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Research Article

Linguistic Contributions to Word-Level Spelling Accuracy in Elementary School Children With and Without Specific Language Impairment

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Purpose: Children with specific language impairment (SLI) are more likely than children with typical language (TL) to exhibit difficulties in word-level spelling accuracy. More research is needed to elucidate the contribution of linguistic knowledge to word-level spelling accuracy in this population. The purpose of this study was to explore the contributions of linguistic knowledge to spelling accuracy in a group of 2nd- to 4th-grade children with SLI and a group of 2nd- to 4th-grade children with TL.
Method: Participants were 32 children with SLI and 32 children with TL in Grades 2 through 4. Five areas of linguistic knowledge were assessed: phonological awareness, morphological knowledge, orthographic pattern knowledge, mental grapheme representation knowledge, and vocabulary knowledge. Mixed-effects logistic regression models were utilized to address the research aim.
Results: Mental grapheme representation knowledge was selected as a significant predictor in both models; however, phonological awareness was the only additional significant predictor in the model for children with SLI, whereas morphological knowledge was the only other significant predictor in the model for children with TL. Orthographic pattern knowledge and vocabulary knowledge were not significant for either group.
Conclusions: The results suggest that spelling instruction and intervention for children with SLI should take linguistic knowledge into account and explicitly relate linguistic knowledge to spelling. Additionally, future research should consider if instructional targets for children with SLI should differ from targets for children with TL and if these findings represent a delay or a disorder in spelling acquisition for children with SLI.

Children with specific language impairment[1] (SLI), the most common form of developmental language disorder, are much more likely than children with typical language (TL) to exhibit difficulties in developing literacy skills (e.g., Catts, Fey, Tomblin, & Zhang, 2002). The literacy difficulties of children with SLI are not surprising given the linguistic basis of reading and writing. The evidence base on the word recognition and reading comprehension skills of children with SLI is extensive (e.g., Bishop & Snowling, 2004; Botting, Simkin, & Conti-Ramsden, 2006; Catts, Adlof, Hogan, & Weismer, 2005; Catts et al., 2002; Werfel & Krimm, 2017), but there is far less information on the writing skills of children with SLI. Given the adverse impact of limited writing proficiency on academic success and the links between reading and writing difficulties, there is a critical need for a more extensive, programmatic inquiry into the writing skills of children with SLI.

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[1]We use the term *specific language impairment* (National Institute on Deafness and Other Communication Disorders, 2017) to refer to the most common form of developmental language disorder, in which language skills are affected in children who have normal hearing, nonverbal intelligence in the average or above-average range, and no other developmental delays.

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The current investigation explored the word spelling abilities of children with SLI; two reasons motivated a focus on spelling. First, understanding the spelling skills of children with SLI is critical to providing intervention that leads to proficient written expression. An ability to spell words accurately and with ease strongly influences written expression proficiency. Second, to date, there is an extremely limited evidence base on the word-level spelling skills of children with SLI. Current investigations of spelling in typical learners have emphasized the need to explore the multiple areas of linguistic proficiency that may influence word-level spelling accuracy.

Linguistic Basis of Spelling

Spelling involves encoding units of spoken language into written language. In English, spellings often reflect morphology and morphophonology, as well as orthographic rules, at the expense of surface phonology (Venezky, 1999). Therefore, the present investigation was driven by a linguistic repertoire theoretical approach to spelling development (Apel, Masterson, & Hart, 2004). The linguistic repertoire theory posits that children draw from multiple areas of linguistic knowledge—phonological awareness, morphological knowledge, orthographic pattern knowledge, mental grapheme representation (MGR) knowledge, and vocabulary knowledge—across the developmental period of learning to spell. According to the repertoire theory of spelling, an individual child draws from his or her linguistic knowledge to spell a particular word; the area(s) of linguistic knowledge accessed depends on the individual child's level of linguistic knowledge in that particular area as well as the linguistic structure of the target word.

The roles of phonological processing, morphological knowledge, orthographic pattern knowledge, MGR knowledge, and vocabulary knowledge have been the focus of most studies on the development of English spelling (Bourassa & Treiman, 2001). With few exceptions (e.g., Apel, Wilson-Fowler, Brimo, & Perrin, 2012; Walker & Hauerwas, 2006), these studies have evaluated the role that each type of linguistic knowledge plays in relative isolation. The roles that phonological processing, morphological knowledge, orthographic pattern knowledge, MGR knowledge, and vocabulary knowledge play in spelling are discussed below.

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 an important precursor of spelling ability (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. For example, preschool and early elementary children are more likely to represent voiceless stops on the basis of sound structure than conventional spelling (e.g., sdop for *stop*; sgat for *skate*; Hannam, Fraser, & Byrne, 2006).

Children with SLI exhibit difficulties in phonological awareness skills as compared to children with TL. The mean performance of children with SLI in preschool through adolescence is lower than age- and language-matched TL learners (e.g., Boudreau & Hedberg, 1999; Joffe, 1998; Kamhi, Lee, & Nelson, 1985). Catts et al. (2005) reported that, after second grade, children with SLI who had comorbid word-level reading deficits continued to have deficits in phonological awareness, whereas children with SLI without word-level reading deficits performed comparably on phonological awareness to children with TL. Young et al. (2002) reported that phonological awareness contributes to the spelling proficiency of adolescents with SLI.

Morphological Knowledge

Morphological knowledge is the understanding of the morphological structure of words, that is, base words and affixes, derivational as well as inflectional. There is ample evidence that morphological knowledge influences the spelling proficiency of children with TL (e.g., Apel et al., 2012; Treiman, Cassar, & Zukowski, 1994). For example, elementary school children correctly represent flaps in words that contain two morphemes (e.g., *dirty*) more so than in words that contain only one morpheme (e.g., *city*; Treiman et al., 1994).

There is extensive literature focused on the oral language inflectional morphology deficits of children with SLI, particularly the protracted development of verb morphology (e.g., Leonard, Eyer, Bedore, & Grela, 1997; Oetting & Horohov, 1997; Rice, Wexler, & Hershberger, 1998). The use of inflectional morphology has been studied typically in spontaneous language sample data of children in preschool. The growing literature on derivational morphology involves experimental tasks; children with SLI are less proficient on forced-choice tasks and on elicited marking tasks of derivational morphology in spoken language than age-matched children (Windsor & Hwang, 1999) and language-matched children (Marshall & van der Lely, 2007). Derivational morphology is typically studied in elementary school and beyond.

Orthographic Pattern Knowledge

Orthographic pattern knowledge is one component of orthographic knowledge and involves knowledge of the language-specific rules for how spoken language is represented in print (Apel, 2011). It includes alphabet knowledge, or how phonemes map to graphemes, as well as the constraints on how graphemes are distributed in orthography (e.g., double-consonant graphemes cannot occur at the beginning of words, *stuff* but not *ffat*). Not surprisingly, children who are good spellers have higher levels of orthographic pattern knowledge than children who are poor spellers (e.g., Schwartz & Doehring, 1977).

Relatively little is known about the orthographic pattern knowledge of children with SLI. Orthographic pattern knowledge may be a relative strength in terms of linguistic knowledge for children with SLI; a few studies have demonstrated that children with SLI may possess similar orthographic pattern knowledge as compared to children with TL. For example, Silliman, Bahr, and Peters (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.

MGR Knowledge

The ability to form, store, and access mentally the accurate string of letters, or orthographic representation, of a specific written word is referred to as *MGR knowledge* (Apel, 2011). MGRs can be thought of as the written counterpart of phonemic representations of spoken words. As early as preschool, the ability of children with TL to rapidly store MGRs is related to general spelling skill (Apel, Wolter, & Masterson, 2006), and MGR knowledge is generally considered a linguistic, rather than a visual skill (e.g., Ehri, 2000). MGR knowledge also has been referred to as *orthographic images* (Ehri & Wilce, 1982), *word-specific knowledge* (Reitsma, 1983), and *(stored) orthographic representations* (Conrad, 2008; Ouellette & Senechal, 2008), among other terms.

Children with SLI have less robust MGR knowledge than children with TL. Children with SLI exhibit poorer ability than children with TL to rapidly acquire MGRs (Wolter & Apel, 2010). This poorer ability to form MGRs was related to spelling, but not reading, performance. In a follow-up study, Wolter, Self, and Apel (2011) demonstrated that the relation of the ability to rapidly acquire MGRs and spelling performance in children with SLI remains strong through at least fourth grade.

Vocabulary Knowledge

Vocabulary knowledge refers to knowledge of words and their meanings. Vocabulary knowledge includes the number of words an individual understands and can produce, as well as an individual's ability to learn new words or retrieve known words. Vocabulary knowledge predicts general long-term academic and professional outcomes (Duncan et al., 2007). We focus here on the understanding of words, or receptive vocabulary knowledge. Receptive vocabulary knowledge has been reported to be related to word-level spelling accuracy in some studies of children with TL (Apel et al., 2012), but not others (Apel & Lawrence, 2011).

For children with SLI, impairments of vocabulary knowledge can take the form of smaller vocabulary size, more difficulty learning new words, and difficulty with lexical access and/or retrieval (McGregor, Newman, Reilly, & Capone, 2002). As with children with TL, research on the relation of vocabulary knowledge and word-level spelling abilities of children with SLI has been mixed. Some researchers have reported that vocabulary knowledge predicts spelling in this population (van Weerdenburg, Verhoeven, Bosman, & van Balkom, 2011), whereas other researchers have reported no relation (McCarthy, Hogan, & Catts, 2012). More research is needed to clarify the role of vocabulary knowledge in word-level spelling for children with SLI.

Integration of Linguistic Knowledge in Spelling

Few studies have addressed the concurrent influence of multiple types of linguistic knowledge on the general spelling skills of elementary school children with TL. With few exceptions (e.g., Apel et al., 2012; Walker & Hauerwas, 2006), researchers have evaluated the role that each individual type of linguistic knowledge plays without consideration of the combined influence of these types of linguistic knowledge.

Walker and Hauerwas (2006) evaluated the influence of phonological awareness, morphological knowledge, and orthographic pattern knowledge on first, second, and third graders' spellings of inflected verb endings. 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 by morphological knowledge. However, these findings are limited in what they mean for spelling in general. A very narrow scope of spelling (i.e., inflected verb endings) was evaluated, and there is no basis on which to infer that these findings are meaningful to explain how linguistic skills relate to spelling at large.

Apel et al. (2012) evaluated the influence of phonological awareness, morphological knowledge, orthographic pattern knowledge, and receptive vocabulary on the whole-word spelling performance of second and third graders. Only morphological knowledge was a unique predictor of spelling. However, the morphological knowledge measure in Apel et al. required written responses; thus, this measure potentially tapped orthographic knowledge as well as morphological knowledge, masking the contribution of orthographic knowledge to spelling. Additionally, the phonological awareness task required children only to count phonemes rather than manipulate them, which is a relatively low-level phonemic awareness task for elementary school students. Clearly, more work in the area of the integration of linguistic knowledge in spelling is needed.

Spelling in Children With SLI

Because spelling is dependent on an individual's linguistic knowledge and children with SLI have compromised linguistic abilities, it is reasonable to hypothesize that children with SLI will exhibit difficulties in spelling. Indeed, children with SLI score lower on measures of spelling as compared to children with TL, with effect sizes indicating a large group difference in spelling proficiency (Bishop & Adams, 1990; Young et al., 2002). Much less is known, however, about how linguistic knowledge

predicts English spelling in elementary school children with SLI. Two studies provide preliminary evidence that the linguistic knowledge that predicts spelling in elementary school children with SLI and their peers with TL may differ. Mackie and Dockrell (2004) reported that 9- to 12-year-old 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- and language-matched children with TL. Silliman et al. (2006) reported that spelling errors of 6- to 11-year-old children with SLI demonstrated diffuse difficulty, with equally distributed phonological, morphological, and orthographic errors. In contrast, same-age children with TL primarily exhibited orthographic errors, with fewer errors in the other categories. Such findings lead us to hypothesize that linguistic knowledge may be differentially associated with spelling accuracy across children with SLI and children with TL.

In summary, the small body of research characterizing the spelling performance of children with SLI suggests three findings worthy of further exploration. First, children with SLI are less proficient spellers than peers with TL. Second, the types of linguistic knowledge that predict spelling accuracy may differ for children with SLI and children with TL. Finally, spelling errors of children with SLI differ in nature from errors made by children with TL. These findings call for a systematic exploration of the contributions of linguistic knowledge to spelling accuracy in children with SLI. Because spelling is a linguistic skill and children with SLI have poor spelling achievement compared to peers with TL skills, understanding how linguistic skills underlie word-level spelling accuracy in children with SLI is needed to develop effective spelling interventions for this population. The purpose of this study, therefore, was to explore the contributions of linguistic knowledge to spelling accuracy in a group of second- to fourth-grade children with SLI and a group of second- to fourth-grade children with TL.

Method

All study procedures were approved by the Vanderbilt University Institutional Review Board.

Participants

Participants were recruited from public and private elementary schools in a southeastern U.S. state. Our goal was to recruit a sample of second through fourth graders who met the study criteria for SLI and a group of grade-level peers who did not meet the criteria for SLI. In the public schools, school speech-language pathologists sent consent forms home with children with an individualized education program who received special education services as a student with a speech impairment, language impairment, or specific learning disability. We recruited broadly within these categories because SLI is underidentified in school-age children (Tomblin et al., 1997); 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). Although we recruited broadly within these categories, only children who met the study criteria for SLI were included in the SLI group. In the private schools, the principal or special education director sent consent forms home with children who had language assessment scores from their most recent annual assessment that met our criteria for SLI, as well as children whose teachers and/or parents were concerned about language impairment or specific learning disability. To recruit a sample of grade-level peers, children with TL were recruited from the classrooms of the children with SLI. For each child with SLI, consent forms were sent home to three children in the same classroom who were judged by the teacher to have TL development. Nine children with SLI were recruited from a school for children with language learning disabilities; therefore, children with TL were not recruited from their classrooms. In total, 79 children were consented.

Eligibility

The first step of eligibility determination required that each consented child be verified to speak English as a first language, pass a hearing screening bilaterally, and have nonverbal intelligence in the average or above-average range. Exclusion on the basis of English language status was determined by information derived from school and/or parent report. The first author conducted hearing screenings for each consented child. Children with thresholds above 20 dB HL at 250, 500, 1000, or 2000 Hz in either ear were excluded from participation. Finally, children who received standard scores below 85 on the Test of Nonverbal Intelligence–Fourth Edition (Brown, Sherbenou, & Johnsen, 2010) were excluded. Five children (two referred SLI [one failed the hearing screening, one did not speak English as a first language], three referred grade-level peers [two failed the hearing screening, one did not speak English as a first language]) were excluded from study participation at this first step.

The second step of eligibility required each remaining consented child to complete the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003) for assignment to the SLI participant group or the TL participant group. The CELF-4 (Semel et al., 2003) is an omnibus measure of receptive and expressive language. Participants completed the subtests needed to calculate the Core Language Index: (a) for 7- and 8-year-olds: Concepts & Following Directions, Recalling Sentences, Formulated Sentences, and Word Structure and (b) for 9- and 10-year-olds: Concepts & Following Directions, Recalling Sentences, and Formulated Sentences. Test–retest reliability reported in the test manual is .80–.92 for each subtest. Children assigned to the SLI group received a Core Language Index score below 85, and children assigned to the TL group

received a Core Language Index score of 85 or above on the CELF-4 Core Language Index. Because the recruitment process for children with SLI was broad, children who were referred originally to participate during this process but who had typical oral language and reading scores (i.e., scored within the average range on the CELF-4 Core Language Index and the Woodcock Reading Mastery Tests–Third Edition [Woodcock, 2011]; $n = 9$) became part of the TL participant group. These children overwhelmingly had been served for speech impairment and did not have histories of language difficulties. Two children with persistent speech sound disorder in the TL group were excluded from analysis. Thus, the study included 64 participants—32 children with SLI (M_{age} = 9;4 [years;months], SD = 12 months; eight second graders, 14 third graders, 10 fourth graders; 21 boys, 11 girls) and 32 children with TL (M_{age} = 8;9, SD = 12 months; 12 second graders, 14 third graders, six fourth graders; 18 boys, 14 girls). Chi-square analysis confirmed that the distribution of grade across groups did not differ, $\chi^2(2, N = 64) = 1.80$, $p = .407$.

Procedure

Each participant completed an individually administered assessment battery (described below). Commercially published measures were administered according to published test manuals, with one exception as noted below. Research measures were administered according to instructions published in the cited literature. The majority of data collection was conducted by the first author; doctoral and master's students in speech-language pathology assisted with data collection. Assessment took place at participating schools in a quiet room. The dependent and predictor measures were administered in predetermined randomized orders for each participant. Testing sessions were scheduled for no more than 2 hr at one time. The mean number of testing sessions per participant was 3.4. All testing for individual participants was completed within 1 month.

Dependent Measure

The Test of Written Spelling–Fourth Edition (TWS-4; Larsen, Hammill, & Moats, 1999) evaluates children's ability to formulate spellings of single words, provided as spoken stimuli. The examiner says a word, reads a sentence containing the word, repeats the word, and then asks the child to spell 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 because the ceiling is child specific, the raw score is not derived from the same corpus of words for all children. According to the TWS-4 manual, second and third graders should begin at Item 1, and fourth graders should begin at Item 10. The dependent variable for the primary study analysis was spelling accuracy for each word between the basal and ceiling (coded as 1 or 0) for each participant. To calculate the standard scores reported in Table 1, we determined basals on the basis of standardized administration protocols. Test–retest reliability reported in the test manual is .95.

Predictor Measures

The Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) evaluates phonological processing skills. Of interest in this study was phonological awareness. On the Phonological Awareness subtests, the examiner asks the child to delete syllables or phonemes from words and to blend sounds together to form words. Because multiple subtests of this standardized assessment were administered, the Phonological Awareness composite score served as the phonological awareness predictor variable. Test–retest reliability reported in the test manual is .70–.92.

The Test of Morphological Structure (TMS; Carlisle, 2000) evaluates children's morphological knowledge with two spoken language subtests. In the Derivation subtest, the examiner says a base word and asks the child to complete a sentence that requires a derived form of the given word (e.g., *farm. My uncle is a ____ [farmer]*). In the Decomposition subtest, the examiner says a derived word and asks the child to complete a sentence that requires the base form of the word (e.g., *driver. Children are too young to ____ [drive]*). The raw score for each subtest is the number of correct responses (maximum of 28 each). The TMS raw score (sum of two subtests) served as the morphological knowledge predictor variable. Split-half reliability calculated with the study sample was .91 for Derivation and .93 for Decomposition.

The Orthographic Constraints Test (OCT; Treiman, 1993) evaluates children's orthographic pattern knowledge. The examiner instructs the child to read 16 pairs of nonwords and circle the nonword in each pair that looks more like a real word (e.g., *yinn, yikk [yinn]*). The raw score is the number of correct responses (maximum of 16). The OCT raw score served as the orthographic pattern knowledge predictor variable. Split-half reliability calculated with the study sample was .62.

The Spelling Recognition subtest of the Peabody Individual Achievement Test–Revised/Normative Update (PIAT-R/NU; Markwardt, 1998) evaluates children's visual recognition of conventional spelling of real words (i.e., MGRs). The examiner says a word, uses it in a sentence, and asks the children to select the correct spelling of the word from four phonologically and orthographically plausible choices. It should be noted that, although the PIAT-R/NU subtest is titled "Spelling" because it measures children's ability to select the conventional spelling of a word from four phonologically and orthographically plausible spellings, it is a measure of MGR knowledge and not a measure of formulating word spellings. Masterson and Apel (2000) argued that tasks of MGR knowledge and spelling formulation clearly measure different skills. The raw score was used as the MGR predictor variable. Test–retest reliability is .85–.93.

The Peabody Picture Vocabulary Test–Fourth Edition (Dunn & Dunn, 2007) evaluates children's receptive vocabulary knowledge. The examiner shows the child a page with four pictures and asks the child to point to a target word. The raw score is the number of correct responses

Table 1. Means (*SD*s) of eligibility, dependent, and predictor measures, as well as standard scores for available measures.

Variable	SLI	TL	*p*	*d*
Age in months	112.06 (12.44)	105.19 (12.45)	.031	0.55
Eligibility measures				
TONI-4 standard score	97.81 (8.13)	104.41 (8.76)	**.003**	0.78
CELF-4 Core Language Index	71.53 (9.83)	107.81 (10.21)	**< .001**	3.62
Dependent measures				
TWS-4 raw (max 50)	11.16 (6.36)	18.63 (7.12)	**< .001**	1.11
TWS-4 standard score	84.91 (12.00)	106.50 (16.08)	**< .001**	1.52
Predictor measures				
CTOPP phonological awareness standard score	91.47 (14.16)	110.13 (14.71)	**< .001**	1.30
TMS Derivation subtest raw (max 28)	6.34 (5.00)	14.09 (5.21)	**< .001**	1.52
TMS Decomposition subtest raw (max 28)	10.00 (6.70)	19.69 (5.20)	**< .001**	1.62
OCT raw (max 16)	12.78 (2.39)	13.78 (1.72)	.059	0.48
PIAT-R/NU MGR raw (max 100)	47.97 (13.32)	59.94 (14.62)	**.001**	0.86
PIAT-R/NU MGR standard score	94.38 (12.80)	112.19 (15.20)	**< .001**	1.23
PPVT-4 raw (max 228)	125.59 (17.13)	151.09 (20.12)	**< .001**	1.37
PPVT-4 standard score	87.94 (12.77)	111.69 (15.63)	**< .001**	1.66

Note. Bolded *p* values are significant at $p < .004$. SLI = specific language impairment; TL = typical language; TONI-4 = Test of Nonverbal Intelligence–Fourth Edition; CELF-4 = Clinical Evaluation of Language Fundamentals–Fourth Edition; TWS-4 = Test of Written Spelling–Fourth Edition; CTOPP = Comprehensive Test of Phonological Processing; TMS = Test of Morphological Structure; OCT = Orthographic Constraints Test; PIAT-R/NU = Peabody Individual Achievement Test–Revised/Normative Update; MGR = mental grapheme representation; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition.

(maximum of 228); standard scores were calculated according to test manual instructions. The raw score was used as the vocabulary predictor variable. Test–retest reliability reported in the test manual is .93.

Reliability of Scoring

Testing sessions were audio-recorded to allow the subsequent calculation of reliability of written transcription of child responses on measures that required a verbal response. A research assistant listened to audio-recorded responses for a random selection of 30% of participants and wrote child responses on a clean form without access to the examiner's online transcription of child responses. The first author compared the written responses of the examiner and the research assistant. Reliability was calculated on an item-by-item basis for the scoring of each transcription on each measure for each participant. For each measure, reliability across participants was averaged (TL: CELF-4 94%, CTOPP 99%, TMS 98%; SLI: CELF-4 87%, CTOPP 98%, TMS 95%). Finally, overall reliability for each participant (i.e., on each measure) was calculated and averaged. Mean reliability for accurate online recording of child responses across all tests was 98% for children with TL and 95% for children with SLI. To assure reliability in scoring (each item, sum of points for raw scores, derivation of standard scores from the manual), all test forms were double-scored by a research assistant trained in test scoring. Disagreements, albeit rare, were resolved by mutual consensus, resulting in final agreement of 100%.

Analysis

We utilized two mixed-effects logistic regression models. Logistic regression was selected over linear regression, because each participant spelled a different set of skill-appropriate words. Logistic regression allowed for control of item-level variance. Separate models were fit for children with SLI and children with TL to ensure power to detect significant predictive variables for each group. Each model is described below.

Model 1: To test the association of linguistic knowledge and word-level spelling accuracy of children with TL, we fit a mixed-effects logistic regression model using the lme4 package (Bates, Mäechler, & Bolker, 2015) in the R statistical program (R Core Team, 2015). This model contained 862 observations from only the 32 participants with TL. The dependent variable was the accuracy of each spelling item (1 or 0). The independent variables were selected on the basis of zero-order correlations between the predictor variables and word-level spelling accuracy for children with TL. We included subject and item as random effects, allowing for random intercepts. Moreover, *p* values were obtained using the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2017).[2]

Model 2: To test the association of linguistic knowledge and word-level spelling accuracy of children with SLI, we fit a second logistic mixed-effects model. This model included 565 observations from only the 32 participants with SLI. Again, the dependent variable was the accuracy of each spelling item (1 or 0), and the independent variables were selected on the basis of zero-order correlations between the predictor variables and word-level spelling accuracy for children with SLI. We included subject and item as random effects, allowing for random intercepts. Moreover, *p* values were obtained using the lmerTest package.

[2]We recognize that not all researchers agree with *p*-value testing for mixed models. As a check of the results, we ran likelihood ratio tests for each independent variable. The results were consistent with the lmerTest results; thus, we chose to describe the more familiar *p* values.

Results

Descriptive statistics for study measures are provided in Table 1. Using a Bonferroni correction for multiple comparisons, the significance level was set at $\alpha < .004$ for these comparisons. Children with SLI scored below children with TL on the majority of measures; effect sizes ranged from 0.55 to 3.62 for significant differences, indicating medium to large group effects. The only two variables for which the groups did not differ significantly were age and orthographic pattern knowledge. For children with SLI, the mean overall language score was well below the average range; however, the mean scores on measures of the individual components of linguistic knowledge that we assessed generally fell within the low-average range for standardized measures. Spelling performance was related to overall language for children with TL ($r = .59$, $p < .001$) but not for children with SLI ($r = .16$, *ns*). Spelling performance was not related to nonverbal intelligence for either group. Correlations of the dependent and predictor measures are reported in Table 2, separately for children with SLI and children with TL. For children with TL, word-level spelling accuracy was correlated with all measures except phonological awareness. For children with SLI, word-level spelling accuracy was correlated with only phonological awareness, MGR knowledge, and morphological knowledge. Additionally, age was related to word-level spelling accuracy for children with SLI ($r = .43$, $p < .05$) but not for children with TL ($r = .24$, *ns*). Therefore, we included age in the model for children with SLI.

Children With TL

For children with TL, morphological knowledge, orthographic pattern knowledge, MGR knowledge, and receptive vocabulary were entered into the model, because each was correlated with word-level spelling accuracy in this group. As shown in Table 3, morphological knowledge and MGR knowledge were unique predictors of word-level spelling accuracy for children with TL. Morphological knowledge was associated with increased word-level spelling accuracy ($z = 2.430$, $p = .015$) of 0.05 ± 0.02 (*SEs*). MGR knowledge additionally was associated with increased word-level spelling accuracy ($z = 5.045$, $p = .000$) of 0.07 ± 0.01 (*SEs*). Orthographic pattern knowledge and receptive vocabulary were not significant ($p = .975$ and .470, respectively).

Table 2. Correlations of outcome and predictor measures for children with specific language impairment (below the diagonal) and children with typical language (above the diagonal).

Variable	1	2	3	4	5	6
1. TWS-4	—	.35	**.65**	**.38**	**.83**	**.51**
2. CTOPP Phonological Awareness[a]	**.67**	—	.30	.05	.12	.23
3. TMS	**.72**	**.49**	—	.14	**.52**	**.71**
4. OCT	.28	.32	.10	—	**.51**	.09
5. PIAT-R/NU (MGR)	**.84**	**.50**	**.72**	**.40**	—	**.48**
6. PPVT-4	.22	.10	**.37**	.10	.18	—

Note. Bolded correlations are significant at $p < .05$.TWS-4 = Test of Written Spelling–Fourth Edition; CTOPP = Comprehensive Test of Phonological Processing; TMS = Test of Morphological Structure; OCT = Orthographic Constraints Test; PIAT-R/NU = Peabody Individual Achievement Test–Revised/Normative Update; MGR = mental grapheme representation; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition.

[a]Standard scores were used in correlations.

Children With SLI

For children with SLI, age, phonological awareness, MGR knowledge, and morphological knowledge were entered into the model, because each was correlated with word-level spelling accuracy in this group. As shown in Table 4, phonological awareness and MGR knowledge were unique predictors of word-level spelling accuracy for children with SLI. Phonological awareness was associated with increased word-level spelling accuracy ($z = 3.270$, $p = .001$) of 0.04 ± 0.01 (*SEs*). MGR knowledge additionally was associated with increased word-level spelling accuracy ($z = 4.783$, $p = .000$) of 0.08 ± 0.02 (*SEs*). Age and morphological knowledge were not significant ($p = .787$ and .840, respectively).

Follow-Up Analysis

The models presented in Tables 3 and 4 show that MGR knowledge is a strong predictor of the ability of children to formulate word spellings. It is possible that MGR measures are simply measures of visual memory and not of linguistic knowledge. To test this hypothesis, we administered the Visual Memory Index of the Wide Range Assessment of Memory and Learning–Second Edition (Sheslow & Adams, 2001). MGR knowledge (PIAT-R/NU) was not related to visual memory (Wide Range Assessment of Memory and Learning–Second Edition) but was significantly related to orthographic pattern knowledge (OCT) in both groups (see Table 5).

Discussion

The purpose of this study was to examine concurrently the relative contributions of phonological awareness, morphological knowledge, orthographic pattern knowledge, MGR knowledge, and receptive vocabulary knowledge to word-level spelling accuracy of elementary school children with and without SLI. Previous research (Mackie & Dockrell, 2004; Silliman et al., 2006; Young et al., 2002) suggested that children with SLI utilize at least some linguistic knowledge differently from children with TL; these findings led us to hypothesize that we would find differences in the patterns of contribution of the linguistic knowledge variables to word-level spelling accuracy across groups. Our findings confirmed this hypothesis, indicating that patterns of correlation between the linguistic knowledge measures and word-level spelling accuracy differed across

Table 3. Coefficients of a logistic mixed-effects regression model fitted to spelling accuracy of children with typical language, and associated statistics.

Variable	Coefficient	*SE*	*z*	*p*
Intercept	–5.365	1.67	–3.206	.001
Test of Morphological Structure	0.053	0.02	2.430	.015
Orthographic Constraints Test	–0.003	0.09	–0.032	.975
PIAT-R/NU (MGR)	0.069	0.01	5.045	< .001
PPVT-4	–0.007	0.01	–0.722	.470

Note. PIAT-R/NU = Peabody Individual Achievement Test–Revised/Normative Update; MGR = mental grapheme representation; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition.

groups, as did the prediction of spelling by these linguistic knowledge measures.

Linguistic Contributions to Word-Level Spelling Accuracy in Children With TL

The first model evaluated the association of linguistic knowledge to the accuracy with which children with TL formulate word-level spellings. Evidence across multiple previous studies suggested that linguistic knowledge is related to spelling in children with TL. In this study, we found that, for children with TL, although all linguistic predictor variables, except phonological awareness, were related to spelling accuracy, only morphological knowledge and MGR knowledge were selected as significant unique predictors of word-level spelling accuracy in the logistic regression model.

The significant findings for the prediction of spelling of children with TL by morphological knowledge converge with those of Walker and Hauerwas (2006) and Apel et al. (2012). In Walker and Hauerwas, morphological knowledge was a significant predictor of children's spelling of words with inflectional morphology in Grades 1 through 3. Apel et al. reported that morphological knowledge was a significant predictor of second and third graders' word-level spelling. Additionally, Wolter, Wood, and D'zatko (2009) reported that morphological knowledge predicted first-grade children's spelling of words with flaps and final clusters denoting morphological structures after accounting for phonological awareness. Therefore, the present findings converge with and add to the literature suggesting that morphological knowledge is an important factor in the spelling abilities of young children with TL.

Additionally, MGR knowledge was a significant, and in fact the strongest, unique predictor of spelling proficiency in children with TL in the elementary grades. MGR knowledge, or word-specific orthographic knowledge, is a strong predictor of the ability of children with TL to formulate word spellings. It is not surprising, perhaps, that children who have more stored mental graphemic images of words are better spellers, and this finding may raise questions about the linguistic versus visual basis of spelling. To address these questions, we conducted a follow-up analysis to examine the relation of MGR knowledge to another orthographic (linguistic) measure—orthographic pattern knowledge—as well as a measure of visual memory of nonlinguistic stimuli. The findings of this follow-up analysis support the argument that MGR knowledge is not simply a component of general visual memory abilities but, instead, is a component of orthographic knowledge (e.g., Apel, 2011). Ehri (2000) has argued that children form new MGRs not by simply visually memorizing strings of letters of individual words but by analyzing stored MGRs of words with similar linguistic features. It stands to reason, then, that simply memorizing words is not an efficient means of adding MGRs to one's mental lexicon; rather, MGRs are formed more efficiently when children utilize their linguistic knowledge to analyze how new words are similar to written words already in their mental lexicon. Thus, MGR knowledge is more so an outgrowth of linguistic knowledge, and not visual memory, for the spelling proficiency of elementary school children.

Finally, the finding that phonological awareness, orthographic pattern knowledge, and receptive vocabulary did not uniquely predict word-level spelling accuracy in

Table 4. Coefficients of a logistic mixed-effects regression model fitted to spelling accuracy of children with specific language impairment, and associated statistics.

Variable	Coefficient	*SE*	*z*	*p*
Intercept	–9.251	2.15	–4.305	< .001
CTOPP Phonological Awareness	0.036	0.01	3.270	.001
Test of Morphological Structure	–0.040	0.02	–0.202	.840
PIAT-R/NU (MGR)	0.077	0.02	4.783	< .001

Note. CTOPP = Comprehensive Test of Phonological Processing; PIAT-R/NU = Peabody Individual Achievement Test–Revised/Normative Update; MGR = mental grapheme representation.

Table 5. Correlations of mental grapheme representation (MGR) knowledge, orthographic pattern knowledge, and visual memory for children with specific language impairment (below the diagonal) and children with typical language (above the diagonal).

Variable	1	2	3
1. PIAT-R/NU (MGR)	—	**.51**	.13
2. OCT	**.40**	—	−.20
3. WRAML-2 Visual Memory Index	.27	.18	—

Note. PIAT-R/NU = Peabody Individual Achievement Test–Revised/Normative Update; OCT = Orthographic Constraints Test; WRAML-2 = Wide Range Assessment of Memory and Learning–Second Edition.

older elementary school children is also consistent with the findings of Apel et al. (2012) and Walker and Hauerwas (2006). It is hypothesized that the contributions of these skills to children's spelling abilities likely occur earlier in spelling acquisition than measured in this study.

Linguistic Contributions to Word-Level Spelling Accuracy in Children With SLI

The second model evaluated the association of linguistic knowledge to the accuracy with which children with SLI formulate word-level spellings. Evidence across multiple previous studies suggested that linguistic knowledge is related to spelling in children with SLI. This investigation extended the existing research base by evaluating four types of linguistic knowledge concurrently in children with SLI. We found support for the hypothesis that some of these areas of linguistic knowledge predict spelling accuracy of school-age children with SLI and that the patterns of prediction differed from those of school-age children with TL. Specifically, phonological awareness and MGR knowledge—but not orthographic pattern knowledge, morphological knowledge, or vocabulary knowledge—were significant predictors of word-level spelling accuracy for second- through fourth-grade children with SLI.

Phonological awareness was one area of linguistic knowledge selected as a unique predictor in the model fit to word-level spelling accuracy in children with SLI. This is a novel finding among studies that have assessed multiple linguistic contributions to spelling in elementary school children. Two possible explanations of this finding are proposed. First, it is possible that children with SLI continue to rely on phonological awareness for spelling for a longer period of time than children with TL. Walker and Hauerwas (2006) reported that phonological awareness was not a unique predictor of spelling of inflectional morphemes after first grade. For children with SLI, it may be that this relation extends for a longer period than in children with TL. Second, task differences between studies may account for disparate findings. The outcome measure in Walker and Hauerwas involved only the spelling of the morphological unit; therefore, it is not surprising that phonological awareness did not contribute significantly beyond orthographic and morphological knowledge to this type of spelling task. Likewise, Apel et al.'s (2012) phonological awareness task differed from the task used in this study. Students in the study of Apel et al. were asked to count phonemes, whereas in this study, students were asked to delete and blend phonemes. The latter tasks represent higher level analysis of phonemes than simply counting phonemes in words. These task differences may account for the disparate findings.

Similar to children with TL, MGR knowledge was a significant unique predictor of spelling proficiency in children with SLI in the elementary grades. Thus, word-specific orthographic knowledge is a strong predictor of the ability of children with and without SLI to formulate word spellings. Interestingly, MGR knowledge was the only linguistic variable that contributed significant unique variance for children with SLI and children with TL. This finding highlights the importance of developing strong MGR knowledge for spelling proficiency. Future work should continue to explore intervention techniques that are optimal for increasing MGR knowledge for children in both groups and if that instruction/intervention should be similar across the groups.

In contrast, morphological knowledge was not selected as a unique predictor in the model fit to word-level spelling accuracy in elementary school children with SLI. This finding differs from previous research of morphological knowledge in the spellings of elementary school children with TL (Apel et al., 2012; Walker & Hauerwas, 2006). Our study employed the same measure and scoring protocol as in Apel et al.'s investigation of spelling in children with TL in this age group. We propose two non–mutually exclusive explanations of this finding. First, a majority of the words spelled by children in the current investigation were monomorphemic. The first multimorphemic word on the TWS-4 occurs at Item 16. The mean raw score on the TWS-4 for children with SLI in this investigation was well below the first multimorphemic word, and only eight children with SLI had raw scores of 16 or above. In fact, the majority of the children with SLI had spelling levels that were developmentally below spelling of multimorphemic words, on the basis of their ceilings on the TWS-4 (i.e., their spelling levels were developmentally below the level at which that assessment would introduce multimorphemic words to attempt). It is likely that the words attempted by the children with SLI on the TWS-4 did not allow demonstration of their ability to use morphological knowledge in spelling. Second, analyzing the morphological structure of words involves analysis of phonological structure as well. It is possible that the phonological awareness task subsumed the morphological awareness knowledge contributions for children with SLI. This hypothesis is supported by the moderate correlations of performance of children with SLI on this study's phonological awareness and morphological knowledge task ($r = .49$); this correlation for the children with TL was not significant. Future research should match spelling levels of children with SLI and children with TL to further examine the role of morphological knowledge in early developmental stages of spelling.

Likewise, orthographic pattern knowledge was not related to word-level spelling accuracy in elementary school children with SLI. Previous research has identified orthographic pattern knowledge as a relative strength in linguistic knowledge for children with SLI (e.g., Mackie & Dockrell, 2004; Silliman et al., 2006). This study's findings are consistent with this research. Children with SLI did not differ from children with TL on the orthographic pattern knowledge measure. Therefore, children with SLI have relative strengths in this area of linguistic knowledge, but it was not associated with word-level spelling accuracy in this population. It is possible that the contributions of MGR knowledge subsumed the contributions of orthographic pattern knowledge. Because children's spellings were scored as correct or incorrect, rather than as a degree of adherence to orthographic pattern rules in English, it is not surprising that MGR knowledge, not orthographic pattern knowledge, predicted spelling in this population. Additionally, Walker and Hauerwas (2006) reported that orthographic pattern knowledge was a unique predictor of spelling of inflectional morphemes for first graders, a unique predictor of spelling of only some inflectional morphemes for second graders, and not a unique predictor of spelling of inflectional morphemes for third graders. Apel et al. (2012) reported that orthographic pattern knowledge was not a unique predictor of the general spelling performance of a group of children that included second and third graders. Consistent with these findings, orthographic pattern knowledge did not contribute unique variance to the spelling performance of second through fourth graders in this study. Walker and Hauerwas argued, and we concur, that orthographic pattern knowledge plays an early role in spelling performance and then is surpassed by other types of linguistic knowledge, including other types of orthographic knowledge, such as MGR knowledge, as spelling acquisition proceeds. The findings of this study, along with those of Walker and Hauerwas, suggest that this shift happens rather early in spelling development, even for children with SLI.

Finally, vocabulary knowledge was not related to word-level spelling accuracy in elementary school children with SLI. Previous research was mixed on the relation of vocabulary knowledge and word-level spelling accuracy in elementary school children with SLI. Our findings add to studies that have concluded that vocabulary knowledge is not related to spelling in this population. It should be noted that our vocabulary measure was a measure of general receptive vocabulary knowledge and not specific knowledge of the words on the spelling task. It is possible that receptive vocabulary may emerge as a predictor of word-level spelling accuracy when it is measured in a specific, rather than general, task.

Predictions of Word-Level Spelling Accuracy Across Groups

Notably, children with SLI and children with TL displayed similarities and differences in the patterns of linguistic knowledge skills that predicted word-level spelling accuracy. For both groups, MGR knowledge predicted word-level spelling accuracy. Likewise, for both groups, vocabulary knowledge and orthographic pattern knowledge were not predictors of word-level spelling accuracy. It appears that other areas of linguistic knowledge play a greater role in word-level spelling than does receptive vocabulary knowledge or orthographic pattern knowledge at this point in spelling acquisition. In contrast, the groups differed on phonological awareness and morphological knowledge. Phonological awareness was a unique predictor of word-level spelling accuracy for children with SLI but not for children with TL, whereas morphological knowledge was a unique predictor of word-level spelling accuracy for children with TL but not for children with SLI. These findings align with the linguistic repertoire theory of spelling acquisition, which posits that children draw from multiple areas of linguistic knowledge on the basis of their linguistic skills and the characteristics of the word being spelled. First, both groups had multiple linguistic skills that were unique predictors of word-level spelling accuracy. Second, differences in predictors can be explained in light of the types of words spelled by children in each group. Recall that children in the SLI group had an average raw score of 11, whereas children in the TL group had an average raw score of 18. Children are predicted to utilize phonological awareness early in development, when they would be spelling words that are earlier on the TWS-4, and more complex morphological knowledge skills on later developing words (Moats, 1995).

Implications for Spelling Instruction and Intervention

This investigation has implications for spelling instruction and intervention for children with SLI. Traditional spelling instruction does not guide children to explicitly connect spoken and written language. Carreker, Joshi, and Boulware-Gooden (2010) reported that educators overwhelmingly report teaching visually based, rather than linguistic-based, spelling strategies. However, the findings reported here suggest that at least some types of linguistic knowledge predict spelling for children with SLI. Weiser and Mathes (2011) reported robust effects of linguistic-based instruction on spelling outcomes for students at risk for literacy difficulties in a recent meta-analysis. Additionally, because our findings suggest that children with SLI and children with TL differ in terms of the types of linguistic knowledge that contribute to single-word spelling accuracy, it is reasonable to hypothesize that linguistic-based spelling instruction may need to be further individualized for children with SLI in ways that are not necessary for children with TL. Future research should evaluate empirically the effectiveness of linguistic-based spelling instruction, with particular focus on improving MGR knowledge and phonological awareness, for children with SLI in these grades.

Limitations and Suggestions for Future Research

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. It will be important to explore possible between-grades differences in children's use of linguistic knowledge for spelling because grade as a proxy for time in instruction may be an important factor to consider. One method could be to follow the same group of children with SLI over time to determine how the contributions of types of linguistic knowledge to spelling accuracy change over time. Second, it is possible that our sample of children with SLI was 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. Children who receive services in schools tend to exhibit more severe language impairment than children who have unidentified SLI. 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. Additionally, our sample size limited our ability to perform one primary regression analysis that included group as a predictor (along with associated interactions). Although the findings presented here provide a preliminary insight into the linguistic predictors of spelling of children with SLI compared to children with TL, future research should include larger sample sizes that allow for direct comparison rather than comparison of models. Future research could also include a comparison group that is matched on spelling level rather than grade. Finally, future research should address this research question with a sample of students with developmental language disorder that have low nonverbal intelligence, the subgroup traditionally called nonspecific language impairment, to determine if the same patterns of performance are observed for these children.

Conclusion

At least some types of linguistic knowledge were related to and uniquely predicted word-level spelling accuracy for children with SLI and children with TL. However, the patterns of these relations and predictions differed somewhat across groups. MGR knowledge and phonological awareness predicted word-level spelling accuracy for children with SLI, whereas morphological knowledge and orthographic pattern knowledge predicted word-level spelling accuracy for children with TL. The results support further research of the hypothesis that spelling instruction and intervention should tap children's linguistic knowledge and explicitly relate their linguistic knowledge to spelling. Future research should evaluate whether these different patterns of performance indicate that instructional targets in spelling should differ for children with SLI and children with TL.

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