Research Article

Preliteracy Speech Sound Production Skill and Linguistic Characteristics of Grade 3 Spellings: A Study Using the Templin Archive

Megan S. Overby,^a Julie J. Masterson,^b and Jonathan L. Preston^{c,d}

Purpose: This archival investigation examined the relationship between preliteracy speech sound production skill (SSPS) and spelling in Grade 3 using a dataset in which children's receptive vocabulary was generally within normal limits, speech therapy was not provided until Grade 2, and phonological awareness instruction was discouraged at the time data were collected.

Method: Participants ($N = 250$), selected from the Templin Archive (Templin, 2004), varied on prekindergarten SSPS. Participants' real word spellings in Grade 3 were evaluated using a metric of linguistic knowledge, the Computerized Spelling Sensitivity System (Masterson & Apel, 2013). Relationships between kindergarten speech error types and later spellings also were explored.

Results: Prekindergarten children in the lowest SPSS (7th percentile) scored poorest among articulatory subgroups on both individual spelling elements (phonetic elements, junctures, and affixes) and acceptable spelling (using relatively more omissions and illegal spelling patterns). Within the 7th percentile subgroup, there were no statistical spelling differences between those with mostly atypical speech sound errors and those with mostly typical speech sound errors.

Conclusions: Findings were consistent with predictions from dual route models of spelling that SSPS is one of many variables associated with spelling skill and that children with impaired SSPS are at risk for spelling difficulty.

In today's global society, competent literacy skills are needed for educational advancement, adequate personal health management, and competitive employment. Spelling is an essential literacy skill (Rankin, Bruning, Timme, & Katkanant, 1993), more valued than all other writing conventions (Turbill, 2000), and a notable characteristic of education (Robinson, 2005). Learning to spell strengthens reading and writing skills (Ehri, 2000; Ehri & Snowling, 2004; Moats, 2005) and draws upon meta-linguistic skills associated with broad literacy development (McNeill & Kirk, 2014). It is not surprising, then, that most teachers report spending dedicated time each week to spelling instruction (Fresch, 2003). For example, Graham

et al. (2008) surveyed 168 primary grade teachers and found that all but four reported teaching spelling to their students, devoting approximately 90 min a week to spelling instruction. More recently, the implementation of Common Core Standards means that teachers must now address spelling skills as early as Grade 1 (Common Core State Standards Initiative, 2014).

Many children have difficulty learning to spell, especially children with dyslexia (Bailet, 2004; Stanovich, Siegel, & Gottardo, 1997; Uhry & Clark, 2005) or speech-language disorders (Apel & Lawrence, 2011; Bishop & Adams, 1990; Lewis, Freebairn, & Taylor, 2002; Nathan, Stackhouse, Goulondris, & Snowling, 2004). Poor spelling may affect 27% of elementary school-age students (Graham et al., 2008), remaining a life-long problem despite intervention and possibly limiting career advancement (Bruck, 1990; Maughan et al., 2009).

An oft-cited model of spelling, the dual route model (DRM) of spelling, predicts that speech sound production skill (SSPS) will be associated with spelling. Although some studies have reported SSPS to be a possible risk factor for poor spelling (Clarke-Klein & Hodson, 1995; Holm,

^aDuquesne University, Pittsburgh, PA

^bMissouri State University, Springfield

^cSyracuse University, NY

^dHaskins Laboratories, New Haven, CT

Correspondence to Megan S. Overby: overbym@duq.edu

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Farrier, & Dodd, 2008; Lewis et al., 2002, 2011; Snowling & Stackhouse, 1983; Stackhouse, 1982), other studies have not confirmed this link (Bishop & Robson, 1989; Hesketh, 2004). Some investigators (e.g., Holm et al., 2008; Peterson, Pennington, Shriberg, & Boada, 2009) have emphasized the need for additional studies of the relationship between SSPS and spelling that (a) consider possible protective factors against literacy problems; (b) use fine-grained, not binary, spelling measures; (c) evaluate spelling as an isolated literacy skill and not as a combined reading and spelling literacy variable; and (d) examine subgroups of children at particular risk for spelling difficulty. The aim of the current investigation was to address this need using an archival data set of children's speech sound articulatory skill and a linguistically sensitive spelling measure.

DRM of Spelling

The DRM of spelling proposes that spelling occurs as a consequence of two separate but mutually interactive systems, the phonological route and/or the orthographic (or visual) route (Bates et al., 2007; Berninger et al., 1998; Cipolotti & Warrington, 1996; Ellis, 1993; Ward, 2003). The *phonological route*, which maintains phonological information about words, is tapped for unfamiliar words that require encoding, whereas the *orthographic route*, which operates the passive and temporary storage of visuospatial information, is used to spell familiar words automatically. Young typically developing spellers initially rely on a phonological strategy to spell, whereas older, more proficient spellers increasingly utilize the visual system because executive functions have become more adept in managing and integrating sound-grapheme connections.

Phonological Route of Spelling

The phonological system of the DRM of spelling includes the semantic system, phonological output lexicon, phoneme level, phoneme-grapheme conversion, grapheme output buffer, allographic level, and graphomotoric patterns (Ward, 2003; see Figure 1, for a simplified version of the many variations of this model). The *semantic system* contains an individual's word knowledge and is derived from the *visual input lexicon* (a repository of vocabulary). The pronunciation and phonemic characteristics of a word are contained in the *phonological output lexicon* within which the effects of impaired SSPS are realized by hindering the formation and retention of accurate phonological representations.

The *phoneme level* is where the coordinated articulatory movement sequence needed to speak a word is held passively in short-term storage, typically for approximately 2 s, although subvocal repetition of the phonological memory trace can prevent memory decay during spelling (Baddeley, 2012). This process of phonological storage and subsequent subvocal rehearsal is known as the *phonological loop* (Baddeley & Hitch, 1974). Thereafter, *phoneme-grapheme conversion* occurs, made possible in part by sound-to-symbol mapping in the language. The grapheme sequence for the latter part of a word is held in storage in the *grapheme*

Figure 1. Ward's (2003) adaptation of Ellis' (1993) DRM of spelling. Ward, J. (2003). Understanding oral spelling: A review and synthesis. *Neurocase*, 9, 1–14. Reprinted by permission of the publisher (Taylor & Francis Ltd, <http://www.tandfonline.com>).

output buffer, whereas the first part of the word is spelled, then the letter shape is selected (*allographic level*) and the *graphomotoric writing pattern* initiated.

Visual Route of Spelling

The visual route consists of the semantic system, orthographic output lexicon, grapheme output buffer, allographic level, and graphomotoric patterns. The *orthographic output lexicon* contains all the words the speller has stored in memory, as well as spelling rules and patterns that govern them. This lexicon receives information from the semantic system and the phonological output lexicon, suggesting that spelling a familiar word is a result of knowing both its meaning and sound form.

Linguistic Aspects of Spelling

Aspects of the DRM of spelling are related to several linguistic variables associated with spelling, including phonological, orthographic, and morphological awareness, as well as the ability to store complete mental graphemic representations (Masterson & Apel, 2007). Because the phonological output lexicon stores the articulatory aspects of phonemes of a word, it accounts for *phonological awareness* (the conscious ability to manipulate phonemes), a significant spelling predictor (Ball & Blachman, 1991; Bradley & Bryant, 1983; Bruck & Treiman, 1990; Smith, Simmons, & Kame'enui, 1995; Tangel & Blachman, 1992, 1995). The orthographic output lexicon stores words based upon spelling rules and sound patterns and can explain the role of *orthographic pattern awareness* (the understanding and use of rules which govern translating spoken words to written form), a variable associated with spelling outcomes (Calfee, 1998; Garcia, Abbott, & Berninger, 2010; Graham, Harris, & Chorzempa, 2002; Masterson & Apel, 2000; McBride-Chang, 1998). The orthographic output lexicon can similarly explain *morphological awareness* (the ability to

modify word bases with inflectional and derivational morphemes), also known to be associated with spelling (Apel & Lawrence, 2011; Carlisle, 1987; Nunes, Bryant, & Olsson, 2003; Treiman & Cassar, 1996). Last, the *visual orthographic lexicon* (where word, syllable, and morpheme templates are stored in visual memory) accounts for the storage of adequate *mental graphemic representations* needed for rapid access to spelling details about words or parts of words (Apel, 2009; Apel, Thomas-Tate, Wilson-Fowler, & Brimo, 2012; Share, 1999; Wolter & Apel, 2010).

Speech Sound Production as an Aspect of Spelling Skill

Speech sound disorder (SSD) involves impaired accuracy in producing the sounds of the language. In addition to accounting for linguistic aspects of spelling, the DRM of spelling predicts a relationship between SSPS and spelling such that poor SSPS (i.e., SSD) can impair the accuracy of phonological representations in the phonological loop (Baddeley, 1986; Baddeley, Gathercole, & Papagno, 1998; Stanovich, 1988; Stanovich & Siegel, 1994), weakening the quality of metaphonological engagement for spelling. Although there are many variations of the DRM of spelling (e.g., regarding which components are included, which are bidirectional, etc.), all acknowledge that phonological representations of sounds and their articulatory sequence are accessed in the phonological output lexicon or similar construct(s). Weak or poorly specified phonological representations may hinder this access and coding. Compared to typical speech sound errors, atypical speech sound errors are suspected of having a more significant deleterious impact on underlying phonological representations, with possible phonological and literacy long-term consequences (Leitao & Fletcher, 2004; Preston, Hull, & Edwards, 2013). By contrast, the *multiple deficit hypothesis* predicts that spelling is a multifactorial skill, and although poor SSPS can influence spelling, it interacts with other risk and protective variables, weakening the predictive power of SSPS (Pennington, 2006). Peterson et al. (2009) directly tested the phonological deficit theory and found that language variables (such as syntax and nonverbal IQ) had a stronger association with a literacy composite of reading and spelling than SSPS. The authors cautioned, however, that the role of persistence of SSD in later literacy outcomes may vary among SSD subgroups.

Compared to studies of SPSS and reading skill, or SPSS and combined spelling and reading outcomes, there are relatively few studies examining the specific relationship between SSPS and spelling. Elementary school-age children with early isolated SSD have been found to have poor spelling relative to their reading and language abilities (Lewis et al., 2006; Overby, Trainin, Smit, Bernthal, & Nelson, 2012), though in some investigations, observed spelling differences did not reach statistical significance (Lewis et al., 2002, 2011). At age 6;9 (years;months), persistence of SSD was reported to be marginally associated with spelling outcomes (Nathan et al., 2004), but only seven of the

19 participants had a history of speech-only disorder, whereas the remaining 12 had a history of speech-language difficulty. Some investigations have not found any association between early SSPS and spelling outcomes (Bishop & Robson, 1989; Hesketh, 2004).

Limitations in Studies of SSPS and Spelling

We identify three methodological limitations that may partially explain these mixed findings. First, some subgroups of children may be at more risk for spelling difficulty than others. For example, children with SSD based in underlying phonological deficits, particularly atypical speech sound errors, may be at more risk for spelling difficulty than those with SSD arising from peripheral articulatory deficits (Leitao & Fletcher, 2004; Peterson et al., 2009). Preston, Hull, and Edwards (2013) examined 25 children with speech delay and language skills generally in the average to above-average range. Children with >10% atypical speech sound errors in preschool scored significantly lower at school age on spelling than children with few atypical speech sound errors.

Second, speech therapy intervention may provide ameliorative effects that protect against later literacy or spelling difficulty (Bird, Bishop, & Freeman, 1995; Bishop & Adams, 1990; Snowling, Bishop, & Stothard, 2000). As described in Overby et al. (2012), one approach to addressing this issue is to identify the quantity and nature of speech therapy each participant received prior to data collection, but this type of documentation is rarely provided in investigations. A separate approach is to use methodological designs in which one or more conditions represent minimal speech therapy (e.g., Gillon, 2000).

Third, most contemporary spelling assessments simply classify spelling errors as binary (i.e., either correct or incorrect), thereby missing important information about the linguistic deficits underlying those errors and making relative differences of spelling skill within a population difficult, if not impossible, to discern (Bourassa & Treiman, 2003; Calhoon, Greenberg, & Hunter, 2010; Masterson & Apel, 2013). For example, both SAK and SAINK are incorrect spellings for the word *sank*, but both reflect different types of linguistic knowledge. In SAK, the nasal is deleted from the cluster, which has a common phonological basis. Many children typically have difficulty spelling a nasal consonant in a final consonant cluster because they tend to treat a vowel and a nasal immediately following it as a single phonetic unit (Treiman & Cassar, 1996). In SAINK, a plausible, albeit incorrect, spelling is used for the long vowel pattern, indicating awareness of the word's phonological properties as well as acceptable orthographic patterns. Thus, although both spellings may be incorrect, that designation does not capture potential developmental differences.

Two contemporary resources can be used to address these limitations. The Templin Archive allows exploration of children with varying levels of SSPS and control of potential effects of treatment upon literacy skills (Overby et al., 2012). The Computerized Spelling Sensitivity System (Masterson & Hrbec, 2011) provides additional insight

into the level of linguistic knowledge indicated by student spellings.

Contemporary Resources

Templin Archive

The Templin Archive (Templin, 2004)¹ is a repository for longitudinal data (1960–1972) from a study carried out by Mildred C. Templin on the speech sound development of 485 children (252 boys and 233 girls) selected from an initial cohort of 1,500 prekindergarten children. The Archive contains children's scores on investigator-made and standardized measures of speech sound skill, and of academic, linguistic, cognitive, social, perceptual, and motor development, and can be used to study child and adolescent speech sound production, including its association with academic, reading, and spelling skills. Speech sound assessments, conducted approximately every 6 months between prekindergarten and Grade 4 and then once in Grade 11, included measures of spontaneous and imitative productions of single words and were administered by experienced speech-language pathologists (SLPs), most of whom had a master's degree and public school experience (Templin, 1976). Academic measures, such as spelling, were administered by the child's classroom teacher.

Children were selected for the longitudinal study on the basis of their prekindergarten speech sound skills. In spring 1960, SLPs evaluated the SSPS of the initial cohort of 1,500 children just before the children entered kindergarten. The children's articulatory skills were assessed with the Templin Prekindergarten Imitation Articulation Test (TPIAT; Templin, 1976), a measure specifically created for the Templin longitudinal study to assess productions of 47 phonemes across initial, medial, final positions: 37 singletons, 8 phonemes within two-element consonant clusters, and 2 phonemes within a three-element consonant cluster. Templin (1976) used children's scores on the TPIAT to construct five articulatory percentile subgroups as well as four other, nonoverlapping subgroups (based upon specific phoneme errors or error patterns). Membership in the percentile subgroups consisted of children whose SSPS clustered at the 7th, 15th, 30th, 50th, and 98th percentiles of the cohort. Shortly before entering kindergarten, school personnel screened the children for oral mechanism dysfunction, hearing loss, and "mental retardation"; these children were excluded from the study. Templin then randomly selected approximately 50 children to remain in each subgroup, enrolling similar numbers of boys and girls. The exception was the 50th percentile subgroup, for which she selected 71 children.

Scored forms of subsequent articulation assessments allow investigators to identify the number of speech sound production errors made by the participants, as well as to describe the errors as articulatory peripheral or phonological

linguistic, thereby permitting investigation of subgroups of children at risk for literacy delay. The archival data also allow examination of the relationship between SSPS and other variables without the confound of speech therapy intervention and/or phonological awareness instruction. By agreement with the participants' local school districts, children participating in the longitudinal study received minimal to no speech therapy until after Grade 2. Five children had as much as 10 hr of therapy by the fall of Grade 2 (Templin, 1976); the amount of therapy after Grade 2 is unreported. A detailed description of the archival data, collection process, and contemporaneous state guidelines for teaching reading and spelling can be found in Overby et al. (2012).

Computerized Spelling Sensitivity System

The Computerized Spelling Sensitivity System (Masterson & Apel, 2010, 2013; Masterson & Hrbec, 2011) is an accuracy metric that considers linguistic accuracy by quantifying a child's knowledge of the graphophonemic elements underlying the spelling of a word. The system allows an investigator to consider the correctness of three types of elements within the spelling of a word: base word elements (phonemes), juncture(s), and affix(es). *Base word phonemes* of a word consist of the phonemic elements associated with the phonetic transcription of the base word, though some phonemes may be represented by more than one grapheme. For example, the word *chase* has five graphemes but only three base word elements. *Juncture* is an orthographic change to a base word. In the word *chasing*, for example, juncture occurs when a speller omits the *e* to add the affix. Last, *affixes* are prefixes and/or suffixes added to a base word, as when the affix *ing* is added to *chase* to indicate present progressive tense.

The Computerized Spelling Sensitivity System contains a large dictionary of target words that have been parsed into individual elements reflecting the phoneme–grapheme correspondences and orthographic rules of the English language. Monomorphemic examples of targets include *dog* parsed as D-O-G, *snake* as S-N-aCe (A-consonant-E)-K, *dress* as D-R-E-SS, and *butter* as B-U-TT-ER. For words with more than one morpheme, the base word is divided into its respective elements, any juncture changes are noted, and the affix is parsed as a single unit, rather than into separate phonemes. For example, *played* is parsed as P-L-AY-ED (no juncture change), *hopping* as H-O-P-P-ING (the second P is categorized as a juncture change), and *making* as M-A-K-#-ING (the # indicates the omission of the final *e* as the juncture change). By comparing the dictionary's parsing of a word to the parsing of the word as spelled by the speller, an investigator can identify the speller's linguistic deficits. Additional details can be found in Masterson and Apel (2010, 2013).

Purpose

The purpose of this investigation was to examine the relationship between SSPS of kindergartners and their

¹A full description of the Templin Archive measures and collection process is available at <http://www.he.k-state.edu/fshs/templinarchive/>. Information can also be found there for obtaining specific information from the dataset.

real-word spelling accuracy 3 years later, using contemporary resources and addressing some of the methodological limitations previously described. Our research questions were as follows:

1. What are the differences in spelling accuracy in Grade 3 across a range of SSPS at kindergarten? We hypothesized that poorer SSPS in kindergarten would relate to poorer spelling in Grade 3.
2. What is the relationship between type of speech sound error (typical, atypical) present at kindergarten and spelling accuracy at Grade 3? We hypothesized that children with SSD who produced atypical speech sound errors in kindergarten would be poorer spellers in Grade 3 than children with SSD whose errors were primarily typical in nature.

Method

Participants

Participants ($N = 250$) for the current study were from the 485 participants in the Templin Archive. Inclusionary criteria were assignment to one of five articulatory subgroups on the basis of prekindergarten performance on the TPIAT and the availability of assessment data regarding kindergarten SSPS, kindergarten receptive vocabulary, and Grade 3 real-word spelling. Only children for whom scores were available on all three measures were included in the analysis. Kindergarten SPSS was assessed using the Kindergarten Articulation Test (KAT; described below). Kindergarten receptive vocabulary skill was measured with the Full-Range Picture Vocabulary Test (Ammons & Ammons, 1948) and Grade 3 real-word spelling was assessed with the Spelling subtest of the Metropolitan Achievement Test (Durost, Bixler, Wrightstone, Prescott, & Balow, 1959). When possible, scores for Full Scale IQ, assessed via administration of the California Test of Mental Maturity (Sullivan, Clark, & Tiegs, 1957) in Grade 2, were also accessed. IQ scores were missing for 34 of the 250 participants.

Comparison of Subgroups on Descriptive Variables

Descriptive statistics are shown in Table 1. Analysis indicated no subgroup differences in gender, $\chi^2(4) = 1.97$, $p = .741$, or socioeconomic factor as measured by the Hollingshead two-factor index of social position (Hollingshead, 1956), $\chi^2(24) = 27.1$, $p = .301$. The subgroups were similarly divided into boys and girls, and the most frequent socioeconomic category was 4, with the exception of the 98th percentile subgroup, with a mode of 3. Potential subgroup differences in age, articulation scores, receptive vocabulary, and general and nonverbal cognition were explored with a series of one-way analyses of variance (ANOVAs). A Bonferroni adjustment set the alpha level for main effects at .01 (.05/5).

The mean age for all participants at kindergarten articulation testing was 70 months. There was a significant

main effect for age, $F(1, 4) = 3.7$, $p = .007$. Post hoc analyses (Scheffé) indicated that the children in the 98th percentile subgroup ($x = 71.75$) were significantly older than the other four subgroups; no other age subgroup differences were significant. As expected, the main effect for articulation accuracy was significant, $F(1, 4) = 152.5$, $p < .0001$, and post hoc analyses indicated that each percentile subgroup was significantly different from the others.

There were no significant subgroup differences in receptive vocabulary, $F(1, 4) = 2.73$, $p = .03$, or in nonverbal cognition, $F(1, 4) = 3.2$, $p = .014$. Only 2.9% (eight of 250 children) attained a receptive vocabulary score 1 *SD* or more below the normative mean. The main effect for overall cognition was significant, $F(1, 4) = 7.7$, $p < .0001$. Post hoc analyses indicated the overall cognition scaled score for children in the 98th percentile was significantly higher than the other subgroups. There were no significant differences among the overall cognitive scores for children in the middle three percentile subgroups (50th, 30th, 15th); however, all three of these groups scored significantly higher than the children in the 7th percentile group.

Measures

SSPS Assessment

Multiple measures of SSPS were obtained from 1960–1972. For the current study, we selected the KAT, a measure created by Templin for the longitudinal study. It was administered twice at each testing session to all participants, first using spontaneous naming of picture stimuli followed by an imitation assessment. We selected the initial administration of the KAT, spring of the kindergarten year, and chose the spontaneous picture-naming version because we reasoned it was a better reflection of underlying phonological representations as described by the DRM of spelling than the imitative version. In addition, we observed that the KAT was highly correlated with the TPIAT ($r = .968$, $p < .001$) and was more inclusive of speech sound skill (addressing all English initial and final consonants; see Appendix A), though it only assessed consonants and *r*-colored vowels.

Transcribers who administered the KAT in the longitudinal study indicated substitution, omission, or distortion of target phonemes, as well as additions surrounding the targets (e.g., epenthetic [ə]). When substitutions were made, the transcribers indicated the phone that replaced the target. Each target word contained one to three target phonemes, and notations of phoneme errors were limited to only those made within the target word.

Spelling Assessment

When the children in the longitudinal study were in Grade 3, the Spelling subtest of the Metropolitan Achievement Tests: Form B-Elementary (Durost et al., 1959) was administered. This is a 40-word dictation spelling test in which the examiner says each word, uses it in a sentence, and then repeats it. Children spell each word on

Table 1. Means and standard errors for participant demographics in each percentile subgroup of speech accuracy at kindergarten and Grade 2.

Percentile group	Gender		SES ^a (Mode)	Age in months	Spring of Kindergarten			Fall of Grade 2	
	Boys	Girls			KAT ^b RS	KAT #Phonemes [range]	Ammons ^c SS	CTMM ^d FSS	CTMM ^e NLS
7th	21	22	4	69.33 (0.46)	28.26 (1.14)	55.02 (0.34) [46–57]	106.63 (2.33)	101.68 (2.27)	101.24 (2.66)
15th	23	25	4	69.71 (0.49)	38.15 (0.76)	55.42 (0.27) [50–57]	108.83 (1.99)	107.33 (2.02)	106.74 (2.82)
30th	23	24	4	69.79 (0.46)	43.72 (0.66)	55.79 (0.22) [50–57]	112.36 (2.94)	108.17 (2.18)	104.85 (2.50)
50th	37	31	4	70.06 (0.39)	47.44 (0.53)	56.07 (0.14) [50–57]	112.66 (1.90)	109.51 (1.65)	107.23 (1.68)
98th	18	26	3	71.75 (0.55)	51.80 (0.33)	56.07 (0.14) [54–57]	117.14 (2.40)	117.66 (1.94)	113.39 (2.50)

Note. Missing data for CTMM: Not all participants whose speech sound skill was assessed in kindergarten were present when the CTMM was administered in Grade 2.

^aHollingshead Two-Factor Index of Social Position (Hollingshead, 1956). ^bTemplin Kindergarten Articulation Test, Raw Score (out of 57; Templin, 1968). ^cAmmons Full-Range Picture Vocabulary Test, Scaled Score (Ammons & Ammons, 1948). ^dCalifornia Test of Mental Maturity, Full-Scale Score (Sullivan et al., 1957). ^eCalifornia Test of Mental Maturity, Non-Language Score (Sullivan et al., 1957).

a form provided to them. The words dictated are shown in Appendix B.

Analysis

Speech Sound Production Skill

We quantified error types on the KAT as typical speech sound errors, atypical speech sound errors, or distortions, using procedures outlined by Preston (2008) and reported in previous studies (Macrae & Tyler, 2014; Preston & Edwards, 2010; Preston et al., 2013). Because the KAT was a spontaneous naming measure, some words were not produced (see Table 1) and so error types were calculated on the basis of the proportion of errors per consonant produced. Typical error patterns were those phonological error patterns (or phonological processes) commonly observed in typical phonological development. For example, typical syllable structure errors include final consonant deletion, /s/ cluster reduction and liquid cluster reduction; typical substitution patterns include fronting of velars or palatals, stopping of fricatives and affricates, gliding of liquids, and initial voicing. Atypical patterns were those that rarely, if ever, show up in children with typically developing phonology in English and are therefore primarily observed among children with SSDs (Smit, 1993). Atypical syllable structure errors included patterns such as initial consonant deletion of singletons or atypical cluster reduction (in which the marked element of the cluster is retained and the unmarked element is deleted); atypical substitution patterns included patterns such as backing anterior consonants to velar or glottal place of articulation, nasalization, and initial devoicing. Distortions included instances in which diacritics or notes were used by the transcribers to indicate imprecise articulation, such as tongue protrusion during /s, z/, distortion of /r/, or other phonetic errors. For a complete list of all error patterns, see appendix A of Preston (2008). Instances where the transcribers indicated errors that could plausibly be accounted for by dialect variation (such as producing *wheel* /wɪl/ as [wɪl], or *garage* /gəɹɑːʒ/ as [gəɹɑːʒ]) were reviewed by the authors on a word-specific basis and were not counted as errors. For each participant,

the total number of typical speech sound errors, atypical speech sound errors, and distortions were tallied and used for analysis.

Reliability for SSPS Scoring

Point-to-point reliability between the first and third author for the coding of phoneme errors as typical, atypical, or distortions was obtained for 10% of participants' KAT assessments. Initial reliability (92%) revealed most disagreements revolved around a lack of clarity about the diacritics used by the transcribers. The diacritic that caused the most disagreements was discussed and reviewed on all participants to ensure consistent scoring. Final point-to-point reliability was 95%.

Spelling

The first two authors trained four student research assistants (three graduate and one undergraduate) on data entry and analysis for the Computerized Spelling Sensitivity System. Data entry was supervised by each author who held weekly discussions with the students to review data entry policy and questions.

Spellings for each of the 250 participants were taken from scanned copies of the handwritten Spelling subtest of the Metropolitan Achievement Test (Durost et al., 1959), parsed according to phoneme, juncture, and affix, and the accuracy of each element determined on a scale of 0–3. An element score of 0 was given if the element was not represented, 1 if it was represented but not plausible or legal (e.g., as in the vowel element of *pot* when spelled as P-I-T), 2 if the element was legal or plausible but not correct (e.g., as in the second vowel element of *even* when spelled as E-V-I-N), and 3 if the element was correct. Transposition errors were defined as errors in which an element was illegally represented because the correct letter representation was placed elsewhere within the word (e.g., F A M L I Y for f a m i l y). However, if two letters were switched within the same element, it was not considered a transposition error (e.g., B R I D for b i r d). Items considered unreadable

by the investigators were excluded from analysis on an individual basis.²

Four dependent spelling variables were obtained. First, number of analyzable attempts reflected the fact that, for some participants, the spelling of some words could not be analyzed with the Computerized Spelling Sensitivity System (e.g., spelling *bird* as *B*). Therefore, each word was coded as either an analyzable attempt (i.e., it included two correct letters or two elements represented by a common legal spelling or diagraph) or a nonanalyzable attempt of the target spelling.

The second variable, the Spelling Sensitivity Score-Elements (SSS-Elements), was the average score of the elements within the word. For example, *cat* has three elements. If the speller spelled this word as K-A-T, the word received 8 element points (2 points for K, 3 points for A, and 3 points for T) and the SSS-Elements score for that word was 2.67 (8 element points/three total elements). If the spelling was T-A-T, the word received 7 element points, and the SSS-Elements score was 2.33 (1 point for T, 3 points for A, and 3 points for T (7 element points/three total elements).

The third variable, the Spelling Sensitivity Score-Words (SSS-Words), represented the level of linguistic accuracy of the whole word. That is, if the entire word was spelled correctly, it was scored as a 3. If the word was misspelled but contained all plausible spellings, it received a score of 2. If the word was completely represented phonologically but contained at least one illegal spelling, it received a score of 1. If one or more elements in the word were not represented with a spelling, the score was 0.

Finally, frequency of types of spelling at the word level (i.e., correct, legal, illegal, and spellings containing one or more element omissions) were considered to capture potential descriptive differences of linguistic spelling knowledge across the articulatory percentile subgroups. Subgroups with spellers who had comparatively more linguistic knowledge would have high frequencies of correct spellings (where all spelling elements were spelled correctly), and/or legal spellings in which all spelling elements were included and spelled legally (plausible) but at least one element was incorrect (as in spelling *cat* as K-A-T). Subgroups with spellers who had comparatively less linguistic knowledge would have high frequencies of illegal words (which contained all spelling elements but at least one element was illegal), and/or omissions in which at least one spelling element was omitted.

Reliability for SSS Scoring

Reliability for scoring in the Computerized Spelling Sensitivity System was determined by having one student research assistant reparse spellings of 20% of another student's participants. In the event that results were not identical, the second author decided which coding and parsing

would be accepted. If these decisions affected other results from the remaining participants, changes were generalized. Percent agreements were calculated for parsing target words (96%), number of analyzable attempts (98%), SSS-Elements score (98%), and SSS-Words score (97%).

Results

Spelling Accuracy Across a Range of SSPS

Group means, standard errors, and effect sizes (partial eta squared) for measures of spelling accuracy for each SPSS subgroup are shown in Table 2. For each of the three spelling measures, an analysis of covariance was conducted and the overall cognition scaled score was used as a covariate due to significant group differences. A Bonferroni correction calculated to modify the original alpha level ($.05/3 = .0167$) and post hoc (Duncan) pairwise comparisons of the percentile subgroups were carried out for significant main effects.

Number of Words Analyzable

The main effect of subgroup was not significant for the number of words analyzable, $F(1, 4) = 2.67, p = .033$. There was a small effect size of .048. Means and standard errors are illustrated in Figure 2.

SSS-Words

The main effect of subgroup was significant for SSS-Words, $F(1, 4) = 3.56, p = .008$, and the effect size was .063. As illustrated in Figure 3, post hoc analyses revealed that the 98th percentile subgroup performed significantly better than the other four subgroups and that the 7th percentile subgroup performed significantly worse than the highest three subgroups. Differences between the lowest two groups (7th, 15th) and the middle three groups (15th, 30th, 50th) were not significant.

SSS-Elements

The main effect of subgroup was significant for SSS-Elements, $F(1, 4) = 3.728, p < .006$, and the effect size was .066. Post hoc analyses indicated that the 98th percentile subgroup performed significantly better than the other four groups and that the 7th percentile subgroup performed significantly worse than the highest three groups. Differences between the lowest two groups (7th, 15th) and the middle three groups (15th, 30th, 50th) were not significant. These results are shown in Figure 4.

Frequencies of Types of Spelling

Frequencies of each type of spelling (correct, legal, illegal, and spellings containing one or more omissions) at the word level were calculated for each subgroup, and results indicated significant differences ($\chi^2 = 366.4, p < .0001$). Figure 5 illustrates the frequencies of spellings characterized by less linguistic knowledge (i.e., illegal spelling patterns or omitted elements) used by each group. It also reflects the expected frequency for each type of spelling. Expected frequencies were calculated in the chi square analysis by multiplying

²The target word *aide* was dropped from analysis for all participants because the Computerized Spelling Sensitivity System dictionary could not be programmed to accept its alternative legal spellings. This reduced the maximum number of words analyzed per participant from 40 to 39.

Table 2. Spelling accuracy for each group of speech sound production skill.

Measure of spelling accuracy	Percentile group					<i>F</i>	<i>p</i>	Partial eta squared
	7th	15th	30th	50th	98th			
Number analyzable								
<i>M</i>	28.60	31.90	33.0	35.10	38.10	2.67	.033	.048
<i>SE</i>	1.57	1.49	1.50	1.25	1.55			
SSS-Words								
<i>M</i>	1.41	1.59	1.70	1.75	2.25	3.56	.008	.063
<i>SE</i>	0.10	0.10	0.10	0.08	0.10			
SSS-Elements								
<i>M</i>	2.32	2.39	2.50	2.51	2.75	3.73	.006	.066
<i>SE</i>	0.05	0.05	0.05	0.04	0.05			

Note. *F* values reflect the main effect for subgroup from three individual ANOVAs. SSS-Words = Spelling Sensitivity Score-Words; SSS-Elements = Spelling Sensitivity Score-Elements.

each column total by each row total and dividing the result by the overall total. The 7th percentile subgroup demonstrated more omissions and more illegal spellings than any other subgroup and exceeded the expected frequencies for both types of spellings. Figure 6 displays the frequencies of words spelled correctly or with legal, but incorrect, spellings; it also includes expected frequencies generated by the chi square analysis. These findings indicate that the children with the poorest speech accuracy produced spellings with less linguistic knowledge than expected levels. On the other hand, correct or linguistically plausible spellings exceeded expected levels for children with the highest speech accuracy.

Type of Speech Sound Error and Spelling Accuracy

The final analyses addressed our second hypothesis, that spelling performance would vary on the basis of the

relative occurrence of atypical speech sound errors. Only the 7th percentile subgroup (those with the lowest speech sound production scores) contained sufficient atypical speech sound errors for this analysis. Within this group, there was no significant correlation between the number of kindergarten atypical errors per consonant and Grade 3 spelling scores: SSS-Elements ($r = .10$, $p = .37$); SSS-Words ($r = .02$, $p = .089$). Because the total number of errors differed among the 43 participants in the subgroup, a secondary analysis compared two categories of participants, all of whom had an equivalent total number of errors. The high atypical category ($n = 11$) included those in the subgroup with more than 0.08 atypical errors per consonant, and the low atypical category ($n = 11$) included children with fewer than 0.04 atypical errors per consonant. Results of a Mann-Whitney test indicated no group difference on either SSS-Elements ($p = .28$) or SSS-Words ($p = .61$) scores. This suggests that among the children with the lowest SSPS, the

Figure 2. Number of analyzable words by SSPS percentile subgroup. Error bars represent 1 SEM.

Figure 3. SSS-Word score by SSPS subgroup. Error bars represent 1 SEM.

relative frequency of atypical errors was not associated with later spelling.

Discussion

Spelling, like reading, is a complex developmental linguistic skill that draws on multiple sources of knowledge. Investigators have speculated that SSPS would be associated with spelling skill, but findings from investigations of this association have been mixed. In the current study, we aimed to explore the relationship between SSPS and spelling by using two contemporary resources to examine linguistics aspects of spelling across a spectrum of SSPS

subgroups and guard against possible protective effects of speech therapy.

Differences in Spelling Accuracy Across a Range of SSPS

Similar to some studies of SSPS and spelling (Bird et al., 1995; Lewis et al., 2006; Overby et al., 2012), our results revealed that children with isolated poor articulatory skill (7th percentile subgroup) on an articulation test in kindergarten had poor spelling of real words 3 years later. Children in the lowest percentile subgroup produced notably fewer correct spelling elements and demonstrated more

Figure 4. SSS-Element score by SSPS percentile subgroup. Error bars represent 1 SEM.

Figure 5. Relative frequencies of spellings with omissions or illegal orthographic patterns by SSPS percentile subgroup. The expected frequency of each type of spelling error also is provided. Omission: The word contained at least one omitted spelling element. Illegal: All spelling elements were included; however, at least one was illegal.

omissions and illegal spelling patterns within a word than grade level peers with typical speech sound skills, suggesting that the children with poor articulatory mastery had less access to sound–symbol relationships than those with more proficient speech sound skills.

These findings are consistent with our first hypothesis and support predictions from the DRM of spelling regarding the role of SSPS as a variable relevant to spelling performance. In the DRM of spelling, the phonological output lexicon is responsible for the storage of speech-based

information needed to effectively map phonemes to graphemes during encoding. For this mapping to occur, the sound system of the language must first be segmented into phonemes. As Fowler (1991) observed, the cohesiveness and phonetic accuracy of phonemes during their production (as well as in perception and memory) influence the ease with which a child achieves conscious awareness of the phonemes and the ability to manipulate them. Therefore, SSD may adversely affect the stability of representations of the sound structures of the language needed for purposeful

Figure 6. Relative frequencies of acceptable spellings that contained legal misspellings or were entirely correct by SSPS percentile subgroup. The expected frequency of each type of spelling also is provided. Legal: All spelling elements were included and spelled legally; however, at least one was incorrect. Correct: All spelling elements were spelled correctly.

manipulation of phonemes and graphemes, particularly when spelling phonetically predictable words (Lewis et al., 2002; Sandburg, 2001). Thus, children with SSD may experience difficulty in phonological awareness, setting the stage for encoding difficulty. It is not surprising, then, that speech sound remediation alone may be insufficient to address spelling difficulty and that phonological awareness training is necessary for adequate long-term spelling outcomes (Gillon, 2005; Kirk & Gillon 2007).

It may well be that it is the persistence of the SSD that underlies the poor categorization and representation of phonemes (Bird et al., 1995), creating impaired phonetic templates of phonemes that, when mapped to graphemes, result in more illegal spellings and omissions than expected. In the current investigation, the speech sound errors of the participants had persisted until the spring of kindergarten. Speech sound therapy was minimal until at least Grade 2, so intervention effects on speech could not plausibly account for the observed association between kindergarten speech and later spelling.

If impaired speech-based information in the phonological output lexicon is associated with reduced spelling accuracy, then it stands to reason that superior SSPS would be associated with superior spelling skills. As phonemes become stable and ultimately accessible as control over articulation is achieved, children who demonstrate typical or superior speech sound skills at an early age (or whose speech sound errors are remediated) should then be less likely to demonstrate later spelling difficulty. Our results showed that even when cognition was accounted for, children in the 98th percentile articulatory subgroup outperformed all the other subgroups in spelling accuracy and in frequency of correct and legal spellings. The fact that this group was older than the other subgroups may well have been responsible for their superior spelling, but it should be noted that the mean difference in age was at most only 2 months.

Type of Speech Sound Error at Kindergarten and Spelling Accuracy at Grade 3

In the present investigation, the type of speech sound error (typical vs. atypical) in kindergarten did not relate to spelling skill in Grade 3, a finding in contrast to similar investigations of type of speech sound error and spelling (Leitao & Fletcher, 2004; Leitao, Fletcher, & Hogben, 2000). However, it may have been the case that the articulation assessment used in this investigation was designed to identify the frequency, not the types, of phoneme errors, and as suggested by Morrison and Shriberg (1992), a citation test alone provides neither optimal nor typical measures of speech performance. As described by Preston and Edwards (2010), atypical errors can be captured in speech samples with phonological complexity, and it is possible that the sample here did not have sufficiently complex word forms to elicit many atypical errors.

Little is known about what types of spelling errors may distinguish children with histories of SSD from the spelling errors of other children. Clarke-Klein and Hodson

(1995) found that children with histories of SSD used fewer phonetic strategies and more nonphonetic strategies when spelling than children without histories (33%, 13% vs. 78%, 1%, respectively). However, they did not explore differences across severity of SSD. Our finding that kindergarteners in the lowest articulatory subgroup used more omissions and illegal spellings in Grade 3 than subgroups with better articulatory proficiency adds new perspective about the nature of children's spelling errors. Children with the lowest SSPS demonstrated less linguistic spelling knowledge than those with less articulatory skill, using more omissions and fewer conventional patterns for spelling. These findings indicate that children with poorer SSPS struggle not only with the phonological components of literacy, but also with mastering the orthographic patterns for coding sounds and morphemes. In fact, the children with poor SSPS made more orthographic than phonological errors.

Clinical Implications

These findings are consistent with others who have highlighted the link between SSPS and literacy (e.g., Overby et al., 2012; Preston et al., 2013; Skebo et al., 2013), but the unique contribution of the present study is its focus on spelling skills. Because children scoring in the 7th percentile subgroup in the longitudinal study would likely have been similar to children with SSDs identified by present day SLPs (Overby et al., 2012), our results imply that kindergarteners with persistent SSD appear to be at risk for later spelling difficulty; their spellings were characterized by fewer than expected correct elements, more than the expected number of omissions, and/or frequent illegal spellings. Additional study is needed regarding the spelling risks posed by children with atypical speech sound errors. Because inaccurate speech output in older children (6;9) is also predictive of spelling difficulties (Nathan et al., 2004), it appears that treatment for both preschoolers and elementary school-age children with SSD, which typically focuses on improving articulatory accuracy, should include intervention that emphasizes skills that support spelling.

Clinicians can identify specific orthographic patterns warranting intervention and pinpoint the linguistic knowledge area requiring improvement through a multilinguistic model of prescriptive assessment described by Masterson and Apel (2007, 2010, 2013). This approach, often labeled as *word study*, links specific types of spelling errors to tailored treatment activities that support children's spelling and reading and has been shown to improve spelling performance (Bell, Cron, Jones, & Borneman, 2013; Berninger et al., 1998; Calfee, 1998; Graham et al., 2002). Omission errors are addressed primarily with phonological awareness training that focuses on segmenting phonemes within words and tying letters to each phoneme. Gillon and colleagues (Gillon, 2005; Kirk & Gillon, 2007) noted that after children with phonological impairments received phonological awareness intervention, there were improvements in the children's performance on various spelling tasks (e.g., 10 real words, morphologically complex words).

Errors in orthographic pattern knowledge are targeted with activities that contrast the salient features of the desired spelling pattern (e.g., spelling phonemes in base words or morphological elements such as junctures and affixes) with the way(s) that the child is currently spelling the target. Word sorts (Zutell, 1998) help the child to consciously identify differences in spellings and then formulate a reason for the differences, thus resulting in an explicit acknowledgment of the spelling principle.

Error patterns that are orthographically plausible (e.g., RANE for *rain*) are considered to result from incomplete mental graphemic representations, so treatment must focus on word-specific learning. Activities, such as backward spelling or describing the number of vowel letters, consonant letters, and so on, that direct the child's attention to the specific ways individual words are spelled are beneficial to address this skill. It is important to note that such techniques are used only after ensuring that the requisite phonological, orthographic, and morphological knowledge are in place.

Following word study, it is critical that authentic writing and reading activities are implemented (Bell et al., 2013; Masterson & Apel, 2007, 2010, 2013). Writing tasks related to reading material will ensure opportunities to spell the targeted patterns, and semantic awareness can be emphasized through proofing activities.

Limitations and Future Directions

Limitations of the Templin Archive (Templin, 2004) are discussed in Overby et al. (2012). Additional limitations of this investigation include the administration of a single 40-item subtest to assess spelling skill and the use of a brief articulation test as a measure of SSPS. Although language skill is a robust predictor of spelling, only receptive vocabulary skill was considered in this study. Future investigations of spelling are needed which consider the role of SSPS within the context of a more representative speech sample and in which language skill of the participants is better known.

Conclusion

In summary, the results of this investigation are consistent with predictions from DRMs of spelling. Findings also contribute to converging evidence that both preschool and elementary school-age children with SSD are at increased risk for spelling problems (Bird et al., 1995; Clarke-Klein & Hodson, 1995; Nathan et al., 2004; Stackhouse, 1982). Because of this association, it is essential that clinicians consider integrating early spelling-related skill-building activities (such as those described above) to support spelling when providing speech therapy for children with SSD. For children in elementary school, clinicians should also monitor the spelling skills of those with persistent SSD or who have been dismissed from speech therapy.

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Appendix A

The Kindergarten Articulation Test

Templin (Templin Archive, 2004) devised the Kindergarten Articulation Test (KAT), administered initially as a single-word spontaneous picture-naming test and then administered a second time as a single-word imitative test but using different words to elicit the target phonemes. The test was intended to include all English initial and final consonants (33 items testing 55–57 phonemes), depending whether /hw/ in *wheel* and the /ʒ/ in *garage* are included (Table A1). For clusters, individual target consonants were scored rather than the cluster itself. As a result, the /s/ and the /l/ in *slide* were each assessed separately, and the /s/ and the /r/ in *string* were each assessed separately. Total scores on the KAT reflected the number of correct target phonemes. The KAT was administered at every test session, starting with spring, 1961.

Table A1. Words and Target Phonemes in the Kindergarten Articulation Test, Picture-Naming Form

Target phonemes	Words
/w-/	<u>w</u> indow
/j-/	<u>y</u> ellow
/v-/	<u>v</u> acuum cleaner
/ð-/	<u>th</u> ere
/dʒ-/	<u>j</u> ack-in-the-box
/r-/	<u>r</u> oof
/m-/	<u>w</u> heel
/d-/	<u>d</u> og
/p-/	<u>p</u> encil
/-ð/	smoo <u>th</u>
/-b/	tub <u>e</u>
/m-/ , /-ʒ-/	<u>m</u> ea <u>s</u> ure
/k-/ , /-p/	<u>c</u> up
/f-/ , /-ʃ/	<u>f</u> ish
/h-/ , /-t/	<u>h</u> at
/b-/ , /-l/	<u>b</u> ell
/g-/ , /-ʒ/	<u>g</u> arage
/s-/ , /-tʃ/	<u>s</u> and <u>w</u> ich
/ʃ-/ , /-l/	<u>sh</u> ovel
/z-/ , /-r/	<u>z</u> ipper
/t-/ , /-θ/	<u>t</u> ee <u>th</u>
/θ-/ , /-m/	<u>th</u> umb
/n-/ , /-z/	<u>n</u> ose
/l-/ , /-f/	<u>l</u> ea <u>f</u>
/tʃ-/ , /-r/	<u>ch</u> air
/Cl-/ , /-g/	<u>f</u> lag
/Cl-/ , /-s/	<u>g</u> lass
/Cr-/ , /-n/	<u>t</u> rain
/Cr-/ , /-dʒ/	<u>b</u> ridge
/sC-/ , /-k/	<u>s</u> mo <u>k</u> e
/sC-/ , /-v/	<u>s</u> tov <u>e</u>
/sC-/and /Cl-/ , /-d/	<u>s</u> l <u>i</u> d <u>e</u>
/sCC-/ and /CCr-/ , /ŋ/	<u>s</u> <u>t</u> <u>r</u> <u>i</u> <u>n</u> <u>g</u>

Appendix B

Spelling Subtest of the Metropolitan Achievement Tests: Form B-Elementary

The Spelling Subtest of the Metropolitan Achievement Tests: Form B-Elementary (Durost, Bixler, Wrightstone, Prescott, & Balow, 1959) consists of 40 words written to dictation. The examiner said each word, a sentence with the word, and then repeated the word. With the permission of the publisher, Templin rearranged the list presentation from the “easiest” to spell to the “most difficult.” Although individual administration of the subtest required the examiner to stop testing after the child had misspelled five words, the subtest was group administered by the classroom teacher in the longitudinal study. Copyright © 2002 NCS Pearson, Inc. Reproduced with permission. All rights reserved.

1. bird	21. cast
2. door	22. delay
3. butter	23. hardly
4. fine	24. snake
5. plan	25. blame
6. pot	26. true
7. star	27. crowd
8. every	28. cabin
9. rope	29. getting
10. dress	30. wear
11. found	31. aid
12. bite	32. listen
13. homesick	33. family
14. making	34. leaving
15. o'clock	35. careful
16. even	36. single
17. taken	37. cause
18. moving	38. address
19. task	39. parade
20. paint	40. through