the spring; however, silent reading only supported itself and not the two other oral reading fluency variables. Kim et al. (2011) and Price et al. (2016) found that oral reading fluency, not silent reading fluency, contributed to reading comprehension. The current study adds to this body of evidence that indicates silent reading fluency is supported by oral reading, but that this relation is not reciprocal. Silent fluency does not contribute to oral reading fluency or comprehension.

This progression of reading is consistent with prominent theoretical models of reading such as automaticity theory (La Berge & Samuels, 1974), that views accuracy as a requisite skill for speed and automaticity. As students become more automatic in their lower level reading skills, cognitive and attentional resources are freed for higher level skills. The results lend support to automaticity theory due to the findings that accuracy was found to support reading rate in the model. These results are also consistent with the Vygotskian framework many researchers use to conceptualize the transition from oral to silent reading (e.g.., Hiebert & Reutzel, 2010; Prior et al., 2011; Robinson & Meisinger, 2018: Schwanenflguel & Knapp, 2016). It is argued that reading, like language, has deep roots in the sociocultural world. At first, individuals such as parents and teachers read to students, and then the students take in what is being read to them and transition to a stage where they read aloud with scaffolded support. The final stage in this developmental trajectory occurs when the students internalize the oral reading process by engaging in silent reading with equivalent comprehension (Prior & Welling, 2001; Prior et al., 2011). Overall, the results of this study indicate that oral reading appears to be supporting silent reading development, but that this relation is not reciprocal.

In terms of the contributions of the fluency variables to reading comprehension, the results again followed a pattern of progression from lower to higher skills and from oral to silent reading. In particular, oral reading accuracy had the greatest impact on silent and oral reading comprehension. Indeed, accuracy during oral reading at both times points made a significant contribution to reading comprehension across modality. Oral and silent reading rate played lesser roles in comparison to the effects that oral reading accuracy in the model. Oral rate supported silent reading rate, and silent reading fluency only contributed to silent reading comprehension. The results of this study indicate that silent reading fluency does not appear to impact oral reading comprehension, whereas oral reading skill appears to facilitate both oral and silent comprehension. These results are consistent with the handful of studies that have modeled fluency and comprehension across modality, indicating that oral reading fluency, not silent reading fluency, contributes significantly to comprehension (Kim et al., 2011; Price et al., 2016).

Understanding the role of development on the relations among the phonological processing and text-level reading skills was a primary focus of this study. Attempts were made to answer whether relations among the phonological processing and reading skill variables vary across the two developmental groups (early versus late elementary). However, these important developmental questions could not be addressed in this study due to issues with model fit once the sample was split into developmental groups and when age was added as a covariate. These results may suggest that developmental differences do not exist among this clinical sample. Developmental differences were expected based on the literature concerning reading development. Chall (1983; 1996) theorized that students transition from oral to silent reading with equivalent comprehension around fourth-grade. Robinson et al. (2018) found developmental trends consistent with Chall's model in a sample of students with dyslexia; however, that study focused on reading comprehension differences following oral and silent reading of text and did not include broader measures of reading skills. Moreover, Robinson et al. (2018) did not model fluency and reading comprehension separately across modality, and phonological processing variables were not examined. In the current study, the inclusion of the phonological processing variables may have accounted for some of the variation previously attributed to developmental differences. That being said, it is also possible that the model fit was influenced by methodological limitations, namely sample size. A larger sample size is needed to conduct the more sophisticated multi-group analysis required to more fully address this question. Future work may in fact reveal subtle developmental differences between early and late elementary school readers. In sum, it is possible that development did not play an important role in this sample of readers with dyslexia, but it seems more likely that the models fit poorly because it was underpowered. Given these limitations, it may be prudent to exercise caution when interpreting the current study's results regarding the role of development on these important reading skills.

Theoretical Implications

This work adds to the limited number of studies that have modeled the relation between phonological processes and text-level reading skills across both modalities (e.g., Price et al., 2016; Kim et al., 2001). Kim et al. (2011) warned that the lack of research regarding silent reading fluency may lead researchers to conclude that silent and oral reading fluency are essentially the same skill. Importantly, results from this study support that oral and silent fluency represent distinct constructs (Kim et al., 2011; Price et al., 2016), which has sometimes been debated. Additionally, this study supports a bottom-up view to reading that is consistent with automaticity theory, in that reading accuracy was found to support the rate at which one reads. Furthermore, this study supports a Vygotskian view of reading development (i.e., the transition from oral to silent reading fluency), with oral reading variables, particularly accuracy, contributing to both oral and silent reading comprehension. However, more research is needed to shed light on the developmental progression from oral to independent silent reading. Students need proficient silent-reading skills to access content area knowledge, but explicit instruction in how to transition from oral to silent reading with adequate comprehension is often lacking (Hiebert & Reutzel, 2010). Silent reading fluency deserves more attention in the research literature in regard to assessment and intervention.

Moreover, it should be noted that prior research has rarely parsed fluency into its subcomponents of accuracy and rate. Yet, results from this work revealed different patterns of relations observed among these fluency subskills. Past research has indicated that oral reading fluency is difficult to target for intervention and that improvement in rate is particularly difficult achieve (Lyon et al., 2004; Meyer & Felton, 1999; Torgesen et al., 2001; Torgesen, 2005). Having a slow rate when reading text is usually a persistent issue for students with reading deficits even after success with word reading accuracy has been achieved (Torgesen, 2005). Difficulties with silent reading rate are even less understood. In reviewing the extant literature, the National Reading Panel Report (2000) and Hiebert et al. (2012) have noted the paucity of silent reading teaching approaches that are evidence-based. One notable exception is silent scaffolded reading (Reutzel et al.,2008), which was found to be effective in fostering silent reading in the classroom. More data-driven intervention research is needed in the area of silent reading.

Lastly, no studies to date have examined these relations among phonological processing skills, subcomponents of fluency, and comprehension in a clinical sample of students with dyslexia. The current study contributes to the literature by incorporating all three aspects of phonological processing variables that are noted in the literature as important for supporting the acquisition of proficient reading skills (Johnson et al., 2010; Melby-Lervåg et al., 2012) into an all-encompassing model. RAN also appears to be very important component of phonological processing for this group of readers. If the current study's sample had included emergent readers or had focused on word-level skills, phonological awareness most likely would have made a more substantial contribution to the model.

Limitations and Future Directions

Several limitations of this work warrant discussion. Perhaps most importantly, the size of the sample may have undermined the efforts to examine the developmental model (as previously discussed). Future studies should include a larger number of participants in each grade or developmental level. A second limitation pertains to the generalizability of these results. Participants in this study were relatively homogenous in terms of socioeconomic status, race, and ethnicity. Because this study focused on students with reading difficulties that were severe enough to warrant placement at a school providing specialized services for those with dyslexia, this sample did not represent the normal distribution of reading skills. It is possible that important variables were overlooked in the specification of this model. For example, one important component of reading fluency, prosody, was not addressed. Common definitions of reading fluency include prosody, accuracy, and automaticity (often measured by rate) (Kuhn, Schwanenflugel, & Meisinger, 2010). Prosody is commonly overlooked in the literature and should be included in future models of the reading process. In the same vein, future research should examine working memory in addition to short-term memory when considering phonological memory. Lastly, this was a short-term longitudinal study with only two data points collected across a school year. More data points across a longer period of time are needed for a more nuanced examination of developmental trends.

The difficulties surrounding the assessment of silent reading has been cited as an explanation for why reading modality is rarely considered in the literature (Denton et al., 2011). Eye tracking is the gold standard for the assessment of silent reading fluency, but few tools exist that are feasible for use in school settings (Price et al., 2012). Future research should explore ways to make eye-tracking a viable option for elementary school populations. It may be important for intervention research to parse fluency into rate and accurate to better understand why fluency is so resistant to remediation efforts, and to refine fluency-oriented intervention for improved efficacy. Little is known about the variables that predict success in transition from oral to silent reading with equivalent comprehension. Future research is needed to examine the development of oral and silent reading skills to determine what skills are most relevant to each age group to inform clinical practice.

Conclusion

The purpose of this study was to investigate the relations among phonological skills, oral and silent reading fluency, and oral and silent reading comprehension in a longitudinal sample of students who were diagnosed with dyslexia. The results of this study followed a pattern of reading progression from lower to higher skills and from oral to silent reading. This progression of reading is consistent with dominant theoretical models of reading. RAN and accuracy during reading of connected text appear to be the most important indicators of successful comprehension. This study adds to the meager number of studies that have modeled the relation between phonological processes and text-level reading skills across both modalities (e.g., Price et al., 2016; Kim et al., 2001). No studies to date have examined the relations among phonological processing skills, subcomponents of fluency, and comprehension in a clinical sample of students with dyslexia. Research regarding these skills and the successful acquisition of these reading milestones is needed to inform intervention efforts and assessment practices. Future research should aim at determining whether the relations among phonological processing, fluency, and comprehension vary across two developmental reading groups, early elementary and late elementary. In conclusion, phonological processing, fluency, and comprehension are essential skills that students must become proficient in order to succeed in any educational endeavor.

References

AIMSweb Technical Manual. (2012). Retrieved August 12, 2016 from http://www.aimsweb.com/wp-content/uploads/aimsweb-Technical-Manual.pdf

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Baddeley, A. (1986). *Working memory*. New York, NY: Oxford University Press.

Baddeley, A. (1992). Working memory. *Science, 255*, 556-559.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*, 238-246.

Benninger, V. W., Abbott, R. D., Vermeulen, K., & Fulton, C. M. (2006). Paths to reading comprehension in at-risk second-grade readers. *Journal of Learning Disabilities, 39*, 334–351.

Bollen, K. A. & Long, J. S. (1993). Introduction. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 1–9). Newbury Park, CA: Sage Publication.

Bowyer-Crane, C., Snowling, M. J., Duff, F. J., Fieldsend, E., Carroll, J. M., Miles, J., . . . Hulme, C. (2008). Improving early language and literacy skills: Differential effects of an oral language versus a phonology with reading intervention. *Journal of Child Psychology and Psychiatry, 49*, 422–432.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen and J. S. Long (Eds.), *Testing structural equation models* (pp. 136-162). Newbury Park, CA: Sage.

Burge, P. E. (1983). Comprehension and rate: Oral vs. silent reading for low achievers. *Reading Horizons, 23*, 201-206.

Burke, M. D., Crowder, W., Hagan-Burke, S., & Zou, Y. (2009). A comparison of two path models for predicting reading fluency. *Remedial and Special Education*, *30*, 84–95.

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

Chall, J. S. (1996). *Learning to read: The great debate (revised).* New York, NY: McGraw-Hill.

Christ, T. J. & Silberglitt, B. (2007). Curriculum-based measurement of oral reading fluency: The standard error of measurement. *School Psychology Review*, *36*, 30-146.

Daane, M. C., Campbell, J. R., Grigg, W. S., Goodman, M. J., & Oranje, A. (2005). *Fourth-grade students reading aloud: NAEP 2002 special study of oral reading (NCES 2006-469)*. US Department of Education. Institute of Education Sciences, National Center for Education Statistics. Washington, DC: Government Printing Office.

Denton, C.A., Barth, A.E., Fletcher, J.M., Wexler, J., Vaughn, S., Cirino, P.T., & Francis, D.J. (2011). The relations among oral and silent reading fluency and comprehension in middle school: Implications for identification and instruction of students with reading difficulties. *Scientific Studies of Reading*, *15*(2), 109-135.

Dickens, R. H., & Meisinger, E. B. (2015). Examining the effects of skill level and reading modality on reading comprehension. *Reading Psychology*, *37*(2), 318-337.

Dunbar, S. B., Welch, C. J., Hoover, H. D., & Frisbie, D. A. (2011). *Iowa Assessments, Form E.* Orlando, FL: Houghton Mifflin Harcourt.

Dunbar, S. B., Welch, C. J., Hoover, H. D., & Frisbie, D. A. (2014). *Iowa Assessments, Form E and F, Research and Development Guide.* Orlando, FL: Houghton Mifflin Harcourt.

Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. Gough, L. Ehri & R. Treiman (Eds.), *Reading acquisition*. (pp. 107–143). Hillsdale, NJ: Lawrence Erlbaum.

Ehri, L. C. (1998). Grapheme-phoneme knowledge is essential for learning to read words in English. In J. L. Metsala & E. C. Ehri (Eds.), *Word recognition in beginning literacy*. (pp. 3–40). Mahwah, NJ: Erlbaum.

Ehri, L. C. (1999). Phases of development in learning to read words. In J. Oakhill & R. Beard (Eds.), *Reading development and the teaching of reading: A psychological perspective*. (pp. 79–108). Oxford: Blackwell Science.

Ehri, L. C. (2002). Phases of acquisition in learning to read words and implications for teaching. *British Journal of Educational Psychology: Monograph Series, 1*, 7–28.

Ehri, L. C. (2005). Development of sight word reading: Phases and findings. In M. Snowling & C. Hulme, (Eds.), *The science of reading, a handbook* (pp. 135-154). UK: Blackwell.

Elgart, D. B. (1978). Oral reading, silent reading, and listening comprehension: A comparative study. *Journal of Reading Behavior, 10*, 203-207.

Fletcher, J. M., Lyon, G. R., Fuchs, L. S., & Barnes, M. A. (2019). *Learning disabilities: From identification to intervention (2nd ed.)*. New York, NY: Guilford Press.

Fletcher, J., & Pumfrey, P. D. (1988). Differences in text comprehension amongst 7-8 year old students. *School Psychology International, 9*, 133-145.

Fuchs, L. S. & Maxwell, L. (1988). Interactive effects of reading mode, production format, and structural importance of text among LD pupils. *Learning Disability Quarterly, 11*, 97-105.

Fuchs, L. S., Fuchs, D., Hosp, M. D., & Jenkins, J. (2001). Oral reading fluency as an indicator of reading competence: A theoretical, empirical, and historical analysis. *Scientific Studies of Reading, 5*, 239–259.

Gathercole, S. E. & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29,* 336-360.

Gathercole, S. E., Willis, S. C., & Baddeley, A. D. (1991). Differentiating phonological memory and awareness of rhyme: Reading and vocabulary development in children. *British Journal of Psychology, 82*, 387-406.

Georgiou, G., Papadopoulos, T. C., & Kaizer, E. L. (2014). Different RAN components predict reading at different points in time. *Reading and Writing, 27*, 1379–1394.

Good, R. H., Kaminski, R. A., Smith, S., Laimon, D., & Dill, S. (2001). *Dynamic Indicators of Basic Early Literacy Skills* (5th ed.). Eugene, OR: University of Oregon.

Good, R. H., Simmons, D. C., & Kame'enui, E. J. (2001). The importance and decision-making utility of a continuum of fluency-based indicators of foundational reading skills for third-grade high-stakes outcomes. *Scientific Studies of Reading, 5*, 257–288.

Gray, A., & McCutchen, D. (2006). Young readers' use of phonological information: Phonological awareness, memory, and comprehension. *Journal of Learning Disabilities, 39*, 325–333.

Hammill, D. D., Wiederholt, J. L., & Allen, E. A. (2006). *Test of Silent Word Reading Fluency*. Austin, TX: PRO-ED.

Hausbrouck, J. & Tindal, G. A. (2006). Oral reading fluency norms: A valuable assessment tool for reading teachers. *The Reading Teacher, 59*(7), 636-644.

Hiebert, E. H., Wilson, K. M., & Trainin, G. (2010). Are students really reading in independent reading contexts? An examination of comprehension-based silent reading rate. In Hiebert,

E. H. and Reutzel, D. R. Eds., *Revisiting Silent Reading*. Newark, DE: International Reading Association.

Howe, K. B., & Shinn, M. M. (2002). *Standard reading assessment passages (RAPs) for use in General Outcome Measurement: A manual describing development and technical features* (technical manual). Eden Prairie, MN: Edformation.

Hudson, R. F., Pullen, P. C., Lane, H. B., & Torgesen, J. K. (2009). The complex nature of reading fluency: A multidimensional view. *Reading & Writing Quarterly, 25,* 4–32.

Hudson, R. F., Torgesen, J. K., Lane, H. B., & Turner, S. J. (2012). Relations among reading skills and sub-skills and text-level reading proficiency in developing readers. *Reading and Writing, 25*, 483–507.

Hu, L.T, & Bentler, P. M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1-55.

International Dyslexia Association (2002). *Definition Consensus Project*. Retrieved on May 2, 2018, from https://dyslexiaida.org/definition-consensus-project/.

Jenkins, J. R., Fuchs, L. S., van den Broek, P., Espin, C., & Deno, S. L. (2003). Sources of individual differences in reading comprehension and reading fluency. *Journal of Educational Psychology, 95*, 719–729.

Johnson, E. S., Humphrey, M., Mellara, D. F., Woods, K., & Swanson, H. L. (2010). Cognitive processing deficits and students with specific learning disabilities: A selective meta-analysis of the literature. *Learning Disability Quarterly, 33*(1), 3-18.

Kame'enui, E. J., & Simmons, D. C. (2001). Introduction to this special issue: The DNA of reading fluency. *Scientific Studies of Reading, 5*, 203–210.

Kibby, M. Y. (2009). There are multiple contributors to the verbal short-term memory deficit in children with developmental reading disabilities. *Child Neuropsychology, 15*, 485–506.

Kibby, M. Y., and Cohen, M. C. (2008). Memory functioning in children with reading disabilities and/or attention deficit/hyperactivity disorder: A clinical investigation of their working memory and long-term memory functioning. *Child Neuropsychology, 14*, 525–546.

Kibby, M. Y., Lee, S. E, & Dyer, S. M. (2014). Reading performance is predicted by more than phonological processing. *Frontiers in Psychology, 5*, 1-7.

Kim, Y. S., Petscher, Y. Schatschneider, C., & Foorman, B. (2010). Does growth rate in oral reading fluency matter in predicting reading comprehension achievement? *Journal of Educational Psychology, 102*(3), 652-667.

Kim, Y. S., Wagner, R. K. & Foster, E. (2011). Relations among oral reading fluency, silent reading fluency, and reading comprehension: A latent variable study of first-grade readers. *Scientific Studies of Reading*, *15*(4), 338-362.

Kirby, J. R., Georgiou, G. K., Martinussen, R., & Parrila, R. K. (2010). Naming speed and reading: A review of empirical and theoretical literature. *Reading Research Quarterly, 45*, 341-362.

Kirby, J. R., Parrila, R. K., & Pfeiffer S. L. (2003). Naming speed and phonological awareness as predictors of reading development. *Journal of Educational Psychology, 95*, 453-464.

Kline, R. B. (2016). *Principles and practices of structural equation modeling* (4th ed.). New York: The Guildford Press.

Kline, R. B. (2010). *Principles and practices of structural equation modeling* (3rd ed.). New York: The Guildford Press.

Kragler, S. (1995). The transition from oral to silent reading. *Reading Psychology, 16*, 395-408.

Kudo, M. F., Lussier, C. M., Swanson, H. L. (2015). Reading disabilities in children: A selective meta-analysis of the cognitive literature. *Research in Developmental Disabilities, 40*, 51-62.

Kuhn, M. R., & Schwanenflugel, P. J. (2007). *Fluency in the classroom.* New York, NY: Guilford Press.

Kuhn, M. R., Schwanenflugel, P. J., & Meisinger, E. B. (2010). Aligning theory and assessment of reading fluency: Automaticity, prosody, and definitions of fluency. *Reading Research Quarterly*, *45*(2), 230-251.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6*, 293-323.

Lefly, D. L. & Pennington, B. F. (1991). Spelling errors and reading fluency in compensated adult dyslexics. *Annals of Dyslexia, 41*, 143-162.

Lepola, J., Poskiparta, E., Laakkonen, E., & Niemi, P. (2005). Development of and relationship between phonological and motivational processes and naming speed in predicting word recognition in Grade 1. *Scientific Studies of Reading, 9*, 367-399.

Leslie, L., & Caldwell, J. A. (2011). *Qualitative Reading Inventory, Fifth Edition*. Boston, MA: Pearson Education.

Liao, C.-H., Deng, C., Hamilton, J., Lee, S-C., Wei, W., & Georgiou, G. K. (2015). The role of RAN in reading development and dyslexia in Chinese. *Journal of Experimental Child Psychology, 130*, 106-122.

Logan, G. D. (1997). Automaticity and reading: Perspectives from the instance theory of automatization. *Reading and Writing Quarterly, 13*(2), 123-146.

Lyon, G. R., Fletcher, J. M., Torgesen, J. K., Shaywitz, S. E., & Chhabra, V. (2004). Preventing and remediating reading failure: A response to Allington. *Educational Leadership, 61*(6), 86-88.

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53,* 1-14.

Manolitsis, G., Georgiou, G. K., Parrila, R. (2011). Revisiting the home literacy model of reading development in an orthographically consistent language. *Learning and Instruction, 21,* 496-505.

McBride-Chang, C. & Ho, C.-S. H. (2000). Naming speed and phonological awareness in Chinese children: Relations to reading skills. *Journal of Psychology in Chinese Societies, 1*, 93-108.

McCallum, R. S., Sharp, S., Bell, S. M., & George, T. (2004). Silent versus oral reading comprehension and efficiency. *Psychology in the Schools, 41*, 241-246.

Meisinger, E. B., Bloom, J. S., & Hynd, G. W. (2010). Reading fluency: Implications for the assessment of children with reading disabilities. *Annals of Dyslexia, 60*(1), 1-17.

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

Meyer, M. S. & Felton, R. H. (1999). Repeated reading to enhance fluency: Old approaches and new directions. *Annals of Dyslexia, 49*, 283-306.

Miller, S. D., & Smith, D. E. (1985). Differences in literal and inferential comprehension after reading orally and silently. *Journal of Educational Psychology, 77,* 341-348.

Moll, K. Ramus, F., Barling, J., Bruder, J., Kunze, S., Neuhoff, N.,…Landeri, K. (2014). Cognitive mechanism underlying reading and spelling development in five European orthographies. *Learning and Instruction, 29*, 65-77.

National Institute for Literacy. (2008). *Developing early literacy: Report of the Early Literacy Panel: A scientific synthesis of early literacy development and implications for intervention.* Jessup, MD: National Institute for Literacy.

Parrila, R. K., Kirby, J. R., & McQuarrie, L. (2004). Articulation rate, naming speed, verbal memory, and phonological awareness: Longitudinal predictors of early reading development. *Scientific Studies of Reading, 8*, 3-26.

Perfetti, C.A. (1977). Language comprehension and fast decoding: Some psycholinguistic prerequisites for skilled reading comprehension. In J. Guthrie Ed., *Cognition, curriculum and comprehension*. Newark, DE: International Reading Association.

Perfetti, C.A. (1984). Reading ability. In R. Sternberg (Ed.), *Human abilities: An information processing approach* (pp. 59-81). New York: W. H. Freeman and Co.

Perfetti, C.A, & Hart, L. (2001). The lexical bases of comprehension skill. In D. Gorfien (Ed.), *On the consequences of meaning selection* (pp. 67-86). Washington, DC: American Psychological Association.

Pikulski, J. J., & Chard, D. J. (2005). Fluency: Bridge between decoding and reading comprehension. *International Reading Association,* 510-519.

Price, K. W., Meisinger, E. B., D'Mello, S. K., & Louwerse, M. M. (2012). Silent reading fluency using underlining: Evidence for an alternative method of assessment. *Psychology in the Schools, 49*, 606–618.

Price, K. W., Meisinger, E. B., Louwerse, M. M., & D'Mello, S. (2016). The contributions of oral and silent reading fluency to reading comprehension. *Reading Psychology, 37*(2), 167-201.

Puolakanaho, A., Ahonen, T., Aro, M., Eklund, K., Leppanen, P. T., & Poikkeus, A. (2008). Developmental links of very early phonological and language skills to second grade reading outcomes: strong to accuracy but only minor to fluency. *Journal of Learning Disabilities, 41*, 353–370.

Reed, D. K., & Vaughn, S. (2012). Retell as an indicator of reading comprehension. *Scientific Studies of Reading, 16(3),* 187-217.

Robinson, M. F., Meisinger, E. B., & Waters, R. E. (2018). *A longitudinal investigation of the relation between reading modality and reading comprehension in students with reading disabilities.* Unpublished manuscript.

Samuels, S. J. (2006). Reading fluency: Its past, present, and future. In Rasinksi, T., Blachowicz, C., Lems, K. (Eds.), *Fluency instruction: Research-based practices* (pp. 7-20). New York: Guilford.

Samuels, S. J., & Farstrup, A. E. (2006). *What research has to say about fluency instruction.* Newark, DE: International Reading Association.

Schmidt, A. M. & Flege, J. E. (1995). Effects of speaking rate changes on native and nonnative speech production. *Phonetica, 52*(1), 41-54.

Schwanenflugel, P. J., Hamilton, A. M., Kuhn, M. R., Wisenbaker, J. M., & Stahl, S. A. (2004). Becoming a fluent reader: Reading skill and prosodic features in the oral reading of young readers. *Journal of Educational Psychology, 96*, 119–129.

Schwanenflugel, P. J., & Knapp, N. F. (2016). *The psychology of reading: Theory and* *applications.* New York, NY: Guilford Press.

Schwanenflugel, P. J., Meisinger, E. B., Wisenbaker, J. M., Kuhn, M., Strauss, G. P., & Morris, R. D. (2006). Becoming a fluent and automatic reader in the early elementary school years. *Reading Research Quarterly, 41,* 496–522.

Share, D. L. (2008). On the anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin, 134*(4), 584-615.

Share, D. L., & Stanovich, K. E. (1995). Cognitive processes in early reading development: Accommodating individual differences into a model of acquisition. *Issues in Education: Contributions from Educational Psychology, 1,* 1-57.

Stanovich, K. E. (1992). Speculations on the causes and consequences of individual differences in early reading acquisition. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 307–342). Hillsdale, NJ: Erlbaum.

Steiger, J. H. (1998). A note on multiple sample extensions of the RMSEA fit index. *Structural Equation Modeling, 5*(4), 411-419.

Shaywitz, S. E. (2003). *Overcoming dyslexia: A new and complete science-based program for reading problems at any level*. New York, NY: A. A. Knopf.

Speece, D. L., Mills, C., Ritchey, K. D., & Hillman, E. (2003). Initial evidence that letter fluency tasks are valid indicators of early reading skill. *The Journal of Special Education, 36*(4), 223–233.

Speece, D. L., & Ritchey, K. D. (2005). A longitudinal study of the development of oral reading fluency in young children at risk for reading failure. *Journal of Learning Disabilities, 38*, 387–399.

Speece, D. L., Ritchey, K. D., Silverman, R., Schatschneider, C., Walker, C. Y., & Andrusik, K. N. (2010). Identifying children in middle childhood who are at risk for reading problems. *School Psychology Review, 39*, 258–276.

Swanson, H. L., Trainin, G., Necoechea, D. M., & Hammill, D. D. (2003). Rapid naming, phonological awareness, and reading: A meta-analysis of the correlation evidence. *Review of Educational Research, 73*, 407-440.

Sweet, A., & Snow, C. (Eds.). (2003). *Rethinking reading comprehension*. New York, NY: Guilford Press.

Szenkovits, G., & Ramus, F. (2005). *Exploring dyslexics' phonological deficit I: Lexical vs sub-lexical and input vs output processes. Dyslexia, 11*, 253–268.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Allyn and Bacon.

Torgesen, J. K. (1996). A model of memory from an information processing perspective: The special case of phonological memory. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 157-184). Baltimore, MD: Brookes.

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Rose, E., Lindamood, P., Conway, T., & Garvin, C. (1999). Preventing reading failure in young children with phonological processing disabilities: Group and individual responses to instruction. *Journal of Educational Psychology, 91*, 579– 593.

Torgesen, J. K., Alexander, A. W., Wagner, R. K., Rashotte, C. A., Voeller, K. S., & Conway, T. (2001). Intensive remedial instruction for children with severe reading disabilities: Immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities, 24*(1), 33-58.

Torgesen, J. K. (2005). Recent discoveries from research on remedial interventions for children with dyslexia. In M. Snowling and C. Hulme (Eds.). *The Science of Reading*. (pp. 521-537). Oxford, UK: Blackwell Publishers

Torppa, M., Georgiou, G., Salmi, P., Eklund, K., & Lyytinen, H. (2012). Examining the double-deficit hypothesis in an orthographically consistent language. *Scientific Studies of Reading, 16*, 287-315.

Treiman, R., & Zukowski, A. (1991). Levels of phonological awareness. In S. A. Brady & D. P. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* (pp. 67–83). Hillsdale, NJ: Erlbaum.

Urbaniak, G. C., & Plous, S. (2013). *Research randomizer* (Version 4.0) [Computer software]. Retrieved on July 10, 2016 and December 1, 2016, from http://www.randomizer.org/

van den Boer, M., van Bergen, E., & de Jong, P. F. (2014). Underlying skills of oral and silent reading. *Journal of Experimental Child Psychology, 128,* 138–151.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45,* 2–40.

Wagner, R. K., Balthazor, M., Hurley, S., Morgan, S., Rashotte, C., Shaner, R., Simmons, K., & Stage, S. (1987). The nature of prereaders' phonological processing abilities. *Cognitive Development*, *2*, 355-373.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., & Burgess, S. R. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: a 5-year longitudinal study. *Developmental Psychology, 33,* 468–479.

Wagner, R. K., Torgesen, J., Rashotte, C. A., & Pearson, N. (2010). *Test of Silent Reading Efficiency and Comprehension*. Austin, TX: Pro-Ed.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2013). *Comprehensive Test of Phonological Processing* (2nd ed.). Austin, TX: Pro-Ed.

Wiederholt, J. L., & Bryant, B. R. (2012*). Gray Oral Reading Tests* (5th ed.). Austin, TX: Pro-Ed.

Wolf, M., & Bowers, P. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*, 415–438.

Wolf, M. & Katzir-Cohen, T. (2001). Reading fluency and its intervention. *Scientific Studies of Reading, 5*(3), 211-239.

Xue, J., Shu, H., Li, H., Li, W., & Tian, X. (2013). The stability of literacy-related cognitive contributions to Chinese character naming and reading fluency. *Journal of Psycholinguistic Research, 42*, 433-450.

Institutional Review Board
Office of Sponsored Programs
University of Memphis
315 Admin Bldg
Memphis, TN 38152-3370

PI: Elizabeth Meisinger
Co-Investigator: Ashley Mayhew, Melissa Fetterer-Robinson
Advisor and/or Co-PI: Jennifer Johnson
Department: Psychology, Users loaded with unmatched Organization affiliation.
Study Title: The Growth of Reading Skills in Children with Dyslexia
IRB ID: 3814
Submission Type: Renewal
Level of Review: Expedited

IRB Meeting Date:
Decision: Approved
Approval Date: July 13, 2018
Expiration Date: July 13, 2019

The IRB has reviewed the renewal request.

Approval of this project is given with the following obligations:
1. If this IRB approval has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.
2. When the project is finished or terminated, a completion form must be completed and sent to the board.
3. No change may be made in the approved protocol without prior board approval, whether the approved protocol was reviewed at the Exempt, Expedited or Full Board level.
4. Exempt approval are considered to have no expiration date and no further review is necessary unless the protocol needs modification.

Thank you,
James P. Whelan, Ph.D.
Institutional Review Board Chair
The University of Memphis.
Note: Review outcomes will be communicated to the email address on file. This email should be considered an official communication from the UM IRB.