CONTRIBUTION OF LINGUISTIC KNOWLEDGE TO SPELLING PERFORMANCE IN

CHILDREN WITH AND WITHOUT LANGUAGE IMPAIRMENT

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CHAPTER I

GENERAL INTRODUCTION

More than 40 years of research has confirmed the linguistic basis of literacy (e.g., Catts, Fey, Tomblin, & Zhang, 2002; Mattingly, 1972; Stahl & Murray, 1994; Treiman, Cassar, & Zukowski, 1994). Literacy encompasses reading as well as writing, both of which can be divided into word-level components (word decoding and spelling, respectively) and text-level components (comprehension and written expression, respectively). Studies that have examined the contribution of language skill to literacy have focused almost exclusively on reading skill with much less systematic focus on spelling (e.g., Catts et al., 2002). Proficiency in word decoding does not ensure proficiency in spelling, and instruction focused solely on reading is not an effective means to establish spelling proficiency (Bosman, 1997). Indeed, there are children who are poor spellers but good readers (e.g., Frith, 1980). To fully understand literacy skill, there is a need to investigate the linguistic basis of spelling separately from the linguistic basis of reading.

The purpose of spelling instruction is to store in long-term memory a large number of word spellings that can be quickly accessed in the process of writing. Our interest in spelling as a developmental skill is determining the knowledge bases that are drawn upon to attain written word spellings. Analyzing adults' spelling points to visual memory as the key factor in spelling words, and traditional spelling instruction has closely followed this belief. However, analysis of children's spellings in the preschool

and elementary years points to other types of knowledge, chiefly linguistic knowledge, as major contributors to spelling development.

Historical View of Spelling Development

Spelling historically has been viewed more as an academic subject than a linguistic skill (e.g., Perfetti, 1997). As a result, spelling has long been considered a skill to be taught rather than a developmental skill that is rooted in a child's linguistic abilities. A similar view historically was held for reading; children simply must be taught to recognize the visual pattern of whole words (e.g., Huey, 1901). However, careful research on the process of reading acquisition has shifted the way reading development is approached. Now reading widely is considered a linguistic skill (e.g., Catts, Fey, Zhang, & Tomblin, 1999). The reading shift has had some influence on spelling research, and there have been some studies of the linguistic basis of spelling (e.g., Bourassa & Treiman, 2001) but the influence has not been widespread. Research on the linguistic basis of spelling has been very piecemeal, and multiple areas of linguistic knowledge rarely have been studied concurrently. Thus, a systematic, concurrent evaluation of the areas of linguistic knowledge that predict spelling is needed if methods of instruction and intervention are to be optimized.

Spelling has long been considered a skill that primarily relies on visual memory. Visual memory is thought to play a major role in learning to spell because the English spelling system is complex (i.e., there is not a one-to-one phoneme-to-grapheme correspondence). In this view, words are added one at a time to the spelling lexicon through memorization, as opposed to added systematically via the understanding that

linguistic features of word spellings can inform the spelling of other words (see Schlagal, 2002 for a historical account of classroom spelling instruction).

Visual memory is indeed related to spelling for children. Bradley and Bryant (1981) reported a high correlation (.67) between visual memory and spelling for six- to eight-year-old typical readers. Hilte and Reitsma (2006) found that third graders are more proficient at spelling words they have studied visually (52.8% correct) than words they have only heard during instruction (44.2% correct).

However, several areas of investigation support the conclusion that spelling proficiency depends in part on visual memory but that visual memory alone does not adequately explain the development of spelling proficiency. These investigations provide evidence that linguistic abilities also influence spelling from the outset of learning to read and write. Preliterate children who have little experience with print (and thus little visual memory of words) demonstrate the ability to produce phonetically plausible spellings of words (Read, 1971, 1986). In addition, visual memory deficits do not appear to characterize poor spellers. Adults who are good readers but poor spellers do not have impaired visual memory compared to adults who are good readers and good spellers (Holmes, Malone, & Redenbach, 2008). Finally, individual differences in spelling ability are not attributable to differences in visual memory (for a review, see Kamhi & Hinton, 2000).

Stage Theories of Spelling Development

Several researchers have posited stage theories of spelling development (e.g., Henderson, Gentry, Ehri). These theories propose that as children develop spelling

proficiency, they progress through stages of approaches to spelling words. Moats (1995) proposed the following stages, based largely on the work of Ehri and Gentry. In the initial stage, children know that letters are used in written language but do not yet understand that letters represent sounds. Thus, random letters are used to represent words or ideas (e.g., JK for *butter*; precommunicative writing; preschool). As children come to understand the alphabetic principle (i.e., that letters represent the sounds of spoken language), their spellings begin to reflect the phonological properties of words; however, children's incomplete analysis of sounds in words leads to spellings that represent only some of the sounds in a word (e.g., BR for *butter*; semiphonetic spelling; preschool). As children more fully develop the ability to analyze sounds in words, their spellings begin to represent consistently all sounds of words (e.g., BUTR for *butter*; phonetic spelling; preschool to early elementary school). Next, children's spellings suggest that they are learning that letter-sound correspondence is not always one-to-one but instead that an individual sound might be represented with more than one letter (e.g., BUTTR for *butter*; transitional spelling; elementary school). Finally, over a protracted period of time children more fully understand that spellings integrate phonology, meaning, and orthography (e.g., BUTTER for *butter*; morphophonemic spelling; elementary school and later). Importantly, children's progression through the stages of spelling development is not discrete; there is overlap across the stages. Even proficient adult spellers revert back to previous stages when encoding words for which they do not have mental grapheme representations (MGRs).

Role of Linguistic Knowledge in Spelling Development

Because spelling involves encoding linguistic units of spoken language (i.e., phonemes, morphemes, and words) into written language, recent research has investigated the role that linguistic knowledge plays in English spelling performance (e.g., Apel, Fowler-Wilson, Brimo, & Perrin, 2012; Silliman, Bahr, & Peters, 2006). English is an alphabetic writing system with deep orthography. Spellings in deep orthographies often reflect morphology and morphophonology at the expense of surface phonology (Venezky, 1999). For example, a focus on surface phonology would lead to spelling "buses" as "busiz;" the conventional spelling preserves the morphological plural marker. The complex relationship between speech and print in deep orthographies is hypothesized to make learning to spell in deep orthographies (e.g., English, Danish) more difficult than in languages with more transparent grapheme-phoneme correspondence (e.g., Italian, Icelandic; Juul & Sigurdsson, 2005).

Stage theories of spelling development hypothesize that a person's ability to spell individual words relies on their understanding of the relation between spoken and written language. Specifically, spelling performance is dependent on a person's phonological and morphological knowledge as well as knowledge of how orthography represents these features (i.e., how knowledge of phonology, morphology, and orthography contribute to forming MGRs for individual words). Despite a continued focus on memorization in the teaching of spelling, there is evidence that children in second to fourth grade recognize that a link exists between spoken and written language and attempt to represent various linguistic properties of words in their spellings (see below for a detailed discussion). Researchers have begun to explore the

role of linguistic knowledge in spelling, but most studies have addressed only one area of linguistic knowledge. Two studies have explored the relation of linguistic knowledge to spelling more broadly. Consistent with stage theories of spelling development, the roles of phonological processing, morphological knowledge, and orthographic knowledge have been the focus in most studies of the development of English spelling (Bourassa & Treiman, 2001). With few exceptions (e.g., Apel et al., 2012; Walker & Hauerwas, 2006), most studies of the linguistic basis of English spelling have evaluated the role that each type of linguistic knowledge plays in isolation. The roles that phonological processing, morphological knowledge, and orthographic knowledge individually play in spelling are discussed below.

Phonological Processing

Most commonly, research on the linguistic basis of English spelling has focused on the role of phonological processing (e.g., Read, 1986; Treiman, 1991). Phonological processing is defined as the use of one's knowledge of the sounds of language to process spoken and written language (Wagner & Torgesen, 1987). Phonological processing is comprised of three interrelated but separate components: phonological awareness, phonological memory, and rapid naming (Wagner & Torgesen, 1987, but see Wolf & Bowers, 1999 for an alternate view; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993).

Phonological awareness. Because English has an alphabetic writing system, phonological awareness, the ability to analyze the sounds of spoken language (Mattingly, 1972), has long been considered one important precursor of spelling ability

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(e.g., Read, 1971). Before children are able to assign graphemes to the phonemes that comprise words, they must be able to analyze and isolate the phonemes in spoken words. Having done so, they can then assign a letter (or multiple letters) to represent each sound. Phonological awareness appears to guide young children's spelling early in spelling development (Read, 1971), even before children begin formal spelling instruction.

Correlational studies support the hypothesis that proficiency at analysis of the sound structure of language relates to spelling proficiency. For example, Stahl and Murray (1994) reported a correlation of .63 between phonological awareness and spelling for kindergarten and first grade students. Also, children who scored above criterion on onset-rime awareness were better spellers than children who performed below criterion. Bradley and Bryant (1983) reported that performance on an odd-one-out phonological awareness task at age four correlated .48 with spelling at age seven and accounted for 8% of the variance in spelling performance, after controlling for intelligence, memory, and vocabulary.

Additional support for the role of phonological awareness in spelling comes from the analysis of children's early writing attempts prior to formal spelling instruction. From the invented spelling of preschoolers, Read (1986) concluded that the earliest spelling attempts largely reflect the phonological properties of words rather than conventional English spelling, which relies on morphology and orthographic constraints in addition to sound structure (Read, 1986; Treiman, 1993). One particularly salient example of this characteristic of young children's spelling is the spelling of words with initial s-blends. Voiceless stops /p/, /t/, and /k/ that occur after /s/ (i.e., *spit, stop, skate*) are unaspirated,

making them sound similar to their voiced counterparts /b/, /d/, and /g/ (Reeds & Wang, 1961). Preschool and early elementary children are more likely to represent voiceless stops based on sound structure than conventional spelling (e.g., sdop for *stop*; sgat for *skate*; Hannam, Fraser, & Byrne, 2006).

Phonological memory. Phonological memory refers to the element of working memory that stores speech-based information (Baddeley & Hitch, 1994). Investigations that have explored the role of phonological memory in spelling proficiency have yielded somewhat mixed findings. Kroese, Hynd, Knight, Hiemenz, and Hall (2000) reported that for 8- to 12-year-old children, phonological memory was correlated with spelling (.53) and was a significant predictor of the variance in spelling, when considered concurrently with phonological awareness. Other studies have cast doubt on the status of phonological memory as a unique predictor of spelling. Savage et al. (2005) reported that for 7- to 10-year-old children, although phonological memory was significantly correlated with spelling (.28), it was not a unique contributor to the variance in spelling after accounting for the influence of phonological awareness (r = .21-.68) and nonword reading (r = .72). Similarly, Plaza and Cohen (2003) reported that for French-speaking first grade children, phonological memory was correlated significantly with spelling (.34) but was not a unique contributor to the variance in spelling after accounting for the influences of syntactic awareness (r = .52), phonological awareness (r = .80), and rapid automatized naming (r = .35-.53). Thus, the extant literature supports the relation of phonological memory and spelling but suggests that phonological memory does not account for unique variance in spelling but instead may influence spelling indirectly through other linguistic skills (e.g., phonological awareness).

Rapid automatized naming. The third component of phonological processing is the efficiency with which an individual can retrieve phonological codes from long-term memory (Wagner et al., 1993). Phonological recoding is most frequently measured using tasks of rapid automatized naming (RAN), the ability to name rapidly visual symbols such as objects, colors, numbers, or letters. This component of phonological processing is often referred to simply as RAN. Similar to phonological processing and phonological memory, RAN is correlated with spelling skill (.53; Swanson, Trainin, Necoechea, & Hammill, 2003). Swanson et al. (2003) included both alphanumeric and nonalphanumeric RAN in their RAN variable for analysis. However, differences in the relation of spelling and RAN may exist depending on the type of stimuli used in the naming task. For example, in a study of 7- to 13-year-old children, alphanumeric RAN (i.e., RAN of letters and numbers) was positively correlated to spelling ability and accounted for 8 to 10% of unique variance in spelling. Conversely, nonalphanumeric RAN (i.e., rapid naming of colors and objects) was a weak correlate of spelling performance and did not account for a significant amount of variance in spelling (Savage, Pillay, & Melidona, 2008). RAN, particularly naming letters and numbers, appears to be an important contributor to spelling in children.

In summary, phonological awareness, as well as RAN, contributes unique variance to spelling proficiency, whereas phonological memory although related to spelling does not contribute unique variance after accounting for other linguistic skills. Phonological awareness seems particularly important in young children's early spelling attempts. The influence of RAN is mediated by the type of naming task, with only alphanumeric naming being a unique predictor of spelling. Phonological awareness and

RAN may be the driving components of phonological processing in the influence on spelling; however, the influence of phonological processing on spelling rarely has been studied concurrently with other types of linguistic knowledge (e.g., Kroese et al., 2000; Savage et al., 2005). Even within phonological processing, the three components rarely have been studied concurrently.

Morphological Knowledge

Because written English is a deep orthography that often reflects morphological structure at the expense of surface phonology, phonological processing alone cannot explain spelling proficiency. To be proficient spellers, children must recognize that word spellings reflect morphological structure as well as phonological structure. Morphology refers to the study of word structure, or morphemes (Crystal, 2005). Morphemes are the smallest units of language that convey meaning.

There is indeed evidence that children's knowledge of the morphological structure of words influences their spellings, even at the earliest stages of writing. For example, if children use a purely phonological strategy to spell words, misspellings of alveolar flaps should be equally prevalent in words with one morpheme (e.g., *city*) and words with two morphemes (e.g., *dirty*). However, as early as kindergarten children are less likely to misspell alveolar flaps in words with two morphemes (e.g., *dirty, bloody*) than alveolar flaps in words with one morpheme (e.g., city, spider; Treiman et al., 1994). The case of final consonant blends provides additional evidence that children use morphological knowledge to spell words. Again, if children use a purely phonological strategy to spell words, misspellings of final blends should be equally prevalent in words

with one morpheme (e.g., *band*) and words with two morphemes (e.g., *canned*).

However, first and second grade children were more likely to represent both phonemes

of final consonant blends when the blend represented two morphemes (e.g., *canned*)

than when the blend represented one morpheme (e.g., band; Treiman & Cassar, 1996).

Thus, from the earliest stages of writing, children's spellings convey that they are

sensitive to morphological as well as phonological characteristics of words.

Few studies have examined the contribution of morphological knowledge to

spelling in elementary school children. Preliminary evidence from French spelling

suggests that morphological knowledge contributes unique variance, along with

phonological awareness and RAN, to spelling for second graders (Plaza & Cohen,

2004). For English spellers, Nagy, Berninger, and Abbott (2006) reported that

morphological knowledge and spelling were correlated in fourth and fifth graders (r =

.66) and that morphological knowledge contributed unique variance beyond

phonological memory and nonword decoding (Z = 2.77).

Orthographic Knowledge

Orthographic knowledge is the understanding of how spoken words are

represented in print in a written language system (for a tutorial, see Apel, 2011). There

are two components of orthographic knowledge: (a) stored mental grapheme

representations (MGRs) and (b) orthographic pattern knowledge.

Stored MGRs. One component of orthographic knowledge is stored MGRs of

single words. An MGR is the mental representation of the string of letters of a

conventionally spelled word (Apel, 2011). Also referred to in the literature as

orthographic images (e.g., Ehri & Wilce, 1982) and in lay terms as memorization of word spellings, fully-formed MGRs allow for fluent spelling of words. When an individual has a fully-formed MGR for a word, he or she is able to fluently access the specific string of letters that comprises that written word and does not need to use other types of linguistic knowledge (e.g., phonological or morphological) to create a word spelling (Wolter & Apel, 2010). Wolter and Apel reported that kindergarten children's ability to rapidly store an MGR (or partial MGR) for a word was related to spelling (r = .64).

Orthographic pattern knowledge. Another component of orthographic knowledge is orthographic pattern knowledge. Whereas MGRs are word-specific representations, orthographic pattern knowledge refers to knowledge of language-specific patterns for representing phonology and morphology in written words. The first step in developing orthographic pattern knowledge is relating letters to speech sounds, or alphabetic knowledge. Letter-sound knowledge is one of the strongest predictors of kindergarten children's spelling (r = .76) and along with phonological awareness, accounted for 68% of variance in spelling (Caravolas, Hulme, & Snowling, 2001). Beyond alphabetic knowledge, knowledge of more complex orthographic patterns is required to master the English spelling system. Children necessarily must begin to understand, for example, that single phonemes can be represented by multiple letters (e.g., "sh" for /ʃ/), multiple phonemes can be represented by a single letter (e.g., "x" for /ks/), and vowel sounds are represented with different letters depending on context (e.g., *day* versus *bait*).

With increased print exposure, children develop deeper understanding of orthographic patterns. For example, in English /k/ can be represented in many ways,

including CK; however, CK cannot represent /k/ at the beginning of words. As early as the first semester of first grade, children's spellings demonstrate emerging knowledge of orthographic patterns in addition to phonology (e.g., using consonant doublets at the end but not beginning of words; Treiman, 1993). Children who are poor spellers demonstrate less knowledge of orthographic patterns than children who are good spellers (Schwartz & Doehring, 1977).

In summary, clearly three types of linguistic knowledge—phonological processing, morphological knowledge, and orthographic knowledge—in addition to visual memory predict children's ability to gain proficiency in spelling English words. A major limitation of the extant knowledge base is that the three types of linguistic knowledge rarely have been studied concurrently within the same sample of children.

Concurrent Study of Areas of Linguistic Knowledge

Two previous studies have attempted to advance the knowledge base by addressing the shortcoming of studying types of linguistic knowledge in isolation (Apel et al., 2012; Walker & Hauerwas, 2006); in these studies the contribution of several aspects of linguistic knowledge to spelling was considered. The results of these investigations are summarized next and methodological weaknesses that limit the inferences that can be drawn are brought to light.

Walker and Hauerwas (2006) evaluated the influence of phonological awareness, morphological knowledge, and orthographic knowledge on the spelling of inflected verb endings in first, second, and third grade. First graders' performance was predicted by phonological awareness and orthographic knowledge, second graders' performance

was predicted by orthographic and morphological knowledge, and third graders' performance was predicted primarily by morphological knowledge. These findings are limited in what they can mean for spelling in general. First, a very narrow scope of spelling was evaluated and there is no basis on which to suggest these findings are meaningful to the entirety of spelling. Second, the scoring system for spellings of the inflected endings did not measure conventional spelling but rather phonological representation. Third, Walker and Hauerwas did not control for visual memory.

Apel et al. (2012) evaluated the influence of phonological awareness, morphological knowledge, and orthographic knowledge on the whole word spelling performance of second and third graders. Only morphological knowledge was a unique predictor of spelling. Several limitations argue against concluding a non-unique role for phonological awareness and orthographic knowledge. First, Apel et al.'s morphological knowledge measure required written responses, leading to concern that this measure tapped orthographic knowledge as well as morphological knowledge. Not surprisingly, this measure of morphological spelling knowledge was very highly correlated with the spelling outcome measure ($r = .75$). Using the spelling of morphology as a linguistic predictor, rather than a spoken morphological knowledge task is a critical flaw of the Apel et al. study. Second, also similar to Walker and Hauerwas, Apel et al. did not control for visual memory.

In summary, linguistic knowledge predicts children's spelling of English words. The extant literature points to the importance of three areas of language in learning to spell in the elementary grades: phonological processing, morphological knowledge, and orthographic knowledge. However, the two studies that have evaluated concurrently the

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influence of all three types of linguistic knowledge on spelling performance have methodological limitations that limit the conclusions that can be drawn. To fully understand the role of language in spelling proficiency, a systematic evaluation of the concurrent effects of phonological processing, morphological knowledge, and orthographic knowledge on spelling is needed.

Spelling of Children with Specific Language Impairment

Although research demonstrates that literacy outcomes for children with specific language impairment (SLI) are compromised (e.g., Catts et al., 2002), the knowledge base for reading outcomes is far more extensive than that of writing outcomes. Because spelling is a skill dependent on an individual's linguistic knowledge and children with SLI by definition have compromised linguistic abilities, they are expected to exhibit spelling difficulties. Indeed, multiple studies have reported that children with SLI score lower on measures of spelling than children with typical language (Bishop & Adams, 1990; Cordewener, Bosman, & Verhoeven, 2012; Young et al., 2002). However, there is a paucity of information that explains group differences in spelling outcomes.

Young et al. (2002) concluded that the relation between phonological processing and spelling in 18- to 19-year-old adolescents with SLI does not parallel the relation in typical children. Specifically, only phonological awareness contributed to the spelling performance of adolescents with SLI, whereas phonological awareness, phonological memory, and RAN contributed to the spelling performance of adolescents with typical language. Interestingly, performance on the RAN task (digit naming) was similar for the two groups. Thus, even when adolescents with SLI have rapid naming skills equivalent

to peers with typical language, performance on RAN tasks does not predict spelling. In addition to differences in phonological processing, Wolter and Apel (2010) reported that kindergarten children with SLI acquired less mental grapheme representation information in an orthographic fast mapping task than kindergarten children with typical language. They suggested that this difference in orthographic knowledge contributes in part to the spelling difficulties of children with SLI. Thus, Young et al. and Wolter and Apel provide preliminary evidence that the linguistic knowledge that predicts spelling in individuals with SLI in spelling may differ from the linguistic knowledge that predicts spelling in individuals with typical language.

Mackie and Dockrell (2004) concluded that deficits in both phonological awareness and orthographic knowledge contribute to spelling errors of 9- to 12-year-old children with SLI. Children with SLI exhibited proportionately more phonologically inaccurate (i.e., spellings that were not possible phoneme-to-grapheme correspondences in English) and orthographically inaccurate (i.e., spellings that contained an illegal sequence of letters in English) spellings than both age-matched and language-matched children with typical language. In a study of 6- to 11-year-old children, Silliman (2006) reported that spelling errors of children with typical language were most frequently orthographic errors. In contrast, children with SLI exhibited diffuse difficulty with spelling, with errors equally distributed across phonological, morphological, and orthographic categories. Analysis of the types of spelling errors also provided preliminary evidence that children with SLI use linguistic knowledge to spell words differently than children with typical language (Silliman, 2006).

In summary, the small body of research characterizing the spelling difficulties of children with SLI provides motivation for further systematic exploration. Children with SLI exhibit more spelling errors than children with normal language (i.e., their ability to spell words correctly is impaired). In addition, at least some language and cognitive abilities predict spelling differently for children with SLI than children with typical language. Finally, spelling errors of children with specific SLI differ in nature from errors made by typically developing children.

Conclusions

Extant literature provides evidence that the development of spelling proficiency is predicted by phonological processing, morphological knowledge, and orthographic knowledge in addition to visual memory. However, the literature does not provide a clear picture of how these areas of linguistic knowledge predict spelling when considered concurrently. The weight of prediction for each area of linguistic knowledge likely changes across development. In addition, the spelling of children with SLI differs from spelling of children with typical language both quantitatively (i.e., number of spelling errors) and qualitatively (i.e., types of spelling errors). Evidence from multiple investigations suggests that these differences arise from differences in linguistic knowledge. The next step in this line of inquiry is to consider concurrently the contribution of phonological processing, morphological knowledge, and orthographic knowledge to spelling in children with typical language (Study 1) and to compare the linguistic predictors of spelling for children with typical language to linguistic predictors of spelling for children with SLI (Study 2).

CHAPTER II

STUDY 1: LINGUISTIC CONTRIBUTIONS TO SPELLING IN

ELEMENTARY SCHOOL CHILDREN

Abstract

Historically, spelling has been considered an academic skill that relies primarily on visual memory. Recent research indicates that spelling skill is also dependent on linguistic knowledge. However, the contribution of linguistic knowledge to spelling skill is not well understood. The purpose of this investigation was to explore systematically the relation of phonological processing, morphological knowledge, and orthographic knowledge to spelling performance independent of visual memory in elementary school children. After controlling for age, nonverbal intelligence, articulation, and visual memory, orthographic knowledge and morphological knowledge contributed unique variance to children's spelling performance. Linguistic knowledge influences spelling in elementary school children, and instruction and intervention practices should reflect this finding.

Introduction

Although research over the past 40 years has confirmed definitively the linguistic basis of reading (e.g.,Catts et al., 2002), much less research has focused on elucidating the linguistic basis of spelling. Reading and spelling depend on many of the same linguistic skills (e.g., phonological awareness, morphological knowledge; Ehri, 2000).

However, because proficiency in reading does not ensure proficiency in spelling (Bosman, 1997), spelling must rely on at least some linguistic skills that differ from those used for reading or, alternatively, the same processes as those used for reading, but different levels of proficiency. Thus, there is a need to explore the linguistic basis of spelling separately from the linguistic basis of reading. The purpose of this investigation was to evaluate the relative contribution of three types of linguistic knowledge— phonological processing, morphological knowledge, and orthographic knowledge—to spelling performance in second to fourth grade elementary school children.

Historical View of Spelling as a Visual Skill

Historically, spelling has been considered an academic skill that relies primarily on visual memory, and spelling instruction largely reflects this belief (Schlagal, 2002). Traditional spelling instruction involves the presentation of a list of words on Monday, practice and memorization throughout the week, and a spelling test on Friday. This manner of instruction presumes that words are added to the spelling lexicon one at a time with limited teaching about how the spelling of some words can inform the spelling of other words (Bear, Invernizzi, Templeton, & Johnston, 2011).

Visual memory is indeed important for spelling. Spelling is highly correlated with visual memory in the elementary grades (Bradley & Bryant, 1981), and elementary school children are more proficient at spelling words that they have seen during instruction than words they have only heard (Hilte & Reitsma, 2006). However, it is also clear that visual memory alone cannot account for the entirety of an individual's spelling skill. Preliterate children produce phonetically plausible spellings of words with which

they have little or no visual experience (Read, 1971), and visual memory deficits do not characterize poor spellers (Holmes et al., 2008; Kamhi & Hinton, 2000). Thus, visual memory plays a role in spelling performance but cannot adequately explain spelling on its own.

Spelling Development

Several theorists have posited stage theories of spelling development (e.g., Henderson, Gentry, Ehri). These theories propose that as children develop spelling proficiency, they progress through stages of approaches to spelling words. Moats (1995) proposed the following stages, based largely on the work of Ehri and Gentry. In the initial stage, children know that letters are used in written language but do not yet understand that letters represent sounds. Thus, random letters are used to represent words or ideas (e.g., JK for *butter*; precommunicative writing). As children come to understand the alphabetic principle (i.e., that letters represent the sounds of spoken language), their spellings begin to reflect the phonological properties of words; however, children's incomplete analysis of sounds in words leads to spellings that represent only some of the sounds in a word (e.g., BR for *butter*; semiphonetic spelling). As children more fully develop the ability to analyze sounds in words, their spellings begin to represent consistently all sounds of words (e.g., BUTR for *butter*; phonetic spelling). Next, children's spellings suggest that they are learning that letter-sound correspondence is not always one-to-one but instead that an individual sound might be represented with more than one letter (e.g., BUTTR for *butter*; transitional spelling). Finally, over a protracted period of time children more fully understand that spellings

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integrate phonology, meaning, and orthography (e.g., BUTTER for *butter*; morphophonemic spelling). Importantly, children's progression through the stages of spelling development is not discrete; there is overlap across the stages. Even proficient adult spellers revert back to previous stages when encoding words for which they do not have MGRs.

Linguistic Basis of Spelling

Spelling involves encoding units of spoken language into written language (orthography). In English, spellings often reflect morphology and morphophonology, as well as orthographic rules, at the expense of surface phonology (Venezky, 1999). For example, a focus solely on surface phonology would lead a child to spell *skipped* as SKIPT; the conventional spelling represents the morphological past tense marker and the orthographic consonant doubling rule.

Stage theories of spelling development hypothesize that an individual's ability to spell individual words relies on their understanding of the relation between spoken and written language. Specifically, spelling performance is dependent on an individual's phonological and morphological knowledge as well as knowledge of how orthography represents these features (i.e., how knowledge of phonology, morphology, and orthography contribute to forming MGRs for individual words). Despite a continued focus on memorization in the teaching of spelling, there is evidence that children in second to fourth grade recognize that a link exists between spoken and written language and attempt to represent various linguistic properties of words in their spellings (see below for a detailed discussion). Researchers have begun to explore the

role of linguistic knowledge in spelling, but most studies have addressed only one area of linguistic knowledge. Two studies have explored the relation of linguistic knowledge to spelling more broadly. Consistent with stage theories of spelling development, the roles of phonological processing, morphological knowledge, and orthographic knowledge have been the focus in most studies of the development of English spelling (Bourassa & Treiman, 2001). With few exceptions (e.g., Apel et al., 2012; Walker & Hauerwas, 2006), most studies of the linguistic basis of English spelling have evaluated the role that each type of linguistic knowledge plays in isolation. The roles that phonological processing, morphological knowledge, and orthographic knowledge play in spelling are discussed below.

Phonological processing. Of all types of linguistic knowledge, phonological processing has received perhaps the most attention with regard to spelling. Phonological processing is the use of one's knowledge of the sounds of language to process spoken language. It is comprised of phonological awareness, phonological memory, and rapid automatized naming (Wagner & Torgesen, 1987 but see Wolf & Bowers, 1999 for an alternate view). Within the three components of phonological processing, the relation of phonological awareness and spelling has been studied most.

Phonological awareness, the ability to analyze and manipulate the sounds of spoken language (Mattingly, 1972), appears to guide children's spelling early in development (i.e., from preschool; Read, 1986). Phonological awareness begins to develop in preschool and continues to develop across the elementary grades (Anthony & Lonigan, 2004; Berninger, Abbott, Nagy, & Carlisle, 2010). Before children experience formal spelling instruction, their early spelling attempts in preschool and early

elementary school primarily reflect phonological properties of words (e.g., SDOP for stop, CHRUK for truck; Read, 1986; Treiman, 1993). Indeed, Oullette and Senechal (2008) reported that phonological awareness explained over 40% of the unique variance of invented spelling of five-year-olds. As suggested by stage theories of spelling development, phonological awareness and spelling are moderately correlated in elementary school children (e.g., .63, Stahl & Murray, 1994 .48, Bradley & Bryant, 1983), and phonological awareness accounts for unique variance in the spelling performance of elementary school children (Savage et al., 2005). Berninger et al. (2010) reported that children's growth in phonological awareness decelerates after third grade, indicating that children master phonological awareness during elementary school. Perhaps this mastery allows more resources to be devoted to relating other types of linguistic knowledge to spelling.

In addition to phonological awareness, phonological memory, the component of working memory that stores speech-based information (Baddeley & Hitch, 1994), may play a role in spelling elementary school children's spelling performance. Phonological memory and spelling are moderately correlated in elementary school children (.53, Kroese et al., 2000); however, phonological memory is not a unique contributor to spelling skill after accounting for other linguistic skills (e.g., phonological awareness, syntactic awareness; Ouellette & Senechal, 2008; Savage et al., 2005). Berninger et al. (2010) posited that because words must be stored in working memory for children to analyze the component sounds, phonological memory may underlie phonological awareness development. Perhaps this explanation accounts for the lack of unique variance reported in the literature.

The third component of phonological processing is the efficiency with which an individual can retrieve phonological codes from long-term memory (Wagner et al., 1993). Phonological recoding is most frequently measured using tasks of rapid automatized naming (RAN), the rapid naming of visual symbols such as objects, colors, numbers, or letters. This component of phonological processing is often referred to simply as RAN. Similar to phonological processing and phonological memory, RAN is correlated with spelling skill (.50, measured by digit naming in a study of 3rd and 5th graders, Savage et al., 2005; .53 in a meta-analysis of all types of rapid naming that included 49 independent samples ranging in ages from 5 to 43, Swanson, Trainin, Necoechea, & Hammill, 2003). In a study of 7- to 13-year-old children, alphanumeric rapid automatized naming (i.e., rapid naming of letters and numbers) was positively correlated to spelling ability and accounted for 8 - 10% of unique variance in spelling, whereas nonalphanumeric (i.e., rapid naming of colors and objects) was a weak correlate of spelling performance and did not account for a significant amount of variance in spelling (Savage et al., 2008).

In summary, phonological awareness and alphanumeric RAN contribute unique variance to spelling performance in the elementary grades, and phonological memory is related to spelling but does not contribute unique variance after accounting for phonological awareness. Thus, it appears that phonological processing skills influence spelling; however, the influence of phonological processing on spelling rarely has been studied concurrently with other types of linguistic knowledge (e.g., morphological, orthographic knowledge). Consistent with stage theories of spelling development, the influence of phonological processing on spelling likely is strongest during the preschool

and early elementary years when children primarily represent phonology in word spellings.

Morphological knowledge. Because written English is a deep orthography in which spellings of individual words often reflect morphological structure at the expense of surface phonology, phonological processing ability alone is insufficient for proficient English spelling. To be proficient spellers, children must come to understand that word spellings (i.e., English orthography) reflect morphology as well as phonology. Morphology refers to the smallest units of language that convey meaning. Morphemes can be free (i.e., can stand alone; *spell*) or bound (i.e., cannot stand alone; *spelled*) and inflectional (i.e., creates different form of the same word to express grammatical features such as third person singular; *spells*) or derivational (i.e., creates new word; *speller*).

Children's morphological knowledge, the knowledge of morphological structure of words, influences their spellings, even in early stages of spelling development when phonological processing may have the strongest influence. Treiman, Cassar, and Zukowski (1994) illustrated the influence of morphological knowledge on children's spellings as early as kindergarten. If children used a purely phonological strategy to spell words, misspellings of alveolar flaps should be equally prevalent in words with one morpheme (e.g., *city*) and words with two morphemes (e.g., *dirty*). However, Treiman et al. found that as early as first grade, children were less likely to misspell alveolar flaps in words with two morphemes (e.g., *dirty*, *bloody*) than alveolar flaps in words with one morpheme (e.g., *city*, *spider*; $d = .78$ for /t/ flaps and .50 for /d/ flaps). The case of final consonant blends provides additional evidence that elementary school children use

morphological knowledge to spell words. Kindergarten children have particular difficulty

representing both phonemes of final consonant blends in words with one morpheme

(Werfel & Schuele, 2012). Again, if children used a purely phonological strategy to spell

words, misspellings of final blends should be equally prevalent in words with one

morpheme (e.g., *band*) as in words with two morphemes (e.g., *canned*). However,

Treiman and Cassar (1996) reported that first grade children were more likely to

represent both phonemes of final consonant blends when the blend represented two

morphemes (e.g., *canned*) than when the blend represented one morpheme (e.g., *band*;

d = .39).

Children continue to exhibit growth in morphological knowledge (e.g., derivational

morphology) beyond the elementary grades (Berninger et al., 2010). In a study of fourth

to sixth graders, Leong (2000) reported that spoken language derivational morphology

knowledge was related to spelling performance. Similarly, Apel, Fowler-Wilson, Brimo,

and Perrin (2012) measured second and third grade children's spelling of words with

derivational morphology and reported a very high correlation with spelling of general

words (i.e., not selected for any particular linguistic feature; r = .75). Throughout spelling

development, children appear to rely on morphological knowledge to spell, primarily

inflectional morphology early in spelling development and derivational morphology

beginning as early as second grade.

Orthographic knowledge. Orthographic knowledge, or the understanding of

how spoken words are represented in print in a written language system, also

influences children's spelling performance. There are two components of orthographic

knowledge: (a) stored mental grapheme representations (MGRs) and (b) orthographic

pattern knowledge (Apel, 2011). Research suggests that children simultaneously develop knowledge of orthographic patterns and mental grapheme representations, beginning as early as kindergarten (e.g., Apel, Wolter, & Masterson, 2006; Cassar & Treiman, 1997; Treiman, 1993; Wolter & Apel, 2010).

One component of orthographic knowledge is stored MGRs of single words. An MGR is the mental representation of the string of letters of a conventionally spelled word (Apel, 2011). Also referred to in the literature as orthographic images (e.g., Ehri & Wilce, 1982) and in lay terms as memorization of word spellings, fully-formed MGRs allow for fluent spelling of words. When an individual has a fully-formed MGR for a word, he or she is able to fluently access the specific string of letters that comprises that written word and does not need to use other types of linguistic knowledge (e.g., phonological or morphological) to create a word spelling (Wolter & Apel, 2010). Wolter and Apel (2010) reported that kindergarten children's ability to rapidly store an MGR (or partial MGR) for a word was related to spelling (r = .64).

Another component of orthographic knowledge is orthographic pattern knowledge. Whereas MGRs are word-specific representations, orthographic pattern knowledge refers to knowledge of language-specific patterns for representing phonology and morphology in written words. The first step in developing orthographic pattern knowledge is relating letters to speech sounds, or alphabetic knowledge. Letter-sound knowledge is one of the strongest predictors of kindergarten children's spelling (r = .76) and along with phonological awareness, accounted for 68% of variance in spelling (Caravolas et al., 2001). Beyond alphabetic knowledge, knowledge of more complex orthographic patterns is required to master the English spelling system.

Children necessarily must begin to understand, for example, that single phonemes can be represented by multiple letters (e.g., "sh" for /ʃ/), multiple phonemes can be represented by a single letter (e.g., "x" for /ks/), and vowel sounds are represented with different letters depending on context (e.g., *day* versus *bait*).

With increased print exposure, children develop deeper understanding of orthographic patterns. For example, in English /k/ can be represented in many ways, including CK; however, CK cannot represent /k/ at the beginning of words. As early as the first semester of first grade, children's spellings demonstrate emerging knowledge of orthographic patterns in addition to phonology (e.g., using consonant doublets at the end but not beginning of words; Treiman, 1993). Children who are poor spellers demonstrate less knowledge of orthographic patterns than children who are good spellers (Schwartz & Doehring, 1977).

In summary, clearly three types of linguistic knowledge—phonological processing, morphological knowledge, and orthographic knowledge—in addition to visual memory predict children's ability to gain proficiency in spelling English words. A major limitation of the extant knowledge base is that the three types of linguistic knowledge rarely have been studied concurrently within the same sample of children. Two previous studies have attempted to address the gap in the literature, but methodological limitations impede the extent to which the study findings contribute to the knowledge base of the relation of linguistic knowledge and spelling.

Concurrent Investigations of Linguistic Knowledge Prediction of Spelling

Walker and Hauerwas (2006) evaluated the influence of phonological awareness,

morphological knowledge, and orthographic knowledge on the ability of first, second, and third graders to represent inflected verb endings in writing. First graders' performance was predicted by phonological awareness and orthographic knowledge, second graders' performance was predicted by orthographic and morphological knowledge, and third graders' performance was predicted primarily by morphological knowledge. These findings are limited in what they can mean for spelling in general .First, a very narrow scope of spelling was evaluated and there is no basis on which to suggest these findings are meaningful to the entirety of spelling. Second, the scoring system for spellings of the inflected endings did not measure conventional spelling but rather phonological representation. Third, Walker and Haurwas did not control for visual memory.

Apel et al. (2012) evaluated the influence of phonological awareness, morphological knowledge, and orthographic knowledge on the whole word spelling performance of second and third graders. Only morphological knowledge was a unique predictor of spelling. Several limitations argue against concluding a non-unique role for phonological awareness and orthographic knowledge. First, Apel et al.'s morphological knowledge measure required written responses, leading to concern that this measure tapped orthographic knowledge as well as morphological knowledge Not surprisingly, this measure of morphological spelling knowledge was very highly correlated with the spelling outcome measure (r = .75). Using the spelling of morphology as a linguistic predictor (which measures orthographic knowledge in addition to morphological knowledge), rather than a spoken morphological knowledge task is a critical flaw of the Apel et al. study. Second, also similar to Walker and Hauerwas, Apel et al. did not

control for visual memory.

In summary, linguistic knowledge predicts children's spelling of English words. The extant literature points to the importance of three areas of language in learning to spell in the elementary grades: phonological processing, morphological knowledge, and orthographic knowledge. However, the two studies that have evaluated concurrently the influence of all three types of linguistic knowledge on spelling performance have methodological limitations that limit the conclusions that can be drawn.

To fully understand the role of language in spelling proficiency, a systematic evaluation of the concurrent influence of phonological processing, morphological knowledge, and orthographic knowledge on spelling is needed. The present investigation addressed this gap in the literature and differed from (a) Walker and Hauerwas (2006) and Apel et al. (2012) by controlling for visual memory, (b) Apel et al. by measuring morphological knowledge in spoken language, and (c) Walker and Hauerwas by measuring spelling performance of whole words, not word parts. The following research question was addressed: Do phonological processing, morphological knowledge, and/or orthographic knowledge uniquely predict spelling in elementary school children with typical language?

Method

Participants

Participants were 40 children in second (n = 16), third (n = 17), and fourth grades (n = 7; *M* age = 9;4, SD = 12 months) recruited from public and private elementary

schools in middle Tennessee. The children were recruited as part of a larger study on the contribution of linguistic knowledge to spelling in children with language impairment (Study 2). The participants with typical language were recruited from the classrooms of the participants with language impairment. For each child recruited with language impairment (n = 32), consent forms were sent home to three children in the same classroom who were judged by the teacher to have typical language development.[1] Parents or guardians provided consent for children to participate, and all participants were assented prior to each testing session. Forty-three children with typical language in second, third, and fourth grade were consented (27 classrooms) but three were excluded from the study (two failed a hearing screening and one did not speak English as a first language).

All participants scored within normal limits (i.e., standard score of 85 or above; M = 106.30; SD = 10.34; range 88-124) on the Core Language Score of the Clinical Evaluation of Language Fundamentals-Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003; test-retest reliability = .70 - .92). They passed a hearing screening bilaterally prior to study participation. Additionally, all participants spoke English as a primary language.

Measures

Participants completed a language, reading, and writing assessment battery. Commercially available measures were administered according to published test manuals, and research measures were administered according to instructions published

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[1] Nine of the children with language impairment were recruited from a school for children with learning disabilities and therefore children with typical language were not recruited from their classrooms.

in the cited literature. The majority of assessment was conducted by the first author; doctoral and master's students in speech-language pathology who were familiar with the measures assisted with data collection. Assessment took place in a quiet room other than students' classrooms at participating schools. First, the inclusionary and nonverbal intelligence measures were administered. Second, the remaining control and predictor measures were administered in a random order for each participant. Randomized orders of assessment were generated using an Excel macro. Testing sessions were scheduled for no more than two hours at one time (with one exception as requested by the school). Mean number of testing sessions per participant was 3.33.

The dependent measure evaluated word-level spelling accuracy. The control measures evaluated nonverbal intelligence, age, visual memory, and articulation. Consistent with the framework presented in the introduction, the predictor measures evaluated phonological processing, morphological knowledge, and orthographic knowledge.

Dependent measure. The *Test of Written Spelling-4th Edition* (TWS-4; Larsen, Hammill, & Moats, 1999) evaluates spelling in isolation and requires children to spell single words. The examiner says a word, uses it in a sentence, and then repeats the word. Ceiling on the TWS-4 is five consecutive incorrect spellings. The raw score is the number of words spelled correctly prior to ceiling and therefore, it is not derived from the same corpus of words for all children[2]. Test-retest reliability is .95.

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[2] According to the TWS-4 manual, 4th graders should begin at item 10. However, because standard scores were not used in this study and we did not want to give credit for words that children could potentially misspell, all participants began at item 1.

Control measures. The *Test of Nonverbal Intelligence-4th Edition* (TONI-4; Brown, Sherbenou, & Johnsen, 2010) evaluates nonverbal intelligence. Nonverbal rather than full scale intelligence was measured because nonverbal intelligence is minimally influenced by linguistic knowledge. The TONI-4 requires children to respond nonverbally to problem-solving tasks that incorporate one or more of the following characteristics: shape, position, direction, rotation, contiguity, shading, size, and movement. Ceiling on the TONI-4 is three incorrect responses out of five consecutive items. The raw score is the number of correct responses prior to ceiling; children ages 10 years and older begin at item 20 and receive credit for all previous items (if a basal of 5 consecutive correct responses is not established, items below item 20 are administered in reverse order until a basal is established). Test-retest reliability is .83 - .89.

The Visual Memory Index of the *Wide Range Assessment of Memory and Learning-2nd Edition* (WRAML-2; Sheslow & Adams, 2001) consists of two subtests: Design Memory and Picture Memory. The Design Memory subtest is a measure of visual memory of objects that minimally convey meaning. The examiner displays for five seconds a card that contains multiple geometric shapes. After a 10-second delay the examiner asks children to draw the shapes. The subtest consists of five cards, and all children complete all cards. The raw score is the number of selected features (as described in the published test manual) that children represent in their drawings. The Picture Memory subtest is a measure of immediate recall of pictures that convey meaning. The examiner displays for 10 seconds a picture depicting an everyday scene. The examiner immediately shows a similar picture that contains some changes and

asks the child to physically point to the changed elements. No verbal response is required. The subtest consists of four picture scenes, and all children complete all pictures. The raw score is the number of differences children correctly identify. The two raw scores contribute to the Visual Memory Index standard score. Test-retest reliability is .85 - .87.

The *Arizona Articulation Proficiency Scale-3rd Edition* (Fudala, 2000) evaluates children's speech sound production in isolated words. The examiner asks children to name pictures that depict objects or actions. Each targeted sound is assigned an error value. The error score for each child is calculated by adding the error values of the particular sounds that he or she produced incorrectly. The Arizona Total Score is the error score subtracted from 100 (max 100).

Predictor measures. The *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) evaluates children's phonological processing skills with two subtests for each of the three components of phonological processing. On the phonological awareness subtests, the examiner asks children to (a) to delete syllables or phonemes from words and (b) to blend sounds together to form words. On the phonological memory subtests, the examiner asks children (a) to repeat digits and (b) to repeat nonwords. All children start with the first item. Ceilings on the phonological awareness and phonological memory subtests of the CTOPP are three consecutive incorrect responses. Raw scores are the number of correct responses prior to ceiling. On the RAN subtests, the examiner asks children to rapidly name (a) numbers and (b) letters displayed on a picture plate. The raw score for each subtest is

the number of seconds that a child takes to name all the (a) numbers and (b) letters on each page. Test-retest reliability is .70 - .92.

The *Test of Morphological Structure* (Carlisle, 2000), an experimental task, evaluates children's morphological knowledge with a spoken language task. In the Derivation subtest, the examiner provides a base word and asks children to complete a sentence that requires a derived form of the given word (e.g., *farm. My uncle is a ____*). In the Decomposition subtest, the examiners says a derived word and asks children to complete a sentence that requires the base form of the word (e.g., *driver. Children are too young to ____*). Each subtest contains 26 items. All children complete all items. The raw score is the number of correct responses (max 26).

The Letter Names and Letter Sounds subtests of the *Phonological Awareness and Literacy Screening: 1-3* (PALS:1-3; Invernizzi, Meier, & Juel, 2003) evaluate children's ability to provide names for the 26 letters of the alphabet (uppercase) and to provide sounds for 23 letters and 3 digraphs. All children complete all items. The raw score for each subtest is the number of correct responses (max 26 each). Test-retest reliability for the Letter Sounds subtest is .90[3].

The *Orthographic Constraints Test* (Treiman, 1993) evaluates children's knowledge of orthographic constraints in English. The examiner instructs children to read 16 pairs of nonwords and circle the nonword in each pair that looks more like a real word (e.g., *yinn, yikk*). All children complete all items. The raw score is the number of correct responses (max 16).

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[3] Test-retest reliability for the Letter Names subtest is not reported for the PALS 1-3.

The Spelling Recognition subtest of the *Peabody Individual Achievement Test-Revised* (PIAT-R; Markwardt, 1998) evaluates children's visual recognition of conventional spelling of words (i.e., MGRs). The examiner says a word, uses it in a sentence, and asks children to select the correct spelling of the word from four phonologically and orthographically plausible choices. Basal on the PIAT-R is the highest five consecutive correct responses, and ceiling is five incorrect responses out of seven consecutive items. The raw score is the ceiling item minus the number of incorrect responses after basal. Test-retest reliability is .85 - .93.

Reliability

Testing sessions were audio recorded to allow for calculation of reliability of written recording of child responses on tests that required a verbal response (CELF-4, Arizona, CTOPP, TMS, and PALS 1-3). A research assistant listened to audio recorded responses of 30% of participants and wrote child responses on a clean test form. The first author compared the written responses of the examiner and the research assistant. Reliability was calculated on an item-by-item basis on each measure for each participant. For each measure, reliability of each participant was averaged (CELF-4: 94.1%, CTOPP: 98.9%, PALS 1-3: 99.6%, Arizona: 99.9%, TMS: 98.0%). Finally, overall reliability for each participant (i.e., on each measure) was calculated and averaged. Average reliability for accurate online recording of child responses across all tests was 98.1%.

To assure reliability in scoring (items, raw scores, standard scores), all test forms were double-scored by a research assistant familiar with test scoring. Any disagreements were resolved by mutual consensus.

Data entry. Data was entered into REDCap, a secure, web-based application for building and managing online databases, housed at Vanderbilt University (redcap.vanderbilt.edu). Data was simultaneously entered into the database and checked for accuracy. The research assistant read scores from test forms; the author entered the raw scores, standard scores, and percentiles of study measures into the REDCap database; and the research assistant simultaneously checked the REDCap display projected to a screen visible to the research assistant and author.

Analysis

For each linguistic knowledge variable, composites were generated from two to six measures (see Table 2.1). To create composites, raw scores for each measure were converted to z-scores based on the study sample, and Cronbach's alpha was used to ensure that measures contributing to each linguistic knowledge variable had shared variance.

The Phonological Processing Composite consisted of z-scores from the CTOPP Elision, Blending Words, Memory for Digits, Nonword Repetition, Rapid Digit Naming, and Rapid Letter Naming subtests (6 items; $\alpha = .748$). The Morphological Knowledge Composite consisted of z-scores from the Test of Morphological Structure Derivation and Decomposition subtests (2 items; $\alpha = .870$). The Orthographic Knowledge Composite consisted of z-scores from the PIAT-R Spelling subtest and the Orthographic

Constraints Test (2 items; α = .682). The PALS 1-3 Letter Names and Letter Sounds

subtests were not included in the Orthographic Knowledge Composite because

Cronbach's alpha with their inclusion was unacceptably low (4 items; α = .415) and they

were not significantly correlated with the spelling outcome measure (see Results).

Table 2.1. Measures Contributing to Each Composite

Phonological Processing	Morphological Knowledge	Orthographic Knowledge
CTOPP Elision	TMS Derivation	PIAT-R Spelling
CTOPP Blending Words	TMS Decomposition	OCT
CTOPP Memory for Digits		
CTOPP Nonword Repetition		
CTOPP Rapid Digit Naming		
CTOPP Rapid Letter Naming		

Note. CTOPP = Comprehensive Test of Phonological Processing (Wagner et al., 1999); OCT = Orthographic Constraints Test (Treiman, 1993); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); TMS = Test of Morphological Structure (Carlisle, 2000).

Hierarchical multiple regression analyses were used to examine the relative

contributions of phonological processing, morphological knowledge, and orthographic

knowledge in explaining the variance in word-level spelling in elementary-aged children.

First, age, nonverbal intelligence, visual memory, and articulation scores were entered

to control for these factors. Next, the linguistic composite variables were entered.

Results

Descriptive statistics for study measures are provided in Table 2.2. As expected,

means for all study measures fell within the expected average range. Correlations of

study measures are provided in Table 2.3. All predictor measures, with the exception of

PALS 1-3 Letter Names and Letter Sounds, were significantly correlated with the

dependent measure, TWS-4 Raw spelling score.

Table 2.2. Means and Standard Deviations of Study Measures.

	Mean	SD	Range
Dependent Measure			
TWS-4 Raw	16.50	7.80	5-34
Control Measures			
TONI-4 SS	104.40	8.13	88-121
Arizona Total Score (max 100)	98.78	2.85	88-100
WRAML-2 Visual Memory Index	99.13	16.25	70-141
Predictor Measures			
CTOPP Elision Raw	13.23	4.98	2-20
CTOPP Blending Words Raw	14.83	3.19	8-20
CTOPP Memory for Digits Raw	12.03	3.42	5-19
CTOPP Nonword Repetition Raw	10.35	3.28	3-18
CTOPP Rapid Digit Naming Raw	38.58	8.16	24-60
CTOPP Rapid Letter Naming Raw	42.33	10.86	24-76
TMS Derivation (max 28)	13.53	5.37	3-26
TMS Decomposition (max 28)	19.20	5.12	6-27
PALS 1-3 Letter Names (max 26)	25.73	0.64	23-26
PALS 1-3 Letter Sounds (max 26)	24.15	1.98	19-26
OCT (max 16)	13.75	1.65	10-16
PIAT-R Spelling Raw	57.98	15.27	28-83

Note: SS = standard score; CELF-4 = Clinical Evaluation of Language Fundamentals-4th Edition (Semel et al., 2003); CTOPP = Comprehensive Test of Phonological Processing (Wagner et al., 1999); Orthographic Constraints Test (Treiman, 1993); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); PALS:1-3 = Phonological Awareness Literacy Screening: 1-3 (Invernizzi et al., 2003); Test of Morphological Structure (Carlisle, 2000); TONI-4 = Test of Nonverbal Intelligence-4th Edition (Brown et al., 2010); TWS-4 = Test of Written Spelling-4th Edition (Larsen et al., 1999); WRAML-2 = Wide Range Assessment of Memory and Learning-2nd Edition (Sheslow & Adams, 2001).

Table 2.3. Correlations of Study Measures.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. TWS-4[a]	--																	
2. CELF-4 Core	**.495**	--																
3. TONI-4 SS	.054	.283	--															
4. Arizona Total Score	**.367**	.268	-.065	--														
5. WRAML-2 VMI	.137	-.110	-.183	-.164	--													
6. CTOPP Elision[a]	**.495**	**.682**	**.366**	.160	.013	--												
7. CTOPP Blending Words[a]	**.468**	**.400**	.148	**.325**	.148	**.391**	--											
8. CTOPP Memory for Digits[a]	**.373**	.292	**.373**	.047	.018	.298	**.427**	--										
9. CTOPP Nonword Rep[a]	**.441**	.277	.131	.217	-.092	.224	**.366**	**.449**	--									
10. CTOPP Digit Naming[a]	**-.532**	-.224	-.218	-.192	.008	**-.339**	-.116	**-.466**	**-.430**	--								
11. CTOPP Letter Naming[a]	**-.445**	-.131	.030	-.205	-.127	-.205	.037	**-.349**	-.232	**.718**	--							
12. TMS Derivation[a]	**.532**	**.591**	.073	.295	-.135	**.476**	**.474**	**.467**	.266	**-.423**	-.280	--						
13. TMS Decomposition[a]	**.602**	**.533**	.069	.304	.031	**.574**	**.424**	**.491**	.266	**-.545**	**-.433**	**.769**	--					
14. PALS Letter Names[a]	.239	.203	-.008	-.028	.191	.277	.189	.214	.267	-.068	-.090	**.334**	.283	--				
15. PALS Letter Sounds[a]	.098	**.373**	**.332**	.120	-.107	.288	**.337**	.071	.209	-.091	-.129	.152	.111	.195	--			
16. OCT[a]	**.322**	.051	-.284	.223	.188	.041	.128	.183	.126	-.075	-.081	.099	.189	.104	-.130	--		
17. PIAT-R[a]	**.784**	.296	-.087	**.321**	.186	**.314**	.117	.183	.208	**-.440**	**-.506**	**.346**	**.501**	.235	-.019	**.517**	--	
18. Age	.233	-.048	**-.373**	.074	.251	.040	.169	.282	-.036	-.286	**-.313**	**.517**	**.525**	.302	-.039	.099	.262	--

Note. Arizona = Arizona Articulation Proficiency Scale-3 (Fudala, 2000); CELF-4 = Clinical Evaluation of Language Fundamentals-4th Edition (Semel et al., 2003); CTOPP = Comprehensive Test of Phonological Processing (Wagner et al., 1999); Orthographic Constraints Test (Treiman, 1993); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); PALS:1-3 = Phonological Awareness Literacy Screening: 1-3 (Invernizzi et al., 2003); TMS = Test of Morphological Structure (Carlisle, 2000); TONI-4 = Test of Nonverbal Intelligence-4th Edition (Brown et al., 2010); TWS-4 = Test of Written Spelling-4th Edition (Larsen et al., 1999); WRAML-2 = Wide Range Assessment of Memory and Learning-2nd Edition (Sheslow & Adams, 2001).

[a] = raw scores; bolded correlations are significant at *p* < .05.

Do phonological processing, morphological knowledge, and/or orthographic knowledge uniquely predict spelling in elementary school children when considered concurrently?

Multiple regression analysis was utilized to determine whether the linguistic variables predicted spelling performance. Overall, the multiple regression model accounted for 57.8% of the variance (R^2 = .65, $F(7,39)$ = 8.50, p < .001; see Table 2.4). After controlling for age, nonverbal intelligence, articulation, and visual memory (10.8% of the total variance), orthographic knowledge and morphological knowledge both contributed unique variance to spelling performance (22.5% and 15.5% of the total variance, respectively).

Table 2.4. Multiple Regression Model

Step		B	SE B	β	t	p
1	Control Variables					
	Age in months	-.113	.103	-.173	-1.106	.227
	Nonverbal IQ	.043	.124	.044	.344	.733
	Articulation	.323	.319	.118	1.012	.319
	Visual Memory	.061	.056	.128	1.095	.282
2	Predictor Variables					
	Phonological Processing	.619	.320	.251	1.936	.062
	Morphological Knowledge	3.281	1.354	.396	2.424	.021
	Orthographic Knowledge	3.473	1.140	.388	3.045	.005

Note. R^2_{adj} = .146 for Step 1; ΔR^2_{adj} = .432 for Step 2 (p <.001).

Discussion

The present investigation concurrently examined the relative contributions of phonological processing, morphological knowledge, and orthographic knowledge to spelling performance of second through fourth grade children. In addition, the present investigation improved on the extant literature by controlling for nonverbal intelligence, articulation, and visual memory in addition to age when considering the effects of linguistic knowledge on spelling. The results of the investigation indicated that linguistic knowledge influences spelling in children in the elementary grades. Specifically, orthographic knowledge and morphological knowledge contributed unique variance to spelling. In addition, phonological processing explained considerable variance; however, its contribution did not reach statistical significance.

The multiple regression model used in the investigation explained almost 60% of the variance in spelling. Combined, the linguistic variables accounted for 48.5% of the total variance, indicating that linguistic knowledge is a strong predictor of spelling in elementary school children. In contrast to the philosophy that drives much spelling instruction, visual memory did not contribute significant unique variance to spelling for second through fourth graders (only about 3%), nor was visual memory correlated with spelling (r = .137).

Orthographic knowledge was a significant unique predictor of spelling performance in children in the elementary grades, accounting for almost 23% of the total variance. It is not surprising that the knowledge of how spoken language units are represented in written language was the strongest predictor of spelling. Children in the elementary grades develop increased understanding of the intricacies of this relation,

and not surprisingly, this knowledge predicts their spelling performance. An examination of the correlations of the PIAT-R (MGRs) and OCT (orthographic pattern knowledge) indicated that the relation of stored MGRs and spelling was stronger than that of orthographic pattern knowledge and spelling (r = .784 and .322, respectively). Therefore, a child's fund of stored MGRs predicts spelling to a greater extent than orthographic pattern knowledge in the elementary grades. It is possible that measuring MGRs is simply a measure of visual memory. However, the PIAT-R was not correlated with the WRAML-2 Visual Memory Index (r = .186), and the correlation of the PIAT-R and the OCT was much stronger (r = .517). This finding supports the argument that stored MGRs are not simply dependent on a general visual memory skill but instead are components of orthographic knowledge. Children likely form new MGRs not by simply memorizing strings of letters of individual words but by analyzing stored MGRs of words with similar linguistic features. Future research should empirically evaluate this hypothesis.

In addition to orthographic knowledge, morphological knowledge was also a significant unique predictor of spelling performance for elementary school children, accounting for almost 16% of the total variance. Interestingly, on the TWS-4 only 20% of words contain more than one morpheme, and the first multimorphemic word occurs at item 26. The mean raw score on the TWS-4 in this investigation was 16.5, well below the first multimorphemic word, and only six children had raw scores above 26. Therefore, the majority of the words that children spelled in this investigation contained only one morpheme. Morphological knowledge predicts spelling in elementary school children, even when words do not contain more than one morpheme.

Finally, contrary to our expectation, phonological processing as a predictor of spelling performance did not contribute significant unique variance ($p = .06$) but accounted for approximately 11% of the total variance. Despite its prominence in studies investigating the linguistic contributions to spelling performance, the results of this investigation suggest that phonological processing may not be a strong predictor of spelling in relation to other types of linguistic knowledge as children progress in elementary school. Perhaps as words become more linguistically complex, morphological and orthographic knowledge increasingly influence spelling and the influence of phonological processing is not as prominent as in kindergarten and first grade. A longitudinal empirical investigation of the relative contributions of the three types of linguistic knowledge that begins with younger children could test this hypothesis.

The present investigation's findings differ from Apel et al. (2012), who reported that morphological knowledge was the only unique predictor of spelling performance in second and third graders. However, their measure of morphological knowledge was not a pure measure of morphological knowledge but also measured orthographic and possibly phonological knowledge. To receive credit for an item on the Apel et al. task, children had to either correctly spell or phonologically represent a derived morpheme. With this scoring system, it would be possible to successfully complete this task without using morphological knowledge at all. Children could simply analyze the phonological structure of words and represent the final sounds with orthographically plausible letters. Other researchers have opted for oral, and not written, measures of morphological knowledge (e.g., Plaza & Cohen, 2004; Walker & Hauerwas, 2006). The use of oral

tasks ensures that researchers actually measure the construct of morphological knowledge and do not tap orthographic and/or phonological knowledge. Measuring morphological knowledge in written form using this particular scoring system may have obscured the unique contribution of other types of linguistic knowledge to spelling for elementary school children. Those types of linguistic knowledge likely were being tapped to provide correct responses on the measure. In the present investigation, morphological knowledge was measured in the oral modality. Children were not required to produce a spelling to demonstrate morphological knowledge. Future research must address measurement issues when tapping the construct of morphological knowledge.

Implications for Teaching Spelling

This investigation adds to a growing body of literature that indicates that linguistic knowledge predicts spelling in elementary school children beyond visual memory. Thus, there is reason to believe that spellings are "figured out" to a greater extent than simply memorized. However, teaching practices still focus primarily on memorization of spelling words with little attention to the linguistic structure of words. The findings lead us to hypothesize that spelling instruction that teaches children to analyze the linguistic structure of words (i.e., phonological, morphological, and orthographic) and explicitly relates linguistic structure to spelling will be more effective than spelling instruction that places the primary emphasis on visual memory because linguistic spelling instruction takes advantage of skills that predict spelling in children. An experimental evaluation of

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intervention that addresses each area of linguistic knowledge is needed to test this hypothesis.

Limitations and Future Directions

The small sample size and the nature by which we recruited participants limited our ability to explore the unique contributions of linguistic knowledge to spelling in each of second through fourth grades. The study was designed to broadly examine predictors of spelling across these grades. Walker and Hauerwas (2006) found differential linguistic contributions to the spelling of inflected verb endings for first, second, and third graders. Thus, future investigations should clarify the present findings at a grade level. It is possible that linguistic knowledge also influences general spelling differently across grades. The results of this investigation should be interpreted with this limitation in mind.

In addition, this study did not evaluate the influence of linguistic knowledge on spelling beyond that of phonological processing, morphological knowledge, and orthographic knowledge. It is possible that other types of linguistic knowledge (e.g., vocabulary) also influence spelling ability.

Finally, this study did not evaluate individually the subcomponent skills that formed each linguistic composite. Phonological awareness was not a significant predictor of spelling. It is possible that one or more subcomponents of phonological processing predict spelling but others do not and, if so, these differences may have influenced the results.

Future research should explore possible between grade differences in children's use of linguistic knowledge for spelling. In addition, future research should follow the

same group of children over time, beginning in preschool through the school age and adolescent years to determine what types of linguistic knowledge are used for spelling throughout development. Such knowledge could greatly inform spelling instructional practices. Future research also should evaluate each subcomponent individually to identify specific skills to focus on for teaching, as well as evaluate other areas of linguistic knowledge that might influence spelling. Limited research on the effectiveness of linguistic spelling intervention suggests that it is more effective than spelling instruction based on visual memory (Hall, Cunningham, & Cunningham, 1995; Joseph, 2000).

Conclusion

Linguistic knowledge predicts spelling for children in the elementary grades. Orthographic knowledge and morphological knowledge contributed unique variance to spelling performance; however, phonological processing did not. The results of this investigation add to a growing body of evidence that linguistic knowledge influences literacy development, including spelling as well as reading. The results suggest that simply memorizing words is not sufficient for creating the fund of MGRs needed to be a proficient speller and that spelling instruction should take into account children's linguistic knowledge and explicitly relate their linguistic knowledge to spelling. Future research should evaluate the effectiveness of such spelling instruction.

CHAPTER III

STUDY 2: LINGUISTIC CONTRIBUTION TO SPELLING IN ELEMENTARY SCHOOL
CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT

Abstract

To understand the nature of spelling difficulties in children with SLI, it is important to
elucidate the areas of linguistic knowledge that influence children's spelling. The
purpose of this investigation was to (a) to evaluate the contribution of linguistic
knowledge to spelling in children with SLI and (b) to compare the linguistic knowledge
predictors of spelling by children with SLI to those of children with typical language.
After controlling for age, nonverbal intelligence, articulation, and visual memory, only
morphological knowledge contributed unique variance to spelling performance of
children with SLI; the contributions of phonological processing and orthographic
knowledge, despite explaining approximately 10% of the total variance each, were not
statistically significant. Interaction effects of linguistic variables and language group
status were not statistically significant, although examination of the individual models for
children with SLI and children with typical language revealed differences in the types of
knowledge that predicted spelling in each group. The results indicate that spelling
instruction should take into account children's linguistic knowledge and explicitly relate
their linguistic knowledge to spelling and that it likely is necessary to teach spelling to
children with language impairment using approaches that may differ in some ways from
those used to teach children with typical language.

Introduction

Children with specific language impairment (SLI) are much more likely than the general population to exhibit difficulties in developing literacy skills (e.g., Catts et al., 2002). Much research has addressed the reading skills of children with SLI. However, research on the spelling skills of children with SLI has been sparse. When literacy outcomes for children with SLI have been discussed, often only reading has been reported (e.g., Catts et al., 2002). Even when spelling has been measured, many studies report those scores only in the context of a composite literacy variable, not separately from reading (e.g., Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998). Although reading and spelling are highly related skills, there is evidence of at least some independence of the two skills (Ehri, 2000).

The low performance of children with SLI on literacy skills is not surprising given the linguistic basis of reading and writing. To understand the nature of spelling difficulties in children with SLI, it is important to elucidate the areas of linguistic knowledge that influence children's spelling. The purpose of this investigation was (a) to evaluate the contribution of linguistic knowledge to spelling for children with SLI and (b) to compare the contribution of linguistic knowledge to spelling for children with SLI to that of children with typical language.

Linguistic Basis of Spelling

Three areas of linguistic knowledge have been most studied with regard to spelling: phonological processing, morphological knowledge, and orthographic knowledge. Theories of spelling development indeed point to these three areas of

linguistic knowledge as of primary importance during the early elementary years. The results of Study 1 indicated that linguistic knowledge contributes substantial variance to spelling performance in children with typical language.

Phonological processing. Phonological processing is the use of one's knowledge of the sounds of language and is comprised of phonological awareness (the ability to analyze sounds of spoken language), phonological memory (the component of working memory that stores speech-based information), and rapid automatized naming (RAN; automatic phonological recoding from long-term memory; Wagner & Torgesen, 1987, but see Wolf & Bowers, 1999 for an alternate view). Each component area of phonological processing individually is related to spelling performance (e.g., Catts et al., 2002; Plaza & Cohen, 2004; Stahl & Murray, 1994; Swanson et al., 2003). However, in Study 1 phonological processing did not account for unique variance in the spelling of children with typical language.

Children with SLI exhibit difficulties with phonological processing skills as compared to children with typical language. On measures of phonological awareness, preschool children and adolescents with SLI on average score lower on average than both age- and language-matched children with typical language (e.g., Boudreau & Hedberg, 1999; Joffe, 1998; Kamhi, Lee, & Nelson, 1985; Thatcher, 2010) However, Catts et al. (2005) reported that after 2nd grade, children with SLI performed comparably on phonological awareness to children with typical language, except for those children with SLI who had comorbid word-level reading deficits. In contrast, Catts et al. reported that as a group, children with SLI exhibited deficits in phonological memory through eighth grade (the highest grade reported), regardless of reading outcome (although

children with SLI and comorbid word-level reading deficits scored even lower as a group). In addition, Briscoe, Bishop, and Norbury (2001) reported that 5- to 10-year-old children with SLI scored well below age-matched typical language children on measures of phonological memory (*d*s range from 1.43 - 2.87). Young et al. (2002) reported a similar trend for adolescents; adolescents with SLI scored lower on a measure of phonological memory than adolescents with typical language (*d* = .75) Finally, with respect to RAN, Bishop et al. (2009) reported that 9- to 10-year-old children with SLI performed comparably to children with typical language, unless they also had comorbid word-level reading deficits. Catts (1993) reported that phonological awareness and RAN in kindergarten both contributed unique variance to word-level reading in first and second grade for children with SLI (phonological memory was not measured). Hence there is an evidence base that demonstrates that deficits in phonological processing in children with SLI are related to difficulties in reading outcomes. However, no studies to date have investigated the relation of phonological processing skills in spoken language and spelling in children with SLI.

Morphological knowledge. Morphological knowledge is the understanding of morphological structure of words (i.e., base words and affixes). There is ample evidence that in addition to phonological processing, morphological knowledge also influences typically developing children's spellings. For example, children are more likely to correctly represent flaps in words that contain two morphemes (e.g., *dirty*) than in words that contain only one morpheme (e.g., city; Treiman et al., 1994). In Study 1, morphological knowledge accounted for 15.5% of unique variance in the spelling of children with typical language.

Most research on morphological knowledge of children with SLI has focused on inflectional morphology (e.g, Leonard, Eyer, Bedore, & Grela, 1997; Oetting & Horohov, 1997; Rice, Wexler, & Hershberger, 1998), rather than derivational morphology. Within inflectional morphology, it is well established that children with SLI exhibit deficits in performance compared to their peers with typical language. In fact, deficits in marking inflectional morphemes in spoken language are considered the hallmark clinical marker of SLI (e.g., Bedore & Leonard, 1998; Rice & Wexler, 1996). Although research in later developing derivational morphology has been more limited, findings suggest that as with inflectional morphology, children with SLI perform lower on both forced choice tasks and on elicited marking of derivational morphology in spoken language than age-matched children (Windsor & Hwang, 1997, 1999) and language-matched children (Marshall & van der Lely, 2007).

Orthographic knowledge. Orthographic knowledge is one's knowledge of the rules for how spoken language is represented in print. Orthographic knowledge consists of orthographic pattern knowledge (i.e., alphabet knowledge and knowledge of language-specific orthographic constraints) and stored mental grapheme representations (i.e., knowledge of conventional spellings of specific words). Children who are good spellers have higher levels of orthographic knowledge than children who are poor spellers (e.g., Schwartz & Doehring, 1977). In Study 1, orthographic knowledge accounted for 22.5% of unique variance in the spelling of children with typical language.

Compared to other areas of linguistic knowledge, relatively little is known about the orthographic knowledge of children with SLI. Limited research suggests that

orthographic knowledge, particularly orthographic pattern knowledge, may be a relative strength in terms of linguistic knowledge for children with SLI. It appears that children with SLI may possess similar orthographic pattern knowledge as children with typical language, but they have fewer stored MGRs. For example, Silliman et al. (2006) reported that the spellings of 6- to 11-year old children with SLI reflected knowledge of orthographic constraints more so than phonological accuracy. Similarly, Mackie and Dockrell (2004) reported that children with SLI and language-matched children did not differ in proportion of orthographically inaccurate spellings. Wagovich, Pak, and Miller (2012) reported that 10- to 16-year-old children with SLI were more likely than typical language peers to indicate that nonwords that were orthographically similar to rare real words encountered in a story reading task a few days earlier were in fact real; however, the groups did not differ in indicating that the rare real words they had encountered in the story were real.

Spelling In Children with SLI

Because spelling is a skill dependent on an individual's linguistic knowledge and children with SLI by definition have compromised linguistic abilities, children with SLI are expected to exhibit difficulties in spelling. Indeed, they score lower on measures of spelling as compared to children with typical language (Bishop & Adams, 1990; Cordewener et al., 2012; Young et al., 2002). However, little is known about how linguistic knowledge predicts spelling in children with SLI.

Young et al. (2002) concluded that the relation between phonological processing and spelling in 18- to 19-year-old adolescents with SLI does not parallel the relation in

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typical children. Specifically, only phonological awareness contributed to the spelling performance of adolescents with SLI, whereas phonological awareness, phonological memory, and RAN contributed to the spelling performance of adolescents with typical language. Interestingly, performance on the RAN task (digit naming) was similar for the two groups. Thus, even when they have rapid naming skills equivalent to peers with typical language, RAN of adolescents with SLI does not predict spelling. In addition to differences in the use of phonological processing, Wolter and Apel (2010) reported that kindergarten children with SLI acquired less mental grapheme representation information in an orthographic fast mapping task than kindergarten children with typical language. They suggested that this difference in orthographic knowledge contributes in part to the spelling difficulties of children with SLI. Thus, Young et al. and Wolter and Apel provide preliminary evidence that the linguistic knowledge that predicts spelling in individuals with SLI in spelling may differ from the linguistic knowledge that predicts spelling individuals with typical language.

Mackie and Dockrell (2004) concluded that deficits in both phonological awareness and orthographic knowledge contribute to spelling errors of 9- to 12-year-old children with SLI. Children with SLI exhibited proportionately more phonologically inaccurate (i.e., spellings that were not possible phoneme-to-grapheme correspondences in English) and orthographically inaccurate (i.e., spellings that contained an illegal sequence of letters in English) spellings than both age-matched and language-matched children with typical language. In a study of 6- to 11-year-old children, Silliman (2006) reported that spelling errors of children with typical language were most frequently orthographic errors. In contrast, children with SLI exhibited diffuse

difficulty with spelling, with errors equally distributed across phonological, morphological, and orthographic categories. Analysis of the types of spelling errors also provides preliminary evidence that children with SLI use linguistic knowledge to spell words differently than children with typical language.

In summary, the small body of research characterizing the spelling difficulties of children with SLI provides motivation for further systematic exploration. Children with SLI exhibit more spelling errors than children with normal language (i.e., their ability to spell words correctly is impaired). In addition, at least some language and cognitive processes that predict in spelling differ for children with SLI and children with typical language. Finally, spelling errors of children with specific SLI differ in nature from errors made by typically developing children. The purpose of this study was to explore the contribution of linguistic knowledge to spelling for children with SLI. Two research questions were addressed:

1. Do phonological processing, morphological knowledge, and/or orthographic knowledge uniquely predict spelling in elementary school children with SLI?

2. Does linguistic knowledge predict spelling differently for children with SLI and children with typical language?

Method

Participants

Participants were 32 children with SLI (*M* age = 8;9, SD = 12 months; 8 2nd graders,14 3rd graders, 10 4th graders) and 40 children with typical language (*M* age =

9;4, SD = 12 months; 16 2nd graders, 17 3rd graders, 7 4th graders). The typical language children participated in Study 1. All participants were recruited from public and private elementary schools in middle Tennessee. School speech-language pathologists sent consent forms home with children with an IEP who received speech-language and/or reading disability services. We recruited broadly within these categories because SLI is largely undiagnosed in school-age children (Tomblin et al., 1997), and children with SLI have higher rates of speech impairment (5 – 8%; Shriberg, Tomblin, & McSweeny, 1999) and reading disability (approximately 40%; Catts et al., 2002) than the general population (2 – 4% and 8%, respectively). Children identified during this process who did not qualify as SLI (see below; n = 13) were added to the typical language group, because we did not exclude any participants on the basis of speech or reading status. The remaining children with typical language (n = 27) were recruited from the classrooms of the children with SLI. For each child with language impairment, consent forms were sent home to three children in the same classroom who were judged by the teacher to have typical language development.[1] Parents or guardians provided consent for children to participate, and all participants were assented prior to each testing session. Seventy-nine children were consented but five (two with SLI, 3 with typical language) were excluded from the study (three failed a hearing screening and three due to referral error).

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[1] Nine of the children with language impairment were recruited from a school for children with learning disabilities and therefore children with typical language were not recruited from their classrooms.

Children with diagnoses other than speech impairment and/or reading or writing impairment (i.e., cognitive impairment, autism, hearing loss) were excluded. Exclusion was determined by information derived from school and/or parent report.

All children passed a hearing screening bilaterally prior to testing and spoke English as a first language. Children in the typical language group scored within normal limits (i.e., standard score of 85 or above) and children in the SLI group scored below a standard score of 85 on the Core Language Index of the Clinical Evaluation of Language Fundamentals-Fourth Edition (CELF-4; Semel et al., 2003).

Measures

Participants completed a language, reading, and writing assessment battery. Commercially available measures were administered according to published test manuals, and research measures were administered according to instructions published in the cited literature. The majority of assessment was conducted by the first author; doctoral and master's students in speech-language pathology who were familiar with the assessments assisted with data collection. Assessment took place in a quiet room other than students' classrooms at participating schools. First, the inclusionary and nonverbal intelligence measures were administered. Second, the remaining control and predictor measures were administered in random orders for each participant. Randomized orders of assessment were generated using an Excel macro. Testing sessions were scheduled for no more than two hours at one time. Mean number of testing sessions per participant was 3.35 (3.38 for SLI, 3.33 for typical language).

The dependent measure evaluated word-level spelling. The control measures evaluated nonverbal intelligence, age, visual memory, and articulation. Consistent with the framework presented in the introduction, the predictor measures evaluated phonological processing, morphological knowledge, and orthographic knowledge.

Dependent measure. The *Test of Written Spelling-4th Edition* (TWS-4; Larsen et al., 1999) evaluates spelling in isolation and requires children to spell single words. The examiner says a word, uses it in a sentence, and then repeats the word. Ceiling on the TWS-4 is five consecutive incorrect spellings. The raw score is the number of words spelled correctly prior to ceiling and therefore, it is not derived from the same corpus of words for all children[2]. Test-retest reliability is .95.

Control measures. The *Test of Nonverbal Intelligence-4th Edition* (TONI-4; Brown et al., 2010) evaluates nonverbal intelligence. Nonverbal rather than full scale intelligence was measured because nonverbal intelligence is not influenced by linguistic knowledge. The TONI-4 requires children to respond nonverbally to a variety of problem-solving tasks that incorporate one or more of the following characteristics: shape, position, direction, rotation, contiguity, shading, size, and movement. Ceiling on the TONI-4 is three incorrect responses out of five consecutive items. The raw score is the number of correct responses prior to ceiling; children ages 10 years and older begin at item 20 and receive credit for all previous items (if a basal of 5 consecutive correct responses is not established, items below item 20 are administered in reverse order until a basal is established). Test-retest reliability is .83 - .89.

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[2] According to the TWS-4 manual, 4th graders should begin at item 10. However, because standard scores were not used in this study and we did not want to give credit for words that children could potentially misspell, all participants began at item 1.

The Visual Memory Index of the *Wide Range Assessment of Memory and Learning-2nd Edition* (WRAML-2; Sheslow & Adams, 2001) consists of two subtests: Design Memory and Picture Memory. The Design Memory subtest is a measure of visual memory of objects that minimally convey meaning. The examiner displays for five seconds a card that contains multiple geometric shapes. After a 10-second delay the examiner asks children to draw the shapes. The subtest consists of five cards, and all children complete all cards. The raw score is the number of selected features (as described in the published test manual) that children represent in their drawings. The Picture Memory subtest is a measure of immediate recall of pictures that convey meaning. The examiner displays for 10 seconds a picture depicting an everyday scene. The examiner immediately shows a similar picture that contains some changes and asks the child to physically point to the changed elements. No verbal response is required. The subtest consists of four picture scenes, and all children complete all pictures. The raw score is the number of differences children correctly identify. The two raw scores contribute to the Visual Memory Index standard score. Test-retest reliability is .85 - .87.

The *Arizona Articulation Proficiency Scale-3rd Edition* (Fudala, 2000)evaluates children's speech sound production in isolated words. The examiner asks children to name pictures that depict objects or actions. Each targeted sound is assigned an error value. The error score for each child is calculated by adding the error values of the particular sounds that he or she produced incorrectly. The Arizona Total Score is the error score subtracted from 100 (max 100).

Predictor measures. The *Comprehensive Test of Phonological Processing* (CTOPP; Wagner et al., 1999) evaluates children's phonological processing skills with two subtests for each of the three components of phonological processing. On the phonological awareness subtests, the examiner asks children to (a) to delete syllables or phonemes from words and (b) to blend sounds together to form words. On the phonological memory subtests, the examiner asks children (a) to repeat digits and (b) to repeat nonwords. All children start with the first item. Ceilings on the phonological awareness and phonological memory subtests of the CTOPP are three consecutive incorrect responses. Raw scores are the number of correct responses prior to ceiling. On the RAN subtests, the examiner asks children to rapidly name (a) numbers and (b) letters displayed on a picture plate. The raw score for each subtest is the number of seconds that a child takes to name all the (a) numbers and (b) letters on each page. Test-retest reliability is .70 - .92.

The *Test of Morphological Structure* (Carlisle, 2000), an experimental task, evaluates children's morphological knowledge in spoken language. In the Derivation subtest, the examiner provides a base word and asks children to complete a sentence that requires a derived form of the given word (e.g., *farm. My uncle is a ____*). In the Decomposition subtest, the examiners says a derived word and asks children to complete a sentence that requires the base form of the word (e.g., *driver. Children are too young to ____*). Each subtest contains 26 items. All children complete all items. The raw score is the number of correct responses (max 26).

The Letter Names and Letter Sounds subtests of the *Phonological Awareness and Literacy Screening: 1-3* (PALS:1-3; Invernizzi et al., 2003) evaluate children's ability

to provide names for the 26 letters of the alphabet (uppercase) and to provide sounds for 23 letters and 3 digraphs. All children complete all items. The raw score for each subtest is the number of correct responses (max 26 each). Test-retest reliability for the Letter Sounds subtest is .90[3].

The *Orthographic Constraints Test* (Treiman, 1993) evaluates children's knowledge of orthographic constraints in English. The examiner instructs children to read 16 pairs of nonwords and circle the nonword in each pair that looks more like a real word (e.g., *yinn, yikk*). All children complete all items. The raw score is the number of correct responses (max 16).

The Spelling Recognition subtest of the *Peabody Individual Achievement Test-Revised* (PIAT-R; Markwardt, 1998) evaluates children's visual recognition of conventional spelling of words (i.e., MGRs). The examiner says a word, uses it in a sentence, and asks children to select the correct spelling of the word from four phonologically and orthographically plausible choices. Basal on the PIAT-R is the highest five consecutive correct responses, and ceiling is five incorrect responses out of seven consecutive items. The raw score is the ceiling item minus the number of incorrect responses after basal. Test-retest reliability is .85 - .93.

Reliability

Testing sessions were audio recorded to allow for calculation of reliability of written recording of child responses on tests that required a verbal response (CELF-4, Arizona, CTOPP, TMS, and PALS 1-3). A research assistant listened to audio recorded

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[3] Test-retest reliability for the Letter Names subtest is not reported for the PALS 1-3.

responses of 30% of participants and wrote child responses on a clean test form. The first author compared the written responses of the examiner and the research assistant. Reliability was calculated on an item-by-item basis on each measure for each participant. For each measure, reliability of each participant was averaged (Typical Language: CELF-4: 94.1%, CTOPP: 98.9%, PALS 1-3: 99.6%, Arizona: 99.9%, TMS: 98.0%; SLI: CELF-4: 87.0%, CTOPP 97.9%, PALS 1-3: 99.5%, Arizona: 97.4%, TMS: 95.1%). Finally, overall reliability for each participant (i.e., on each measure) was calculated and averaged. Average reliability for accurate online recording of child responses across all tests was 98.1 % for children with typical language and 95.4% for children with SLI.

To assure reliability in scoring (items, raw scores, standard scores), all test forms were double-scored by a research assistant familiar with test scoring. Any disagreements were resolved by mutual consensus.

Data entry. Data was entered into REDCap, a secure, web-based application for building and managing online databases, housed at Vanderbilt University (redcap.vanderbilt.edu). Data was simultaneously entered into the database and checked for accuracy. The research assistant read scores from test forms; the author entered the raw scores, standard scores, and percentiles of study measures into the REDCap database; and the research assistant simultaneously checked the REDCap display projected to a screen visible to the research assistant and author.

Analysis

Hierarchical multiple regression analyses were used to examine the relative

contributions of phonological processing, morphological knowledge, and orthographic

knowledge in explaining the variance in word-level spelling in elementary-aged children

with SLI. For each linguistic knowledge variable, composites consisting of two to six

measures were generated (see Table 3.1). To create composites, raw scores for each

measure were converted to z-scores using the analysis sample, and Cronbach's alpha

was used to ensure that measures contributing to each linguistic knowledge variable

had shared variance.

Table 3.1. Measures Contributing to Each Composite

Phonological Processing	Morphological Knowledge	Orthographic Knowledge
CTOPP Elision	TMS Derivation	PIAT-R Spelling
CTOPP Blending Words	TMS Decomposition	OCT
CTOPP Memory for Digits		PALS 1-3 Letter Names
CTOPP Nonword Repetition		
CTOPP Rapid Digit Naming		
CTOPP Rapid Letter Naming		

Note. CTOPP = Comprehensive Test of Phonological Processing (Wagner et al., 1999); OCT = Orthographic Constraints Test (Treiman, 1993); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); TMS = Test of Morphological Structure (Carlisle, 2000).

For the first research question, only scores of children with SLI contributed to the

composites used in the multiple regression analysis. The Phonological Processing

Composite consisted of z-scores from the CTOPP Elision, CTOPP Blending Words,

CTOPP Memory for Digits, and CTOPP Nonword Repetition subtests (6 items; α = .745). The Morphological Knowledge Composite consisted of raw scores from the TMS Derivation and TMS Decomposition subtests (2 items; α = .933). The Orthographic Knowledge Composite consisted of z-scores from the PIAT-R Spelling subtest, the OCT, and the PALS 1-3 Letter Names subtest (3 items; α = .581). The PALS 1-3 Letter Sounds subtest was not included in the Orthographic Knowledge Composite because Cronbach's alpha with its inclusion was unacceptably low (4 items; α = .459), and it was not significantly correlated with the spelling outcome measure (see Results).

For the second research question, scores of all children contributed to the composites used in the multiple regression analysis. The Phonological Processing Composite consisted of z-scores from the CTOPP Elision, CTOPP Blending Words, CTOPP Memory for Digits, and CTOPP Nonword Repetition subtests (6 items; α = .815). The Morphological Knowledge Composite consisted of raw scores from the TMS Derivation and TMS Decomposition subtests (2 items; α = .935). The Orthographic Knowledge Composite consisted of raw scores from the PIAT-R Spelling subtest and the OCT (2 items; α = .651). The PALS 1-3 Letter Names and Letter Sounds subtests were not included in the Orthographic Knowledge Composite because Cronbach's alpha with its inclusion was unacceptably low (4 items; α = .463).

To address the first research question, first age, nonverbal intelligence, visual memory, and articulation scores were entered to control for these factors. Next, the linguistic composite variables were entered. To address the second research question, first age, nonverbal intelligence, visual memory, and articulation scores were entered to control for these factors. Next, group was dummy coded and entered. Finally, the

linguistic predictor variables, as well as group x linguistic variable interaction terms for each composite were entered.

Results

Descriptive statistics for study measures are provided in Table 3.2. Children with SLI scored significantly lower than children with typical language on all tasks except the Arizona, WRAML-2 Visual Memory Index, and PALS 1-3 Letter Names and Letter Sounds. Correlations of study measures for children with SLI are provided in Table 3.3.

Table 3.2. Means (SDs) of Study Measures.

	TL	SLI	*p*	*d*
TWS-4 Raw	16.50 (7.79)	11.16 (6.36)	.003	0.75
CELF-4 Core SS	106.30 (10.34)	71.53 (9.83)	.000	3.45
TONI-4 SS	104.40 (8.13)	97.81 (8.13)	.001	0.81
Arizona Total Score (max 100)	98.78 (2.85)	98.61 (2.27)	.790	0.07
WRAML-2 Visual Memory Index	99.13 (16.25)	93.31 (15.10)	.124	0.37
CTOPP Elision Raw	13.23 (4.98)	9.41 (4.94)	.002	0.77
CTOPP Blending Words Raw	14.83 (3.19)	12.56 (3.54)	.006	0.67
CTOPP Memory for Digits Raw	12.03 (3.42)	8.84 (1.83)	.000	1.16
CTOPP Nonword Repetition Raw	10.35 (3.28)	6.75 (2.17)	.000	1.29
CTOPP Rapid Digit Naming Raw	38.38 (8.16)	46.44 (14.82)	.005	0.67
CTOPP Rapid Letter Naming Raw	42.33 (10.86)	52.56 (21.65)	.011	0.60
TMS Derivation (max 28)	13.53 (5.37)	6.34 (5.00)	.000	1.39
TMS Decomposition (max 28)	19.20 (5.12)	10.00 (6.70)	.000	1.54
PALS 1-3 Letter Names (max 26)	25.73 (0.64)	25.50 (0.98)	.246	0.27
PALS 1-3 Letter Sounds (max 26)	24.15 (1.98)	23.84 (2.10)	.527	0.15
OCT (max 16)	13.75 (1.65)	12.78 (2.39)	.046	0.47
PIAT-R Spelling Raw	57.98 (15.27)	47.97 (13.32)	.005	0.70

Note: SS = standard score; CELF-4 = Clinical Evaluation of Language Fundamentals-4th Edition (Semel et al., 2003); CTOPP = Comprehensive Test of Phonological Processing (Wagner et al., 1999); Orthographic Constraints Test (Treiman, 1993); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); PALS:1-3 = Phonological Awareness Literacy Screening: 1-3 (Invernizzi et al., 2003); Test of Morphological Structure (Carlisle, 2000); TONI-4 = Test of Nonverbal Intelligence-4th Edition (Brown et al., 2010); TWS-4 = Test of Written Spelling-4th Edition (Larsen et al., 1999); WRAML-2 = Wide Range Assessment of Memory and Learning-2nd Edition (Sheslow & Adams, 2001)

Table 3.3. Correlations of Study Measures for Children with SLI

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. TWS-4 [a]	--																	
2. CELF-4 Core	.098	--																
3. TONI-4	.160	.203	--															
4. Arizona	**.406**	.306	.117	--														
5. WRAML-2 Visual Memory	**.398**	.223	.049	-.010	--													
6. CTOPP Elision [a]	**.673**	.195	.331	.216	.178	--												
7. CTOPP Blending Words [a]	**.642**	.041	.153	.279	.142	**.741**	--											
8. CTOPP Mem for Digits [a]	.182	.139	.191	-.081	.071	**.363**	**.501**	--										
9. CTOPP Nonword Rep [a]	.232	.018	-.165	.118	.026	.148	-.231	.193	--									
10. CTOPP Digit Naming [a]	**-.426**	.046	-.230	-.079	-.153	**-.510**	.221	-.090	-.155	--								
11. CTOPP Letter Naming [a]	**-.393**	.028	-.246	.017	-.081	**-.433**	-.147	.059	-.135	**.896**	--							
12. TMS Derivation [a]	**.734**	.058	.140	.283	.205	**.620**	**.556**	.242	**.421**	-.192	-.181	--						
13. TMS Decomposition [a]	**.664**	.066	.119	.290	.172	**.583**	**.531**	.355	.324	-.244	-.223	**.874**	--					
14. PALS Letter Names [a]	**.441**	.192	.194	.054	.135	**.395**	.334	.188	.151	**-.387**	**-.438**	.344	**.416**	--				
15. PALS Letter Sounds [a]	.196	-.155	-.036	-.139	.077	.230	.104	-.082	.027	-.104	-.068	.258	.175	.149	--			
16. OCT [a]	.282	.215	.333	.174	.261	.324	.289	**.360**	.064	**-.404**	-.252	.055	.133	.021	-.290	--		
17. PIAT-R [a]	**.840**	.135	.253	.278	.347	**.584**	**.447**	.156	.080	**-.482**	**-.396**	**.687**	**.701**	**.533**	.241	**.395**	--	
18. Age	**.433**	-.152	-.112	.101	-.058	**.428**	**.534**	**.507**	.236	-.191	-.160	**.534**	**.654**	.203	.044	.224	**.368**	--

Note: SS = standard score; CELF-4 = Clinical Evaluation of Language Fundamentals-4th Edition (Semel et al., 2003);CTOPP = Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999); PIAT-R = Peabody Individual Achievement Test-Revised (Markwardt, 1998); PALS = Phonological Awareness Literacy Screening: 1-3 (Invernizzi, Meier, & Juel, 2003); Test of Morphological Structure (Carlisle, 2000); TONI-4 = Test of Nonverbal Intelligence-4th Edition (Brown, Sherbenou, & Johnson, 2010); TWS-4 = Test of Written Spelling-4th Edition (Larsen, Hammill, & Moats, 1999); WRAML-2 = Wide Range Assessment of Memory and Learning-2nd Edition (Sheslow & Adams, 2001). Bolded correlations are significant at *p* < .05.

Do phonological processing, morphological knowledge, and/or orthographic knowledge uniquely predict spelling in elementary school children with SLI?

To determine whether the linguistic variables predicted spelling performance in children with SLI, hierarchical multiple regression analysis was used. Overall, the multiple regression model accounted for 68.8% of the variance in spelling performance (see Table 3.4). After controlling for age, nonverbal intelligence, articulation, and visual memory (32.1% of the total variance, articulation = 17.4%, visual memory = 12%), only morphological knowledge contributed unique variance to spelling performance (17.1% of the total variance). Phonological processing and orthographic knowledge did not significantly predict spelling for elementary school children with language impairment (but accounted for 11.4% and 10.6% of the total variance, respectively).

Table 3.4. Multiple Regression Model for Children with SLI

Step		B	SE B	β	t	p
1	Control Variables					
	Age in months	-.017	.074	-.034	-.236	.815
	Nonverbal IQ	-.069	.090	-.088	-.771	.448
	Articulation	.692	.307	.247	2.251	.034
	Visual Memory	.086	.047	.204	1.812	.083
2	Predictor Variables					
	Phonological Processing	2.630	1.500	.271	1.753	.092
	Morphological Knowledge	2.238	1.004	.341	2.228	.036
	Orthographic Knowledge	2.243	1.323	.260	1.695	.103

Note. R^2_{adj} = .451 for Step 1; ΔR^2_{adj} = .237 for Step 2 ($p < .01$).

Does the contribution of linguistic knowledge to spelling words differ for children with SLI and children with typical language?

To determine whether the linguistic variables predicted spelling performance differently for children with SLI and children with typical language, hierarchical multiple regression analysis was used with language status as an interaction term. Overall, the multiple regression model accounted for 69.6% of the variance in spelling performance (see Table 3.5). After controlling for age, nonverbal intelligence, articulation, and visual memory (10.8% of the total variance), group, phonological processing, and orthographic knowledge contributed unique variance to spelling performance (7.0%, 14.1%, and 21.5% of the total variance, respectively). Morphological knowledge did not significantly predict spelling (3.8% of the total variance). None of the interaction terms contributed significant unique variance to the model (6.8% of the total variance).

Table 3.5. Multiple Regression Model with Interaction Effects

	B	SE B	β	t	p
Control Variables					
Age in months	-.058	.058	-.095	-.997	.323
Nonverbal IQ	-.019	.074	-.021	-.254	.801
Articulation	.382	.215	.130	1.778	.080
Visual Memory	.056	.035	.117	1.617	.111
Group	3.498	1.650	.230	2.120	.038
Predictor Variables					
Phonological Processing	5.147	1.640	.488	3.139	.003
Morphological Knowledge	2.241	1.459	.285	1.536	.130
Orthographic Knowledge	3.960	.976	.451	4.059	.000
Interactions					
PP x group	-2.067	2.297	-.130	-.900	.372
MK x group	1.386	1.723	.116	.804	.424
OK x group	-2.067	1.493	-.193	-1.665	.101

Note. R^2_{adj} = .696 (p < .001)

Discussion

Study 2 extended the investigation of Study 1 to examine concurrently the relative contributions of phonological processing, morphological knowledge, and orthographic knowledge to spelling performance of children with SLI in the elementary grades. Because children with SLI exhibit deficits in spoken language, it was hypothesized that they would also exhibit deficits in spelling and that linguistic knowledge would predict spelling differently from children with typical language.

Not surprisingly and consistent with previous investigations (e.g., Bishop &

Adams, 1990; Young et al., 2002), children with SLI spelled significantly fewer words

correctly than children with typical language in the present investigation. Of particular

interest was the relative contribution of three types of linguistic knowledge implicated in

spelling development, phonological processing, morphological knowledge, and

orthographic knowledge, to spelling performance for children with SLI.

Overall, the multiple regression model for children with SLI explained almost 70%

of the variance in spelling performance. Combined the linguistic variables accounted for

39.1% of the total variance, indicating that for children with SLI (like children with typical

language) linguistic knowledge is a strong predictor of spelling performance. The only

unique linguistic predictor of spelling for children with SLI was, somewhat surprisingly,

morphological knowledge, accounting for 17.1% of the total variance. Recall that the

morphological knowledge composite consisted of two measures of derivational

morphology. However, the TWS-4 does not contain any words that contain more than

one morpheme until well beyond the average raw score of the children with SLI. Thus, it

appears that morphological knowledge predicts spelling performance for children with

SLI (as with the children with typical language in Study 1) even when they are spelling

only base words. An alternate explanation may be that derivational morphological

knowledge is a proxy for overall language skill; perhaps children who are more

proficient at using derivational morphology in spoken language simply have better

language skills than children with poorer derivational morphological knowledge.

However, derivational morphological knowledge was not correlated with overall

language skill for children with SLI (r = .066 and .192). An interesting question for future

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research is how exactly children use derivational morphological knowledge to spell words that do not contain derivational morphology.

In contrast to morphological knowledge, the contributions of phonological processing and orthographic knowledge to spelling were not significant for children with SLI. Children with SLI are more likely to produce phonologically inaccurate spellings than children with typical language (e.g., Mackie & Dockrell, 2004; Silliman et al., 2006). Taken together with the findings of the present investigation, the growing literature base on spelling errors of children with SLI suggests that children with SLI may be less able than children with typical language to correctly analyze the phonological structure of words and accurately pair sounds with plausible letters. Based on previous research that indicated that orthographic pattern knowledge may be a relative strength in linguistic knowledge for children with SLI (e.g., Mackie & Dockrell, 2004; Silliman et al., 2006), it was somewhat surprising that orthographic knowledge did not contribute significant variance to the spelling of children with SLI. Future research should further elucidate the relation of orthographic knowledge and spelling performance for children with SLI.

Previous research suggested that children with SLI utilize at least some linguistic knowledge differently from children with typical language (although no research had considered the linguistic variables in this investigation concurrently); these findings led us to hypothesize that we would find differences in relative contribution of each linguistic variable to spelling between groups. However, contrary to our hypothesis, interactions of linguistic variables and language group status were not significant.

Although the interactions were not significant, an examination of the relative contribution of each linguistic variable to spelling for each group individually suggests that there may be some differences that were not captured by our overall multiple regression interaction model. As reported in Study 1, control variables (i.e., age, nonverbal intelligence, articulation, and visual memory) accounted for 10.8% of the total variance and none of the control variables contributed significant unique variance to the spelling performance of children with typical language. In contrast, control variables accounted for 32.1% of the total variance for children with SLI, and articulation contributed significant unique variance to the spelling performance of children with SLI (17.4% of the total variance). Thus, children with SLI may rely more on nonlinguistic skills when they spell than children with typical language. Differences between children with SLI and children with typical language in the relative contribution of orthographic knowledge were also observed (10.6% and 22.5% of the variance, respectively). For children with SLI, orthographic knowledge did not contribute unique variance to spelling. As previously discussed, one possible explanation for this is that children with SLI have fewer stored MGRs than children with typical language and that MGR storage, and not orthographic pattern knowledge, drives differences in spelling performance. The relative contributions of phonological processing and morphological knowledge were similar for children with SLI and children with typical language (phonological processing: 10.5% and 11.4%, morphological knowledge: 17.1% and 15.5%, respectively).

Implications for Teaching Spelling to Children with SLI

At least some types of linguistic knowledge predict spelling for children with SLI, yet typical spelling instruction does not guide children to explicitly connect spoken and written language (for a review, see Schlagal, 2002). Because children with SLI are less accurate at spelling words, particular attention on how to effectively teach spelling to this population is warranted. Future research should evaluate empirically the effectiveness of linguistic spelling instruction for children with SLI. Spelling instruction for children with SLI should focus on improving linguistic knowledge that is used by children with typical language to spell words and explicitly teaching children about the links between spoken and written language.

Limitations

The results of this investigation should be interpreted with the following limitations in mind. First, the sample size limited our ability to explore the unique contributions of linguistic knowledge to spelling of children with SLI in specific grades. Future research should explore possible between grade differences in children's use of linguistic knowledge for spelling. One method could be to follow the same group of children with SLI over time, beginning in preschool through the school age years to determine what types of linguistic knowledge are used for spelling throughout development. Such knowledge could greatly inform how to individualize spelling instruction and intervention for children with SLI. Second, it is possible that our sample of children with SLI is skewed toward children with more severe language impairment. We recruited children with SLI through school speech-language pathologists. Therefore,

all the children in the present investigation were identified and receiving language

services through school systems. Tomblin et al. (1997) reported that only 29% of

kindergarten children identified as SLI in an epidemiological study had been identified

by early intervention or school systems; a greater percentage of identified children

scored below two standard deviations below the mean than above. Finally, some of the

constructs studied in this investigation are not well defined in the extant literature. For

example, RAN tasks that involve naming letters and numbers are related to spelling

performance in children with typical language but tasks that involve naming colors and

objects are not (Savage et al., 2008). However, all RAN tasks should measure the

efficiency with which an individual can retrieve phonological codes from long-term

memory (Wagner et al., 1993). Therefore, it is unclear why retrieving phonological

codes for letters and numbers should differ from retrieving phonological codes for colors

and numbers. It may be that alphanumeric tasks measure orthographic knowledge in

addition to phonological processing. Future research should further explore the

construct validity of RAN tasks.

Conclusions

At least some areas of linguistic knowledge predict spelling for children with SLI

in the elementary grades. Only morphological knowledge contributed unique variance to

spelling performance; the contributions of phonological processing and orthographic

knowledge, despite explaining approximately 10% of the total variance each, were not

significant. Interaction effects of linguistic variables and language group status were not

significant, although examination of the individual models for children with SLI and

children with typical language revealed differences in the types of knowledge that predicted spelling by each group. The results suggest that spelling instruction should tap children's linguistic knowledge and explicitly relate their linguistic knowledge to spelling. It may be necessary to teach spelling to children with language impairment using different approaches than those used to teach children with typical language.

CHAPTER IV

GENERAL DISCUSSION

The present investigation was the first to examine concurrently the relative

contributions of phonological processing, morphological knowledge, and orthographic

knowledge to spelling performance of children with SLI and children with typical

language in the elementary grades. In addition, the present investigation improves on

the extant literature by controlling for nonverbal intelligence, articulation, and visual

memory in addition to age when considering the effects of linguistic knowledge on

spelling. The results of the investigation indicated that linguistic knowledge predicts

spelling in children in the elementary grades. Specifically for children with typical

language, orthographic knowledge and morphological knowledge contributed unique

variance to spelling. Phonological processing did not contribute unique variance. For

children with SLI, the only significant unique linguistic predictor of spelling was

morphological knowledge. Phonological processing and orthographic knowledge did not

contribute unique variance to spelling for children with SLI.

Contribution of Linguistic Knowledge to Spelling of

Children with Typical Language

The multiple regression model for children with typical language in Study 1

explained almost 60% of the variance. Combined, the linguistic variables accounted for

48.5% of the total variance. In contrast to the philosophy that drives much spelling

instruction, visual memory did not contribute unique variance to spelling (only about 3%).

Orthographic knowledge was a significant predictor of spelling performance in children in the elementary grades, accounting for almost 23% of the total variance. Children in the elementary grades increasingly understand the intricacies of how spoken language units are represented in written language. It is not surprising that orthographic knowledge was the strongest predictor of spelling. Future research should further explore what types of orthographic knowledge are related most robustly to spelling performance in the elementary grades.

In addition to orthographic knowledge, morphological knowledge was also a unique predictor of spelling performance for elementary school children, accounting for almost 16% of the total variance. Interestingly, on the TWS-4 only 20% of words contain more than one morpheme, and the first multimorphemic word occurs at item 26. The mean raw score on the TWS-4 in this investigation was 16.5, well below the first multimorphemic word, and only six children had raw scores above 26. Therefore, the majority of the words that children spelled in this investigation contained only one morpheme. Morphological knowledge predicts spelling in elementary school children, even when words do not contain more than one morpheme.

Finally, phonological processing as a predictor of spelling performance was not statistically significant (p = .06). Despite its prominence in studies investigating the linguistic contributions to spelling performance, the results of this investigation suggest that phonological processing may predict spelling less than other types of linguistic knowledge as children progress in elementary school. As words that children attempt to

spell become more linguistically complex, perhaps other types of linguistic knowledge

influence their spellings and the influence of phonological processing is not as

prominent as in the preschool and kindergarten years (e.g., Read, 1971). A longitudinal

empirical investigation of the relative contributions of the three types of linguistic

knowledge over time beginning in the preschool years could test this hypothesis.

Contribution of Linguistic Knowledge to Spelling in Children with SLI

Study 2 extended the investigation of Study 1 to examine concurrently the

relative contributions of phonological processing, morphological knowledge, and

orthographic knowledge to spelling performance of children with SLI in the elementary

grades. Because children with SLI exhibit deficits in spoken language, it was

hypothesized that they would also exhibit deficits in spelling and that linguistic

knowledge would predict spelling differently than in children with typical language.

Not surprisingly and consistent with previous investigations (e.g., Bishop &

Adams, 1990; Young et al., 2002), children with SLI spelled significantly fewer words

correctly than children with typical language in the present investigation. Of particular

interest in Study 2 was the relative contribution to spelling performance of three types of

linguistic knowledge implicated in spelling development, phonological processing,

morphological knowledge, and orthographic knowledge, for children with SLI.

Overall, the multiple regression model for children with SLI explained almost 70%

of the variance in spelling performance. For children with SLI, unlike children with typical

language, articulation contributed unique variance to spelling (17.4%). This finding

indicates that speech sound production influences spelling in children with SLI but not

children with typical language. Combined the linguistic variables accounted for 39.1% of the total variance, indicating that linguistic knowledge is a strong predictor of spelling in children with SLI (like children with typical language). The only significant linguistic predictor of spelling for children with SLI was, somewhat surprisingly, morphological knowledge, accounting for 17.1% of the total variance. Recall that the morphological knowledge composite consisted of two measures of derivational morphology. However, the TWS-4 does not contain any words that contain more than one morpheme until well beyond the average raw score of the children with SLI. It appears that, as with the children with typical language in Study 1, morphological knowledge predicts spelling in children with SLI, even when they are spelling only base words. An alternate explanation may be that derivational morphological knowledge is a proxy for overall language skill; perhaps children who are more proficient at using derivational morphology in spoken language simply have better language skills than children with poorer derivational morphological knowledge. However, derivational morphological knowledge was not correlated with overall language skill for children with SLI ($r = .066$ and $.192$). An interesting question for future research is how exactly children use derivational morphological knowledge in spelling words that do not contain derivational morphology.

In contrast to morphological knowledge, the contributions of phonological processing and orthographic knowledge to spelling were not significant for children with SLI. Children with SLI are more likely to produce phonologically inaccurate spellings than children with typical language (e.g., Mackie & Dockrell, 2004; Silliman et al., 2006). Taken together with the findings of the present investigation, the growing literature base

on spelling errors of children with SLI suggests that children with SLI are less able than children with typical language to correctly analyze the phonological structure of words and accurately pair sounds with plausible letters. Based on previous research that indicated that orthographic pattern knowledge may be a relative strength for children with SLI (e.g., Mackie & Dockrell, 2004; Silliman et al., 2006), it was somewhat surprising that orthographic knowledge did not contribute significant variance to the spelling of children with SLI. However children with SLI recognized, on average, 10 fewer conventional word spellings than children with typical language (d = .70). The effect sizes for measures of orthographic pattern knowledge were less robust. Perhaps by the early elementary grades, spelling depends more on stored MGRs than orthographic pattern knowledge. It is also possible that the orthographic pattern knowledge measures were not sufficiently difficult to capture the full range of orthographic pattern knowledge in second through fourth grades. Future research should further elucidate the relation of orthographic knowledge and spelling performance.

Previous research suggested that at least some linguistic knowledge predicts spelling performance differently for children with SLI than children with typical language (although no research had considered the linguistic variables in this investigation concurrently); these findings led us to hypothesize that we would find differences in relative contribution of each linguistic variable to spelling between groups. However, contrary to our hypothesis, interactions of linguistic variables and language group status were not significant.

Although the interactions were not significant, an examination of the relative contribution of each linguistic variable to spelling for each group individually suggests that there may be some differences that were not captured by our overall multiple regression interaction model. As reported in Study 1, control variables (i.e., age, nonverbal intelligence, articulation, and visual memory) accounted for 10.8% of the total variance and none of the control variables contributed significant unique variance to the spelling performance of children with typical language. In contrast, control variables accounted for 32.1% of the total variance for children with SLI, and articulation contributed significant unique variance to the spelling performance of children with SLI (17.4% of the total variance). Thus, children with SLI may rely more on nonlinguistic cues when they spell. Differences between children with SLI and children with typical language in the relative contribution of orthographic knowledge were also observed (10.6% and 22.5% of the variance, respectively). For children with SLI, orthographic knowledge did not contribute unique variance to spelling. As previously discussed, one possible explanation for this is that children with SLI have fewer stored MGRs than children with typical language and that MGR storage, and not orthographic pattern knowledge, drives differences in spelling performance. The relative contributions of phonological processing and morphological knowledge were similar for children with SLI and children with typical language (phonological processing: 10.5% and 11.4%, morphological knowledge: 17.1% and 15.5%, respectively).

Importance of Selecting Appropriate Tasks to Measure Linguistic Knowledge

The findings of Study 1 differ from those presented by Apel et al. (2012). Apel et al. reported that morphological knowledge was the only unique predictor of spelling performance in second and third graders. However, their measure of morphological knowledge was not a pure measure of morphological knowledge but also measured orthographic and possibly phonological knowledge. To receive credit for an item on the Apel et al. task, children had to either correctly spell or phonologically represent a derived morpheme. With this scoring system, it would be possible to successfully complete this task without utilizing morphological knowledge at all. Children could simply analyze the phonological structure of words and represent the final sounds with orthographically plausible letters. Other researchers have opted for oral, and not written, measures of morphological knowledge (e.g., Plaza & Cohen, 2004; Walker & Hauerwas, 2006). The use of oral tasks helps ensure that researchers actually measure the construct of morphological knowledge and do not tap orthographic and/or phonological knowledge. Those types of linguistic knowledge likely were being tapped to provide correct responses on the measure. In the present investigation, morphological knowledge was measured in the oral modality. Conclusions drawn from written measures of morphological knowledge are problematic because those measures do not isolate morphological knowledge, whereas we believe oral measures of morphological knowledge do.

Implications for Teaching Spelling to Children with Typical Language

The findings of Study 1 add to a growing body of literature that indicates that linguistic knowledge predicts spelling in elementary school children. Thus, there is reason to believe that spellings are "figured out" to a greater extent than simply memorized. However, teaching practices still focus primarily on memorization of spelling words with little attention to the linguistic structure of words. The findings of this study lead us to hypothesize that spelling instruction that teaches children to analyze the linguistic structure of words (i.e., phonological, morphological, and orthographic) and explicitly relates linguistic structure to spelling will be more effective than spelling instruction that places the primary emphasis on visual memory. Limited research on the effectiveness of linguistic spelling intervention suggests that it is more effect than spelling instruction based on visual memory (e.g., Hall et al., 1995; Joseph, 2000). Future research should study in more detail the types of linguistic knowledge that should be included in spelling instruction.

Implications for Teaching Spelling to Children with SLI

Linguistic knowledge predicts spelling in children with SLI, yet typical spelling instruction does not guide children to explicitly connect spoken and written language (for a review, see Schlagal, 2002). Because children with SLI are less accurate at spelling words, particular attention on how to effectively teach spelling to this population is warranted. Although interactions of group of linguistic knowledge composites were not significant, differences were observed in an examination of the linguistic knowledge predictors of spelling in the multiple regression models for the two groups. These

potential differences need to be better elucidated. Future research should evaluate empirically the effectiveness of linguistic spelling instruction for children with SLI. Spelling instruction for children with SLI should focus on improving linguistic knowledge that is used by children with typical language to spell words and explicitly teaching children about the links between spoken and written language.

Limitations

The results of this investigation should be interpreted with the following limitations in mind. First, the small sample size limited our ability to explore the unique contributions of linguistic knowledge to spelling of children with typical language and children with SLI across grades. Walker and Hauerwas (2006) found differential linguistic contributions to the spelling of inflected verb endings for first, second, and third graders. It is possible that linguistic knowledge also influences general spelling differently across grades. Future research should explore possible between grade differences in the contribution of linguistic knowledge to spelling. A longitudinal study that follows the same group of children over time, beginning in preschool through the school age years could determine what types of linguistic knowledge are used for spelling throughout development. Such knowledge could greatly inform spelling instruction and intervention. Second, we recruited children with SLI through school speech-language pathologists. Therefore, all the children in the present investigation were identified and receiving language services through school systems. Tomblin et al. (1997) reported that only 29% of kindergarten children identified as SLI in an epidemiological study had been identified by early intervention or school systems.

Children with more severe language impairment were more likely to have been identified as SLI. It is possible that our sample of children with SLI is skewed toward children with more severe language impairment. Third, it is possible that other types of linguistic knowledge (e.g., vocabulary) influence spelling ability. Future studies should evaluate this possibility. Fourth, this study did not evaluate individually the subcomponent skills that formed each linguistic composite. Future studies should evaluate the subcomponent individually to identify specific skills to focus on for teaching. Finally, some of the constructs studied in this investigation are not well defined in the extant literature. For example, RAN tasks that involve naming letters and numbers are related to spelling performance in children with typical language but tasks that involve naming colors and objects are not (Savage et al., 2008). However, all RAN tasks should measure the efficiency with which an individual can retrieve phonological codes from long-term memory (Wagner et al., 1993). Therefore, it is unclear why retrieving phonological codes for letters and numbers should differ from retrieving phonological codes for colors and numbers. It may be that alphanumeric tasks measure orthographic knowledge in addition to phonological processing. Future research should further explore the construct validity of RAN tasks.

Conclusions

Linguistic knowledge predicts spelling for children with typical language and children with SLI in the elementary grades. For children with typical language, orthographic knowledge and morphological knowledge contributed unique variance to spelling performance. For children with SLI, only morphological knowledge contributed

unique variance to spelling performance; the contributions of phonological processing and orthographic knowledge were not significant. Interaction effects of linguistic variables and language group status were not significant, although examination of the individual models for children with SLI and children with typical language revealed differences in the types of knowledge that predicted spelling for each group. The results of this investigation add to a growing body of evidence that linguistic knowledge influences literacy development, including spelling as well as reading. Spelling instruction should tap children's linguistic knowledge and explicitly relate their linguistic knowledge to spelling. It may be necessary to teach spelling to children with language impairment using different approaches than those used to teach children with typical language.

REFERENCES

Anthony, J., & Lonigan, C. (2004). The nature of phonological awareness: Converging evidence from four studies of preschool and early grade school children. *Journal of Educational Psychology, 96*, 43-55.

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools, 42*, 592-603.

Apel, K., Fowler-Wilson, E., Brimo, D., & Perrin, N. (2012). Metalinguistic contributions to reading and spelling in second and third grade students. *Reading and Writing, 25*, 1283-1305.

Apel, K., Wolter, J., & Masterson, J. (2006). Effects of phonotactic and orthotactic probabilities during fast mapping on 5-year-olds' learning to spell. *Developmental Neuropsychology, 29*, 21-42.

Baddeley, A., & Hitch, G. (1994). Developments in the concept of working memory. *Neuropsychology, 8*, 485-493.

Bear, D., Invernizzi, M., Templeton, S., & Johnston, F. (2011). *Words their way: Word study for phonics, vocabulary, and spelling instruction* (5th ed.). New Jersey: Prentice Hall.

Bedore, L., & Leonard, L. (1998). Specific language impairment and grammatical morphology: A disciminant function. *Journal of Speech, Language, and Hearing Research, 41*, 1185-1192.

Berninger, V., Abbott, R., Nagy, W., & Carlisle, J. (2010). Growth in phonological, orthographic, and morphological awareness in grades 1 to 6. *Journal of Psycholinguistic Research, 39*, 141-163.

Bishop, D., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders, and reading achievement. *Journal of Child Psychology and Psychiatry, 31*, 1027-1050.

Bishop, D., McDonald, D., Bird, S., & Hayiou-Thomas, M. (2009). Children who read words accurately despite language impairment: Who are they and how do they do it? *Child Development, 80*, 593-605.

Bosman, A. (1997). Why spelling is more difficult than reading. In C. A. Perfetti, L. Reiben & M. Fayol (Eds.), *Learning to spell: Research, theory and practice across languages* (pp. 173-194). Hillsdale, NJ: Erlbaum.

Boudreau, D., & Hedberg, N. (1999). A comparison of early literacy skills in children with specific language impairment and their typically developing peers. *American Journal of Speech-Language Pathology, 8*, 249-260.

Bourassa, D., & Treiman, R. (2001). Spelling development and disability: The importance of linguistic factors. *Language, Speech, and Hearing Services in Schools, 32*, 172-181.

Bradley, L., & Bryant, P. (1981). Visual memory and phonological skills in reading and spelling backwardness. *Psychological Research, 43*, 193-199.

Bradley, L., & Bryant, P. (1983). Categorizing sounds and learning to read: A causal connection. *Nature, 301*, 419-421.

Briscoe, J., Bishop, D., & Norbury, C. (2001). Phonological processing, language, and

    literacy: A comparison of children with mild-to-moderate sensorineural hearing

    loss and those with specific language impairment. *Journal of Child Psychology*

    and Psychiatry, 42, 329-340.

Brown, L., Sherbenou, R., & Johnsen, S. (2010). *Test of Nonverbal Intelligence* (4th

    ed.). Austin, TX: Pro-Ed.

Caravolas, M., Hulme, C., & Snowling, M. (2001). The foundations of spelling ability:

    Evidence from a 3-year longitudinal study. *Journal of Memory and Language, 45*,

    751-774.

Carlisle, J. (2000). Awareness of the structure and meaning of morphologically complex

    words: Impact on reading. *Reading and Writing, 12*, 169-190.

Cassar, M., & Treiman, R. (1997). The beginnings of orthographic knowledge:

    Children's knowledge of double letters in words. *Journal of Educational*

    Psychology, 89, 631-644.

Catts, H. (1993). The relationship between speech-language impairments and reading

    disabilities. *Journal of Speech and Hearing Research, 36*, 948-958.

Catts, H., Adlof, S., Hogan, T., & S. Ellis Weismer. (2005). Are specific language

    impairment and dyslexia distinct disorders? *Journal of Speech, Language, and*

    Hearing Research, 48, 1378-1396.

Catts, H., Fey, M., Tomblin, J. B., & Zhang, X. (2002). A longitudinal investigation of

    reading outcomes in children with language impairments. *Journal of Speech,*

    Language, and Hearing Research, 45, 1142-1157.

Catts, H., Fey, M., Zhang, X., & Tomblin, J. (1999). Language basis of reading and
reading disabilities: Evidence from a longitudinal investigation. *Scientific Studies
of Reading, 3*, 331-361.

Cordewener, K., Bosman, A., & Verhoeven, L. (2012). Characteristics of early spelling
of children with specific language impairment. *Journal of Communication
Disorders, 45*, 212-222.

Crystal, D. (2005). *How language works: How babies babble, words change meaning,
and languages live or die*. New York, NY: The Overlook Press.

Ehri, L. (2000). Learning to read and learning to spell: Two sides of a coin. *Topics in
Language Disorders, 20*, 19-36.

Ehri, L., & Wilce, L. (1982). Recognition of spellings printed in lower and mixed case:
Evidence for orthographic images. *Journal of Reading Behavior, 14*, 219-230.

Frith, U. (1980). Unexpected spelling problems. In U. Frith (Ed.), *Cognitive Processes in
Spelling* (pp. 495-515). New York, NY: Academic Press.

Fudala, J. (2000). *Arizona Articulation Proficiency Scale* (3rd ed.). Torrance, CA:
Western Psychological Services.

Hall, D., Cunningham, P., & Cunningham, J. (1995). Multilevel spelling instruction in
third-grade classrooms. In K. Hinchman, D. Leu & C. Kinzer (Eds.), *Perspectives
on Literacy Research and Practice* (pp. 384-389). Chicago: National Reading
Conference.

Hannam, R., Fraser, H., & Byrne, B. (2006). The sbelling of sdops: Preliterate children's
spelling of stops after /s/. *Reading and Writing, 20*, 399-412.

Hilte, M., & Reitsma, P. (2006). Spelling pronunciation and visual preview both facilitate learning to spell irregular words. *Annals of Dyslexia, 56*, 301-318.

Holmes, V., Malone, A., & Redenbach, H. (2008). Orthographic processing and visual sequential memory in unexpectedly poor spellers. *Journal of Research in Reading, 31*, 136-156.

Huey, E. (1901). On the psychology and physiology of reading. *The American Journal of Psychology, 12*, 292-312.

Invernizzi, M., Meier, J., & Juel, C. (2003). *Phonological Awareness and Literacy Screening: 1-3*. Charlottesville, VA: Virginia State Department of Education and University of Virginia.

Joffe, V. (1998). Rhyming and related skills in children with specific language impairment. *Current Psychology of Cognition, 17*, 479-512.

Joseph, L. (2000). Developing first graders' phonemic awareness, word identification, and spelling: A comparison of two contemporary phonic instructional approaches. *Literacy Research and Instruction, 39*, 160-169.

Juul, H., & Sigurdsson, B. (2005). Orthography as a handicap? A direct comparison of spelling acquisition in Danish and Icelandic. *Scandinavian Journal of Psychology, 46*, 263-272.

Kamhi, A., & Hinton, L. (2000). Explaining individual differences in spelling ability. *Topics in Language Disorders, 20*, 37-49.

Kamhi, A., Lee, R., & Nelson, L. (1985). Word, syllable, and sound awareness in language-disordered children. *Journal of Speech and Hearing Disorders, 50*, 207-212.

Kroese, J., Hynd, G., Knight, D., Hiemenz, J., & Hall, J. (2000). Clinical appraisal of

    spelling ability and its relationship to phonemic awareness (blending,

    segmenting, elision and reversal), phonological memory and reading in reading

    disabled, ADHD and normal children. *Reading and Writing: An Interdisplinary*

    Journal, 13, 105-131.

Larsen, S., Hammill, D., & Moats, L. (1999). *Test of Written Spelling* (4th ed.). Austin,

    TX: Pro-Ed.

Leonard, L., Eyer, J., Bedore, L., & Grela, B. (1997). Three accounts of the grammatical

    morpheme difficulties of English-speaking children with specific language

    impairment. *Journal of Speech, Language, and Hearing Research, 40*, 741-753.

Leong, C. (2000). Rapid processing of base and derived forms of words and grades 4,

    5, and 6 children's spelling. *Reading and Writing, 12*, 277-302.

Mackie, C., & Dockrell, J. (2004). The nature of written language deficits in children with

    SLI. *Journal of Speech, Language, and Hearing Research, 47*, 1469-1480.

Markwardt, F. (1998). *Peabody Individual Achievement Test-Revised/Normative*

    Update. Circle Pines, MN: American Guidance Service, Inc.

Marshall, C., & van der Lely, H. (2007). Derivational morphology in children with

    grammatical-specific language impairment. *Clinical Linguistics & Phonetics, 21*,

    71-91.

Mattingly, I. (1972). Reading, the linguistic process, and linguistic awareness. In J.

    Kavanagh & I. Mattingly (Eds.), *Language by ear and by eye: The relationships*

    between speech and reading (pp. 133-147). Cambridge, MA: MIT Press.

Moats, L. (1995). *Spelling: Development, disability, and instruction*. Baltimore, MD: York Press.

Nagy, W., Berninger, V., & Abbott, R. (2006). Contributions of morphology beyond phonology to literacy outcomes of upper elementary and middle-school students. *Journal of Educational Psychology, 98*, 134-147.

Oetting, J., & Horohov, J. (1997). Past-tense marking by children with and without specific language impairment. *Journal of Speech and Hearing Research, 40*, 62-74.

Ouellette, G., & Senechal, M. (2008). A window into early literacy: Exploring the cognitive and linguistic underpinnings of invented spelling. *Scientific Studies of Reading, 12*, 195-219.

Perfetti, C. (1997). The psycholinguistics of spelling and reading. In C. Perfetti, L. Reieben & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages*. Mahweh, NJ: Lawrence Erlbaum.

Plaza, M., & Cohen, H. (2003). The interaction between phonological processing, syntactic awarenss, and naming speed in the reading and spelling performance of first-grade children. *Brain and Cognition, 53*, 287-292.

Plaza, M., & Cohen, H. (2004). Predicitive influence of phonological processing, morphological/syntactic skill, and naming speed on spelling performance. *Brain and Cognition, 55*, 368-373.

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

Read, C. (1986). *Children's creative spelling*. London: Routledge & Kegan Paul.

Reeds, J., & Wang, W. (1961). The perception of stops after /s/. *Phonetica, 6*, 78-81.

Rice, M., & Wexler, K. (1996). Toward tense as a clinical marker of specific language impairment in English-speaking children. *Journal of Speech and Hearing Research, 39*, 1239-1257.

Rice, M., Wexler, K., & Hershberger, S. (1998). Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 41*, 1412-1431.

Savage, R., Frederickson, N., Goodwin, R., Patni, U., Smith, N., & Tuersley, L. (2005). Relationships among rapid digit naming, phonological processing, motor automaticity, and speech perception in poor, average, and good readers and spellers. *Journal of Learning Disabilities, 38*, 12-28.

Savage, R., Pillay, V., & Melidona, S. (2008). Rapid serial naming is a unique predictor of spelling in children. *Journal of Learning Disabilities, 41*, 235-250.

Schlagal, B. (2002). Classroon spelling instruction: History, research, and practice. *Reading Research and Instruction, 42*, 44-57.

Schwartz, S., & Doehring, D. (1977). A developmental study of children's ability to acquire knowledge of spelling patterns. *Developmental Psychology, 13*, 419-420.

Semel, E., Wiig, E., & Secord, W. (2003). *Clinical Evaluation of Language Fundamentals* (4th ed.). San Antonio, TX: The Psychological Corporation.

Sheslow, D., & Adams, W. (2001). *Wide Range Assessement of Memory and Learning* (2nd ed.). Lutz, FL: Psychological Assessment Resources, Inc.

Shriberg, L., Tomblin, J., & McSweeny, J. (1999). Prevalence of speech delay in 6-year-old children and comorbidity with language impairment. *Journal of Speech, Language, and Hearing Research, 42*, 1461-1481.

Silliman, E., Bahr, R., & Peters, M. (2006). Spelling patterns in preadolescents with atypical language skills: Phonological, morphological, and orthographic factors. *Developmental Neuropsychology, 29*, 93-123.

Stahl, S., & Murray, B. (1994). Defining phonological awareness and its relationship to early reading. *Journal of Educational Psychology, 86*, 221-234.

Stothard, S., Snowling, M., Bishop, D., Chipchase, B., & Kaplan, C. (1998). Language-impaired preschoolers: A follow-up into adolescence. *Journal of Speech, Language, and Hearing Research, 41*, 407-418.

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

Thatcher, K. (2010). The development of phonological awareness with specific language-impaired and typical children. *Psychology in the Schools, 47*, 467-480.

Tomblin, J., Records, N., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research, 40*, 1245-1260.

Treiman, R. (1991). Children's spelling errors on syllable-initial consonant clusters. *Journal of Educational Psychology, 83*, 346-360.

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

Treiman, R., & Cassar, M. (1996). Effects of morphology on children's spelling of final

       consonant clusters. *Journal of Experimental Child Psychology, 63*, 141-170.

Treiman, R., Cassar, M., & Zukowski, A. (1994). What types of linguistic information do

       children use in spelling? The case of flaps. *Child Development, 65*, 1318-1337.

Venezky, R. (1999). *The American way of spelling: The structure and origins of*

       American English orthography. New York, NY: Guilford Press.

Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its

       causal role in the acquisition of reading skills. *Psychological Bulletin, 101*, 192-

       212.

Wagner, R., Torgesen, J., Laughon, P., Simmons, K., & Rashotte, C. (1993).

       Development of young readers' phonological processing abilities. *Journal of*

       Educational Psychology, 85, 83-103.

Wagner, R., Torgesen, J., & Rashotte, C. (1999). *Comprehensive Test of Phonological*

       Processing. Austin, TX: Pro-Ed.

Wagovich, S., Pak, Y., & Miller, M. (2012). Orthographic word knowledge growth in

       school-age children. *American Journal of Speech Language Pathology, 21*, 140-

       153.

Walker, J., & Hauerwas, L. (2006). Development of phonological, morphological, and

       orthographic knowledge in young spellers: The case of inflected verbs. *Reading*

       and Writing, 19, 819-843.

Werfel, K., & Schuele, C. M. (2012). Segmentation and representation of consonant

       blends in kindergarten children's spellings. *Language, Speech, & Hearing*

       Services in Schools, 43, 292-307.

Windsor, J., & Hwang, M. (1997). Knowledge of derivational suffixes in students with

      language learning disabilities. *Annals of Dyslexia, 47*, 57-68.

Windsor, J., & Hwang, M. (1999). Derivational suffix productivity for students with and

      without language-learning disabilities. *Journal of Speech, Language, and Hearing*

      Research, 42, 220-230.

Wolf, M., & Bowers, P. (1999). The double-deficit hypothesis for the developmental

      dyslexias. *Journal of Educational Psychology, 91*, 415-438.

Wolter, J., & Apel, K. (2010). Initial acquisition of mental graphemic representations in

      children with language impairment. *Journal of Speech, Language, and Hearing*

      Research, 53, 179-195.

Young, A., Beitchman, J., Johnson, C., Douglas, L., Atkinson, L., Escobar, M., & Wilson,

      B. (2002). Young adult academic outcomes in a longitudinal sample of early

      identified language impaired and control children. *Journal of Child Psychology*

      and Psychiatry, 43, 635-645.