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Longitudinal Relationships Between Reading and Spelling In Early Elementary Grades: Testing Causality Using a Cross-Lagged Panel Design

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Education

by

Ekaterina Petrovna Forrester

June 2013

Dissertation Committee:
Dr. Rollanda O'Connor, Chairperson
Dr. H. Lee Swanson
Dr. Michael Orosco

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2013

The Dissertation of Ekaterina Petrovna Forrester is approved:

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_____

Committee Chairperson

University of California, Riverside

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DEDICATION

To my family

ABSTRACT OF THE DISSERTATION

Longitudinal Relationships Between Reading and Spelling In Early Elementary Grades: Testing Causality Using a Cross-Lagged Panel Design

by

Ekaterina Petrovna Forrester

Doctor of Philosophy, Graduate School of Education
University of California, Riverside, June 2013
Dr. Rollanda O'Connor, Chairperson

Although considerable research has focused on the nature of reading-spelling relationships and its implications for practice, most of the literature is outdated, having been published in 1980s and 1990s. Moreover, limitations in the research base inhibit the full understanding of how reading and spelling development influence each other at different stages and whether reading-spelling relationships might differ in certain at-risk populations compared to typically developing readers. Several researchers suggested the existence and provided evidence for stages of reading and spelling development (Frith, 1985; Ehri, 1989; Henderson & Beers, 1980; Shanahan & Lomax, 1986). The present study examined the reading-spelling relationship hypothesis suggested by Uta Frith (1985) to determine whether evidence can be provided to support specific directionality of influences between reading and spelling. Using a sample of 386 elementary school students who were followed from first through fourth grade, a cross-lagged panel analysis explored across-time reciprocal influences of reading and spelling in Grades 1 and 3. The results indicated that during the alphabetic stage the relationship between reading and

spelling was significantly influenced by other early literacy skills, specifically students' knowledge of letter names and the ability to read words correctly. Additionally, students' ability to use alphabetic knowledge in decoding was a causal determinant of their ability to use this knowledge in spelling at later time points. During the orthographic stage, orthographic knowledge in reading facilitated the orthographic knowledge acquisition in spelling. While the results of this study provided additional support for the Frith's hypothesis of the orthographic knowledge transfer, it was not able to provide evidence for the alphabetic knowledge transfer hypothesis that suggests that alphabetic knowledge is first acquired in spelling and then facilitates alphabetic knowledge acquisition in reading. Instead, reading was found to be an antecedent and facilitator of both alphabetic and orthographic knowledge. Differences between typically developing and struggling readers were also examined. The implications of these findings for reading and spelling instruction and future directions for research are discussed.

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Chapter 1: Introduction

In the 1980s the issue of whether and how reading and writing influence each other was a popular topic. Researchers attempted to analyze the nature of this connection and created theoretical models that would guide the development of integrated teaching strategies (e.g. Shanahan & Lomax, 1988; Tiernay & Shanahan, 1991). Also interventions were implemented, in which researchers taught skills in one domain (reading) and measured achievement in the other (writing) (Ehri, 1989; Ehri & Wilce, 1987; Santa & Hoien, 1999). Since then, the topic of the reading-writing relationship has been nearly forgotten, evidenced by few new studies pertaining to this issue appearing in the last decade. Furthermore, most recent researchers who discussed a reading-writing relationship simply synthesized previous research (Wanzek et al., 2006).

Considering the aforementioned issues that exist in the literature on reading-writing relationships, more research is necessary at this point to both replicate and go beyond the earlier studies that examined this interrelationship. Most of the earlier studies on the nature of reading-spelling development utilized correlational analysis that simply established a relationship between the two domains concurrently, as well as the degree of strength of such relationship. Such analyses, however, fail to determine the direction of relationship (whether reading influences spelling or vice versa) and whether that directionality changes over time. Being able to know how reading and spelling influence each other in the process of reading-spelling development will allow researchers and practitioners in the field to create instruction strategies that will be reflective of the nature of the reading-spelling relationship. In addition to attempting to examine the directions in

the reading-spelling relationship, it would also be of interest to investigate how the reading-writing relationship changes across grade levels for different populations: minorities, English language learners, and struggling readers. Such investigation will add to the literature on the topic by explaining the possible differences that exist in the reading-spelling development process of certain populations at-risk and allow for generation of better teaching practices geared toward those specific populations.

During the past few years my interest has been in examining the nature of reading-spelling relationships. This interest resulted in a study that investigated the relationship between early reading skills and spelling in first grade and described how that relationship changed over the course of one year (Forrester & O'Connor, under review). The study also described how this relationship differed for struggling readers compared to typical readers. That research gave rise to the new wave of questions that I was not able to answer with the first-grade sample, particularly: How does the reading-spelling relationship change as children progress to mid-elementary grades? Does spelling influence reading development, reading skills impact spelling achievement, or is this relationship bidirectional? How do first grade skills predict later reading and spelling outcomes? In order to answer these questions I examined the reading-spelling relationship longitudinally and employed statistical analyses that evaluated the directionality of the relationship between the two domains. Another question of interest in this study is whether the longitudinal patterns of relationship between reading and spelling differ for certain populations. Specifically, with this dataset, I examined the

nature of the reading-spelling relationship for struggling readers and compared it to that of typical readers.

This study provides insights for the generation of theoretical models of reading-spelling development in typically developing children and struggling readers. Evidence of specific directionality in the relationships between the two domains found in this study resulted in implications that could guide the development of integrated curricula that incorporates reading and spelling instruction.

I sought to examine the longitudinal relationship between reading and spelling in first and third grades and evaluate the moderating effects of struggling reader status on this relationship by answering the following questions:

1. For Grade 1 does early reading ability exert an impact on later spelling development or does spelling influence reading?
2. Does the directionality of the reading-spelling relationship change for the same students in Grade 3?
3. Are longitudinal relationships between reading and spelling similar across typically developing and struggling readers?
4. Do longitudinal relationships between reading and spelling differ according to students' ELL status?

Chapter 2: Review of the Literature

Cognitive Processes in Spelling

According to Louisa Moats (1995) there are two currently accepted models that describe mental processes involved in spelling. The dual-route theory proposed by Stuart

and Coltheart (1988) gathered evidence for two separate neural pathways that are responsible for storing and processing different information involved in spelling. The phonological processor stores information about the sound structure of the word, while the visual-orthographic processor accumulates information about letters in printed words (Moats, 1995; Stuart & Coltheart, 1988). Depending on whether the spelling of the word is well-known and memorized or not yet known and has to be spelled by generating appropriate letters for speech sounds, one of the two processors is used to generate the spelling. The visual-orthographic processor holds visual representations of words that have been learned and remembered. These whole word representations can be retrieved in response to hearing or thinking about a particular word. The phonological processor, on the other hand, makes it possible for us to spell words that we have not yet learned. It stores spoken representations of the words in the form of a sound sequence. By using the phonological processor one determines the spellings for each sound or combination of sounds without having spelled that particular word before (Moats, 1995). Children in early elementary grades rely heavily on spelling words by activating their phonological processor and matching speech sounds to the letters they know. Their visual-orthographic processor does not hold many whole word representations yet, since children have not had much exposure and processing of print. As children progress through elementary grades and are exposed to more and more print through reading they become able to recall whole words automatically. In adults, phonological and visual-orthographic processors interact with each other as they try to spell a combination of unknown and memorized words. Therefore, the dual route theory proposes that when children are

beginning to learn to read and spell, their spelling is highly related to their phonological skills, but as children acquire larger sight word vocabularies through exposure to print, spelling becomes more related to visual-orthographic processing or memories of the whole words, at least for words that are remembered.

The other model of cognitive processes involved in spelling – a connectionist theory – emphasizes the relationships between different types of word knowledge and how these relationships come into play and influence one another when spelling occurs (Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). Similarly to dual-route theory, the connectionist model posits the existence of separate processors responsible for carrying out certain functions during the process of reading and spelling (phonological, orthographic, and semantic). Processors store different information but during word production all of these processors work together in generating appropriate letters and letter strings for speech sounds in spelling and producing accurate oral representations of printed words in reading. As children have more exposure to and practice in reading and spelling, the connections between processors are reinforced. The strength of the relationship between phonological, orthographic, and semantic representation of the letters, letter patterns, or whole words in individuals' memory determines how easily certain patterns or words can be recalled. Therefore, the patterns or words that are most common in a person's writing and/or reading can be recalled more easily because strong interconnections between the processors have been established. According to this theory, individuals will attempt to spell unknown words by using the familiar, most commonly experienced patterns because stronger interprocessor

connections have been established for these patterns through multiple exposures. In situations when an individual needs to spell a word that has been memorized as a whole, only the orthographic processor is explicitly used because the word can be spelled as a whole without phonological analysis of sound patterns. Nevertheless, the phonological processer is still activated and acts as a monitor that checks the correct spelling.

In addition to the cognitive processes involved in reading and spelling, it is important to turn attention to the issue of reading and spelling development and whether development in one of these domains affects development in the other. In the next section I evaluate the theoretical models of reading-spelling development chronologically by emphasizing how these theories have changed over time. I also introduce empirical studies that tested each theory and discuss the limitations of these studies that require further research. These limitations set the stage for this study that attempts to clarify the unanswered questions on the topic.

Theoretical Models of Reading and Spelling Development

The notion that reading and spelling rely on shared knowledge and progress through similar stages in their development has been emphasized in theories of reading-spelling development. Most theories of reading and spelling development introduce the notion of stages the children progress through at different points of their reading and spelling development and describe specific language patterns and strategies that are mastered at each stage. Despite some apparent similarities among these theories of reading-spelling development, there are some notable differences and new perspectives that appeared in those models as the knowledge of reading and spelling development has

changed over the years. In this literature review, I examine the chronological development of these models by focusing on important elements introduced by each, as well as note existing gaps in the models that have not been addressed and require further investigation.

Throughout the first half of the twentieth century the predominant approach to spelling was structured around memorizing word lists. This approach was grounded in what Templeton and Morris (2000) calls "the phonocentric view of English spelling system" (p.358). Guided by the fact that the English spelling system has deep orthography (irregular spelling), researchers and educators of the beginning of the twentieth century believed that because of the large number of irregular spellings in English, the most productive spelling instruction should focus on rote memorization of words. The research on spelling and spelling instruction manuals produced during this period (Horn, 1926; McKee, 1924) emphasized the importance of finding the most frequent words and patterns used in writing and generating word lists to be used for spelling instruction. Memorizing words presented in columns and lists was considered more effective than learning spelling words through context.

The first developmental theories of spelling introduced the idea of spelling as a developmental progression and described the process by which children acquire understanding of the relationships between sounds and letters through their developing phonological awareness and knowledge of the alphabetic principle (Chomsky, 1970; Read, 1971). The idea of a developmental sequence proposed by Chomsky and Read was picked up and extended by other researchers in the field of reading and writing

development (Ehri, 1989, 2000; Frith, 1985; Juel, Griffith & Gough, 1986; Moats, 1995; Shanahan & Lomax, 1986; Templeton & Bear, 1992). Henderson and Beers (1980) were the first to identify and name distinct stages in reading and spelling development and note that by examining children's spelling one can gain insight into their reading development. These researchers were the first to propose the relationship between learning to spell and learning to read (Henderson, 1981; Henderson & Beers, 1980). The specific stages introduced by the researchers comprised the:

a) Preliterate stage when children do not have knowledge of letters and cannot correspond sounds with appropriate letters
b) Letter-name stage when learners acquire knowledge of simple letter-sound correspondences
c) Within-word pattern stage of letter pattern acquisition
d) Syllable juncture stage of more complicated syllable patterns acquisition
e) Derivational constancy stage when spellings reflect the knowledge of complicated conventional patterns

At each of these stages learners master certain spelling strategies and patterns to the point where the application of these particular patterns becomes automatic, while at the same time accumulating other more complicated strategies (Henderson & Beers, 1980).

Several researchers provided support for this developmental theory of spelling acquisition by examining how children's invented spelling changes as they acquire more knowledge about the phonological and orthographic systems of English language.

Invernizzi and colleagues (Invernizzi, Abouzeid & Gill, 1994) supported Henderson's theory by finding evidence for the stages proposed by Henderson through a qualitative analysis of invented spelling of three children (6, 8 and 14 years of age). Researchers noticed that spelling mistakes students make are not random and that each stage of spelling development is characterized by a particular mistake pattern. Similar to Henderson (1981) and Henderson and Beers (1980), they posited that in learning to spell children progressively move from matching single sounds to specific letters of the alphabet, to applying within-word patterns (e.g., digraphs, blends, or silent e), to finally being able to identify and use meaning units of the word to assist them in spelling multisyllabic words. Invernizzi et al. (1994) also suggested a spelling instruction approach that focused on the current stage of student spelling development. They described how teachers' understanding of the changes in students' invented spellings can inform classroom instruction.

Uta Frith (1985) in her research also supported the notion of developmental progression in reading and spelling development but additionally suggested that as children progress through stages of reading and spelling development they not only experience performance of the acquired skills as they practice more and more, but also experience drops in performance when they are using new unpracticed patterns. The researcher viewed a process of spelling development as a combination of increases and drops in spelling performance. Frith identified three stages in reading and spelling development:

a) Logographic – children do not have knowledge of letter order in the words and possess little to no phonological awareness. Children may recognize familiar words by relying on contextual or pragmatic cues (being able to read and spell the names of popular brands etc).
b) Alphabetic – characterized by learners' knowledge of phonemes and letters and their simple correspondences. Children read by matching each letter in the word with an appropriate sound and spell by generating a letter representation for every sound in the spoken word.
c) Orthographic – children acquire the ability to read and spell by analyzing the words into their orthographic units without having to decode every single letter or generate a grapheme for every single sound. Learners no longer exclusively rely on phonological representation of the words but are able to use bigger language units (letter patterns, morphemes, syllables).

Frith suggests that once learners acquire knowledge of orthographic strategies, they start using the two previous strategies (logographic and alphabetic) less frequently and that these two strategies might even become less accessible due to the lack of usage (Frith, 1985). For both reading and spelling, the developmental stages follow each other and each subsequent stage capitalizes on the knowledge received during the earlier stages. However, according to Uta Frith the aforementioned stages do not happen simultaneously for reading and spelling (Frith, 1985).

According to this theory, at the logographic stage of literacy development learners have to become advanced in logographic reading before they would be ready to apply

logographic knowledge in spelling. Because during the logographic stage children rely on certain salient features of the words to internalize them in memory, it takes multiple exposures for children to be able to recognize the word (logographic reading) and even more exposures to create a mental representation of the word to be able to spell it from memory (logographic spelling). The alphabetic stage, according to Frith, is first acquired through spelling, while learners continue to use the logographic knowledge for reading until the alphabetic strategy in spelling becomes relatively advanced. Frith (1985) hypothesized that the reason that the alphabetic strategy is first acquired through spelling is that the alphabet system is primarily made for writing rather than for reading. To learn how to spell simple words, learners need to know a relatively small set of letters. In order to learn how to read, however, learners need to be able to map each letter of the alphabet with an appropriate sound and be able to realize that one letter might create different sounds depending on the surrounding letters (Frith, 1980, 1985). When children master simple letter-sound correspondences and move on to learning more complex orthographic patterns and morphological rules, learning to read these patterns precedes the ability to spell them. In other words, children first learn to read new orthographic patters and will need several exposures in print before they become ready to apply those patterns in spelling. When children are new to orthographic knowledge, they are able to recognize the orthographic patterns when they see them in print, but are not yet able to have sufficient mental representations of those patterns to direct their spelling (Frith, 1985).

Frith also proposed the existence of causal links between the two domains. She suggested that improved spelling of simple letter-sound correspondences leads to

improved reading of the words that follow simple letter-sound rules in early stages of reading and spelling development (alphabetic stage). She also hypothesized that improved reading of the more complex orthographic rules precedes and leads to improved spelling of those patterns (orthographic stage). To summarize the model, initially the experiences that children have learning how to spell promote their ability to read simple letter-sound correspondences, but as letter patterns and orthographic rules become more difficult, exposure to those patterns in print provides a necessary foundation and precedes the ability to apply those principles in spelling.

As one of the implications of this theory, Frith (1985) suggested that in order to promote successful reading and spelling development in children, educators should focus on introducing simple letter-sound correspondences in spelling to promote phonological awareness and initial reading ability in kindergarten and first grade. In later grades, according to the theory, it is important to ensure that children have frequent exposures to more complex orthographic rules in reading, as it will foster the ability to use those orthographic regularities in spelling.

One limitation of the model proposed by Frith (1985) is that only one study to date has tested and produced evidence for these particular causal connections between reading and spelling. A study by Davis and Bryant (2006) employed a cross-lagged panel correlation analysis to test Frith's causal hypothesis that children first acquire knowledge of orthographic patterns in reading and then as a consequence become able to use those patterns in spelling. The authors specifically tested whether the ability to use the conditional split-digraph rule (the final –e) in reading precedes and causes the ability to

spell this pattern. Two groups of students (those who started testing in second grade and those who started in third grade) were tested three times over the period of two years on their ability to read and spell pseudo-words that followed the split-digraph rule (the final –e). A cross-lagged panel design was used to examine the longitudinal correlations between reading and spelling and to determine whether causal links existed in the reading-spelling development of split-digraphs. The results indicated that the ability to read split-digraph words at age 7 directly influenced the ability to spell such words at age 8 and the success in reading split-digraphs at age 8 further caused the improvement in the ability to spell this pattern at age 9. In the last analyzed period between 9 and 10 years of age, the cross-lag correlation between reading and spelling was no longer significant, meaning that success in reading split-digraphs was no longer affecting how well children used split-digraphs in spelling at age 10, which suggested a change in the causal relationship between reading and spelling this particular pattern. The results of the study provided support for the Frith's hypothesis about the development and usage of orthographic knowledge in reading and spelling tasks. As an educational implication, Davis and Bryant suggested that teachers should enhance students' reading experiences with the split-digraph words in order to promote the ability to use this pattern in spelling.

Linnea Ehri (1989, 2000) initially developed stages of reading development and later extended her notion of developmental stages to spelling development as she proposed that reading and spelling progress through similar stages as learners acquire specific types of knowledge at each stage. Ehri distinguishes four stages that students progress through in the process of reading and spelling development. The *pre-alphabetic*

stage is characterized by limited knowledge of alphabetic system and inability to form letter-phoneme correspondences to spell words. Learners' initial spellings look like random scribbles. Children, however, might know how to read and spell certain words by remembering visual and pragmatic cues. This stage corresponds to the preliterate stage identified by Henderson and colleagues (Henderson & Beers, 1980).

Contrary to Henderson, who proposed only one alphabetic stage, Ehri's (1989) theory proposed *partial* and *full alphabetic* stages of reading and spelling development. During the *partial alphabetic* stage learners have some knowledge of the alphabetic system and phonological awareness, but their skills in those domains are incomplete. Children make partial connections between the phonemes and letters in words, typically by identifying first and final letter sounds. However, they still have trouble segmenting words into all their phonemes, which results in incomplete representations of words in spelling and incorrect pronunciations in reading. Ehri calls this processes phonetic cue reading because learners at this stage take cues from some of the letters and sounds in the word but leave out others (Ehri & Wilce, 1987). Children read or spell words by either memorizing them as a whole or guessing the rest of the word relying on surrounding letters. Learners have the most difficulty with the vowels and their sounds because they lack full knowledge of letter-sound correspondences.

The *full alphabetic* stage is characterized by the ability to make complete phonetic connections between letters in spelling and phonemes in spoken words. Students spell words phonetically, connecting every sound with a letter. The spellings generated by the students at this stage are more complete as they reflect the knowledge of appropriate

letter-sound correspondences; however, they might not be aware of conventional spelling patterns and morphological rules. Through continuous exposure to reading and spelling children learn about types of syllables, morphological patterns, and syntactic rules, and their reading and spelling skills reach the *consolidated* stage. Children acquire knowledge about different types of syllables and affixes and are able to retain more spelling patterns in memory. Applying larger letter and word patterns makes it easier for students to spell longer multisyllabic words with irregular spellings and spell by analogy to known words (Ehri, 2000).

Ehri and her colleagues produced several studies that supplied evidence for the proposed relationship between reading and spelling. In their study of kindergarteners who were learning to read and spell, Ehri and Wilce (1987) examined whether teaching children to spell phonetically would improve their later reading development. Researchers taught the experimental group how to spell consonant-vowel-consonant (CVC) words phonetically using letter tiles, while the control group just practiced associating single sounds with letters without specific spelling instruction. After the spelling training children were given several trials to learn to read 12 CVC words. The results indicated that the experimental group, who received instruction on how to spell phonetically, learned to read more words than their control peers. The experimental group also outperformed controls on the measure of phonemic segmentation. Ehri and Wilce (1987) concluded that early spelling training improves learners' ability to read words and use their phonemic segmentation skills. In other words, during the alphabetic stage of reading and spelling development, there exists a knowledge transfer from spelling to

reading as evidenced by the study described above. This particular study illustrates how reading and spelling are related during the alphabetic stage but does not shed light on how this relationship changes as learners progress to the consolidated stage and start relying less on phonemic spelling and more on spelling with larger morphological and syllabic patterns.

Other studies conducted by Ehri and colleagues illustrated how reading development and instruction influence spelling. Ehri and Wilce (1986) introduced two groups of second graders to 12 words that all had middle alveolar sounds that are pronounced like "d" in American English (e.g. meteor, critter, huddle, modify). The experimental group read the words, while the control group only heard the words read by a researcher without seeing them in print. On the next day both groups of students were asked to spell the words they had learned the day prior. As predicted by the researchers, students who saw and read the words were in most cases able to differentiate between d and t and produce correct spelling for the words, whereas students who only heard the words spelled them phonetically (as d) in most cases. This study again focused mostly on children who rely heavily on phonemic representations of the words and have not yet reached the consolidated stage in their spelling. Research that examines the relationships between reading and spelling at the consolidated stage when learners spell by applying more complicated letter and word patterns and rely less on spelling phonetically is necessary.

One major difference between the stage theories proposed by Frith (1985) and Ehri (1989, 2000) is that even though Frith (1985) supports the notion of a developmental

sequence in reading and spelling development, she proposed that the time-course of the stages differs for reading and spelling (non-concurrent). Ehri, on the other hand, (2000) suggests that learners' progression through different stages in spelling and reading occurs simultaneously. However, this claim of simultaneous progression is not supported by any experimental evidence, as most of the studies conducted by Ehri and Wilce (1986, 1987) in support of their stage theory just showed that reading and spelling development are related without specifically addressing whether children learn the skills necessary for each stage simultaneously or whether, for example, learning to read certain patterns precedes the ability to spell them.

Contrary to Ehri's belief of simultaneous progression, Frith (1985) hypothesizes that progression through stages does not happen simultaneously and at different stages either reading or spelling development set the pace for later development in the other domain. For instance, logographic knowledge, according to Frith (1985), is first acquired through reading and later transferred to spelling. It typically takes fewer exposures to a familiar word to remember its salient features and recognize it through reading than memorizing it well enough to spell it. Reading and spelling development at the alphabetic stage, however, follows a different path. Frith proposed that children first learn alphabetic knowledge through spelling and then employ this new knowledge in reading. Similarly to the logographic stage, during the orthographic stage (the final stage in the Frith's theory) children learn how to use certain orthographic patterns and rules first through reading and later, once they become familiar and somewhat advanced in reading these patterns, they become able to apply them in spelling.

This hypothesis of asynchronous development of reading and spelling skills sounds logical if we think about children who at certain point of their literacy development are able to read words that they cannot yet spell. Davis and Bryant (2006) provided some evidence to support Frith's developmental hypothesis, but the nature of their data only allowed them to test the last part of the hypothesis, that states that children first acquire orthographic knowledge through reading and have to become relatively advanced in using orthographic strategies before they can transfer and start applying this type of knowledge in spelling. The question still remains whether other parts of the hypothesis can be tested and validated by studying the relationships between reading and spelling in the earlier stages of literacy development. The nature of the data available for the present study allowed a test of both the alphabetic and the orthographic stages of Frith's hypothesis, thus adding to existing knowledge of reading-spelling relationships at various stages of development.

Views of Spelling Difficulty and Reading-Spelling Relationships of Struggling Readers

Dual-route and connectionist theories described earlier attempted to explain reading and spelling difficulty by using the abovementioned notion of processors. The dual-route theory posits that when the phonological processor is impaired and individuals rely solely on the orthographic processor, a deep dyslexia or deep dysgraphia is present (Marshall & Newcombe, 1973; Moats, 1995). Deep dyslexia manifests itself as an inability to read nonsense words phonetically by distinguishing individual sounds, while deep dysgraphia affects the ability of an individual to spell nonsense words by producing

letters for each sound. Other symptoms of deep dyslexia and deep dysgraphia are producing semantically similar but phonetically distant words in reading and spelling (big for large, chair for desk) and more difficulty spelling and reading abstract than concrete words.

On the opposite side of the spectrum are individuals with an impaired orthographic processor but intact phonological and semantic processing. In this case individuals have a good understanding of phonetic processes (can blend the word sounds together and spell by producing letter representations for the sounds they hear), but are unable to recognize and spell whole words that have irregular spellings (Moats, 1995). Impairments associated with this process are called surface dyslexia and surface dysgraphia (in contrast with deep dyslexia and dysgraphia).

A connectionist theory approach to individual differences in spelling ability suggests that how well individuals can spell depend on how strong and clear their images in phonological and orthographic processors are. When students are unable to or have difficulty with detecting phonemes they are not able to produce correct phoneme-letter correspondences and therefore spell words incorrectly. Individuals who lack clear representations of whole words in their orthographic processor produce incomplete or incorrect word representations from their memory.

Another approach to the nature of reading-spelling difficulty suggests that in individuals who have difficulty spelling, phonological and orthographic processing have weaker relations than in typically developing readers (Ehri, 1989). While for typical readers, Ehri suggests reading and spelling are highly correlated, for struggling readers

and spellers these relationships are tenuous. The orthographic processor is less developed in struggling spellers, which makes them over reliant on phonological spelling.

Several correlational studies that examined and compared relationships between reading and spelling in typically developing readers and readers with reading disabilities suggested that in populations with reading disabilities the reading-spelling relationships tend to be significantly less correlated. Greenberg, Ehri, and Perin (1997) conducted a study where they compared correlations between reading and spelling production tasks in typically developing third and fifth graders and reading-level matched adults with reading disabilities. Researchers found that while in both cases correlations between reading and spelling were significantly greater that zero, the correlations found for reading-disabled adults were significantly lower than those found for typically developing children.

Studies that examined error patterns found in spelling of typically developing children found that those errors reflect the current stage of spelling development and specific types of knowledge that learners need to acquire at that stage. Moats (1995) suggests that spelling errors are dependent on the current stage of spelling development and can be associated with: a) the learner's inability to segment spoken words into phonemes, b) confusion between similar phonemes, and c) failure to remember appropriate orthographic rules. Do learners with spelling difficulties produce similar error patterns?

Several studies on spelling disability have examined whether individuals with learning difficulties produce similar error patterns in their spellings. Some researchers argue that there are indeed significant differences in the error patterns of learners with

spelling difficulties; others found that error patterns in learners with spelling difficulties were comparable to those produced by typically developing students (Moats, 1983; Worthy & Invernizzi, 1990). There is no definitive answer to whether the spelling error patterns differ in struggling spellers, nor is research conclusive on whether the nature of reading-spelling relationships differ for struggling learners compared to typically developing children. What is the extent to which reading and spelling influence each other in students with learning difficulties?

Louisa Moats (1995) suggests that spelling difficulties are linguistic in nature, because many individuals with spelling difficulties also have reading difficulties. And even in cases where no apparent reading difficulties are associated with spelling disorder, other language difficulties such as impaired ability to learn a foreign language or other types of language processing problems can be found (Moats, 1995). Our study (Forrester & O'Connor, under review) that described the nature of reading spelling relationships in first graders, suggested that in struggling readers correlations between spelling and early literacy skills, as well as reading, were weaker on average than those same relationships in typically developing readers. We concluded that struggling readers experience less knowledge transfer between reading and spelling.

Another important view on reading and spelling difficulties suggests that struggling readers often lack sufficient decoding skills and have to read texts that are too difficult for them, which results in negative reading experiences and promotes reading-avoiding behaviors. As their negative reading experiences multiply, the reading achievement suffers more and more. Conversely, typical readers who have better

decoding skills, read texts of appropriate reading difficulty and experience more rewarding reading experiences. As they read, they learn more and more about decoding. They become more proficient readers and at certain point the decoding becomes less cognitively demanding and frees some mental resources to other reading-related skills (vocabulary, comprehension, syntax knowledge). Such process is called bootstrapping, which refers to the ability of good readers to learn more about reading every time they read (Stanovich, 1986). According to Frith (1986), reading, at least during the orthographic stage, is an important contributor to the development of orthographic knowledge in spelling. Therefore, the increased reading exposures to the orthographic patterns in reading have important implications for children's ability to use those patterns in spelling. On the other hand, struggling readers who have more negative reading experiences due to the lack of proficient decoding skills, and who try to avoid reading as much as possible will experience less exposure to the orthographic patterns in reading. This might affect the orthographic knowledge transfer between reading and spelling and inhibit the development of orthographic knowledge in spelling. It can be hypothesized that struggling readers in this study might experience less bootstrapping through their reading activities.

As described earlier, Frith (1985) proposed that while reading and spelling progress through similar stages of development, the time-course of these stages is different for the two domains. Specifically, she suggested that during the logographic stage of development, the ability to recognize words by remembering certain salient features of the words is first acquired through reading and that it takes multiple successful

recognitions of the words before learners are able to spell those words. At the alphabetic stage, however, the ability to spell words phonetically (match each phoneme of the spoken word with an appropriate letter of the alphabet) becomes an antecedent for the ability to read using phonemic awareness. By the orthographic stage, the ability to recognize certain orthographic patterns in print precedes the ability to apply the knowledge of those patterns in spelling. As already discussed, only one study to date has examined the validity of this hypothesis (Davis & Bryant, 2006) and this study only investigated the nature of reading-spelling of one orthographic rule (silent –e) in typically developing learners. Therefore, a study to examine whether reading-spelling relationships in struggling readers would follow the same developmental progression and whether reading and spelling in struggling learners influence each other similarly compared to typically developing readers is needed.

Rationale for Conducting This Study

Testing Frith's developmental hypothesis. Although considerable research has focused on the nature of reading-spelling relationships and its implications for practice, most of the literature is outdated, having been published in 1980s and 1990s. Moreover, limitations in the research base inhibit the full understanding of how reading and spelling development influence each other at different stages and whether reading-spelling relationships might differ for certain at-risk populations compared to typically developing readers. The present study examined the reading-spelling relationship hypothesis suggested by Frith (1985) to determine whether evidence can be provided to support

causal relationships between reading and spelling. Important issues addressed in the present study are as follows:

a) A hypothesis proposed by Uta Frith was purely speculative and needs data driven evidence to support the presence of the proposed relationships. The causal claims proposed by Frith have not been extensively tested, as only one study to date has examined whether causal connections between reading and writing exist, as suggested in Frith's theory (Davis & Bryant, 2006). The aforementioned study by Davis and Bryant only tested the part of the Frith's theory (1985) regarding the reading-spelling relationship present at the orthographic stage of development and only for typically developing readers. In that study children first gained knowledge of one orthographic pattern through reading and then later on applied it to spelling. The nature of the data used in the present study allowed me to simultaneously examine two stages of the Frith's reading-spelling development hypothesis: alphabetic and orthographic.

b) The spelling measure used by Davis and Bryant was a researcher-developed measure of pseudo-words. Researcher-developed measures are typically created for a particular study and do not undergo rigorous procedures that allow generalization to larger samples and different populations. Researcher-developed measures are also typically associated with higher effect sizes (Swanson, Hoskyn & Lee, 1999). The data used in the present study include scores on standardized and often used spelling assessments: The Test of

Written Spelling (Larsen, Hammill & Moats, 1999) that was utilized to assess spelling achievement of participants in second through fourth grades and the Developmental Spelling Test (Tangel & Blachman, 1992) that was used with students in kindergarten and first grade. The present study employed these assessments, as these measures have been standardized for use with large samples and different populations.

c) Davis and Bryant (2006) tested the developmental hypothesis proposed by Frith (1985) with typically developing readers. There are no studies to date that have examined whether this hypothesis is valid for struggling readers. The present study investigated this issue by comparing the reading-spelling relationships for typical and struggling readers.

Cross-lagged design. A number of studies that described the nature of reading-writing relationships have employed correlational statistics (Langer, 1986; Shanahan, 1986; Tiernay & Shanahan, 1991) or observational qualitative research with invented spelling (Bear & Templeton, 1998; Henderson, 1981; Invernizzi, Abouzeid, & Gill, 1994). Correlational approaches can describe the strength of the relationship between the variables of interest; however, they do not explain the directions in that relationship. Some statistical approaches including path analysis and cross-lagged panel designs can reveal both patterns and directions in the relationship. The present study sought to develop models of reading-writing relationships using validated assessments of reading and spelling and employing advanced statistical methods to discern the patterns and direction in each relationship.

Cross-lagged panel correlation analysis (Kenny, 1979) examines correlations between two variables over time and allows researchers to determine whether one variable is significantly correlated with changes in the other variable. For example, if we have several time points of reading and spelling scores we can investigate whether reading achievement at the first time point determines spelling achievement at latter time points. This is done by comparing the correlation between reading at time point 1 (R1) and spelling at time point 2 (Sp2) and the correlation between spelling at time point 1 (Sp1) and reading at time point 2 (R2). If the former correlation is significantly greater than the latter, then it can be concluded that reading ability at time point 1 determines spelling achievement at time point 2.

Uta Frith's hypothesis proposes the existence of causal links between the two domains. She suggested that at the alphabetic stage of reading-spelling development spelling knowledge acts as an antecedent in acquiring knowledge of the alphabetic system and that improved spelling of simple letter-sound correspondences leads to improved reading of the words that follow simple letter-sound rules. Therefore, during the beginning stages of reading and spelling, spelling ability determines later reading development. When children start using within-word and morphological patterns in producing spellings for longer multisyllabic words, the ability to recognize those patterns in print (i.e. reading) becomes the "pacemaker" and precedes the ability to spell them (Davis & Bryant, 2006; Frith, 1985). As children acquire orthographic knowledge (ability to read and spell patterns that do not follow simple letter-sound correspondence), learners are first only able to use those patterns to read words and require extensive practice in

order to transfer the knowledge of these patterns to being able to spell them. Therefore, Frith posited that improved reading of the more complex orthographic rules precedes and leads to improved spelling of those patterns. A cross-lagged panel design used in this study allowed for testing of this specific hypothesis by examining whether the ability to use alphabetic knowledge in spelling precedes and improves a later ability to use alphabetic knowledge in reading. It also helped determine whether orthographic knowledge is first acquired through reading and then transfers to spelling.

Testing developmental hypothesis in struggling readers. Models of spelling development proposed in the Virginia studies (Bear & Templeton, 1998; Henderson, 1981; Invernizzi, Abouzeid & Gill, 1994; Read, 1971) and by Moats (1995), as well as theories of reading and spelling relationships introduced by Ehri (1989, 2000) and Frith (1985) were based on typically developing students without identified learning difficulties. Multiple studies have demonstrated that reading and writing development progress through similar stages for typically developing students. Several studies have also been conducted to identify the nature of reading-spelling relationships and spelling development in struggling readers. Those studies suggest that on average reading-spelling relationships and transfer between the two domains are weaker for struggling readers and that even though spelling development follows the same order in learners with difficulties, it is usually delayed.

The present study investigated whether models of reading-spelling relationships hypothesized by Frith (1985) apply for struggling readers. Specifically, I tested whether

similar causal relationships exist between reading and spelling as in the general population.

Proposed stages of reading and spelling development. To test the developmental hypothesis of the relationships between reading and spelling I had to choose participants progressing through specific stages of literacy development: alphabetic and orthographic. The alphabetic stage of reading and spelling development is characterized by the ability to read and spell by using one-to-one letter-sound correspondences. Frith proposed that first grade is the time when most children progress through the alphabetic stage of reading and spelling development, since they still rely heavily on phonemic awareness in their reading and spelling tasks. In my previous study (Forrester & O'Connor, under review) I discovered that both spelling and single word reading ability correlated highly with phonemic awareness at the beginning and middle of first grade. At the end of first grade these correlations became smaller, though still significant, suggesting that as children start acquiring knowledge about orthographic patterns, they rely less on using simple letter-sound correspondences in their reading and spelling. Therefore, I selected first grade with three data collection points (fall, winter, and spring) to represent students' alphabetic stage of reading and spelling development and to test the developmental hypothesis.

The orthographic stage of reading and spelling development is characterized by the ability to read and spell words by analyzing the words into their orthographic units without having to decode every letter or generate a grapheme for every single sound. Learners no longer exclusively rely on phonological representation of the words, but are

able to use larger language units (letter patterns, morphemes, syllables). For this study orthographic knowledge will be defined as knowledge about specific letter and word patterns (digraphs, split-digraphs, inflections, and other morphological and irregular word patterns) that cannot be represented by one-letter-to-one-sound correspondences.

To determine whether particular measures might be used to identify phonological and orthographic stages, I evaluated the items on the Word Identification subtest of the Woodcock Reading Mastery Test-Revised (1997) for the presence of orthographic patterns. All items subsequent to item #25 require the knowledge of certain orthographic patterns (digraphs, split digraph –e, word chunks, etc) (Table 1). I decided to examine students' performance on the Word Identification subtest WRMT-R in the winter of third grade to determine what percentage of the children had a raw score below 25, which would indicate that they were unable to read the words that contained orthographic patterns and therefore were not yet at orthographic stage of reading and spelling development. Students in the third grade sample are labeled as two subsamples: struggling readers and typically developing readers. The typically developing readers subsample all scored above the cut point of 25. The minimum Word ID score in the typical subsample was 43 (well above the cut-off). A one sample t-test performed on the typical sample that compared this sample's mean to the cutoff point of 25 indicated that the typical sample's mean (59) was indeed significantly different than 25.

I performed a similar analysis on the struggling reader subsample WRMT-R Word ID scores. The minimum Word ID score in the struggling reader subsample was 28. A one sample t-test that compared the struggling reader sample mean (47) to the cut-

off value of 25 showed that the struggling reader sample mean was significantly greater than the cut-off value.

Even though all of the students in the sample were above the cutoff point of 25 at which words become purely orthographic, I could not assume that all of the students had fully reached the orthographic stage of reading and spelling development. Students might possess knowledge of a few orthographic patterns, but still rely heavily on phonological decoding when they encounter words with unfamiliar patterns. I, therefore, needed to establish a point at which the students' performance on WRMT-R Word ID subtest becomes predominantly orthographic. I tabulated the first 50 words of Word ID subtest according to the type of knowledge needed to read the word (Table 1). Of the first 50 words, 12 words were phonologically decodable, 10 are high frequency sight words and 28 words contained orthographic patterns. Next, I added the number of phonologically decodable and sight word together to obtain the number of non-orthographically spelled words. Of the first 50 there were 22 non-orthographic and 28 orthographically structured words. Visual analysis of the frequency distribution of scores revealed that all of the typically developing students in the sample scored above 43. In order to obtain a score of 43 a student had to read 22 words correctly with various orthographic patterns (ai, ch, ee, er, ou, ight, able, -e, -y) and 21 phonologically decodable or sight words. A score of 43 could represent a point at which children have to be able to read relying mainly on their knowledge of orthographic patterns. Thirty-one students from the struggling reader subsample (26%) scored below 43, suggesting that in the sample of struggling readers by this criterion more than 70% of students had reached the predominantly orthographic

stage. Therefore, I concluded that in the fall of third grade the majority of students in the sample had fully reached the orthographic stage of literacy development and third grade can be used to test the developmental hypothesis at the orthographic stage.

By addressing some of the limitations of previous research on reading-writing relationships, the findings of the present study have the potential to impact the generation of theoretical models as well as guide the development of integrated curriculum that incorporates reading and spelling instruction and focuses on learners' current stage of reading and spelling.

Chapter 3: Method

In this chapter I present the procedures and data collection methods as well as research design that were used in the present study and describe the analyses of the data. First, the conceptual framework based on the Uta Frith's developmental hypothesis (1985) is presented along with the models of reading-spelling relationships that were tested in the study. Next, the hypotheses are presented, followed by the description of the data used in the study.

Conceptual Framework

In the literature review, existing theories of reading-spelling development were presented and the possible avenues for future research on the nature of reading-spelling relationships were discussed. Specifically it was determined that a developmental hypothesis in which the direction of facilitation between reading and spelling changes over time proposed by Uta Frith (1985) remains speculative and lacks strong evidence. I found only one study to date that provided evidence for the directionality during the

orthographic stage of Frith's hypothesis (Davis & Bryant, 2006). This study, therefore, by using a longitudinal dataset, examines whether evidence supports the specific directions hypothesized for two stages of the aforementioned hypothesis: alphabetic and orthographic.

Davis and Bryant (2006) attempted to find proof for the developmental hypothesis by investigating the nature of reading-spelling development in typically developing students. It is unclear, however, whether their finding holds for students with reading difficulties. This research examines whether the reading and spelling relationships follow the same pattern in struggling readers.

Hypotheses

Based on a literature review presented earlier and the conceptual framework generated for this study, three major hypotheses guided the analysis of data. First, it is hypothesized that early on in the process of reading-spelling development students acquire alphabetic knowledge by learning how to spell words using one-sound-to-one letter mapping, then later they transfer this knowledge of letter-sound correspondences to reading. Therefore, I expect to find that in first grade cross-lag correlations between students' spelling scores at time 1 and their reading scores at time 2 will be significantly greater than the correlation between their reading at time 1 and spelling at time 2, suggesting that learning alphabetic knowledge in spelling determines later ability to apply this knowledge in reading. I tested this hypothesis by examining: 1) the relationships between a measure of phonological decoding and a measure of phonological spelling and, 2) the relationships between a measure of correct word reading and a measure of correct

word spelling. These two separate analyses allowed me to see the directions of relationships based on the type of knowledge assessed. Specifically, are relationships found between precise measures of alphabetic decoding and spelling generalize to the relationships found between more general measures of correct word reading and word spelling?

Second, Frith's hypothesis states that after children master individual grapheme-phoneme correspondences they begin to recognize more complex orthographic patterns and rules within words. At this stage, they first learn orthographic patterns through reading and then apply this knowledge in spelling. I hypothesize to find a pattern of relationship opposite to that in the first grade. In other words, I expect that by third grade the correlation between reading at time point 1 and spelling at time point 2 will be significantly greater than the correlation between spelling at time point 1 and reading at time point 2. I test this hypothesis by examining: 1) the reading-spelling relationships present between the measure of orthographic reading (described in the measures section) and the measure of orthographic spelling to tap into the reading-spelling relationships associated with orthographic knowledge, and 2) a measure of oral reading and a measure of word spelling (general measures that do not tap into any specific knowledge).

Finally, it is predicted that these directions might not be found in struggling readers, as several studies on the nature of reading-spelling relationships have suggested that these relationships tend to be weaker in struggling readers. I expect to find that correlations between reading and spelling are weaker for struggling readers and that reading and spelling do not impact each other to the same extent as for typical readers.

Participants

The data proposed for this study were obtained from a four-year longitudinal study of reading development and intervention using a Response to Intervention model (RTI). The original dataset available for the RTI study, from which the data for the present study was obtained, contained two waves of first through third grade assessments that were collected one year apart. Kline (2005) suggests that with regard to the ratio of subjects to parameters in the SEM models, researchers should have at least 5 subjects for each parameter and ideally 10 subjects per parameter. The proposed models in the study have 20 parameters, so a sample size of at least 100 is necessary for the results to be reasonably stable. I initially had planned to use a sample size of 186 obtained from the second wave of students participating in a large RTI study. These students began first grade in fall 2008 and were followed for three years until they finished third grade in spring 2011. When this sample size was divided into typical and struggling reader subsamples to compare the models, the sample size dropped to 50 students for struggling reader sample and 136 for the typical sample. A sample size of 50 subjects might not be sufficient to perform the proposed analysis reliably for the struggling reader sample. In addition to the 186 students that were initially considered, data on the same assessments were available for 236 students who began first grade in fall 2007 and finished third grade in spring 2010. These students attended the same schools and were instructed by the same teachers the year before the second cohort of 186 students. If the two cohorts are not significantly different on the demographic or study variables, they could be combined to create a larger sample size consisting of two waves of data with a total of

422 cases, which would provide a sufficiently larger sample size to perform the proposed analysis.

Independent sample t-tests performed on the 2 cohorts revealed that the cohorts were not significantly different on any reading or spelling scores collected in third grade. Mann-Whitney U tests were conducted on first grade early literacy and spelling assessments due to non-normality of distributions of Word Identification Fluency (WIF), Developmental Spelling Test, and correct word spelling scores in the fall of first grade. Mann-Whitney U tests indicated that cohorts were not significantly different on developmental spelling, correct word spelling or any early literacy scores. Cohorts were also not significantly different on gender or ELL distributions as evident by the Chi-square tests performed on pairs of categorical variables. Therefore, the two cohorts were combined. Combined dataset, consisting of 422 cases was examined on the presence of missing data (missing data analysis is described in the results section). After cases with missing data on more than half of the assessments necessary for the proposed analysis were removed, the final dataset contained 386 cases.

Demographic data are shown in Table 2. The combined ethnic composition of the sample was approximately 71% Hispanic, followed by African American (13%) and Caucasian (12%). In the final sample of 386 students Hispanic students accounted for 71% (n=274) of the total sample and 80% of the minority students in the sample. A total of 54% of the sample were English Language Learners (n=208) with Spanish being a predominant first language.

The five participating schools represented two school districts in Southern California. Students in the schools were comparable with regard to their age and gender characteristics. Girls represented 45% of the total sample (n=174). Students included in the analyses were grouped in 22 different classrooms in first grade with an average number of students per classroom being 8 and 15 different classrooms in third grade with an average number of students per classroom being 11.

Identifying Struggling Readers

The following subtests and scores of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS, Good & Kaminski, 2003) (each described below) were used in the fall of first grade to identify students who scored below the at-risk criteria: Letter Naming Fluency (< 40), Phoneme Segmentation Fluency (<25), Nonsense Word Fluency (<25), and the Oral Reading Fluency (<1). At the beginning of third grade Oral Reading Fluency subtest of DIBELS was used with cut-off of 65 words correct per minute that signified reading difficulty. Of 386 participants who represent the final data set, 119 were struggling readers as identified by aforementioned assessments in first grade.

Measures

Data for this study was obtained from whole class screening datasets maintained by the RTI study. Spelling and reading measures were collected three times per academic year at 3 observation periods during the whole-class screenings: fall, winter, and spring of first and third grade. Trained graduate students individually administered the early literacy and reading assessments. Spelling assessments were administered by the classroom teachers to their entire class.

First Grade Assessments. In first grade, literacy measures collected consisted of three DIBELS subtests (Dynamic Indicators of Basic Early Literacy Skills; Good & Kaminski, 2003): Letter Naming Fluency (LNF), Phoneme Segmentation Fluency (PSF), and Nonsense Word Fluency (NWF). Word Identification Fluency (WIF) was used to assess automaticity of correct word reading (Fuchs, Fuchs & Compton, 2004). The Developmental Spelling Test (Tangel & Blachman, 1992) assessed phonological spelling ability.

***Alphabetic decoding*.** The Nonsense Word Fluency subtest of DIBELS (Kaminsky & Good, 1996) was used a measure of alphabetic decoding. Nonsense Word Fluency is a test of letter-sound correspondence of the English alphabet. The student is shown a list of randomly ordered vowel-consonant and consonant-vowel-consonant nonsense words (sim, aj) and asked to produce the individual letter sound for each letter or say the whole word. The final score is the number of correct letter-sound correspondences produced in one minute (Kaminski & Good, 1996). The one-month, alternate-form reliability for NWF in January of first grade is .83 (Good, Kaminski, Shinn, Bratten, Shinn, Laimon, Smith, & Flindt, 2004).

Word identification fluency (WIF). The Word Identification Fluency measure (Fuchs, Fuchs & Compton, 2004) was used to assess the automaticity of correct word reading skill in fall, winter, and spring. The child was presented with a list of 100 high-frequency words. Students had 1 minute to correctly name as many words as they could. The final score is the number of words identified correctly per minute. The alternate-test

form stability coefficient for two consecutive weeks was .92 in the beginning of first grade (Compton, Fuchs, Fuchs, & Bryant, 2006).

Developmental spelling. The Developmental Spelling Test (Tangel & Blachman, 1992) is a measure of students' understanding of how words can be spelled. To administer the test, the examiner dictates 10 words and the student attempts to spell each word. Developmental scores range from 0 to 6 points per word. One point is given for a phonetically related letter, 2 points for a correct first letter, 3 for more than one correct letter, but not all the sounds represented with letters, 4 – all sounds are represented with correct and incorrect letters, 5 – all phonemes represented with conventional letters, and 6 points for correct spelling. Inter-rater reliability is above .9. The test of developmental spelling measures phonological proximity of the spelled word to the correct spelling on phoneme-by-phoneme basis.

***Correct word spelling*.** To obtain a measure of correct word spelling (as opposed to developmental spelling) the Test of Developmental Spelling was re-scored by calculating the number of correctly (conventionally) spelled words without allowing for partial and phonologically correct but unconventional spellings.

LNF subtest of DIBELS. The LNF is an individually administered measure of accuracy and speed of naming upper and lower-case letters that are randomly arranged. Students are given a list of 100 letters and asked to name as many as they can within 1 minute. The final score is the number of the letters named correctly in 1 minute. Inter-rater reliability on this subtest was .94.

PSF subtest. Phoneme Segmentation Fluency measures student's ability to segment 3- and 4-phoneme words into their individual phonemes (Kaminski & Good, 1996). The examiner orally presents words to the students and the students respond by saying individual phonemes for the presented word. If the examiner says "mop" the child needs to say m/o/p to receive 3 points (one for each phoneme identified correctly). The final score consists of the number of correctly identified phonemes in one minute. The two-week, alternate-form reliability for the PSF measure is .88 (Kaminski & Good, 1996), and the one-month, alternate-form reliability is .79 in May of kindergarten (Good, Kaminski, Shinn, Bratten, Shinn, Laimon, Smith, & Flindt, 2004). Inter-rater reliability for this subtest for the first grade sample is 0.95.

Third Grade Assessments. In third grade students were administered the DIBELS Oral Reading Fluency (ORF) subtest as a measure of students' reading fluency. The Developmental Spelling test was replaced by the Test of Written Spelling (Larsen, Hammill & Moats, 1999), which was more developmentally appropriate for this specific age group. All of the assessments were administered 3 times per year (fall, winter and spring).

***Spelling*.** The Test of Written Spelling (Larsen, Hammill & Moats, 1999) is a norm-referenced spelling assessment with two alternate equivalent forms that consist of words with predictable and unpredictable spellings. The test is administered by dictating 20 progressively more difficult words to students. According to the publisher "The TWS-4 was standardized on more than 4,000 students. The characteristics of this normative sample approximate those for the projected 2000 U.S. Census." The Test of Written

Spelling evidences high reliability across three different types: coefficient alpha, test-restest and interrater reliability (with all of these coefficients consistently being above .9). According to Salvia and Ysseldyke (1998) the standard for test reliability for situations where test results are used to make educational decisions is 0.9. The coefficients that are presented in examiner's manual for the Test of Written Spelling were all above this cut-off, suggesting high reliability of the test. A final score on the Test of Written Spelling is the number of words spelled correctly.

***Orthographic spelling*.** The Test of Written Spelling (third grade form) contains a combination of decodable and non-decodable words. In order to assess how students apply their orthographic knowledge in spelling I selected the words from the spelling list that require the use of orthographic knowledge (non-decodable) and rescored the spelling tests by using only those non-decodable words. Upon visual examination of the third grade spelling tests I found that 14 out of 20 words on the assessment were not readily decodable and required knowledge of certain orthographic patterns. Therefore, participants' spelling tests were rescored for all 3 timepoints using 14 identified words that assess the students' orthographic knowledge.

***Oral reading fluency*.** The DIBELS subtest of Oral Reading Fluency (ORF) is an individually administered reading measure of rate and accuracy. Students are administered three 1-minute passages at their grade level and the median passage score is calculated for the final score. ORF was administered in fall, winter, and spring of third grade. The median alternate form reliability is .94 (Good & Kaminski, 2002).

Orthographic reading. In order to obtain a measure of students' ability to read words containing orthographic patterns from the general Oral Reading Fluency measure, I rescored the passage with the median score for each time point by calculating the number of non-decodable words (words that contain orthographic patterns as opposed to phonologically decodable words) read correctly per minute.

Research Design

The present study employed a three-wave longitudinal panel design to determine the effects that reading and spelling have on each other over time. One of the techniques that has been used for assessing causal directions using observational data is a cross-lagged panel design. This design was first introduced by Kenny (1979) and Campbell and Kenny (1999) as a method of dealing with longitudinal correlations between two variables for determining whether the history of one variable (X) can predict the other variable (Y) after accounting for the history of (Y). This type of design allows for examination of causal association between two variables measured simultaneously over several time points, controlling for effects at earlier time points and autoregression effects. Each of the two variables in cross-lagged panel designs is regressed on itself at earlier time points (the autoregression effect) and also regressed on the second variable in order to test the influence of one variable on another over time. This type of design is helpful in determining the directionality of the relationship between two variables.

For example, in the present study, where I had several time points of reading and spelling scores in Grade 1, I could examine whether spelling achievement at the first time point determines reading achievement at later time points. In order to answer this

question I compared the correlation between spelling at time point 1 (Sp1) and reading at time point 2 (R2) and the correlation between reading at time point 1 (R1) and spelling at time point 2 (Sp2). If the coefficients are of the same sign and the former correlation is significantly greater than the latter then it can be concluded that spelling ability at time point 1 precedes and directly influences reading achievement at time point 2, or in other words spelling has causal predominance over reading.

Kenny (1979) suggests that in order to determine causal relationships in non-experimental data through cross-lagged panel designs three criteria should be present between the variables:

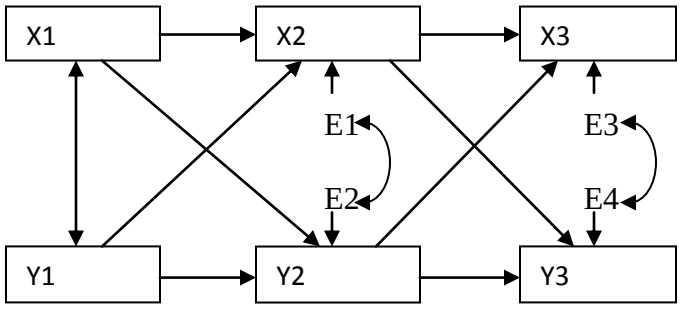
- Correlation
- Time precedence
- Nonspuriousness

The cross-lagged panel design used in the study addressed the correlation and time precedence criteria. I modeled longitudinal correlations between reading and spelling over time from time point 1 to time point 2 and from time point 2 to time point 3. Kenny (1975) proposed that in order to be able to accurately measure the causal influences between X and Y one must reject a null hypothesis of spuriousness that states that the relationship between X and Y is not due to direct influences between X and Y but rather a result of common influence of an unmeasured third variable (s) on both X and Y. Rogosa (1980) proposed an extension of a cross-lagged correlation model that allows for both testing the direct effects of X on Y and adjusting for possible effects of unexplained third variables. In his model two exogenous variables X_1 and Y_1 are correlated at time

point 1. Each of the endogenous variables in this path model is expressed as a function of other variables in the model and a residual or a disturbance term. If, for example, an unexplained variable causes both endogenous variables X_2 and Y_2 but is not included in the model, the residuals of X_2 and Y_2 will be significantly correlated (Anderson & Williams, 1992). Therefore, for endogenous variables X_2 and Y_2 residuals are allowed to correlate. If the correlations between residuals are not estimated, the model might produce biased estimates of cross-lagged parameters.

The conceptual model of a cross-lagged panel design using two variables measured over three time points is presented in Figure1.

Figure 1.



The cross-lagged panel approach allowed for evaluation of the developmental hypothesis suggested by Frith by determining proposed temporal precedence of spelling at the early stages of reading-spelling development and reading at later stages by controlling for the cross-sectional association between the two domains.

Chapter 4: Results

Preliminary Analysis

Several preliminary steps were carried out on the data to assure that data met the normality assumption and missing data patterns were analyzed and properly handled. Additionally, classroom analysis was performed to determine how much variance in the reading and spelling scores can be attributed to classroom differences and whether further analysis can proceed without estimating classroom-level effects. Considering that roughly half of the participants were English Language Learners (ELL), reading and spelling scores of the ELL students were compared to the scores on the same measures of English Only students (EO). Further descriptions of these preliminary analyses are presented below.

Missing data. The combined dataset containing 422 cases was analyzed for the presence of missing data. As with most longitudinal datasets, the obtained dataset contained several cases of missing data. Some of the common reasons for missing data in longitudinal datasets are attrition of cases and missed assessments due to absence (Little & Rubin, 2002). This study sample was characterized by high mobility rates, and considering that participants had to be present and assessed throughout three grade levels, data collected in first grade was matched with data for the same students collected in third grade. If a student moved at any time during first or second grade and was not present in third grade, his case was omitted from the analysis, due to the lack of data for estimating both first and third grade models. Students that moved at any time before entering third grade had missing data on all assessments in third grade. Upon examining a

combined dataset, 15 cases were identified that had missing data on all third grade variables. These cases were removed from the analysis. Additionally, 9 cases were removed from both 1st and 3rd datasets due to missing data on more than half of the variables necessary for the first grade models, and 12 cases were removed due to missing more than half of the data necessary for third grade models.

The final dataset contained 386 cases, with 170 cases obtained from 2008-2011 cohort and 216 cases from 2007-2010 cohort. Ninety-two percent of the remaining third grade dataset contained complete data on all of the variables. Eighty-eight percent of the first grade dataset contained complete data on all of the first grade variables. Little's MCAR (Missing Completely at Random) Chi-square test was insignificant for both first and third grade datasets indicating that we can retain the null hypothesis, stating that data in these sets were missing completely at random. First grade Little's MCAR was χ^2 = 65.342, p= 0.340. Third grade Little's MCAR was χ^2= 40.625, p= 0.732. Missing data were handled using the Maximum Likelihood with Robust Standard Errors Parameter Estimatior in Mplus (MLR estimator). This estimator can use missing data and produces a chi-square test statistic that is robust to non-normality, which is essential for this dataset since three of the first grade variables have a non-normal distribution (Muthen & Muthen, 2010).

Normality. All of the study variables were tested for univariate and multivariate normality at both grade levels. Frequency distributions were examined for the visible presence of skewness and kurtosis, and skewness and kurtosis indices were calculated. For all of the variables in the third grade dataset skewness was less than 3 and kurtosis

was less than 8, suggesting univariate normality of all variables (DeCarlo, 1997). Additionally, the Shapiro-Wilks statistics for all of the variables were insignificant suggesting that the null hypothesis of normality can be retained (Tables 3 & 4). In the first grade dataset 3 of the variables – WIF (Word Identification Fluency) in the fall, developmental spelling in the fall and correct word spelling in the fall were non-normally distributed according to Shapiro-Wilks statistics ($p > 0.01$). However, skewness and kurtosis for these variables did not indicate extreme skewness or kurtosis. Kurtosis was less than 8 and skewness was less than 3 for all three variables. To account for the non-normality of these variables, an MLR estimator in MPLUS was used.

Data were also analyzed for univariate and multivariate outliers. Each study variable had 1 to 3 extreme points suggested as outliers in the box plots generated by SPSS. None of the extreme datapoints were beyond 3 standard deviations of the mean, which is a common rule of thumb for the detection of outliers (Stevens, 2002). Those extreme points were checked with the original data sources and determined to be legitimate scores. A value of 5% trimmed mean was also calculated in SPSS to find out how much influence was associated with these outlying cases. SPSS removes 5% of the cases and recalculates the mean without them. Two mean values (trimmed and original) were then compared. For none of the variables was the trimmed mean significantly different from the original mean, suggesting that outliers did not have much influence on the mean. Detected univariate outliers were therefore kept in the dataset for further analysis.

Datasets were also visually examined for the presence of multivariate outliers or cases that had extreme scores on two or more variables or some other unusual combination of values on several variables (Kline, 2005). In addition to the visual inspection, probabilities of Mahalanobis d^2 distances were calculated for each case using a combination of 12 variables (six reading scores and six spelling scores) for first and third grade datasets. A probability of Mahalanobis d^2 of 0.001 or less indicates a case with an unusual combination of scores on the combinations of variables, which suggests a multivariate outlier (Kline, 2005). All of the probability values in both datasets were larger than 0.001, so neither dataset contained multivariate outliers.

Classroom analysis. Educational data are typically collected in schools and classrooms, which might lead to lack of independence among individual scores. For instance, scores of students nested in a particular school or classroom are not only due to individual differences, but also to the shared instructional environment, for example, instruction delivery, teacher effectiveness, and classroom dynamics (Raudenbush & Bryk, 2002). Thus, students within a particular classroom can be more similar to each other than to a randomly selected independent sample of students. Data for this study were obtained from 5 different schools and 22 classrooms nested within those schools, so it was important to conduct a classroom analysis to determine whether any significant variance in the reading and spelling scores of participants can be attributed to classroom differences. Unconditional two-level models can be used to determine how much variation in the outcome can be attributed to student-level and classroom-level characteristics (Raudenbush & Bryk, 2002). In this study two-level hierarchical linear

models were estimated using the HLM 7 student version software (Raudenbush, Byrk, Cheong, Congdon, & Toit, 2011). Nonsense Word Fluency (NWF) and Developmental Spelling Test (DST) scores collected in spring of first grade were used as outcomes and intraclass correlation coefficients (ICC) were computed to determine the percentage of variance in the outcome attributed to classrooms.

The first grade unconditional model with NWF as an outcome revealed an ICC of 0.0325, $\chi^2(21) = 25.21529$, $p = 0.286$. Thus, 3.2% of the variance in NWF scores in spring of first grade was between classrooms and 96.8% was at the student level. A Chi-square test of whether the level-2 variance was significantly different than zero was non-significant. For the developmental spelling model an ICC of 0.074 was obtained, $\chi^2(21) = 31.91118$, $p = 0.079$. This suggested that for spelling 7.4% of variance could be attributed to differences between classrooms. Despite the somewhat larger proportion of variance between the classrooms, according to the accompanying chi-square test, this variance was not significantly different from 0. Therefore, it can be concluded that for both first grade outcomes variance attributed to classroom differences was small and insignificant.

Classroom analysis was repeated for the third grade sample using third grade measures as outcomes. Third grade students were nested in 15 classrooms. Oral Reading Fluency (ORF) and the Test of Written Spelling (TWS) scores collected in spring were used as outcomes in third grade unconditional models. The third grade unconditional model with ORF as outcome produced an ICC of 0.0381, $\chi^2(14) = 32.12861$, $p = 0.073$. An unconditional model with the Test of Written Spelling (TWS) as an outcome had an

ICC of 0.0422, $\chi^2(14) = 35.09410$, $p = 0.054$. In both third grade models variance attributed to classrooms was small and insignificant, as indicative by ICC. Considering the results of the 2-level models, no further classroom effects were examined in this study and only student-level data were analyzed.

ELL students. The study sample had a high rate of English Language Learners (ELL). Specifically, frequency analysis of the first grade sample revealed that 54% of the participants were ELL and received a California English Language Development Test (CELDT). The CELDT scores are measured on a 5-point scale and vary from 1-beginning to 5-advanced, with 3 being intermediate. Further analysis showed that mean CELDT score within the ELL group was 2.9 in first grade, suggesting that ELL students in the sample had an intermediate level of overall English language proficiency. Taking into account the high rate of ELL students in the sample, it was important to determine whether reading and spelling scores for this group differ significantly from the scores of English Only students (EO). If reading and spelling scores of ELL students are significantly different from those of EO students, then it cannot be assumed that cross-lagged models of reading and spelling will produce similar patterns of relationships for these subsamples. In this case ELL variable would have to be added into the model as a covariate or, if sample size allows, different models would be estimated for ELL and EO students.

Independent sample t-tests were performed using the entire sample (N=386) on all three timepoints of the reading and spelling scores in first and third grade. In first grade, differences in nonsense word fluency (NWF) and word identification fluency (WIF)

scores from fall, winter and spring and Developmental Spelling Test (DST) scores from the same 3 data points were analyzed. No significant differences on these reading or spelling measures were found in first grade for ELL compared to EO students. Likewise, third grade t-tests produced no significant differences in reading and spelling performance. T-test statistics and probability estimates for this analysis are presented in tables 5 & 6.

Additionally, to examine whether cross-lagged relationships between reading and spelling differed significantly between ELL and EO students, two multiple-group analyses were performed using the proposed first and third grade models. Multiple-group analyses tested the equality of fit for the proposed models across 2 subgroups: ELL and EO to explore the generalizability of the findings. For both grade levels, I tested and compared the following two models: a) an unconstrained model where all path coefficients in question (cross-lagged and autoregressive paths) were allowed to be unequal across subgroups (EO and ELL), and b) a model where all path coefficients were constrained to be equal across subgroups. When robust estimation procedures are used, chi-square values cannot be directly compared. Chi-square difference tests were computed based on log-likelihood values and the scaling correction factor obtained from the MLR estimator (Muthen & Muthen, 2010). A non-significant difference in chi-square between the constrained and unconstrained models for both grade levels suggested that the proposed models fit equally well for both subgroups. This indicated that the overall model did not differ significantly based on ELL status. Chi-square difference tests were also conducted for each separate cross-lagged and autoregressive path to compare models

with a single path constrained to equality between the groups with a model where all paths were freely estimated. Table 7 presents all comparisons made across ELL/EO subgroups for first grade model. Table 8 presents all comparisons made across ELL status subgroups for third grade model. No single path emerged as different for ELL subgroup. It can be concluded that the relationship between reading and spelling in first and third grades was not different for ELL students compared to EO students. Potential reasons for no differences in reading and spelling relationship of ELL and EO students are discussed later in the discussion. For the sake of this study, scores of ELL and EO students were combined in the later analysis.

Struggling readers analysis. To determine whether it would be appropriate to divide the study sample into typical and struggling reader subsamples and then estimate the proposed models separately for two subsamples, I performed another set of multiple-group analyses and estimated and compared the following two models for both grade levels: a) an unconstrained model where cross-lagged and autoregressive paths were allowed to freely vary across typical and struggling reader subgroups, and b) a model where all path coefficients in question were constrained to be equal across subgroups. Chi-square difference tests demonstrated a significantly different fit for typical versus struggling reader samples in both first and third grade. Chi-square difference tests were again calculated using log-likelihood values and the scaling correction factor obtained from the MLR estimator (Muthen & Muthen, 2010). First grade chi-square difference was $\Delta\chi^2(11) = 27.316$, $p<.05$*. Third grade chi-square difference was $\Delta\chi^2(11) = 39.11$, $p<.05$*. Next, chi-square differences tests were conducted for each separate path to

determine what specific paths contributed to the difference in model fit for typical versus struggling reader samples. I compared models with a single path constrained to equality between subgroups to a model where all paths were freely estimated. See table 9 for a description of all comparisons made across typical/struggling reader status in first grade model. This analysis revealed that in first grade the cross-lagged path from fall alphabetic decoding (NWF) to winter developmental spelling (DST) was significantly higher in typical sample, $\Delta\chi^2$ (1) = 6.825, p<.05*. The cross-lagged path from winter alphabetic decoding to spring developmental spelling was also significantly higher for typical sample, $\Delta\chi^2$ (1) = 5.694, p<.05*. Similar patterns of differences emerged in third grade model. The cross-lagged path from fall orthographic reading to winter orthographic spelling was higher for typical sample, and that difference was statistically significant, $\Delta\chi^2$ (1) = 10.557, p<.05*. The cross-lagged path from winter orthographic reading to spring orthographic spelling was also significantly higher for typical sample, $\Delta\chi^2$ (1) = 3.945, p<.05*. Additionally, the third grade model revealed that the correlation between the two exogenous variables – fall orthographic reading and fall orthographic spelling was significantly higher in the typical sample, $\Delta\chi^2$ (1) = 19.599, p <.05*. Table 10 contains all comparisons made across typical/ struggling reader groups in third grade model. Since overall model fit and several specific parameters were significantly different, as indicated by multiple-group analysis, the dataset was divided into two subsamples: typical and struggling readers' and the proposed models were estimated separately for the two subsamples.

Descriptive statistics. Table 2 shows frequencies and percentages for the demographic variables. First grade means and standard deviations for the study variables at each time point are presented in Table 11. Third grade descriptive statistics are presented in Table 12. Correlations between study variables for grades 1 and 3 are provided in Tables and 13-20. All correlations were moderate to strong and significant. In the first grade dataset developmental spelling scores were highly correlated with the correct word spelling scores (table 13). It is important to note that these two scoring variations were derived from the same measure. Correct word spelling scores were obtained from the developmental spelling protocol by calculating the number of correctly (conventionally) spelled words without allowing for partial and phonologically correct but unconventional spellings. Though high, none of the correlations between the two scores were more than .85, which would indicate multicollinearity, so both spelling measures were retained in the analysis.

In the third grade dataset oral reading fluency scores (ORF) were highly correlated with orthographic reading fluency scores, and written spelling scores were highly correlated with orthographic spelling scores. As in the first grade dataset, orthographic reading and spelling scores were derived from the respective general reading (ORF) and spelling (test of written spelling) scores by calculating only the number of read and spelled words with orthographic patterns. These correlations between general reading and spelling scores and orthographic reading and spelling in the third grade dataset were all above .85, suggesting multicollinearity (table 18). This indicated that in third grade general and orthographic measures of reading and spelling were

measuring the same ability and would be redundant if both were included in the analysis. Orthographic reading and spelling measures were, therefore, retained in the analysis, while scores on Oral Reading Fluency and Test of Written Spelling were removed. The analysis and the proposed models were estimated using only scores on orthographic reading and spelling.

First Grade Analysis (Typical Sample)

To examine the longitudinal relationships between reading and spelling in the first grade typical sample (N=267), I tested two alternative models of reading and spelling development at the alphabetic stage: alphabetic (using a measure of alphabetic decoding and developmental spelling) and conventional (using a measure of correct word reading and correct word spelling). Both models had adequate data fit as indicative by the insignificant chi-square statistic and acceptable values of RMSEA as well as CFI and TLI indices. Fit indices for both models are presented in Table 21.

For the alphabetic model, all four cross-lagged paths were initially statistically significant. The correlations between the residuals (unknown variance) in winter and spring were also significant indicating an unknown common influence that causes both alphabetic decoding and developmental spelling. Several potential covariates were included in the model. Letter Naming Fluency (LNF) and Word Identification Fluency (WIF) were significant predictors of winter alphabetic decoding (NWF) and developmental spelling (DST), and when entered in the model brought the correlations between the residuals in winter to insignificance. The winter residual correlation was reduced from .154 ($p = .01$) to .023 ($p = .703$). A combination of letter names knowledge

and a correct word reading ability was therefore a common influence on winter alphabetic decoding and spelling. In spring, LNF was no longer a significant predictor of alphabetic decoding and alphabetic spelling, but WIF was still a significant covariate. Entering WIF into the model in spring brought the spring residual correlation to non-significance, suggesting that a correct word reading ability was a common influence on spring alphabetic decoding and spelling. The spring residual correlation went down from .213 (p=.000) to .063 (p = .103).

Entering covariates into the model reduced the magnitude of all four cross-lagged paths and changed two of them to insignificant. The visual comparison of models with and without the covariates showed that for the path from fall developmental spelling to winter alphabetic decoding the magnitude decreased from β=.091 to β=.065 and it became insignificant (p = .149). For the cross-lagged path from winter developmental spelling to spring decoding, the magnitude decreased from β=.128 to β=.050 and it became insignificant (p = .181). The path from alphabetic decoding in fall to developmental spelling in winter was decreased from β=.211 to β=.139 but remained significant (p = .017). The cross-lagged path from winter alphabetic decoding to spring developmental spelling was reduced from β=.160 to β=.117 and remained significant (p = .039). Therefore, once common influences were included in the model, the remaining significant cross-lagged paths revealed that alphabetic decoding was a significant longitudinal causal predictor of developmental spelling, but the reverse was not true. See figure 1 for graphical depiction of the final first grade typical model of alphabetic knowledge.

Next, the conventional model was examined, where a measure of correct word reading (WIF) and a measure of correct word spelling was used. Similar to the alphabetic knowledge model, the residual correlations between correct word reading (WIF) and correct word spelling in winter and spring were significant suggesting a presence of third variables that caused both correct word reading and spelling that were not included in the model. Covariate analysis indicated that letter naming fluency (LNF) and Nonsense Word Fluency (NWF) in winter and Nonsense Word Fluency (NWF) in spring were significant covariates of correct word reading and spelling. After the covariates were entered in the model the winter and spring residual correlations became insignificant. In the conventional model after the covariates were controlled for, correct word reading ability emerged as a significant causal longitudinal predicator of correct word spelling as evidenced by significant cross-lagged paths from correct word reading to correct word spelling, with path coefficients $\beta = .110$ in fall to winter, and $\beta=.154$ in winter to spring. Correct word spelling was not a significant longitudinal predictor of correct word reading See figure 3 for graphical depiction of the final first grade typical model of conventional knowledge.

First Grade Analysis (Struggling Reader Sample)

A model of longitudinal relationship between alphabetic decoding and developmental spelling was also tested for the struggling reader sample (N=119). Model fit statistics indicated that this model was a good fit for the data. Chi-square statistic, CFI and TLI fit indices and RMSEA estimate for this model are reported in table 21. Initially, one cross-lagged path emerged as significant in the first-grade struggling reader model –

from fall alphabetic decoding to winter developmental spelling (β=.112, p=.033). However, the correlations between the residuals for winter and spring were also both statistically significant indicating the unknown variable(s) that had an effect on alphabetic decoding and developmental spelling in struggling reader sample. Different combinations of early literacy measures were entered in the analysis as possible covariates. For the winter time point, scores of Letter Naming Fluency (LNF) and Word Identification Fluency (WIF) were found to be significantly influencing alphabetic decoding and developmental spelling in the struggling reader sample. In spring, only WIF remained a significant covariate in a relationship between developmental spelling and alphabetic decoding. Upon entering the aforementioned covariates, the correlations between the residuals in winter in spring became insignificant suggesting that knowledge of letter names (LNF) in winter and the ability to read words correctly (WIF) in winter and spring were significant predictors of alphabetic decoding and developmental spelling ability in the struggling reader sample. The combination of covariates that were identified as common influences on alphabetic decoding and developmental spelling in struggling reader sample was the same as in typical sample, indicating that throughout first grade alphabetic decoding and developmental spelling were influenced by the same early literacy skills. However, entering covariates in the model reduced the magnitude of all cross-lagged paths and brought the only previously significant cross-lagged path to non-significance. The path from alphabetic decoding in fall to developmental spelling in winter went from β=.112 to β=.043. After the significant early literacy covariates were entered in the first grade struggling reader model, alphabetic decoding did not

significantly predict later developmental spelling and developmental spelling was not a significant longitudinal predictor of alphabetic decoding. Potential reasons for the insignificant cross-lagged paths between reading and spelling in the first grade struggling reader sample are presented in the discussion section. See figure 2 for graphical depiction of the final first grade struggling reader model.

Third Grade Analysis (Typical Sample)

Third grade cross-lagged model for the typical sample (N=267) was estimated using a measure of orthographic reading and orthographic spelling measured at three time points in third grade (fall, winter and spring). The fit for this model was adequate, Chi-square χ^2 (4) = 2.639, p = 0.6938; CFI = .998; TLI = .994; RMSEA = .000 (90% CI: 0.000 - 0.089). Students' orthographic reading was stable over time (autoregressive coefficients β=.815 and β=.707). Stability of the autoregressive paths was determined by constraining the autoregressive path from fall orthographic reading to winter orthographic reading and the path from winter orthographic reading to spring orthographic reading to be equal and comparing this model to the initial unconstrained model. The chi-square difference test (computed based on log-likelihood values and the scaling correction from MLR estimator) was insignificant which indicated that autoregressive paths for orthographic reading were not significantly different across time intervals. Chi-square difference test was repeated for the other set of the autoregressive paths. The orthographic spelling was also stable over time (autoregressive coefficients were β=.605 and β=.687). Cross-lagged paths from orthographic reading to orthographic spelling from fall to winter and from winter to spring were both significant (β=.135 and β=.179

respectively). This suggested that orthographic reading was a strong causal longitudinal predictor of orthographic spelling. Cross-lagged paths from orthographic spelling to orthographic reading from fall to winter and from winter to spring were β=.055 and β=.048 and both insignificant. Correlations between the reading and spelling residuals (unexplained variance) in winter and spring were insignificant (.078, p =.128 and .025, p= .196 respectively), so there was no evidence of common third variables that might cause both reading and spelling. In other words the relationship between the orthographic reading and spelling in third grade was non-spurious and a causal longitudinal relationship between the two variables could be established. See figure 5 for graphical representation of third grade typical model.

Third Grade Analysis (Struggling Reader Sample)

The third grade cross-lagged model for the struggling readers sample (N=119) was estimated using a measure of orthographic reading and orthographic spelling measured at three time points in third grade (fall, winter and spring). This model also fit the data well: Chi-square χ^2 (4) = 6.482, p = 0.1132; CFI = .989; TLI = .975; RMSEA = .027 (90% CI: 0.000 - 0.110). Orthographic reading was stable across third grade for the struggling readers sample with autoregressive coefficients of .762 from fall to winter and .686 from winter to spring. Orthographic spelling was also stable across the third grade with autoregressive coefficients of .565 from fall to winter and .600 from winter to spring. Residual correlations in winter and spring were insignificant, so there was no evidence of common causes that might influence both reading and spelling. However, none of the cross-lagged paths were significant, suggesting that after the autoregressive

and cross-sectional effects were accounted for, orthographic reading and spelling were not significant longitudinal predictors of each other in the third grade struggling reader sample. Cross-lagged path coefficients from orthographic reading to orthographic spelling were $\beta = .071$ at fall to winter and $\beta = .048$ at winter to spring. Cross-lagged path coefficients from orthographic spelling to orthographic reading were $\beta = .063$ at fall to winter and $\beta = .031$ at winter to spring. Third grade struggling readers' model is presented in figure 6.

Discussion

This study examined the stages of reading-spelling development and directionality of specific knowledge acquisition as suggested by Uta Frith's model (1985). This model proposed the presence of three stages of reading and spelling development: logographic, alphabetic and orthographic – each emphasizing the distinctive type of knowledge that needs to be mastered in each stage. Frith's model corresponds closely to the other theories of interrelated reading and spelling development – Ehri's (1989, 2000) reciprocal theory of reading and spelling, Henderson and Beers' (1980) stage theory of reading and spelling, and the phonological linkage hypothesis (Hatcher, Hulme, & Ellis, 1994). However, while other models suggested simultaneous progression of reading and spelling through the stages, Frith posited that reading and spelling development at different stages happen asynchronously, and depending on the stage, either reading or spelling acts as facilitator.

I explored the alphabetic and orthographic stages of reading and spelling development to determine whether specific directionality patterns exist at different stages. Reading and spelling performance of 386 students was examined in first through third grade to determine how reading-spelling relationships changed over time. Several three-wave cross-lagged panel models were first tested on a sample of typically developing readers using first and third grade reading and spelling measures to assess the directionality of reading and spelling development (n = 267) . The same cross-lagged panel models were then tested on a sample of struggling readers (n = 119) to examine

whether patterns of interrelationships between reading and spelling, as well as the directionality of knowledge acquisition, are different for struggling readers.

Major conclusions of the present investigation are listed here. The grade 1 directional relationship between reading and spelling was found to be significantly influenced by other common causes for both the alphabetic model and the conventional model. Several variables that influenced the relationship between reading and spelling in the first grade sample were identified. Letter Naming Fluency (LNF) and correct word reading (WIF) were found to be common predictors of the alphabetic decoding (NWF) and developmental spelling relationship, while Letter Naming Fluency (LNF) and alphabetic decoding (NWF) were common influences on the relationship between correct word reading (WIF) and correct word spelling. After common influences were accounted for in the analysis, alphabetic decoding (NWF) emerged as a significant longitudinal predictor of developmental spelling but the reverse was not true. For the conventional model (i.e., correct reading and spelling), correct word reading was a significant longitudinal predictor of correct word spelling after the common influences were accounted for. Overall, the results of the first grade models indicated that regardless of the type of knowledge examined (alphabetic or conventional), the relationship between reading and spelling was not a simple relationship between two variables but rather a complex relationship between a combination of early literacy skills. Additionally, reading words (whether nonsense or real) was found to be a significant longitudinal predictor of spelling in both first grade models, which is contrary to Frith's proposed reading-spelling relationship during alphabetic stage.

The results of the grade 3 analysis indicated that, as proposed by Frith, reading had a predictive causal influence over spelling throughout third grade, meaning that earlier reading achievement predicted later spelling ability. There were no third variables that influenced the longitudinal relationship between reading and spelling in the third grade sample, so earlier reading skill had predictive causal influence on later spelling ability and this relationship was not attributable to any other common causes.

Analysis of the struggling reader sample suggested that in first and third grades, after autoregressive influences were taken into account, neither reading nor spelling were significant longitudinal predictors of each other, as evidenced by non-significant cross-lagged paths between the two variables. Additionally, it was found that the longitudinal relationship between reading and spelling did not significantly differ according to ELL status of the students for either typical or struggling reader samples. All of these findings, as well as implications and limitations of this study, are discussed in more detail in the following sections.

Stages of Reading and Spelling Development

Uta Frith did not identify any particular ages for the different stages of reading and spelling development. She proposed that reading and spelling development follow a progression from a logographic to an orthographic stage, and that each subsequent stage builds on knowledge received during the previous stages. Thus, according to Frith, stages of reading and spelling development are knowledge-specific, meaning that a specific type of knowledge guides progression through a certain stage (logographic, alphabetic, or orthographic). Once it is mastered children are ready to acquire a new, more complex

type of knowledge. However, it can be gleaned from observing and studying reading and spelling development that most learners (with average reading and spelling ability) learn and start using alphabetic knowledge and letter-sound correspondences in their reading and spelling sometime in Kindergarten. Alphabetic knowledge and phonemic awareness continue to play a very important role in reading and spelling development throughout first grade. By second grade learners typically master simple letter-sound correspondences and start learning about larger language units – orthographic and morphological patterns. Children become progressively aware that not all words can be sounded out phoneme-by-phoneme or spelled letter-by-letter. So when exactly does this transition from alphabetic to orthographic stage happen? In this study, I attempted to determine when students in this specific sample exhibited characteristics of going through alphabetic and orthographic stages.

When learners progress through the alphabetic stage of reading and spelling development, they learn how to read and spell words by using one-to-one letter-sound correspondences. In my previous research, using the same sample of 1st grade students (Forrester & O'Connor, under review), I found that single-word reading and spelling were highly related to alphabetic decoding and phonemic awareness in fall and winter of first grade, suggesting that when reading and spelling words, learners relied heavily on letter-sound correspondences. By the spring of first grade, those relations weakened significantly, indicating that at that point in their development, children move away from reading sound by sound and spelling letter-by-letter and onto using more complete representations of words (i.e., orthographic knowledge).

In this study, cross-lagged panel models of first grade single-word reading and spelling and alphabetic reading and spelling relationships demonstrated that through winter of first grade knowledge of letter names had a strong and significant influence over both types of reading and spelling. Therefore, students in this sample were in the alphabetic stage in the first grade.

With regard to determining when students entered the orthographic stage, I examined students' reading performance on the Word Identification subtest of the Woodcock Reading Mastery Test-Revised (1997) in winter of third and second grade to determine how many words containing orthographic patterns students could read. This subtest consists of isolated words that students are asked to read aloud to the tester. It begins with simple sight words and words that can be phonologically decoded (i.e., using alphabetic knowledge) and becomes progressively more difficult by adding words with various orthographic patterns that can only be read if students apply their knowledge of these orthographic patterns. After analyzing the words used in this subtest, I determined that a score of 43 would require a student to be able to read 21 phonologically decodable and sight words and 22 words with orthographic patterns. A score of 43 was, therefore was used as a cut-off point, at which students' reading becomes predominantly orthographic. I examined students' performance on this subtest in winter of second and winter of third grade to decide at which grade level students reached the orthographic stage. In winter of second grade only 40% of typically developing students and less than 15% of struggling readers reached the orthographic stage. By winter of third grade, all typically developing students scored above 43 on WRMT-R Word ID, suggesting they

had reached the orthographic stage. Over 70% of struggling readers scored at or above 43, putting most of the struggling reader sample in the orthographic stage as well.

This stage determination was, however, specific to the sample used in this study. There is not enough evidence to suggest that typically developing students reach the alphabetic stage in first grade and the orthographic stage in third. Learners have different patterns of literacy skills acquisition, with a number of factors determining when a particular child reaches a certain stage of reading and spelling development. In order to properly determine a student's stage of reading and spelling development, it is important to examine her individual assessment scores on reading and spelling measures that are indicative of a specific type of knowledge attributable to each stage (e.g. alphabetic or orthographic). However, as interesting as this stage determination analysis was, it was only performed as a preliminary data preparation process. This study did not examine this topic any further, as the stage determination was not among one of the study questions and the main reason for determining the stages was to carry out the cross-lagged analysis. An investigation of how certain measures of reading and spelling collected in this study inform the stages of reading and spelling development can be an important future extension of this research.

Alphabetic Stage (First Grade)

The first of the three hypotheses tested in this study was that during the alphabetic stage children acquire alphabetic skills (ability to recognize and use individual graphemes and phonemes) through spelling and later transfer this knowledge into reading (Frith, 1985). No other study to date tested whether the longitudinal relationships and patterns of

alphabetic knowledge transfer proposed by Frith were plausible. Results obtained in this study for the first grade models did not support the alphabetic stage hypothesis proposed by Frith. I estimated two models – the alphabetic knowledge model and conventional knowledge model. In the alphabetic model I used measures of alphabetic decoding (NWF) and developmental spelling (DST). Findings of this model suggested that in first grade alphabetic decoding (NWF) and developmental spelling (TDS) were significantly influenced by several other early literacy skills and that the relationship between these two variables was due to that influence. Covariate analysis indicated that alphabetic knowledge in reading and spelling in winter of first grade was significantly influenced by a combination of letter-name knowledge (LNF) and the ability to read words correctly (WIF). In spring, letter-name knowledge (LNF) was no longer a significant predictor of alphabetic decoding and developmental spelling, but correct word reading (WIF) was still a common influence that accounted for some significant variance in the alphabetic decoding – spelling relationship. This suggests that a relationship between alphabetic reading and spelling can be partially attributed to the knowledge of letter names in winter and the ability to read words correctly in winter and spring of first grade.

In my previous research (Forrester & O'Connor, under review) I found that developmental spelling in first grade was highly correlated with letter names knowledge (LNF) in the beginning of first grade, but by the end of first grade that relationship weakened significantly, while the relationship between alphabetic spelling and the ability to read words correctly (WIF) grew significantly from fall to spring of first grade. This study supported this previous finding of the important influence of letter naming fluency

on developmental spelling in the beginning and middle of first grade, and correct word reading ability at the end of first grade. In this study, the relationship between alphabetic decoding and developmental spelling was not a simple longitudinal relationship between two variables, rather multiple skills contributed to the knowledge transfer between alphabetic knowledge in reading and spelling during the alphabetic stage of literacy development.

After common influences of alphabetic decoding and spelling were accounted for, the analysis of the remaining cross-lagged associations between alphabetic decoding and developmental spelling indicated that alphabetic spelling was not a significant longitudinal predictor of alphabetic decoding. Both cross-lagged paths from alphabetic spelling to alphabetic decoding were insignificant ($\beta_{\text{fall-winter}}$ =.065 and $\beta_{\text{winter-spring}}$ = 0.50). Conversely, alphabetic decoding was found to be a significant longitudinal causal predictor of alphabetic spelling with significant cross-lagged paths from alphabetic decoding to alphabetic spelling ($\beta_{\text{fall-winter}}$ =.139 and $\beta_{\text{winter-spring}}$ = 0.117).

Similar patterns of relationship were found in the conventional model where measures of correct word reading (WIF) and correct word spelling were used. The relationship between correct word reading and spelling was spurious, meaning that other variables were influencing a relationship between them. Letter Naming Fluency (LNF) and alphabetic decoding (NWF) were responsible for some significant unexplained variance in the correct word reading and spelling relationship in winter. In spring, only alphabetic decoding (NWF) remained a significant predictor of correct word reading and spelling. This again, indicated that the relationship between the ability to read and spell

words correctly was in part attributed to the knowledge of letter names (LNF) in winter and alphabetic decoding ability (NWF) in winter and spring of first grade. This is an important finding because Nonsense Word Fluency is a measure of alphabetic decoding and was significant for predicting the ability to correctly read high frequency words, many of which cannot be alphabetically decoded. After the common influences of correct word reading (WIF) and spelling (DST) were controlled for, there was evidence that correct word reading ability at earlier time points predicted correct word spelling ability during the following time points. The cross-lagged paths from correct word reading to correct word spelling were both significant ($\beta_{\text{fall-winter}}$ =.110 and $\beta_{\text{winter-spring}}$ = .154). Correct word spelling was not found to be a significant causal longitudinal predictor of correct word reading as evidenced by insignificant cross-lagged paths from spelling to reading in both waves of analysis ($\beta_{\text{fall-winter}}$ =.045 and $\beta_{\text{winter-spring}}$ = 0.53). This finding indicated that even when a different type of reading and spelling knowledge was tested in a first grade model, the results still disproved Frith's hypothesis of temporal precedence of spelling over reading during the alphabetic stage. Potential reasons for the inconsistency of current results with Frith's model are discussed in the implications section.

Orthographic Stage (Third Grade)

The second hypothesis of the present study was that during the orthographic stage of reading and spelling development, orthographic knowledge is first acquired in reading and is used to recognize words with orthographic patterns and then this knowledge is transferred into the ability to spell words by analyzing them into orthographic units

(Frith, 1985). This hypothesis has been previously tested in Davis and Bryant's study (2006), where authors provided support to the precedence of reading in the orthographic knowledge transfer by testing students' ability to use a particular orthographic rule (split diagraphs) in reading and spelling. In that study, children's ability to recognize split diagraphs in reading in second and third grade was a causal longitudinal predictor of their ability to use split diagraphs in spelling a year later. I was interested in examining whether other aspects of orthographic knowledge development followed the proposed pattern. Initially, I proposed to estimate two models to test knowledge transfer during the orthographic stage of reading and spelling development. First, a general reading and spelling model using measures of oral reading fluency (ORF) and test of written spelling (TWS) that consisted of a combination of phonologically decodable, sight, and orthographically spelled words, and next an orthographic knowledge model utilizing measures of orthographic reading and orthographic spelling was tested. The orthographic reading measure was derived from the ORF measure by calculating only the number of correctly read words with orthographic patterns. Similarly, orthographic spelling scores were derived from the TWS protocols by calculating the number of correctly spelled words with orthographic patterns. Correlation matrices for general reading (ORF) and spelling scores (TWS) and orthographic reading and spelling scores indicated that orthographic reading and spelling scores were multicollinear with the general reading and spelling scores from which they were derived. Correlations between orthographic measures and their respective general measures at different timepoints ranged from .86 to .89, indicating that orthographic knowledge scores were capturing the same ability as

their respective general reading and spelling scores. High correlations between the two scores can partially be explained by the fact that they were obtained from the same measures. Another reason for the high correlations between the two scores could be that in third grade the majority of students in the sample had reached the full orthographic stage, and therefore read and spelled by analyzing words into orthographic units without phonological conversion, also known as chunking word patterns (Frith, 1981). Given the multicollinearity, it was pointless to estimate two different models measuring the same knowledge, so only measures of orthographic knowledge were retained in the analysis and only one model of orthographic knowledge transfer was estimated since it was the type of knowledge proposed by Frith.

The third grade orthographic model suggested that, as proposed by Frith, orthographic reading ability was a causal longitudinal predictor of orthographic spelling skill. Orthographic reading in the fall predicted orthographic spelling ability in winter ($\beta_{\text{fall-winter}}$ =.135) and orthographic reading in winter predicted orthographic spelling ability in spring ($\beta_{\text{winter-spring}}$ =.179). Orthographic spelling was not a significant causal longitudinal predictor of orthographic reading at either time point.

Overall, the third grade cross-lagged model revealed that the relationship between orthographic reading and spelling was unidirectional. Students' ability to read words with orthographic patterns was found to be a causal longitudinal predictor of their ability to spell words with orthographic patterns at later time points in both fall to winter and winter to spring of third grade, but the reverse was not true. This was in line with Frith's

hypothesis that during the orthographic stage of reading and spelling development, orthographic knowledge is first acquired through reading and then transfers to spelling.

Reading and Spelling Relationships in Struggling Readers

The majority of studies that explored the relationship between reading and spelling used data collected from typically developing readers without identified learning difficulties, so it has been unclear whether and how the patterns of reading-spelling relationships differ for struggling readers. Fitzgerald and Shanahan (2000) suggested that struggling readers might experience less knowledge transfer between reading, writing, and spelling. The third hypothesis tested in this study was whether patterns of directionality in reading and spelling relationships differ significantly for struggling readers compared to typical readers. To determine if it would be appropriate to estimate the proposed models separately for these two subsamples, I performed a set of multiple-group analyses on the entire sample for the first and the third grade. These multiple-group analyses tested the equality of fit for the proposed models across typically developing readers and students with reading difficulty. The multiple-group analyses performed on typical and struggling reader subsamples in both grade levels suggested that longitudinal reading-spelling relationships differed significantly for these two subgroups. The study sample was therefore divided into struggling and typical readers and the proposed models were estimated separately for the two groups.

Results of the first grade struggling reader models indicated that -- similar to the typical sample for both the alphabetic model and the conventional model -- common third variables were influencing the relationship between reading and spelling. Moreover, the

same variables were found to be common influences of reading and spelling in the first grade struggling reader sample. Letter Naming Fluency (LNF) in winter and correct word reading ability (WIF) in winter and spring were significant common influences on alphabetic decoding and developmental spelling in the struggling reader alphabetic model. For the conventional model, Letter Naming Fluency (LNF) in winter and alphabetic decoding (NWF) in winter and spring were significant common influences on correct word reading (WIF) and correct word spelling.

While the common influences on first grade reading and spelling were the same in both struggling and typical models, the cross-lagged relationships between reading and spelling in struggling readers followed a different pattern. No cross-lagged paths emerged as significant in the first grade models, indicating that neither reading nor spelling were significant longitudinal predictors of each other. This was true for both the alphabetic and the conventional model. Therefore, contrary to what was found in typical models, struggling readers' early alphabetic knowledge in reading did not predict later alphabetic skills in spelling. Additionally, the ability to read words correctly did not predict correct word spelling significantly at later time points in the first grade struggling reader sample.

The third grade struggling reader model indicated that after autoregressive effects were accounted for, there was no significant effect of earlier orthographic reading on later orthographic spelling or earlier orthographic spelling on later orthographic reading. All four cross-lagged paths were insignificant. The lack of significant predictive influence of reading and spelling on each other found in both first and third grade struggling reader models is consistent with the hypothesis that students with reading difficulties might

experience less knowledge transfer between reading and spelling skills, which might hinder their learning in both domains. Struggling readers might experience more difficulty learning orthographic patterns and thus have a hard time reading texts containing those orthographic patterns. This leads to negative reading experiences, less desire to read, and avoidance of reading activities. By avoiding reading activities, these students limit their exposure to the orthographic patterns they find too difficult. Less exposure to orthographic patterns in reading leads to lack of bootstrapping evidenced by no mutually facilitative influences of reading on spelling (or vice versa) found in the struggling reader sample in this study.

English Language Learner Analysis

The study sample used in this analysis had a high proportion of English Language Learners (54%), and it was important to examine whether the reading and spelling achievement of ELLs in the study was significantly different from the achievement of English Only (EO) students, to assure that both groups can be combined in the analysis without accounting for their ELL status. Existing research suggests that at least for word-level skills (decoding, oral reading, spelling), the performance of ELL students is comparable to that of EO students, when socio-economic variables are accounted for (Kieffer, 2008; Lesaux, Rupp, & Siegel, 2007; Roberts, Mohammed, & Vaughn, 2010). Data from this sample suggested a similar pattern.

I compared performance of these two groups on various first and third grade reading and spelling assessments using independent sample t-tests. No significant differences were found in reading or spelling performance in first or third grade between

ELL and EO students in the sample. Additionally, multiple-group analyses were conducted that simultaneously estimated the proposed first and third grade models across ELL and EO samples to determine whether the model parameters vary across the ELL and EO groups. Group differences on individual parameters and a combination of all parameters (cross-lagged and auto-regressive) were tested through the specification of cross-group equality constraints. Chi-square difference statistics were calculated comparing the fit of the constrained models to that of a model with no equality constraints between ELL and EO groups.

The results of this analysis did not indicate a presence of any significant differences in reading-spelling relationships patterns for ELL students compared to EO students in the sample, as no single parameter was significantly different in two samples. The majority of the students in the study, regardless of the ELL status, came from low-income families and high-poverty neighborhoods. This finding is consistent with previous research (Kieffer, 2008; Lesaux, Rupp, & Siegel, 2007) that suggests that for word-level skills such as decoding and spelling ELL students achieve similarly to their EO peers when socioeconomic variables are accounted for.

Implications

This study tested the developmental hypothesis proposed by Frith (1985). These findings provided additional support for the orthographic stage hypothesis first examined by Davis and Bryant (2006) and extend them by examining reading-spelling relationships in typical and struggling readers. This study was also the first one to examine the alphabetic stage hypothesis proposed by Frith (1985). The third grade typical model

examined in this study indicated that during the orthographic stage, orthographic knowledge in reading had an ongoing predictive influence on the ability to use orthographic patterns in spelling at later time points. This finding is in line with both Frith's proposed hypothesis for the direction of influences during the orthographic stage and findings of Davis and Bryant (2006). One of the important implications of this finding is that due to its important predictive influence on spelling skill, continuous study of words with orthographic patterns may prove beneficial for achievement in both domains.

The present study also makes a contribution to the research literature on reading-spelling relationships by examining the earlier stage of Frith's developmental hypothesis – alphabetic. No study to date has provided support or disproved the proposed directionality of reading-spelling relationships during the alphabetic stage. The observed patterns of directionality of reading-spelling relationships in first grade have several important implications for theoretical models and classroom practices.

First, the results of the first grade models suggest that regardless of the type of knowledge examined (alphabetic or conventional knowledge) the relationship between reading and spelling at that stage was not a simple association between two skills but was influenced by several other early literacy skills. Specifically, I found that the relationship between alphabetic reading and developmental spelling was significantly influenced by students' knowledge of letter names and their ability to read real words correctly. These common influences on the alphabetic reading and spelling relationship were present in typically developing, as well as struggling readers. So regardless of reading ability levels,

knowledge of letter names and the ability to read words correctly were important influences on alphabetic reading-spelling relationships in first grade. Therefore, it can be concluded that at this stage, literacy instruction should focus on teaching letter name knowledge, letter-sound correspondences, and phonological spelling in conjunction with each other to assure thorough understanding of reading and spelling connections and knowledge transfer between the two domains. This key finding could be used to improve first grade reading and spelling curriculum by focusing on specific skills that play important roles at particular points of first grade reading and spelling development.

Second, with this sample, I was unable to support Frith's alphabetic stage hypothesis that suggests that alphabetic knowledge in spelling facilitates later alphabetic knowledge acquisition in reading. Instead, the results of this study indicated that after accounting for significant early literacy influences on alphabetic reading and spelling, alphabetic reading had an ongoing predictive influence on alphabetic spelling. This pattern of directionality is not consistent with Frith's alphabetic knowledge transfer hypothesis. A potential explanation for the observed directionality could be that the relationship between alphabetic reading and spelling was strongly influenced by correct word reading throughout the first grade. This might suggest that even though students are still in the alphabetic stage, they are starting to learn how to read and spell words as wholes without phonologically converting every single letter to a sound.

To take advantage of potential transfer effects from reading to spelling, spelling instruction might need to be explicit, connected to the reading activities, and proceed in step with letters or letter patterns introduced to the students through their reading

activities. To make spelling instruction more productive in first grade, instead of requiring students to memorize words as a whole, teachers should instruct students to examine the words on spelling lists using a sound-by-sound decoding strategy, thus emphasizing the connection between decoding and encoding, and taking advantage of the alphabetic stage common to students in first grade. It would also be beneficial, if during the weekly spelling tests, at least initially, teachers remind the children to say all the sounds in a given word and then spell it out letter-by-letter. Spelling activities that typically conclude the phonics lesson could utilize the words from a decodable story – a reading activity that precedes spelling -- to make more explicit connections between decoding and spelling.

Explicit and integrated reading/spelling instruction is even more important for students with reading difficulties as the findings of this study indicated that there is less knowledge transfer and bootstrapping between reading and spelling in the struggling reader' sample regardless of the type of knowledge or grade level. Classroom teachers could make the connection between reading and spelling more explicit for these students by embedding spelling into reading activities and vice versa.

It would be interesting to explore whether the directionality pattern would be different if students' alphabetic knowledge was tracked back to kindergarten, when they just begin formal instruction in letter-sound correspondences and have very little to no ability and experience reading words. Such investigation however was beyond the scope of this study, as data on alphabetic decoding scores in kindergarten were only available for two of the three time points, which made it impossible to estimate a three-wave model

with kindergarten data. Additionally, kindergarten data were only available for less than half of the entire sample used in this study, so no direct comparisons can be made between kindergarten and first grade samples.

These results also offer possibilities for improving spelling instruction in third grade. Orthographic knowledge of letter and word patterns is first acquired through reading and only after multiple exposures to certain patterns in print do children have strong enough mental representation of these patterns to be able to use them for spelling. When children are introduced to specific orthographic patterns (letter patterns, morphemes) they need frequent encounters with these patterns through their reading activities in addition to practice spelling words with these patterns. The more times children see the orthographic patterns, the stronger their mental representations of these patterns will be, which will improve not only their ability to read words containing the patterns but also their ability to use them appropriately in their spelling. Since orthographic knowledge in reading had an ongoing causal influence on orthographic knowledge in spelling at later time points, it might be useful to introduce certain orthographic patterns first through reading activities and exercises and then, several weeks later, in spelling. Having encountered these patterns in reading for some time, children could create solid understanding of how these patterns are used and could potentially make learning how to use these patterns in spelling easier.

Limitations

Although this study provides an important contribution to the existing literature on reading-spelling relationships by examining the patterns of directionality during

alphabetic and orthographic stages of reading, several limitations of this research should be noted. First, measures of orthographic reading and spelling were obtained from measures of oral reading fluency and written spelling by calculating correctly read and spelled words with orthographic patterns. These measures were not specifically constructed to measure orthographic knowledge. Future studies examining orthographic knowledge in reading and spelling are advised to use alternative measures that are specifically created to measure orthographic knowledge.

Second, although students were sampled from five schools and two school districts, all the data were collected in the Southern California region characterized by socio-economically, linguistically, and culturally diverse populations, and thus the results of the study may not be generalizable to other states or regions of the United States. Specifically, the majority of the students in the sample were of lower socio-economic status and many were English Language Learners. Further research is needed to examine the generalizability of current findings in other geographic regions and with samples from different cultural backgrounds. Despite these limitations, this study provides an important insight on the nature of reading-spelling relationships during two stages of literacy development – alphabetic and orthographic.

Future Directions

This study was the first to examine the directionality of reading-spelling relationships during the alphabetic and orthographic stages proposed by Frith. The developmental hypothesis proposed by Frith focuses on three stages of reading and spelling development: logographic, alphabetic and orthographic. Future longitudinal

studies could attempt to track students' literacy development from the logographic through orthographic stages, which would allow for testing of the entire developmental hypothesis proposed by Frith.

Future research could also focus on examining the utility of existing measures of reading and spelling ability for accurately determining stages of reading and spelling development. Such research could lead to practical suggestions for classroom teachers for using specific measures to determine their students' stages of reading and spelling development.

The developmental hypothesis proposed by Frith refers to stages of development characteristic of word-level skills: decoding and spelling. It would be of interest to examine the directionality of reading-writing relationships present in higher-level processes such as reading comprehension and written composition that become important in upper elementary grades.

It is likely that instruction and curriculum used play important roles in the complex nature of reading-spelling relationships. It would be of interest to examine whether different types of reading and spelling curricula affect the directionality patterns of reading-spelling relationships at different grade levels. All of the participants of this study received reading and spelling instruction based on the California-mandated reading curriculum. Obtaining samples of students that receive reading and spelling instruction through differing curricula and investigating potential differences in reading-spelling relationships could shed light on how specific curricula affect knowledge transfer between reading and spelling across developmental stages.

References

Anderson, S. & Williams, L. J. (1992). Assumptions about unmeasured variables with studies of reciprocal relationships: the case of employee attitudes. Journal of Applied Psychology 77, 638-650.

Bear, D. R., & Tempelton, S. (1998). Explorations in developmental spelling: Foundations for learning and teaching phonics, spelling and vocabulary. *Reading Teacher*, 52, 222-243.

Berninger, V., Abbot, R., Rogan, L., Reed, E., Abbot, S., Brooks, A., Vaughn, K., & Graham, S. (1998). Teaching spelling to children with specific learning disabilities: The mind's ear and eye beat the computer or pencil. *Learning Disability Quarterly*, 21, 106-122.

Bernstein, S. E., & Treiman, R. (2001). Learning a novel grapheme: Effects of positional and phonemic context on children's spelling. *Journal of Experimental Child Psychology*, 79, 56–77.

Bourassa, D., & Treiman, R. (2003). Spelling in children with dyslexia: Analyses from the Treiman-Bourassa early spelling test. *Scientific Studies of Reading*, 7, 309–333.

Bourassa, D., Treiman, R., & Kessler, B. (2006). Use of morphology in spelling by children with dyslexia and typically developing children. *Memory and Cognition*, 34, 703–714.

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.

Campbell, D. T., & Kenny, D. A. (1999). *A Primer on Regression Artifacts.* London: The Guilford Press.

Chomsky, C. (1970). Invented spelling in the open classroom. *Word, 27,* 499-518.

Compton, D. L., Fuchs, D., & Fuchs, L. S (2006). Selecting at-risk readers in first grade for early intervention: A two-year longitudinal study of decision rules and procedures. *Journal of Educational Psychology* 98 (2), 394-409.

Davis, C., & Bryant, P. (2006). Causal connections in the acquisition of an orthographic rule: a test of Uta Frith's developmental hypothesis. *Journal of Child Psychology and Psychiatry,* 47(8), 849-856.

DeCarlo, L.T. (1997). On the meaning and use of kurtosis. *Psychological Methods,* 2, 292-307.

Ehri, L.C. (1989). The development of spelling knowledge and its role in reading acquisition and reading disability. (1989). *Journal of Learning Disability, 22 (6),* 356-365.

Ehri, L. C. (2000). Learning to read and learning to spell: Two sides of a coin. *Topics in Language Disorders,* 20(3), 191–236.

Ehri, L.C. (2005). Learning to read words: Theory, findings and issues. *Scientific Studies of Reading,* 9(2), 167-188.

Ehri, L.C., & Wilce, L. S. (1986). The influence of spellings on speech: Are alveolar flaps /d/ or /t/? In D. Yaden & S. Templeton (Eds.), *Metalinguistic awareness and beginning literacy* (pp. 101-114). Portsmouth, NH: Heinemann.

Ehri, L. C., & Wilce, L. S. (1987). Does learning to spell help beginners learn to read words. *Reading research quarterly, 22*(1), 47-65.

Fitzgerald, J., & Shanahan, T. (2000). Reading and writing relations and their

development. *Educational Psychologist, 35*, 39-51.

Frith, U. (1980). Unexpected spelling problems. In U.Frith (Ed.), *Cognitive processes in spelling* (pp. 495-516). London: Academic.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K.E. Patterson, J.C. Marshall, & M. Coltheart (Eds), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading (*pp.301-330). London: Lawrence Erlbaum Associates, Inc.

Fuchs, L. S., Fuchs, D., & Compton, D. L. (2004). Monitoring early reading development in first grade: word identification fluency versus nonsense word fluency. *Exceptional Children* 71(1), 7-21.

Greenberg, D., Ehri, L. C., & Perin, D. (1997). Are word-reading processes the same or different in adult literacy students and third–fifth graders matched for reading level? *Journal of Educational Psychology*, 89(2), 262-275.

Good, R. H., & Kaminski, R. A. (Eds.). (2002). *Dynamic Indicators of Basic Early Literacy Skills* (6th ed.). Eugene, OR: Institute for Development of Educational Achievement.

Good, R.H., & Kaminski, R.A. (2003). *Dynamic Indicators of Basic Early Literacy Skills* (6^{th} ed.). Longmont, CO: Sopris West Educational Services.

Good, R. H., Kaminski, R.A., Shinn,M., Bratten, J., Shinn, M., Laimon, L., Smith, S., & Flindt,N. (2004). *Technical Adequacy and Decision Making Utility of DIBELS* (*Technical Report No. 7)*. Eugene, OR: University of Oregon.

Henderson, E.H. (1981). *Learning to read and spell: The child's knowledge of*

words. DeKalb, IL: Northern Illinois Press.

Henderson, E.H., & Beers, J. (Eds.). (1980). *Developmental and cognitive aspects of learning to spell: A reflection of word knowledge.* Newark, DE: International Reading Association.

Horn, E. (1926). *A basic vocabulary of 10,000 words most commonly used in writing.* Iowa City, IA: University of Iowa.

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.

Hatcher, P. J., Hulme, C., & Ellis, A. W. (1994). Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development*, 65, 41–57.

Invernizzi, M., Abouzeid, M., & Gill, J.T. (1994). Using students' invented spellings as a guide for spelling instruction that emphasizes word study. *Elementary School Journal, 95,* 155-167.

Joshi, R. M., Treiman, R., Carreker, S., & Moats, L. (2009). How words cast their spell: Spelling instruction focused on language, not memory, improves reading and writing. *American Educator*, 32(4), 6–16, 42–43.

Juel, C., Griffith, P. L., & Gough, P.B. (1986). Acquisition of literacy: A longitudinal study of children in first and second grade. *Journal of Educational Psychology*, 78(4), 243-255.

Kaminski, R. A., & Good, R. H. (1996). Toward a technology for assessing basic early literacy skills. *School Psychology Review, 25,* 215–227.

Kenny, D.A. & Harackiewicz, J. M. (1979). Cross-lagged panel correlation: Practice and promise. *Journal of Applied Psychology,* 64, 372-379.

Kieffer, M.J. (2008). Catching up or falling behind? Initial English proficiency, concentrated poverty, and the reading growth of language minority learners in the United States. *Journal of Educational Psychology,* 100 (4), 851-868.

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

Langer, J.A.(1986). Reading, writing and understanding: An analysis of the construction of meaning. *Written communication,* 3(2), 219-267.

Larsen, S., Hammill, D.D., & Moats, L. (1999). *Test of Written Spelling: Examiner's Manual.* Pro-Ed.

Lesaux, N. K., Rupp, A., & Siegel, L. S. (2007). Growth in reading skills of children from diverse linguistic backgrounds: Findings from a 5-year longitudinal study. *Journal of Educational Psychology, 99,* 821–834.

Little, R. J. A., & Rubin, D.B. (2002). *Statistical analysis with missing data (2nd ed.).* New York: Wiley.

Marshall, J. C., & Newcombe, F. (1973). Patterns of paraplexia: A psycholinguistic approach. *Journal of Psycholinguistic Research,* 2(3), 175-199.

McKee, P. (1924). *Teaching and testing spelling by column and context forms.* Unpublished doctoral dissertation, University of Iowa, Iowa City.

Moats, L. C. (1983). A comparison of spelling errors of older dyslexic and second-grade normal children. *Annals of Dyslexia,* 33, 121-40.

Moats, L.C. (1995). *Spelling: Development, disabilities and instruction*. Timonium, MD: York Press.

Muthen, L., & Muthen, B. (2010). MPlus (Version 6.12) [Computer Software]. Los Angeles: Muthen & Muthen.

Nunes, T., Bryant, P., & Bindman, M. (1997). Morphological spelling strategies: Developmental stages and processes. *Developmental Psychology*, 33, 637–649.

Raghunathan, T.E., Rosenthal, R., & Rubin, D. B. (1996). Comparing correlated but nonoverlapping correlations. *Psychological Methods*, 1, 178-183.

Raudenbush, S.W., Byrk, A.S., Cheong, Y.F, Congdon, R. T., & Toit, M. (2011). *HLM 7: Linear and nonlinear modeling.* Lincolnwood, IL: Scientific Software International, Inc.

Raudenbush, S.W., & Byrk, A.S. (2002). *Hierarchical Linear Models* (2nd ed.). Thousand Oaks, CA: Sage.

Read, C. (1971). Preschool children's knowledge of English phonology. *Harvard Educational Review, 41,* 1-34.

Roberts, G., Mohammad, S.S., Vaughn, S. (2010). Reading achievement across three language groups: Growth estimates for overall reading and reading subskills obtained with the Early Childhood Longitudinal Survey. *Journal of Educational Psychology, 102*(3), 668-686.

Rogosa, D.A. (1980). A critique of cross-lagged correlation. *Psychological Bulletin*, 88, 245-258.

Salvia, J., & Ysseldyke, J. (1998). *Assessment (7th ed.)*. Boston: Houghton Mifflin.

Santa, C. M., & Hoien, T. (1999). An assessment of Early Steps: A program for early intervention of reading problems. *Reading Research Quarterly, 34,* 54–79.

Seidenberg, M.S., & McClelland, J. L. (1989). A distributed developmental model of word recognition and naming. *Psychological Review*, 96(4), 523-568.

Shanahan, T., & Lomax, R.G. (1986). An analysis and comparison of theoretical models of the reading-writing relationship. *Journal of Educational Psychology, 78,* 116-123.

Shanahan, T., & Lomax, R. G. (1988). A developmental comparison of three theoretical models of the reading of the reading-writing relationship. *Research in the Teaching of English, 22,* 196-212.

Stage, S. A., & Wagner, R. K. (1992). Development of young children's phonological and orthographic knowledge as revealed by their spellings. *Developmental Psychology*, 28, 287–296.

Stanovich, K.E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly,* 21, 360-406.

Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Hillsdale, NJ: Erlbaum.

Stuart, M., & Coltheart, M. (1988). Does reading develop in sequence of stages? *Cognition,* 30, 139-181.

Swanson, H. L., Hoskyn, M., & Lee, C. (1999). Interventions for students with learning disabilities. New York: Guilford.

Tangel, D.M., & Blachman, B.A. (1992). Effect of phoneme awareness instruction on kindergarten children's invented spelling. *Journal of Reading Behavior*, *24*, 233–261.

Tangel, D. M. & Blachman, B. A. (1995). Effect of phoneme awareness instruction on the invented spelling of first-grade children: A one-year follow-up. *Journal of Reading Behavior*, 27 (2), 153-185.

Templeton, S., & Bear, D.R. (Eds.). (1992). *Development of orthographic knowledge and the foundations of literacy: A memorial Festschrift for Edmund H. Henderson.* Hillsdale, NJ: Erlbaum.

Tempelton, S., & Morris, D. (2000). Reconceptualizing spelling development and instruction. In M.L. Kamil, P.B. Mosenthal, P.D. Pearson, & R. Barr. (Eds.), *Handbook of reading research: Volume III*, Mahwah, NJ: Erlbaum.

Tempelton, S., & Morris, D. (1999). Questions teachers ask about spelling. *Reading Research Quarterly*, 54, 102-112.

Tiernay, R.J., & Shanahan, T. (1991). Research on the reading-writing relationship: Interactions, transactions and outcomes. In R.Barr, M,L. Kamil, P. Mosenthal, & P.D. Pearson (Eds.), *The handbook of reading research* (Vol. 2, pp. 246-280). New York: Longman.

Treiman, R. (1993). *Beginning to spell: A study of first-grade children*. New York: Oxford University Press.

Treiman, R., & Bourassa, D. C. (2000). The development of spelling skill. *Topics in Language Disorders*, 20, 1–18.

Varnhagen, C. K., McCallum, M., & Burstow, M. (1997). Is children's spelling naturally stage- like? *Reading and Writing: An Interdisciplinary Journal*, 9, 451–481.

Van Orden, G.C., Pennington, B. F., & Stone, G.O. (1990). Word identification in reading and the promise of symbolic psycholinguistics. *Psychological Review*, 97(4), 488-522.

Wanzek, J., Vaughn, S., Wexler, J., Swanson, E. A., Edmonds, M., & Kim, A. (2006). A synthesis of spelling outcomes of students with LD. *Journal of Learning Disabilities, 39*, 528-543.

Woodcock, R. N. (1997). *Woodcock Reading Mastery Tests - Revised Examiner's Manual*. Circle Pines, MN: American Guidance Service.

Woodcock, R. N. (1997). *Woodcock Reading Mastery Tests - Revised/Normative Update.* Circle Pines, MN: American Guidance Service.

Worthy, M. J & Invernizzi, M. (1990). Spelling errors of normal and disabled students on achievement levels one through four: Instructional implications. *Annals of Dyslexia,* 40(1), 138-151.

Ysseldyke, J., & Olsen, K. (1999). Putting alternate assessments into practice: what to measure and possible sources of data. *Exceptional Children*, *65*(2), 175-85.

Tables

Table 1
WRMT Word ID item representation according to type of word

Phonological	**Sight words**	**Orthographic**
3. and	1. is	10.book
4.up	2. you	11.play
5.cat	7. come	13.blue
6.stop	14.two	13.boy
8.jump	15.no	17.little
9.help	27.said	20.car
12.sun	31.woman	23.down
18.bed	34. work	25.with
19.milk	42. watch	26.find
21.swim	44. early	28.night
22.fast		29.sleep
24.rug		30.after
		32.summer
		33.table
		35.stove
		36.ground
		37.airplane
		38.chair
		39.because
		40.beautiful
		41.slowly
		43.heavy
		45.already
		46.laugh
		47.hurry
		48.largest
		49.expert
		50.evening

Table 2
Demographic Information (Entire Sample)

Participant Demographics	*Frequency*	*Percentage*
N	386	100%
Ethnicity		
African American	50	13%
American Indian	1	< 1%
Asian	4	1%
Hispanic	274	71%
Caucasian, non-Hispanic	45	12%
Other	12	3%
Gender		
Girls	174	45%
Boys	212	55%
ELL status		
English only	178	46%
English language learners	208	54%
At Risk Status		
Typical	267	69%
Struggling	119	31%

Table 3
Test of Normality (third grade variables)

	Shapiro-Wilk	df	
Oral Reading Fluency (ORF) Fall	.984	386	.093
Oral Reading Fluency (ORF) Winter	.984	386	.114
Oral Reading Fluency (ORF) Spring	.989	386	.325
Test of Written Spelling (TWS) Fall	.983	386	.078
Test of Written Spelling(TWS)	.983	386	.076
Test of Written Spelling (TWS)	.981	386	.059

Table 4
Test of Normality (first grade variables)

	Shapiro-Wilk	df	Sig.
Nonsense Word Fluency (NWF) Fall	.987	385	.116
Nonsense Word Fluency (NWF) Winter	.989	385	.265
Nonsense Word Fluency (NWF) Spring	.989	385	.288
Word Identification Fluency (WIF) Fall	**.829**	**385**	**.000**
Word Identification Fluency (WIF)Winter	.983	385	.071
Word Identification Fluency (WIF) Spring	.987	385	.092
Developmental Spelling (DTS) Fall	**.833**	**385**	**.000**
Developmental Spelling (DTS) Winter	.982	385	.061
Developmental Spelling (DTS) Spring	.983	385	.076
Correct Word Spelling (CWS) Fall	**.826**	**385**	**.000**
Correct Word Spelling (CWS) Winter	.978	385	.059
Correct Word Spelling (CWS) Spring	.981	385	.063

Table 5
ELL vs EO independent samples t-tests (first grade)

	t	df	Sig. (2-tailed)	95% Confidence Interval of the	
				Lower	Upper
NWF Fall	-.678	385	.498	-5.14770	2.50850
NWF Winter	-1.166	385	.245	-8.92207	2.28093
NWF Spring	-1.055	385	.292	-9.75010	2.94216
DTS Fall	-.762	385	.447	-1.89799	.83820
DTS Winter	-.706	385	.480	-1.48648	.70081
DTS Spring	-.713	385	.477	-1.46318	.68480

Table 6

ELL vs EO independent samples t-tests (third grade)

	t	df	Sig. (2-tailed)	95% Confidence Interval of the	
				Lower	Upper
Orth.Spell Fall	-.573	385	.567	-1.16344	.63845
Orth.Read Winter	.326	385	.745	-4.70910	6.57926
Orth.Read Spring	1.331	385	.184	-1.72685	8.95950
Orth.Read Fall	.337	385	.736	-4.37857	6.19080
Orth.Spell Winter	-1.120	385	.263	-1.34355	.36837
Orth.Spell Spring	-.224	385	.823	-1.00636	.80020

Table 7

Multiple groups analysis for ELL/EO status (first grade)

Model Description	**χ^2 difference test**
Allow all paths and correlations to freely vary	$\Delta\chi^2$ (11) = 4.75 , p>.05
Allow the path from fall alph.decoding to winter alph.decoding to freely vary	$\Delta\chi^2$ (1) =.010 , p>.05
Allow the path from winter alph.decoding to spring alph.decoding to freely vary	$\Delta\chi^2$ (1) = .209, p>.05
Allow the path from fall dev.spelling to winter dev.spelling to freely vary	$\Delta\chi^2$ (1) = .326, p>.05
Allow the path from winter dev.spelling to spring dev.spelling to freely vary	$\Delta\chi^2$ (1) = 1.012 , p>.05
Allow the path from fall alph.decoding to winter dev.spelling to freely vary	$\Delta\chi^2$ (1) = .534, p>.05
Allow the path from winter alph.decoding to spring dev.spelling to freely vary	$\Delta\chi^2$ (1) =.803 , p>.05
Allow the path from fall dev.spelling to winter alph.decoding to freely vary	$\Delta\chi^2$ (1) =1.254 , p>.05
Allow the path from winter dev.spelling to spring alph.decoding to freely vary	$\Delta\chi^2$ (1) = .170, p>.05
Allow the correlation between fall alph.decoding to fall dev.spelling to freely vary	$\Delta\chi^2$ (1) =.335 , p>.05

All models are compared to a model where all paths are constrained to equality across ELL status (χ^2 (15) = 7.583). If chi-square values are statistically significant, the new model is significantly different than the fully-constrained model. N=386

Table 8

Multiple groups analysis for ELL/EO status (third grade)

Model Description	**χ^2 difference test**
Allow all paths and correlations to freely vary	$\Delta\chi^2$ (11) = 8.365, p>.05
Allow the path from fall orth.reading to winter orth.reading to freely vary	$\Delta\chi^2$ (1) = .149, p>.05
Allow the path from winter orth.reading to spring orth.reading to freely vary	$\Delta\chi^2$ (1) = .226, p>.05
Allow the path from fall orth.spelling to winter orth.spelling to freely vary	$\Delta\chi^2$ (1) = .555, p>.05
Allow the path from winter orth.spelling to spring orth.spelling to freely vary	$\Delta\chi^2$ (1) = .419, p>.05
Allow the path from fall orth.reading to winter orth.spelling to freely vary	$\Delta\chi^2$ (1) = .347, p>.05
Allow the path from winter orth.reading to spring orth.spelling to freely vary	$\Delta\chi^2$ (1) = .273, p>.05
Allow the path from fall orth.spelling to winter orth.reading to freely vary	$\Delta\chi^2$ (1) = 1.449, p>.05
Allow the path from winter orth.spelling to spring orth.reading to freely vary	$\Delta\chi^2$ (1) = .428, p>.05
Allow the correlation between fall orth.reading to fall orth.spelling to freely vary	$\Delta\chi^2$ (1) = .164, p>.05

All models are compared to a model where all paths are constrained to equality across ELL status (χ^2 (15) = 44.871). If chi-square values are statistically significant, the new model is significantly different than the fully-constrained model. N=386.

Table 9

Multiple group analysis for typical/struggling reader status (first grade)

Model Description	**χ^2 difference test**
Allow all paths and correlations to freely vary	**χ^2 (11) = 27.316 , p<.05***
Allow the path from fall alph.decoding to winter alph.decoding to freely	χ^2 (1) = 2.894, p>.05
Allow the path from winter alph.decoding to spring alph.decoding to freely	χ^2 (1) = .004, p>.05
Allow the path from fall alph.spelling to winter alph.spelling to freely vary	χ^2 (1) = .388, p>.05
Allow the path from winter alph.spelling to spring alph.spelling to freely	χ^2 (1) = .757, p>.05
Allow the path from fall alph.decoding to winter alph.spelling to freely vary	**χ^2 (1) = 6.825, p<.05***
Allow the path from winter alph.decoding to spring alph.spelling to freely	**χ^2 (1) =5.694 , p<.05***
Allow the path from fall alph.spelling to winter alph.decoding to freely vary	χ^2 (1) = .359 p>.05
Allow the path from winter alph.spelling to spring alph.decoding to freely	χ^2 (1) = 1.246., p>.05
Allow the correlation between fall alph.reading to fall alph.spelling to freely vary	χ^2 (1) = .127, p >.05

Table 10

Multiple groups analysis for typical//struggling reader status (third grade)

Model Description	**χ^2 difference test**
Allow all paths and correlations to freely vary	**χ^2 (11) = 39.11 , p>.05***
Allow the path from fall orth.reading to winter orth.reading to freely vary	χ^2 (1) = 1.183, p>.05
Allow the path from winter orth.reading to spring orth.reading to freely vary	χ^2 (1) = 1.13, p>.05
Allow the path from fall orth.spelling to winter orth.spelling to freely vary	χ^2 (1) = .906, p>.05
Allow the path from winter orth.spelling to spring orth.spelling to freely vary	χ^2 (1) = .014, p>.05
Allow the path from fall orth.reading to winter orth.spelling to freely vary	**χ^2 (1) = 10.557, p<.05***
Allow the path from winter orth.reading to spring orth.spelling to freely vary	**χ^2 (1) = 3.945, p<.05***
Allow the path from fall orth.spelling to winter orth.reading to freely vary	χ^2 (1) = .044 p>.05
Allow the path from winter orth.spelling to spring orth.reading to freely vary	χ^2 (1) = .323, p>.05
Allow the correlation between fall orth.reading to fall orth.spelling to freely vary	**χ^2 (1) = 19.599, p <.05***

Table 11
First Grade Descriptive Statistics

	Mean	Std.Deviation
NWF Fall	33.90	18.905
NWF Winter	52.97	27.498
NWF Spring	62.62	31.190
DST Fall	39.38	6.677
DST Winter	51.78	5.372
DST Spring	61.51	5.329
WIF Fall	**16.21**	**15.509**
WIF Winter	**39.12**	**22.368**
WIF Spring	49.28	23.143
CWF Fall	6.16	1.143
CWF Winter	8.20	.919
CWF Spring	9.83	.930

Table 12
Third Grade Descriptive Statistics

	Mean	Std. Deviation
ORF Fall	88.2041	28.37471
ORF Winter	92.6327	29.70178
ORF Spring	103.2857	30.51024
OrthRead Fall	42.9592	14.54012
OrthRead Winter	45.6735	14.29071
OrthRead Spring	50.8776	13.93083
OrthSpell Fall	6.3878	4.63598
OrthSpell Winter	6.5306	3.37331
OrthSpell Spring	7.8980	4.27320
TWS Fall	11.6939	5.41296
TWS Winter	12.3265	4.00722
TWS Spring	13.5306	4.77014

Table 13

Pairwise Spearman correlations among first grade variables (entire sample, N=386)

	NWF Fall	NWF Winter	NWF Spring	DST Fall	DST Winter	DST Spring	WIF Fall	WIF Winter	WIF Spring	CWS Fall	CWS Winter	CWS Spring
NWF Fall	1.000											
NWF Winter	.530**	1.000										
NWF Spring	.522**	.666**	1.000									
DST Fall	.346**	.141**	.152**	1.000								
DST Winter	.315**	.269**	.297**	.566**	1.000							
DST Spring	.305**	.263**	.350**	.581**	.717**	1.000						
WIF Fall	.703**	.466**	.515**	.407**	.395**	.382**	1.000					
WIF Winter	.600**	.654**	.648**	.290**	.435**	.447**	.738**	1.000				
WIF Spring	.556**	.608**	.673**	.231**	.418**	.447**	.666**	.788**	1.000			
CWS Fall	.309**	.125*	.148**	**.827****	.529**	.541**	.373**	.249**	.206**	1.000		
CWS Winter	.307**	.265**	.311**	.482**	**.797****	.624**	.381**	.414**	.395**	.528**	1.000	
CWS Spring	.304**	.252**	.324**	.582**	.690**	**.831****	.372**	.424**	.416**	.460**	.590**	1.000

Table 14

Pairwise Spearman correlations among first grade alphabetic variables (typical sample, N=267)

	NWF Fall	NWF Winter	NWF Spring	DST Fall	DST Winter	DST Spring
NWF Fall	1					
NWF Winter	.521**	1				
NWF Spring	.540**	.712**	1			
DST Fall	.364**	.162**	.179**	1		
DST Winter	.328**	.278**	.311**	.591**	1	
DST Spring	.316**	.268**	.373**	.547**	.723**	1

Table 15

Pairwise Spearman correlations among first grade conventional knowledge variables (typical sample)

	WIF Fall	WIF Winter	WIF Spring	CWS Fall	CWS Winter	CWS Spring
WIF Fall	1					
WIF Winter	.606**	1				
WIF Spring	.735**	.877**	1			
CWS Fall	.386**	.262**	.211**	1		
CWS Winter	.328**	.446**	.414**	.532**	1	
CWS Spring	.316**	.428**	.432**	.482**	.604**	1

Table 16

Pairwise Spearman correlations among first grade alphabetic variables (struggling reader sample, N=119)

	NWF Fall	NWF Winter	NWF Spring	DST Fall	DST Winter	DST Spring
NWF Fall	1					
NWF Winter	.369**					
NWF Spring	.255**	.611**				
DST Fall	.296*	.096*	.089*	1		
DST Winter	.210**	.203**	.240**	.561**	1	
DST Spring	.204*	.189**	.296**	.481**	.666**	1

Table 17

Pairwise Spearman correlations among first grade conventional knowledge variables (struggling reader sample)

	WIF Fall	WIF Winter	WIF Spring	CWS Fall	CWS Winter	CWS Spring
WIF Fall	1					
WIF Winter	.392**	1				
WIF Spring	.431**	.840**	1			
CWS Fall	.310**	196**.	.189**	1		
CWS Winter	.292**	.340**	.326**	.481**	1	
CWS Spring	.286**	.319**	.364**	.434**	.572**	1

Table 18

Pairwise Spearman correlations among third grade variables (entire sample)

	ORF Fall	ORF Winter	ORF Spring	OrthRead Fall	OrthRead Winter	OrthRead Spring	OrthSpell Fall	OrthSpell Winter	OrthSpell Spring	TWS Fall	TWS Winter	TWS Spring
ORF Fall	1											
ORF Winter	.798**	1										
ORF Spring	.778**	.788**	1									
OrthRead Fall	**.890****	.790**	.483**	1								
OrthRead Winter	.746**	**.869****	.696**	.780**	1							
OrthRead Spring	.732**	.819**	**.873****	.773**	.768**	1						
OrthSpell Fall	.567**	.416**	.430**	.508**	.509**	.441**	1					
OrthSpell Winter	.498**	.474**	.436**	.486**	.484**	.454**	.730**	1				
OrthSpell Spring	.503**	.392**	.467**	.502**	.499**	.480**	.717**	.704**	1			
TWS Fall	.586**	.440**	.454**	.561**	.423**	.448**	**.875****	.763**	.697**	1		
TWS Winter	.529**	.512	.461**	.520**	.431**	.439**	.708**	**.861****	.705**	.724**	1	
TWS Spring	.526**	.497**	.492**	.513**	.417**	.452**	.691**	.743	**.886****	.711**	.713**	1

Table 19

Pairwise Pearson correlations among third grade orthographic variables (typical sample)

	OrthRead Fall	OrthRead Winter	OrthRead Spring	OrthSpell Fall	OrthSpell Winter	OrthSpell Spring
OrthRead Fall	1					
OrthRead Winter	.805**	1				
OrthRead Spring	.787**	.801**	1			
OrthSpell Fall	.616**	.530**	.516**	1		
OrthSpell Winter	.547**	.493**	.469**	.752**	1	
OrthSpell Spring	.567**	.512**	.524**	.800**	.764**	1

Table 20

Pairwise Pearson correlations among third grade orthographic variables (struggling reader sample)

	OrthRead Fall	OrthRead Winter	OrthRead Spring	OrthSpell Fall	OrthSpell Winter	OrthSpell Spring
OrthRead Fall	1					
OrthRead Winter	.778**	1				
OrthRead Spring	.711**	.759**	1			
OrthSpell Fall	.359**	.373**	.315**	1		
OrthSpell Winter	.354**	.368**	.447**	.664**	1	
OrthSpell Spring	.330**	.487**	.379**	.572**	.653**	1

Table 21
Fit indices for first grade models

Tested models	Fit indices				
	χ^2, p	**Df**	**CFI**	**TLI**	**RMSEA (90%**
Alphabetic (typical)	1.671, p = 0.6890	4	.999	.996	.000 (.000 –
Alphabetic (struggling)	2.138, p = 0.3433	4	.989	.971	.024 (.000 –
Conventional (typical)	1.150, p = 0.7649	4	.998	.993	.000 (.000 -
Conventional (struggling)	2.045, p = 0.3948	4	.992	.989	.013 (.000 -

Table 22
Path coefficients for first grade typical model with covariates (alphabetic model)

Path	**Parameter Estimate**
NWF Fall → DTS Winter	.139*
NWF Winter → DTS Spring	.117*
DTS Fall → NWF Winter	.065 (ns)
DTS Winter → NWF Spring	.050 (ns)
NWF Winter ↔ DTS Winter	.023 (ns)
NWF Spring ↔ DTS Spring	.063 (ns)
NWF Fall → NWF Winter	.511*
NWF Winter → NWF Spring	.526*
DTS Fall → DTS Winter	.536*
DTS Winter → DTS Spring	.623*

Table 23
Path coefficients for first grade struggling reader model with covariates (alphabetic model)

Path	**Parameter Estimate**
NWF Fall → DTS Winter	.043 (ns)
NWF Winter → DTS Spring	.054 (ns)
DTS Fall → NWF Winter	.036 (ns)
DTS Winter → NWF Spring	.041 (ns)
NWF Winter ↔ DTS Winter	.056 (ns)
NWF Spring ↔ DTS Spring	.048 (ns)
NWF Fall → NWF Winter	.462*
NWF Winter → NWF Spring	.486*
DTS Fall → DTS Winter	.400*
DTS Winter → DTS Spring	.498*

Table 24
Path coefficients for first grade typical model with covariates (correct word knowledge)

Path	**Parameter Estimate**
WIF Fall → CWS Winter	.110*
WIF Winter → CWS Spring	.154*
CWS Fall → WIF Winter	.045 (ns)
CWS Winter → WIF Spring	.053 (ns)
WIF Winter ↔ CWS Winter	.011 (ns)
WIF Spring ↔ CWS Spring	.047 (ns)
WIF Fall → WIF Winter	.523*
WIF Winter → WIF Spring	.631*
CWS Fall → CWS Winter	.514*
CWS Winter → CWS Spring	.484*

Table 25
Path coefficients for first grade struggling reader model with covariates (correct word knowledge)

Path	**Parameter Estimate**
WIF Fall → CWS Winter	.046 (ns)
WIF Winter → CWS Spring	.039 (ns)
CWS Fall → WIF Winter	.053 (ns)
CWS Winter → WIF Spring	.013 (ns)
WIF Winter ↔ CWS Winter	.025 (ns)
WIF Spring ↔ CWS Spring	.059 (ns)
WIF Fall → WIF Winter	.444*
WIF Winter → WIF Spring	.486*
CWS Fall → CWS Winter	.406*
CWS Winter → CWS Spring	.395*

Table 26
Fit indices for third grade models

Tested models	Fit indices				
	χ^2, p	**Df**	**CFI**	**TLI**	**RMSEA (90% CI)**
Orthographic(typical)	2.639, p =	4	998	.994	.000 (.000 – .089)
Orthographic(struggling)	6.482, p =	4	989	.975	.027 (.000 - .110)

Table 27
Path coefficients for third grade typical model

Path	**Parameter Estimate**
Orth.Read Fall → Orth.Spell Winter	.135*
Orth.Spell Fall → Orth.Read Winter	.055 (ns)
Orth.Read Winter → Orth.Spell Spring	.179*
Orth.Spell Winter → Orth.Read Spring	.048 (ns)
Orth.Read Winter ↔ Orth.Spell Winter	.078 (ns)
Orth.Read Spring ↔ Orth.Spell Spring	.025 (ns)
Orth.Read Fall → Orth. Read Winter	.815*
Orth.Read Winter → Orth. Read Spring	.707*
Orth.Spell Fall → Orth. Spell Winter	.605*
Orth.Spell Winter → Orth.Spell Spring	.687*

Table 28
Path coefficients for third grade struggling reader model

Path	**Parameter Estimate**
Orth.Read Fall → Orth.Spell Winter	.071 (ns)
Orth.Spell Fall → Orth.Read Winter	.063 (ns)
Orth.Read Winter → Orth.Spell Spring	.048 (ns)
Orth.Spell Winter → Orth.Read Spring	.031 (ns)
Orth.Read Winter ↔ Orth.Spell Winter	.037 (ns)
Orth.Read Spring ↔ Orth.Spell Spring	.035 (ns)
Orth.Read Fall → Orth. Read Winter	.762*
Orth.Read Winter → Orth. Read Spring	.686*
Orth.Spell Fall → Orth. Spell Winter	.565*
Orth.Spell Winter → Orth.Spell Spring	.600*

Figures

Figure 1. First grade alphabetic model with covariates (typical sample)

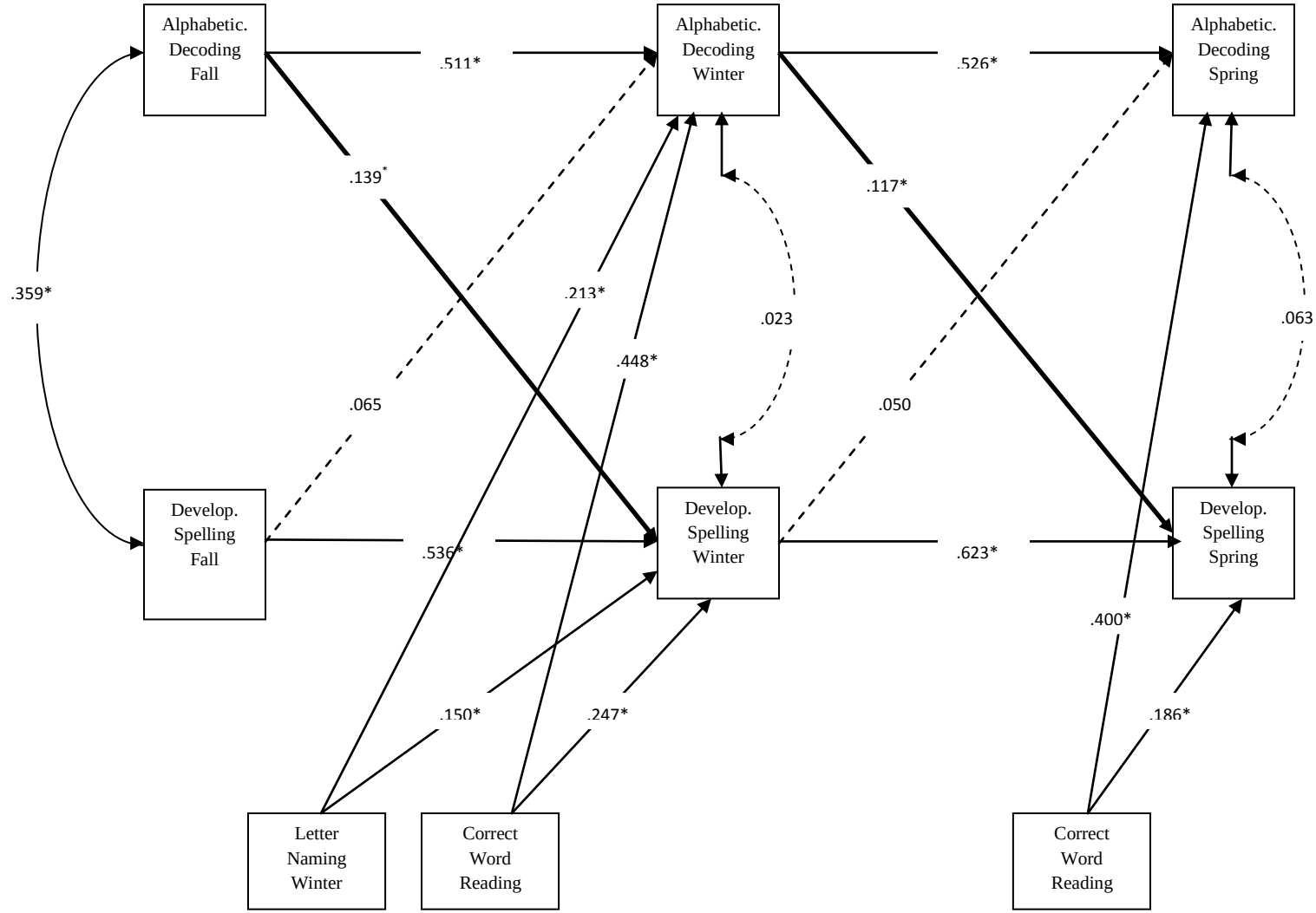


Figure 2. First grade alphabetic model with covariates (struggling reader sample)

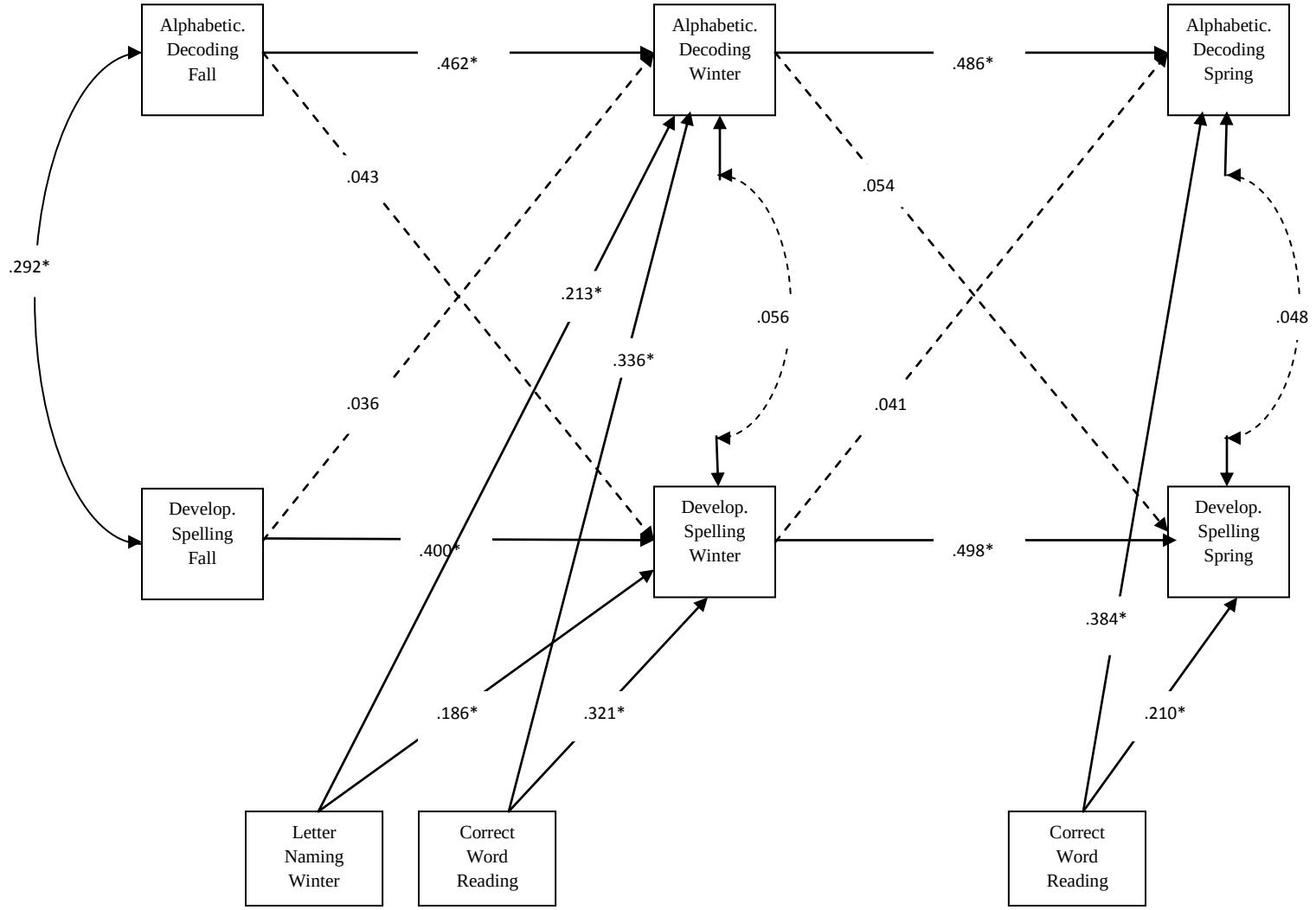


Figure 3. First grade conventional knowledge model with covariates (typical sample)

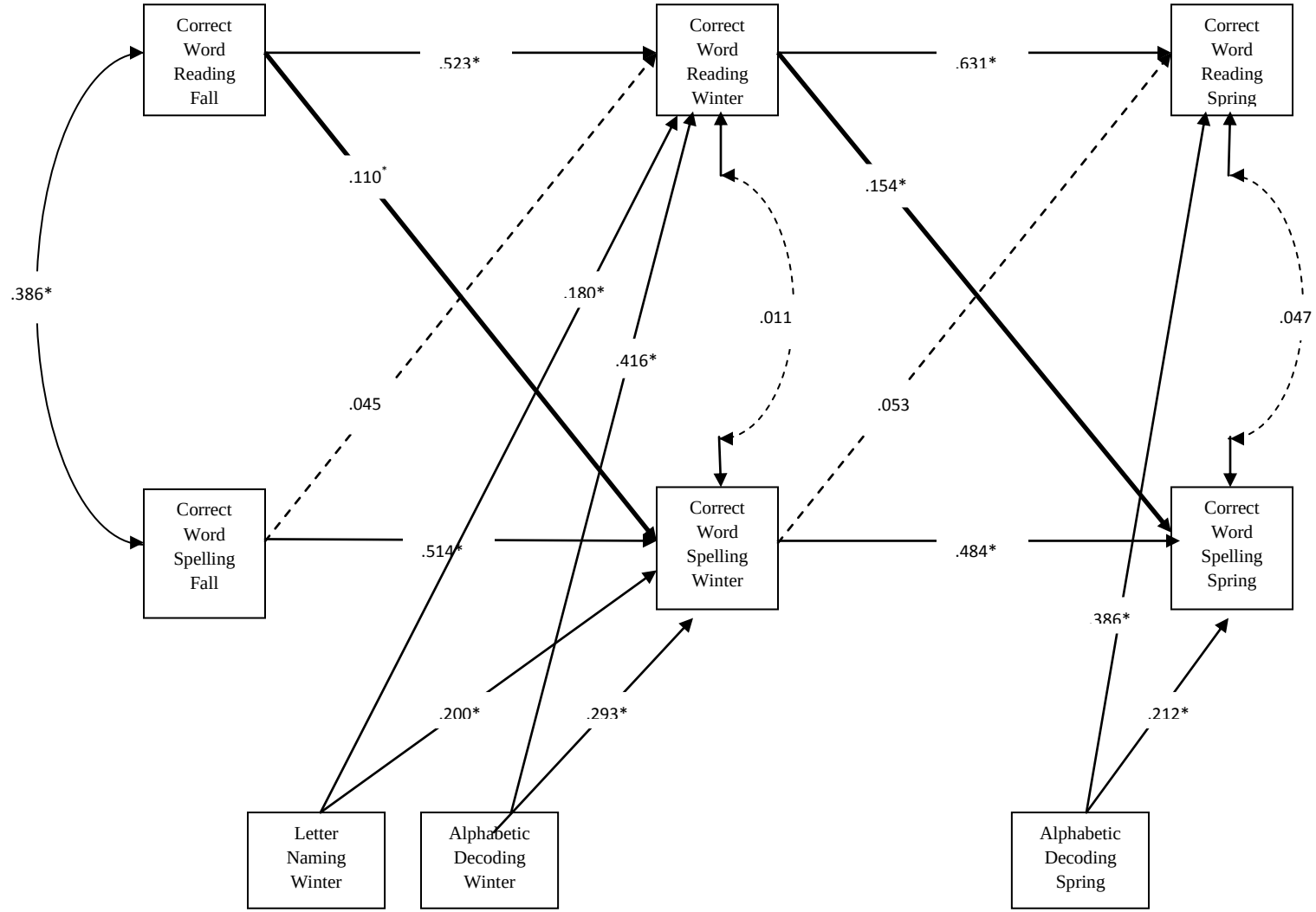


Figure 4. First grade conventional knowledge model with covariates (struggling reader sample)

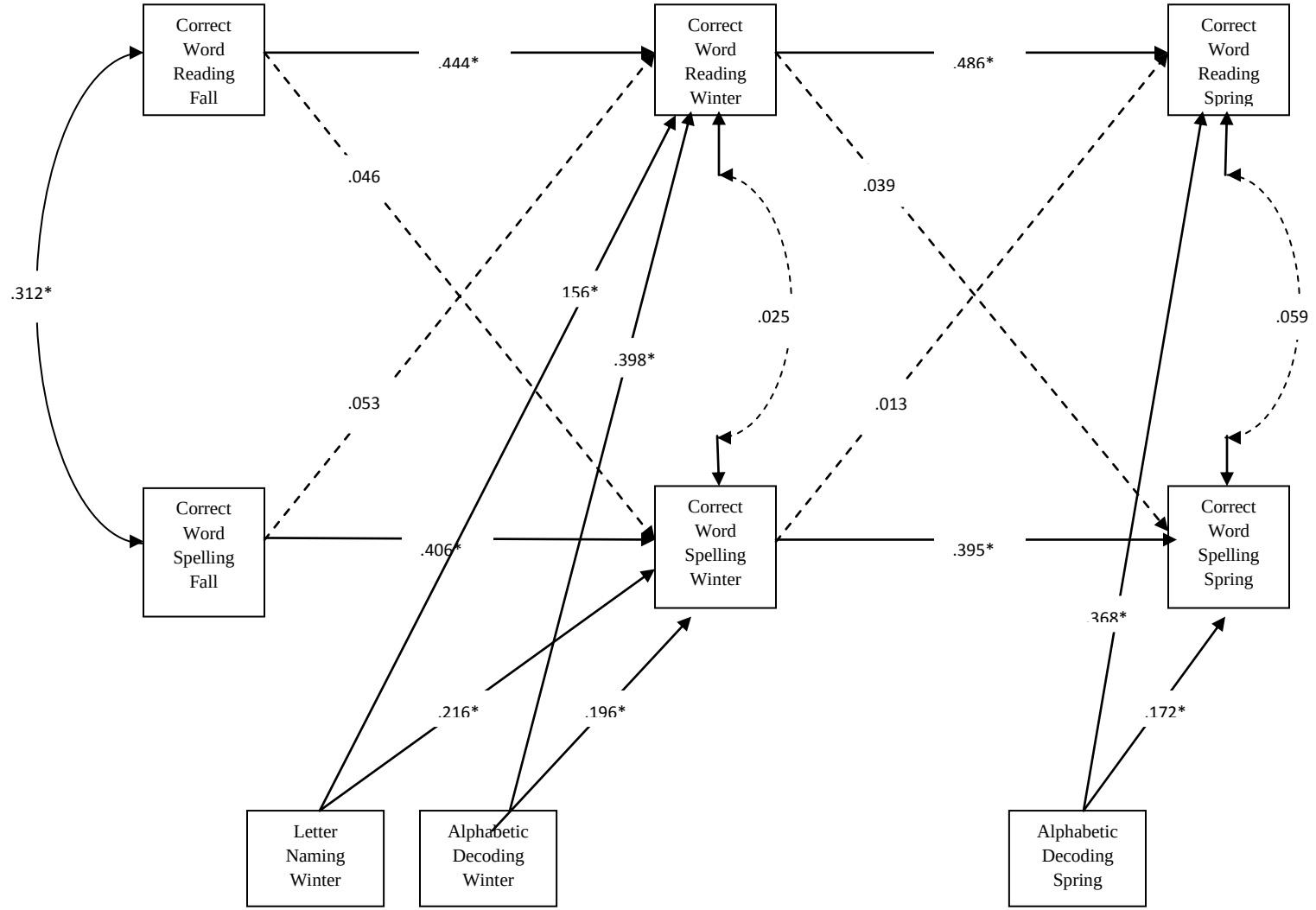


Figure 5. Third grade orthographic model (typical sample)

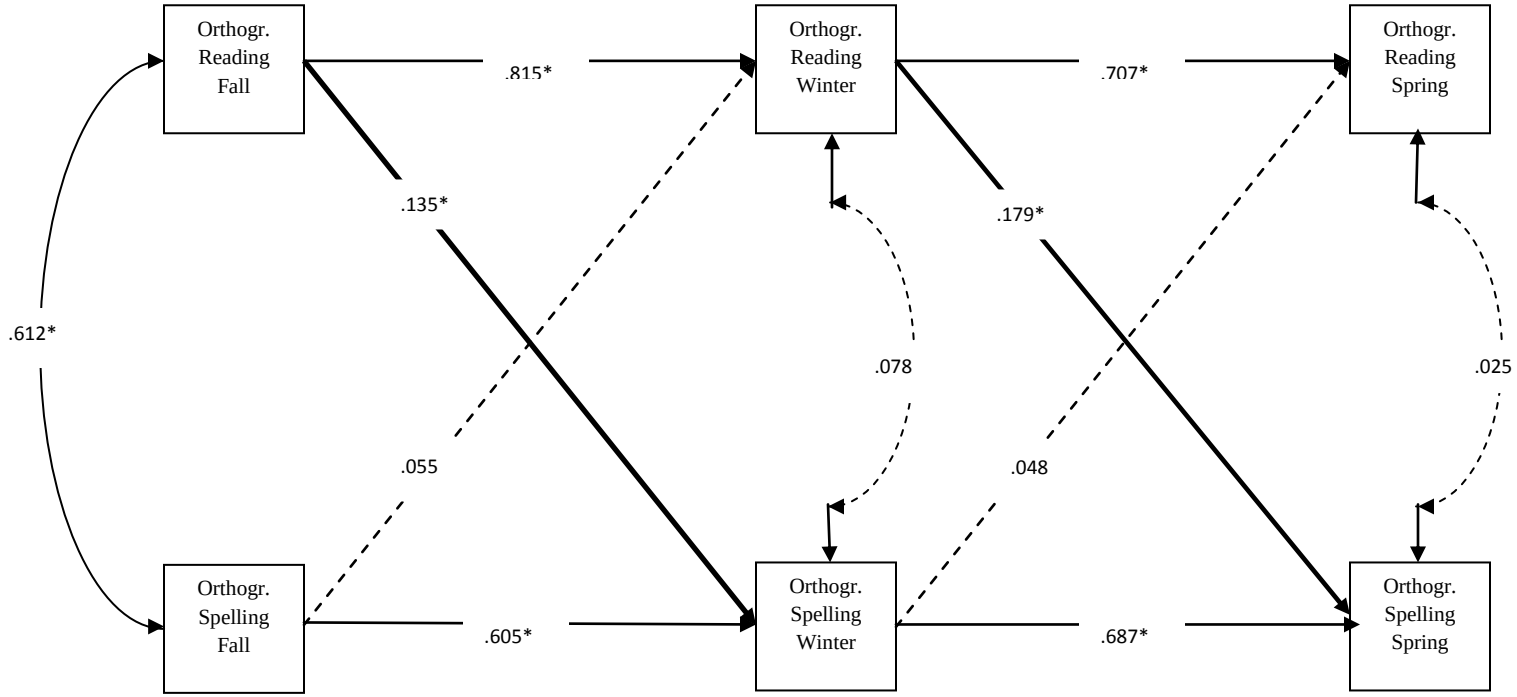
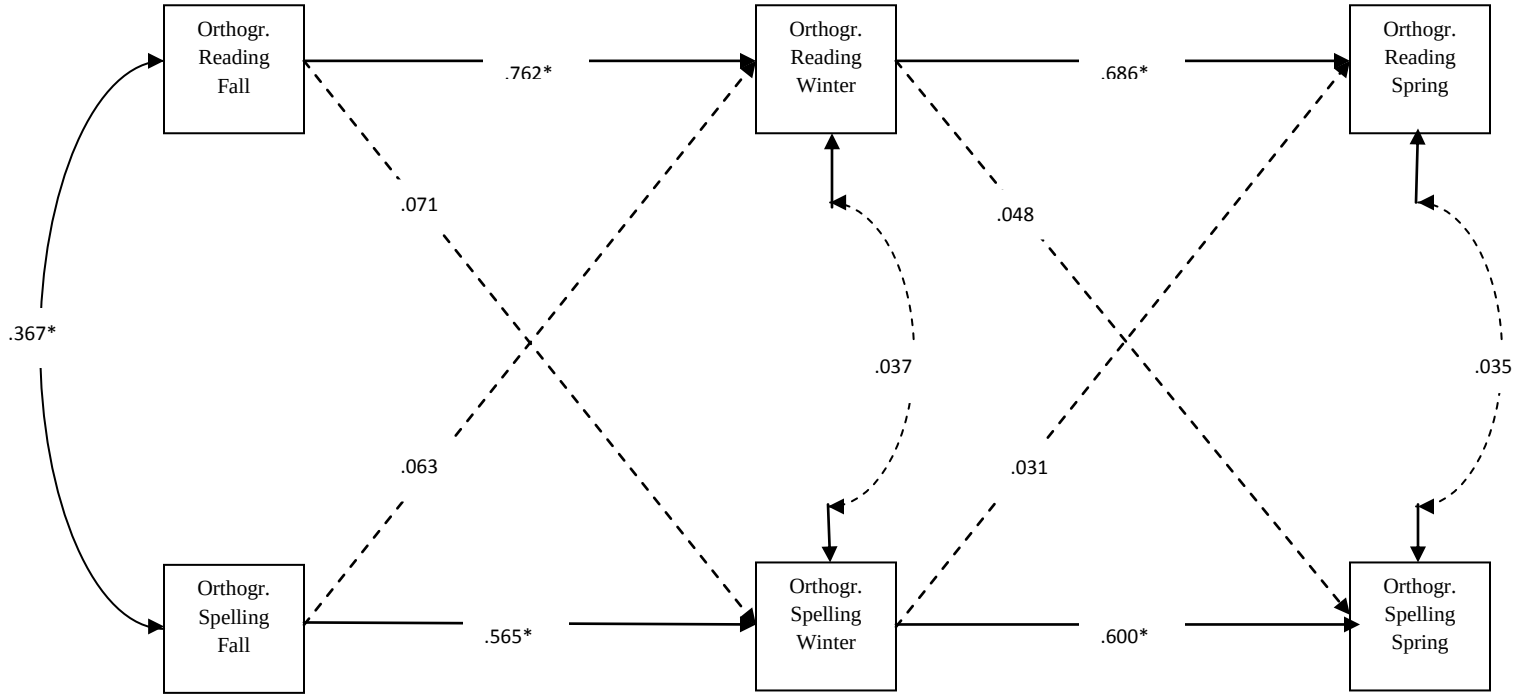



Figure 6. Third grade orthographic model (struggling reader sample)