Morphological Word Families and Learning to Spell

by

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Abstract

Research has demonstrated the facilitative effect of morphological word families on the development of orthographic representations and children's spelling accuracy. Specifically, related words that pronounce silent-letter endings increase the accuracy of children's attempts at spelling these particularly challenging French words. The current study intended to replicate and extend these findings in large-scale analyses assessing spelling accuracy by word for a large corpus of French words spelled by 40 children in Grades 1 through 5. Results supported the word family hypothesis in demonstrating the facilitative effect of morphological word families for all children. The derivative diversity hypothesis extended research on adult orthographic representations in finding that the diversity of derivatives was the stronger predictor of spelling across grades. Finally, the feminine form hypothesis was generally supported in that the feminine inflection was related to spelling only in Grade 1, however, this was only after controlling for the diversity of derivatives.

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Morphological Word Families and Learning to Spell

Learning to spell is a challenging process for young minds, yet essential to academic success. In alphabetic languages, spelling refers to the ability to produce the correct sequence of letters that represent a given word (Treiman & Kessler, 2014). When the spelling of a word has become established in memory, it can be retrieved automatically (Ehri, 1987). When learning to spell, however, children must produce the letter sequence using their existing knowledge about language and literacy. Learning to spell is therefore highly intertwined with learning to read (Ehri, 1987; Shanahan, MacArthur, Graham, & Fitzgerald, 2006; Shankweiler & Lundquist, 1992), and both spelling and reading build on children's oral language skills (Ehri, 1987; Shanahan et al., 2006). Therefore, to understand fully how children develop the ability to spell, it was essential to consider children's cognitive processing and how it applies to the learning of language and literacy, in addition to understanding what external factors influence learning.

While learning to spell is influenced by children's approach to learning, it is also influenced by the words being learned. Previous research has identified word characteristics that influence spelling attempts, such as a word's length and frequency in printed text (Caravolas, 2004; Caravolas, Kessler, Hulme, & Snowling, 2005; Lété, Peereman, & Fayol, 2008; Spencer, 2007; Treiman & Kessler, 2006). The present study focused on how knowledge of these characteristics facilitates spelling, emphasizing the facilitative effect of morphology, or the system for forming related words in a language (Carlisle, 1984, 2003; Sénéchal & Kearnan, 2007). The present study extended the small-scale experimental work demonstrating the facilitative effect of morphological word families on children's spelling accuracy.

In the following sections, how children learn and store information necessary for spelling success was reviewed. Subsequently, an extensive review of morphology was

conducted, with special attention given to the experimental work on morphological word families with related words that pronounce the silent-letter endings of French words. In the final section, the other word characteristics known to influence spelling accuracy were described, highlighting how they influence learning.

Spelling Development

Learning to spell a word builds on children's existing linguistic knowledge of that word (Ehri, 1987; Shanahan et al., 2006). Knowledge of oral language starts very early in life, from exposure to language heard in the environment (Kirkham, Slemmer, & Johnson, 2002; Saffran, Aslin, & Newport, 1996). Language acquisition is influenced by statistical learning, referring to the innate cognitive process of extracting information through analysis of the frequency of events and the probability of co-occurring events in one's environment (Estes, Evans, Alibali, & Saffran, 2007; Negro, Bonnotte, & Lété, 2014; Treiman & Kessler, 2014). During language acquisition, infants and toddlers learn to identify words from the repeating sounds in the speech stream they hear, thereby constructing phonological representations of words in memory (Gebhart, Aslin, & Newport, 2009). Phonological representations also become interconnected with the cognitive representation of the words meaning, known as sematic representations (Dahan & Tanenhaus, 2004). The precision of phonological and semantic representations, as well as the strength of their association, increase with exposure to the word, instruction, and practice using the word (Budd, Hanley, & Griffiths, 2011). With sufficient strength, these interconnected cognitive mappings result in the automatic co-activation of related representations (Ehri, 1992; Perfetti & Hart, 2001). This cognitive mapping is the foundation of a lexicon, or a vocabulary, which is brought to the task of learning to read and spell (Ehri, 1987, 1992).

In the first grade, children receive explicit literacy instruction. This instruction may include teaching the names and sounds of letters if not already known, as well as reading and

spelling. From this instruction, children begin to build cognitive representations for the printed forms of words, known as orthographic representations (Ehri, 1992; Share, 1999). This means the smallest units encoded in orthographic representations are graphemes, referring to individual letters or letter combinations that represent one sound in speech. This sub-lexical layer of orthographic representation is inherently connected to the sub-lexical phonological representations of the associated phonemes (sounds). Knowledge of the mappings between graphemes and phonemes is relied on for early reading and spelling, when children attempt to decode (i.e., translate graphemes to phonemes) and encode (i.e., translate phonemes to graphemes) words, respectively (Caravolas, Hulme, & Snowling, 2001; Ehri, 1992; Treiman & Kessler, 2014). According to Share's (1995, 1999) self-teaching hypothesis, decoding a new word results in the development of preliminary lexical (i.e., whole-word) orthographic representations. In addition, repeatedly decoding a word increases the precision of orthographic representations and strengthens their connections with phonological and semantic representations (Bowey & Muller, 2005; Nation Angell, & Castles, 2007; Share, 1995, 1999). Because it is such a fundamental aspect of early literacy, it was essential to consider how decoding is impacted by the nature of relations between phonemes and graphemes in the language being learned.

Previous research has found that the speed with which children learn to read (Seymour, Aro, & Erskine, 2003) and spell (Marinelli, Romani, Burani, & Zoccolotti, 2015) is influenced by the nature of the language being learned. In alphabetic languages, graphemes represent phonemes in speech, however, the reliability of the relation between phonemes and graphemes differs between languages (Seymour et al., 2003). Consistent languages, such as Italian, have highly reliable phoneme to grapheme mappings, which facilitates reading (Seymour et al., 2002) and spelling (Marinelli et al., 2015) development. The English language, however, is considered to be one of the least consistent orthographies due to the

highly unreliable mappings between phonemes and graphemes (Seymour et al., 2003; Ziegler et al., 2010). Consider Marinelli's comparison between Italian and English children's spelling development: children learning Italian mastered spelling by the second grade, while children learning English continued to have lower spelling accuracy into the fifth grade. In the present review, only research on orthographically complex languages was considered, focusing primarily on the French language.

The French orthography is described as inconsistent because of the many unreliable graphemic representations of phonemes (e.g., the phoneme /o/ can be spelled with the graphemes *au, aud, aut, aux, eau, o, oc, op, os, ot,* and *ôt*; Gingras & Sénéchal, 2016). Specifically, the 36 phonemes in the French language can be represented by an estimated 130 graphemes (Catach, 1978). This instability in the phoneme-to-grapheme direction of mapping negatively impacts spelling performance in French (Lété et al., 2008). In contrast, grapheme-to-phoneme mappings are relatively consistent, such that reading development is not as negatively impacted in French as compared to English (Ziegler, Jacobs, & Stone, 1996). This instability in phoneme-to-grapheme mappings is due in part to the high number of silent letters in the French orthography. To illustrate, consider the silent letters *d, t, x, c, p, and s* in the preceding example of the graphemic representations of the phoneme /o/. It has been estimated that 61% of words in speech and texts in French end in silent letters (Gingras & Sénéchal, 2016). A more conservative estimate of a French vocabulary, not including words ending in silent-letter inflections such as a silent *s* to mark a plural, still found that approximately 28% of words ended in silent letters. Considering their frequency, understanding how children learn to spell silent letters was the goal of the present study.

Silent letters are harder for young children to learn because they must remember to include a letter for which there is no phonological clue (Sénéchal, Gingras, & L'Heureux, 2016). According to fuzzy representations model (Sénéchal et al., 2016), consistently spelled

phonemes are quickly mapped, providing a framework for budding orthographic representations. Sources of orthographic inconsistency such as silent letters, however, are not readily mapped or activated and often remain underspecified in orthographic representations. Jubenville, Sénéchal, and Malette (2014) supported this assumption in a learning study during which children in Grades 1 to 3 were implicitly exposed to pseudo-words that ended with a silent ending (e.g., *pocrat*). These children had little difficulty spelling the consistent parts of the pseudo-words accurately, but often omitted or substituted the silent letters (i.e., 95% of errors). Therefore, the goal of the present study was to understand how silent letters become represented in memory and what factors might help children more accurately spell these words.

As children become more experienced readers and spellers, they improve the quality and precision of lexical and sub-lexical representations (Ehri, 1987; Perfetti, 1984; Share, 1995, 1999). This means children can read and spell more words directly with the automatic activation of precise orthographic representations (Ehri, 1987; Invernizzi & Hayes, 2004). Underspecified phonemes in representations are also more accurately determined through the increasingly precise sub-lexical knowledge. Sub-lexical knowledge beyond phoneme-to-grapheme mappings also develops to include layers of representations pertaining to orthographic regularities such as permissible and commonly co-occurring graphemes (Hayes, Kessler, & Treiman, 2005; Treiman & Kessler, 2006) and morphology (Bahr, Silliman, Berninger, & Dow, 2012; Bosse & Pacton, 2013; Giraudo & Grainger, 2001). For example, children are influenced by the phonemes and graphemes surrounding inconsistently spelled phonemes (Kessler & Treiman, 2001; Sénéchal et al., 2016). It should be noted that this information is often implicitly acquired through repeated exposure to printed texts and statistical learning (Steffler, 2000).

As described in the next section, children's knowledge of the morphological structure of the language influences spelling development, particularly in orthographically inconsistent orthographies (Bahr et al., 2012; Bosse & Pacton, 2013; Giraudo & Grainger, 2001). Specifically, it has been suggested that morphemes, the smallest units in a word associated with meaning, are encoded and interconnected in a morphological layer of orthographic, phonological, and semantic representations (Caravolas, 2004; Giraudo & Grainger, 2001; Pacton, Fayol, & Perruchet, 2005; Perfetti, 1984). In turn, knowledge of morphological characteristics of target words influences children's spelling attempts (Giraudo & Grainger, 2001). The goal of the present study was to assess the influence of morphological word families on the spelling accuracy of French words ending in silent letters. As such, in the following section, an extensive review of morphology was presented, including a general overview and relevant past research.

Morphology

Morphology refers to the system for the formation of words and the relationships between related words in a language (Carlisle, 1984, 2003; Sénéchal & Kearnan, 2007). Words are formed from morphemes, the smallest units of meaning in words (e.g., the word *cat* has one morpheme; *cats* has two). Morphemes can be classified as free-standing or bound. Free-standing morphemes are also called root words, referring to roots that are independent lexical entities, meaning they can stand alone as a word (e.g., the root *lait* /lɛ/ [milk] in *laitier* /letje/ [dairy]). Bound morphemes, however, have no independent lexical status, which means they must be connected to other morphemes to form words. Bound morphemes can include roots (e.g., *réalis* in the word *irréalisable* /iʁealizabl/ [unrealizable]; Nemat, 2016), and affixes, which are prefixes and suffixes (e.g., *ir* and *albe* in *irréalisable,* respectively) that are added to roots to alter their original meaning. Therefore, a morphological word family refers to a family of related words that are formed from the same

root, thereby sharing in both orthographic form and meaning (Nagy, Anderson, Schommer, Scott, & Stallman, 1989).

Information pertaining to morphemes and the morphological structure of words is encoded in a morphological layer of interconnected phonological, orthographic, and semantic representations (Caravolas, 2004; Giraudo & Grainger, 2001; Pacton et al., 2005; Perfetti, 1984). For example, reading the French word *chats* /ʃa/ [cats] activates the sub-lexical representations for the root *chat* /ʃa/ [cat] and the suffix *s,* in addition to the activation of the whole word (Giraudo & Grainger, 2001; Reichle & Perfetti, 2003). While morphological knowledge can be explicitly taught, information is also encoded implicitly beginning from a very young age (Pacton et al., 2005). The repeated use of morphemes in a language facilitates their acquisition, resulting in more precise representations that are more readily co-activated (Giraudo & Grainger, 2001; Perfetti, 1984; Verhoeven & Calisle, 2006). This theory has been supported by recent research on the facilitative effect of morphologically related words in spelling the inconsistently spelled phonemes in words (Deacon & Bryant, 2005, 2006; Sénéchal, 2000; Sénéchal, Basque, & Leclaire, 2006; Treiman, Cassar, & Zukowski, 1994).

Consider the case in spoken English where the graphemes *t* and *d* can be representative of a very similar phoneme, as in the examples of *duty* and *waited* (Treiman et al., 1994). Based on phonology alone, children with underspecified representations would likely spell the *t* in these words with a *d*. However, knowledge of the morphological roots *wait* and *loud* facilitates spelling because the roots clearly pronounce the inconsistently spelled phoneme. Because knowledge of morphology cannot clarify the spelling of the word *duty*, it is the most challenging word to spell. This was confirmed with kindergarten to second grade children (Treiman et al., 1994). Children well into the second grade were more likely to spell words containing this *d* sound with a *d*. However, when comparing the spelling accuracy of the two-morpheme words (e.g., *waited,* which has the *t* clearly pronounced in the

root *wait*) to one-morpheme words (e.g., *duty*), children as young as five spelled the two-morpheme words accurately significantly more often. This suggested they were using knowledge of the root words in their spellings (Treiman et al., 1994).

In response to this evidence, researchers questioned whether the facilitative effect of the two-morpheme words was due to morphology or the statistical probability of the co-occurring graphemes in the language (Deacon & Bryant, 2005, 2006). In other words, was *waited* spelled accurately more often than *duty* because children were isolating the free root *wait,* or because *wait* was a more frequently occurring combination of graphemes than *dut.* To test this alternative explanation, children spelled one- and two-morpheme words that were matched for letter-sound sequences (Deacon & Bryant, 2005, 2006). For example, children were asked to complete the spelling *rock* in both of the one-and two-morpheme words *rocket* and *rocked,* respectively, and *turn* in *turnip* and *turning.* Children were also asked to complete the spelling of *–ness* in the words *witness* and *illness,* and *–er* in *corner* and *warmer* respectively. Results found that 6- to 8-year-old children consistently spelled the two-morpheme words accurately more often, supporting the theory that children use morphological knowledge when spelling.

Knowledge of morphology can also help children learn the silent-letter endings of French words (Sénéchal, 2000). Specifically, silent-letter endings can be pronounced when a suffix is added to the word, such as when the silent *t* at the end of the word *chant* /ʃɑ̃/ [singing] is pronounced in the morphologically related words *chanter* /ʃɑ̃te/ [sing] and *chanteur* /ʃɑ̃tœʁ/ [singer] (Bosse & Pacton, 2013). These morphologically related words that reveal silent-letter endings, labelled revealing-related words, provide a phonological cue for children attempting to supplement underspecified orthographic representations that could increase spelling accuracy.

Researchers have found that the existence of revealing-related words increased children's spelling accuracy (Pacton, Foulin, Casalis, & Treiman, 2013; Sénéchal, 2000; Sénéchal et al., 2006). For example, Sénéchal et al. found that fourth grade children accurately spelled target words ending in silent letters more often when they had a revealing-related word. Specifically, words with revealing-related words (e.g., *chat* /ʃa/ [cat], with the related word *chaton* /ʃatɔ̃/ [kitten]) were spelled accurately more often than target words without revealing-related words (e.g., *foulard* /fulaʁ/ [scarf]) and target words with related words that did not pronounce the silent letter (e.g., *tabac* /taba/ [tabacco], with related words *tabagie* /tabaʒi/ [cigarette shop] and *tabatière* /tabatjɛʁ/ snuffbox]). In addition, Sénéchal et al. asked children to report the strategy they used when spelling inconsistently spelled words, including retrieving the word from memory, phonologically sounding out the word, and recalling orthographic rules and knowledge of morphologically related words. Results indicated that children who reported using a morphological strategy were equally accurate at spelling morphological words compared to children who reported retrieving the word from memory. In sum, these results supported the expectation that revealing-related words facilitate spelling development.

The primary goal of the present study was to extend these findings in a large-scale analysis of spelling accuracy by word. It was expected that the existence of a revealing-related word would increase spelling accuracy in a large sample of French words ending in silent letters. For this general hypothesis, any form of revealing-related word was considered. However, differential effects between types of revealing-related words were also explored. Specifically, revealing-related words were compared based on their categorization between the two main branches of morphology: derivational and inflectional morphology.

Derivational morphology. Derivational morphology refers to the formation of morphologically related words by combining roots and derivational affixes. There are a large

number of derivational affixes which can be combined on a single root and have the ability to change the syntactic class and meaning of a word (Reichle & Perfetti, 2003; Sénéchal & Kearnan, 2007). For example, in English, the verb *compare* can be made an adverb, *comparably*, an adjective, *comparable*, and a noun, *comparability*. In addition, derivational affixes lack consistent rules of application. Consider the two similar English words *terror* and *horror* (Carlisle, 1984). They share two similarly derived forms: *terrible/horrible* and *terrify/horrify*. However, the derivative *terrorize* does not have an equivalent for the word *horror*, and *horrid* does not have an equivalent for the word *terror*.

A final and significant challenge posed by derivational suffixes includes the nature of their transformation to the root, which is traditionally classified by two categories of suffixes (Tyler & Nagy, 1989). Neutral suffixes attach directly to the root and do not alter their spelling or pronunciation, labelled a simple transformation. Examples of neutral suffixes includes *ment* (e.g., *pave/pavement*) and *ness* (e.g., *sad/sadness*) in English, and *er* (e.g., *ski* /ski/ [ski] to *skier* /skje/ [to ski]) in French. Contrarily, non-neutral suffixes alter the spelling and pronunciation of the root, called an irregular transformation. For example, in French, the roots *vieux* /vjø/ [old] and *fruit* /fʁɥi/ [fruit] are irregularly transformed into the derivatives *vieillesse* /vjɛjɛs/ [old age] and *fructueux* /fʁyktɥø/ [fruitful], respectively. Despite the abundance of challenges posed by the complex system of derivational morphology, research has found that children can use knowledge of this system to spell in French.

Pacton et al. (2005) found that second grade children's spelling of the phoneme /ɛt/ was influenced by morphological status. In French, /ɛt/ can be spelled as *aite* (e.g., *défaite* /defɛt/ [defeat]), *ète* (e.g., *planète* /planɛt/ [planet]), and *ette* (e.g., *assiette* /asjɛt/ [plate]). When the /ɛt/ sound is added to a root as a suffix to mark a diminutive (i.e., to mean a little version of the root), it is always spelled *ette* (e.g., *fille* / fij/ [girl] and *fillette* /fijɛt/ [little girl]). In this study, 40 children in each of Grades 2, 3, and 5, were asked to spell 24 non-

words ending in /ɛt/. The non-words were presented in the context of a sentence to indicate whether the /ɛt/ sound marked a diminutive (e.g., "a little /soriv/ is a /sorivɛt/"). Children in all three grades used the *ette* spelling significantly more often when marking diminutives, suggesting children used knowledge of morphological derivation as early as the second grade.

Research has also found that different measures of derivatives, namely their diversity and cumulative frequency, had different relations to the development of orthographic representations. Specifically, Reichle and Perfetti (2003) used computer simulations of adult word reading performance to assess the precision of orthographic representations. They showed that words with more derivatives (e.g., *observe: observer, observation, observant, observance, observable, observatory*) had higher quality representations (i.e., were read more accurately) as compared to words with smaller word families (e.g., *poison: poisonous*) while controlling for the cumulative frequency of the derivatives. However, the cognitive representations of words with highly frequent derivatives did not differ from words with low frequency derivatives when controlling for the number of related words. This finding suggested that having more derivatives strengthened the quality of morphemic orthographic representations beyond mere increased exposure to the morphemes.

A second goal of the present research was to extend this finding to spelling in French. In light of Reichle and Perfetti's (2003) findings, it was expected that the diversity of derivatives that pronounce silent-letter endings would predict spelling accuracy while controlling for the cumulative frequency of derivatives. As Reichle and Perfetti's study was conducted on adult reading performance, it was expected that only the older children in Grades 3 to 5 would demonstrate this effect. Before discussing the final hypothesis of the present study, an understanding of the second branch of morphology, namely inflectional morphology, was required.

Inflectional morphology. Inflectional morphology refers to a language's use of suffixes that are added to words to mark grammatical information (Sénéchal & Kearnan, 2007). Compared to derivational morphemes, inflectional suffixes adhere more consistently to rules of use. This facilitates learning, increasing use of inflections in spelling from a younger age (Fayol, Totereau, & Barrouillet, 2006; Pacton & Deacon, 2008). Inflections can be added to all words within a syntactic class, but do not change the class of the word (Carlisle, 2003). For example, a plural noun is still a noun and a past tense verb is still a verb. In French, inflections can inform about verb person (e.g., I, you, or he) and tense (e.g., present, past, or future), and can mark plurality (e.g., *s* in *chats* /ʃa/ [cats]) and gender (e.g., *petit* /pəti/ [small] masculine, and *petite* /pətit/ [small] feminine; Sénéchal & Kearnan, 2007). While most inflections in French are silent, simply transformed feminine inflections (i.e., words with an *e* added to the end) often results in the pronunciation of the silent letter. There is limited evidence of the unique role of feminine inflections in facilitating spelling development, however, one study was the foundation for the third hypothesis in the present study.

Sénéchal (2000) assessed the effects of different types of revealing-related words on spelling accuracy. Specifically, children in Grades 2 and 4 (*n*s = 57 and 55, respectfully) spelled ten French words ending in silent letters from each of four categories: 1) inconsistent words with no revealing-related words; 2) morphological-feminine words that had feminine inflections that resulted in the pronunciation of the silent letter; 3) morphological-nominal words that only had morphological derivatives that revealed the silent letters; and 4) consistent words that could be spelled through phoneme-to-grapheme mappings. Notably, these words were equated in terms of word length, word frequency, and orthographic neighbours, and the pattern of results was the same for children in both grades. Results indicated that morphological words were spelled accurately more often than inconsistent

words. Interestingly, morphological-feminine words were spelled accurately significantly more often than morphological-nominal words. This suggested that feminine inflections might provide the most insight into the silent-letter endings compared to other derivatives. However, the existence of any derivative still facilitated spelling. The third and final goal of the present study was to extend these results in a large-scale analysis: it was hypothesized that the existence of a feminine inflection would facilitate spelling in addition to the variance accounted for by morphological derivatives.

To summarize, the present study intended to extend the current research on the facilitative effect of revealing-related words on spelling accuracy into large-scale analyses. However, to fully understand the influence of morphology in the context of existing literature on spelling development, it was essential to assess the additive effect of morphology in addition to the other known predictors of spelling accuracy. These were reviewed in the following section.

Other Predictors of Spelling

Previous research has identified lexical and sub-lexical characteristics of words that affect the development of orthographic representations (Lété et al., 2008; Spencer, 2007). While most of these predictors stem from research on reading, the following description focused solely on research on spelling accuracy. The review of these predictors drew from information available in the orthographically complex French and English languages. The section began with a description of four word characteristics relevant to all types of words in both languages, labelled word-general predictors. Next in the section, the characteristics unique to French words ending in silent-letters were reviewed.

Word-general predictors. Cumulative research on spelling accuracy has identified orthographic characteristics that predict spelling and that should be considered when evaluating the role of other predictors of spelling development (Lété et al., 2008; Pacton &

Deacon, 2008; Spencer, 2007). These include the frequency of the word in printed text (Alegria & Mousty, 1996; Caravolas et al., 2005; Martinet, Valdois, & Fayol, 2004), word length (Naylor, 2014; Spencer, 2007), and orthographic consistency (Kreiner, 1992; Kreiner & Gough, 1990; Lété et al., 2008; Peereman, Content, & Bonin, 1998; Sénéchal et al., 2006) and complexity (Spencer, 2007; Sprenger-Charrolas, Siegel, & Bonnet, 1998). Each of these influences of spelling accuracy was described in turn, followed by a section on research assessing multiple characteristics simultaneously.

Word Frequency. Word frequency refers to an approximate measure of children's previous exposure to the word. Because it is not possible to assess how often children are exposed to the printed form of words, frequency is measured as the number of occurrences of the word in age-appropriate texts (Weekes, 1997). Frequent words are likely seen by children more often, which facilitates the development of high quality orthographic representations and increases spelling accuracy (Hino & Lupker, 2000; Lété et al., 2008; Sénéchal et al., 2006; Sénéchal et al., 2016; Share, 1999; Weekes, 1997).

Research on word frequency has compared spelling accuracy between high and low frequency word lists. For instance, Martinet et al. (2004) had 36 French children spell high and low frequency words at the middle and end of their first year of school. Results indicated that at both test points, children accurately spelled high frequency words more often than less frequent words. Alegria and Mousty (1996) however, found that frequency effects were moderated by reading ability. Specifically, of the 75 typically developing children in Grades 2 to 5, only the stronger readers demonstrated frequency effects. Spelling accuracy did not differ between the frequent and infrequent words for children with the lowest reading ability. These results indicated that only children with more extensive exposure to printed texts through reading benefit from the frequency of a word in texts.

Research on word frequency has also found that a continuous variable for the frequency of a word predicted spelling accuracy by word in regression analyses in English (Caravolas et al., 2005; Spencer, 2007) and in French (Lété et al., 2008). Caravolas et al. found that frequency significantly predicted the spelling accuracy of 95 monosyllabic words by 152 first grade English children, explaining an additional 2% of the variance after controlling the orthographic consistency of the word. These results were further corroborated by Lété et al.'s analyses of spelling accuracy based on a large commercially-available database of French words spelled by 40 French children in each of Grades 1 to 5. In this study, 12 predictor variables were regressed on spelling accuracy by word for 3,430 target words. Predictors included nine variables pertaining to orthographic consistency, word length, word frequency, and phonographic neighbourhood. Frequency was calculated based on a series of French books used in the school curriculum for Grade 1, Grade 2, and Grades 3 to 5. Results indicated that frequency was one of the top three predictors in Grades 2 and 3 to 5, but only the seventh predictor in Grade 1. Specifically, word frequency accounted for only 1.5% of the variance for children in Grade 1, compared to 11.8% and 12.7% for children in Grades 2 and 3 to 5, respectively. It was therefore expected that frequency would be a stronger predictor of spelling accuracy for older children in Grades 2 and 3 to 5 who have had sufficient exposure to printed texts in the present study.

Word Length. Word length is one of the most studied characteristic that influences spelling attempts (Bloomer, 1956; Gibson, Osser, & Pick, 1963) Research has used different measures of word length, counting orthographic units such as the number of letters (Rapp & Dufor, 2011; Weekes, 1997) and graphemes (Rastle & Coltheart, 1998) in research on reading, and phonological units such as the number of phonemes (Spencer, 2007) and syllables (Naylor, 2014) in research on spelling. To illustrate the difference in these counts, consider that the French word *chat* /ʃa/ [cat] has 4 letters, 3 graphemes, 2 phonemes, and 1

syllable. Early research assumed longer words were harder to spell because of the larger potential for error given the increased number of letters to produce (Bloomer, 1956). Contemporary research, however, has found that longer words were more challenging to spell because young children must activate and hold more information in their underdeveloped working memory while each letter was selected sequentially during production (Rapp & Dufor, 2011). This suggested that word length was a stronger predictor of spelling for younger children. In the present study, the phonological length of a word in terms of phonemes was expected to negatively predict the spelling accuracy of younger children in Grades 1 and 2.

Research in English has found the length of a word to predict the accuracy of young children's spelling. Spencer (2007) used the number of phonemes in his assessment of the spelling accuracy of 120 of the most frequent words in English by children in Grades 2 to 6. Word length was a significant predictor only in Grades 2 and 3 in these step-wise regression analyses, supporting the expectation that word length had a greater impact on younger children. However, the resulting beta weights were small and length only predicted 0.3% of the variance. Therefore, the results were interpreted with caution.

The negative effect of word length on spelling accuracy has also been found in research in French. Lété et al. (2008) used a composite measure that considered the number of letters, graphemes, phonemes, and syllables into one index of word length. Recall Lété et al. used regression analyses with 12 word characteristic predictors on the spelling accuracy of 3,430 French words by children in Grades 1, 2, and 3 to 5. They found that word length was one of the top three predictors of spelling accuracy for children across grades. These results differed from Spencer (2007) in that word length was one of the stronger predictors for all age groups, not just younger children. This may have been accounted for by the stronger statistical power in Lété et al.'s study due to the larger number of words, the different

assessment of word length, the differing frequency of the words, or by Spencer's inclusion of orthographic complexity. Regardless, these results provided support for the necessity to include word length as a predictor of spelling accuracy in the present study. It was expected that the phonological length of a word would negatively predict spelling accuracy of younger children in Grades 1 and 2.

Orthographic consistency. Orthographic consistency refers to the stability of the relation between phonemes and graphemes in a given orthography. This stability can be evaluated from a reading or spelling perspective (Lété et al., 2008). In spelling, phoneme-to-grapheme consistency refers to the probability of using the correct grapheme given the number of plausible graphemes that could represent a given phoneme. Increases in the number of plausible phoneme-to-grapheme mappings render spelling more difficult. This is illustrated by the following three examples. First, the phoneme /m/ (e.g., *maple* /meɪpəl/) is a consistently spelled phoneme as it can only be represented with the letter *m*. Second, the phoneme */k/* is a less consistently spelled phoneme as it can be represented with five different graphemes in English, *c, k, ck, ch,* or *q*. Finally, consider the word *maybe* /meɪbi/*,* which has two phonemes that can be represented with more than one grapheme: The phoneme /eɪ/ can be represented by the graphemes *a, ay, ai, ey,* and *ei,* and the phoneme /i/ can be represented by the graphemes *ee, ea,* and *y*. In light of these examples, it is clear that orthographic consistency is best measured on a continuum of phoneme-grapheme correspondences rather than as a consistent-versus-inconsistent dichotomy (Treiman & Kessler, 2014).

The orthographic consistency of a word impacts spelling development by decreasing young children's ability to rely on their existing knowledge of phoneme-to-grapheme associations when attempting to spell a word (Treiman & Kessler, 2014). In addition, sources of orthographic inconsistency such as silent letters can remain weak or underspecified in existing orthographic representations well into adulthood. For instance, lower consistency

indices predicted, in adult samples, longer reaction times to start spelling and total spelling time in French (Delattre, Bonin, & Barry, 2006) as well as spelling accuracy in English (Burt & Blackwell, 2008).

Research has demonstrated that children and adults are more likely to misspell and require more time in spelling words that are less consistent in English (Caravolas et al., 2005; Kreiner, 1992; Kreiner & Gough, 1990; Spencer, 2007) and in French (Lété et al., 2008; Peereman et al., 1998). For example, Spencer assessed 7- to 11-year-old children's spelling accuracy of 120 of the most frequent words in English. In this study, two different phoneme-to-grapheme consistency indices were compared on their ability to predict spelling. Results of these regression analyses indicated that the consistency index of the least consistently spelled phoneme in a word was a stronger predictor than the average consistency index of all the phonemes in the word. Similarly, Caravolas et al. demonstrated that the spelling accuracy of 152 5- to 6-year-old English children was most strongly predicted by the consistency indices of the vowels, considered the least consistently spelled phonemes in English words. This research suggested that orthographic consistency, particularly indices for the least consistently spelled phoneme of a word, was important to consider as a predictor of spelling accuracy in the present study.

Research in French has also demonstrated a long-lasting effect of orthographic consistency on the spelling accuracy of elementary school children (Lété et al., 2008). Specifically, children's spelling accuracy was significantly predicted by phoneme-to-grapheme consistency across Grades 1 to 5. It was therefore expected that orthographic consistency would predict spelling accuracy of children of all ages in the present study.

Orthographic complexity. Orthographic complexity refers to a whole-word assessment of the difference between the number of letters and the number of phonemes (Spencer, 2007). In English and French, this is often a positive value because of the existence

of multi-letter graphemes that represent one phoneme and silent-letters (Gingras & Sénéchal, 2016). For example, the long /*o*/ phoneme in French can be spelled with a one-letter grapheme (*o*), a two-letter grapheme (*au*), or a three-letter grapheme (*aud*). Therefore, multi-letter graphemes and silent letters increase the orthographic complexity of a language. However, orthographic complexity is not captured by traditional assessments of orthographic consistency or phonetic length. Consider that the English words *might* /maɪt/ and *sly* /slaɪ/ each have three phonemes. According to Spencer, the least consistently spelled phoneme in these words, the /aɪ/, have the same phoneme-to-grapheme consistency probability of 0.1. That is, for every 100 occurrences of the phoneme /aɪ/, it is represented by the grapheme *igh* ten times and by the grapheme *y* ten times. However, the words differ in complexity: a score of two representing the silent *gh* in *might* and zero representing the absence of additional letters for *sly*. As this increase in complexity is not accounted for by other word characteristics, Spencer incorporated this variable as a unique predictor in his research.

Spencer (2007) assessed the spelling accuracy of 120 of the most frequent English words by children in Grades 2 through 6. Orthographic complexity was operationalized using three dichotomous variables: words with a complexity score of 1, 2, or 3 and 4 (3/4), each compared to words with a complexity score of 0 representing one-to-one phoneme-to-letter mappings. Results from the step-wise regressions indicated that a complexity index of 2 and 3/4 significantly predicted spelling accuracy for children in Grades 2 through 6 inclusively, while a complexity index of 1 was significant only in Grade 2 and 6. These results indicated that spelling accuracy decreased when orthographic complexity was not 0 for children of all ages.

To date, research on orthographic complexity in French remains scarce. Evidence for the effect of orthographic complexity can be inferred, however, from Sprenger-Charrolas et al. (1998). In this study, 57 first grade children were asked to spell 12 simple phonetic words

with one-to-one phoneme-to-letter mappings (e.g., *table* /tablə/ [table]), 12 complex phonetic words with multi-letter graphemes that could still be determined phonetically (e.g. *poche* /pɔʃ/ [pocket]), and 12 inconsistently spelled words that had highly inconsistent phoneme-grapheme mappings (e.g., *femme* /fam/ [woman]) or silent-letters (e.g., *pied* /pje/ [foot]). Notably, each group was equally divided between high and low frequency words. Results indicated that simple phonetic words were spelled accurately more often than complex phonetic words. This can be interpreted to suggest a negative impact of increased orthographic complexity, in terms of a larger number of letters than sounds, on the spelling accuracy of French words. It was therefore expected that orthographic complexity would predict spelling accuracy for children in all grades in the present study.

The unique role of each word-general predictor. Due to the cumulative research on these predictors of spelling, they have commonly been used in research as control variables when selecting lists of stimuli (Alegria & Mousty, 1996; Martinet et al., 2004; Sénéchal, 2000; Sprenger-Carrolas et al., 1998). For example, Sprenger-Charrolas et al. controlled for word frequency, length, and orthographic consistency when selecting lists of words with differing levels of orthographic complexity to be spelled. Moreover, contemporary research has combined these predictors in English and French, demonstrating their ability to simultaneously and uniquely predict spelling accuracy (Lété et al., 2008; Spencer, 2007). For example, Spencer (2007) regressed word frequency, length, orthographic consistency, and orthographic complexity on English spelling accuracy in Grades 2 through 6. Similarly, Lété et al. (2008) regressed word frequency, length, and nine variables pertaining to orthographic consistency, the predictor of interest in this study, on spelling accuracy in Grades 1, 2, and 3 to 5. The variables found to be significant and their order of entry varied between the studies and grades. Consistent across analyses, however, was that the majority of these

characteristics simultaneously and uniquely predicted elementary school children's spelling accuracy, explaining between 30% and 66% of the variance.

In sum, these studies offer support for the need to control for these known characteristics when assessing other predictors of spelling accuracy. In addition to the aforementioned word characteristics pertinent to all words across languages, statistical properties of silent-letter endings in French also influence children's attempts to spell these words. Therefore, these silent-letter characteristics were considered as predictors in the present study and were described in the following section.

Silent-letter predictors. The present study focused on the spelling accuracy of French words ending in silent-letters. Hence, characteristics of silent-letter endings known to predict spelling accuracy were also considered. This included the frequency of the silent letter in the terminal position of words and the conditional consistency of the silent letter considering the preceding orthographic context.

Silent letter frequency. In French, the difficulty posed by the presence of letters with no phonological value has been investigated. Research has shown that words that end with a silent letter are particularly difficult for children to spell (Jubenville et al., 2014; Sénéchal, 2000; Sénéchal et al., 2016). Although generally difficult, children's attempts at spelling silent-letter endings is sensitive to the statistical properties of the orthography. In Gingras and Sénéchal's (2016) lexical database of French words, Silex, there exist 15 letters that can be silent when in the final position of a word (i.e., *b, c, d, e, f, g, h, l, p, r, s, t, x, w,* and *z*). These may also be combined to form multi-letter graphemes that are silent in the terminal position of a word (e.g., *gt, ds, ps,* and *ch*). However, these silent-letter endings differ in the frequency of their occurrence in words. For example, *p* occurs as a silent-letter ending in only 10 words, while *t,* one of the most frequent silent-letter endings, occurs in 1,708 non-inflected words.

Research has demonstrated that the relative frequency of these silent-letter endings impacts children's spelling accuracy. Specifically, Sénéchal et al. (2016) found that children in Grades 1 to 3 spelled words ending in the more common silent letter *t* accurately significantly more often than words ending with a silent *d* when controlling for length, frequency, and the phonological context preceding the silent letter. It was therefore expected that silent letter frequency would predict spelling accuracy for all children in the present study.

Preceding phonological context. Before orthographic representations are precise enough to be recalled, children use their implicit knowledge of the statistical properties of the co-occurrences of graphemes when spelling (Caravolas et al., 2005; Hayes et al., 2005; Treiman & Kessler, 2006). In other words, when attempting to spell orthographic inconsistencies, children consider the surrounding sounds and letters. In regards to silent-letter endings, this means children use their knowledge of the phonological and orthographic ending of the word when determining the most likely silent-letter ending. The context surrounding orthographic inconsistencies has been measured with conditional consistency indices in research (Kessler & Treiman, 2001). Conditional consistency refers to a calculation of phoneme-to-grapheme consistency that is weighted based on the probability of the co-occurrence of the graphemes in the syllable. For example, the same vowel phoneme, /ʌ/, is found in both the words *love* /lʌv/ and *fun* /fʌn/. The unweighted consistency index for this phoneme to be represented by the grapheme *o* is very low across all words. However, if only words in which /ʌ/ is followed by /*v*/ (e.g., *love*, *shove*) are considered, this conditional consistency index of /ʌ/ being represented by the grapheme *o* is drastically increased. In fact, conditional consistency indices are typically higher for inconsistently spelled phonemes (Kessler & Treiman, 2001).

Conditional consistency indices stem from research on the highly inconsistent English vowels (Kessler & Treiman, 2001), however, this construct has been adapted to predict the spelling accuracy of silent-letter endings in French (Sénéchal et al., 2016). Specifically, Sénéchal et al. computed conditional consistency indices of the silent-letter ending weighted for the probability of two preceding phonological contexts: the preceding phoneme and the preceding rime (i.e., the vowel and following consonant of a syllable, such as /aʁ/ in *bavard* /bavaʁ/ [talkative]). In this study, the larger phonological context, or the rime preceding the silent-letter ending, was the stronger predictor of spelling accuracy. Specifically, while *t* is one of the most frequently occurring silent-letter endings, these Grade 1 and 3 children were able to use their implicit knowledge that a silent *t* does not follow the rime /aʁ/, and were therefore more likely to put a silent *d*.

As reviewed, previous research has established the effects of known predictors of spelling accuracy. Specifically, multiple predictors uniquely and significantly predicted spelling accuracy simultaneously, explaining between 30% (Lété et al., 2008) and 66% (Spencer, 2007) of the variance. However, there remains variance in children's spelling performance to be explained. Consequently, the goal of the present study was to assess morphological influences on the spelling accuracy of French words ending in silent letters after controlling for these well-established predictors. A thorough description of the three hypotheses follows.

The Present Study

Previous research on the spelling accuracy of French words with silent-letter endings has demonstrated the facilitative effect of morphological word families (Sénéchal, 2000; Sénéchal et al., 2006). Specifically, the existence of revealing-related words facilitated spelling compared to words without word families or with related words that do not pronounce the silent letter. However, this research was conducted with a limited number of

words. Therefore, the goal of the present study was to extend previous research by assessing the influence of morphological word families in a large database of spelling accuracy obtained from children in Grades 1 to 5.

This was accomplished with the *Échelle d'acquisition de l'orthographe lexicale* (ÉOLE: Pothier & Pothier, 2004) database of spelling accuracy. ÉOLE provides the average spelling accuracy scores for a corpus of 11,979 French words spelled by 40 children in each of Grades 1 through 5. Accordingly, analyses were conducted by word. While this database provided spelling accuracy for a large corpus of French words, the present study focused exclusively on words ending in silent letters. Specifically, the present study set three objectives in order to fully assess the influence of revealing-related words on the spelling accuracy of French words ending in silent letters.

The first objective was to replicate previous research demonstrating the facilitative effect of revealing-related words on the spelling accuracy of French words ending in silent letters, labeled target words, in a large-scale analysis. The first hypothesis, or the word family hypothesis, stated that spelling accuracy of target words should be positively predicted by the existence of revealing-related words for children in all grades. Target words for this objective included all French words with silent-letter endings that had the possibility of being pronounced in morphologically related words. The morphological variable in this hypothesis was dichotomous to reflect the existence or not of at least one revealing-related word in the target word's morphological word family.

The second objective of the present study was to assess whether it was the number of derivatives in the target word's family or the cumulative frequency of those derivatives that facilitated spelling. In accord with Reichle and Perfetti (2003), the derivational diversity hypothesis stated that the association between the cumulative frequency of derivatives and spelling accuracy should be mediated by the diversity of derivatives in a word family for the

children in Grades 3 to 5 with advanced knowledge of morphological word families. This hypothesis was tested on the spelling accuracy of target words that had at least one morphological derivative that revealed the silent-letter ending.

The final objective of the present study was to compare the influence of derivatives and feminine inflections. In previous work, Sénéchal (2000) found that target words with feminine inflections that revealed the silent letter were easier to spell than words with other kinds of derivatives. This was attributed to the nature of the related words: as discussed, inflections follow more consistent rules of application compared to derivatives and are more likely to influence spelling from younger ages (Fayol et al., 2006; Pacton & Deacon, 2008). Therefore, the final hypothesis of this study, or the feminine form hypothesis, stated that the existence of feminine inflections that pronounce the silent-letter ending of a target word would positively predict spelling accuracy after controlling for the diversity of derivatives. This hypothesis was tested on target words that had at least one revealing-related word in their morphological word family. The facilitative effect of feminine inflections, however, was expected to be limited to children in Grades 1 and 2. This was in line with previous research that the more easily learned inflections are predictive of younger children's spelling (Pacton & Deacon, 2008).

In the present study, all tests of hypotheses were conducted with regression analyses in which word characteristics known to predict spelling were entered first and morphological variables were entered last.

Methods

Stimuli

Target words were 584 French words ending in silent letters that were selected from a commercially available database of spelling accuracy in Grades 1 to 5. The database and word selection are described below.

Database of spelling accuracy. Spelling accuracy scores were retrieved from the ÉOLE database of spelling accuracy (Pothier & Pothier, 2004). ÉOLE was designed to capture the spelling difficulty of typical words found in written French in France. Therefore, a total of 11,979 uninflected French words (i.e., no conjugated verbs, plural forms, or feminine forms) that appeared more than three times in magazines and newspapers published in France in the year 2000 were included. In order to gather spelling accuracy scores for these words, Pothier and Pothier (2004) had 40 children in each of Grades 1 through 5 spell each word. In total, 48,902 children from 464 schools spelled 50 words in a dictation administered at the end of the school year. During the dictation, sufficient linguistic context was provided for target words to avoid the addition of unnecessary grammatical inflections (e.g., a silent /s/ to mark the plural) and to disambiguate homophones (e.g., *ver* /vɛʁ/ [worm], *vert* /vɛʁ/ [green], and *verre* /vɛʁ/ [glass]). In line with previous studies using ÉOLE (Gingras & Sénéchal, 2017; Lété et al., 2008), analyses were conducted on spelling accuracy in Grade 1, Grade 2, and averaged across Grades 3 to 5, due to floor effects found in Grade 1.

Target word selection. Of the 11,797 words in ÉOLE, words were selected for the present study if they met three criteria: 1) the words were found in two databases of word characteristics, namely, Silex (Gingras & Sénéchal, 2016) and Manulex-infra (Peereman, Lété, & Sprenger-Charolles, 2007); 2) the words ended with a silent letter that could be pronounced in morphologically related words; and 3) the silent-letter ending was not part of a suffix. Criterion 1 resulted in the selection of 7,008 words. Criterion 2 resulted in 1,394 target words, after the removal of words ending in pronounced letters (n = 4,827), words ending in the silent letters *e* and *h* that could never be pronounced in related words (n = 779), and function words that did not have morphological word families (n = 8), including prepositions (e.g., *dans* /dɑ̃/ [in]), pronouns (e.g., *nous* /nu/ [us]), and conjunctions (e.g., *quand* /kɑ̃/ [when]). Application of Criterion 3 resulted in the removal of 810 suffixed words. For

example, *début* /deby/ [beginning] was a target word, but *débutant* /debytɑ̃/ [beginner] was not because the silent *t* is part of the suffix *ant*. Criterion 3 was established because few suffixed words had revealing-related words (*n* = 177/810), and of these, the majority had a feminine inflection only (*n* = 159/177). The application of these three criteria resulted in the selection of 584 words ending in silent letters that could be pronounced in morphologically related words. In the following section, the coding of morphological word families was described.

Coding of Morphological Word Families

In order to complete the present study, it was necessary to code the morphological word families of the target words. Although some information pertaining to inflectional morphology was available in Manulex-morpho (Peereman, Sprenger-Charolles, & Messaoud-Galusi, 2013) for approximately 10,000 French words, the coding for the present study was the first large-scale attempt at incorporating entire morphological word families into a lexical database. Word family information was taken from the dictionary in the electronic writing software Antidote 9 (Druide informatique, 2016). For each of the 584 target words, the related words in the target word's morphological family were copied from Antidote into a word family database for further coding.

In the word family database, each related word was categorized based on its transformation of the target word. Related words that contained the exact spelling of the target word plus the addition of a graphemic unit at the end, thereby resulting in the pronunciation of the silent letter, were labelled revealing-related words. For example, the word *fruit* /fʁɥi/ [fruit] had *fruité* /fʁɥite/ [fruity] as a revealing-related word. This information was used in the calculation of the morphological word family variables. It should be noted that related words that were the result of transformations to the root, or irregular-related words, were also copied into the word family database. Specifically, irregular-related

words were coded under two categories: 1) complex if they retained the silent-letter despite orthographic changes to the root; or 2) misleading if the silent-letter ending was removed. Continuing with the example of the morphological word family for the word *fruit*, the related words *fructueux* / fʁyktɥø/ [fruitful] and *frugivore* /fʁyʒivɔʁ/ [frugivorous] were coded as complex and misleading irregular-related words, respectively. Note that while this information was coded to facilitate and complete the coding process for entire morphological word families of target words, irregular-related words were not assessed as it was beyond the scope of the present study.

In a second step, revealing-related words were further categorized based on their morphological status, that is, whether the word was a feminine inflection or a derivative. For example, *courtois* / kuʁtwa / [courteous] had two revealing-related words: *courtoise* /kuʁtwaz/ [courteous], coded as a feminine inflection, and *courtoisie* / kuʁtwazi / [courtesy], coded as a derivative. From the words copied into the word family database, analyses were conducted to obtain the necessary variables.

Morphological word family variables. For the purpose of this study, unique variables pertaining to revealing-related words were created for each hypothesis.

Word family hypothesis. In order to assess the impact of revealing-related words for the word family hypothesis, a dummy variable was created for the entire sample of words ending in silent letters (N = 584). The 295 target words with at least one revealing-related word, including derivatives and/or inflections, were coded as one. The remaining 289 words were coded as zero, including target words without word families (e.g., *foulard*) and target words with families containing only irregular-related words (e.g., *tabac* /taba/ [tabacco], with misleading derivatives *tabagie* /tabaʒi/ [cigarette shop] and *tabatière* /tabatjɛʁ/ [snuffbox]).

Derivational diversity hypothesis. Two variables were computed for the 233 target words with derivatives to test the derivational diversity hypothesis. The diversity of

derivatives was calculated as a conservative count of the number of derivatives in a morphological word family. This excluded feminine inflections of the target words and inflections of derivatives. For example, the word *fruit* /fʁɥi/ [fruit] had the derivative *fruité* /fʁɥite/ [fruity], but inflections of *fruité*, including the plural masculine *fruités* /fʁɥite/ [fruity], the singular feminine *fruitée*/fʁɥite/ [fruity], and the plural feminine *fruitées*/fʁɥite/ [fruity], were excluded from the count. This was justified because inflections do not add to the diversity of a word family and would artificially inflate the number of derivatives. The resulting derivative diversity count was positively skewed (skewness = 2.19, SE = 0.16) because the majority of target words had a single derivative (n = 94). Remaining target words had two (n = 74), three (n = 40), four (n = 14), five (n = 1), six (n = 4), seven (n = 3), and 10 derivatives (n = 1). The target word with 10 derivatives, *dent* /dɑ̃ / [tooth], was examined as a potential outlier but was retained in analyses because it did not significantly alter the pattern of results. Importantly, transformation of this skewed variable did not fix the distribution or alter analyses, so the variable was left unaltered.

The cumulative frequency of derivatives was computed by adding the word frequency for each derivative in a target word's family. The frequency counts for the derivatives were extracted from the counts available for Grades 1 through 5 in Manulex-infra (Peereman et al., 2007). The frequencies of all inflected forms of the derivatives were included in the cumulative frequency variable because the goal was to account for children's exposure to the derivatives in texts. This coding resulted in a positively skewed variable, ranging from 0.01 to 997 occurrences per million words (M = 23.5, SD = 80.5, skewness = 8.4, SE = 0.16). A log transformation improved the distribution of this variable (skewness = -0.23, SE = 0.16) and subsequent regression analyses. The transformed variable was therefore used in all analyses.

Feminine form hypothesis. A final variable was computed for the 295 target words with revealing-related words assessed in the feminine form hypothesis (*N* = 295). A dummy variable was created whereby the 143 target words with feminine inflections that revealed the silent-letter endings were coded as one (e.g., *froid* /fʁwa/ [cold] singular masculine and *froide* /fʁwad/ [cold] singular feminine), and the remaining 152 target words were coded as zero.

Word Characteristic Control Variables

Word characteristics known to influence spelling performance were included as control variables when testing each hypothesis in the present study. These word characteristics were taken from the Silex lexical database (Gingras & Sénéchal, 2016), which originated from Manulex-infra (Peereman et al., 2007), a lexical database of words from the books used in France's elementary curriculum. Silex was preferred because it included a distinct variable for silent-letter endings which allowed for a quantification of the impact of silent letters on the calculation of phoneme-to-grapheme consistency.

Word-general predictors. Word-general predictors included the whole-word characteristics that are word frequency, length, and orthographic complexity, as well as the sub-lexical characteristic that is orthographic consistency.

Word frequency. Statistical information pertaining to the frequency of a word in printed, age-appropriate text was taken from Silex (Gingras & Sénéchal, 2016), but were originally from Manulex-infra (Peereman et al., 2007). Given the grade levels of the spelling accuracy data, the combined frequency counts for Grades 1 through 5 were used in the present study. The target word frequencies were positively skewed (skewness = 9.7, SE = 0.10), consequently the variable was log transformed. The transformation normalized the distribution (skewness = -0.51, SE = 0.10) and improved predictive power of the variable in regressions analyses. The transformed variable was therefore used in all analyses.

Word length. Word length was operationalized as the number of phonemes in a word and was directly extracted from Silex. For example, the word *chaton* /ʃatɔ̃/ [kitten] has 4 phonemes. Phonemic length was used because it corresponds to the input young children hold in working memory and upon which they must map letters.

Orthographic complexity. Orthographic complexity, a continuous variable, was operationalized as the difference between the number of letters and the number of phonemes in a word (Spencer, 2007). In French, this most often leads to a positive value due to the multitude of multi-letter graphemes that represent one phoneme and the number of silent letters (e.g., the graphemes *haut, eau,* and *au* are all pronounced as the phoneme /o/). Therefore, a higher value should reflect greater spelling difficulty.

Orthographic consistency. For spelling, orthographic consistency refers to the stability of the relation between a given phoneme and its graphemic representation. Given the focus of the present study, phoneme-to-grapheme consistency indices were taken from Silex (Gingras & Sénéchal, 2016) for all the pronounced phonemes in a word, while silent-letter endings were considered separately. It was also decided to use type counts, not token counts, as the denominator in the consistency calculations, in line with previous research (Caravolas et al., 2005; Gingras & Sénéchal, 2016; Kessler & Treiman, 2001). Type counts represent the different types of words whereas token counts include the total number of words weighted for their respective frequencies in texts (Caravolas et al., 2005; Gingras & Sénéchal, 2016). Theoretically, statistical learning would suggest the use of token counts because the frequency of exposure should have an impact on children's learning of phoneme-grapheme mappings. However, the type count is more often used because of token counts distributional anomalies due to a short list of extremely frequent words.

The orthographic consistency indices extracted from Silex were the proportion of time a phoneme in a given word was represented by a particular grapheme, divided by the number

of words containing that phoneme. This resulted in a value between zero and one for each phoneme in a word. Consider the calculations for the French word *main* /mɛ̃/ [hand]. Because the /*m*/ phoneme was always spelled with the letter *m*, the consistency score for this phoneme was one. The /ɛ̃/ phoneme however, only had a phoneme-to-grapheme consistency score of .19. This meant that of every 100 times the phoneme /ɛ̃/ appeared in the database, it was spelled with the grapheme *ain* 19 times only. Previous research comparing different consistency indices found that the index for the least consistently spelled phoneme was a stronger predictor of spelling accuracy than was the average consistency index of all phonemes in a word (Spencer, 2007). Hence, as in previous research (Caravolas et al., 2005; Delattre et al., 2006), the value of the least consistently spelled phoneme in a word was used as the index for orthographic consistency in the present study.

Silent-letter predictors. The present study focused on French words ending in silent-letters. Therefore, control variables in the present study included characteristics of silent-letter endings that are known to predict spelling accuracy (Sénéchal et al., 2016). This included the frequency and conditional consistency of the silent-letter endings.

Silent letter frequency. The silent letter frequency available in Silex was the number of different words that ended with the silent letter in the database. For example, the letter *t* was the most frequent silent-letter ending with a score of 1,708, which represented the number of different words ending in a silent *t* in Silex. In contrast, *p* was an infrequent silent-letter ending with a score of only 10. In the present study, the 584 target words had a total of 19 different silent-letter endings, including 13 individual letters and 6 multi-letter graphemes. The frequency of the silent-letter endings ranged from 1 to 1,708. Due to this large range of values, the log transformed silent letter frequency variable was found to be a stronger predictor and was therefore used in all analyses.

Conditional consistency of the silent letter. Conditional consistency refers to the probability of a grapheme considering the surrounding context of the word. In the present study, the conditional consistency for a silent letter weighted for the preceding phonological rime was taken from Silex (Gingras & Sénéchal, 2016). The phonological rime preceding the silent letter was used because it was more strongly related to spelling accuracy compared to the preceding phoneme (Sénéchal et al., 2016). In linguistics, a rime refers to the part of a syllable that includes the vowel and any following consonants. For example, in the word *foulard* /fulaʁ/ [scarf], the rime preceding the silent letter *d* is /aʁ/. The conditional probability of the silent letter *d* in all words ending with the phonological rime /aʁ/was 0.594, which indicated that a silent letter *d* occurred at the end of approximately 59% of the words ending in the phoneme /aʁ/.

Results

Testing each of the three hypotheses in the present research required different sub-samples of words, therefore, each hypothesis section included descriptive statistics and a correlation matrix. Each hypothesis was tested with hierarchical regression analyses in which the first step consisted of control variables that were the word-general characteristics, namely, word frequency, length, consistency, and complexity. Because there was no specific hypothesis for the control variables, they were entered in a step-wise fashion. The next step(s) were specific to each hypothesis. When correlated, silent-letter controls that were the frequency and conditional consistency of the silent letters were entered in a second step. In all analyses, the key variable(s) for the hypothesis was entered last. Each hypothesis was tested separately for Grades 1, Grade 2, and Grades 3 to 5, and all results were reported in that order. In addition, all final regression models were statistically significant.

The Word Family Hypothesis

It was hypothesized that target words with silent-letter endings would be easier to spell if they had morphological word families with related words that pronounced the silent letters as compared to when they did not. Target words for this hypothesis were 584 French words ending in silent letters, including 295 words with and 289 words without revealing-related words.

Descriptive statistics and correlations. The descriptive statistics and correlation matrix for the word characteristics and spelling accuracy variables are found in Table 1. As seen in the means and standard deviations section at the bottom of the table, spelling accuracy increased across grades, although performance remained low. Only 51.8% of children in Grades 3 to 5 accurately spelled these words, which suggested they were challenging for young children to spell. The standard deviations, however, were very large, which meant spelling accuracy was highly variable across the target words. Comparing words with and without revealing-related words resulted in a 5%, 10%, and 13% difference in spelling accuracy favoring words with revealing-related words. The only difference in word characteristics was that target words with revealing-related words had more frequent silent-letter endings compared to words without, which supported the need to control for this confound.

From the top of the correlation matrix, it was evident that the four word-general predictors were significantly correlated to spelling accuracy at all grade levels and among each other. Regarding the silent-letter predictors, silent letter frequency was related to spelling accuracy in Grades 2 and 3 to 5, so it was included in the hierarchical regression analyses. However, the conditional consistency of the silent letter was not correlated with spelling accuracy and was therefore not further analyzed. Words with revealing-related words were significantly related to greater spelling accuracy across grade levels, however, the magnitude of the correlation was small.

Table 1

Correlation Matrix and Descriptive Statistics for Spelling Accuracy and Word Characteristics for Testing the Word Family Hypothesis (N = 584)

Predictors		G1	G2	G3	1	2	3	4	5	6
1. Frequency		**.39**	**.54**	**.64**	**-**					
2. Length		**-.27**	**-.28**	**-.25**	**-.31**	**-**				
3. Consistency		**.30**	**.34**	**.37**	**.21**	**-.25**	**-**			
4. Complexity		**-.15**	**-.16**	**-.21**	**-.13**	**.12**	**-.40**	**-**		
5. SL Frequency		.03	.09*	.11*	-.05	**.23**	**-.12**	-.02	-	
6. Cond. Consistency		-.07	-.03	-.04	-.07	**.18**	**-.33**	**.27**	**.33**	**-**
7. RRW Effect		**.17**	**.17**	**.23**	.08*	-.09*	.08	-.09*	**.13**	-.04
Whole Sample	*M*	10.3	25.0	51.8	1.0	4.2	0.4	1.9	2.7	0.4
	SD	16.8	25.4	27.7	1.2	1.5	0.3	0.8	0.7	0.4
With RRW	*M*	13.1	29.3	58.1	1.1	4.1	0.5	1.8	2.7	0.4
(*n* = 295)	*SD*	19.2	27.5	26.3	1.1	1.4	0.3	0.8	0.7	0.4
Without RRW	*M*	7.5	20.6	45.4	0.9	4.4	0.4	1.9	2.6	0.4
(*n* = 289)	*SD*	13.4	22.3	27.6	1.3	1.5	0.3	0.8	0.8	0.4

Note. G = grade level; SL = silent letter; Cond = conditional; RRW = revealing-related word. All correlations significant at $p < .001$ are in boldface.
* = significant at $p < .05$

Hierarchical Regression Analysis. Results of the three-step hierarchical regression analyses testing the facilitative effect of word families on spelling accuracy over the well-established predictors are in Table 2. Results indicated that word frequency, the first predictor entered in Step 1, explained approximately 15%, 29%, and 41% of the variance in spelling accuracy. The second predictor entered for each grade was orthographic consistency, which explained an additional 5%, 5%, and 6% of the variance. Finally, phonological length significantly predicted an additional 1% and 0.6% of the variance in spelling accuracy in Grades 1 and 2, respectively, but was not a statistically significant predictor in Grades 3 to 5. In Step 2, silent letter frequency significantly contributed an additional 1% to 3% of the variance in spelling accuracy in all grades.

In support of the hypothesis, the existence of a revealing-related word in a word family significantly explained an additional 1%, 0.7%, and 2% of the variance in spelling accuracy, over and above the well-established predictors. The final models were significant and explained a total of 23%, 38%, and 52% of the variance in spelling accuracy. Note, this increase in explained variance across grades was to be expected given the increase in spelling performance. These results supported the hypothesis that French words ending in silent-letters were easier for children to spell when they had morphological word families with related words that pronounced the silent-letter ending.

Table 2

Hierarchical Regression Analyses Testing the Effects of Revealing-Related Words on Spelling Accuracy in Grade 1, 2, and 3 to 5 (N = 584)

	Grade 1				Grade 2				Grades 3 to 5			
Predictors	R^2 change	β	95% CI	UV	R^2 change	β	95% CI	UV	R^2 change	β	95% CI	UV
Step 1												
Frequency	.15***	.30	[.03, .05]	.08	.29***	.45	[.08, .11]	.18	.41***	.58	[.12, .15]	.32
Consistency	.05***	.21	[.07, .15]	.04	.05***	.23	[.12, .23]	.05	.06***	.26	[.17, .27]	.06
Length	.01**	-.13	[-.02, -.01]	.01	.01*	-.11	[-.03, -.01]	.01	.00	-.01	[-.01, .01]	.00
Complexity	.00	-.01	[-.02, .01]	.00	.00	-.00	[-.02, .02]	.00	.00	-.05	[-.04, .01]	.00
Step 2												
SL Freq	.01**	.09	[.00[a], .03]	.01	.03***	.16	[.03, .08]	.02	.03***	.15	[.03, .08]	.02
Step 3												
RRW effect	.01*	.01	[.00[a], .01]	.01	.01**	.09	[.01, .08]	.01	.02***	.14	[.05, .11]	.02
Total R^2	.23				.38				.516			

Note. UV = unique variance; SL Freq = silent letter frequency; RRW = revealing-related word. All regression models were statistically significant, Fs (5, 578) > 35.398, $p < .001$ and $F(4, 579) = 154.042$, $p < .001$.
* $p < .05$, ** = $p < .01$, *** $p < .001$
[a] CI lower bound = .003 and .006 for silent letter frequency and revealing-related word effect, respectively.

The Derivative Diversity Hypothesis

In line with Reichle and Perfetti (2003), it was hypothesized that the diversity of derivatives would mediate the relation between the cumulative frequency of derivatives and spelling accuracy for older children. Because this hypothesis pertained exclusively to morphological derivation, feminine inflections were excluded from analyses. Therefore, target words included the 232 French words ending in silent letters for which the silent letter was pronounced in at least one derivative.

Descriptive statistics and correlations. Descriptive statistics and the correlation matrix for this sub-sample of words are in Table 3. As with the first hypothesis, spelling performance increased across grades and word-general control variables were related to spelling accuracy. With this subsample of words, however, the silent-letter controls were not correlated with spelling accuracy across grades and were excluded from further analyses. As expected, the diversity and cumulative frequency of derivatives were significantly correlated and were both significantly related to spelling accuracy across grades.

Table 3

Correlation Matrix and Descriptive Statistics for Spelling Accuracy and Word Characteristics for Testing the Derivational Diversity Hypothesis (N = 232)

Predictors	G1	G2	G3	1	2	3	4	5	6	7	8
1. Frequency	**.44**	**.52**	**.60**	-							
2. Length	**-.27**	**-.28**	**-.26**	**-.32**	-						
3. Consistency	**.31**	**.40**	**.42**	**.22**	**-.20**	-					
4. Complexity	-.10	-.09	**-.17**	-.13*	.04	**-.46**	-				
5. SL Frequency	.02	.11	.10	-.03	**.18**	-.09	-.04	-			
6. CondCons	-.06	-.004	-.01	-.02	.06	**-.33**	**.31**	**.33**	-		
7. Diversity Der.	**.26**	**.28**	**.27**	**.29**	**-.32**	.07	.03	.15*	-.01	-	
8. Frequency Der.	**.20**	**.16**	**.26**	**.26**	**-.18**	-.02	.06	-.06	-.04	**.46**	-
M	14.0	31.9	60.4	1.2	3.9	0.5	1.7	2.7	0.4	2.1	0.3
SD	20.1	28.0	26.2	1.0	1.4	0.3	0.7	0.7	0.4	1.3	1.2

Note. G = grade level; SL = silent letter; CondCons. = conditional consistency; Der. = derivatives. All correlations significant at $p < .001$ are in boldface.
* = significant at $p < .05$

Hierarchical Regression Analysis. The present study intended to build on existing literature by cumulatively assessing known predictors of spelling accuracy. Specifically, the influence of morphological word families was assessed after controlling for other known predictors of spelling accuracy in a large-scale analysis. Therefore, before beginning the test of mediation, both the diversity and cumulative frequency of derivatives were individually tested after the word-general controls. As shown in Table 4, word frequency was entered first in the equation, followed by orthographic consistency, for all grade levels. Results differed for the two derivative variables when entered individually after the controls; whereas the diversity of derivatives significantly predicted 2.4%, 2.4%, and 1.7% of the variance in spelling accuracy, the cumulative frequency of derivatives was only a significant predictor in Grades 3 to 5, explaining 1.6% of the variance. This meant the hypothesized mediation was not possible in Grades 1 and 2. However, this result did support the expectation that the diversity of derivatives was the stronger predictor of spelling accuracy. The test of mediation was therefore conducted only in Grades 3 to 5.

Table 4

Two Independent Hierarchical Regression Analyses Testing the Effects of the Diversity and Cumulative Frequency of Derivatives on Spelling Accuracy in Grade 1, 2, and 3 to 5 (N = 232)

	Grade 1				Grade 2				Grades 3 to 5			
Predictors	R^2 change	β	95% CI	UV	R^2 change	β	95% CI	UV	R^2 change	β	95% CI	UV
Step 1												
Frequency	.19***	.36	[.05, .09]	.11	.27***	.44	[.09, .15]	.17	.36***	.50	[.10, .15]	.22
Consistency	.05***	.23	[.07, .21]	.05	.09***	.37	[.21, .41]	.10	.09***	.32	[.17, .33]	.09
Complexity	.00	.08	[-.02, .06]	.00	.01*	.13	[.01, .10]	.01	.00	.05	[-.02, .06]	.00
Length	.01	-.11	[.07, -.03]	.01	.00	-.07	[-.04, .01]	.00	.00	-.03	[-.03, .01]	.00
Step 2												
First Analysis												
Diversity Der.	.02**	.16	[.01, .04]	.02	.02**	.16	[.01 .06]	.02	.02**	.13	[.01 .05]	.02
Total R^2	.27				.39				.46			
Second Analysis												
Frequency Der.	.01	.11	[-.00[a], .04]	.01	.00	.05	[-.02, .04]	.00	.02*	.13	[.01, .05]	.02
Total R^2	.25				.37				.46			

Note. UV = unique variance; Der. = derivatives. All regression models were statistically significant, $Fs(3, 228) > 25.816$ and $Fs(4, 227) > 33.585$, $p < .001$.
* $p < .05$, ** = $p < .01$, *** $p < .001$
[a] CI lower bound = .001.

Mediation Analysis. It was expected that the diversity of derivatives would mediate the relation between the frequency of derivatives and spelling accuracy in Grades 3 to 5. This test began with the four steps to testing mediation suggested by Baron and Kenny (1986), followed by the more contemporary recommendation of testing the significance of mediation using the bootstrapping method (Preacher & Hayes, 2004).

Step 1 in testing mediation required the independent variable to affect the mediator (Baron & Kenny, 1986). This was tested with a simple regression, with the cumulative frequency of derivatives regressed on the diversity of derivatives, and results were significant ($\beta = .465$, $p < .001$, $R^2 = .216$). Step 2 required the confirmation that the independent variable predicted the outcome variable (i.e., spelling accuracy in Grades 3 to 5). This was established in the hierarchical regression analysis in Table 4, however it was repeated in a simple regression to obtain necessary statistics ($\beta = .255$, $p < .001$, $R^2 = .065$). For the third step, the mediator must predict the outcome variable while controlling for the independent variable. Results of a multiple regression confirmed that the diversity of derivatives predicted spelling accuracy after controlling for the cumulative frequency of derivatives ($\beta = .19$, $p = .008$, R^2 change = .072).

The final step in establishing mediation was to show a decrease in the predictive value of the independent variable between the analysis in Steps 2 and 3. In the analysis in Step 3, the frequency of derivatives remained significantly predictive of spelling accuracy while controlling for the diversity of derivatives ($\beta = .17$, $p = .02$, R^2 change = .022). This indicated full mediation had not occurred. However, the cumulative frequency of derivatives explained 6.5% of the variance in spelling accuracy when entered alone in Step 2, but that was reduced to 2.5% in Step 3. This decrease in predictive value, labeled an indirect effect, was indicative of partial mediation (Baron & Kenny, 1986).

The significance of the partial mediation was tested using the bootstrapping method with bias-corrected confidence estimates. Bootstrapping has been recommended for the significance test in mediation analyses because the assumption of normality of the sampling distribution of the indirect effect required by the Sobel test is often violated (Preacher & Hayes, 2004). The 95% confidence interval of the indirect effect was obtained with 5000 bootstrap samples and was significant (β = .02, SE = .007, CI = .007 to .034). These results confirmed that the diversity of derivatives partially mediated the relation between the frequency of derivatives and spelling accuracy. In sum, these results generally supported the derivative diversity hypothesis and the overall expectation that the diversity of derivatives was the stronger predictor of spelling accuracy.

The Feminine Form Hypothesis

It was expected that, for children in Grades 1 and 2, the existence of a feminine inflection that revealed the silent-letter would facilitate spelling accuracy over and above the variance accounted for by the diversity of derivatives. The 232 target words with derivatives assessed in the derivative diversity hypothesis were included in this analysis, of which 80 had feminine inflections and 152 did not. For these words, the diversity of derivatives variable from the previous hypothesis was used and a dummy coded variable was created to identify words with and without feminine inflections, coded as 1 and 0 respectively. An additional 63 French words ending in silent letters that only had feminine inflections were also included in this subsample of words. These words had a feminine inflection code of 1 and a diversity of derivatives score of 0. Therefore, the feminine form hypothesis assessed a total of 295 target words, of which 143 had feminine inflections and 152 did not. However, it was important to clarify that all words without feminine inflections had morphological derivatives, whereas the words with feminine inflections were divided between words with (n = 80) and without (n = 63) derivatives.

Descriptive Statistics and correlations. The descriptive statistics and correlation matrix for the predictor and outcome variables for this subsample of target words are found in Table 5. As with hypothesis 2, spelling performance increased across grades, and word-general controls and the diversity of derivatives were related to spelling accuracy. The silent-letter controls remained uncorrelated with spelling accuracy and were not included in analyses. The dichotomous variable for the existence of a feminine inflection in a morphological word family was not correlated with spelling accuracy. However, there was a slight difference in the mean spelling accuracy favoring words with feminine inflections in Grade 1, whereas the reverse was true in Grades 2 and 3 to 5. Finally, a significant negative correlation was found between the feminine inflection and diversity of derivatives variables. This was attributed to the 63 words with feminine inflections that did not have derivatives included in the subsample. Specifically, words with feminine inflections had an average of only one derivative, while words without feminine inflections had an average of two derivatives.

The intended analysis of the feminine form hypothesis was the inclusion of the feminine inflection variable after the diversity of derivatives in the hierarchical regression model. While the bivariate correlations between feminine inflections and spelling accuracy were not significant in Table 5, the partial correlations controlling for the diversity of derivatives were examined. Results of the partial correlations were significant in Grade 1 ($r = .145$, $p = .013$), which indicated the feminine inflection was related to spelling accuracy only after accounting for the diversity of derivatives. This suggested the diversity of derivatives could be acting as a suppressor variable. The planned hierarchical regression analysis were therefore conducted on spelling accuracy in Grade 1 only to further explore these results.

Table 5

Correlation Matrix and Descriptive Statistics for the Spelling Accuracy and Word Characteristics for Testing the Feminine Inflection Hypothesis (N = 295)

Predictors		G1	G2	G3	1	2	3	4	5	6	7
1. Frequency		**.44**	**.55**	**.63**	-						
2. Length		**-.29**	**-.34**	**-.29**	**-.38**	-					
3. Consistency		**.33**	**.43**	**.46**	**.26**	**-.22**	-				
4. Complexity		**-.12**	**-.15**	**-.24**	**-.20**	.02	**-.48**	-			
5. SL Frequency		-.01	.07	.07	-.06	**.22**	-.12*	.04	-		
6. CondCons.		-.09	-.07	-.08	-.11*	.12*	**-.33**	**.39**	**.35**	-	
7. Diversity Der		**.24**	**.31**	**.29**	**.25**	**-.37**	**.16**	-.11	**-.23**	-.09	-
8. FI effect		.06	-.03	-.05	.00[a]	-.11	**.19**	.14*	**-.17**	.00[a]	**-.32**
Whole Sample	*M*	13.1	29.3	58.1	1.1	4.1	0.5	1.8	2.7	0.4	1.6
	SD	19.2	27.5	26.3	1.1	1.4	0.3	0.8	0.7	0.4	1.4
With FI	*M*	14.2	28.5	56.9	1.1	4.3	0.4	1.9	2.9	0.4	1.1
(*n* = 143)	*SD*	19.2	28.9	26.9	1.1	1.4	0.3	0.9	0.5	0.4	1.4
Without FI	*M*	12.1	30.0	59.3	1.1	3.9	0.5	1.6	2.6	0.4	2.1
(*n* = 155)	*SD*	19.2	26.2	25.9	1.1	1.4	0.3	0.7	0.8	0.4	1.3

Note. G = grade level; SL = silent letter; CondCons. = conditional consistency; Der = derivatives; FI = feminine inflection. All correlations significant at $p < .001$ are in boldface.
* = significant at $p < .05$
[a]*r*s = .001 and .002 for feminine inflection and frequency, and feminine inflection and conditional consistency, respectively

Hierarchical Regression Analysis. Results of the hierarchical regression analysis were summarized in Table 6. In Step 1, word frequency, orthographic consistency, and phonological length were entered in that order, explaining 18.9%, 5.1%, and 1.1% of the variance in spelling accuracy, respectively. In the final model, the diversity of derivatives variable entered in Step 2 did not predict a significant amount of variance, but the feminine inflection variable entered in Step 3 significantly explained an additional 1.6% of the variance in spelling accuracy. This was in support of the feminine form hypothesis in that the feminine inflections significantly predicted spelling accuracy only for the younger children in Grade 1. An important nuance to these results, however, was that it was only after controlling for the significant negative correlation with the diversity of derivatives that the existence of a feminine inflection was predictive of spelling accuracy in Grade 1. Therefore, to fully understand these results, it was essential to further explore the presence of a suppression effect.

Table 6

Hierarchical Regression Analyses Testing the Effects of Feminine Inflections on Spelling Accuracy in Grade 1 (N = 295)

Predictors	R^2 change	β	95% CI	Unique Variance
Step 1				
Frequency	.19**	.31	[.03, .07]	.08
Consistency	.05**	.22	[.07, .19]	.04
Length	.01*	-.09	[-.03, -.003]	.01
Complexity	.00	-.07	[-.01, .04]	.00
Step 2				
Diversity of Derivatives	.01	.14	[.004, .03]	.02
Step 3				
Existence Feminine Inflection	.02*	.14	[.01, .09]	.02
Total R^2	.23			

Note. Regression model was statistically significant, $F(5, 289) > 21.974$, $p < .001$.
* $p < .05$, ** = $p < .001$

The increase in predictive value of the feminine inflections after controlling for the diversity of derivatives suggested the presence of a suppression effect. However, it was also important to note that both the diversity of derivatives and feminine inflection variables had nearly identical statistically significant final betas (β = 0.143 and 0.137, respectively). This indicated that the diversity of derivatives was a significant predictor of spelling accuracy when entered last in the equation. This meant the classical suppression effect, wherein the suppressor variable is not related to the outcome variable (Horst, 1941), was not found in the present study. However, results were indicative of a reciprocal suppression effect, when two highly correlated predictors mutually suppressed variance in the other, increasing their ability to predict the outcome variable (Lancaster, 1999; Lutz, 1983; Tzelgov & Henik, 1991). This was evidenced by the greater beta weights for the diversity of derivatives and feminine inflections in the multiple regression (β = .292, p < .001 and β = .149, p = .013, respectively), as compared to their bivariate correlations (r = .244, p < .001 and r = .055, p = .350, respectively). In addition, these variables accounted for a greater amount of variance in the multiple regression (R^2 = .073) compared to individually (R^2s = .003 and .059 for the feminine inflection and diversity of derivatives, respectively). The reciprocal suppression effect suggested by these results indicated that the diversity of derivatives and feminine inflection variables were stronger predictors of spelling accuracy in Grade 1 when considered together. Overall, these results supported the feminine form hypothesis and the overall facilitative effect of morphological word families.

Discussion

The present study assessed the effect of morphological word families on the spelling accuracy of French words ending in silent letters. In previous small-scale experimental research, target words with at least one morphologically related word that pronounced the silent-letter ending were spelled accurately more often compared to words without a

revealing-related word (Sénéchal, 2000; Sénéchal et al., 2006). The goal was to replicate and extend this finding in large-scale hierarchical regression analyses assessing spelling accuracy by word while controlling for other known predictors. Results supported the word family hypothesis in that morphological word families that included revealing-related words facilitated spelling over-and-above the cumulative effect of the other well-established predictors of spelling. The derivative diversity hypothesis was generally supported because the cumulative frequency of derivatives was not strongly related to spelling accuracy in Grades 1 and 2, and the relation was mediated by the diversity of derivatives in Grades 3 to 5. Finally, the feminine form hypothesis was generally supported: after controlling for the diversity of derivatives, the existence of a feminine inflection was found to facilitate spelling for children in Grade 1 only. The findings for each hypothesis along with their implications are discussed in the following sections.

The Word Family Hypothesis

The primary purpose of the present study was to extend previous research demonstrating the facilitative effect of morphological word families that pronounced silent-letter endings of French words. It was hypothesized that the existence of at least one revealing-related word in a morphological word family would predict spelling accuracy in stringent analyses controlling for other known predictors of spelling. In support of the hypothesis, results indicated that target words with a word family containing at least one revealing-related word were spelled accurately more often than words without revealing-related words. Unfortunately, the magnitude of the effect of word families on spelling was small.

These findings were in accord with previous research indicating that knowledge of morphologically related words encoded at a sub-lexical layer of cognitive representations is activated when children are attempting to spell (Giraudo & Grainger, 2001). As previously

described, this is likely automatically co-activated implicit knowledge stemming from the statistical learning of morphological patterns obtained through repeated exposure to the word families (Giraudo & Grainger, 2001; Steffler, 2000). However, knowledge of morphological word families may also become a conscious tool for children when attempting to spell, as seen in children's self-report of using morphologically based spelling strategies (Sénéchal et al., 2006). These results provided additional support regarding the acquisition and use of a morphological layer of sub-lexical representations by children in Grades 1 through 5.

Results of the present study also extended the existing literature on the facilitative effect of morphological word families by replicating findings in a large-scale item analysis. Specifically, previous research has largely focused on children's spelling accuracy of small lists of target words grouped by morphological word family status (Sénéchal, 2000; Sénéchal et al., 2006). While these studies did planned contrasts assessing spelling accuracy by word type, the present study was the first known assessment of the facilitative effect of morphological word families in a large-scale regression analysis of spelling accuracy by word. In addition, the present study further extended these results by testing the additive effect of morphological word families over other known predictors. These results successfully confirmed that morphological word families provide children with a unique source of information to facilitate spelling.

The present study also offered a developmental perspective on the influence of morphology by assessing the average spelling accuracy by word for 40 children in each of Grades 1 through 5. Results indicated that the effect of morphological word families on spelling accuracy was significant, albeit of low magnitude, across all grades. While a small increase in the magnitude of the effect was observed in Grades 3 to 5, overall the results indicated that morphological word families facilitated spelling for all children equally in the present study. This was in accord with previous research indicating that children begin to

learn of morphology from a very young age (Giraudo & Grainger, 2001; Pacton et al., 2005) and use their existing knowledge when attempting to spell (Ehri, 1987; Shanahan et al., 2006). To further understand how knowledge of morphological word families is acquired and used in spelling, effects of the different types of revealing-related words were further explored.

The Derivational Diversity Hypothesis

The second goal of the present study was to understand how revealing-related words influence the development of orthographic representations and subsequently, spelling accuracy. Previous research has found that different measures of morphological derivatives in a word family do not equally relate to literacy development. Specifically, Reichle and Perfetti's (2003) adult reading simulation study indicated that the diversity of derivatives predicted high-quality orthographic representations while controlling for their cumulative frequency, however, the reverse was not found. In other words, Reichle and Perfetti found that target words with bigger word families had higher quality representations, whereas the frequency of exposure to the related words was not a contributing factor to development. In line with this research, the second hypothesis of the present study stated that the diversity of derivatives should mediate the relation between the cumulative frequency of derivatives and spelling accuracy for the older children in Grades 3 to 5.

The second hypothesis was assessed with the same stringent analyses, assessing the morphological derivative variables uniquely over the other known predictors of spelling accuracy. Results indicated that the diversity of derivatives predicted spelling accuracy across grades. The cumulative frequency of derivatives, however, was not an additive predictor of spelling accuracy in Grades 1 and 2. This finding was nonetheless in accord with the theoretical expectation that it was a greater number of derivatives that facilitated the

development of high-quality orthographic representations and, in extension, increased spelling accuracy, even though this was only expected for children in Grades 3 to 5.

Because both the diversity and cumulative frequency of derivatives were unique predictors of spelling accuracy in Grades 3 to 5, mediation analyses were conducted. In support of the hypothesis, results indicated that the diversity of derivatives partially mediated the relation between the cumulative frequency of derivatives and spelling accuracy. Full mediation was not indicated as both the diversity and cumulative frequency of derivatives remained significant in predicting spelling accuracy. This was in accord with a previous suggestion that full mediation is rare in psychology research and that the more realistic expectation is for partial mediation (Baron & Kenny, 1986). It should be noted that the final beta weight for the cumulative frequency of derivatives was of a similar size as that for the diversity of derivatives. While it was observed that a nearly identical pattern of results was found when forcing the diversity of derivatives to enter the equation last, results indicated that the diversity of derivatives was the stronger predictor and was therefore entered first.

In sum, these results supported the expectation that the diversity of derivatives in a word family has a stronger effect on spelling development than derivatives that are more frequent in texts. These results successfully extended previous research on the quality of adult orthographic representations (Reichle & Perfetti, 2003) into research on children's spelling accuracy. These findings implied that the utility of related words encoded at a morphological layer of representation was not reliant on the precision of the representations or their strength of association acquired through the frequency of exposure. Specifically, it was a greater number of interconnected related words that facilitated the activation and use of morphological knowledge in spelling words with underspecified orthographic representations. This suggested that was a greater number of contexts in which the root appeared that provided the most insight for children.

Regarding the development pattern of these results, it was essential to note that the diversity of derivatives was the stronger predictor of spelling accuracy across all grades. This provided an insightful nuance to the suggestion that it is 8-year-old children and older who use knowledge of morphological derivation in spelling (Pacton & Deacon, 2008). As the diversity of derivatives was likely related to a greater number of related phonological representations, even the youngest children in the current sample were influenced by knowledge of morphological derivatives. However, only the children in Grades 3 to 5 were influenced by the frequency of exposure to derivatives in texts (i.e., the cumulative frequency of derivatives). This suggested that it is 8-year-old children and older who are influenced by the precision of morphemic orthographic representations acquired through increased exposure to the word in texts. In sum, these results provided support for the derivative diversity hypothesis and successfully extended research on these variables into research on spelling accuracy. Results of the final hypothesis were discussed in the following section.

The Feminine Form Hypothesis

The final goal of the present study was to assess whether the existence of a feminine inflection of the target word that pronounced the silent-letter ending facilitated spelling accuracy over-and-above the effect of morphological derivatives for children in Grades 1 and 2. This hypothesis intended to extend previous research indicating that children more accurately spelled words with feminine inflections compared to other morphological derivatives that pronounced the silent-letter ending (Sénéchal, 2000). The hypothesis was generally supported in that the existence of a feminine inflection that pronounced the silent-letter ending was related to spelling accuracy only for the children in Grade 1, but not the older children in Grades 2 or 3 to 5. This was in line with the expectation that the variance accounted for by the feminine inflection would likely be subsumed by more advance knowledge of morphology for older children. Results in Grade 1, however, suggested the

presence of a suppression effect because the feminine inflection variable was only significantly predictive after controlling for the diversity of derivatives.

Results of the feminine form hypothesis indicated the presence of a reciprocal suppression effect wherein the diversity of derivatives and the feminine inflection variables were stronger predictors of spelling accuracy when considered simultaneously. This result was related to the significant negative correlation between these two variables due to the fact that half of the feminine inflection words had no derivatives, whereas all words without feminine inflections had at least one derivative. These results suggested that spelling accuracy in Grade 1 was best predicted by morphological word families when accounting for both derivatives and inflections that pronounced silent-letter endings. In other words, first grade children's ability to supplement underspecified orthographic representations of silent-letter endings was influenced by a greater number of revealing-related words, regardless of their morphological status. These results helped further the understanding of children's use of knowledge of morphology in spelling: for the youngest children in Grade 1, the facilitative effect of revealing-related words is best understood when considering both derivatives and inflections. However, the facilitative effect of feminine inflections is limited to children in Grade 1 as the effect was subsumed by knowledge of morphological derivation in older children.

In sum, these results supported the existing literature indicating that knowledge of morphological word families increases the accuracy of children's attempts at spelling French words ending in silent letters. The findings were consistent with the view that connections between related words in a morphological word family are activated at a morphological sub-lexical layer of representation (Caravolas, 2004; Giraudo & Grainger, 2001; Pacton et al., 2005). In addition, the pronunciation of silent-letter endings in these related words improved the quality of cognitive representations and provided insight for children attempting to spell

words with underspecified orthographic representations. An additional component of the present study, however, was the cumulative assessment of known predictors of spelling accuracy. Specifically, the influence of morphological word families was strong enough to account for unique variance in spelling accuracy after controlling for the other well-established predictors. The specific results and implications of the control variables were discussed in the following sections.

Other Predictors of Spelling

Previous research on spelling development has identified word characteristics that predict the development of orthographic representations and subsequent spelling accuracy (Alegria & Mousty, 1996; Caravolas et al., 2005; Lété et al., 2008; Martinet et al., 2004; Sénéchal et al., 2016; Spencer, 2007). In the present study, these characteristics were categorized as word-general and silent-letter controls. Specifically, word-general controls included word characteristics stemming from research across word types and languages, while silent-letter controls included word characteristics unique to the silent-letter endings of French words. These control variables were entered first in the hierarchical regression models before assessing the additive effect of morphological word families. Results for these controls were presented in the following section, beginning with the predictors unique to French words ending in silent letters.

Silent-letter controls. Silent-letter controls in the present study included the frequency of the silent letter and the conditional consistency of the silent letter considering the preceding phonological rime. While correlated with spelling accuracy, results across all analyses indicated that the conditional consistency of the silent letter did not predict unique variance when considered in addition to the other predictors of spelling. While significantly correlated to spelling accuracy, evidently the variance accounted for by this variable

consisted entirely of variance shared with the other predictors. This variable was therefore not analyzed further.

Results indicated that the frequency of the silent-letter ending significantly predicted spelling accuracy across all grades in the analysis for the word family hypothesis. Specifically, more frequent silent-letter endings were spelled accurately more often than less frequent silent-letter endings. This finding corroborated previous research that young children are sensitive to the statistical probabilities of the occurrence of silent-letter endings (Sénéchal et al., 2016). That is, more frequently occurring silent-letter endings are likely more precise in budding orthographic representations due to the increased exposure and statistical learning of those frequencies. In addition, this effect was consistent across grade levels, indicating the knowledge is acquired early in literacy development.

Results of the derivational diversity and feminine form hypotheses found that the frequency of the silent letter was not related to spelling accuracy in theses subsamples of words. Neither silent-letter control was therefore included in these hierarchical regression analyses. This change could have been due to the change in the number of silent-letter endings between the subsamples of target words. Specifically, the original 584 target words had 19 different silent-letter endings, whereas the 232 target words in the derivative diversity hypothesis had only 12. Words containing seven infrequent silent-letter endings were removed as they did not have word families with a revealing-related word. Perhaps this change in the nature of the variable decreased its power to account for variance in addition to the other predictors.

In sum, results of the silent-letter control variables did indicate that these word characteristics were related to spelling accuracy, however, only the frequency of the silent-letter ending was an additive predictor of spelling accuracy for the whole sample of target words. These results confirmed children's acquisition of statistical information pertaining to

the silent-letter endings, encoded at sub-lexical layers of representations. However, the variance accounted for by these variables may be subsumed by the word-general controls, particularly in the analyses on the smaller subsets of words.

Word-general controls. Previous research has identified word characteristics that uniquely predict spelling accuracy when entered simultaneously in large-scale regression analyses in both English (Spencer, 2007) and French (Lété et al., 2008). Consider for example Lété et al.'s finding that word frequency, orthography consistency, and length each uniquely predicted spelling accuracy, cumulatively explaining up to 32% of the variance in Grades 1, 2, and 3 to 5. The goal of the present study was to incorporate this research by testing these control variables before including the morphological word family variables.

Results from all regression analyses conducted in the present study indicated that word frequency was the strongest predictor of spelling accuracy. Specifically, frequent words were spelled accurately more often than less frequent words by children in all grades. This was expected considering sufficient exposure to the printed form of a word is required for the statistical learning of orthographic patterns, essential to the development of orthographic representations (Alegria & Mousty, 1996; Lété et al., 2008; Martinet et al., 2004; Sénéchal et al., 2006; Sénéchal et al., 2016; Share, 1995, 1999; Weekes, 1997). While it was expected that word frequency would predict spelling accuracy of the older children in Grades 2 and 3 to 5, these results suggested children at the end of Grade 1 had been sufficiently exposed to printed text to benefit from word frequency in these subsets of French words. This result confirmed that the greatest aid in teaching children in all grades to spell words is increased interactions with the printed form of words.

Orthographic consistency was the second word-general control variable found to uniquely predict spelling accuracy across all analyses. Results indicated that more consistently spelled words were spelled accurately more often than words containing less-

consistently spelled phonemes. This result was in accord with the fuzzy representation model (Sénéchal et al., 2016), which states consistently spelled phonemes are readily mapped in budding orthographic representations while inconsistently spelled phonemes remain underspecified longer, hindering spelling development (Jubenville et al., 2014). This finding was also reliably found in the spelling accuracy of children in all grades assessed in the present study. This was expected as the youngest children attempting to spell rely on their knowledge of phoneme-to-grapheme mappings (Caravolas, Hulme, & Snowling, 2001; Ehri, 1992; Treiman & Kessler, 2014) and consistency has been demonstrated to continue to influence spelling into adulthood (Kreiner, 1992; Kreiner & Gough, 1990).

Word length was the third word-general predictor of spelling accuracy entered in Grades 1 and 2 in the word family hypothesis and in the feminine form hypothesis. This was in line with the expectation that longer words were significantly more challenging for younger children to spell, but not for older children (Rapp & Dufor 2011; Spencer, 2007). The grade level expectations were attributed to longer words being more challenging for younger children to maintain in their underdeveloped working memories as each letter is selected in order for production (Rapp & Dufor, 2011). In the subsample of words assessed in the derivational diversity hypothesis, word length was not a significant predictor. This change may be attributed to a decrease in the average length of the words assessed. Specifically, the 584 target words in the first hypothesis had an average word length of 4.2 phonemes, whereas the 232 target words in this hypothesis were on average only 3.9 phonemes long.

A final result for the word-general controls was the inclusion of orthographic complexity as a predictor of spelling accuracy in Grade 2 in the derivational diversity hypothesis only. Because this variable was not a significant predictor in any other analysis, this finding was not overly interpreted. In general, the results regarding orthographic

complexity suggest it was not an additive predictor of spelling accuracy despite the significant correlations.

In sum, the results of the word-general control variables of the present study confirmed previous research indicating their unique and additive effect on spelling development (Lété et al., 2008; Spencer, 2007). In addition, considering the stringent analyses including these well-established predictors of spelling accuracy, results of the present study confirmed the unique effect of morphological word families in facilitating spelling development. This research furthers the understanding of how children acquire and store knowledge that is used when spelling.

Limitations and Future Research

Limitations of the present study must be discussed. To begin, the results were limited due to the near floor effects in spelling accuracy in Grade 1. That is, spelling accuracy for these French words ending in silent letters was very low in Grade 1, with large variability across words. While this floor effect was not surprising considering the challenge posed by silent letters to young spellers (Jubenville et al., 2014), the results should be interpreted with caution. However, it was also noted that the pattern of results generally did not differ across grades in the word family and derivative diversity hypotheses. In addition, the grade level differences found in the feminine form hypothesis was in line with expectations. Therefore, this supported the interpretations of results in Grade 1.

A limitation to the research on morphological word families to date is the understudied influence of related words that do not contain the exact spelling of the root. As previously described, the formation of morphologically complex words with the addition of affixes is classified under two categories of transformation: simple and irregular. Simple transformations are the result of the addition of an orthographic unit that does not alter the spelling of the root. In the case of French words ending in silent-letters, it is these simply

transformed derivatives that result in the pronunciation of the silent-letter ending. Contrarily, irregular transformations to the root can result in the removal of the silent letter. For example, the silent *x* in the French word *heureux* /øʁø/ [happy] is transformed into an *s* in the feminine inflection *heureuse* / øʁøz/ [happy].

Previous research has largely ignored these irregularly transformed derivatives, such as when target words with only these irregular-related words were grouped with the words without derivatives (Sénéchal, 2000; Sénéchal et al., 2006). However, one study mentioned the possibility of a detrimental effect of irregular-related words as they found that some children had misspelled words such as *numéro* / nymeʁo/ [number], adding a silent *t* as indicated by the derivative *numéroter* /nymeʁɔte/ [number] (Pacton & Casalis, 2006). In the present study, irregular-related words in the morphological word families were not considered. However, it should be noted that only 18.8% of target words in the word family hypothesis had an irregular-related word in its morphological word family. For example, the target word *fruit* /fʁɥi/ [fruit] had *fruité* /fʁɥite/ [fruity] as a revealing-related word and *fructueux* /fʁyktɥø/ [fruitful] as an irregular-related word. In addition, the mean spelling accuracy did not appear to differ between words with and without irregular-related words (*M*s = .09/.22/.51 and .10/.26/.51 for words in Grades 1, 2, and 3 to 5 with and without irregular-related words, respectively). This was lack of difference was corroborated by non-significant correlations between the existence of an irregular-related word and spelling accuracy (*r*s between -.01 and -.05, *p*s > .214). The facilitative effect of morphological word families demonstrated in the present study can therefore be interpreted confidently. However, the exploration of the effect of irregular-related words is recommended for future research.

In sum, the current study supported the additive influence of morphological word families in facilitating spelling development over other known predictors of spelling accuracy. In addition, the present study offered an extension of previous research in

conducting word-item analyses for a large corpus of words spelled by 40 children in each of Grades 1 to 5. Findings confirmed the expectation that morphological word families containing related words that pronounce silent-letter endings provided children with an additional source of information to rely on when spelling. In addition, these results suggested that more numerous connections with related words facilitated spelling, while stronger connections acquired through more frequent exposure to the related words did not have the same impact. This research could also have implications for education. For instance, these findings may encourage teachers to highlight morphological word families as an additional tool in helping children learn to spell words with silent letters. In addition, encouraging knowledge of all revealing-related words in a word family could have the strongest effects on spelling development. Finally, teachers of younger children may be encouraged to highlight the more easily learned feminine inflections, however, older children are less likely to benefit from this tool. In creating and strengthening connections between related words in a morphological word family, children can develop higher quality cognitive representations, thereby facilitating literacy development and academic success.

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