7-3-2016

Analyzing Spelling Errors by Linguistic Features among Children with Learning Disabilities

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by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
Department of Communication Sciences and Disorders
College of Behavioral and Community Sciences
University of South Florida

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Date of Approval:
July 1, 2016

Keywords: Spelling, Phonology, Orthography, Morphology, Dyslexia, Dysgraphia, Oral-Written Language Learning Disability (OWL-LD)

Acknowledgements

First, I would like thank my major professor Dr. Ruth Huntley Bahr, who constantly challenged and encouraged me throughout the writing process. I truly appreciate the time you have dedicated to my education. I am a better writer, clinician, and consumer of research as a result of your knowledgeable guidance.

I would also like to extend my gratitude to Dr. Maria Brea-Spahn and Michelle Hite. Thank you for taking the time to be a part of my defense committee. Your insightful comments and constructive criticisms helped me to further develop the ideas of this study.

Finally, I would like to thank my family and friends for their unwavering love and support. I feel grateful to be surrounded by such positive and encouraging people. All of life's endeavors are possible with you by my side.

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Abstract

In order to spell fluently and accurately, phonology, orthography, and morphology must be integrated and stored into long term memory (Berninger & Richards, in press; Berninger, Nagy, Tanimoto, Thompson, Abbott, 2015). Children with dysgraphia, dyslexia, and OWL-LD have specific deficits in linguistic processing that impede the cross-mapping of these linguistic elements. This study analyzes the frequency and nature of spelling errors produced by children with dysgraphia, dyslexia, and OWL-LD during an academic writing task in order to determine if known deficits in linguistic processing affect the type and severity of spelling errors made by these children.

The present study analyzed error severity and frequency of spelling errors produced by children with dysgraphia (*n*=13), dyslexia (*n*=17), or OWL-LD (*n*=5) during the academic writing tasks obtained in the Berninger et al. (2015) study. In the previous study, students read or listened to computerized lessons about basic mathematical concepts and then typed summaries of what they learned. For the current study, all spelling errors made during the typed summary writing tasks were extracted and analyzed using the Phonological, Orthographic, Morphological Assessment of Spelling (POMAS) and then recoded with POMplexity (a measure of error severity) to determine the severity and frequency of spelling errors made in the linguistic categories of phonology, orthography, and morphology.

Results indicated that the students did not differ in error severity by diagnostic category. However, a qualitative analysis using the POMAS revealed that children from different diagnostic categories produced different types of errors. With respect to error frequency, only

students with dysgraphia made significantly fewer errors than students with OWL-LD, and all participants, regardless of diagnostic category produced more errors in typed summaries following the reading condition.

These results are consistent with previous research indicating that children with learning disabilities do not produce deviant spelling errors when compared to typically-developing, age-matched peers or typically-developing, spelling-matched peers (Silliman, Bahr, and Peters, 2006, among others). The current results demonstrate that the spelling errors of children with learning disabilities reflect the expected linguistic breakdowns in cross-code mapping, and that children with learning disabilities may display these spelling deficits beyond an appropriate age.

Chapter 1

Introduction

Children do not learn to spell by memorizing spelling lists. Likewise, early learners do not rely solely on phonetics to spell. At all ages, the process of spelling involves a complex interaction of phonology, orthography, and morphology that must be acquired and developed through exposure to written language and writing (Apel, Wolter, & Masterson, 2006; Bahr, Silliman, Berninger, & Dow, 2012; Garcia, Abbott, & Berninger, 2010).

Moreover, spelling is an integral part of the process that allows thought to be conveyed through written expression. Poor spelling results in poor written communication of thoughts, opinions, and ideas (Singer & Bashir, 2004). Difficulty with spelling makes the process of writing burdensome, and students who cannot spell well tend to write fewer words in their compositions (Moats, Foorman, & Taylor, 2006). In addition, changes in academic standards require that children are able to spell correctly within the context of an academic writing task. Spelling during this type of task requires the writer to allocate cognitive resources between text construction and spelling.

Children with specific learning disorders (SLDs) may be at an added disadvantage due to difficulties with reading, writing, and spelling. This study analyzes the nature, frequency, and severity of the spelling errors produced by children with dyslexia, dysgraphia, and oral-written language learning disability (OWL-LD). Such an analysis may help identify specific difficulties with linguistic processes, which may lead to more individualized intervention strategies. If such individualized spelling intervention can ease the process of spelling, then these children will be able to write more effectively.

This chapter reviews the literature of the spelling process as it pertains to typically-developing spellers. It focuses on the contributions of phonology, orthography, and morphology inthe process of spelling, discusses the definition of specific learning disorder, defines dysgraphia, dyslexia, and OWL-LD, and lastly discusses the types of spelling errors that are expected from each of these SLDs based on their group's specific linguistic processing deficits.

The Linguistic Process of Spelling

It may seem that spelling is inconsistent and that the placement of every letter within a word must be memorized to produce conventional spellings. However, this is not the case. Children can transcribe phonology and morphology into written representations quite effortlessly when provided school-based instruction. Typically-developing spellers have little trouble storing and mapping phonology, morphology, and the morphophonemic changes necessary to transcribe orthographic patterns. As described within the parameters of statistical learning theory (Saffran, Aslin, & Newport, 1996), repeated exposure to orthographic patterns reinforces those patterns' importance to the written language system. Therefore, these patterns are important enough to be mapped into a child's orthographic memory (Apel, 2011). During a transcription task, a writer can use stored orthographic patterns to make judgments about conventional spellings of words. Thus, the ability to map and store orthography rules and patterns to morphemes at the meaning level for later lexical retrieval is essential for the production of conventional spelling.

While memorizing every letter placement is not how children learn to spell, memory processes do play an important role. Memory is the foundation onto which the linguistic bricks of the spelling process must be laid. The process of spelling itself involves complex interactions among phonology, orthography, and morphology which must be acquired and developed through exposure (reading) and use (writing) (Apel, 2011; Apel, Wolter & Masterson, 2006; Bahr et al.,

2012; Garcia et al., 2010). Additionally, the process of learning to spell involves the cross-code mapping of phonology, morphology, orthography, and semantics into long-term memory (Berninger & Richards, in press).

Cross-code mapping requires contemporaneous integration of phonology, orthography, morphology, and orthographic patterns (Berninger & Richards, in press). Additionally, the morphophonemic changes that occur in speech must be mapped to their corresponding letter sequences. Maps can occur at several levels: the whole word (i.e., semantic level) or subword levels (i.e., phoneme-grapheme, onset-rime, and morpheme level). At the whole word level, an orthographic pattern represents a phonological pattern that is associated with a specific morpheme at the meaning level. This is called a *"word-specific spelling,"* which is created through cross-code mapping and is stored in long-term memory (LTM) for future decoding and encoding tasks (Berninger & Richards, in press). Access to a *word-specific spelling* results in a word that is spelled conventionally and fluently.

At the subword level, phoneme-grapheme maps are the most basic correspondence of sounds to letters. This process is useful when spelling words that are regular, meaning that there is a one-to-one letter/sound correspondence, as in *cat*. Another subword level is the onset-rime map, which is the correspondence of an onset (i.e., a phoneme-grapheme correspondence associated with the initial sound in a syllable) and a rime (i.e., a patterned group of letters that represents the core of a syllable). In contrast, morpheme level mapping connects sounds of linguistically meaningful morphemes to letter patterns. The morpheme level maps are the most complex of the subword category as these maps move the user's knowledge closer to a *word-specific spelling*. The chart below provides definitions and examples of word-level and subword level maps adapted from the Berninger and Richards (in press) spelling model.

Table 1. Word Map Model (Adapted from Berninger & Richards (2015))

Mapping Level	Explanation	Example of mapping
Whole Word (lexical)	Word-specific spelling is achieved.	Correct spelling of target word (all levels are integrated).
Subword – phoneme-grapheme	Phonology is cross mapped to orthography	The sound /f/ is represented orthographically as *f* or *ph* or *gh*.
Subword – onset-rime	Chunks of sound are mapped to chunks of letter patterns	/ɑf/ mapped to orthography as *off* or –*ough*, but is not connected to a specific meaning (although *off* could be connected to a specific meaning, whereas the phonologically same –*ough* is not).
Combined subword and word level (morpheme level)	Phonology and orthography are mapped to morphemic units	/ɑləgɪ/ is mapped orthographically as -*olog*y and connected to the meaning "study of".

When a speller of any age is tasked with spelling a word that is not represented in LTM as a *word-specific spelling*, knowledge from the subword level is used to make judgments about how the unknown word is spelled. For example, the novice speller often uses phoneme-grapheme correspondences to spell unfamiliar words due to his/her inexperience with connections between morphology and orthographic patterns. However, this strategy may also be

used as a last resort for experienced spellers attempting to spell linguistically complex words that are less familiar to them (Bahr et al., 2012). A reliance on phoneme-grapheme correspondences is only successful when the proportion of phoneme-grapheme correspondences is high. Research has shown that this correspondence ratio is not only a significant predictor of spelling accuracy in the early years, but also for all grade levels (Sadoski, Willson, Holcomb & Boulware-Gooden, 2005). Students of all ages are able to use the phoneme-grapheme correspondence technique with success when the ratio of sounds to letters is 1:1. However, English spellings frequently do not have a 1:1 ratio between phonology and orthography. For this reason, the linguistic elements of subword knowledge must be cross-code mapped in order to produce conventional spellings for words that are more opaque, i.e., do not follow the usual patterns of phoneme-grapheme correspondences.

Thus, when a child uses a phoneme-grapheme strategy to spell a word that does not have a 1:1 ratio of phonemes to graphemes or contains phonemes that may blend together, s/he may make a phonological error, such as an omission. For example, although the word *jump* has a 1:1 ratio of phonemes to graphemes, the /m/ sound may be omitted because it is difficult to perceive, especially if phonemic awareness is underdeveloped. Treiman, Zukowski, & Richmond-Welty (1995) found that children will regularly omit a phoneme in a consonant cluster, such as the /m/ in *jump,* because that phoneme is less perceptually salient because of its placement near a vowel. Although the child has the necessary orthographic knowledge to spell the target word, a breakdown in phonological awareness results in cluster reduction (i.e., *-mp* goes to *-p*). Even when phonological awareness is strong, the use of a phoneme-grapheme correspondence strategy does not always produce a conventional spelling. For example, it is phonetically plausible to spell the word *hate* as *hat,* if the letter ‘a’ is pronounced as its alphabetic name (i.e., long a)

(Treiman & Bourassa, 2000). This type of error demonstrates phonological awareness in the presence of inchoate orthographic knowledge. In this example, the speller demonstrates difficulty with the knowledge of the silent *e* rule, which makes the vowel nucleus of the syllable long.

So, while phonology can support spelling, a deeper understanding between phonology and orthography must be acquired to form orthographically plausible or correct spellings (Treiman & Bourassa, 2000). Specifically, children must learn the alternate orthographic representations of the phonemes in their language, which requires the successful cross-code mapping of one phoneme to various forms of orthography. For example, the long *i* sound can be represented orthographically as *i-e* such as in *bite*, *-igh*, such as in *flight*, *-y* as in *sky*, and *-ie*, such as in *tie*. In addition, children must learn the legal and illegal letter sequences of their language-specific orthography. For example, the /k/ sound can be represented orthographically as *c* (as in *cat*), *k* (as in *kettle*), *ck* (as in *duck*), and *ch* (as in *chorus* or *echo*). But, in English, it is always only legal to use *ck* in the word final position following a short vowel; it is orthographically illegal in all other word positions.

Once children know the various orthographic patterns that correspond with certain phonological patterns, they are able to spell more accurately. Repeated exposure to words while reading allows children to learn and map which letter combinations are plausible and which are not. This knowledge can then be used to make judgments about word spellings. For instance, Cassar and Treiman (1997) tested children's orthographic judgments in a letter doubling task. They found that orthotactic (letter sequencing and position) knowledge was present in kindergarten and continued to develop into middle school. In kindergarten, children could determine that *nnus* was less word-like than *nuss*. Hence, by 1st grade, knowledge of allowable

double letter sequences emerges (i.e., *t* is more likely to be doubled than *v*), and by 6th grade, children were able to demonstrate clear knowledge that letters were doubled in the medial position following short vowels. These findings demonstrate that children are consistently acquiring orthographic knowledge and using this knowledge to make judgments about word spellings. As a child learns the more complex letter sequences of their language, s/he can rely less on their phonological system and more on their orthographic pattern knowledge.

Finally, morphological awareness and semantic knowledge are also necessary for accurate spelling (Green, McCutchen, Schwiebert, Quinlan, Eva-Wood, & Juelis, 2003). Morphological awareness assists in making better judgments about how an unfamiliar word is spelled. For example, children tend to omit the nasal in a final nasal cluster. However, they are less likely to omit the /n/ in *tuned* than *brand* (Treiman & Cassar, 1996). Phonologically, the coda of the rime in both words is /nd/, but *tuned* is less likely to have the /n/ omitted since the /nd/ sound is comprised of two different morphemes (i.e., the past tense marker). In like fashion, early spellers are more likely to misspell the word c*ity* by substituting the /t/ with a [d] to represent the flap, but are less likely to misspell the word *dirty* using a flap. *Dirty* is a derivation of *dirt*, which ends in the /t/ sound. Children use this word-level knowledge to help them determine the correct orthographic representation for the flap sound in the word *dirty*. (Treiman, Cassar, & Zukowski, 1994). Hence, children have morphological knowledge of words and can use this knowledge to make judgments about spelling rather than relying on phoneme-grapheme correspondences alone.

In summary, children are constantly learning, mapping, and integrating linguistic knowledge and using this knowledge to make judgments about spelling. When tasked with spelling an unknown word, they can use any whole word or subword linguistic knowledge they

have acquired to determine how a word is spelled. However, the integration of morphological knowledge is especially important as it allows children to map phonology and orthography to larger units (morphemes), forming *word-specific spellings,* which can be quickly accessed during a writing task (Berninger & Richards, in press; Green, et al., 2003). Children who have difficulty acquiring and integrating linguistic knowledge will not have access to as much linguistic information when tasked with spelling an unfamiliar word, as is the case with children who have specific learning disabilities.

Specific Learning Disabilities and Spelling

According to the *Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition* (DSM-V), in order to meet criteria for specific learning disorder (SLD), a child must display difficulties with learning and using academic skills that have been explicitly targeted in intervention (American Psychiatric Association, 2013). The child must demonstrate one or more of the following difficulties for at least 6 months: difficulty with word reading, reading comprehension, spelling, written expression, mastering number sense or calculation, and/or mathematical reasoning (American Psychiatric Association, 2013). Once a specific diagnosis is made in a domain (i.e., reading, writing, mathematics), it is then given a severity rating of mild, moderate, or severe.

Reading and/or writing difficulties are present in dysgraphia, dyslexia, and OWL-LD. However, little is known about how weaknesses in these linguistic tasks may affect spelling ability. According to the *DSM-V,* difficulties with spelling include omissions, additions, and substitution of vowels and consonants (American Psychiatric Association, 2013). A better understanding of how specific cognitive and linguistic processing deficits influence spelling skill may have diagnostic utility and could provide more guidance for individualized intervention. To

this end, a description of three different SLDs will be presented to demonstrate unique patterns of deficit areas and to highlight potential difficulties with spelling.

Dysgraphia. Dysgraphia is a motor-based disorder that affects letter production, which results in illegible handwriting. In time, this motor problem results in an impaired ability to store orthographic information and produce accurate spellings; however, decoding abilities are maintained (Berninger & Richards, in press; Berninger, Richards, & Abbott, 2015). This disorder is not diagnosed until formal school-based instruction begins since these children do not present with oral language impairments and appear to be developing typically.

Currently, there are few, if any, studies that compare the spelling ability of children with dysgraphia to typically-developing children or to children with other language impairments. However, since children with dysgraphia have difficulties with orthographic coding and storing, it is expected that this group will struggle with acquiring and manipulating the orthographic codes that correspond with phonology at the subword level and with morphology at the whole word level. For this reason, children with dysgraphia are expected to struggle with the process of legible handwriting and struggle with the transcription of orthographic patterns while spelling.

Dyslexia. Dyslexia is marked by a specific difficulty in learning to read and spell, despite normal intelligence and no history of delays in oral language development (Berninger & Richards, in press; Berninger et al., 2015; Bourrassa & Treiman, 2003; Connelly & Dockrell, 2015; Snowling, 2000). Since oral language development appears to proceed normally, the deficits in reading and writing are not apparent until formal, school-based instruction begins (Berninger & Richards, in press; Berninger et al., 2015). Furthermore, children with dyslexia have an impairment at the phonological and orthographic processing level (Silliman & Berninger, 2011). Impairments in the cross-code mapping between phonology and orthography

results in a degraded orthographic system, which in turn, impedes access to orthographic knowledge during a spelling task (Cassar, Treiman, Moats, Pollo, & Kessler, 2005; Goswami, 1999).

Children with dyslexia have an impairment in short term memory that involves the phonological and othrographic loops (Silliman & Berninger, 2011). These difficulties make it difficult to analyze the sounds of spoken words in working memory, which impairs the child's ability to analyze letters within words. For children with dyslexia, poor integration of phonology and orthography begins early. In first grade, children with dyslexia begin displaying difficulties with cross-code mapping, characterized by difficulties with associating phonemes to graphemes (Silliman & Berninger, 2011). For this reason, errors in spelling are expected to be seen at the subword level where phonemes must be associated with graphemes and rimes must be associated with letter sequences.

In an attempt to uncover whether known deficits in linguistic processing affect the spelling of children with dyslexia, several studies have compared children with dyslexia to younger, typically-developing peers. The resulting research has indicated that despite having a specific impairment in phonological and orthographic processing, children with dyslexia produce misspellings that are similar to errors produced by younger, typically developing children (Bourassa & Treiman, 2003; Bruck & Treiman, 1990; Cassar, et al., 2005; Moats, 1983; Nelson, 1980). These researchers reported that the phonological and orthographic processing of children with dyslexia is delayed, resulting in an inability to create *word-specific spelling* at the subword level. Thus, children with dyslexia may know the pronunciation and meaning of a word, but may not be able to map the correct orthographic pattern of the word due to impairments in phonological processing.

Oral and Written Language Learning Disability. Oral-written language learning fisability (OWL-LD) is a term coined by Silliman and Berninger (2011) to describe a developmental profile, in which the child has a history of oral language delays in preschool that persist into oral and written language during formal, school-based instruction. The OWL-LD profile shares characteristics with the specific language impairment (SLI) profile. Children with SLI have expressive language disabilities characterized by weaknesses in morphological and phonological processing (Larkin, Williams, & Blaggan, 2013). Children with SLI also have phonological awareness deficits which may impair early mapping of phonemes to graphemes (Larkin et al., 2013), and these children often omit inflectional morphemes (Silliman, Bahr, & Peters, 2006).In comparison, children with OWL-LD have receptive and/or expressive language scores two standard deviations or more below the mean on standardized tests. These children also have impaired reading and listening comprehension at the word, sentence, and/or text level (Silliman & Berninger, 2011). Finally, children with OWL-LD have delays that negatively impact writing, such as impairments in morphological coding, syntax coding, and word retrieval (Silliman & Berninger, 2011). Given the similarities in the language profiles of children with OWL-LD and SLI and the relative newness of the OWL-LD term, the literature on spelling errors in children with SLI was reviewed.

Previous research that compared children with SLI to typically-developing and younger, ability-matched peers found that children with SLI have delayed spelling abilities rather than deviant or different spelling abilities (Larkin et al., 2013; Silliman et al., 2006). However, when a qualitative analysis of spelling errors was conducted comparing children with SLI to age-matched peers, children with SLI demonstrated weaknesses with the phonological structure of

words, resulting in more phoneme omissions during spelling than their age-matched peers (Bishop & Clarkson, 2003; Larkin et al., 2013; Silliman et al., 2006).

Furthermore, previous research has found that children with SLI make more morphological errors than age-matched peers, but performed similarly to ability-age matched peers (Deacon et al., 2013; Larkin et al., 2013; Silliman et al., 2006). Others have found that children with SLI have difficulties with derivational and inflectional morphology (Larkin et al., 2013; Silliman et al., 2006). In particular, the SLI group had significantly more omissions of past and progressive verb tense markers than age-matched peers (Larkin et al., 2013). In addition, children with SLI omitted the plural –s markers more than both their spelling-matched and age-matched peers (Larkin et al., 2013). These results suggest that children with SLI have difficulties at both the sub-word and word levels when spelling.

Spelling Errors Expected by Diagnostic Category. Children with learning disabilities take longer to form *word-specific spellings* due to deficits in linguistic processing. The deficits present in each profile impede the linguistic mapping of phonology, orthography, and morphology in different ways. Children with dysgraphia have a motor-based handwriting disorder, which results in difficulty with coding, storing, and manipulating orthography in working memory (Silliman & Berninger, 2011). As a result, these children have difficulties mapping orthographic codes into LTM to form *word-specific spellings.* Children with dyslexia have trouble cross-code mapping phonology to orthography. These children struggle with phonemic awareness, which affects analyzing sounds in words and manipulating the sounds of words in working memory (Silliman & Berninger, 2011). Poor phonemic awareness in this group results in incomplete mapping of phonology to orthography resulting in degraded orthographic representations. Spelling errors can then be expected at the subword level (i.e., phoneme-

grapheme, onset-rime) involving phonology and orthography. Lastly, children with OWL-LD share the phonological processing deficits experienced by children with dyslexia, but children with OWL-LD have additional deficits in semantics and syntax (Bishop & Snowling, 2004). These difficulties suggests that children with OWL-LD will make errors at the subword level, in addition to errors in morphology at the whole word level.

Purpose of the Present Study

In order to spell fluently and accurately, phonology, orthography, and morphology must be integrated and stored into long term memory (LTM) (Berninger & Richards, in press; Berninger et al., 2015). Children with dysgraphia, dyslexia, and OWL-LD have specific deficits in linguistic processing that impede the mapping of the aforementioned linguistic elements. This study analyzes the frequency and nature of spelling errors produced by children with dyslexia, dysgraphia, and OWL-LD during an academic writing task in order to determine if known deficits in linguistic processing affect the type and severity of spelling errors made by these children.

Common Core standards require that children begin composing texts as early as kindergarten. At this age, children are expected to use basic inflected morphemes and demonstrate an understanding of phoneme-grapheme correspondence knowledge (National Governor's Association Center for Best Practices & Council of Chief State School Officers, 2016a). By third grade, students are expected to use conventional spelling for high-frequency words and generalize spelling patterns to new words (i.e. word families, position-based spellings, syllable patterns, ending rules, and meaningful word parts) (National Governor's Association Center for Best Practices & Council of Chief State School Officers, 2016b). From sixth grade on, the standard reads “spell correctly” (National Governor's Association Center for Best Practices &

Council of Chief State School Officers, 2016c). Moreover, these skills must be demonstrated during writing tasks. Thus, it is important to assess spelling in the context of a text construction.

Text generation is a cognitively demanding task that requires the coordination of many higher-level executive functions (Hayes & Berninger, 2014). The cognitive resources needed for text construction include: *attention* for monitoring (past content), planning (future content), and organizing ideas; *working memory* for information processing (i.e. the ability to hold on to information and manipulate it); and *long-term memory* to access stored vocabulary, syntax, phonology, and orthographic knowledge. However, learning disabilities can interfere with the use of the available cognitive resources during the writing process. If cognitive resources are being appropriated for text construction, then fewer resources are available for spelling (and vice versa). In this way, the cognitive resources used for spelling and text construction are in constant competition.

When spelling is fluent, it takes some cognitive burden off the writer, thus allowing for more cognitive resources to be used for narrative construction. However, children with learning disabilities are often delayed spellers (Bourassa & Treiman, 2003; Cassar et al., 2005; Larkin et al., 2013; Moats, 1983; Nelson, 1980; Silliman et al., 2006). Immature spelling abilities requires children to use more cognitive resources when spelling. Poor spelling ability then acts as a road block on the bridge that connects thought to written expression. The goal of this study is to determine if the unique cognitive and linguistic deficits associated with dysgraphia, dyslexia, and OWL-LD will result in differences in the nature and severity of misspellings. The following research questions were asked were:

1) Are the types and severity of spelling errors produced by children with SLDs unique to their diagnostic category?

2) Is the frequency of spelling errors made by children with learning disabilities influenced by diagnostic category?
3) Is the frequency of spelling errors influenced by the type of learning context associated with the narrative task?

Chapter 2

Methods

Participants

De-identified spelling data were taken from a previous experiment (Berninger, Nagy, Tanimoto, Thompson, & Abbott, 2015). These data included students (*N*=35) in grades 4-9, who were diagnosed with either dysgraphia (*n*=13), dyslexia (*n*=17), or OWL-LD (*n*=5). The participants were recruited from local schools in an urban area in the Pacific Northwest. This study was approved by the Institutional Review Board (IRB) at the local university.

Parents interested in having their children included in the previous study (Berninger et al., 2015), participated in a phone interview to determine eligibility. The results of these interviews revealed that all participants had current problems in handwriting, spelling, and/or oral and written language syntax. These problems were persistent despite normal development and presented in the absence of a medical diagnosis that would better explain their learning difficulties. Individuals with a medical diagnosis of a Specific Learning Disability (SLD) or Attention Deficit Hyperactivity Disorder (ADHD), which often co-occurs with SLDs, met inclusion criteria.

After the phone interview, parents and students were invited to the local university for further testing. At that time, the parents completed a case history form, which included the student's family, medical, educational, and developmental history, which was used to confirm the information that was given during the phone interview.

The defining features of each SLD were drawn from interdisciplinary research that focused on the writing process (Berninger & Richards, in press; Berninger et al., 2015). For a student to be diagnosed with dysgraphia, s/he had to score 2-3 sd below the mean on two or more handwriting measures, while demonstrating typical reading capabilities. Additionally, the student had a parent-reported history of past and current handwriting problems that began in the early school-age years. Individuals diagnosed with dyslexia fell below the population mean for word reading and spelling, and also scored 1 standard deviation (sd) below the mean on two or more reading and spelling measures. Additionally, these students had a parent-reported history of past and current word reading and spelling problems that started in the early school-age years. A participant diagnosed with OWL-LD scored 2-3 sd below the mean on at least two measures of either syntactic listening, reading comprehension, or syntactic oral or written expression. The student also had a parent-reported history of aural and/or oral language problems that began before the school-age years. For more information on the parameters of these diagnostic categories, see Silliman and Berninger (2011).

The ages of the participants ranged from 10 years, 4 months to 14 years, 9 months with 80% of the distribution being male (Berninger et al., 2015). The ethnicity of the participants was self-reported by parents. The distribution of the participants was 78% European American (*n*=29), 2% Asian American (*n*=1), 2% Pacific Islander (*n*=1), 2% Hispanic (*n*=1), 2% Black (*n*=1), 2% Asian (*n*=1), and 8% identified as Mixed (*n*=3) (Berninger et al., 2015). The education level of the participants' parents were also self-reported and are presented in Table 2 below:

Table 2. Self-Reported Education Level of Parents

Level of Education	Less than High School	High School Graduate	College	More than College
Mother	0	1	16	18
Father	4	1	9	20

Materials

Writing Intervention Lessons. Once identified, participants completed a writing intervention program that required them to either read or listen to a lesson on a computer and then write a summary. In total, there were 18 lessons. The present study focused on lessons 7-12, which consisted of 12, two-hour writing sessions about basic mathematical concepts (lessons 7-9), cultural concepts of mathematics, and uses of mathematics (lessons 10-12) (Niedo-Jones, 2014).

The Phonological Orthographical Morphological Assessment of Spelling. The Phonological, Orthographic, and Morphological Assessment of Spelling (POMAS) (Bahr et al., 2012) was developed using triple word-form theory (Bahr, Silliman, & Berninger, 2009; Garcia et al., 2010; Richards et al., 2006) as its foundational framework. The POMAS is an unconstrained system that first categorizes an element of a spelling error as either phonological, orthographic, or morphological, and then further classifies it by type of linguistic feature in error. For example, the word *cultures* spelled as *cutuers* was given an P-code to describe the *l* omission. Then a P-code was assigned to describe the phonological reversal error, i.e., the *r* was placed after the *e* rather than before it. The overall integrity of the aforementioned word was given a score of 1 in the M-code category to represent the misspelling of the root word in the inflected form. In another example, the word *middle* spelled as *midal* received two O-codes in the orthography category. The word was then further classified as a letter doubling error and a

syllabic /l/ error. This word did not receive a score in the POMplexity M-code category as no morphology was needed for this word.

POMplexity. POMplexity (Benson-Goldberg, 2014) was developed to quantify the severity/complexity of misspellings. POMplexity scores consider both error frequency and severity. Coders used the scoring system to represent how far the misspelled word was from the target word. A numerical value for the categories of phonology, orthography, and morphology was assigned. First, a phonological or orthographic code was assigned a severity rating, then the overall integrity of the target word was coded for morphology to indicate how well the student was able to parse the target word.

The POMplexity scoring system does not assign any points for a word that is spelled correctly. If a word is misspelled, then it provides a severity rating from 0.5-3 points with 0.5 being the least severe rating and 3 being the most severe rating (see Table 3). These scores then reflect the relative contribution of each linguistic category to error severity.

The POMplexity scale for phonology is as follows: 0.5 of a point is given when the error accurately represents the phonological structure of the word, but an entire syllable is missing (i.e., syncope). One point is awarded for a substitution related to poor phonological awareness, and two points are awarded for omissions and additions of sounds (i.e., a misrepresentation of the phonological structure of the word). For examples of phonological errors (see Table 3).

The POMplexity rating for orthography is as follows: 0.5 of a point is given for errors in capitalization, word-spacing, and letter sequencing. One point is given for orthographic errors that reflected a grapheme selection error, which includes digraph errors, diphthong errors, and missing silent letters. Two points are given to orthographic errors that reflect word position violations. For examples of orthographic errors (see Table 3).

Table 3. POMplexity Scoring Instructions					
	0	**.5**	**1**	**2**	**3**
P	Correct Spelling	Errors related to syncope	Substitutions	Omissions/ Additions	Omission of a syllable (stressed or unstressed), but not syncope
	jump	intrest/interest famly/family	junp	jup jumpe	consion/conclusion unstand/understand
O	Correct spelling	Sequencing error – all graphemes present but in wrong order; or real word used to represent aspect of phonological structure or word spacing/ capitalization /hyphen errors	Grapheme Selection Error – including digraph and diphthong errors, silent letters are not represented	Positional Errors – graphemes in illegal positions	
	watermelon	watermlone liquidies for liquidize exsightment for excitement	hause for house cant for chant com for comb	ckat for cat	
M	All morphemes represented correctly	Correctly spelled homophone used / missing apostrophe in a contraction	Either root or affix misspelled, including real word errors	Both root and affix spelled incorrectly – but can recognize attempt to spell two morphemes	Word appears to be syllabified, the syntactic role is unrecognizable, or only the root was represented.
	walked painting	wait for weight cereal for serial	juped for jumped amusemnt for amusement liquidies for liquidize	jupt for jumped amusmnt for amusement liquadise for liquidize	asdet jump for jumped

The POMplexity scores for morphology are as follows: 0.5 of a point is given for a correctly spelled homophone. One point is given if the root or the affix is misspelled. Two points are given if the root and the affix are misspelled, but a clear attempt to spell two morphemes is present. Three points are given if a morpheme is not represented or is misused in a way that renders the word structure unrecognizable. This is considered to be the most severe morphological error since it appears that either no attempt was made to use morphology when it was required, or an error was made that rendered the syntactic role of the target word unrecognizable. For examples of morphological errors, see Table 3.

Procedures

Participants listened to lessons about mathematics through headphones or read the lessons on a computer monitor (Niedo-Jones, 2014). They were allowed to take typed notes on an iPad during lessons presented in either format. Using the same iPad, participants used their notes to type summaries about the lesson. For this study, the spelling errors produced during the summary writing tasks were extracted and analyzed using the POMAS (Bahr et al., 2012) and then scored for error severity using POMplexity (Benson-Goldberg, 2014).

Spelling errors and their targets were extracted from all typed summaries and placed into separate Excel spreadsheets for each participant. The misspelled word was then compared to the target word and each misspelled element received POMAS linguistic category and feature codes. Once coding with the POMAS was complete, the researchers used POMplexity to rate how far the misspelled word deviated from the target. The result was a severity rating (i.e., POMplexity score) that represented phonological, orthographic and morphological deviations separately.

Reliability of Scoring

A second rater, trained in the linguistic analysis of spelling errors, rescored all of the misspelled words. A third rater then compared the POMplexity scores for all spelling words and noted discrepancies between raters. When POMplexity scores differed across raters, the errors were discussed among the three raters and consensus on scoring was obtained. The final scores resulting from the evaluation of three raters served as the data for analysis.

Data Analysis

POMplexity data were collapsed across lessons to yield mean POMplexity scores for phonology, orthography and morphology for each participant in the reading and listening narrative conditions. These data were then compared across diagnostic categories and narrative conditions with an analysis of variance (ANOVA).

The second analysis focused on error frequency. The number of errors was normed by the number of words produced in each summary in each narrative condition. Differences across diagnostic category were analyzed with an ANOVA.

Qualitative Analysis

A qualitative analysis was conducted to describe the linguistic feature errors unique to specific SLDs. One participant from each diagnostic category who had completed both a reading and listening session in Lessons 10-12 was chosen for further analysis. Each of the chosen students had completed typed summaries for lessons 10-12 in both the listening and reading conditions. The types of errors made by each student were analyzed by linguistic category using the POMAS codes (i.e., phonology, orthography, and morphology) and linguistic feature (e.g., phonology: cluster reduction, orthography: letter doubling, morphology: misspelling inflection). The POMAS code categories within each linguistic category (phonology, orthography and

morphology) were counted in order to determine which linguistic feature was predominate. These values were compared across diagnostic groups to determine if children with dyslexia, dysgraphia, and OWL-LD made different types of errors.

Chapter 3

Results

The present study analyzes error severity and frequency of errors produced by children with dysgraphia (*n*=13), dyslexia (*n*=17), or OWL-LD (*n*=5) during an academic writing task. Students read or listened to computerized lessons and then typed summaries of those lessons. The lessons included in this study were about basic mathematical concepts, which required students to use vocabulary from the academic registry. All spelling errors made during the summary writing task were extracted and analyzed using the POMAS and then recoded with POMplexity to determine the severity of the error made in the linguistic categories of phonology, orthography, or morphology.

The first analysis examined whether the type and severity of spelling error was influenced by diagnostic category. The goal was to understand how known deficits in linguistic processing uniquely affected the spelling ability of children with learning disabilities. The second analysis considered whether the frequency of the spelling errors was influenced by diagnostic category or narrative condition. The third section is a description of the results from the qualitative analysis, which analyzed types of errors produced within each diagnostic category.

Type and Severity of Spelling Errors Made Within Each Diagnostic Category

The results of a three-way analysis of variance (ANOVA) with diagnostic category, narrative condition, and type of POMplexity score as the independent variables (IVs) and POMplexity severity score as the dependent variable was run. This analysis did not reveal any

significant interactions, only the main effect of type of POMplexity score was significant, $F(2,56) = 3.719$; $p = .024$, $\eta^2_p = .125$. This finding indicated that the only significant difference in this analysis involved the severity scores across the three POMplexity categories. Post-hoc testing using the LSD procedure revealed that two out of three pairwise comparisons for POMplexity score were significant; the morphology POMplexity score was significantly lower than the phonology and orthography POMplexity scores. Figure 1 displays the performance of each diagnostic group across the three POMplexity categories. One can see that the morphology scores were consistently lower than the phonology and orthography scores. However, no differences in performance were noted across diagnostic categories.

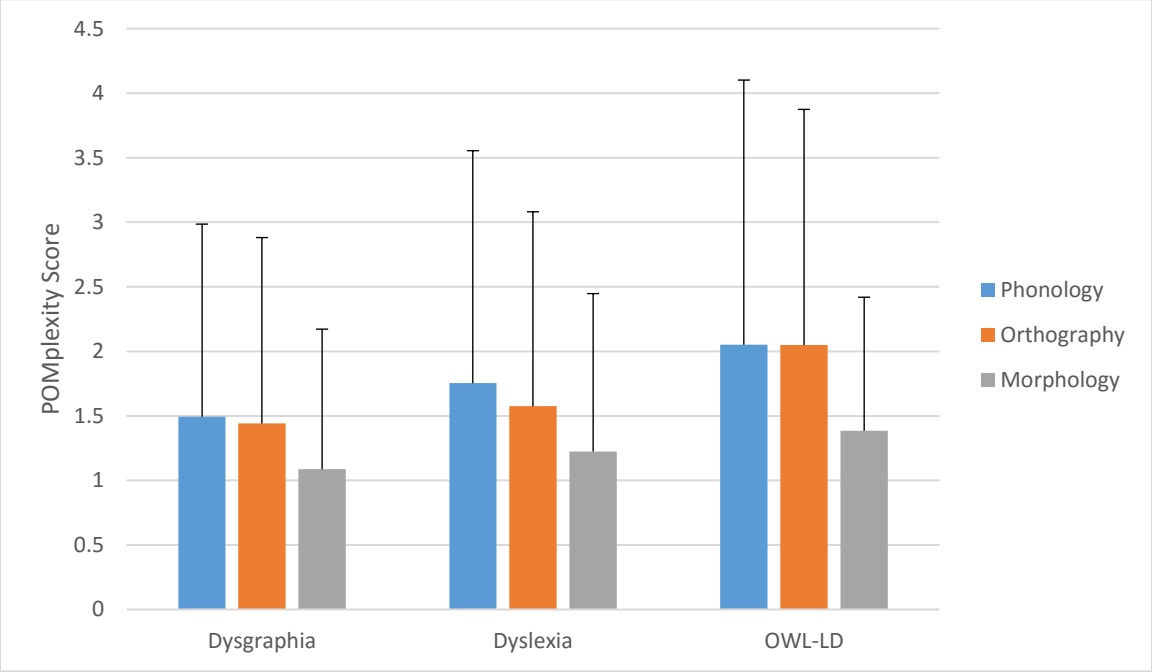

Figure 1. POMplexity scores for the Spelling Errors by Diagnostic Category.

Frequency of Spelling Errors by Diagnostic Category and Narrative Condition

The results of the two-way ANOVA with diagnostic category and narrative condition as the IVs and the normed number of spelling errors produced during the summary writing task as

the dependent variable did not reveal a significant interaction between diagnostic category and narrative condition. However, the main effect of narrative condition was significant, $F(1,24) = 15.983$, $p = .001$, $\eta^2_p = .400$. Specifically, the number of errors in the reading condition was always greater than the number of errors in the listening condition, regardless of diagnosis. In addition, the main effect for diagnostic category approached significance $F(2,24) = 3.237$, $p = .057$, $\eta^2_p = .212$. Post-hoc testing with the LSD procedure indicated that error frequency was only significantly different between groups with dysgraphia and OWL-LD. As illustrated in Figure 2, all students performed more poorly in the reading condition and students with dysgraphia made significantly fewer errors than students with OWL-LD. It is interesting to note that the performances of the groups with dyslexia and OWL-LD were similar. This finding further underscores the similarities between these groups in terms of linguistic processing capabilities.

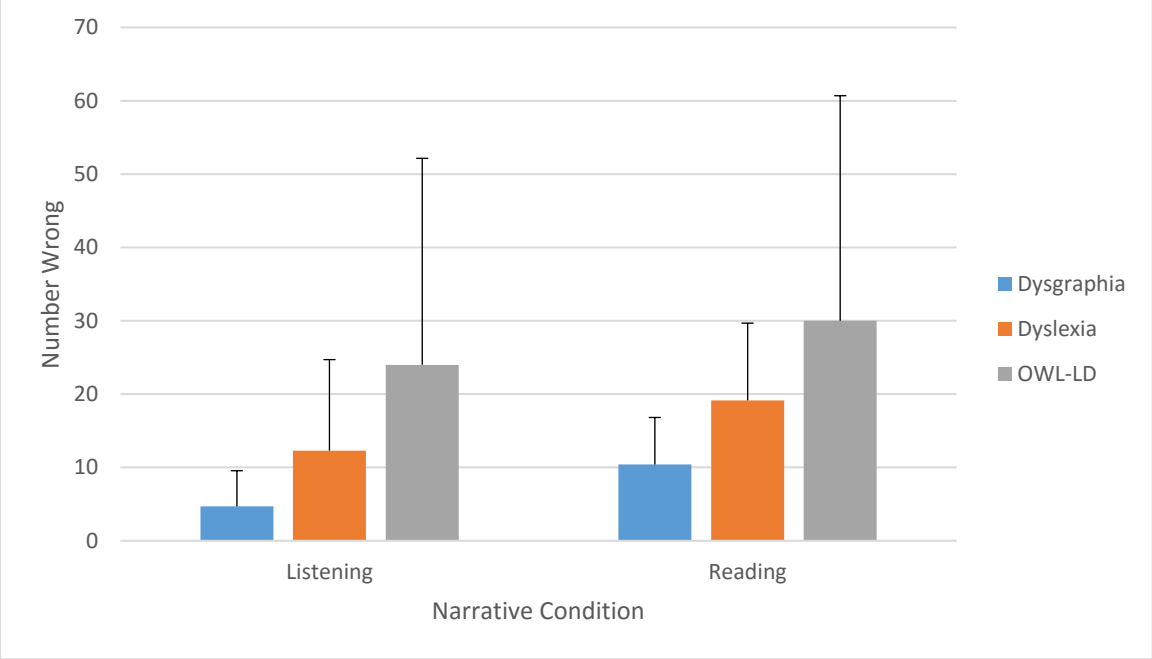

Figure 2. Differences in Error Frequency by Diagnostic Category and Narrative Condition.

Qualitative Results

The POMplexity assigns a numerical value to represent error severity by linguistic category; however, it does not provide an in-depth description of various types of errors produced. For this reason, the POMAS was used to qualitatively analyze the error types made by a student from each diagnostic category. One student from each diagnostic category, who had written a summary for both conditions in lessons 10-12, was selected for further analysis. The total number of POMAS codes were counted for phonology, orthography, and morphology. Then each linguistic element from each POMAS category was counted. The POMAS categories and elements were compared between subjects to determine if children with dyslexia, dysgraphia, and OWL-LD made different types of errors. A description of these error patterns follows.

Types of Errors. The student with dysgraphia had 7 phonological errors, 16 orthographic errors, and 12 morphological errors, which were found in 35 misspelled words. In the category of phonology, the linguistic element that was found to be in error most frequently was missing vowels, which accounted for 3 of the 7 phonological errors. The remainder of the phonological errors were as follows: consonant deletion (2), epenthesis (1), and cluster reduction (1). In the category of orthography, the linguistic element that was found to be in error most frequently was the spelling of unstressed vowels (i.e., vowels that were reduced to schwa). This error accounted for 7 of the 16 orthographic errors. The other orthographic errors included: capitalization errors (4/16), letter doubling errors (4/16), and word boundary errors (1/16). In the category of morphology, the majority of errors were made on attempts to spell the base word of derived forms (7/12), base words of inflected forms (4/12), and one error was made on a suffix of an inflected form.

The student with dyslexia had 25 phonological errors, 18 orthographic errors, and 17 morphological errors, which were found in 34 misspelled words. In the category of phonology, the linguistic element found to be in error most frequently was the phonological-orthographic letter reversals (9/25) and epenthesis (6/25). In the category of orthography, errors were spread across several different elements, including unstressed vowel errors (4/19), word boundary errors (3/19), and 2 errors in each of the following: grapheme doubling, rhotic vowel errors, silent letter deletion, ambiguous letter confusions, and letter name errors. No discernible pattern emerged in orthography for this student. In the category of morphology, the student with dyslexia produced errors that involved the misspelling of both the base word and the affix in words involving derivational and inflection morphology. This student also used homonyms more frequently than the other students evaluated (e.g., the word *witch* for *which).*

The student with OWL-LD made 32 phonological errors, 71 orthographic errors, and 30 morphological errors, which were found in 63 misspelled words. In the category of phonology, the linguistic elements found most frequently in error were those that pertained to omissions, such as syllable reduction and consonant deletion. In the category of orthography, the linguistic features found most frequently in error were those involving ambiguous letters (for example, *serkal* for *circle*) and unstressed vowels. Errors involving these two linguistic elements accounted for 33 of the 71 orthographic errors made. In the category of morphology, this student always misspelled the base word regardless of the word type (i.e., inflection or derivational).

Table 4. Examples of Most Common Errors in Phonology and Orthography by Diagnostic Category		
Dysgraphia	**Dyslexia**	**OWL-LD**
Phonology: **POVM (vowels missing/deleted)** myans/Mayans x2 multiplcation/multiplication	**Phonology:** **POR (phonological-orthographic reversal)** concultions/conclusions wrothless/ worthless from/form Egyptains/Egyptians porpus/purpose	**Phonology:** **PCD (consonant deletion):** evry/ every difrents/difference bisness/business PSR (syllable reduction): seval/several ecsep/excepts
Orthography: **OUE (unstressed vowel error)** independantly/independently multiplecation/multiplication calender/calendar mathamatician/mathematician negitive/negative	**Orthography:** **OUE (unstressed vowel error)** algibreakic/algebraic algrabra/ algebra creadt/ credit **OAL (ambiguous letter)** sucsessfull/ successful alijbrea/ algebra	**Orthography:** **OAL (ambiguous letter):** serkal/circle achent/ ancient advansed/advanced sivilisaltions/civilizations colchers/cultures **OUE (unstressed vowel error):** carickters/characters sitom/system **OAL/OUE:** langwige/ language

Summary of Results

The quantitative results for type of errors made by diagnostic category revealed that there was no difference in the severity of errors (phonology, orthography, and morphology) produced by the students in the three diagnostic categories. These results suggest that specific deficits in linguistic processing do not influence the severity of the error produced. The morphology POMplexity score was found to be significantly lower than the phonology and orthography POMplexity scores across all diagnostic categories. Lower morphology codes are likely due to the structure of the POMplexity itself, given that morphology scores were based on the entire word instead of individual grapheme errors.

Frequency of errors made by diagnostic category was only significantly different between the students with dysgraphia and OWL-LD. Specifically, the students with dysgraphia made significantly fewer errors than the students with OWL-LD. By definition, children with OWL-LD have the more severe language impairment, and for this reason, increased numbers of spelling errors might be expected, but it is interesting to note that error frequency did not differ between students with dyslexia and those with OWL-LD. Finally, more errors were produced in the reading condition than in the listening condition, regardless of diagnosis. More errors in the reading condition were expected for students with dyslexia and OWL-LD since these disorders are characterized by a reading impairment; however, this was not expected for students with dysgraphia.

A qualitative analysis revealed that the student with dysgraphia and the student with OWL-LD produced more orthographic errors than phonological or morphological errors. The student with dyslexia produced more phonological errors, than orthographic or morphological errors, which was expected given the known phonological processing deficits in dyslexia. In the

category of phonology, the student with dysgraphia displayed the most errors on vowel omissions. The student with dyslexia produced the most errors with phonological-orthographic reversals and epenthesis, and the student with OWL-LD displayed the most errors with elements involving omissions, such as syllable reduction and consonant deletion. In the category of orthography, the student with dysgraphia displayed the most errors with unstressed vowels, the student with dyslexia did not display a clear error pattern for orthography, but did have more errors involving unstressed vowels. The student with OWL-LD displayed the most errors involving ambiguous letters and unstressed vowels. In the category of morphology, the student with dysgraphia had the most difficulty spelling base words found in derived forms, the student with dyslexia had the most difficulty spelling base words and suffixes in derived and inflected forms, and student with OWL-LD had the most difficulty with spelling base words, regardless of the word type. These results suggest that while the severity of the misspelling did not differ across diagnostic groups, there were notable differences in the use of specific linguistic features.

Chapter 4

Discussion

Spelling is a task that involves the cross-code mapping of phonology to orthography at the subword level, and the mapping of phonology and morphology to orthographic patterns at the meaning level to form a *word-specific spelling.* Most children acquire these abilities with little effort; however, children with learning disabilities experience difficulty with spelling accuracy. Therefore, the goal of this study was to determine if the linguistic processing deficits found in children with dysgraphia, dyslexia, and OWL-LD resulted in spelling errors that differed in severity, frequency, and type from each other. This study also sought to determine if frequency of spelling errors was influenced by diagnostic category and lesson presentation (i.e., reading condition vs. listening condition).

Students (*N*=35) in grades 4-9, who were diagnosed with either dysgraphia (*n*=13), dyslexia (*n*=17), or OWL-LD (*n*=5), read or listened to computerized lessons about basic mathematical concepts. The students typed summaries about these lessons on an iPad. Spelling errors were identified in the students' summaries. The severity of the error (or how far the misspelling was from the target) was scored with POMAS and rated with POMplexity. Results indicated that the students did not differ in error severity by diagnostic category. In other words, error severity was not contingent upon the type of learning disability. However, in regards to number of errors made (i.e., frequency of errors), students with dysgraphia made significantly fewer errors than students with OWL-LD, and all participants produced more errors in

summaries following the reading condition. Finally, a qualitative analysis using the POMAS revealed that children from different diagnostic categories produced different types of errors.

This chapter first addresses the results as they relate to the research questions. Then, study strengths and limitations are discussed, followed by the educational and clinical implications. Lastly, directions for future research are proposed.

Spelling Errors by Diagnostic Category

The goal of the first research question was to determine if known deficits in the cross-code mapping (i.e., the integration of phonology, orthography, and morphology) influenced the severity of spelling errors produced by children with dysgraphia, dyslexia, and OWL-LD. The statistical findings revealed that the severity of spelling errors, as scored by POMplexity, was not significant different across diagnostic categories. Hence, all participants tended to make spelling errors that were equal in severity. However, these findings do not suggest that these children are producing the same patterns or types of errors. POMplexity scores are weighted by error frequency and severity, not linguistic feature type. The result is that individuals could achieve the same POMplexity score for very different reasons. For instance, in the category of phonology, a score of two could be given for either epenthesis, cluster reduction, or consonant deletion. So, while each of these processes will be represented with a severity score of 2 on the POMplexity, this score will not explain why the child made a particular error. Or, the student could make two orthographic substitutions and achieve the same score as one phonological omission. Thus, POMplexity does provide an estimate of how far the misspelling is from the target word, but did not identify unique error patterns for each diagnostic category.

These results are generally consistent with the findings of previous research, which found that children with learning disabilities do not produce deviant spelling errors when compared to

typically-developing, age-matched peers or typically-developing, spelling-matched peers (Bourassa & Treiman, 2003; Cassar et al., 2005; Larkin, et al., 2013; Moats, 1983; Nelson, 1980; Silliman et al., 2006). Hence, the spelling errors of children with learning disabilities reflect the expected breakdowns in cross-code mapping, albeit children with learning disabilities may display these deficits in their spelling beyond an appropriate age.

Since the POMplexity does not differentiate between the types of linguistic processes in error, a qualitative analysis was conducted using the POMAS. One student from each diagnostic category was selected and their spelling errors were analyzed. First, the number of errors in each category (i.e. phonology, orthography, morphology) were counted and then the elements within each category were counted. This analysis revealed that the student with dysgraphia did not struggle as much with phonology but experienced difficulties with orthography; specifically, unstressed vowels. Errors in orthography would be expected because students with dysgraphia have deficits in orthographic working memory and storage, which are secondary to their motor-based handwriting impairment. In morphology, this student had the most difficulty with spelling the base words in a derived word form. This pattern appears to align with the expected increase in morphological errors as the complexity of the spelling task increases (Bahr et al., 2012; Green et al., 2003).

The student with dyslexia experienced difficulty with orthographic patterns, as well as difficulties with phonology, specifically, with letter sequence reversals and epenthesis. These types of errors are consistent with the characterization of dyslexia as an impairment in the phonological integration of letters and sounds. This difficulty results in degraded orthographic sequencing (Silliman & Berninger, 2011) and hinders the process of forming *word-specific spellings* at the subword level. In morphology, the student with dyslexia had difficulty spelling

the base word and the affix. This suggests that impairments in the cross-code mapping of phonology and orthography (subword level) are also realized at the morphological (whole word) level.

Lastly, the student with OWL-LD produced a high number of errors in each of the linguistic categories. In phonology, this student demonstrated omission errors (i.e., syllable reduction and consonant deletion). This is consistent with previous research which found that children with SLI (which is similar to OWL-LD) display more omissions in their misspellings than their typically-developing peers (Bishop & Clarkson, 2003; Larkin et al. 2013; Silliman et al., 2006). In the orthographic category, this student had the most difficulty with ambiguous letter patterns and unstressed vowels, indicating inadequate mapping of alternate uses of orthography (i.e., /k/ can be represented as *c, k, ck, ch*). In morphology, this student struggled with spelling base words in both inflected and derived forms. Research has shown that children with OWL-LD have trouble coding morphology and syntax which impedes access to semantic knowledge (Silliman & Berninger, 2011). This means that they have difficulty mapping phonology and orthography to morphology at the meaning level. Thus, limited semantic access hinders the ability to form a *word-specific spelling* at the whole word level because they have difficulty breaking the words into manageable parts.

Overall, the student with dysgraphia demonstrated a typically developing error pattern characterized by frequent production of orthographic errors. This student demonstrated difficulties mapping orthography at the subword level. This student also made more errors in spelling the base word in derived forms, which is also common in typically-developing children (Green et al., 2003). The student with dyslexia demonstrated an error pattern characteristic of younger children. This student produced more phonological errors, fewer orthographic errors,

and experienced difficulty with spelling words with affixes. The student with OWL-LD displayed the most severe impairment in spelling characterized by a large number of errors in all linguistic categories; specifically, omissions, alternate orthographic representations of phonology, and morphological knowledge. The qualitative analysis revealed that the POMAS was able to detect individual strengths and weaknesses in linguistic knowledge for a child in each diagnostic category by analyzing spelling errors.

Error Frequency

Error Frequency and Diagnostic Category. The main effect of diagnostic category approached significance. Post hoc testing revealed that the group with dysgraphia produced significantly fewer errors than the group with OWL-LD. Given that the children with OWL-LD have the more severe language impairment, it is not surprising that they produced a greater number of spelling errors in their writing. This finding would suggest that the more severe the language impairment, the more difficult it is for the child to integrate phonology, orthography, and morphology for accurate spelling. In contrast, the group with dyslexia did not differ significantly from the group with OWL-LD in error frequency. The lack of significant difference in error frequency among the group with dyslexia and the group with OWL-LD suggests that their spelling accuracy is similar within the context of a text construction task. Error frequency did not differ significantly between the children with dysgraphia and dyslexia. These students seem to have stronger language skills than the students with OWL-LD.

Error Frequency and Narrative Condition. The main effect for narrative condition was significant. Specifically, there were always more errors in the reading condition than in the listening condition, regardless of diagnostic categories. This finding was expected for students with dyslexia and OWL-LD because they have difficulties with reading. However, it was

surprising for students with dysgraphia and it may be related to their known deficits in orthographic working memory. In other words, students with dysgraphia were able to read the passage, but experienced difficulty holding the spelling of new words in LTM.

The reading condition requires children with dyslexia and OWL-LD, who already have difficulty reading, to read a lesson and then compose what was read into their own written words. When composing a written text, the writer must be re-reading and evaluating previously written sentences for relevance and future planning of composition (Hayes & Berninger, 2014). For this reason, there may have been more errors in the reading condition since this condition places a high demand on working memory, LTM, and attention. In this way, the reading condition may exacerbate deficits in an already weak linguistic processing system. Hence, processing deficits would leave fewer cognitive resources for creating and evaluating the spelling of words, which could result in a greater number of spelling errors in this condition. This explanation would also hold for the group with dysgraphia. These students did not have a reading impairment, yet they had more spelling errors in the summary following the reading condition. Given that the read material was present during the writing of the summary of read lessons, It may be that the coordination of visual input with the process of composition and transcription stressed working memory more than just the listening to material before generating typed text.

Study Strengths and Limitations

Strengths. The strengths of this study include the POMAS and the nature of the writing sample. The POMAS was able to detect spelling errors in the area of phonology, orthography, and morphology, which is a useful tool for the identification of linguistic feature errors in while writing. Since spelling requires cross-code integration, a tool is needed to assess which linguistic features are in need of remediation and where more explicit instruction is needed to aid in the

development of word-specific spellings. For example, the qualitative analysis revealed that the student with dyslexia had more errors in the phonological category, specifically with the reversal of letter sequences and epenthesis. This type of linguistic knowledge can be used by educators and clinicians to provide treatment and instruction that is specific to a student's unique needs..

Another strength of this study was the way in which the spelling errors were collected. In a single-word spelling test, all cognitive resources can be used for the construction of one word, which is not a realistic spelling environment. The act of writing a composition requires the coordination of many high-level executive function skills (Hayes & Berninger, 2014). The use of these abilities for text construction leaves fewer cognitive resources available for spelling. For this reason, spelling that is analyzed within the context of a written narrative task is more representative of real-world spelling conditions.

Limitations. The first study limitation was the small number of participants in the group with OWL-LD. Fewer participants means that the statistical variables are more influenced by individual variation among participants. In addition, the data generated by this size group may not be representative of the population mean. These factors make it more difficult to get a significant finding with this group.

The other study limitation was the unequal opportunity to use morphology codes compared to phonology and orthographic codes. POMplexity allows for multiple codes in the phonology and orthography categories to be added together to reflect the severity of misspellings in these categories; however, the morphology score is limited to a single score reflecting the integrity of spelling at the word level. Thus, morphology scores will always be lower. Therefore, it was not surprising that the morphology scores were significantly lower than the phonology and orthography scores.

In the future, more morphology codes could be added to the POMplexity scoring system. Severity rating codes that differentiate between the transparency and the opacity of the root word may provide more opportunities for morphology codes to be used and added together. In addition, the scoring system could account for multiple affixes in a word. This score is critical as a measure of integration at the word level, while the phonology and orthography POMplexity scores reflect difficulties at the subword level. Thus, future research using POMplexity may demonstrate better outcomes if morphology is considered separately from phonology and orthography.

Educational and Clinical Implications

Although these students with different learning disabilities have known differences in linguistic processing, there were not differences in the severity of their spelling errors. These results indicate that spelling errors cannot be used to profile children with learning disabilities into distinct categories. This finding supports the changes in the new *Diagnostic and Statistical Manual of Mental Disorders V* (*DSM-V;* American Psychiatric Association, 2013) that places SLDs on a continuum rather than as distinct profiles. In other words, individual differences among students can be greater than differences in learning disability profiles. In addition, students can move between diagnostic categories as they learn new skills. Hence, the notion of a continuum more adequately represents the linguistic deficits in SLDs.

Regardless of where a student falls on the continuum of SLDs, poor spelling makes the process of text composition daunting. Composing a written text requires the coordination and integration of complex cognitive skills (Hayes & Berninger, 2014). When *word-specific spellings* are not available or poor mapping of phonology, orthography, and morphology results in gaps in subword knowledge, then spelling becomes an added burden to the writing process.

Fluent spelling, which is accomplished thorough the formation of *word-specific spellings*, is important to efficiently bridge thoughts into written expression. Thus, spelling intervention may improve the writing process for children with learning disabilities (Singer & Bashir, 2004).

Directions for Future Research

The present study analyzed spelling errors obtained from typed summaries. Future research that analyzes the spelling errors produced in handwritten essays may provide a useful comparison to the current results. Keyboarding and handwriting are both motor processes that facilitate the writing process. However, specific neural pathways involved in letter perception are activated when letters are formed by hand rather than typing (Berninger & Richards, in press; Berninger et al., 2015). In addition when a letter is formed by hand, it must be done from memory; in contrast, a keyboarding task provides a visual cue for the composer as the letters are already printed on the keys. Furthermore, the motor movement involved in typing involves tapping while writing involves multiple finger sequences for letter formations (Silliman & Berninger, 2011).

Previous research has demonstrated that forming letters by hand rather than typing letters on a keyboard is more effective for learning letter recognition in young children (Longcamp, Zerbato-Poudou, & Velay, 2005). Future research that focuses on spelling interventions which require handwriting vs. typing may provide different outcomes for integrating orthographic patterns. If handwritten spelling intervention proves to support better spelling outcomes, then it may provide evidence for the reintroduction of handwriting curriculum into the classroom.

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