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Spelling of Derivationally Complex Words: The Role of Phonological, Orthographic, and Morphological Features

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Spelling of Derivationally Complex Words: The Role of Phonological, Orthographic, and Morphological Features

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
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Abstract

Spelling ability is not static; rather, as children age, learning how to encode morphophonologically complex words in conventional ways is motivated by the increasingly complex demands imposed by academic experiences with morphologically complex words. Success requires ongoing integration of phonological (P), orthographic (O) and morphological (M) knowledge. However, current research on the development and assessment of spelling has not sufficiently accounted for the way word features and participant characteristics interact with students’ POM knowledge in the spelling of derived words. This study used a linear mixed effects regression approach to provide new insights about how both word characteristics and students' linguistic knowledge affected the application of POM from grades 3-7 in the spelling of derived forms.

Spelling data (WIAT-II) were taken from a larger longitudinal study focused on reading development (Garcia et. al., 2010). Eleven words from the WIAT-II with derivational morphology (including one inflected form with a derived homophone possibility) were analyzed first with the Phonological Orthographic Morphological Analysis of Spelling (POMAS; an unconstrained scoring system) in order to identify linguistic feature errors within misspellings. Next, misspellings were quantified with the POMplexity metric to evaluate the individual and combined influences of POM to derivational misspellings over time.

Results indicated item-level and participant characteristics, as well as time significantly predicted variation in P, O, M, and total POMplexity scores. Frequency had
a significant impact on scores, with high frequency words resulting in lower POMplexity scores than low frequency words and these effects were most obvious in grades 3 and 4. Slope differences between words suggested that low frequency misspellings resolve more rapidly than high frequency words.

Derivational shift was shown to have a significant interaction with time for O, M and Total scores, but not P scores. In all cases, the slopes for derived words with no shift improved more quickly than other shift categories. Finally, performance on measures on the measures of linguistic skill correlated to improved scores for the related POMplexity code.

These results strongly suggest that the developmental course of learning to spell derivations is not a linear accumulation of POM knowledge, but instead is a recursive process with both general and word-specific knowledge affecting how an individual student produces a derivational spelling at any given point in time. Contributions of word characteristics, such as frequency and number/type of derivational shift, suggest that morphemic features challenge encoding; that is, increased complexity taxes the system's ability to represent both sound and meaning orthographically. Educational and clinical implications will be described.
Chapter 1

Spelling is a dynamic linguistic activity through which words are encoded into graphemes (letters) to preserve oral language. The English orthographic system demands that sound and meaning be interconnected; as meaning is encoded onto morphemes while sound is simultaneously mapped to phonemes. Preservation of meaning is more important than encoding sounds, and as such, morphology uniquely contributes to spelling success. The morphophonemic nature of English requires morphology to shine through the orthography, even for the sake of phonology (Seidenberg, 2011).

The morphophonemic nature of English requires children to recognize the complex relationships among phonemes, graphemes, and meaning. Nagy and Anderson (1984) found that, of the 10,000 new words that fifth graders encountered every year, half were either derivations or inflections of high frequency words. Thus, morphological awareness is necessary for students to appreciate how morphology creates depth within language as new words are created through the affixation of morphemes to stem words. By analyzing the contributions of morphology, patterns within orthography are revealed (Silliman, Bahr, Nagy, & Berninger, in press). Unfortunately, students with weak morphological awareness often rely on phonological strategies to spell, even when those strategies are unreliable (Bahr, Silliman, Berninger & Dow, 2012). Relying solely on phonological knowledge not only impacts encoding, but also demonstrates a weakness in, linguistic knowledge (Templeton, 1980).
This paper examines how morphological knowledge develops over time and how it is integrated with phonological and orthographic awareness to produce a system that can be accessed to reliably encode words. Error analysis will be examined as a tool to undercover the composition of linguistic skills used to encode derivations over time. The effects of morphology on word composition and the role of orthography in preserving phonology and morphology is assessed longitudinally in order to demonstrate the complex linguistic demands spelling imposes.

The current chapter first examines the contributions and strategic employment of the three linguistic components of spelling, phonology (P), orthography (O) and morphology (M). Second, the role of constrained and unconstrained error analysis are discussed, in order to demonstrate the role of unconstrained analysis in describing the interaction of the three independent linguistic components.

**Linguistic Components of Spelling**

Encoding oral language requires the integration of several linguistic skills (Apel, 2011; Apel, Wolter & Masterson, 2006; Arndt & Foorman, 2010; Bahr et al., 2012; Beers & Henderson, 1977; Garcia, Abbott, & Berninger, 2010). Various models consider the contributions of these three linguistic skills along different timelines; all agree that no one linguistic skill is responsible for spelling. The following discussion describes P, O and M as linguistic skills, all of which contribute unique significance to spelling outcomes (Deacon, Kirby, & Casselman-Bell, 2009).

**Phonological and Orthographic Awareness**

Early spelling success is highly correlated with phonological awareness, or, the ability to identify, reflect about and manipulate the sound elements of language. Many
studies have shown early phonological awareness skills predict literacy outcomes (Bird, Bishop & Freeman, 1995; Bradley & Bryant, 1983; Bryant, MacLean, Bradley & Crossland, 1990; Wood & Terrell, 1998). As such, this skill enables children to rhyme, segment the sub-syllabic units of syllables, including onset (initial consonant) and rime, as well as engage in the segmentation, blending, and manipulation of the phoneme directly (Apel, Masterson & Neissen, 2004). Subsequently, the ability to chunk words into sub-syllabic units enables successful phoneme to grapheme encoding (Bourassa & Treiman, 2001) that characterizes spelling.

Orthographic knowledge describes how graphemes and grapheme combinations are stored and retrieved from memory with the intent of writing and reading the spoken word (Apel, 2011). Awareness of orthographic rules has been shown to play an important role not only in spelling, but also in acquiring reading fluency, because the contributions of statistical patterns reduce and may eliminate the need to memorize individual words (Berninger et. al., 2006; Castles & Nation, 2008; Deacon, Conrad & Pacton, 2008; Rey, Ziegler & Jacobs, 2000; Treiman, Kessler & Bick, 2002; Wright & Ehri, 2007). Statistical patterns are the frequency-governed patterns for how likely a grapheme or grapheme sequence is to be in a given context. Orthographic rules also enable encoding, as children as young as age 5 years have been shown to use orthographic pattern knowledge to assess plausible orthographic representations of a word (Apel, 2011; Wolter & Apel, 2010). Orthographic pattern knowledge is part of general word knowledge, as opposed to word specific knowledge; explaining why children produce plausible, albeit incorrect, spellings when faced with novel words.
Morphological Awareness

Orthography alone does not account for all of the statistical patterns in spelling. Morphology, also rule governed, offers statistically predictable patterns, both in regard to the graphemes that compose individual morphemes and with respect to the rules by which morphemes are affixed to words (Deacon, 2008). Morphological awareness helps to limit the range of possible spelling options and makes a significant contribution to spelling as early as the first and second grades (Beers & Beers, 1992; Deacon et. al., 2009; Walker & Haeurwas, 2006; Wolter et. al., 2009). Development of morphological awareness improves spelling accuracy because the student is aware that the suffix represents a change in meaning to the root word, rather than a phonological extension of a novel word. When two words have the same phonological structure, features in the word that are either inflected or derived are more likely to be spelled correctly, even when the segments have the same orthography (Deacon, 2008). For example, children are more likely to represent a grapheme sequence correctly when that section is a root morpheme than when it is not: “e.g. free in freely compared to freeze” (Deacon, 2008, p. 402).

Children are also more successful representing consonant clusters when the second phoneme is the result of a second morpheme unit, than when it is part of a single morpheme unit: /nd/ in tuned versus /nd/ in trend (Deacon, 2008). When Deacon and Bryant (2005) offered a word to children in grades 1-3, whose ending matched that of a two-morpheme target as a visual cue, the two morpheme words (e.g., payment) facilitated more accurate spellings than single morpheme words (e.g., pigment). The children more often borrowed patterns resulting from a derivation than those that were not. This
suggests children will borrow a letter sequence when there “is a morphemic reason for
doing so,” and not simply to reproduce a phonetic sequence (Deacon & Bryant, 1995, p. 590).

Another contribution of morphological awareness, beyond exposing the patterns
that exist within words, is that it allows spellers to store information systematically in
their mental lexicon (Nagy, Berninger & Abbot, 2006). For example, to represent the past
tense, most verbs take on the suffix –ed in order to demonstrate that the action has
already taken place. Although there are irregular forms, the inflection prevents students
from having to access and store a different variation for every word. Similarly,
morphology enables encoding new words, as students can make predictions about how to
create new words using prefixes and suffixes (or affixes) (Nagy et. al., 2006). Awareness
of the role of morphology in this way assists children in improving their metalinguistic
abilities, as they are able to think above the level of letter-sound correspondences in
order to realize the deeper semantic relationships among words, word parts and meaning
(Garcia, Abbott & Berninger, 2010; Nagy et. al, 2006).

*Inflectional vs. derivational morphemes.* Although both inflectional and
derivational morphemes reside under the branch of morphology, they have different
patterns of affixation that influence student’s spelling. Since inflected morphemes are
suffixes used to create variations of word forms that enable a word to fit the syntactic
environment, their existence is more transparent (Anderson, 1982). Despite several
irregular orthographic rules for adding inflections, all inflected forms involve a base word
and one of seven set inflected suffixes: plural -s and possessive –s (noun inflections),
third person singular -s, past tense -ed, the past participle –en, the present participle -ing

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(verb inflections), the comparative –er, and the superlative –est (the latter two are adjectival and adverbial inflections). Unlike inflectional morphemes, derivational morphemes create new, semantically related words, as well as a change in word class – for example, from noun to verb or verb to adjective.

Inflected morphemes are appear to be attempted (Bahr et al., 2012; Green et. al., 2003) and stabilized in the spellings of school-aged children before derived morphemes (Beers & Beers, 1992; Carlisle, 1995; Green et. al., 2003; Walker & Hauerwas, 2006). When they first appear in a student’s spelling, inflected morphemes are written as though they are phonetic extensions of the root word, as when students represent the past tense – ed as a voiceless stop, as in jumpt for jumped (Beers & Beers, 1992). However, by the third grade, most students’ spellings demonstrate the understanding that there are standard spellings for inflectional morphemes, regardless of pronunciation (Beers & Beers, 1992; Walker & Hauerwas, 2006). Beers and Beers’ (1992) discovery that the inflection was consistently represented correctly, despite errors with the root, contradicts early theories that postulated that students must master the spelling of the base form in order to successfully spell the inflected and derived forms (Carlisle, 1985). Mastery of the base form is not a prerequisite for the acquisition of suffixes; rather, the relationship between the affixation and the base word is important when considering the spelling of inflected and derived forms.

Derivational affix acquisition is less a “matter of learning morphological operations,” and more related to lexical learning and growth of the internal lexicon (Domahs, Lohmann, Moritz & Kauschke, 2013, p. 555). Although they create novel words, these affixes extend the core meaning of the root words to which they are affixed.
For example, the word *person* can take the suffixes *-ify, -al, -ly, -able, -ity*. Here it is important to note that the application of derivational affixes is more restricted than that of inflections, meaning that they cannot be applied to all root words. For example, in English, we have *horrible* and *terrible* but only *horrendous* and not *terrendous*. Exposure to derived forms allows students to observe not only how derivational affixes allow for lexical expansion, but also enables the opportunity to discover the rules for affixation – which are also lexically governed (Templeton, 2012). The lexical nature of derivational affixes allows for easier storage, retrieval and decomposition of derived forms, as one need not store each derived word as a unique lexical item, but rather can simply store the affixes as lexical items while learning the rule governed patterns of affixation (Carlisle, 2003).

*Derivational shifts and transparency.* Unlike prefixes, which rarely change the phonological structure of a stem word, derivational suffixes frequently obscure the phonology of the stem (Marslen-Wilson, Tyler, Waksler & Older, 1994). When the phonetic shape of an affixed form differs from its unaffixed version, the affixed form is said to be phonetically opaque (i.e., a phonological shift). The shift from *magic* to *magician* is phonetically opaque. While the phonetic integrity of the stem (*magic*) has been compromised, the orthography preserves the relationship between the root and derived form, as the orthographic representation of the stem remains accessible.

Not only can the addition of a suffix result in a phonological shift, but it can also result in an orthographic shift. When the present progressive –ing is added to the word *hop*, the resulting word is orthographically represented as *hopping*. This is an example of orthography working to preserve the phonological skeleton of the word, even though it
may obscure the root morpheme hop. In this case, if the p was not doubled, the resulting word would be produced with a long vowel and would become homophonous with the word hoping.

Sometimes, morphology results in words that demonstrate a combined shift, meaning both the orthography and the phonology of the root morpheme changes. This type of shift is the most opaque, as the root morpheme is obscured in both the written and the spoken form (e.g. space to spatial). The word spatial presumably would not only be difficult to spell, but it would also be challenging to extract the relationship between the root and derived forms, possibly masking both the meaning and the spelling.

Derivations can often result in a phonological or orthographic shift, but when a shift does not occur, the resulting words are said to be phonologically transparent. Since prefixes rarely change the phonological structure of the stem, they are considered to be transparent in nature. In the case of the root magic, the derivation magical is an example of a transparent shift since the a and c both remain mapped to the original phonemes (/æ/ and /k/, respectively). Transparent shifts are easier lexical items for children to spell because both meaning and orthography are accessible (Carlisle, 2000).

Influence of frequency on morphological awareness. Statistical learning refers to the process of discovering the regularities within a given input (Saffran, Aslin, & Newport; 1996). Exposure to print allows children to uncover the morphophonemic patterns in English orthography. In accord with statistical learning, frequency of exposure to specific patterns will impact the acquisition of these patterns (Deacon & Leung, 2010; Stahl & Nagy, 2005). The influence of morphology on the productions of even very young spellers’ suggests that the patterns of frequency of all three linguistic sources are
utilized for learning. Deacon and Leung (2010) point out that children are not uniquely sensitive to the morphological features of words, but rather, specifically sensitive to the “co-occurrence of sounds, letters, and meaning” (p. 1095).

Frequency of word features varies naturally across language and uniquely within individuals. Several studies have demonstrated that both the surface frequency (the frequency of the whole word) and the frequency of the base of the derived form influence students’ ability to read two morpheme words (Carlisle, 2000; Carlisle & Katz, 2006; Carlisle & Stone, 2005; Deacon, Whalen & Kirby, 2011; Mann & Singson, 2003). However, the relationship between the frequency of the base, the surface form and the student’s success decoding and comprehending of that word is complicated. For example, high base frequencies do not help overcome disparities between surface frequencies when decoding words with similar base frequencies (Carlisle, 2000). Nevertheless, the frequency of the base appears to significantly contribute to the accuracy, but not speed, of reading derivationally complex words with low surface frequency (Carlisle & Stone, 2005). The complexity of the relationship between frequency and decoding begs the question of whether there is there a relationship between frequency and encoding.

Deacon and Leung (2010) found that frequency of both orthographic and morphologic patterns influenced the spelling of both one and two morpheme words. Using The Educator’s Word Frequency Guide (Zeno, 1995), the authors selected 36 words ending in /ər/, half in the allomorph –er and half in –or. The pattern –er can be inflectional (as in the comparative bigger) or derivational (as in the agentive swimmer); however, the derivation is more frequent in English than is the inflection. To compare the differences between the derivational, inflectional and non-morphemic –erendings, the
authors chose six of each to represent the 18 –er words, while –or was evenly divided (nine each) between one and two morpheme words. Children were presented with the base words or features on the left, and the choice of –er, -r, and –or to select on the right. They were prompted to circle the ending that best completed the target word, which was read aloud by the examiner, both on its own and in the context of a sentence.

From the participants’ responses, Deacon and Leung (2010) determined that semantic frequency influenced spelling, as the correct ending was chosen more often for words requiring either a derivation or inflection. Contrary to serial models, which predict inflections are stabilized before derivations, scores on words requiring the derivation –er- were higher than the inflected forms. Orthographically, –er, which is the more frequent form, was more accurately chosen than its allomorph –or. The allomorph –or did not appear to have the same semantic impact on spelling, as scores on one and two morpheme words ending in –or demonstrated no statistically significant differences (Deacon & Leung, 2010). These findings demonstrate the complexity of the interaction between morphophonemic orthography and the child’s linguistic system, suggesting that the frequency of features within targets should be examined when considering the assessment of students’ spelling.

The three linguistic sources of knowledge (P, O and M) each uniquely and significantly contribute to spelling success (Deacon, et. al., 2009). Derivationally complex words demand students use all three sources simultaneously to ensure both meaning and sound are encoded while navigating challenges posed by derivational shifts and frequency. Linguistic skill strength is not static, but rather task dependent. As tasks increase with difficulty, skill development or integration may not be sufficient to
complete the task. Examining linguistic knowledge awareness independently allows for the identification for the possible cause of spelling errors – whether it is due to insufficient linguistic knowledge (P, O or M) or whether the challenge imposed by the task impedes a child's ability to integrate the three.

Just as the nature of the task, (i.e. the composition of the target words) impacts spelling performance, the nature of the analysis similarly impacts the interpretation of misspellings. The following section will discuss how different error analysis frameworks examine misspellings, focusing first on constrained and then on unconstrained systems. Each will be defined, and then uses of each will be discussed in order to contrast each system’s use of linguistic feature analysis. Finally, the need to go beyond a qualitative, unconstrained analysis of linguistic features will be discussed.

**Error Analysis Frameworks**

Studies of spelling development rely on the results of an error analysis to demonstrate changes in spelling accuracy. Thus, how errors are described and accounted for affect the outcomes of any study. Both the way errors are elicited (type of spelling assessment) and how the resulting spellings are coded can affect both the quantitative and qualitative aspects of assessment.

In an educational setting, spelling is often scored using a binary system, with responses being coded as either correct (1) or incorrect (0). Similarly, most standardized assessments utilize a binary system (Masterson & Apel, 2013). However, in order to demonstrate development and the linguistic processes employed by students, researchers agree that a more sensitive scoring system must be used, whereby spelling attempts are credited based on the use of linguistic features to represent the target. When identifying
linguistic features in misspellings is important to first note the integrity of the phonological skeleton (Bourassa & Treiman, 2003), that is, whether the consonant-vowel sequencing (CV, CVC, CCVC, etc.) is represented or not. When the production represents the phonological skeleton of a target, the spelling is considered plausible, and the representations for each phoneme can be analyzed based on its relationship to the target.

The phonetic features of a spelled word are described using either constrained or unconstrained systems of analysis, depending on whether or not phonology is viewed as being driven by orthographic rules (Bruck & Waters, 1988). Constrained analyses consider misspelled words to be phonetically accurate if legal orthographic patterns are used to create a match for the target. For example, if the target rain is spelled rane, a constrained analysis allows for this type of production since it is one way to represent the phonological structure of the target (i.e., the vowel-e pattern is a legal orthographic pattern resulting in a long vowel sound). In an unconstrained analysis, a misspelled production does not need to include orthographically legal patterns to be considered phonologically plausible. As long as each sound in the word is represented by a plausible grapheme, an unconstrained analysis assumes the phonological structure is represented. For example, in the misspelling of the word charge as crg, an unconstrained analysis would acknowledge the plausibility of the spelling because the c is marking the digraph representing /tɹ/, the r the rhotic vowel /ɹ/ and the g represents the /dɹ/; thereby maintaining the phonological structure of the target /tɹɹdɹ/. The following sections focus on different ways that constrained and unconstrained analyses have been used to describe spelling errors.
Constrained Frameworks

Most research studies have employed a constrained analysis system; wherein productions are only considered to be phonetically plausible if legal orthographic rules have been followed (e.g., Apel, Masterson & Niessen, 2004; Masterson & Apel, 2000; Masterson, Apel, & Wasowicz, 2006). All other spellings are deemed illegal spellings and typically are not analyzed further. Constraining error analysis by orthographic plausibility enables researchers to describe errors qualitatively and quantitatively (Wasowicz, 2007). Errors are defined in terms of the orthographic patterns in violation, and are quantified based on the number of times a given target pattern is observed to be in error. By assigning errors to orthographic patterns, mastery of the patterns can be charted over time. In this way, the constrained analysis enables researchers to create models of development that indicate linear acquisition and the mastery of orthographic patterns of increasing difficulty.

A few systematized evaluation procedures exist to evaluate the contributions of unique linguistic skills from a constrained point of view, i.e. the Spelling Sensitivity Score (SSS) and the Spelling Performance Evaluation for Language and Literacy, Second Edition (SPELL-2) (Masterson & Apel, 2010; Masterson, Apel, & Wasowicz, 2006). Most other coding systems were created in the context of a research question (Beers and Beers, 1992; Nunes, Bryant and Bindman, 1997). For example, in asking when children cease to represent the past tense marker –ed as a phonetic extension of a root word, Nunes, Bryant and Bindman (1997) created a system that only coded the final consonants as either an unsystematic spelling, a phonetic transcription or appropriate orthographic
target. With only one inflected form and three categories based strictly on orthographic legality, they were able to propose a structured stage model of acquisition for their data.

*Uses of constrained frameworks.* Beers and Beers (1992) utilized a constrained analysis to describe the nature of the misspellings they collected since they were interested in identifying when school-aged children applied orthographic rules to the affixation of inflectional morphemes (e.g., doubling when adding –ing). The authors used five categories to describe the phonological errors produced in encoding the affix: prephonetic, early phonetic, phonetic, structural and correct spellings. The categories represented a continuum of orthographic legality, from a production devoid of any inflectional representation to the correct production of both the affix and any subsequent orthographic changes to the root morpheme. Using this system, Beers and Beers (1992) demonstrated stabilization of the inflected form by the second grade.

Constrained analyses not only chart developmental trends, but have also been employed to create assessment tools that demonstrate increased linguistic proficiency despite continued misspelling. To this end, Masterson and Apel (2010) created *The Spelling Sensitivity Scoring* (SSS) with the intent of creating an analysis of spelling that could be used both by researchers and educators to measure very small changes over time. The SSS begins by dividing words into individual elements, with phonemes and affixes each representing a unique “element” (Masterson & Apel, 2010, p. 37). A given element can earn up to three points for being encoded accurately and points are subsequently taken away depending on the error type: phonetically plausible spellings receive two points, illegal representations receive a point and, if the element is not represented at all, it receives no points (Apel & Lawrence, 2011). Although the SSS is
effective in documenting change, as a three-point scale it only acknowledges errors as being either orthographically plausible or illegal representations of elements. The linguistic context of the error is disregarded and the specific linguistic knowledge missing from the child’s attempt is not described.

Based on the SSS, Masterson, Apel and Wasowicz (2006) created the Spelling Performance Evaluation for Language and Literacy, Second Edition (SPELL-2), a computer program that analyzes spelling errors using the constraint-based theory of the SSS to produce individualized spelling objectives. SPELL-2 is not a norm-referenced test, but rather uses misspellings to gather information about the linguistic processes employed by the student. By capitalizing on orthographic constraints, the authors were able to create software algorithms to analyze patterns of misspellings (Masterson et. al., 2006). What enables the SPELL-2 algorithm is also what limits the program’s ability to analyze the interactions of the three linguistic processes, as phonology and morphology are only analyzed within the context of orthographic plausibility.

Unconstrained Frameworks

An unconstrained analysis of spelling errors allows for the evaluation of underlying linguistic features employed in each spelling attempt, while also allowing an examination of how P, O and M impact spelling strategies over time (Bahr et. al., 2012; Wasowicz, 2007). At this time, the Phonological, Orthographic, and Morphological Assessment of Spelling (POMAS; Silliman, Bahr, & Peters, 2006) is one of the few systematic methods available to conduct an unconstrained analysis of errors (also see Moats, 2001). Utilizing Triple Word Form Theory (Bahr, Silliman & Berninger, 2009), the POMAS enables researchers to name both the error and the linguistic strategy
employed to produce the misspelling and also allows for individual variance in representing the phonological structure of targets.

Development of the POMAS (Bahr et. al., 2012) was motivated by an interest in demonstrating how an unconstrained approach could reveal the contributions of individual linguistic features as well as the integration of P, O, and M to achieving spelling proficiency. The POMAS not only permits linguistic error patterns to be identified, but also allows one spelling production to demonstrate errors in multiple linguistic features by coding each feature error within a word. For example, if a child misspelled the word *jumped* as *jupt*, the POMAS coded the missing *m* as a sonorant cluster reduction (in the phonological category) and coded the *t* as an error encoding the inflectional suffix–ed (in the morphological category); hence, this misspelling appeared to result from the use of a phonological strategy (i.e., using *t* for -*ed* since that is how it sounds), despite misrepresenting the phonological skeleton – as evidenced by the missing *m*.

*Uses of unconstrained frameworks.* While the POMAS remains one of the only structured guides for the assessment of spelling in the clinical and educational setting, unconstrained systems have been employed to answer research questions about the relationship between spelling accuracy and the strength of individual linguistic awareness. The following will describe how the constraints of orthography might be removed from spelling assessment in order to evaluate the development or strength of underlying linguistic processes.

Landerl and Wimmer (2000) removed the constraints of orthography when analyzing the spellings of both German and English students with dyslexia to evaluate
phonemic spelling performance. The authors modified Bishop’s (1985) distance to score spelling accuracy in terms of phonemic, rather than visual, differences. Using non-word stimuli, students’ spellings were given credit if the grapheme represented a phoneme in English, regardless of “position and graphemic context” (Landerl & Wimmer, 2000, p. 252). According to the distance formula and the authors, both the spellings bruger and brugar were accepted as phonemically accurate representations of the non-word /bruə/. In their original scoring of words, Landerl and Wimmer (2000) only accepted graphemic transcriptions that existed in “real words” (p. 250), while in this subsequent scoring, they considered all phonemically plausible productions (e.g., accepting cellar, celler, sellar, selar, celar, and celer as plausible phonetic representations of the target seller). The unconstrained measure revealed very low phoneme distance scores, indicating good phonemic spelling performance, despite orthographic errors. The unconstrained analysis was employed because the participants were all dyslexic, and the researchers wanted to know whether or not dyslexia impacted children’s ability to represent the phonological skeleton. This demonstrates how researchers can employ both constrained and unconstrained analyses, depending on the research question.

Similarly, Treiman and Cassar (1996) created an unconstrained analysis to answer the question of whether children use morphology to inform their spellings of words. Using single morpheme and two morpheme words ending in the same phonemic consonant cluster (e.g., brand and tuned), they scored spellings based on the representation of the final consonant cluster. A perfect score would yield an AB, with the A representing a plausible representation of the first consonant, and the B representing a plausible representation of the second consonant. If one or both consonants were
implausibly marked, they would not receive the A or B score depending on which was implausible.

Using this system, Treiman and Cassar (1996) were able to demonstrate the influence of morphology, since consonant clusters that resulted from a two-morpheme word received more AB scores than those that were the product of a single morpheme word. However, 13 of the 16 two morpheme words were regular past tense inflections; thus the plausible graphemes were mainly limited to the allomorphs t/d for the B score. Although the emphasis on inflections limited the generalization of the findings to morphologically complex words, it was still important to note how an unconstrained analysis enabled the authors to demonstrate the contributions of morphology.

Coding misspellings of the same word over time enables one to chart the evolution of linguistic features over time by monitoring which categories (P, O, or M) are predominately responsible for errors. For example, a student's misspellings might wholly be explained by gaps in phonological knowledge, as evidenced by epenthesis or deletion of weak syllables. As phonemic awareness improves, misspellings may indicate the child is adequately representing the phonological structure of the target, but continuing to make errors due to still emerging orthographic awareness. Often this is the case when representing diphthongs, or long vowels in English. When a child relies on letter-name, rather than the orthographic pattern, to produce a vowel, he or she might misspell fight as fit. Finally, when both phonology and orthography are developed, errors might predominately exist in regard to morphology. This is especially apparent in the case of the “real word” pattern, where children use legitimate orthographic patterns to encode sounds they hear in unfamiliar words (such as exsightment for excitement). The
orthographic patterns of real words may be employed to represent the phonological skeletons of target words when the features of the target word are incompletely integrated. At this point, although both phonological awareness and orthographic awareness are being employed, the two are not working together to code meaning, but rather to plausibly represent the phonological skeleton.

To summarize, both constrained and unconstrained systems seek to analyze the linguistic components of misspellings. At this time, the POMAS remains the only structured unconstrained system created for professionals to examine the contributions of P, O and M to students’ misspellings. What the constrained SSS system offers, that the POMAS currently doesn’t, is a quantitative measure to compliment its qualitative analysis. In order to consolidate the many qualitative features assigned by the POMAS, another related measure is needed. The following section will summarize the current literature in order to explain the purpose of the present study and the creation of a new system for quantifying the contributions of P, O and M to misspellings.

**Purpose of the Present Study**

Increasing recognition of the demands posed by a morphophonemic orthography challenges the prevailing paradigm in literacy research that only the alphabetic principle matters in learning to spell (Treiman & Bourassa, 2000). Derivationally complex words offer the best source for examining the range of complexity posed by the morphophonemic nature of English orthography, as they result in various phonological and orthographic shifts requiring spellers to navigate the three linguistic sources in order to encode sound, word forms, and meaning. Although the morphological spelling literature has often studied the contributions of inflectional morphology (Beers & Beers,
analyzed the misspellings of derivationally complex words (e.g., Carlisle, 1985; Deacon & Bryant, 2005). Others have generalized inflectional morphology findings to morphology as a whole, and thus to the application and spelling of derivational morphemes (e.g., Deacon, Kirby & Casselman-Bell, 2009; Treiman & Cassar, 1996).

The present study seeks to understand how the integration of the three linguistic processes affects the spelling of morphologically derived words over time. In order to do so, a retrospective analysis was performed on the errors produced on morphologically complex targets on the *Wechsler Individual Achievement Test*, second edition (WIAT-II) collected by Garcia, Abbott and Berninger (2010) in their longitudinal study of reading development. After using the POMAS for an in depth qualitative analysis to describe the linguistic complexity of the participants’ spelling productions, it became apparent that, at this point, there was no measure available to quantify the linguistic complexity of spelling productions, much less derivations. What seemed needed was an unconstrained, quantitative measure that would follow the complexity of derivational misspellings over time and highlight the patterns used in recruiting the linguistic skills necessary to represent the features of a target word.

To meet this void, the POMplexity was devised—a metric used to quantify the qualitative descriptors of the POMAS. The POMplexity evaluates the individual and combined influences of phonology (P), orthography (O), and morphology (M) to misspellings over time. In this way, POMplexity compliments the POMAS in that it
allows for documentation of the dynamic nature not only of derivational spelling but also of linguistic skill recruitment.

To determine the factors uniquely contributing to derivational spelling, the influence of item level and student factors were examined. Item level factors included derivational frequency and derivational shift. Student factors included scores on measures of phonology, orthography, and morphology; as well as their POMplexity scores on the derived words. A linear mixed effects regression approach was used to allow examination of the unique influences and contributions of item-level and participant factors over time. Three research questions were asked:

Q1. How do item-level characteristics influence the spelling of derived words?
Q2. How sensitive are unconstrained scores to differences in word complexity?
Q3. How do unconstrained scores illustrate growth in linguistic skill over time?
Chapter 2

Methods

Participants

Participant data was taken from a larger longitudinal study focused on spelling skill and reading development (Garcia et. al., 2010). The study included two cohorts of children who were followed simultaneously for five years, with the testing of Cohort 1 beginning in grade 1 and Cohort 2 beginning in grade 3. For each spelling ability group, five girls and five boys were selected, resulting in 30 children in each cohort for a total of 60 participants. Students were recruited for the original study through a letter sent home at the end of kindergarten or grade 2. They were part of an urban school district near a large research university in the Pacific Northwest.

Prior to the initiation of testing, parents completed a questionnaire and an interview to determine whether development was outside the normal range. Categories of exclusion included (Garcia et. al., 2010): 1) developmental or medical history of brain injury, 2) intellectual deficit, 3) pervasive developmental disorder (i.e., autism spectrum disorder), 4) primary language disorder, 5) motor disorder, 6) diagnosed psychiatric disorder, 7) severe emotional disturbance, or 7) neurogenic disorder. Of those selected to participate, only one student was African American and none were Hispanic; 70% of students were white, and the remaining students were of Asian ethnicity (Garcia et. al., 2010). Mother’s educational level ranged from high school to graduate school, with 80% of the mothers having a college level education or beyond (Garcia et. al., 2010).
Materials

WIAT II. The WIAT II (Psych Corporation, 2002) Spelling subtest was given to all participants each year. The Spelling subtest is a spelling to dictation task that assesses the ability to write both dictated letters and words. All words are spoken in isolation, then in a sentence, and again in isolation before the student writes the word on the test sheet.

The WIAT II was normed on a sample of students ages 4 to 19 years ($N = 2,950$). The data were collected during the 1999-2000 and 2000-2001 school years and were representative of the US population, as indicated by the October 1998 census (Lichtenberger & Smith, 2005). Split-half reliability coefficient procedures were used as a measure of internal consistency. For the WIAT-II subtests, these scores ranged from .80 to .97. For ages 6-19 years, the mean test-retest correlations of the subtests range from .85 to .98 (Lichtenberger & Smith, 2005).

POMAS. The POMAS (Bahr et al., 2012) is an unconstrained, qualitative scoring system grounded in triple word-form theory. Errors in misspellings are identified as belonging to one of the three linguistic categories: phonological, orthographic, and morphological. Within those broad categories, the POMAS allows for further classification of errors based on specific linguistic features of general American English. For example, if the word bent was misspelled as bet, it would be initially identified as a phonologic error because the student failed to represent all of the elements in the word’s phonological structure. The misspelling would further be specified as an error with sonorant clusters – as the sonorant element /n/ was omitted from the cluster. However, in the case of surtain for certain, the errors are orthographic in nature, as the phonological
skeleton was represented despite the s/c substitution (an error involving ambiguous letters or graphemes that represent many phonemes) combined with a rhotic vowel error.

The POMAS also codes errors inflections or derivations. For example, *misst* for *missed* is a morphological error due to difficulty with the inflected suffix (-ed). Finally, the POMAS recognizes that an error can cross two linguistic categories. For example, the POMAS codes *alawys* for *always* as a phonological-orthographic error because all the letters are present, but their order is reversed within the word. The resulting misspelling is a disruption in the phonological skeleton that is visible in the grapheme sequence produced.

The POMAS has proven clinically useful for qualitatively evaluating misspellings by identifying linguistic skill use. To complement the qualitative contributions of the POMAS, the Phonologic, Orthographic and Morphologic Complexity (POMplexity) metric was designed to demonstrate the complexity of spelling development and to identify the severity of misspellings. The POMplexity, to be discussed in the following section, aligns with the POMAS scores and produces quantitative scores that can be manipulated statistically in order to document change over time.

**POMplexity.** The POMplexity metric was devised for this study in order to evaluate the individual and combined effects of Phonological, Orthographic and Morphological influences on misspelled words. Initially inspired by the Physical Difference score created by Bishop (1985), the POMplexity awards points for deviations from the target in each of the categories (P, O, and M). The aim is to arrive at a composite complexity score. However, Bishop’s (1985) scoring procedure was not used
to quantify misspellings, but rather to quantify the physical and visual difference between the participant's production and the target spelling.

To add depth to the analysis, and to quantify the complex interactions of the three linguistic sources, Stoel-Gammon’s (2010) Word Complexity Measure (WCM) for inspiration was employed. The WCM awards a complexity score to words obtained through articulation testing and conversation. Each word in the sample is examined for evidence of development of levels within the phonological system, and awarded variable points for each pattern represented (i.e. word patterns, syllable structure, and sound classes). Higher scores represent either more complex patterns or later developing patterns/sounds (Stoel-Gammon, 2010).

Rather than quantifying the complexity of productions by awarding points for correct productions, the POMplexity seeks to describe the contributions of the linguistic skills in misspelled productions to demonstrate that deviations from the target result from inadequate integration, not complete absence, of linguistic knowledge. It seeks to quantify (numerically) the qualitative descriptions generated by the POMAS (see Table 1). Just as Stoel-Gammon (2010) created a hierarchy of skill development within phonology, the POMplexity has similar error hierarchies within P, O and M. Weighting errors within the skills allows the POMplexity to be sensitive to the severity of errors. An accurate spelling retains a zero value, as no deviations are present, and represents complete integration of the three linguistic sources in the spelling of that word. Misspellings accrue points for each error and errors are worth varying points depending on the severity of the deviation from the target.
<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P</strong></td>
<td>Skeleton present</td>
<td>Omissions and substitutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>jump</td>
<td>jup</td>
<td>jup</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>O</strong></td>
<td>Correct pattern</td>
<td>Sequencing error – all</td>
<td>Grapheme</td>
<td>Positional</td>
<td></td>
</tr>
<tr>
<td></td>
<td>represented</td>
<td>graphemes present but in</td>
<td>Selection Error –</td>
<td>Errors –</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>wrong order; or real word</td>
<td>including</td>
<td>graphemes in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>used to represent</td>
<td>digraph and</td>
<td>illegal positions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>aspect of phonological</td>
<td>diphthong errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>watermelon</td>
<td>watermlone</td>
<td>hause for house</td>
<td>ckat for cat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>liquidides for</td>
<td>cant for chant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>liquidize for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>excitement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>All morphemes</td>
<td>Correctly spelled</td>
<td>Either root of</td>
<td>Both root and</td>
<td>Word appears to</td>
</tr>
<tr>
<td></td>
<td>represented</td>
<td>homophone used</td>
<td>affix misspelled,</td>
<td>affix spelled</td>
<td>be syllabified,</td>
</tr>
<tr>
<td></td>
<td>correctly</td>
<td></td>
<td>including real</td>
<td>incorrectly –</td>
<td>the syntactic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>word errors</td>
<td>but can</td>
<td>role is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>recognize</td>
<td>unrecognizable,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>attempt to spell</td>
<td>or only the root</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>two morphemes</td>
<td>was represented.</td>
</tr>
<tr>
<td></td>
<td>walked</td>
<td>wait for weight</td>
<td>juped for jumped</td>
<td>jupt for jumped</td>
<td>asdet</td>
</tr>
<tr>
<td></td>
<td>painting</td>
<td>cereal for serial</td>
<td>amusment for amusement</td>
<td>amusment for amusement</td>
<td>jump for jumped</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>liquid for liquidize</td>
<td>liquidise for liquidize</td>
<td></td>
</tr>
</tbody>
</table>
When a deviation in a misspelling is due to a phonological deviation, as indicated by its POMAS description, then that deviation is awarded one point. Orthographic errors earn variable points, depending on the nature and severity of the error, as demonstrated in Table 1. When an error is a sequencing error, meaning all the phonemes are present, but not in the right order (watermlone for watermelon), one point is awarded. Similarly, when a real word is used to represent the phonological structure of a segment (designh for design, exsightment for excitement), one point is again awarded. Grapheme selection errors – omission, substitutions and digraph reductions (e.g. c/ch; ow/au) - are given two points apiece. In the case of ambiguous grapheme-phoneme correspondences, such as c/k and c/s, substituting an ambiguous letter for the target letter is a grapheme selection error. For example, in kareless the k would be considered a grapheme selection error (resulting in +2 points) because the child substituted an ambiguous letter for the phoneme /k/.

Lastly, when a grapheme is placed in an illegal position, as in the case with “ck” in the initial position (ckault for careless), that error is given three points. The reason is that the error represents a grapheme selection and a positional constraint error.

Morphological errors are also awarded variable points depending on the severity of the violation. In the event of a correctly spelled homophone, the misspelling is awarded a total score of one point. No other phonologic or orthographic points are awarded, as the sole error was in word selection. When either the root or the affix is misspelled, two points are awarded, even in the event that a real word was used in either segment – as in the case of exsightment for excitement where the real word sight was used in the root. As indicated earlier, this error will be scored twice, as it will receive +1 for orthography due to the real word, and +2 for morphology for producing an error in the
root, while accurately representing the suffix. When the inverse is true, and the suffix is misrepresented while the root is correctly encoded, the misspelling is counted twice, once either phonologically or orthographically and once morphologically. For example, *jumped* spelled *jumpt* would elicit a score for orthography and morphology, since the affix –*ed* was spelled phonologically, which then resulted in the misspelling of the suffix.

If both the root and affix are misspelled, but one can dissect the target from the misspelling, three points are awarded (e.g. *dangrus* for *dangerous*). If the misspelling appears to be syllabified, is unrecognizable, or if only the root was attempted, then it is awarded four points. For example, *ckault* was an attempt for *careless* that was determined to not represent the compound nature of the target word, and thus was awarded four points.

When deciding how to code an error, it is important to note that errors cannot be doubly coded as P and O. For example, in the case of epenthesis, the addition of a sound is a phonological error despite an extra grapheme being present as in, *chaira* (chair+schwa: /tʰəɹə/). Letters can be added without changing the phonological structure, in which case the error is orthographic and is not considered as a phonological epenthesis violation (e.g., doubling final consonants; *hatt* for *hat*). Though P and O-scores cannot be doubly coded, M-scores do represent a secondary code for errors. Any error to a root or affix will yield a P or O-score and then will be scored accordingly for its morphological implications. For example, if the *a* is absent from warmth, resulting in *wrmth*, then the missing *a* would result in +2 O and +2 M due to the misspelling of the root. In this example, the phonological skeleton is still represented, so no points are
accrued for P. The total score would be +4 (0P+2O+2M = 4 Total). Scoring examples are provided in Table 2.

### Table 2. POMplexity Scoring Examples

<table>
<thead>
<tr>
<th>Target</th>
<th>Misspelling</th>
<th>P</th>
<th>O</th>
<th>M</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>careless</td>
<td>ckault</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>+1 for /r/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>vowelization</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>+1 for s/t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>stopping</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+1 for /u/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>omission</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>+3 for illegal grapheme placement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ 4 for absence of syntactic role to careless</td>
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<td></td>
</tr>
<tr>
<td>excitement</td>
<td>exciment</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>+1 for /r/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>omission</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>+2 for silent e omission (utilizing letter name)</td>
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</tr>
<tr>
<td></td>
<td>+2 for error in root, but suffix is correct.</td>
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<td></td>
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<tr>
<td>pharmaceutical</td>
<td>farmisuticle</td>
<td>0</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>phonological structure represented</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+1 for RW farm</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>+2 for /i/a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+2 for s/c, (ambiguous letter)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>+2 for syllabic l</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+3 for errors in both root and affix</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Item-level Characteristics**

The derivational shift and frequency of the derived form were determined for each word, in order to assess the contributions of item level features to students’ spelling success (see Table 3). The derivational shift was described as either having no shift, a phonological shift, orthographic shift, or a combined phonological-orthographic shift. The standard frequency index (SFI) of each word was determined using *The Educator’s Word Frequency Guide* (Zeno, 1995). The higher the SFI, the more frequently the word appears in text.
Table 3. WIAT II Derivational Word Features

<table>
<thead>
<tr>
<th>Target Word</th>
<th>Shift Type</th>
<th>Derivational Frequency (SFI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>careless</td>
<td>No shift</td>
<td>49.8</td>
</tr>
<tr>
<td>strength</td>
<td>Phono + Ortho</td>
<td>59.0</td>
</tr>
<tr>
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</tr>
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</tr>
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<tr>
<td>conscientious</td>
<td>Phono + Ortho</td>
<td>42.7</td>
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Participant-level Characteristics

*Measures of phonological awareness.* Three measures of phonological awareness from the *Process Assessment of the Learner* (PAL; Berninger, 2001) were administered by Garcia et al. (2010) to assess students’ ability to manipulate three unique phonological units: syllable, phoneme, or rime. Students were asked to repeat a word spoken by the examiner, and then they were to repeat the target and delete the designated feature. For example, the student might be instructed to *Say COLD without the /k/.* The expected response would be *old.* These tasks required students to store the word in their working memory, then to use their phonological awareness to manipulate the target in order to produce it with the deleted segment. All three measures were administered to both cohorts in years 1-4. Only scores from the rime portion of the phonological awareness task were used in this study to examine the relationship between phonological awareness and POMplexity P scores.

*Measure of orthographic ability.* To determine factors that uniquely contributed to spelling changes over time, scores from a measure of orthography were extracted from
the original study. The Word Choice subtest of the PAL (Berninger, 2001) was administered every year and required children to circle the correctly spelled word from three options, forcing the child to recognize the correct spelling from two misspellings. For example, the students might be asked to indicate which of the following was spelled correctly: DESIGN, DEZINE or DEESINE. This task theoretically utilized the child’s ability to draw on their orthotactic knowledge of word specific patterns. Data was available yearly for this measure and scores were used to examine the relationship between orthographic awareness and POMplexity O scores.

**Measures of morphological awareness.** To complement the spelling measures, the scores from three morphological-syntactic awareness tasks given in the original study, also were included. The three tasks were the signals task, the Carlisle (2000) derivational task and the Carlisle (2000) decomposition task (Garcia, et. al., 2010). The signals task, which utilized a cloze procedure, required students to select the correctly inflected word to fit in the blank. For example, the examiner might say: *The boy was _____*, and asks the child to select between *swim, swims and swimming*. Successful completion of this task demonstrates an understanding of how the inflected suffix marks number, tense or part of speech. The Carlisle (2000) derivational task also utilized a cloze procedure, and required students to add a derivational suffix to a base word to fit the word to the context of the sentence (e.g. *Warm. He chose the jacket for its _____.*). The Carlisle (2000) decomposition task required students to give the base form, given a cloze sentence and a derived form (e.g. *Growth. She wanted her plant to _____?).

The children in Cohort 1 were given the signals task in years 1, 2, 3 and 5, but the original study only used the scores from the first two years, as the authors of the original
study felt the task was easier to complete since it only required the selection of a word to fit the context, rather than transforming a word (Garcia et. al., 2010). Data for the two Carlisle (2000) tasks was available for Cohort 1 from years 1-3 and for Cohort 2 from years 1-5 of the study. For the purpose of this study, only the Carlisle derivational and decomposition tasks were used in order to examine the relationship between derivational morphological awareness and POMplexity M scores.

Procedures

Data were drawn from the Wechsler Individual Achievement Test, second edition (WIAT-II) Spelling subtest (Psychological Corporation 2001). The spelling subtest was administered according to standard procedures: the examiner read the target word aloud, then read a sentence to provide a syntactic/semantic context for the word and then stated the word again. Based on their performance on the WIAT-II, participants were arranged into three spelling ability groups: poor, average and superior. The highest and lowest spelling score of each group were separated by 10 standard deviation points. The poor group had scores at 95 or below, the average group scored between 105-112 and the superior group had scores of 122 or greater (Garcia et. al., 2010). Students’ spelling ability was assessed using the WIAT-II every year for five years. No students’ score ever resulted in a change of placement within spelling ability groups, for either cohort.

This project focused on the misspellings from the WIAT-II words involving derivational morphology, as well as one inflected form with derived homophone possibilities resulting in 11 words for analysis: (1) careless, (2) strength, (3) absence, (4) excitement, (5) patients (patience), (6) subsidize, (7) edition, (8) assistants, (9) prestigious, (10) pharmaceutical, and (11) conscientious. Since the administration of this
measure involves a basal and a ceiling, the data do not include attempts at all 11 words each year. This means that, especially for the poor spellers, students often reached the ceiling before attempting the derived forms. The most complete set of data were available for the superior group; however, many average spellers attempted these more complex words, as did several poor spellers (see Tables 4-6 for a breakdown of words produced by group for each word by year). To surmount missing data, the data set was used as a whole, ignoring spelling ability and excluding responses from grades 1-2 because the number of their morphological spelling attempts was too low to analyze. Therefore, results will largely reflect the performance of the superior spellers.

_Data coding._ Once the derivationally complex words were identified, POMAS codes for the misspellings were extracted from another study investigating linguistic spelling development (St. John, 2014). Using the POMAS scores as a guide, the first author coded all of the productions using the POMplexity scoring system. To ensure reliability of coding, 20% of the words from each student and each year were selected at random (N = 157 items) for independent coding by the thesis advisor. Both individuals had been instrumental in the creation of the POMplexity and were familiar with both the POMplexity rules and the phonologic, orthographic, and morphologic patterns of the target words. The codes from each examiner were compared for each misspelling. After all were compared, 142 of the 157 items had identical codes, demonstrating 90% inter-rater agreement.
### Table 4. Poor Spellers Word Productions across Years

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<th>Gr. 5</th>
<th>Gr. 6</th>
<th>Gr. 7</th>
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### Table 5. Average Spellers Word Productions across Years

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### Table 6. Superior Spellers Word Productions across Years

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<td>20</td>
<td>17</td>
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<td>8</td>
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<tr>
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<td>8</td>
<td>16</td>
<td>13</td>
<td>9</td>
<td>8</td>
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Statistical analysis of the POMplexity scores. Three linear mixed effects regression analyses, with identical predictor variables and structure, were conducted to determine the impact of word-level characteristics on P, O, and M spelling errors. In each model, students’ intercepts (at 3rd grade) and slopes of change over time were allowed to vary randomly. That is, intercept and slope were modeled as random variables for each student such that each student had unique regression lines. Fixed effects were then added for grade, word frequency, and derivational shifts for the individual spelling words. Consequently, each model estimated main effects for grade, word frequency, and derivational shifts, 2-way interactions for grade*word frequency and grade*derivational shifts, and a 3-way interaction for grade*word frequency*derivational shifts. Word frequency was mean centered. Derivational shifts variable was the number of shifts present in a spelling word such that no shift = 0, phonological shift = 1, and orthographic and phonological shift = 2.

Again, a linear mixed effects regression approach was used to estimate the impact of participants’ phonological, orthographic, and morphological awareness on phonological errors, orthographic errors, and morphological errors, respectively. Three sets of analyses were conducted, one for each dependent variable. Again, in each model, students’ intercepts (at 3rd grade) and slopes of change over time were allowed to vary randomly. That is, intercept and slope were modeled as random variables for each student such that each student had unique regression lines. The first model conducted determined the impact of participant-level phonological awareness (operationalized as rime performance on the PAL) on POMplexity scores over time. The second determined the impact of orthographic awareness (operationalized as performance on the word choice
task [WCT]) on O POMplexity scores over time. The third determined the impact of morphological awareness (operationalized as performance on the Carlisle decomposition and derivational tasks) on M POMplexity scores over time.
Chapter 3

Results

The data were analyzed two ways, to provide insight on the relationship between each dependent measure spelling error (P, O and M POMplexity scores) and the item-level and participant-level characteristics. In the first set of analyses, the impact of item-level characteristics (word frequency and derivational shift) on P, O and M POMplexity scores was conducted. The second set of analyses investigated the relationship between the dependent POMplexity measures (P, O and M) and student’s phonological, orthographic and morphological awareness.

In total, 60 students spelled 11 words in grades 3, 4, and 5, for a total of 1,980 observations. Additionally, 30 of the first 60 students also spelled the 11 spelling words in grades 6 and 7, for a total of 660 observations. Consequently, the data presented here cover 2,550 observations from 60 different students who attempted to spell 11 words from grades 3 through 7. Each spelling attempt was coded with the POMplexity scale. Coding resulted in three dependent measures that characterized the errors made in spelling: phonological, orthographic, and morphological. Descriptive statistics for the POMplexity scale are presented in Table 7.
Table 7. Descriptive Statistics – POMplexity Scores by Grade

<table>
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<tr>
<th>Statistic</th>
<th>Grade 3</th>
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<th>Grade 5</th>
<th>Grade 6</th>
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<tr>
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<td>[2.47 – 2.83]</td>
<td>[1.94 – 2.44]</td>
<td>[2.04 – 2.56]</td>
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<td>2.39</td>
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<td>[2.25 – 2.35]</td>
<td>[2.36 – 2.41]</td>
<td>[2.37 – 2.41]</td>
<td>[2.34 – 2.43]</td>
<td>[2.38 – 2.45]</td>
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</tr>
<tr>
<td><strong>Orthographic Score</strong></td>
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<td></td>
<td></td>
<td></td>
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<td>7.35</td>
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<td>6.38</td>
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<td>[8.18 – 9.06]</td>
<td>[7.04 – 7.94]</td>
<td>[6.91 – 7.77]</td>
<td>[5.51 – 6.78]</td>
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<td>[5.82 – 6.05]</td>
<td>[5.93 – 6.13]</td>
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Note. Values in brackets are 95% bootstrapped confidence intervals.

Effects of Spelling Word Characteristics on POMplexity Scores

*Phonological error analysis.* Results for phonological errors are presented in Table 8. This analysis indicated significant main effects for grade, $b = -0.37$, $t(95) = -4.34$, $p < .001$, word frequency, $b = -0.07$, $t(2509) = -8.71$, $p < .001$, and derivational shift, $b = 0.26$, $t(2509) = 4.20$, $p < .001$. The main effects for grade and word frequency were qualified by a significant interaction between grade and word frequency, $b = 0.02$, $t(2509) = 2.05$, $p = .04$. The main effect for derivational shift indicated that for every additional derivational shift, phonological error scores increased by 0.26. The interaction
between grade and word frequency can be found in Figure 1. Students made significantly more phonological errors on low frequency words in grade 3 compared to high frequency words. In addition, students’ scores improved on low frequency words much more quickly than high frequency words, as indicated by the significantly steeper negative slope.

Orthographic error analysis. Results for orthographic errors are presented in Table 9. The analysis for orthographic errors also indicated significant main effects for grade, \( b = -1.05, t(98) = -5.14, p < .001 \), word frequency, \( b = -0.20, t(2509) = -10.39, p < .001 \), and derivational shift, \( b = 0.49, t(2509) = 3.22, p < .001 \). Each of these main effects were qualified by significant 2-way interactions between grade and word frequency, \( b = 0.06, t(2509) = 3.24, p = .001 \), and grade and derivational shift, \( b = 0.20, t(2509) = 2.47, p = .01 \). The interaction between grade and word frequency is presented in Figure 2. Again, students made significantly more orthographic errors on low frequency words in grade 3 compared to high frequency words. Likewise, students’ scores improved on low frequency scores much more quickly than high frequency words, as indicated by the significantly steeper negative slope. The interaction between grade and derivational shift is presented in Figure 3. Although the mean orthographic error scores did not differ
significantly within each grade as a function of derivational shift, as indicated by the overlapping 95% confidence intervals, the slopes of the three lines are significantly different. Specifically, the negative slope for grade increased by 0.20 as a function of the number of derivational shifts in the word. As shown in Figure 3, the orthographic errors made by students decreased fastest when spelling words contained no derivational shifts, less quickly when they contained only one phonological derivational shift, and the least quickly for spelling words that contained both phonological and orthographic derivational shifts.

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<td>-1.46 to -0.65</td>
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<td>2509</td>
<td>-10.39</td>
<td>.00</td>
<td>-0.24 to -0.17</td>
</tr>
<tr>
<td>Derivational Shifts</td>
<td>0.49</td>
<td>0.15</td>
<td>2509</td>
<td>3.22</td>
<td>.00</td>
<td>0.19 to 0.79</td>
</tr>
<tr>
<td>Grade * Word Frequency</td>
<td>0.06</td>
<td>0.02</td>
<td>2509</td>
<td>3.24</td>
<td>.00</td>
<td>0.02 to 0.10</td>
</tr>
<tr>
<td>Grade * Derivational Shifts</td>
<td>0.20</td>
<td>0.08</td>
<td>2509</td>
<td>2.47</td>
<td>.01</td>
<td>0.04 to 0.35</td>
</tr>
<tr>
<td>3-Way Interaction</td>
<td>-0.01</td>
<td>0.01</td>
<td>2509</td>
<td>-0.56</td>
<td>.58</td>
<td>-0.02 to 0.01</td>
</tr>
</tbody>
</table>

*Morphological error analysis.* The results for the morphological errors analysis are presented in Table 10. The analysis for morphological errors also indicated significant main effects for grade, $b = -0.43$, $t(98) = -6.41$, $p < .001$, word frequency, $b = -0.07$, $t(2509) = -10.09$, $p < .001$, and derivational shift, $b = 0.19$, $t(2509) = 3.77$, $p < .001$. Each of these main effects were qualified by significant 2-way interactions between grade and word frequency, $b = 0.02$, $t(2509) = 3.60$, $p < .001$, and grade and derivational shift, $b = 0.10$, $t(2509) = 3.82$, $p < .001$. The interaction between grade and word frequency is presented in Figure 4. Again, students made significantly more morphological errors on low frequency words in grade 3 compared to high frequency words. Likewise, students’
scores improved on low frequency scores more quickly than high frequency words, as indicated by the significantly steeper negative slope. The interaction between grade and derivational shifts is presented in Figure 5. Although the mean morphological error scores did not differ significantly within each grade as a function of derivational shift, as indicated by the overlapping 95% confidence intervals, the slopes of the three lines are significantly different. Specifically, the negative slope for grade increased by 0.10 as a function of the number of derivational shifts in the spelling word. As shown in Figure 5, the morphological errors made by students decreased fastest when spelling words contained no derivational shifts, less quickly when they contained only one phonological derivational shift, and the least quickly for spelling words that contained both phonological and orthographic derivational shifts.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>b</th>
<th>SE</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.42</td>
<td>0.18</td>
<td>74</td>
<td>18.61</td>
<td>.00</td>
<td>3.06 to 3.79</td>
</tr>
<tr>
<td>Grade</td>
<td>-0.43</td>
<td>0.07</td>
<td>98</td>
<td>-6.41</td>
<td>.00</td>
<td>-0.57 to -0.30</td>
</tr>
<tr>
<td>Word Frequency</td>
<td>-0.07</td>
<td>0.01</td>
<td>2509</td>
<td>-10.09</td>
<td>.00</td>
<td>-0.08 to -0.05</td>
</tr>
<tr>
<td>Derivational Shifts</td>
<td>0.19</td>
<td>0.05</td>
<td>2509</td>
<td>3.77</td>
<td>.00</td>
<td>0.09 to 0.29</td>
</tr>
<tr>
<td>Grade * Word Frequency</td>
<td>0.02</td>
<td>0.01</td>
<td>2509</td>
<td>3.60</td>
<td>.00</td>
<td>0.01 to 0.03</td>
</tr>
<tr>
<td>Grade * Derivational Shifts</td>
<td>0.10</td>
<td>0.03</td>
<td>2509</td>
<td>3.82</td>
<td>.00</td>
<td>0.05 to 0.15</td>
</tr>
<tr>
<td>3-Way Interaction</td>
<td>-0.01</td>
<td>0.00</td>
<td>2509</td>
<td>-1.81</td>
<td>.07</td>
<td>-0.01 to 0.00</td>
</tr>
</tbody>
</table>

Table 10. Morphological Score predicted by time, word frequency, and derivational shifts

Total POMplexity scores analysis. We also analyzed total POMplexity scores, which consisted of the sum of the phonological, orthographic, and morphological scores. The results for the total POMplexity scores analysis are presented in Table 11. This analysis demonstrated the same general pattern of results as the phonological, orthographic, and morphological analyses. There were significant main effects for grade, $b = -1.86, t(95) = -5.25, p < .001$, word frequency, $b = -0.34, t(2509) = -10.20, p < .001$,
and derivational shift, $b = 0.95$, $t(2509) = 3.65$, $p < .001$. Each of these main effects were qualified by significant 2-way interactions between grade and word frequency, $b = 0.10$, $t(2509) = 3.11$, $p < .01$, and grade and derivational shift, $b = 0.33$, $t(2509) = 2.44$, $p < .05$.

The interaction between grade and word frequency is presented in Figure 6. Again, students had significantly higher POMplexity scores on low frequency words in grade 3 compared to high frequency words. Likewise, students’ scores improved on low frequency scores more quickly than high frequency words, as indicated by the significantly steeper negative slope. The interaction between grade and derivational shifts is presented in Figure 7. Although the mean Total POMplexity scores did not differ significantly within each grade as a function of derivational shift, as indicated by the overlapping 95% confidence intervals, the slopes of the three lines are significantly different. Specifically, the negative slope for grade increased by 0.33 as a function of the number of derivational shifts in the spelling word. As shown in Figure 7, students’ Total POMplexity scores decreased fastest when spelling words contained no derivational shifts, less quickly when they contained only one phonological derivational shift, and the least quickly for spelling words that contained both phonological and orthographic derivational shifts.

| Table 11. POMplexity Total Score predicted by time, word frequency, and derivational shifts |
|-----------------|-----------------|---------|---------|---------|---------|---------|
| Predictor       | $b$             | $SE$    | $df$    | $t$     | $p$     | 95% CI   |
| Intercept       | 14.27           | 0.97    | 73      | 14.67   | .00     | 12.33 to 16.21 |
| Grade           | -1.86           | 0.35    | 95      | -5.25   | .00     | -2.56 to -1.16 |
| Word Frequency  | -0.34           | 0.03    | 2509    | -10.20  | .00     | -0.40 to -0.27 |
| Derivational Shifts | 0.95 | 0.26    | 2509    | 3.65    | .00     | 0.44 to 1.45   |
| Grade * Word Frequency | 0.10 | 0.03    | 2509    | 3.11    | .00     | 0.04 to 0.16   |
| Grade * Derivational Shifts | 0.33 | 0.13    | 2509    | 2.44    | .02     | 0.06 to 0.59   |
| 3-Way Interaction | -0.01          | 0.02    | 2509    | -0.64   | .52     | -0.04 to 0.02  |
Figure 1. P Score over Time by Word Frequency

Figure 2. O Score over Time by Word Frequency

Figure 3. M Score over Time by Word Frequency

Figure 4. POM Total Score over Time by Word Frequency
Figure 5. O Score over Time by Derivational Shift

Figure 6. M Score over Time by Derivational Shift

Figure 7. POM Total Score over Time by Derivational Shift
Relationship Between Participant Characteristics and P, O, M POMplexity Scores

*Impact of phonological awareness on POMplexity P scores.* The results for the impact of phonological awareness on POMplexity scores are presented in Table 12. Results indicated significant main effects for grade, \( b = -0.44, t(51) = -4.53, p < .001 \), rime, \( b = -0.43, t(187) = -4.22, p < .001 \), and a significant interaction between grade and rime, \( b = 0.21, t(152) = 3.04, p < .01 \). The interaction between grade and rime is presented in Figure 8. This interaction indicated that students with higher phonological awareness stayed relatively stable in terms of their rime scores over time, as indicated by the flat slope, but students with low phonological awareness improved more quickly over time, as indicated by the negative slope. Specifically, for each additional \( z \)-score increase in rime performance was associated with a 0.21 increase in the negative slope on POMplexity P score.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>( b )</th>
<th>( SE )</th>
<th>( df )</th>
<th>( t )</th>
<th>( P )</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.29</td>
<td>0.18</td>
<td>52</td>
<td>18.21</td>
<td>.00</td>
<td>2.93 to 3.65</td>
</tr>
<tr>
<td>Grade</td>
<td>-0.44</td>
<td>0.10</td>
<td>26</td>
<td>-4.53</td>
<td>.00</td>
<td>-0.64 to 0.24</td>
</tr>
<tr>
<td>Rime</td>
<td>-0.43</td>
<td>0.10</td>
<td>184</td>
<td>-4.22</td>
<td>.00</td>
<td>-0.63 to 0.23</td>
</tr>
<tr>
<td>Grade * Rime</td>
<td>0.21</td>
<td>0.07</td>
<td>164</td>
<td>3.04</td>
<td>.00</td>
<td>0.07 to 0.34</td>
</tr>
</tbody>
</table>

*Impact of orthographic awareness on POMplexity O scores.* The results for the impact of orthographic awareness on POMplexity O scores are presented in Table 13. Results indicated significant main effects for grade, \( b = -0.88, t(47) = -4.62, p < .001 \), and WCT, \( b = -0.05, t(312) = -2.98, p < .001 \), but no significant interaction, \( b = 0.00, t(187) = 0.31, p = ns \). As with the other analyses, POMplexity O scores decreased by .88 for each passing grade, on average. For orthographic awareness, a 20-percentage point increase in
WCT scores was associated with a 1-point decrease in POMplexity O-score, across all grades.

**Table 13. POMplexity O Score predicted by Word Choice Task**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>b</th>
<th>SE</th>
<th>df</th>
<th>t</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>8.49</td>
<td>0.50</td>
<td>52</td>
<td>17.03</td>
<td>.00</td>
<td>7.49 to 9.49</td>
</tr>
<tr>
<td>Grade</td>
<td>-0.88</td>
<td>0.19</td>
<td>48</td>
<td>-4.62</td>
<td>.00</td>
<td>-1.27 to 0.50</td>
</tr>
<tr>
<td>WCT</td>
<td>-0.05</td>
<td>0.02</td>
<td>310</td>
<td>-2.98</td>
<td>.00</td>
<td>-0.09 to 0.02</td>
</tr>
<tr>
<td>Grade * WCT</td>
<td>0.00</td>
<td>0.01</td>
<td>174</td>
<td>0.31</td>
<td>.76</td>
<td>-0.02 to 0.03</td>
</tr>
</tbody>
</table>

**Impact of morphological awareness on POMplexity M scores.** The results for the impact of morphological awareness on M scores are presented in Table 14. Results indicated significant main effects for grade, $b = -0.20$, $t(29) = -3.15$, $p < .01$ and the decomposition task, $b = -0.40$, $t(286) = -2.86$, $p < .01$. Again, POMplexity M scores decreased by .2 points for each passing grade. For morphological awareness, each additional 1 z-score increase in decomposition score was associated with a 0.4-point decrease in POMplexity M scores, across all grades. Similarly, each 1-point z-score increase in derivational score was associated with a .21 decrease in POMplexity M scores, across all grades.

**Table 14. POMplexity M Score predicted by Morphological Awareness**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>b</th>
<th>SE</th>
<th>df</th>
<th>t</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.63</td>
<td>0.14</td>
<td>51</td>
<td>25.22</td>
<td>.00</td>
<td>3.34 to 3.92</td>
</tr>
<tr>
<td>Grade</td>
<td>-0.20</td>
<td>0.06</td>
<td>28</td>
<td>-3.15</td>
<td>.00</td>
<td>-0.33 to 0.07</td>
</tr>
<tr>
<td>Decomposition</td>
<td>-0.40</td>
<td>0.14</td>
<td>272</td>
<td>-2.86</td>
<td>.01</td>
<td>-0.67 to 0.12</td>
</tr>
<tr>
<td>Derivational</td>
<td>-0.21</td>
<td>0.12</td>
<td>299</td>
<td>-1.73</td>
<td>.09</td>
<td>-0.44 to 0.03</td>
</tr>
<tr>
<td>Grade * Decomposition</td>
<td>0.09</td>
<td>0.06</td>
<td>373</td>
<td>1.39</td>
<td>.16</td>
<td>-0.04 to 0.21</td>
</tr>
<tr>
<td>Grade * Derivational</td>
<td>0.05</td>
<td>0.06</td>
<td>409</td>
<td>0.94</td>
<td>.35</td>
<td>-0.06 to 0.16</td>
</tr>
</tbody>
</table>
Figure 8. POMplexity P Score over Time by Rime

Figure 9. POMplexity O Score over Time by WCT

Figure 10. POMplexity M Score over Time by Decomposition
Summary of Results

*Impact of word frequency on POMplexity scores.* For each individual score (P, O and M) as well as the Total (T) POMplexity score, frequency had a significant impact on scores in the third and fourth grades. High frequency words resulted in lower P, O, M and T scores than low frequency words. The significantly steeper negative slope for low frequency words indicates that scores improved more rapidly for low frequency words than for high. This was consistent across P, O, M and T scores. The relatively flat slope indicates that spelling performance on high frequency words remained more stable than performance on low frequency words.

*Impact of derivational shift on POMplexity scores.* The type of derivational shift had a significant interaction with time for O, M and T scores, but not P scores. O, M and T scores were not shown to be significantly different across time by derivational shift. However, for all three, the slopes indicated that scores on derived words with no shift improved more quickly than those with a phonological shift, and scores for words with a combined phonologic-orthographic shift improved the slowest. Regardless of time, P scores increased by .26 points for every derivational shift.

*Impact of linguistic skills on POMplexity scores.* For each P, O and M, a relationship was found between performance on measures of each respective skill without respect to time. At any point in time: a) improvement on the PAL rime task correlated with an improved P score; b) improvement on the word choice task correlated with an improved O score, and c) improvement on both Carlisle tasks correlated with improved M scores. Improved performance on the Carlisle decomposition task correlated to a higher M score than performance on the Carlisle derivational task.
Chapter 4
Discussion

Spelling ability is not static; rather, as children age, learning how to encode morphophonologically complex words in conventional ways is motivated by the increasingly complex demands imposed by academic experiences with derived forms. Complexity requires ongoing integration of POM knowledge. However, current research on the development and assessment of spelling has not sufficiently accounted for the way word features and participant characteristics interact with students’ POM knowledge in the spelling of derived words. This study used a linear mixed effects regression approach to provide new insights about how both word characteristics and students' linguistic knowledge affected the application of POM from grades 3-7 in the spelling of derived forms.

The discussion first addresses study results as they relate to the three research questions. Next, study limitations and strengths are described. Then, the educational and clinical utility of POMplexity is outlined. Finally, four directions for future research are offered.

Influences on the Spelling of Derived Words

The influence of item-level characteristics. In this study, both word frequency and derivational shift were shown to influence the spelling of derived words. In terms of frequency, high frequency words resulted in lower POMplexity scores than low frequency words. This finding means that students spelled low frequency words more
accurately. This was true for the individual P, O and M POMplexity scores and the total POMplexity score. Scores for high frequency words remained relatively stable across time, indicating that, although they may be easier to spell, high frequency word misspellings did not resolve as rapidly as the errors produced when spelling low frequency targets. One possibility accounting for this pattern is that, initially, words with higher frequencies might be easier to spell because students have greater ease of access to both the root and derived features of the target. In this sense, familiarity and automaticity of word forms may co-vary, perhaps due to the frequency of encounters with these word forms in both the oral language and literacy domains.

Opacity also appeared to influence the spelling of derived words – words without a derivational shift resulted in lower POMplexity scores than those with one or two shifts. This pattern paralleled previous research during the middle school years (Goodwin, Gilbert & Cho, 2013) where opacity made the oral reading of words with derivational shifts more difficult. Goodwin et al. suggested this pattern was due either to shifts hiding the semantic relationship between the root and derived words, or, in the case of reading aloud, that students continued to pronounce the root word despite the derivation.

In this study, which focused on spelling and not reading aloud, derivational shifts often resulted in misspelled roots and correctly spelled affixes, as opposed to correctly represented root words. It seems that the opacity of derivationally complex words can obscure the relationship between roots and affixes so completely that students struggle to parse the derivation for the root word. This is especially evident when students use a real, but unrelated, word to represent features of derived words (e.g., FARMaSUITicle, subsiDIES, abSCENTS). Interestingly, these real words often bridge morpheme units in
order to replace syllables, as in \textit{FARMER}suiticle, where the real word \textit{farmer} replaces both the morpheme \textit{pharm-} and the syllables \textit{pharma}. In this case, the meaning of the morphological unit \textit{farmer} is ignored for the sake of representing the syllabic unit. Here, a phonological strategy takes precedence (epenthesi\textit{s} of the \textit{/r/} in \textit{farmer}), where a student sounds out a word and uses a letter-sound correspondence to represent the phonological skeleton of the word. When derivational shifts hinder the meaning-sound relationship, students may revert to earlier developing (and better developed) strategies – especially phonological strategies. In their transcribing of real words, students are selecting plausible orthographic patterns to encode phonological structures; hence, even when unable to encode meaning, students did not produce implausible orthographic or phonological forms.

On the other hand, despite the utilization of more familiar phonological strategies, misspellings of derivationally complex words can demonstrate persisting phonological weaknesses. Regardless of grade, when the target contained either a phonological or a combined phonologic-orthographic shift, the POMplexity P-score worsened. This pattern provides an additional source of evidence for the recursive nature of derivational spellings. This strongly suggests that the developmental course of learning to spell derivations is not a linear accumulation of POM knowledge, but instead is a recursive process with both general and word-specific knowledge affecting how an individual student produces a derivational spelling at any given point in time. For example, when a derivational spelling is not yet automatic, different strategies may be applied depending on how adequately POM are integrated with the conceptual/semantic knowledge of a derivation's meaning and its change in syntactic role. Real word misspellings, such as
FARMaSUITicle, illustrate how general word knowledge, which reflects statistical learning about permissible phonological structures, may be accessed and applied to word-specific items that are more opaque.

An important finding, therefore, is that despite advancing grades, the opacity of the target continued to influence individual students' ability to represent the phonological structure of derivationally complex words. This result challenges the notion that phonology is an early developing skill, which once mastered, remains stable (Anthony & Francis, 2005; Torgesen, Wagner & Rashotte, 1994). Rather, it appears that the strength of an individual's phonological awareness in spelling is word-specific. As the word spelling becomes more difficult, students’ phonological awareness may becomes less stable.

**Unconstrained scores and differences in word form complexity.** Unconstrained scores, as represented by POMplexity codes, appeared sensitive to the influences of word form complexities, as represented by word frequency and derivational shift. P, O and M scores were the most sensitive to changes in word frequency in grades 3 and 4, when scores for all three linguistic sources were significantly different by frequency. This may indicate that frequency plays a greater role in spelling performance in grades 3 and 4 than it does in grades 5, 6 and 7.

Regarding the complexity contributions of derivational shifts, P-scores demonstrated the most sensitivity. Regardless of grade, the type of derivational shift influenced P-scores. For every shift, (none→phonological→combined phonological-orthographic), P-scores increased by 0.26 points. The O, M and T scores (where T represents the total P, O and M scores) did not yield statistically significantly different
scores by grade or shift, but they did demonstrate the same shift hierarchy. Each shift resulted in a .020-point increase in O-score and a 0.10-point increase for M-score over time. Opacity was shown to impact students’ ability to use all three POM sources, but it most greatly challenged students’ ability to represent the phonological skeleton of words.

Unconstrained scores and POM growth. POMplexity scores were compared to scores on measures of P, O, and M awareness for two purposes. One aim was to determine how these scores related. The second intent concerned whether or not POMplexity scores would reflect growth in P, O and M awareness. Results of linear mixed effects regression models revealed that only the POMplexity P-scores, which were compared to performance on the rime portion of the PAL (Berninger, 2001), illustrated growth in phonological awareness over time. POMplexity P-scores for students with relatively high PAL scores remained relatively stable while those with relatively low PAL scores demonstrated significantly greater POMplexity P-score improvement.

Arguably, the students with low PAL scores had more room to improve or better scores could be attributed to regression to the mean. However, when accounting for sample size and missing data which restricted variability, it is noteworthy that improvement in these low-achieving students’ phonological skills over time was evident. This result contradicts the Torgesen et al. (1994) longitudinal finding of stability over time in the development of phonological awareness from kindergarten to grade 2 (the Torgesen et al. (1994) phoneme elision task most closely aligned with the PAL Rime deletion task used in the current study). Possible reasons accounting for the discrepancy in longitudinal results may be due to different focuses (i.e., word reading in Torgesen et al. (1994) versus the derivational spelling emphasis in this study), the use of older
students in this study, as well as the varied phonological awareness measures administered in the two studies.

In contrast to the variability of P-scores over time, O- and M-scores demonstrated a relationship to orthographic and morphological awareness independent of time in both aligned with improved performance When students' accuracy improved on the WCT and the Carlisle (2000) tasks, their O and M scores lowered, indicating fewer orthographic and morphological errors, suggesting growth in analyzing the morphemic unit. In addition, this finding served as another source of converging evidence that the POMplexity coding schema was correctly identifying O and M errors.

In sum, group stability and individual variability co-existed. This suggests that sophisticated statistical models, combined with sensitive measures, are necessary in order to illustrate individual differences despite seemingly stable group trends.

**Study Limitations and Strengths**

Three study limitations may have affected findings to a greater or lesser extent. The first limitation was restricted word sample. The 11 derivational words selected from the WIAT II represented approximately 20% of the total spelling list (N=53 words). One consequence of the limited number of items is that only one word contained a phonological shift and none had an orthographic shift (see Table 3). This means that the statistical analyses really focused on no versus two shifts. These categories represent the extremes of the opacity continuum, so these findings are positive in that they support the expected complexity differences. More research is needed to verify the differences in the other levels of morphological complexity.
Another feature of the words that may have compromised performance was the incidence of homophones. Many of the WIAT-II words are homophones, requiring students to use semantic clues to evaluate and select plausible (i.e., contextually appropriate) orthographic patterns. The possibility of a homophone production impacted the probability of other phonological and orthographic errors occurring. Therefore, the small number of words and word features limits the generalizability of findings to performance on other derived words.

The second limitation was missing data. The division of participants (N=60) into cohorts and spelling ability groups (superior, average and poor), as well as the nature of test administration, limited the available participant data. The WIAT-II was administered with basals and ceilings. This procedure affected the spelling attempts of derived words for younger students and poor spellers, as they often reached the ceiling before spelling any of the derived words. Even with the exclusion of grades 1 and 2, the data predominately reflected the performance of the superior and average spellers, as poor spellers continued to reach the ceiling before attempting many derived forms.

The third limitation concerned the data collection schedules. Another variable potentially influencing participant characteristics was the fact that spelling data were not collected for all derived words every year due to administration procedures (i.e., basals and ceilings). Similarly, scores on measures of related P, O and M awareness were not available for every year. For instance, the Rime task was only administered in years 1-4 in both cohorts, which means that data only existed for grades 3-4 for cohort 1 and for grades 3-6 for cohort 2 in this study.
On the other hand, two study strengths were operative as described below. The first strength was the number of data points. By combining the cohorts and spelling ability groups into one, the spelling performance of 60 children were followed from grades 3-5. Data for 30 of the 60 students were also available for grades 6-7, a remnant of the original study (Garcia et al., 2009), which followed two cohorts of 30 participants from grades 1-5 and 3-7, respectively. With 60 participants, the study had 26,400 data points available for analysis in grades 3-7.

The second strength involves the longitudinal nature of data. Data were collected on the WIAT II spelling words for five consecutive years simultaneously for two cohorts beginning in grades 1 and 3, respectively. The 11 derivations selected for analysis permitted 30 students to be followed for three years and another 30 for five years. Many other studies of spelling performance are cross-sectional (e.g., Bahr, et al., 2012; Beers & Beers, 1992; Hoffman & Norris, 1989; Larkin & Snowling, 2008; Nunes et al., 1997; Templeton, 1980; Walker & Hauerwas, 2006). The long-term nature of the data in this study is unique in that it included spelling outcomes from the same students every year. Hence, it was possible to examine individual variability within the group trends.

In summary, study strengths appear to outweigh study limitations. The primary reason is that, despite the constraints on variance, the mixed effects regression analyses resulted in statistically significant findings.

Educational and Clinical Implications

Based on the relationships found between item features, student characteristics, and unconstrained scores of misspellings, both educators and speech-language pathologists (SLPs) need to consider the implications of word and student characteristics,
POM awareness, and the scoring procedures employed when designing assessment and instruction. The following will discuss the implications for instruction and intervention, as well as the educational and clinical utility of the POMplexity scoring metric.

**Implications for instruction and intervention.** The effect of word features on spelling performance suggests that teachers and SLPs should consider the impact of derivational frequency and opacity when designing and/or implementing spelling/writing curricula. By identifying a hierarchy of targets, educators can form a greater understanding about the cognitive and linguistic demands that different words and word features may pose for students. These findings might offer insight into the expectations educators and clinicians alike have for students’ spelling performance.

According to the Common Core State Standards (CCSS) (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA & CCSSO], 2010) in grades 4 and 5, students should spell grade-appropriate words correctly. For grades 6-12, the CCSS indicates that students’ spelling should be correct. The CCSS does not indicate which words are grade-appropriate for grades 4 and 5. It is not within the scope of this study to suggest which words or word features comprise age- or grade-appropriate words. However, the CCSS expectation of spelling correctly by grade 6 is not based on empirical grounds, much less an understanding of spelling as an evolving means of discovering and consolidating how units of oral language are continuously fitted to written language symbols. As noted earlier, the word-specific nature of this journey was evident from the data since even the superior spellers in continued to make spelling errors in grades 6 and 7 despite previously spelling this same word correctly a year earlier.
Depending on the goal of instruction, intentional selection of greater word complexity has the potential to facilitate linguistic growth, as defined by POM awareness. For example, when first introducing a phonological or orthographic pattern, a teacher or SLP might want to rely on high-frequency words devoid of derivational shifts in order to capitalize on the accessibility of the word features. However, when the aim is to develop POM awareness or to generalize treatment goals, SLPs might consider the role of learnability theory and choose low-frequency words for intervention (Gierut, 2007). The rationale is that the greater complexity of low frequency derivations requires activation of more explicit analytical, or "meta," modes that are necessary for recruiting the breadth of POM knowledge, which comprises derivational forms. Moreover, instruction guided by learnability theory should be informed by statistical learning theory, so that teachers might begin “teaching words for ownership” (Stahl & Nagy, 2005; p. 61) or automaticity. When students have sufficient interaction with words, via several modalities, they are able to acquire ownership over those words so that they might use them easily and immediately as demanded by a given writing task.

*Educational utility of POMplexity.* The POMplexity results suggest that an unconstrained approach to the scoring of spelling may yield more information about POM growth than a constrained system, as demonstrated by the significant relationships demonstrated among measures of POM awareness and related POMplexity scores. Unconstrained scores offer far more information than simply scoring a word as wholly correct or incorrect. However, to become fully competent POMplexity users, teachers would need extensive training in order to identify the P, O and M features of words before being able to identify the source of error. Future research should examine the
length of time and intensity of instruction necessary to train teachers to become proficient POMplexity scorers, as well as modifications to the scoring system that might enhance accessibility for teachers.

Given comprehensive training, teachers could implement the POMplexity to score the misspellings of their struggling students in order to identify areas for intensive instruction, as well to document change overtime. In the meantime, teachers could be taught to classify errors as predominantly being P, O or M in nature so that they might gain general knowledge of areas for explicit instruction. Observing change due to instruction might reduce teacher and student frustrations about spelling performance.

Awareness of the complexity of encoding and the challenges posed by word features would enable teachers to understand the patterns in the seemingly chaotic misspellings produced by their students. Harshbarger (2008) has suggested that language learning can be explained by Complex Systems Theory, which defines complex systems as the result of a dynamic interaction of various elements over time, and as such, the results are not entirely predictable. Emphasizing the cognitive skills necessary to learn, Harshbarger (2008) demonstrates how engagement, noticing, making sense, incorporating, applying, remembering, and organizing can be arranged in a dynamic model. The same model can be applied to the linguistic units being mastered during spelling (P, O, and M). By recognizing that spelling is the result of a complex interaction among unique elements (i.e., word (item) features and individual P, O and M awareness skills), educators might be better able to understand the knowledge that an individual student is attempting to use and where breakdowns in that attempt may be occurring.

Redefining spelling and literacy as a dynamic activity would allow teachers to appreciate
the changes that do occur within misspellings over time. While students may continue to make errors, the teacher could note positive changes in spelling and POM awareness.

Clinical utility of POMplexity. There are at least four possibilities for examining the clinical utility of POMplexity. First, to understand how students arrive at their misspellings in principled ways, clinicians could assess both word features and individual aspects of POM awareness. For example, future studies should investigate the role of unconstrained scoring in the analysis of the misspellings of children who have been identified as late takers and are experiencing literacy learning difficulties (see Silliman & Berninger, 2011). An unconstrained system might be sensitive to subtle changes in the development of spelling for students with language learning disabilities and, potentially, open new doors to distinguish this group of students from those who are poor spellers.

Second, the POMplexity offers the opportunity to assess the strengths and weaknesses of POM awareness during a spelling task. Rather than administer three separate assessments, clinicians can use dictated spelling tests to assess P, O and M development. Not only can this save time by reducing the number of measures administered, but also it would offer more information about student performance on functional academic tasks.

Third, since gains on measures of POM awareness were related to improvements in individual POMplexity scores, the POMplexity might be useful for dynamically assessing intervention outcomes. Further research should be conducted to determine whether the POMplexity scoring system is sensitive to meaningful changes in performance due to interventions designed to enhance P, O and M awareness.
Lastly, the continued prevalence of phonological errors indicates that SLPs should consider continuing to target and strengthen phonological awareness beyond the typical period. As students continue to be challenged by experiences with the complexities of derived words, errors due to stressed linguistic systems should be expected. These findings suggest that clinicians should expect to continue to scaffold skill development to support students' ability to succeed as academic demands of reading and writing increase. For example, both the Carlisle (2000) derivation and decomposition tasks could be modified as activities to improve POM awareness. By using targets that contain different types of shifts, SLPs could intentionally scaffold students to ensure that they can more deeply process phonological and orthographic changes that might occur with the application of derivational affixes. By explicitly improving metalinguistic skills, and bringing attention to the patterns within English orthography, students can become more explicitly aware of the way orthography encodes both sound and meaning.

**Four Directions for Future Research**

Overall, this study highlights the power of an unconstrained scoring system to reveal the contributions of word features and participant characteristics to derived word spelling. The POMplexity coding system was sensitive to students’ POM awareness, especially their word-specific spellings. Contributions of word characteristics, such as frequency and number/type of derivational shift, suggest that morphemic features challenge encoding; that is, increased complexity taxes the system’s ability to represent both sound and meaning orthographically. However, these results are preliminary and future research should be conducted to expand findings. Three research directions are indicated.
POMplexity Application to Inflections

The contributions of word features and the usefulness of unconstrained analysis for the misspelling of words with other features should be examined. The current study emphasized the role of derivations, while future studies should compare the contributions of inflections to the spelling of word-specific derivations. Although both types of affixes are under the branch of morphology, they have different impacts on spelling performance (Deacon & Bryant, 2005). Future studies should examine whether the POMplexity is sensitive to the unique differences between the spelling of inflectional and derivational affixes.

Role of Word Frequency in Spelling Intervention

Concerning word frequency, this study focused on the surface frequency, or the rate of occurrence, of the entire derived form. It was not within the study scope to document the contributions of word feature frequency (base and affix frequency) to spelling performance. Nor did this study examine the impact of instruction on spelling performance. Stahl and Nagy (2005) suggest three main categories for the selection of vocabulary in explicit reading instruction: “1. High-utility literate vocabulary 2. Key content area vocabulary [...] 3. High-frequency words” (pp. 97-98, author’s italics). The authors emphasize the role of high-frequency words for the explicit teaching of reading to facilitate academic language learning and access to learning within the classroom context. This strongly indicates that the role of word frequency in spelling intervention needs investigation. Surely, just as Stahl and Nagy (2005) suggest, it should not be assumed that all students enter school being able to spell very high frequency words. As well, those unable to spell very high frequency words should be given explicit spelling
instruction in targeting these words as 105 of the most frequency occurring words account for approximately 50% of the words used in written English (Adams, 1990). However, when attempting to improve POM awareness, low frequency words might better access metacognitive and metalinguistic processes, thus maximizing opportunities for strengthening of P, O and M and their eventual integration. Future research should examine the role of using both high and low frequency words for explicit spelling instruction in order to assess the outcomes of targeting each feature.

**Variables Comprising Instructional Sequences**

In their study of the impact that word features and reader characteristics had on decoding derived words, Goodwin et al. (2013) examined not only surface frequency and shifts, but also the contributions of root word frequency, morpheme family size, semantic opacity, and the number of morphemes. With more word features represented, the authors were able to suggest a hierarchy for sequencing word instruction, as they were able to place features on a continuum of difficulty. Future studies should include more word and morpheme features in order to create a similar instructional sequence in word-specific spelling.

**Individual Differences in Spelling Development**

Lastly, a dynamic model of typical language learning based on the results of unconstrained scores should be the topic of future research. Such a model would allow insight into individual variation in development.

To create such a model, future studies would need to consider carefully the contributions of word features, participant characteristics, and variations in language input (e.g., the educational curriculum) to demonstrate the unique and complex
interactions that continuously occur in mastering the morphophonemic English orthography.
References


