# Reading Speed and Orthographic Quality: Exploring the Space Between Good and Poor

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## ABSTRACT

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Individuals vary in the speed with which they read printed text. Each person has words in his or her mental lexicon that are of low, intermediate, and high quality. These representations are said to be developed through self-teaching as students are reading text (Cunningham & Stanovich, 1990; Share, 1995). According to the Lexical Quality Hypothesis (LQH), a word with a higher quality mental representation should be accessed more efficiently than a word with a lower quality representation. This ease of access can be observed via faster reading times. However, direct comparison between reading times of words progressing from low to high quality has yet to be studied. Here, reading times were measured for single words and analysed within-participant and within-word, according to orthographic quality (measured through spelling accuracy and stability). The data from this study show that teenagers who read more for pleasure have faster reading times and higher spelling scores. Furthermore, single-word reading speed gets faster as the orthographic quality of single words progresses from low to intermediate to high quality. Therefore, spelling is important; increasing spelling accuracy and stability is a worthwhile way to efficiently access mental representations of words, and thus increase reading speed. Reading for pleasure can help improve spelling abilities and should be an indispensible part of classroom and home activities.

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# Introduction

Word learning is complex. The way words sound (phonology), look (orthography), and convey meaning (semantics) all contribute to how well they are stored in memory (Ehri, 2014). As proposed by the Lexical Quality Hypothesis (LQH), these three word characteristics determine how well the words are read, spelled, and understood (Perfetti & Hart, 2001). According to the LQH, fluent reading will occur more readily when encountering printed words with higher-quality mental representations (Perfetti, 2007). Specifically, high consolidation of each of the three components, as well as high coherence among them, translates into higher quality. This hypothesis argues that all three types of word identities contribute to overall lexical quality; therefore, a deficit in one or many of these areas would result in a word having weaker lexical quality; by extension, reading will be hindered. In my thesis, I will be exploring whether the progression of representational quality as measured by increasingly accurate spelling is reflected in improved word reading fluency.

## Lexical Quality Hypothesis

Perfetti (1992) states that words' representations need to be "redundant" and "specific". When word representations are redundant, auditory input of a word presents a perfect match to its stored phonological representation. Similarly, when word representations are fully specified, visual input of letter strings activates the desired word to the exclusion of all other similar words (Perfetti & Hart, 2002). The development of high quality representations occurs on a word-by-word basis (Castles & Nation, 2006; Perfetti, 2007): when referring to orthographic quality, good spellers have proportionally more redundant and specific (i.e., high quality) representations than poor spellers, as spelling reflects orthographic quality (Perfetti & Hart, 2001). However, in good spellers, there will still be some orthographic representations that are underdeveloped, whereas in poor spellers some (albeit fewer) orthographic representations will be fully specified.

Words with lower quality representations are not specific enough to distinguish them from other similar items (Perfetti, 1992). Lower quality representations would be manifested differently for each of the components. For a phonological representation, a person's pronunciation must convey the precise sounds (i.e., no additional phonemes, no missing phonemes) in the right order (i.e., no transposed phonemes); a low quality phonological representation might not be specific enough to result in differentiating between "*karma*" and "*comma*" (e.g., /k/ar/m/ʌ/ vs /k/ɑ/m/ʌ/) in speech. For orthographic representations to be of high quality, similar requirements are necessary; specific letters must map on to specific positions, and the more position-correct letters contained within a representation, the higher its quality. In this way, encountering the letter string a-b-d-o-m-i-n-a-l could incorrectly activate *abominable* if the orthographic representation of *abdominal* is of low quality. Finally, with semantic representations, the person must be able to retrieve the precise word meaning in the correct context. Semantic representations can range from having never heard of the word (e.g., *gloaming*), to having a partial understanding (e.g., *bolt* = lightening), to having a complete understanding of the word's various meanings (e.g., *bolt* = lightening, speed, locking mechanism, etc.). A low quality representation may impair comprehension by activating the wrong word meaning according to the context, or by delaying the activation, compromising efficiency.

**Spelling and Orthography**

Orthography and spelling, while related, are not synonymous. The term 'Orthography' stems from *orthos* meaning 'correct' and *graphia* meaning 'writing'. In this sense, the literal meaning of “orthography” is ‘correct writing’ (Bond, Kozak, & Martin-Chang, in prep). Therefore, the term orthography applies equally to words with alphabetic and logographic writing systems. On the other hand, spelling relates exclusively to writing systems that employ the alphabetic principle (where letters represent speech sounds). In logographic orthographies, such as Mandarin and Japanese, the concept of spelling is less applicable because the logograms of the language represent meaning and not sound.

In English, the quality of orthographic representations can be measured by spelling accuracy (Perfetti, 2007; Perfetti & Hart, 2001). Spelling accuracy varies in two respects: consistency and stability. For consistency, one can consider the degree to which a word is spelled accurately across attempts. When asked to spell a word several times, it can be spelled consistently accurately (always right), consistently inaccurately (always wrong), or inconsistently accurately (sometimes right). When a word is spelled correctly, it must, by definition also be spelled consistently. For example, if the word *said* is spelled consistently accurately, it will be spelled accurately over all trials (i.e., it will always be spelled as *said*). If the word is spelled consistently inaccurately, then it will be spelled inaccurately over all trials (i.e., it will always be misspelled). If the word is spelled inconsistently accurately, at times it will be spelled correctly, and at other times it will be spelled incorrectly.

A spelling is unstable when it changes from one trial to the next. Thus, when a word is spelled correctly at one time and incorrectly at another, its spelling unavoidably changes across trials. In the cases where a word is spelled inaccurately, the stability of how it is misspelled can be taken into consideration. When a word is spelled inaccurately it can be written in the same incorrect way or in different ways over multiple trials. For instance, when *said* is misspelled, it can be misspelled in the same way across trials (e.g., always spelled as *sed*) or in a variety of ways (e.g., *sed, siad,* and *sead*). The more times the word is misspelled in the same way, the more stable (although inaccurate) the spelling. It is because of these two factors that Perfetti (2007) suggests that accurately spelling a word once is not necessarily an indicator of quality; when a word has a high quality orthographic representation, it is correctly spelled at every opportunity. Therefore, it is important to consider the spelling of a word over multiple trials.

Spelling development occurs on a continuum (Perfetti, 2007); words that are spelled consistently accurately are taken to have the most specified orthographic representations in memory. Words that are spelled incorrectly a variety of different ways are taken to have the least specified representations (Martin-Chang, Ouellette, & Madden, 2014). It follows that representations that are spelled accurately only some of the time (inconsistently accurately) are taken to have orthographic representations that are becoming more specified. While these views are firmly rooted within the literacy research community, research that directly links orthographic quality and reading skill of the same words remains scarce; consequently, the influence of orthographic quality on word reading remains unclear. The goal of the present study is to delve further into the link between word-specific orthographic quality (as determined by spelling accuracy) and word reading fluency. More specifically, I will explore whether the progression of spelling accuracy (as indicated by a word's spelling consistency and stability across trials) impacts the reading speed of accurately read words.

**Reading Fluency**

Fluency is a multifaceted element of reading; it encompasses the accuracy and speed of single-word reading, as well as the prosody of longer segments of text (Wolf & Katzir-Cohen, 2001). Accuracy and speed refer to how precisely and quickly a person can translate print to speech (National Reading Panel, 2005). Prosody refers to elements of expression during reading, such as rhythm, parsing, and tone (Dowhower, 1991). In single-word reading, prosody does not apply; thus, at the single-word level, word reading fluency is defined by the precision and the speed with which the word is read (Martin-Chang & Levy, 2006).

**What Is Orthographic Learning?**

Orthographic learning allows the slow decoding of graphemes to develop into fast and efficient word recognition (Ehri, 2014; Perfetti, 1992; Perfetti, 2007; Perfetti & Hart, 2002; Share, 2004). The formation of word-specific orthographic representations leads to increased orthographic knowledge about the word itself (i.e., knowledge of its spelling), and also about the sublexical units it contains. Overtime, the accumulation of word-specific orthographic knowledge results in general orthographic knowledge of a language. That is, knowing the spelling of specific words (lexical knowledge; Barker, Torgesen, & Wagner, 1992) leads to the knowledge of letter patterns and frequent letter positions specific to a language (sublexical knowledge; Conrad, Harris, & Williams, 2013). Increased orthographic proficiency, in turn, has been proposed to result in increased reading fluency (Share, 2004).

While the constituents that make up orthographic learning are clear, the mechanism with which orthographic learning occurs remains relatively unknown. Castles and Nation (2006) suggest that five factors may contribute to orthographic learning. The first factor is phonological skills. These skills encompass children's ability to identify, segment, and manipulate sounds, and are typically measured through phonemic awareness, rhyme awareness, and verbal short-term memory (Melby-Lervag, Lyster, & Hulme, 2012). The second factor is made up of both alphabetic knowledge and phonological decoding. Alphabetic knowledge is the understanding that letters and letter patterns represent spoken sounds (Bond et al., in prep; Ehri, 2014). Phonological decoding consists of the ability to use the knowledge of the relationship between letters and letter patterns in order to translate written words into speech. The third factor is orthographic processing skills. These allow children to apply pre-existing general orthographic knowledge in order to complete choice tasks and tasks that evaluate sensitivity to orthographic restraints (e.g., Castles & Nation, 2006). The fourth factor is print exposure. Print exposure acts as a proxy for how much the child has read for pleasure (Cunningham & Stanovich, 1990). The fifth factor is semantic knowledge. Semantic knowledge is meaning that is associated with the letter string (Ouellette & Beers, 2010).

### 1. Evidence For Phonological Skills In Orthographic Learning

Phonological skills encompass the ability to segment and produce different sounds (e.g., onset/rimes, blends, phonemes) within spoken words. As phonological skills advance, children progress to being able to remove, insert, combine, and reverse sounds within words (Lewkowicz, 1980). Longitudinal studies have shown that the phonological awareness of prereading children is correlated with, and predictive of, their subsequent reading acquisition (for reviews, see Melby-Lervag et al., 2012; Wagner & Torgesen, 1987). For instance, Share et al. (1984) found that phonemic awareness was the top predictor of reading at the end of Kindergarten, even after accounting for prereading abilities, oral language abilities, motor abilities, personality, and home background. Similar findings were reported by Mann (1984). She also found that Kindergarten children's phoneme awareness was highly correlated with their reading achievement in Grade 1.

### 2. Evidence For Alphabetic Knowledge and Phonological Decoding In Orthographic Learning

Well-known theories of reading acquisition (Ehri, 1995; Frith, 1985; Share, 1995) propose that alphabetic knowledge and decoding skills must be developed before orthographic learning can occur (c.f., Treiman (1993) regarding orthographic processing). Share's (1995) self-teaching hypothesis states that alphabetic decoding skills are fundamental to reading acquisition. His theory posits that children with decoding skills are able to translate print to speech on their own; in turn, recoding a word into speech creates the opportunity to provide word-specific orthographic information that will help with later fluent reading. Thus, according to the self-teaching hypothesis, without decoding skills, orthographic learning cannot occur. Ehri's (1995) phase theory of reading acquisition is also built on a foundation that is heavily focused on alphabetic knowledge; learning letter-sound correspondences pave the way for decoding longer letter strings, and eventually learning the orthographic representations of whole words.

Share (1999) studied children learning to read Hebrew in second grade. These children read stories aloud (without feedback) and were tested for orthographic learning of novel words three days later. Orthographic learning was tested in three ways: recognition, naming speed, and spelling of target words. Share's results show that, in the orthographic choice task, children were five times more likely to recognize the spelling of a word they had seen (e.g., *yait*) compared to a word that sounds the same but is written differently (homophonic foil; e.g., *yate*). In the naming task, children named target words faster than homophonic foils. In the spelling task, children spelled target words accurately three times more often than they spelled target words using a homophonic spelling. Share concluded that orthographic learning occurred through reading text. Share's next experiments examined the impact of minimizing phonological decoding in orthographic learning. In order to impede input from phonological decoding, Experiment 2 limited exposure time of the target word to 300 ms (i.e., too fast to decode the words), and Experiment 3 had children engage in concurrent vocalizations while they were exposed to the target word (i.e., repeating *dubba* out loud in order to saturate the phonological loop). Interestingly, no orthographic learning was observed under these conditions where opportunities for phonological decoding were minimized. Thus, the results from Share's experiments suggest that phonological decoding is a critical factor for orthographic learning to occur.

More recent studies have also shown evidence of the impact of alphabetic skills on orthographic learning, as determined by word recognition. Cunningham (2006) replicated Share's experiment with English speaking children. Children in first grade were asked to read stories containing target (real) words that were likely to be known orally, but not orthographically, by the children. For half of the children, these target words were replaced with homophonic alternatives (e.g., *piece* was replaced with *peece*). Children were asked to choose the spelling that they saw in the story, and to spell these words. Cunningham found a strong correlation between the children's accurate target word reading and their orthographic learning, measured by the orthographic choice task and the spelling task, and transformed into a composite score. This significant positive correlation was also found between the orthographic learning composite scores and more global standardized measures of decoding ability. These correlations indicate a relationship between orthographic learning and alphabetic decoding skills.

Furthermore, on the orthographic choice task, Cunningham (2006) found that children chose the target word almost 50% of the time. If the target word was not chosen, the homophonic alternative was chosen more often (33%) compare to the other nonhomophonic foils (17%). Specifically, printed words, whose letter-sound correspondences match the spoken word, were chosen more often than words that looked similar to the target word but did not sound like the target word (e.g., *chews* and its homophone *chooze* were chosen more often than orthographically similar words *chaws* and *chwes*). This suggests that phonological recoding plays an important part in word recognition.

Ouellette and Fraser (2009) studied the orthographic learning of novel nonwords in Grade 4 students. The researchers performed regression models and determined that decoding skills accounted for 32.4% of the variance in target nonword recognition. The use of nonwords allowed the researchers to be sure that the words were not words that children already knew, hence no previous knowledge of the words could influence the extent of orthographic learning that occurred.

**3. Evidence For Orthographic Processing Skills In Orthographic Learning**

The third factor in Orthographic learning proposed by Castles and Nation (2006) is orthographic processing. Orthographic processing is typically measured by orthographic choice tasks (e.g., Which is a word? gote or goat) and sensitivity to orthographic restraints (e.g., Which looks more like a word? ffim or phim), influence orthographic learning. Decoding skills necessarily influence these types of tasks; however, studies have shown that orthographic knowledge contributes to orthographic learning over and above the contribution of decoding skills. For example, the previously mentioned study by Cunningham (2006) also considered prior orthographic knowledge and its influence on orthographic learning. Cunningham found that by controlling for decoding skills, pre-existing orthographic knowledge (measured by orthographic choice, homophone choice, and orthographic restraint tasks) still significantly contributed to children's word recognition skills.

Similarly, Wang, Marinus, Nickels and Castles (2014) studied the orthographic learning of poor readers, ranging from 7 to 12 years old, and found that their orthographic knowledge predicted orthographic learning of novel words above the contribution of phonological decoding skills. Orthographic knowledge was determined by a test of orthographic choice where participants were presented with two different spellings of words and were requested to choose the correct spelling. Orthographic learning was determined by a spelling task and an orthographic choice task that contained one target word (e.g., *ferb*) and three foils: one homophone (e.g., *furb*) and two visual distractors (e.g., *ferq* and *furq*).

Further support for the role of orthographic processing skills comes from a longitudinal study by Cunningham, Perry, and Stanovich (2001). They evaluated the orthographic processing skills of second grade children on tasks of letter string choice (to test sensitivity to orthographic restraints), orthographic choice, homophone choice, and spelling. One year later, they found that these orthographic processing skills of children accounted for unique variance in their word reading (as assessed by print exposure, pseudoword reading, and word recognition), even after controlling for phonological skills and decoding abilities.

Treiman (1993) also studied the spelling of children in Grade 1 and found that they were more likely to double frequently doubled letters (such as *e* and *l*), compared to letters that are infrequently doubled in English (such as *i* and *h*). Furthermore, children picked up on orthographic regularities. For example, in English the digraph *ck* is illegal in the initial position (e.g., *bucket* and *pack*, but not *ckar*). Children's spelling behaviors seemed to indicate that they have learned this pattern implicitly. For example, they are more likely to produce the orthographic pattern *ck* in the middle and at the ends of words, compared to the beginning of words. Similarly, Cassar and Treiman (1997) studied 6-year-old children and found that they are sensitive to the frequency and legality of English orthographic patterns. More specifically, when asked to identify which sequences of letters looked more like words, these children chose nonwords with allowable doublets and final doublets (e.g., *geed* and *baff*) more often than words with illegal doublets and initial doublets (e.g., *gaad* and *bbaf*).

Orthographic conventions can also be shown in frequency of use of vowels in writing. English and Portuguese prephonological children, as young as 4 years old, were compared in their spelling of words. Portuguese children spelled words more often using vowels than English children (Pollo, Kessler & Treiman, 2009); this correlates with the higher percentage of vowel letters in Portuguese words (51%) than English words (39%; Pollo, Kessler, & Treiman, 2005).

## 4. Evidence For Print Exposure In Orthographic Learning

Castles and Nation (2006) posit that print exposure is an important construct to orthographic learning because it acts as a proxy for child's experience with text, without measuring their reading ability per se (Cunningham & Stanovich, 1990). Print exposure is conceptualized as reading done for pleasure over the lifetime. It is commonly measured by checklists: children are asked to mark titles of books, magazines, or other printed materials they are familiar with (Title Recognition Task; TRT). Older participants are commonly asked to complete an Author Recognition Task (ART), where they select authors that they are familiar with from a list of names. The list contains real titles and foils, to prevent guessing.

In studies with undergraduate students, higher scores on the ART have been associated with greater vocabulary knowledge and verbal ability (Stanovich, West, & Harrison, 1995), as well as better reading comprehension skills (Martin-Chang & Gould, 2008). The amount of time allocated to reading for pleasure in the classroom is related to teachers' knowledge of the importance of print exposure, and to their own experience with print (Kozak & Martin-Chang, submitted).

Print exposure has also been studied with regards to a younger population. Cunningham and Stanovich (1993) studied children in Grade 1 and assessed them on word recognition, phonological and orthographic processing, and print exposure. For these children, variance in orthographic processing ability was associated with differences in print exposure. However, as argued by Castles and Nation (2006) the direction of the relationship between print exposure and orthographic learning is less clear. In order for some orthographic learning to occur, exposure to print must happen; thus, print exposure alone must predict word recognition to some degree. Therefore, it is unclear whether exposure to print promotes orthographic learning, or whether children with better orthographic skills expose themselves to more written text compared to children with poor orthographic skills (i.e., a Matthew effect; Allington, 1984; Stanovich, 1986).

### 5. Evidence For Semantic Knowledge In Orthographic Learning

The fifth and final factor proposed to contribute to orthographic learning (Castles & Nation, 2006), is semantic knowledge. There are two routes by which semantic knowledge could affect word reading, and each may have different consequences for orthographic learning. The first route involves knowledge of the word itself (i.e., vocabulary). The second route involves the use of surrounding context to help decode the words. Ouellette (2006) studied the role of vocabulary in word reading through its influence on visual word recognition. He measured two aspects of vocabulary: the first takes into consideration the number of words individuals know (i.e., breadth), the second refers to the number of different concepts attached to each word (i.e., depth). Ouellette found that both types of vocabulary were associated with 9 and 10-year-old children's visual word recognition. In subsequent research, Ouellette and Beers (2010) studied the vocabulary knowledge of children in Grade 1 and Grade 6. In Grade 1, children's vocabulary depth accounted for 2.9% of the variance in irregular word recognition, after accounting for decoding skills and phonological awareness. In Grade 6, children's vocabulary breadth accounted for 16.7% of the variance, while the contribution of vocabulary depth was not statistically significant.

The contribution of vocabulary knowledge to orthographic learning can also be assessed on a word-by-word basis. Ouellette and Fraser (2009) investigated the role of semantic information in Grade 4 children's learning of novel nonwords. The researchers presented semantic information about the nonwords orally, and exposed children to the words in print. Results revealed that, in an orthographic choice task, nonwords that were previously presented with semantic information were identified more accurately than nonwords presented without semantic pre-exposure. However, when asked to spell the nonwords, the children's spelling performance showed no difference whether the word had been presented with or without semantic information. In a study with Grade 2 children, Ouellette (2010) had the children practice reading and spelling nonwords, presented with and without semantic support. Ouellette found that when words were presented with semantic support, regardless of condition (spelling or reading practice), children accurately spelled the target more often.

The second way in which semantic knowledge can influence orthographic learning is through the use of context to help decode words. As demonstrated in studies by Martin-Chang and colleagues (Martin-Chang & Levy, 2005; Martin-Chang, Levy, & O'Neil, 2007), reading in context leads to more accurate word reading. This was also shown by Cunningham (2006) who found that target words presented in scrambled sentences were read less accurately than words presented in cohesive text; when this contextual support was available, it helped children decode the words. Thus, in accordance with Share's (1995) self-teaching hypothesis, Cunningham concluded that the semantic information provided by surrounding text exerts an effect on accurate reading of target words, and facilitates word recognition. Martin-Chang, Ouellette, and Bond (2017) studied the accuracy of target word reading in children in Grade 2 and reported similar findings; when target words were read in context, children read them more accurately on the first viewing compared to target words read in isolation. Of specific interest to the current study, Martin-Chang, et al. found that in spite of *decoding* the words more accurately in context, they *spelled* words more accurately when they had first been presented in isolation. This suggests that context may be hindering detailed orthographic learning. Thus, there is mixed research when it comes to the effect of context on orthographic learning.

**Measuring Orthographic Learning**

Orthographic learning is often measured by orthographic choice tasks and spelling tasks. Orthographic choice tasks have participants choose the correct spelling from a list containing foils. Typically, the orthographic choice task has four options to choose from: the correct spelling, a homophonic spelling, and two distractor spellings that resemble the target word orthographically but not phonologically. Participants need to *recognize* the correct spelling of a word but they do not need to produce that spelling themselves in order to complete the task.

In contrast, spelling tasks require that the participants *recall* previously seen target words. In order to produce the correct spelling of a word, participants must retrieve the word from their mental lexicon and accurately transfer that memory into written graphemes. From a general memory perspective, recall is more difficult than recognition (Cabeza et al., 1997). Therefore, due to this difference between the demands of these tasks, orthographic learning may be viewed differently depending on how it is evaluated.

The few studies that have used both methods to determine orthographic learning have shown that participants do not do equally well on both tasks. For instance, Cunningham (2006) had children in first grade identify target words (in an orthographic choice task) and spell target words. Not surprisingly, when measuring the orthographic learning of the same words, she found a difference between the response patterns on these two tasks. Children were more likely to correctly identify the target word in the homophonic choice task, than provide the correct spelling of this word. Cunningham suggests that these differences may be due to the increased difficulty of the spelling task, which may not be sensitive enough to detect the beginnings of orthographic learning. Wang and colleagues (2011) worked with older children in Grade 2. Again, orthographic learning was assessed by both orthographic choice and spelling tasks. Wang et al. did not directly compare their results for orthographic learning measured through spelling task and orthographic choice task, however they do report the percentage of correct responses per task. Children in Grade 2 responded correctly more often (73% of the time) in the orthographic choice task, compared to the spelling task (53%). These results suggest that, similar to Cunningham, the different orthographic tasks may have different sensitivities to orthographic learning.  Ouellette and Fraser (2009) also used both tasks and reported more orthographic learning with the orthographic choice task (~83% versus ~75%) when words were accompanied by semantic information, but reported similar accuracy (~75%) for both orthographic choice and spelling tasks when words were learned through exposure on cue cards. As demonstrated by these studies, the measures used to assess orthographic learning may vary in sensitivity with regards to measuring the quality of individuals' newly formed orthographic representations.

**Spelling and Reading Relationship**

As stated above, orthographic learning results in orthographic representations that can be measured by spelling behavior. It has been argued that the consistent production of correct spelling of a word indicates that it has a high quality orthographic representation. This may not be the case for reading (Conrad, 2008; Frith, 1980, 1985; Nation et al., 2007). For instance, the incomplete mental representation of *emb?ar?a?s* will often suffice for reading the word '*embarrass,'* thanks to "partial cue reading" (Frith, 1980, 1985). This partial cue strategy entails using coarse bottom-up orthographic cues, as well as top-down cues in order to arrive at the pronunciation of a word in print. Although accurate reading can still occur in the absence of high quality orthographic representations, the reading processes might be less efficient.

Recent investigations by Martin-Chang, Ouellette, and Madden (2014) and Ouellette, Martin-Chang, and Rossi (2017) have begun to explore this question. Unlike other studies of general reading and spelling abilities, Martin-Chang, Ouellette and colleagues investigated the immediate relationship between spelling accuracy and reading speed at the word level (Martin-Chang et al., 2014; Ouellette et al., 2017). They found that words that participants always spelled correctly were read faster than words that were never spelled correctly. Furthermore, within-word analysis determined that words always spelled accurately by one set of participants were read faster than the same words always spelled inaccurately by a different set of participants. Of interest here, the researchers reported certain instances of inconsistent spelling; that is, some participants spelled a word correctly on one or more of the five trials, but not all five times (Martin-Chang et al., 2014). As reported in a table of spelling scores and reading response times, reading speed seemed to increase along with spelling accuracy. However, due to the limited number of inconsistent spellings, the researchers were not able to statistically evaluate this pattern. This prior research was done with undergraduate students, which may explain the paucity of intermediate instances of spelling; as individuals get older, they gain more experience with print, which may lead to more established orthographic representations (Perfetti, 2007). One way to increase the number of intermediate quality orthographic representations may be to study a younger population of participants. Thus, to further test the relationship between the progression of orthographic quality and reading speed, the first goal of the current investigation was to study these instances of partial orthographic quality and related reading speed in high school students.

Furthermore, Martin-Chang and colleagues (2014) reported the stability of the words that were always or never spelled correctly. Words that were always spelled correctly were considered highly stable, and thus taken to have highly stable orthographic representations. Words that were always misspelled in the same manner were also considered highly stable, as the spelling of the word (although incorrect) did not change from one trial to the next. Words that were always misspelled, but misspelled differently across trials were rated as less stable, with their stability declining with the number of different misspellings that were provided. The analyses revealed that accurately spelled words were read significantly faster than stably misspelled words. Further, words stably misspelled were read faster than words that were unstably misspelled. Importantly, this study was done with undergraduate students, so it remains to be determined whether these findings will hold with a younger population. Thus, the second goal of the current investigation was to study high school students' spelling stability in order to determine if spelling stability influences reading speed in younger students.

**Current investigation**

The goals of this study were twofold. The first was to study whether reading speed increases as spelling accuracy progresses. Specifically, I wanted to determine whether correctly spelled words (3/3; correct on all three spelling attempts) were read faster than incorrectly spelled words (0/3; incorrect on all three spelling attempts), and whether speed differed for occasionally-accurately spelled words (1/3 and 2/3). The second goal was to study how the stability of spelling relates to reading speed. I wanted to determine whether words that were spelled consistently the same way were read faster than words that were spelled in different ways across trials. I had participants spell predetermined words and measured their spelling accuracy and stability of these words. I also measured their reading speed for these same words. High school students were recruited to participate in this study. This population has been chosen because their spellings may be progressing towards accuracy and stability. Furthermore, this population is more representative of a larger population than a sample of undergraduate students.

This research contributes to the literature by providing further evidence for the directly observable relationship between reading speed and orthographic quality as measured via a spelling task.

### Hypotheses

The first hypothesis was that higher spelling accuracy will be reflected in faster reading speed. Similarly, the second hypothesis was that higher spelling stability will be associated with faster reading speed.

## Method

### Participants

Ninety-three students from an English high school participated in this study (62 females). The students were between 13 and 18 years of age (13 years–7 months to 18 years–2 months; $M_{age}$ = 16.30, *SD* = 0.92). All participants were enrolled in Grades 9 (n = 21), 10 (n = 24), and 11 (n = 48; $M_{grade}$ = 10.9, *SD* = 0.81). Testing took place in the months of March and April.

The vast majority of participants indicated that at least one of their native languages was English (88%). In addition, on a scale from 1 to 4, with 1 being “poor” and 4 being “excellent”, participants ranked their English proficiency as 3.52.

### Materials

**Standardized measures.** To assess general spelling abilities, participants completed the Woodcock Johnson Test of Achievement – Third Edition (WJ-III; Woodcock, McGrew, & Mathers, 2001). The WJ-III has high split-half reliability (median r = .90; Schrank, McGrew, & Woodcock, 2001) and has been used in many studies as an index of spelling skill (Conrad, 2008; Conrad et al., 2013; Martin-Chang et al., 2014). The paper and pencil task asks participants to write up to 59 words dictated by the experimenter, increasing in difficulty. Once a participant has made six consecutive errors, scoring is discontinued. The WJ III has good internal consistency, $\alpha$ =.90, and takes approximately five minutes to administer (Schrank et al., 2001).

Participants also completed the reading subtest of the Wide Range Achievement Test – third edition (WRAT4; Wilkinson, 1993) to assess their word level reading ability. The WRAT4 involves reading 42 real words in isolation. Testing is discontinued once a participant fails to read ten consecutive words accurately. Scores are calculated based on participants' age and the total number of items read correctly. The WRAT4 has good internal consistency, $\alpha$ =.89, and takes approximately five minutes to administer (Wilkinson & Robertson, 2006).

**Experimental measures.** A list of 30 target words (see Appendix A) was adapted from Martin-Chang et al. (2014) and Ouellette et al. (2017) to include 16 items deemed appropriate for the younger sample. Many of the new target words were higher in frequency in English speech (*M* = 24.37 frequency per million) than the original target words used from previous lists (*M* = 1.09).

**Author Recognition Test.** The Author Recognition Test (ART; Stanovich & West, 1989) is a proxy for how much participants read for pleasure. The ART used in this study was adapted for the younger audience by including Young Adult authors as well as contemporary fiction authors (Kozak & Martin-Chang, submitted; see Appendix B). The test consisted of a list of 114 names. Ninety-one of these names were real authors, and 23 were foils. Participants were asked to indicate which names they recognized as being real authors, and were told that the list also contained foils in order to detect guessing. Scores were calculated by dividing the real authors identified by total real authors and subtracting the number of foils identified by the total number of foils (real authors identified/ total real authors – foils identified/total foils).

**Procedure**

Participants with parental consent and written assent completed the study in two sessions (see Consent Form, Appendix C; Assent Form, Appendix D). For each activity, the researcher followed a script to assure that all participants received the same information (Appendix E). The first session took place one-on-one with the researcher. To measure target word-reading time, the 30 target words appeared individually on a 13" computer screen. The words were written in Geneva 36-point font to mimic flashcards. Participants were asked to read the words as quickly and as accurately as they could. The target words appeared once in random order within each list, and the lists were read four times in succession (30 words per list x 4 trials = 120 words in total).

SuperLab Pro 5.0 (Cedrus Corporation, 2014) was used to measure participants' word-reading time. The microphone was triggered by the participants' voice. Once tripped, the word disappeared from view. A fixation point (*) appeared on the screen for 2 seconds before the presentation of the next word. The experimenter coded accuracy of reading responses. This reading-response-time activity took approximately 7 minutes to complete. Participants were subsequently given the WRAT4 reading control measure, which took an additional three minutes.

The second session occurred following a two-week delay. All activities for the second session were done with the whole class. Students were seated at their own desks, out of sight of other students' responses and asked to complete the activities independently. The students participated in the activities in the following order: first repetition of target word spelling, participant information questionnaire, second repetition of target word spelling, ART questionnaire, third repetition of target word spelling, and WJ-III spelling control measure.

For the target word spelling, participants wrote down the list of 30 target words dictated by the experimenter. Participants spelled target words using pencil and paper. After each list was spelled once, the paper was removed and placed out of view; thus, participants were unable to reference their previous spellings. In all, this activity was completed 3 times, for a total of 90 words spread over the session.

In the Participant Information Questionnaire (Appendix F), participants indicated information concerning their knowledge of languages: their native languages, and their level of proficiency in English as well as in any other languages they spoke. Participants also indicated their age, date of birth, and grade level.

Participants then completed the ART, and as a final activity, the Woodcock Johnson spelling control measure. Completion of all activities for the second session took approximately 40 minutes.

## Results

Standardized measures of reading and spelling were calculated per participant in order to assure that they fell within the expected range (see Table 1). Average reading times and spelling accuracy scores were analyzed by grade level. Two separate one-way ANOVAs revealed no statistically significant differences in word-reading times ($F$ (2, 90) = .043, $p$ = .96) or spelling accuracy ($F$ (2, 90) = .264, $p$ = .77) when analyzed between grades. Therefore, all participants were included in the analyses that follow.

Correlations were calculated between the control and experimental measures. The standardized measures tap into general ability, while the experimental measures are word specific. As indicated in Table 1, the standardized measures and the experimental measures of reading and spelling were significantly correlated. The positive correlations between WRAT4-reading and WJIII-spelling indicate that as reading skill improved, so did spelling accuracy. The negative correlations with reading rate indicate that higher scores on the other variables were associated with faster reading response times.

Table 1

*Descriptives and Correlation Coefficients*

| Variable | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. WRAT4 reading[a] | – | | | | |
| 2. WJ-III spelling[b] | .58* | – | | | |
| 3. Target word reading time[c] | -.45* | -.54* | – | | |
| 4. Target word spelling accuracy[d] | .58* | .84* | -.62* | – | |
| 5. ART[e] | .44* | .50* | -.38* | .44* | – |
| *Mean* | 108.23 | 108.59 | 730.42 | 1.95 | .07 |
| *SD* | 11.18 | 12.84 | 156.20 | .49 | .06 |
| Range | 84–145 | 74–139 | 505.66–1383.69 | .43–2.87 | -.08–.27 |

* $p < .01$.

[a] Standardized measure of reading ability.

[b] Standardized measure of spelling ability.

[c] Reading rate in milliseconds and averaged across all words, per participant.

[d] Spelling accuracy out of 3, averaged across all words, per participant.

[e] Score on Author Recognition Test

All measures of spelling and reading ability were significantly correlated with the ART. Participants who read more for pleasure also had stronger spelling and reading scores, and faster reading times. However, it could be argued that children who have better general linguistic skills seek out opportunities to interact with text. Orthographic processing is an aspect of linguistic skills, which, as explored in this paper, could increase participants' spelling accuracy. To explore this possibility, a regression analysis was conducted with participants' standardized spelling scores as the dependent variable. Standardized reading was entered into the regression model first as an indicator of general linguistic ability, followed by the participants' scores on the ART. The □ coefficients, the standard errors, and the standardized betas are presented in Table 2. Results indicate that, after accounting for participants' reading abilities, the amount that teenagers read for pleasure is still a statistically significant predictor of teenagers' spelling scores and contributes 7% unique variance ($R^2$ *change* = .341, $F(2, 90) = 31.59$, $p < .001$).

Table 2

*Results of Hierarchical Linear Regression Analysis of Predictors of Spelling Abilities (WJ-III Spelling)*

| | Spelling (WJ-III) | | |
|---|---|---|---|
| Predictor | b | SE b | β |
| Step 1 Constant | .520 | .103 | .453* |
| Step 2 ART | 64.705 | 19.553 | .298* |

*Note.* Keeping reading abilities (WRAT4) constant. For Step 1, $R^2$ = .341, $R^2$ Change for Step 2 = .071; *$p < .001$

### Within-participant analysis

**Target word-spelling accuracy.** The first goal of the present study was to determine whether reading speed of individual words differed as a function of spelling accuracy of these same words. In order to determine word-spelling accuracy, participants' spelling for each word was scored as correct or incorrect, out of a total 3 trials (each word was spelled three separate times). A spelling score of 3 indicated that the word was always spelled correctly, while a spelling score of 0 indicated that the word was never spelled correctly. Intermediate scores indicated that the word was spelled correctly once (1) or twice (2), but not on all three attempts.

Each participant had a different number of words that fell into each of the spelling-score categories. For example, some participants' responses were skewed towards scores of 0/3 while others were skewed towards 3/3. Mean word-reading response times were calculated per participant, for each word and then averaged across participants (see Table 3). In 8% of the cases, the participants read the word accurately but equipment failure resulted in unusable reading times.

Furthermore, data was trimmed by discarding reading response times above 3,000 ms and below 100 ms. Reading times were also discarded when the voice key was inaccurately triggered (e.g., when a noise other than the participant reading the target word triggered the voice key). In total, 12% of data points fell into one of these three categories.

Table 3

*Overall Mean Word-Reading Times by Spelling Accuracy, Within-Participant*

| Spelling accuracy | N[a] | Instances[b] | Mean[c] | SD[c] |
|---|---|---|---|---|
| Always correct (3/3) | 93 | 1625 | 699.56 | 98.35 |
| Twice correct (2/3) | 83 | 197 | 721.77 | 205.68 |
| Once correct (1/3) | 67 | 136 | 748.52 | 247.71 |
| Never correct (0/3) | 93 | 819 | 783.39 | 140.02 |

[a] Number of participants that contributed to the instances.

[b] Total number of individual instances that a word was classified with a particular spelling accuracy.

[c] Mean word-reading times in milliseconds. The word-reading times were calculated separately for each participant, for each spelling classification. These means report the word-reading times averaged across all participants.

A 1 (average word-reading time) x 4 (spelling accuracy) repeated-measures ANOVA was performed where the dependent variable was average word reading speed for all correctly read words and the independent variable was spelling accuracy out of three attempts. Mauchly’s test indicated that the assumption of sphericity had been violated, $x^2 = 35.38$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .772$). Similar to Martin-Chang and colleagues (2014), the repeated-measures ANOVA revealed statistically significant differences in reading response times between the different classification of the spelling accuracy score of words, $F$ (2.316, 143.598) =4.60, $p = .008$, $d = .07$. Correcting for family-wise error ($p = .05/3 = .01667$), post-hoc analyses revealed statistically significant differences between reading response times with words that participants always misspelled (0/3 spelling score; see Table 3 for mean word-reading times) and words that they always spelled accurately (3/3; $p < .001$). There is also a statistically significant difference between words that participants always misspelled (0/3) and words that participants spelled accurately twice (2/3; $p = .016$). However, all other post-hoc analyses failed to reveal statistically significant differences (all *p's* > .01667).

**Target-word spelling stability.** The second goal of this study was to determine whether word-reading speed differed according to spelling stability. Therefore, the 819 words that were always misspelled (i.e., that had a score of 0/3 on accuracy; see Table 3) were analyzed to determine how often they were misspelled in the same fashion (see Table 4).

Participants could misspell words a number of different ways (e.g., *said* could be spelled as *siad*, *sid*, *sed*) or always the same way (e.g., *sed*). Words that are always misspelled in the same way have a more stable orthographic representation than words that are misspelled in different ways. A grading system for spelling stability was thus established, similar to Martin-Chang et al. (2014). Words that were always misspelled were recoded according to how stable their spellings were across all three trials.

Table 4

*Overall Mean Word-Reading Times by Spelling Stability, Within-Participant*

| Spelling Stability[a] | N[b] | Instances[c] | Mean[d] | SD[d] |
|---|---|---|---|---|
| Always correct (3) | 93 | 1625 | 699.56 | 98.35 |
| Always incorrect: | 93 | 819 | 783.39 | 140.02 |
| One unique misspelling (2) | 91 | 469 | 770.17 | 145.67 |
| Two unique misspellings (1) | 75 | 235 | 830.97 | 221.99 |
| Three unique misspellings (0) | 39 | 115 | 910.30 | 304.90 |

[a] Higher scores represent more stable orthographic representations.

[b] Number of participants.

[c] Number of individual instances that a word was classified with a particular spelling stability.

[d] Word-reading times in milliseconds. The word-reading times were calculated separately for each participant, for each spelling stability classification. These means report the word-reading times averaged across all participants.

The highest stability score (3) indicates that the word has both a highly stable and accurate representation given that the word was spelled in the same, correct, manner on all three trials. This spelling score was reserved for words that were always spelled accurately. Words that were always spelled in the same way, but that were misspelled, were considered to have a stable, yet inaccurate, orthographic representation. These words were given a score of 2 (3 trials – 1 unique spelling = 2). Words that were misspelled two different ways were given a score of 1 (3 trials – 2 unique spellings = 1). Finally, words that were misspelled in different ways across all three trials were given a score of 0 (3 trials – 3 unique spellings = 0).

A 1 (average word-reading time) x 4 (spelling stability) repeated-measures ANOVA was performed where the dependent variable was word-reading time and the independent variable was spelling stability. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2 = 25.62$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .658$). The repeated-measures ANOVA revealed statistically significant differences in reading response times between the different classification of the spelling stability score of words, $F$ (1.97, 63.15) = 8.14, $p = .001$, $d = .20$. Correcting for family-wise error ($p = .05/3 = .01667$), post-hoc analyses revealed statistically significant differences between reading response times with words that were always spelled correctly (3), words that were always misspelled in the same way (2; $p = .009$), and words that were always misspelled in different ways by participants (0; $p < .001$). The reading times for words that were always misspelled in different ways (0) were statistically significantly different than for words that were misspelled in the same way (2; $p = .011$). Statistically significant differences were also found between words that were always spelled correctly (3) and words that were misspelled in two different ways (1; $p < .001$).

Although each participant had a different number and combination of words that he or she could and could not spell, it stands to reason that individual word properties (i.e., word length, number of phonemes, number of syllables, frequency in English) may be responsible for a word being more difficult to spell, as well as more difficult to read. Therefore, the analyses of spelling accuracy and spelling stability were also performed using a within-word analysis in order to keep word properties constant.

**Within-word analysis**

**Target-word spelling accuracy.** Some words were much more difficult to spell (e.g., ‘plagiarism’, 3/3 = 12) than others (e.g., ‘reasoning’, 3/3 = 80). Therefore, reading times were also analyzed per word. This kept the word properties constant. This type of analysis showed whether the same words were read faster or slower according to whether different people spelled them accurately or inaccurately. A 1 (average word-reading time) x 4 (spelling accuracy) repeated-measures ANOVA was performed, where the dependent variable was word-reading time and the independent variable was spelling accuracy. Mauchly’s test indicated that the assumption of sphericity had been violated, $x^2 = 25.43$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .613$). Consistent with the within-participant analyses, the repeated-measures ANOVA revealed statistically significant differences in reading response times between the different classification of spelling scores, $F(1.84, 47.82) = 10.24$, $p < .001$, $d = .282$. Correcting for family-wise error ($p = .05/3 = .01667$), post-hoc analyses revealed that the differences lie in reading response times between words never spelled correctly (0/3), words always spelled correctly (3/3; $p < .001$), and words spelled correctly twice (2/3; $p < .001$). Words always spelled correctly (3/3) and words spelled correctly twice (2/3) were also statistically significantly different ($p = .004$). Statistically significant differences were also found between words that were always spelled correctly (3/3) and words that were spelled correctly once (1/3; $p = .015$; see Table 5 for mean word-reading times).

Table 5

*Overall Mean Word-Reading Times by Spelling Accuracy, Within-Word*

| Spelling accuracy | N[a] | Instances[b] | Mean[c] | SD[c] |
|---|---|---|---|---|
| Always correct (3/3) | 29 | 1625 | 686.64 | 62.73 |
| Twice correct (2/3) | 29 | 197 | 735.55 | 130.29 |
| Once correct (1/3) | 29 | 136 | 759.10 | 174.62 |
| Never correct (0/3) | 30 | 819 | 849.18 | 199.81 |

[a] Number of words.

[b] Number of individual instances that a word was classified with a particular spelling accuracy.

[c] Word-reading times in milliseconds. The word-reading times were calculated separately for each word, for each spelling classification. These means report the word-reading times averaged across all words.

**Target-word spelling stability.** A spelling stability score was once again calculated for all 819 words that were misspelled on all three trials; however, this time the word-reading times were calculated within-word (see Table 6).

Table 6

*Overall Mean Word-Reading Times by Spelling Stability, Within-Word*

| Spelling Stability[a] | N[b] | Instances[c] | Mean[d] | SD[d] |
|---|---|---|---|---|
| Always correct (3) | 29 | 1625 | 686.64 | 62.74 |
| Always incorrect: | 30 | 819 | 849.18 | 199.81 |
| One unique misspelling (2) | 29 | 469 | 800.91 | 206.93 |
| Two unique misspellings (1) | 25 | 235 | 829.61 | 146.45 |
| Three unique misspellings (0) | 23 | 115 | 981.30 | 234.55 |

[a] Higher scores represent more stable orthographic representations.

[b] Number of words.

[c] Number of individual instances that a word was classified with a particular spelling stability.

[d] Word-reading times in milliseconds. The word-reading times were calculated separately for each word, for each spelling stability classification. These means report the word-reading times averaged across all words.

A 1 (average word-reading time) x 4 (spelling stability) repeated-measures ANOVA was performed where the dependent variable was word-reading time and the independent variable was spelling stability. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2 = 43.84$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .494$). The repeated-measures ANOVA revealed statistically significant differences in reading response times between the different classification of the spelling stability score of words, $F$ (1.48, 26.68) = 19.23, $p < .001$ , $d = .52$. Correcting for family-wise error ($p = .05/3 = .01667$), post-hoc analyses revealed statistically significant differences between reading response times with words that participants always spelled accurately (3), words that were always misspelled in the same way (2; $p < .001$), words that were misspelled two different ways (1; $p < .001$), and words that were misspelled in three different ways (0; $p < .001$). Post-hocs also revealed statistically significant differences between reading response times with words that were misspelled in the same way (2) and that were misspelled in three different ways (0; $p < .001$). Statistically significant differences were also found between words that were misspelled in two different ways (1) and words that were misspelled in three different ways (0; $p = .016$).

## Discussion

The goal of the present study was to determine whether reading time was affected by orthographic quality on a word-by-word basis. According to the LQH, words that have a higher quality orthographic representation should be accessed more efficiently. In this study, orthographic quality was determined through tests of spelling accuracy and spelling stability. Words spelled consistently accurately were taken to have stronger orthographic representations than when they were spelled accurately only a fraction of the time. Similarly, words consistently misspelled in the same way were taken to have more stable orthographic representations than words that were misspelled in different ways across trials.

Consistent with previous findings (Martin-Chang et al., 2014; Ouellette et al., 2017) the correlational results of this study revealed that participants with stronger general spelling skills also had stronger general reading skills. This pattern was observed at the level of individual words as well. Single-word reading speed was examined from different vantage points. The results were robust; both within-participant and within-word analyses reveal that single-word reading speed was faster with words that were accurately and stably spelled compared to those that were of low quality.

My novel contribution to the field was the investigation of reading speed in relation to orthographic representations that fall in-between high and low quality. Working with a population of teenagers, whose spelling abilities are still developing, provided opportunities to observe orthographic representations that were progressing towards being accurate and highly stable. Results from the repeated measures ANOVA show that as spelling accuracy progressed from inaccurate to accurate, single-word reading speed also became reliably faster.

The data reported here fit nicely with the LQH, which states that fluent reading will occur more readily when encountering words with higher quality mental representations (Perfetti & Hart, 2001). In this study, the orthographic representation of words accurately read aloud by participants was recorded. Indeed, the higher the quality of these representations, the faster the participants' single-word reading time. A recent experimental study showed similar results. Ouellette and colleagues (2017) trained their participants to spell words. Following training, words that participants learned how to spell were read statistically significantly faster than words that participants continued to misspell.

Print exposure has been posited to be one of the primary contributors of orthographic learning (Castles & Nation, 2006). In this study, I performed a regression analysis to determine the influence of print exposure on participants' general spelling skills. As outlined in the results, all measures of reading and spelling skills were significantly and positively[1] correlated with participants' performance on the ART: the more participants read for pleasure, the better their performance with regards to reading and spelling. However, it could be argued that individuals who read more for pleasure have better reading skills, and that it is reading skills that are driving the correlation between the ART scores and spelling skills. By performing a regression analysis and controlling for reading skills, performance on the ART is still predictive of general spelling scores. The analysis was especially stringent because by factoring reading skills out first, I removed both general reading skills and reading skills that have been improved presumably by print exposure itself. Yet, print exposure continued to account for unique variance in spelling skill.

[1] Except in the case of reading speed, where a negative correlation indicates faster reading times

Single-word reading time was also statistically significantly correlated with scores on the ART, indicating that the more a participant read for pleasure, the faster their reading speed. In line with our findings, Lowder and Gordon (2017) revealed that participants with higher print exposure read words at a faster speed on all trials, while participants with less print exposure read words more slowly at first, but were able to catch up after priming repetition. By extension, the results from the current study concur that higher levels of print exposure are associated with faster and more efficient lexical access when reading. Interestingly, the results from the current study point to the fact that higher levels of print exposure are associated with more accurate spelling of individual words.

**Limitations and Future Research**

Limitations of this study include the fact that the focus was on orthographic representations and not on the other facets of the LQH: namely semantic and phonological representations. The chosen target-words were deemed appropriate for teenage population, and the added target-words had a higher frequency in spoken English than the previously-used target words (Martin-Chang et al., 2014; Ouellette et al., 2017). Although efforts were made to use words that students contained in their spoken vocabularies, future research should take into account all three components.

The study was correlational in nature; therefore it could be that a higher-order variable, such as IQ, lead to both faster reading and better spelling. However in this study the within-word comparisons held individual differences between participants constant. At this level of analysis, differences in reading times were measured for each word with regards to the possible spelling scores. Lexical quality of words varies across individuals, as well as within individuals; a specific word will be of higher orthographic quality for some individuals over others. In this way, reading times for individuals with a range of IQ abilities were included in each spelling score of every word. Reading times got progressively faster as spelling accuracy and stability of words improved.

Similarly, repetition priming could have accounted for the faster times. Perhaps when participants read items that were correctly spelled, they were primed to read the words more quickly the next time they were encountered. This same degree of priming would not be anticipated for words that were misspelled. To avoid this complication, target-word reading times were measured first and target-word spelling accuracy was measured two weeks later. This design precludes the priming argument, because all of the words were initially seen in their correct forms. It should be noted that variation in spelling was still observed even though all of the participants saw the correct spelling of the target words. Furthermore, the fact that participants were able to read the words with the correct pronunciation, regardless of their spelling accuracy, indicates that partial or erroneous orthographic representations can still lead to accurate reading (Conrad, 2008).

Future studies can consider the types of spelling errors made and whether they affect reading times differently. For instance, does reading time differ according to how far the spelling of the word deviates from its accurate spelling? Do the locations of the spelling errors (i.e., beginning, middle or end of the word) make a difference in reading times? This is an exciting area of inquiry; these and many more questions should be examined in the near future.

**Implications**

The findings from the current investigation suggest that words with higher quality orthographic representations are read faster. This is critical because it has been posited that reading fluency at the text level frees up resources for comprehension (Perfetti & Hogaboam, 1975). When reading is less fluent and more laborious, it places higher demands on working memory which in turn creates a processing bottleneck with regards to comprehending connected text (Wolf & Katzir-Cohen, 2001). Thus, improving spelling skills could be an untapped resource into enhancing reading fluency.

How might spelling be improved? This data suggest reading for pleasure. The ART is an indicator of how much reading practice an individual has; increasing print exposure could lead to faster reading times and better spelling. This study shows that not only is the ART an index of how much individuals read, it also is an indicator of individuals' lexical access efficiency during reading (Lowder & Gordon, 2017; Moore & Gordon, 2015). Additionally, analyses from the current study point to the ART being an indicator of individuals' spelling abilities. Therefore, getting students to read more for pleasure should be a high educational priority.

In conclusion, this work represents an important step towards understanding the relationship among cognitive mechanisms associated with reading and spelling. Whereas previous work has shown that there is a difference between reading times of low- and high-quality orthographic representations (Martin-Chang et al., 2014; Ouellette et al., 2017), the current study went one step further and confirmed that as spelling progresses towards being accurate and highly stable, reading speed increases incrementally as well. My results also suggested that reading for pleasure may foster spelling abilities in both children and adults, and should be encouraged in school and in the home. In sum, the results support the notion that the more individuals read for pleasure, the faster their reading speed and the higher their spelling skills; reading practice has thus been shown to promote higher quality orthographic representations, and these higher orthographic representations in turn support reading fluency.

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Appendices

Appendix A

Target Word Characteristics

| | Number of letters | Number of phonemes | Number of syllables | Frequency per million[a] |
|---|---|---|---|---|
| (Martin-Chang et al., 2014) | | | | |
| Diaphragm | 9 | 7 | 3 | 2.06 |
| Silhouette | 10 | 6 | 3 | 0.57 |
| Toboggan | 8 | 7 | 3 | 0.08 |
| Zucchini | 8 | 7 | 3 | 0.96 |
| Plagiarism | 10 | 8 | 3 | 0.35 |
| Fluorescent | 10 | 9 | 3 | 0.59 |
| Gradient | 8 | 8 | 3 | 0.18 |
| Hooligan | 8 | 7 | 3 | 0.73 |
| Propeller | 9 | 7 | 3 | 1.53 |
| Salutation | 10 | 9 | 3 | 0.12 |
| Lollipop | 8 | 7 | 3 | 1.78 |
| Disruption | 10 | 9 | 3 | 1.00 |
| | | | | |
| (Ouellette et al., 2017) | | | | |
| Accommodate | 11 | 8 | 4 | 2.14 |
| Nauseous | 8 | 5 | 2 | 3.10 |
| | | | | |
| Additional words | | | | |

| | | | | |
|---|---|---|---|---|
| Supposed | 8 | 6 | 2 | 252.25 |
| Opinion | 7 | 7 | 4 | 42.00 |
| Particular | 10 | 8 | 4 | 27.90 |
| Disappear | 9 | 7 | 3 | 20.96 |
| Embarrass | 9 | 7 | 3 | 8.82 |
| Possibilities | 13 | 11 | 5 | 7.57 |
| Significant | 11 | 11 | 4 | 6.49 |
| Challenging | 11 | 8 | 3 | 3.80 |
| Precision | 9 | 8 | 3 | 2.94 |
| Reasoning | 9 | 7 | 3 | 1.82 |
| Obedience | 9 | 8 | 4 | 1.71 |
| Blizzard | 8 | 6 | 2 | 1.94 |
| Physics | 7 | 6 | 2 | 9.45 |
| Elevation | 9 | 8 | 4 | 0.92 |
| Fascinate | 9 | 7 | 3 | 0.51 |
| Beneficial | 10 | 9 | 4 | 0.78 |

[a] Brysbaert and New (2009)

Appendix B

Author Recognition Test (ART)[2]

**<u>Author Checklist</u>**

On the next page you will find a list of names. Some of these names are popular authors and some are not. Please read the names and put an **'x'** beside the names that you recognize as being **real authors**. <u>Please do not guess.</u> Remember, some of the names are not real, so guessing can be easily detected.

**EXAMPLE:**

| **Author** | **'x' real author** |
|---|---|
| Dr. Seuss | **X** |
| Jane Doe | |
| John Smith | |

If you knew that Dr. Seuss was an author, then you would place an 'X' beside his name. if you were not sure whether Jane Doe or John Smith were authors, then you would NOT place an 'X' beside their names.

[2] For demonstration purposes, foils are italicized.

| **Author** | **Pls 'x' real authors, Do not guess.** | | **Author** | **Pls 'x' real Authors, Do not guess** |
|---|---|---|---|---|
| V. C. Andrews | | | *Robert Emery* | |
| Isaac Asimov | | | Jeffery Eugenides | |
| Margaret Atwood | | | Gordan Korman | |
| Jean M. Auel | | | Timothy Findley | |
| Russell Banks | | | John Flanagan | |
| David Baldacci | | | Robert Fulghum | |
| Sharon Creech | | | Diana Gabaldon | |
| James Dashner | | | Howard Gardner | |
| Roald Dahl | | | Elizabeth George | |
| Martin Ford | | | *Stephen J. Gould* | |
| Cornelia Funke | | | Sue Grafton | |
| *Elliot Blass* | | | Andrew Greeley | |
| *Christopher Barr* | | | *Sheryl Green* | |
| *Lauren Benjamin* | | | John Grisham | |
| Carol Berg | | | Alex Haley | |
| Pierre Berton | | | *Mimi Hall* | |
| *Thomas Bever* | | | Frank Herbert | |
| Maeve Binchy | | | S. E. Hinton | |
| Judy Blume | | | Erin Hunter | |
| Dan Brown | | | John Jakes | |
| *Jennifer Butterworth* | | | E.L. James | |
| *Katherine Carpenter* | | | Erica Jong | |
| Barbara Cartland | | | Wayne Johnston | |
| Agatha Christie | | | Robert Jordan | |

| | | | | |
|---|---|---|---|---|
| Noam Chomsky | | | *Frank Kiel* | |
| Wayson Choy | | | Laurie King | |
| Tom Clancy | | | Stephen King | |
| Arthur Clarke | | | Jeff Kinney | |
| *Suzanne Clarkson* | | | Naomi Klein | |
| James Clavell | | | Sophie Kinsella | |
| Suzanne Collins | | | Dean Koontz | |
| Jackie Collins | | | Judith Krantz | |
| Stephen Coonts | | | Louis L'Amour | |
| *Edward Cornell* | | | Margaret Laurence | |
| Patricia Cornwell | | | Ursula LeGuin | |
| Robertson Davies | | | Madeleine L'Engle | |
| *W. Patrick Dickson* | | | *Pricilla Levy* | |
| C. S. Lewis | | | Gary Paulsen | |
| Lois Lowry | | | Philip Pullman | |
| Robert Ludlum | | | Daniel Quinn | |
| *Alex Lumsden* | | | Anne Rice | |
| George R.R. Martin | | | Mordecai Richler | |
| Ann Marie McDonald | | | Rick Riordan | |
| *Morton Mendelson* | | | J.K. Rowling | |
| Stephenie Meyer | | | Rachel R. Russell | |
| Janet Evanovich | | | Robert J. Sawyer | |
| James Michener | | | *Miriam Sexton* | |
| Rohinton Mistry | | | Carol Shields | |
| Christopher Moore | | | Sidney Sheldon | |

| | | | | |
|---|---|---|---|---|
| Lucy Maud Montgomery | | | *Robert Siegler* | |
| Michael Moore | | | Lemony Snicket | |
| *James Morgan* | | | Danielle Steel | |
| Alice Munro | | | *Mark Strauss* | |
| Katherine Paterson | | | *Destin Shaw* | |
| M. Scott Peck | | | Amy Tan | |
| *David Perry* | | | Miriam Toews | |
| Kate Pullinger | | | Alvin Toffler | |

Appendix C

Consent From

UNIVERSITÉ Concordia UNIVERSITY

**PARENT INFORMATION AND CONSENT FORM**

**Study Title:** The Reading and Spelling Connection
**Researcher:** Maya Rossi
**Researcher's Contact Information:** maya.rossi@concordia.ca
**Faculty Supervisor:** Dr. Sandra Martin-Chang
**Faculty Supervisor's Contact Information:** (514) 848-2424 x8932, (514) 226-6250, or email at: s.martin-chang@concordia.ca
**Source of funding for the study:** NSERC #N01519

Your child is being invited to participate in a research study.

**A. PURPOSE**

The purpose of the research is to examine the connection between reading and spelling.

**B. PROCEDURES**

If your child participates, he/she will be asked to do some reading and spelling, including:

1) Spelling 30 words in class,
2) Reading 30 words off a computer screen, with a Master's student from Concordia, Education Department.

In total, participating in this study will take approximately 30 minutes.

Your child's participation will add to the scientific literature explaining the relationship between reading and spelling in adolescents. The findings generated from such studies are influential in the creation of educational programs, and your child's involvement would be extremely appreciated.

**C. RISKS AND BENEFITS**

There are no risks to your child with regard to his/her involvement in this study.

## D. CONFIDENTIALITY

By agreeing to have your child participate in this study, you agree to let the researcher use the information gathered during testing. No one else will be allowed to access the information, including members of your child's school. Only people directly involved in conducting the research will be able to access the information. The information will only be used for the purposes of research described in this form. The information gathered will be anonymous. That means that it will not be possible to make a link between your child and the information he/she provides. We will protect the information by keeping data in a locked room at all times. We will destroy the information five years after the end of the study. Only group data from this project will be published; all information gathered will only be used for the sake of compiling data and sharing it with a scientific audience. Your child will never be identified by name.

## E. CONDITIONS OF PARTICIPATION

Before working with the researcher, your child will be asked whether he/she chooses to do so. If your child agrees to participate, your child will be advised that he/she can choose to stop participating at any point.

If you sign this form for your child, your child can still stop participating at any time he/she wishes. There are no negative consequences for not participating or stopping in the middle of the study. You or your child can also ask that the information your child provides not be used, and this choice will be respected. If you or your child decide that you do not want us to use your information, please inform the researcher before **April 15th 2017**.

To thank your child for participating in this research, he/she will receive a **$5 gift card to Tim Hortons**. To make sure that research money is being spent properly, auditors from Concordia or outside will have access to a coded list of participants. It will not be possible to identify your child from this list.

## F. PARTICIPANT'S DECLARATION

I have read and understood this form. I have been given contact information where I can ask questions and any questions have been answered. **I agree to let my child participate** in this research under the conditions described.

CHILD'S NAME (please print)_______________________________________________

PARENT'S NAME (please print) ______________________________________________

PARENT'S SIGNATURE ______________________________________________

DATE ______________________________________________

If you have questions about the scientific or scholarly aspects of this research, please contact the researcher. Their contact information is on page 1. You may also contact their faculty supervisor.

If you have concerns about ethical issues in this research, please contact the Manager, Research Ethics, Concordia University, 514.848.2424 ex. 7481 or oor.ethics@concordia.ca.

Appendix D

Assent Form

The following people have given their assent for participation in the experiments conducted by Maya Rossi for Dr. Sandra Martin-Chang, Department of Education, Concordia University, Montreal.

I, ______________________________________________, want to participate in Maya Rossi and Dr. Sandra Martin-Chang's study on *The Reading and Spelling Connection*.

Signature: _______________________________________ Date: __________________________

Appendix E

Script

**Session 1**

**Assent**

*"Would you like to do some reading and spelling activities with me today?"*

**Reading Target Words**

**Instructions.** *"To begin, you are going to be reading words from this computer screen. I ask that you please read these words as accurately and as quickly as possible.*

*Once you begin, a word will appear on the screen. The word will vanish as soon as you read it and be replaced with a star. The star will be on the screen for 2 seconds, and then the next word will appear.*

*First I will show you an example of how it works, and then you will get to do a quick trial run before beginning the real activity.*

*For example, see how the trial starts with a *; the * will be present on the screen for 2 seconds. Then, the word will appear -SPACE-. Once the word appears, read it as quickly and as accurately as you can, speaking into this microphone (kind of like a youtube video ☺). The microphone will not record your voice, it is only picking up on the sound you make when you read the word.*

*Now that you've seen how it works, let's do a trial run."*

****

*"How was that? Do you need a break? Can you do that again for about a minute and thirty seconds?"*

## Session 2

### WRAT4 Spelling

**Instructions.** ***"****Now I am going to read you some words that I would like you write out for me. Please write legibly and in print (not in cursive). I will say the word, then read a sentence with the word in it, and then say the word again. The words start off quite easy but go beyond your grade level and get very difficult. I don't expect you to spell them all correctly. It's OK to make mistakes. Do the best you can. I'll stop you when we get towards the middle. Ready?"*

**Notes.**

- Pronounce each word, then read it in the sentence, then pronounce it again.
- Words may be repeated as necessary.
- Stop after 10 errors in a row.

*"Wow. These words are really hard. I think that's enough for now. You did a great job, there were some really difficult words in there."*

### WRAT4 Reading

**Instructions.** *"I am going to show you a list of words. I want you to notice something about this list. It starts off easy, but gets really, really hard, even for adults. So we're not going to read the whole list. I want you to read as many words as you can, to the best of your ability. You're going to read the words from left to right as if you were reading a story (hold up sheet and motion from left to right). Read the words at a regular reading pace and I'll stop you when we get to the middle of the page."*

(Stopping after 10 errors in a row)

*"Wow. These words are really hard. I think that's enough for now. You did a great job, there were some really difficult words in there."*

**Scoring.** Correct: circle number / Incorrect: slash through number

**Notes:**

- 10 errors in a row: stop
- 1st error: prompt
- Pausing more than 10 seconds: skip
- Circle #: correct
- Line through #: incorrec

**Author Recognition Test**

**Instructions.** *"For the next activity, I am giving you a list of names. Some of these names are popular authors and some are not. Please read the names and put an* ***'x'*** *beside the names that you recognize as being real authors. Please do not guess. Remember, some of the names are not real, so guessing can be easily detected.*

*Please read through the brief instructions and example, and then turn the page to begin."*

**Notes.** While participant is doing the ART, score the WRAT4-Spelling and ask if there are any letters you cannot decipher).

**Participant Information**

**Instructions.** *"Please fill out this short form concerning the languages that you speak. Then we are done ☺"*

Appendix F

Participant Information

1. Please indicate your **DATE OF BIRTH** (day/month/year): ____________________,

   Your **AGE**:______________________,

   Your **GRADE LEVEL**: ______________________,

   Circle: **-Female** **-Male**

2. What is your **NATIVE** language? (The language that you learned as a child)
   a. English
   b. French
   c. Both
   d. Other: __________________

3. Please circle your proficiency in these languages:
   a. English

      Basic Fair Good Excellent

   b. French

      Basic Fair Good Excellent

4. Please write down any other spoken languages and your proficiency in them:

   1. ________________________

      Basic Fair Good Excellent

   2. ________________________

      Basic Fair Good Excellent

   3. ________________________

      Basic Fair Good Excellent

5. What language do you speak most often at **home**?

______________________________________________________________________________
__________

6. What language do you speak most often at **school**?

______________________________________________________________________________
__________

7. What was the primary language of instruction at your Elementary School?
    a. English
    b. French
    c. Both
    d. Other: _________________________

# Thank You!