THE IMPACT OF SPELLING ACCURACY ON READING SPEED:

ORTHOGRAPHIC QUALITY, ERROR LOCATION, AND TYPE OF ERROR

BY

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Abstract

The purpose of this study was to replicate research demonstrating the relation between the quality of orthographic representations (as manifested by spelling accuracy) and reading speed. The impact of error location and consonant versus vowel errors was also evaluated. Seventy-eight participants (56 female; 22 male) with a mean age of 19.82 (*SD* = 2.32) participated in the study. Participants were given two standardized tests – the WJ-III and the TOWRE-2, as well as an experimental spelling task and an experimental reading task consisting of the same words. Results replicated prior studies in that the quality of orthographic representations, as indexed by spelling accuracy, was directly reflected in reading speed. Further, it was found that the location of the first spelling error within a word influenced the reading speed of that word but, there was no significant difference in reading time depending on the type of error (vowel or consonant based). In conclusion, and consistent with previous research, spelling accuracy plays an important role in reading speed on an individual word basis which can, in turn, influence the fluency of reading.

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The ability to effectively spell and read have extensive implications on ones' life from the type of education they receive, the jobs they qualify for, and even the amount of respect given by their community. Unfortunately, not everyone has highly proficient literacy skills. It has been observed that spelling and reading are related to one another; however, the exact relation is unclear. The purpose of the current study is to investigate the relation between spelling ability – a reflection of orthographic representations – and reading speed. Further, it is of interest to explore the effects of different types of spelling errors on an individual's ability to read those same words. In particular, it is not clear if the location of a spelling error within a word or the involvement of consonant vs. vowel errors have different implications for reading. Spelling error location is hypothesized here to have an effect on reading speed meaning that errors in certain parts of a word can be more detrimental to reading than others. In addition, consonants errors are proposed to be more detrimental to reading performance than vowel errors due to their specificity and relation to articulation.

The speed at which an individual can read has been found to be positively correlated with spelling ability (Martin-Chang, Ouellette, & Madden, 2014; Ouellette, Martin-Chang & Rossi, 2017; Perfetti & Hart, 2002; Rossi, Martin-Chang, & Ouellette, 2019). Spelling ability is often used as a measure to assess the quality of orthographic representations. The quality of an orthographic representation refers to the extent to which a word is stored in an individual's lexicon (Rossi et al., 2019). Therefore, higher quality orthographic representations are related to better spelling and predicted to be related to faster reading (Martin-Chang, et al., 2014; Ouellette et al., 2017; Rossi et al., 2019). These findings are explained by many theories, including the lexical quality

hypothesis (LQH), partial cue reading, and descriptive components of spelling ability, such as the accuracy and stability of representations.

Lexical Quality Hypothesis

According to the LQH, variations in the quality in a word representation have an effect on reading skills. High quality lexical representations allow for more rapid and reliable retrieval, which in turn, allows for faster reading. In contrast, low quality orthographic representations have less specified representations, which result in inefficient retrieval, which then slows reading speed (Perfetti, 2007). Lexical quality – the extent to which phonology, orthography, and semantics coherently interconnect – is proposed to be related to reading speed. Martin-Chang et al. (2014) determined that higher quality orthographic representations are related to more fluent and less context dependent reading. Therefore, when poor spellers, with low orthographic representations, are given context, the semantics aid in filling in the gaps that are missing from orthography and phonology in the representation (Perfetti & Hart, 2002). On the other hand, good spellers rely less upon context because their orthographic and phonetic information is intact. However, even good spellers can have some poor quality orthographic representations; whereas, some poor spellers can have some high quality orthographic representations (Conrad, 2008). Good spellers will have some incomplete representations in their lexicon which may slow reading or interrupt fluency for those words. In contrast, poor spellers will have some complete representations in their lexicon which allow for accurate spelling and faster reading of those words.

Considering orthographic quality is operationalized by spelling abilities, research by Martin-Chang et al. (2014) determined that higher spelling abilities overall are

positively correlated with more fluent reading. This research was done using a computer software system that presented words on a screen and measured the time it took for participants to read each word. A spelling test with the same words was administered seven days later. According to the LQH, low quality orthographic representations should take longer to access, and therefore, slow reading time. Martin-Chang et al. found evidence that supported this hypothesis, both between participants (better spellers were faster readers) and within participant (words that a participant spelled accurately were read faster).

Additionally, Rossi et al. (2019) expanded the research on the LQH to include intermediate representations. Intermediate representations are words that are spelled correctly, but only sometimes. They are unstable, since they are sometime spelled correctly and sometimes spelled incorrectly. In addition, they are not accurate, since they are not always spelled correctly, however, they are not completely inaccurate because they are not always spelled incorrectly. Rossi et al. found evidence that intermediate quality representations were read faster than low quality representations, providing further support for the LQH.

Since spelling is a learned skill, we have the ability to increase the quality of our orthographic representations through spelling practice. Ouellette et al. (2017) hypothesized that spelling practice would impact reading abilities on a word-by-word basis. They were correct in that improvements in spelling brought about improved reading speed. Their conclusions suggested that orthographic representations are related to reading speed because improvements in spelling lead to improvements in reading

speed. However, reading practice is less influential – improvements in reading are less generalizable to improvements in spelling.

Partial Cue Reading

Conrad (2008) examined the transfer between spelling and reading and reading and spelling. This was tested by assigning participants (41 second grade children) to one of two practice conditions: reading or spelling practice of the same words. The post-practice phase consisted of reading or spelling the same list of words to test word-specific transfer. That is, those in the reading practice group were instructed to spell the words, and those in the spelling practice group were instructed to read the words. In addition, they were tested with new words to measure the generalizability of their practice. It was determined that transfer goes both ways; reading practice led to improvements in spelling and spelling practice led to improvements in reading. However, practice in spelling was the most beneficial, suggesting that spelling practice leads to better improvements in the quality of ones' orthographic representations. Conrad's suggestion is supported by partial cue reading. Lower quality representations would impede spelling but are sufficient for reading; however, they might slow lexical access, and therefore slow reading speed (Rossi et al., 2019). This is because there are more ways to spell a phoneme then there are ways to pronounce a grapheme (Holmes & Castles, 2001). Although reading will be slowed, partial information about orthographic representations may be enough for reading longer words (Holmes & Carruthers, 1998). High quality orthographic representations are necessary for short words as a single letter can change their pronunciation and meaning (e.g., fold, fond, food). However, in longer words not every letter is necessary as the change does not represent another word (e.g., seperate vs.

separate). The lack of quality in this representation causes a deviation in spelling but may be sufficient to still produce accurate reading (Holmes & Carruthers, 1998).

Accuracy

Different types of orthographic quality can be observed when examining the accuracy of spelling. Accuracy refers to the ability to spell the word always correctly, always incorrectly, or inconsistently across attempts (Rossi et al., 2019). According to the LQH, when a word has an inaccurate representation stored, the word may still be read, however, reading time will be slower; yet prior results have been mixed in supporting this contention. Holmes and Carruthers (1998) determined that accuracy was not related to reading speed on a silent reading task, however, Burt and Tate (2002) concluded that reading speed was affected by the accuracy of a representation. It is important to note that both of these studies had a major flaw – both assessed accuracy over just one spelling trial. As Martin-Chang et al. (2014) stated, accurate spelling over one trial is insufficient to conclude whether a participant has an accurate orthographic representation. Therefore, in subsequent studies by Martin-Chang et al., Ouellette et al. (2017), and Rossi et al. spelling accuracy was measured over three to five trials.

The importance of repeated testing for accuracy was clear in a study conducted by Rossi et al. (2019). Adding to the results of Martin-Chang et al. (2014), they examined the effects of intermediate representations – words spelled correctly only in some trials. Spelling was assessed over three trials and those who spelled the word correctly two out of three times were deemed to have intermediate representations. Words with intermediate representations were read significantly faster than words with low quality representations (i.e., words spelled incorrectly all three times), yet slower than words of

higher quality representations (i.e., words spelled correctly all three times). Although these words have intermediate orthographic quality, they are not completely stable representations, which affects reading speed as well.

Stability

Stability refers to the consistency of spelling. For example, if a word is spelled incorrectly the same way multiple times, it has low accuracy, but high stability. The effects of stability were measured by Martin-Chang et al. (2014) when they examined the LQH. Since stability is a component of the LQH, it was predicted that more stable representations would be read faster. Their results supported the LQH, showing that more stable representations are read significantly faster than unstable representations. Similarly, after Rossi et al. (2019) tested for accuracy, they took words that were never spelled correctly over three trials and examined the stability of the participants' mistakes. Words that were misspelled incorrectly in one unique way were read significantly faster than words spelled incorrectly in two or three unique ways. This finding is evidence that the stability of a representation plays a role in reading speed. However, stability alone is not enough to produce maximum reading speed, accuracy is also required. Words with high stability and high accuracy are read 20 percent faster than words with high stability and low accuracy, providing evidence for the role of both accuracy and stability in orthographic representations (Ouellette et al., 2017).

Spelling Errors

It is unclear if all spelling errors are equally detrimental to orthographic quality and reading. Hypotheses may be derived from several theories, including serial and parallel processing. Serial processing would suggest that errors at the beginning of a word

are more detrimental to reading speed, however, models of parallel processing would counter this hypothesis.

Serial processing. Serial processing suggests that we process words sequentially from left to right (Kwantes & Mewhort, 1999). Therefore, one would assume that spelling errors occurring at the beginning of the word, indicating an orthographic representation that is inaccurate early in the word, would be more problematic for reading than errors at other points in the word. According to the cohort model – a model based on serial processing – as the word is processed potential words, called "candidates", are eliminated (Lima & Inhoff, 1985). Because the initial phonemes of a word are used to activate a cohort of potential words, an error at the beginning would activate the wrong cohort. However, if an error is located at the end of a word, there would be a limited number of candidates left to choose from, making the error less influential on reading. The threshold at which there is only one remaining candidate is known as the uniqueness point (Kwantes & Mewhort, 1999). The orthographic uniqueness point refers to the first letter that distinguishes the word from all other candidates. For example, the word "actress" has an orthographic uniqueness point at position four since the "r" distinguishes the word from all other words (e.g., act, actor, actuary). Kwantes and Mewhort hypothesized that the later the orthographic uniqueness point, the more time the word would take to read since the process of eliminating candidates would be longer. They found early orthographic uniqueness points were significantly, positively associated with reading speed, such that the earlier the orthographic uniqueness point, the faster the reading time. It may be reason then, that errors in the orthographic representations

located closer to the beginning of a word would have a more detrimental effect than errors in the medial or latter sections when it comes to reading that word.

Parallel processing. On the other hand, according to the connectionist triangle model there would be other implications for spelling errors. This model proposes parallel processing – the idea that the elements of a word are processed simultaneously and not necessarily sequentially or in a step by step fashion (Kwantes & Mewhort, 1999). This would thus not lead to similar hypotheses as serial processing models.

Connectionist models arose because a grapheme-phoneme correspondence (GPC), a rule-based system, was deemed insufficient to explain skilled reading on its own (Plaut, 1999). Therefore, a connectionist triangle model was proposed, suggesting that individuals gradually learn language and strengthen their own connections (Plaut, 1999; Seidenberg, 2005). Consisting of three separate distributed patterns – orthographic, phonological, and semantic – the model accounts for words that follow rules and those that deviate from the rules (Seidenberg, 2005). These distributed patterns of orthography, phonology, or semantics share activations with words of similar patterns (Plaut, 1999). For example, the word “have” and “gave” share orthographic activations, but not phonological activations. Since they share different activations for phonology, “gave” and “have” will not have equivalent weights. Weights are used to activate words and are considered high or low based on an individual’s exposure to the word. Word frequency accounts for the weight of a word as well as the weights of a word’s neighbour (Seidenberg, 2005). For example, the weight of the word “gave” can be high even if the word is not encountered frequently, due to its high frequency neighbours “gate” and “save” that aid in creating weights for the word “gave”.

Neighbourhood Density

Neighbourhood density refers to the number of connections one word has to others. This is typically determined by how many words can be created by changing a single letter (e.g., gave & have) creating orthographic neighbourhoods, or a single phoneme in the original word (e.g., bad & bat) creating phonological neighbourhoods. (Sears, Hino, & Lupker, 1999). Words with many neighbours are considered to be part of a dense neighbourhood, whereas words with few neighbours are considered to be part of a sparse neighbourhood. The effects of dense or sparse orthographic neighbourhoods on spelling were observed by Roux and Bonin (2009) when they determined that words in dense neighbourhoods were spelled faster and more accurately than words in sparse neighbourhoods. In contrast, Marinelli, Traficante, Zoccolotti, and Burani (2013) found that orthographic neighbourhood size was determined to have no effect on the speed of typically developing children reading aloud. Multatti, Reynolds, and Besner (2006) conducted two experiments; the first measured the effects of phonological neighbourhood size on reading aloud. They found that words with denser phonological neighbourhoods were read faster than words with sparse phonological neighbourhoods. To build upon their first experiment, the second experiment measured the effects of orthographic neighbourhood density on reading speed while controlling for phonological neighbourhood density. Since words with dense orthographic neighbourhoods generally have dense phonological neighbourhoods too, the researchers eliminated this third variable (Multatti et al, 2006). In contrast to phonological neighbourhoods, there was no difference between the time it took to read words aloud from dense or sparse orthographic neighbourhoods.

Phonological neighbourhood effects were measured by Yates (2009) in terms of spread. The spread, as denoted by *P*, refers to how many phonemes can be changed in the word to create a neighbour. They used words that all had three phonemes where two (*P* = 2) or three (*P* = 3) phonemes could be replaced. A lexical decision task determined that words with a higher spread (*P* = 3) were responded to faster than words with a smaller spread (*P* = 2). Therefore, Yates concluded that it was not the number of phonological neighbours a word had, but the number of positions that could be replaced. Longer words (i.e., more distinct) have a small phonological spread since few phonemes can be replaced in a highly specified word.

Taken together, orthographic neighbourhood density has less of an effect on reading than phonological neighbourhood density. Thus, orthographic neighbourhood density will not be manipulated in the current study as it poses little threat as a confounding variable. Phonological neighbourhoods tend to have a greater impact on less specified words. Since the current study utilizes longer words (highly specified), the response time would be unaffected by the spread of the phonemes (Yates, 2009).

Consonant Bias

Consonant bias is the theory that lexical processing is influenced more by consonants than vowels (Nazzi & Polka, 2018). Nazzi, Poltrock, and Von Holzen (2016) proposed that consonants carry more information about the lexicon than vowels. For example, deleting all consonants in a paragraph is far more detrimental to reading than is deleting all the vowels. It was observed by New, Araújo, and Nazzi (2008) that participants could switch between vowels faster than they could switch between consonants, providing evidence that consonants are more distinct, therefore, requiring

more attention. However, some researchers have been wary about consonant bias theory because previous research focused only on words/syllables that began with consonants as opposed to words/syllables that began with a vowel (New et al., 2008). Nazzi and Polka examined whether the position of the vowel or consonant plays a role in lexical processing, perhaps mediating the conclusion of a consonant bias theory. According to the Cohort model, vowels or consonants at the beginning of the word would be more important to lexical processing (Nazzi & Polka, 2018). Based on their research, they concluded that the position of the vowel or consonant did not play a role in the consonant bias. Even when the vowel was at the beginning of the word, the consonant manipulation still posed the biggest threat to reading speed. Therefore, Nazzi and Polka concluded that more weight was given to consonant information which resulted in consonants being more important than vowels for lexical processing.

In addition to being more important for lexical processing, consonants are also more categorical than vowels – meaning that they are more distinct in terms of articulatory acoustic features (Nazzi et al., 2016; New et al., 2008). Nazzi et al. proposed that more categorical distinction among consonants resulted in more reliable and faster processing cues. Similarly, they suggested that lexical representations are accessed more reliably through consonants because they are more distinct. This may lead to a hypothesis that spelling errors involving consonants would be more detrimental to reading speed. To date, this issue has not been fully explored.

The Current Study

The current study is designed to replicate research suggesting that words with higher quality orthographic representations, as measured by spelling accuracy, are read

faster (Burt & Tate, 2002; Martin-Chang et al., 2014; Ouellette et al., 2017; Rossi et al., 2019). Additionally, Martin-Chang et al. and Rossi et al. demonstrated the importance for repeated spelling trials on determining spelling accuracy. Therefore, the current study will assess spelling over three trials. In addition to replicating prior research, the position of a spelling error was also explored to determine if the location of an error had an effect on reading speed. Previous literature on serial processing suggests that errors at the beginning of a word impede reading speed the most (Kwantes & Mewhort, 1999; Lima & Inhoff, 1985), although a connectionist model would suggest otherwise (Plaut, 1999; Seidenberg, 2005). Lastly, it is hypothesized that consonant errors will be more detrimental to reading speed than vowel errors because they are more distinct.

Method

Participants

Seventy-eight students (56 female; 22 male) enrolled in an Introductory Psychology course were recruited through SONA. They received 1% course credit for their participation. All participants were required to be English native speakers, with 59 speaking English only, 12 speaking English and French, and six speaking English and another language since birth. One participant did not report their language(s). The participants' ages ranged from 18 to 32.75 years old (M = 19.82; SD = 2.32). No participants fell below two standard deviations of the mean on either TOWRE-2 subtest or the WJ-III spelling subtest indicating they had appropriate reading and spelling skills to complete the study.

Materials

Preliminary assessments. Participants completed the Woodcock Johnson Test of

Achievement – Third Edition (WJ-III; Woodcock, McGrew, & Mather, 2001) spelling subset to ensure they had adequate spelling abilities. The WJ-III consists of 24 words that the participant must spell (items 36-59), as dictated by the researcher. These words were chosen from a set of 59 words because they measured college level spelling ability. If six consecutive words are misspelled, testing is stopped. In addition, reading was assessed using the Test of Word Reading Efficiency – Second Edition (TOWRE-2; Torgesen, Wagner, & Rashoette, 2012). The TOWRE-2 is divided into two subsets. The Sight Word Efficiency subset is used to determine how many sight words the participant can read in 45 seconds (max 108) which relates to the completeness of their orthographic representations. The Phonemic Decoding Efficiency Subset consists of non-words (max 66) that participants must pronounce aloud to determine their ability to sound out phonemes, again to see how many they can read in 45 seconds.

Experimental assessments. The experimental spelling test consisted of 25 words, some of which were taken from previous studies (Rossi et al., 2019) and others that were added to include longer words and allow for more variation in possible spelling. The experimental reading task consisted of the same 25 words (See Appendix).

Procedure

Participants began by reading and signing a consent form to indicate their voluntary consent to participate in the study and then filled out a demographic information form. Following that, the WJ-III was administered, and participants were asked to spell 24 words on a piece of lined, numbered paper as dictated by the researcher. Next, the TOWRE-2 Sight Word Efficiency subset was given to participants beginning with a practice trial of eight words to ensure they understand the procedure. Participants

were instructed to say aloud as many words as possible in 45 seconds from a list of 108. Similarly, the Phonemic Decoding Efficiency subset was administered, starting with a practice trial of eight words, and participants were instructed to say aloud as many non-words as possible in 45 seconds from a list of 66. In both subsets, timing began when the participants said the first word and ended when the 45 seconds was up or when the participant finished the word list, in which their time would be recorded.

The first experimental measure consisted of participants spelling 25 words on lined, numbered paper as dictated by the researcher. All three presentations were individually randomized. Spelling was assessed first to minimize priming effects (Rossi et al., 2019). All words were presented a total of three times, resulting in 75 spelling entries. A new sheet of paper was given for each set of 25 words so that they could not see prior spellings. Following the spelling task, participants were instructed to sit in front of the computer screen to begin the reading task. Using SuperLab 5.0, words were presented on the screen one at a time, preceded by a fixation point for 1000ms. Participants were required to say the word aloud, as quickly and accurately as possible, into a microphone attached to a Cedrus SV-1 voice key, which measured their response time. Response time was measured and recorded by SuperLab 5.0 as the time between presentation of the word and voice key activation. The researcher pressed a key indicating whether the participant said the word correct, incorrect, or if the voice key was tripped in error. All 25 words were presented three times to ensure accuracy of measurement.

Participants were then given a debriefing form explaining the purpose of the study and the intended use of their data. Participant were each thanked for their time.

Results

Spelling accuracy scores were obtained by reporting how many times the participant spelled a word accurately out of three (possible scores were zero, one, two, or three for each word). A mean spelling accuracy score across words was used to evaluate if there is a relation between spelling accuracy and reading speed. Mean reading times were obtained by eliminating reading times scored as error or incorrect and determining the average for the remaining, accurately read, trials. As presented in Table 1, there was significant correlations among all literacy measures. Mean reading time was negatively correlated with scores on the WJ-III and mean spelling accuracy, indicating that higher spelling accuracy is related to faster reading times. In addition, the correlation between spelling measures and the TOWRE-2 subtests indicate that spelling accuracy is related to faster reading times, since more accurate spelling was associated with the number of words and nonsense words read in 45 seconds. The data of three participants were removed because they were identified as bivariate outliers by scatterplots.

Table 1

Mean, SD, and Intercorrelations for Literacy Measures (n = 75)

Variable	1	2	3	4	5
1. TOWRE-2 Words					
2. TOWRE-2 Non-Words	.570**				
3. WJ-III	.349**	.584**			
4. Mean Spelling Accuracy	.258*	.521**	.796**		
5. Mean Reading Time (ms)	-.440**	-.458**	-.433**	-.251*	
Mean	106.65	110.91	51.16	1.66	652.36
SD	12.88	12.94	4.62	.646	116.77

Note. ** indicates $p < .001$, * indicates $p < .05$.

A repeated measures analysis of variance (ANOVA) was used to assess whether there was a statistically significant difference between reading time for words participants could spell accurately and those they could not. Low spelling accuracy was identified by a spelling accuracy score of zero, intermediate spelling accuracy was identified by a score of one or two, and high spelling accuracy was identified as a score of three. Mauchly's test of sphericity was significant ($p < .001$), therefore, the Huynh-Feldt adjustment was used. The analyses indicated that mean reading times differed significantly depending on spelling accuracy with a large effect size, $F(1.64, 117.88) = 15.920$, $p < .00$, $\eta_2 = .181$. Bonferroni's post hoc test was used to determined which categories of spelling accuracy differed significantly in reading speed. As presented in Figure 1, there was a significant difference ($p < .001$) between mean reading time for low accuracy words ($M = 686.41$, $SD = 158.18$) and mean reading time for high accuracy words ($M = 642.36$, $SD = 110.6$). In addition, the difference in reading times between intermediate accuracy spelling words ($M = 676.42$, $SD = 136.44$) and the high accuracy words was significant ($p <.001$). The difference between mean reading times for low accuracy words and intermediate accuracy words was not statistically significant ($p = .409$).

To determine if there was a statistically significant difference in reading time between words with spelling errors within the first half of the word versus the latter half of the word, a repeated measures ANOVA was used. Error location was determined by dividing the location of the first error by the total number of letters in the word. If there were multiple errors, only the first error location was used. For example, the word "hooligan" misspelled as "holigan" would have an error location of three, which would then be divided by eight to give an error location of .375% – indicating the error was in

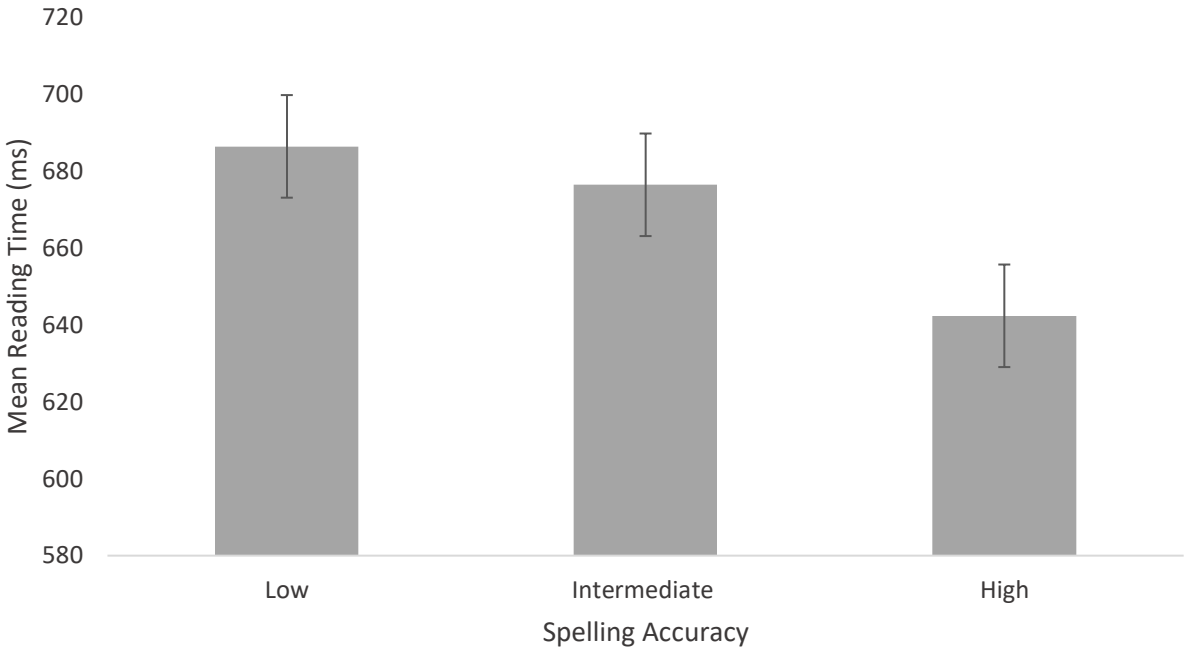

Figure 1. Differences in mean reading time (ms) depending on spelling accuracy. Error bars for all figures represent the standard error.

the first half of the word. The overall test determined that there was a statistically significant difference in mean reading time for compared to words with spelling errors in the latter half of the word (M = 644.43, SD = 117.85), $F(1, 73) = 19.503$, $p < .001$, η_2 = .211, indicating a large effect size. As shown in Figure 2, errors in the first half of the word were read statistically significantly slower than words with errors in the latter half.

Another area of interest was the difference in reading times for words with errors involving consonants versus vowels. A repeated measures ANOVA was conducted to determine if there was a statistically significant difference between mean reading time for words with consonant errors versus words with vowel errors. Nine participants were

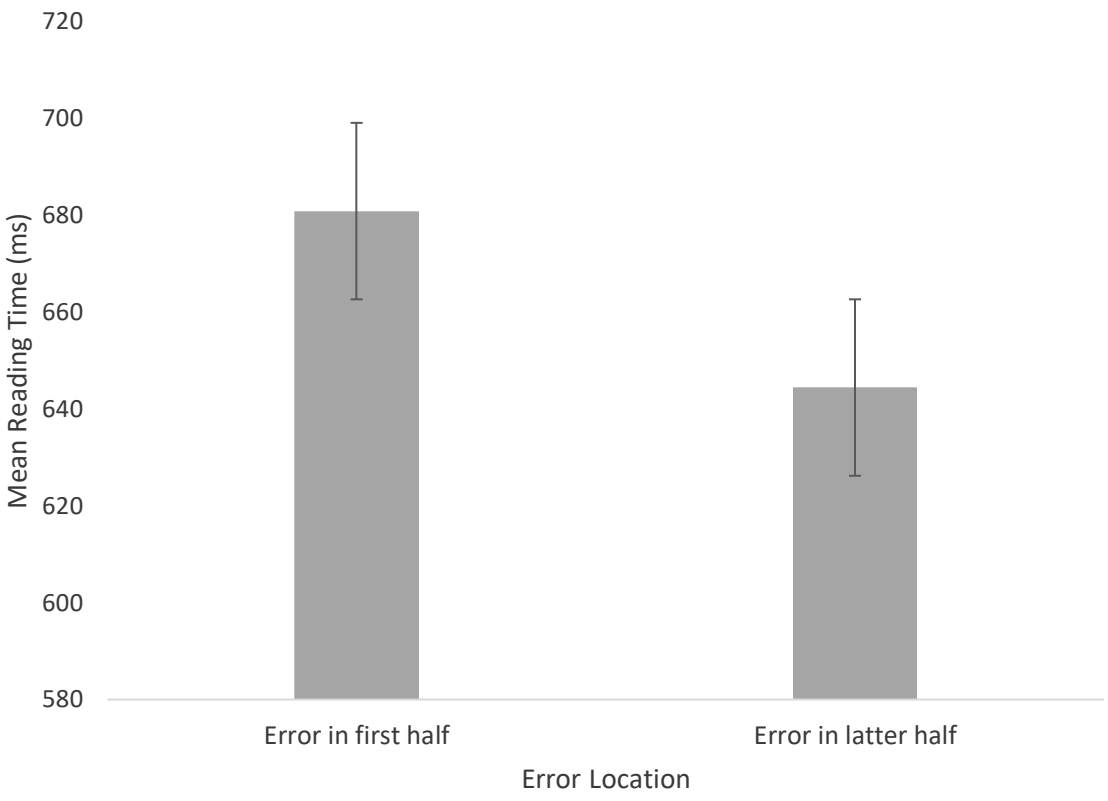

Figure 2. Errors in the first half of a word have a more detrimental impact on reading speed than do errors in the latter half of a word.

excluded from this analysis as they did not have both consonant and vowel errors in their experimental spelling task. The analyses showed there was no statistically significant difference between mean reading times of words misspelled with a consonant (M = 680.99, SD = 167.92) or a vowel (M = 696.25, SD = 216.51), $F(1,65) = .524$, $p = .472$, $\eta^2 = .008$. As shown in Figure 3, vowel errors appear to be more detrimental to reading speed than consonant errors, but the difference was not statistically significant.

Discussion

It was hypothesized that words with high quality orthographic representations, as measured by spelling, would be read significantly faster than words with low and

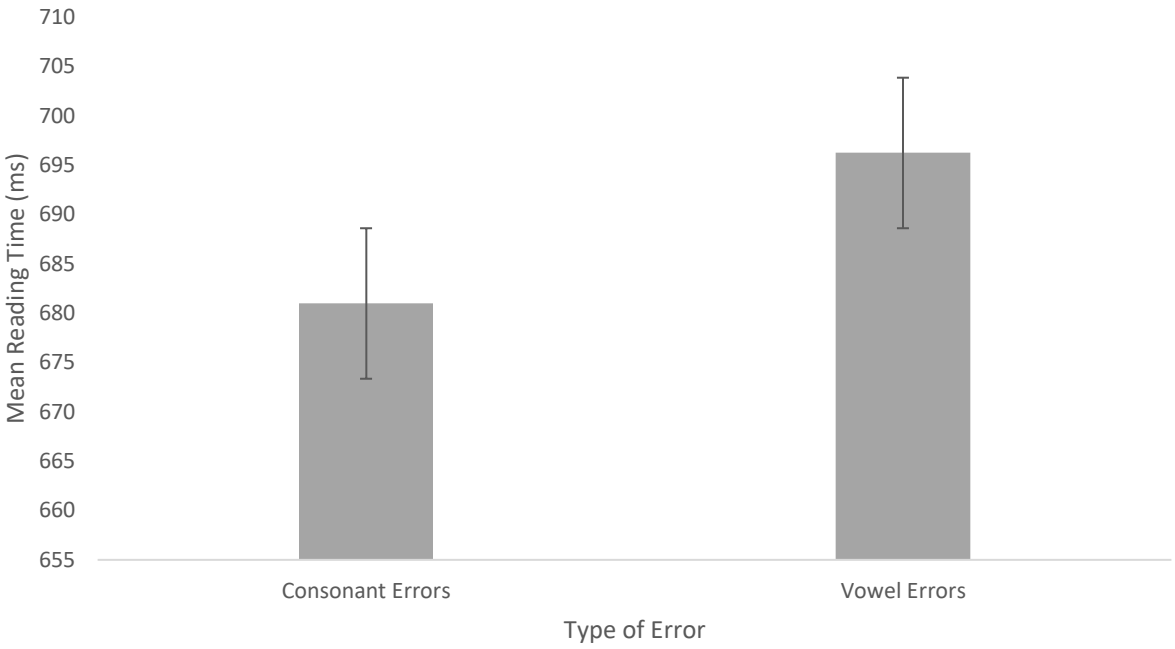

Figure 3. Difference in mean reading time (ms) for words with consonant or vowel errors.

intermediate quality representations. This hypothesis was supported; words spelled correctly were read significantly faster than those that were not. The second hypothesis predicted that spelling errors in the first half of the word would be more detrimental to reading speed than errors in the latter half of the word. This hypothesis was supported as the present study found that words with spelling errors in the first half of the word were read significantly faster than words with errors in the latter half of the word. The last hypothesis predicted that spelling errors involving consonant would be more detrimental to reading speed relative to spelling errors involving vowels. This hypothesis was not supported as no statistically significant difference between reading time for words with different error types was found.

Lexical Quality Hypothesis (LQH)

The LQH states that higher quality orthographic representations for words are

accessed more efficiently and hence those words are read faster (Perfetti & Hart, 2002). The present study found support for the LQH in that words with higher quality orthographical representations were read significantly faster than words with low and intermediate quality orthographic representations; however, there was no significant difference in reading speed between low and intermediate quality orthographic representations in a university level group of participants. In contrast, Rossi et al. (2019) found a significant difference between low and intermediate quality representations in high school participants from diverse economic neighbourhoods. Differing results from Rossi et al. may be due to the way intermediate representations were defined. In the current study, intermediate representations were defined as having one or two correct spellings, whereas Rossi et al. distinguished between words spelled correctly once versus twice. Perhaps if intermediate quality representations were defined in distinct categories (e.g., one versus two correct spellings) the results may have differed. Rossi et al also studied younger participants who may still have developing orthographic representations; it may be that variations in lower orthographic quality are more important at that time in development. Future studies should evaluate intermediate quality representations more closely and, further, investigate whether participant demographics have an influence on results.

In terms of accuracy, a component of the LQH, words spelled accurately would be expected to be read faster. Previous studies demonstrated that words spelled accurately were read significantly faster than words spelled inaccurately or words that had mixed accuracy (Ouellette et al., 2017; Rossi et al., 2019). In the current study, words were spelled over three trials in order to get a better sense of the participants' spelling abilities

(i.e., accuracy and stability). Words spelled correct all three times were read faster than words with less consistent spelling accuracy.

Conrad (2008) showed that words with low quality representations were still able to be read; the present study's results confirm this but shows that reading is at a slower rate because lexical access is impeded. The present study determined that low and intermediate quality orthographic representations were read significantly slower than high quality ones. This supports the theory of partial cue reading – that lexical access is impeded and therefore words spelled inaccurately will be read slower – but they can still be read. The results of this study support partial cue reading; participants were able to read a word (although significantly slower) despite not being able to spell it. However, there are more components of the LQH besides partial cue reading and accuracy that may have played a role in the present results.

The present results demonstrate that stability also played a role in reading speed. Stability is referred to as the consistency of spelling, which is why the current study measured spelling over three trials (Ouellette et al., 2017; Rossi et al., 2019). Since stability is a component of the LQH, it plays a role in determining whether a word has a low, intermediate, or high quality orthographic representation. In this study, words spelled correctly all three times were read significantly faster than those spelled correctly zero, once, or twice out of three times– indicating that as alluded to earlier, highly stable spelling results in faster reading.

Error Location

Error location was an area of interest in the current study. According to serial processing, words are processed sequentially from left to right (Kwantes & Mewhort,

1999). However, parallel processing may assume simultaneous processing of word elements (Kwantes & Mewhort, 1999). In the present study, it was hypothesized that error location would affect reading speed. Because of the vast amount of research supporting serial processing of text, it was hypothesized that words in the first half of the word would result in slower reading (Kwantes & Mewhort; Lima & Inhoff, 1985). The results of this study supported serial processing since words with spelling errors in the first half of the word were read significantly slower than words with spelling errors in the latter half of the word. Lima and Inhoff suggested that this would be because as the word is read and spelled, candidates are eliminated; if a word is misspelled earlier in the word, this can lead to activating the wrong cohort and slows lexical access. Spelling errors in the present study were categorized as occurring in the first or second half of the word due to a recommendation taken by Ingalls (2019), as the researcher suggested quartiles may be too specific – especially with short words.

There is, however, a caveat in the present study– only the location of the first error was evaluated. The current study used difficult words and therefore participants spelling attempts were rife with errors. This may also have had an effect on the results. For example, if there are more errors in the latter half of the word, but the first error occurs in the first half, it may not be logical to conclude that reading speed was impeded due to the first error. Future studies should evaluate the difference between types of errors and amount of errors.

Consonant Versus Vowel Errors

The findings from the current study offer new information regarding this emerging area of research. The theory of consonant bias suggests that consonants carry

more information about the lexicon (Nazzi & Polka, 2018). Consonants are also considered to be categorized more distinctly in terms of articulatory acoustic features meaning that according to lexical access, consonants should have more reliable cues and therefore accessed (and read) faster (Nazzi et al., 2016; New et al., 2016). Therefore, an error in a consonant would slow this otherwise fast activation. According to previous research, the current study proposed that consonant errors would be more detrimental to reading speed. Interestingly, our findings did not support these theories. Although there was no statistically significant result, there was a trend that consonants errors were read faster than vowel errors – the opposite of what was hypothesized. Results were not statistically significant, however, due to large variability between participants in this pattern; indeed, many participants showed the opposite pattern (words with consonant errors were read slower than those with vowel errors). The reason for this between participant variability is not cleat at the present study; since this is an emerging area of research, future research should investigate the effects of consonant versus vowel spelling errors on reading time.

Conclusion

Given the impact of spelling in establishing quality orthographic representations (Ouellette et al., 2017), spelling should be an important component in teaching early literacy. Evidence shows that words that are spelled correctly are read faster. Therefore, in order to become quicker and more fluent in reading, accurate spelling is certainly helpful. Although words can be read even if the reader cannot spell them, there is a cost for fluency. In children, this effect can be more pronounced. The difference in reading speed and fluency in younger children learning to read and spell is more pronounced

because with less knowledge of the word they need to use phonemic decoding more frequently. Indeed, studies have repeatedly shown that practice in spelling improves reading (Graham & Santangelom, 2014).

It is essential to stress the importance of accurate spelling in order to lead to quicker reading speed. For children struggling to read, spelling instruction may be a useful method in increasing their reading skills. As shown in Ouellette et al. (2017) spelling instruction improved the quality of orthographic representations, in turn improving spelling accuracy and decreasing reading time.

Further research is needed on the effect of specific errors on word reading. The location of spelling errors has been determined to be more detrimental when an error is in the first half of a word, providing additional evidence for serial processing and cohort effects. However, the influence of consonant and vowel errors on reading speed remains elusive, while the effects of the sheer number of errors within a word has not been explored.

Appendix

1. Ache
2. Accommodate
3. Annoyed
4. Blizzard
5. Bureaucracy
6. Challenging
7. Connoisseur
8. Decease
9. Deductible
10. Diaphragm
11. Disappear
12. Embarrass
13. Fascinate
14. Fluorescent
15. Foreign
16. Hemorrhage
17. Hooligan
18. Nauseous
19. Pinnacle
20. Plagiarism
21. Recommended
22. Silhouette
23. Toboggan
24. Weird
25. Zucchini

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