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The Effects of Orthography and Phonology on Vocabulary Acquisition

by

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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The purpose of this study was to examine whether orthographic and phonological properties of nonwords facilitate or inhibit vocabulary acquisition in adult skilled readers. Participants' eye movements were measured as they read a series of sentence pairs containing either a familiar word or a nonword. There were three conditions for the nonwords: orthographic, phonological and neutral. The orthographic nonwords were created by changing one letter of a real word. The phonological nonwords sounded like a real word but had a different spelling. The neutral nonwords did not closely resemble real words in both spelling and pronunciation. Data were analyzed on participants' eye movements and performance on a vocabulary test. It was predicted that the processing times and number of regressions back to the target word would be highest for the phonological condition followed by the orthographic and neutral conditions. However, no differences were found for initial processing times. This finding does not support the prediction that phonology is activated early in word processing. There were some significant differences in the rereading times. Some of these findings suggest that orthography and phonology both play a role in word processing. The results may be explained by word recognition models, which will be discussed in this paper.

INTRODUCTION

It is essential for readers to be able to understand the meanings of a wide range of printed words while reading. Although vocabulary growth estimates vary widely, it is clear vocabulary acquisition is an important skill considering the high number of uncommon words that occur in text (Morris & Williams, 2003). Unfamiliar words can be learned through various methods ranging from formal instruction to reliance on contextual information. Some researchers have suggested that deciphering meanings of unfamiliar words through the use of context is a common method of vocabulary acquisition (Morris & Williams, 2003). However, there has not been a large amount of research on the processes involved in gaining new vocabulary in this way.

The Role of Context in Vocabulary Acquisition

Researchers have conducted eye movement studies to examine the role of contextual information on vocabulary acquisition. Chaffin, Morris and Seely (2001) investigated how college students use context to determine the meaning of unfamiliar words. In Experiment 1, participants read sentences that included either a high-familiar, low-familiar, or novel word followed by informative context. A second sentence contained a category word that provided information about the general category to which the word belongs (e.g., a musical instrument). The researchers used an eye tracker to measure eye movements as the participants read the target word, the context, and the category word in the second sentence. When participants read a sentence containing a novel word, they spent a longer amount of time gazing at the context following it than they did for the high- and low-familiar words. For example, when participants read the sentence, "Joe picked up the asdor and began to strum a tune," they spent more time processing the informative phrase "strum a tune" than they did when "asdor" was replaced by the word "guitar" (high-familiar) or "zither" (low-familiar). The researchers also analyzed regressions into the target word, which refers to the number of times the reader looked back to the target word after first leaving the target word region. Participants were more likely to make regressions into the target word when it was a novel word compared to a high- or low-familiar word. Processing time for Sentence 2 did not differ among conditions, which suggests that readers already established the meaning of the target word before their eyes left Sentence 1. The researchers concluded that, based on this experiment, participants were able to effectively use context to deduce the meanings of the novel words while reading silently.

Experiment 2 of Chaffin et al.'s study provided further support for this idea that readers tend to focus on the most informative regions of the text in order to learn new words efficiently. The informativeness of the context in the first sentence was varied in order to examine whether participants would spend the same amount of time processing informative and uninformative context. This manipulation also allowed the researchers to determine whether or not participants realized that Sentence 1 and Sentence 2 both referred to the same object. Data from the novel–neutral condition showed that participants relied on the synonym in Sentence 2 to help determine the meaning of the target word. The first sentence in the novel-neutral condition contained a novel word surrounded by neutral context. An example of a sentence pair in this condition is "Joe picked up the asdor and began to walk home," followed by "He played the instrument to relax." Participants who viewed this version of the sentence pair knew that the synonym embedded in the second sentence (in this case, "instrument") referred to the target word in the first sentence ("asdor"). This supports the conclusions in Experiment 1 and shows readers were able to identify the areas of the text that would facilitate comprehension.

Initial and total processing times, as well as the number of regressions, were higher in the novel word conditions than in the familiar word conditions. Initial processing times were measured by first fixation and gaze duration. First fixation refers to the amount of time spent on the first fixation of a word, regardless of the total number of fixations made on that word. Gaze duration includes all of the fixations made by the reader before she leaves the word or region. In the novel-full context condition, readers spent a longer time gazing at the contextual information than they did in the novel-neutral context condition. The novel-full context condition contained both the novel word and the informative context in the first sentence, as in "Joe picked up the asdor and began to strum a tune." The difference in processing time between the conditions indicates that readers recognized that the novel-full context condition contained more informative text, and they consequently spent more time processing it. This study strongly supports the notion that readers do in fact pay closer attention to informative context than to uninformative context.

Williams and Morris (2004) also conducted an eye movement study investigating the effects of word familiarity. From the eye movement data, they found that the initial processing times were longer for the novel and low-familiar words than for the familiar words. Chaffin et al. (2001) also found that less initial time was spent on high-familiar words, although they did not find a difference between novel and low-familiar words. Williams and Morris explain this inconsistency by describing the differences in the procedures used in the studies. The familiarity ratings utilized by Williams and Morris were higher than those used by Chaffin et al. This suggests that the participants in Chaffin et al.'s study may not have been familiar with the low-familiar words. In addition to examining on-line processing, Williams and Morris also administered a vocabulary test to determine how well participants retained the semantic meanings of the target words. The results of this test showed that readers learned the meanings of the unfamiliar words they encountered during the study.

Williams (2004) provided further evidence that readers are able to effectively use contextual information to determine the meanings of unfamiliar words. In the study, familiar words (e.g., "banjo") and nonwords (e.g., "asdor") were embedded into sentences that began with either semantically constraining text or neutral text. An example of a sentence in the semantically constraining condition was, "Joe began to strum a tune on the asdor that he carried." From the eye movement data, the researcher found that readers spent less time processing the nonwords when the informative context was in the beginning of the sentence than when it was located at the end of the sentence. It was also found that readers spent less time processing familiar words than unfamiliar words. This is consistent with past research (eg., Chaffin et al., 2001; Williams & Morris, 2004).

In addition to examining the role of context and word familiarity, Williams investigated whether reader characteristics such as vocabulary knowledge influence how readers process unfamiliar words. Data analyses indicated that readers with a higher level of vocabulary knowledge spent less time processing both unfamiliar and familiar words than readers who had less vocabulary knowledge. It was also found that readers with less vocabulary knowledge spent less time rereading unfamiliar words when the informative context was in the beginning of the sentence than when it was located at the end. This suggests that readers with less vocabulary knowledge found it easier to learn the meanings of unfamiliar words when informative context is located at the beginning of a sentence. Information from a vocabulary test administered after the reading task indicated that all readers successfully learned the meanings of the unfamiliar words using context.

Orthography and Phonology

While research has been conducted regarding how readers use context to learn new words, researchers have not been as concerned with examining the properties of the unfamiliar words. The ease with which a reader can determine the meaning of an unfamiliar word may depend upon the phonological and orthographic properties of the word. Phonology relates to pronunciation, while orthography refers to spelling. There is a debate regarding the roles of these two sources of information in word processing. While some researchers have proposed that the visual-orthographic route is centrally involved (e.g., Daneman & Reingold, 1993; Daneman, Reingold & Davidson, 1995) others argue for the importance of phonological coding (e.g., Folk, 1999; Rayner, Pollatsek & Binder, 1998; Van Orden, 1987).

Dual-route Theory

Dual-route theory asserts that orthography is the central route by which readers retrieve the meanings of words. According to this theory, there are two methods that readers can use when identifying words. In the first method, the reader uses the lexical route to access the word's meaning. This process can only be activated if the reader has encountered the word previously. After viewing the printed word, the reader is able to access the lexical entry in which the orthographic representation of the word is stored. Following this, the reader accesses the word's phonological representation. Since the reader's internal lexicon is only useful for encounters with familiar words, a non-lexical route is used for identifying unfamiliar words. This route involves making use of letter-sound correspondences. After viewing the printed word, the reader uses the correspondence rules to decipher the word's pronunciation. According to dual-route theorists, orthography is the quickest route by which readers access a word's meaning, and phonology is important only under limited circumstances (Coltheart, Curtis, Atkins & Haller, 1993; Coltheart & Rastle, 1994).

A study by Daneman and Reingold (1993) provides evidence for dual-route theory. The researchers used homophones to determine the role of phonology in word processing. Homophones are words with different spellings that share the same pronunciation (e.g., blue and blew). Homophones should interfere with accessing the correct meaning of the word only if phonological coding is involved. In the study, participants' eye movements were measured while they read passages containing homophonic errors (e.g., "He wore blew jeans") and nonhomophonic errors (e.g., "He wore blow jeans"). The researchers found that gaze duration times were not significantly different for the two types of target words. From this, they concluded that phonology does not play a dominant role early in meaning activation. Phonology was found to be involved after lexical access, when participants engaged in rereading. The results of a study by Daneman et al. (1995) further suggest that phonological coding is not involved in the initial stages of word processing.

Evidence for Phonological Coding

While researchers such as Daneman and Reingold (1993) and Daneman et al. (1995) strongly support the dual-route theory, other researchers have contradicted this theory by suggesting that phonology is activated early in the process of word recognition. Rayner et al. (1998) examined the role of phonological coding in word identification in a study similar to those conducted by Daneman and Reingold (1993) and Daneman et al. (1995) and concluded that phonological coding is activated early in word processing. Participants read passages containing members of homophone pairs (e.g., break-brake) while their eye movements were monitored. Experiment 1 included only high-constraint passages while Experiments 2 and 3 included both high- and low-constraint passages. In the high-constraint condition, only one member of a homophone pair made sense in the context of the passage. An example of a high-constraint passage is, "Breakfast is the most important meal of the day. Even a cold bowl of cereal (serial, verbal) is better than nothing at all." Initial processing times did not differ for the incorrect and correct homophones in the high-constraint condition when the homophones were orthographically similar (e.g., meat-meet as opposed to chute-shoot). This finding indicates that the participants relied on phonology to retrieve the meaning of the incorrect homophone. The meaning that was activated was consistent with the sentence context and did not take the word's spelling pattern into account.

This pattern was not observed when the homophones were orthographically dissimilar and when the context was low-constraint. In these conditions, both orthography and phonology were activated and it was often not clear which source had quicker access. While Rayner et al. found evidence for phonological coding in the high-constraint condition when the homophones were orthographically similar, Daneman and Reingold (1993) and Daneman et al. (1995) did not find a change in processing time differences for orthographically similar and dissimilar homophones.

Rayner et al. also found a difference in gaze duration between the incorrect homophones and the spelling controls. Daneman and Reingold (1993) and Daneman et al. (1995) did not find any differences between these two conditions. This led them to believe that phonology is not activated before orthography. Rayner et al. (1998) offer several possible explanations for these contradictory results. One explanation is that the spelling controls used by Daneman and Reingold (1993) and Daneman et al. (1995) may have a higher level of phonological similarity to the corresponding homophones than those employed by Rayner et al. (1998).

They also note that most of the materials used by Daneman and Reingold (1993) and Daneman et al. (1995) were similar to the low-constraint condition in Experiment 3 of their study. This is important to consider since the strongest evidence for early phonological activation in Rayner et al.'s (1998) study was most clearly seen in the high-constraint conditions. Because the context in the low-constraint condition does not make it clear what word will come next, the amount of time spent on the target word may be influenced by how consistent the reader thinks the word is with the context. If this is the case, the processing times on the target words in the low-constraint condition may not be accurate indicators of the impact of orthography and phonology. These differences in procedures may help explain why Daneman and Reingold (1993) and Daneman et al. (1995) concluded that phonology does not play an early role in word processing.

Van Orden (1987) also used homophones to examine the importance of phonology in word processing. In Experiment 1 of Van Orden's study, participants were presented with a category name (e.g., "a flower") followed by either a member of the category (e.g., "tulip") or a word that is phonologically or orthographically similar to a category member (e.g., "rows" or "robs"). The participants were instructed to pull a lever to indicate "yes" if the target word belongs to the category, or "no" if it does not belong. By including a spelling control condition, the researcher was able to examine whether categorization errors were a result of phonological or orthographic similarity. If participants indicated agreement for "rows" because of the similarity in spelling and not because it sounds like "rose," the rate of agreement would the same for both "rows" and "robs." However, it was found that participants were more likely to indicate agreement when presented with a homophone than an orthographically similar word. This confirms the hypothesis that a homophone such as "rows" activates phonologically similar words such as "rose."

In a subsequent study, Van Orden, Johnston and Hale (1988) found the same results when using nonword homophones, which are also known as pseudohomophones. Participants were as likely to agree that a nonword homophone (e.g., "sute" for the category "an article of clothing") was a member of a category as they were for a word homophone (e.g., "hare" for "a part of the human body"). As the researchers suggest, this finding lends support to the argument that phonological coding is important in word identification for both familiar and unfamiliar words. Coltheart, Patterson and Leahy (1994) replicated this study and produced similar findings.

Lukatela and Turvey (1994) also presented evidence suggesting that phonology is activated early in word recognition. Participants viewed a series of target words (e.g., cats) followed by a word that was either an associate (e.g., paws) or a homophone (e.g., pause) or pseudohomophone of the associate. When asked to name aloud the target words, participants had a higher rate of accuracy when the preceding word was an associate word, a homophone or a psuedohomophone compared to orthographic controls. The finding that phonologically related items facilitated recognition provides strong evidence that phonological coding is the most central, direct route to accessing a word's lexical representations, with orthographic coding playing a secondary role. Lesch and Pollatsek (1993) conducted a similar study and also found a priming effect, although they note that it was only apparent under certain conditions.

Collectively, these studies provide insight into the effect of homophones in a wide variety of tasks by highlighting the important role of phonology. Daneman and Reingold (2000) caution that evidence from homophone studies may not accurately reflect the role of phonology during normal reading. They argue that since these studies often include secondary tasks such as lexical decisions, the situation is different from natural reading. Therefore, they suggest it is more reliable to examine evidence from studies incorporating reading situations that are more typical. On-line reading measures such as those used in Rayner et al.'s (1998) study are especially important to consider for this reason. Evidence from eye movement studies can provide insight into the role of phonological coding and the effect that phonological characteristics of words have on processing.

Evidence for Orthographic Coding

Orthographic properties of words have been shown to have significant effects on the way readers process text. Orthographic neighborhood size refers to the number of words that can be created by changing one letter of a word. For example, "cite" and "pity" can both be created by changing one letter of "city." Therefore, "city" has a neighborhood size of two. This measure is one way to assess orthographic coding. There is substantial amount of research on the effects of orthographic neighborhood size. However, there is conflicting evidence on whether a large neighborhood size facilitates or inhibits reading (Pollatsek, Perea & Binder, 1999). Pollatsek et al. concluded that readers have a more difficult time identifying a word when it has a large number of high frequency neighbors, or neighbors that have been found to occur frequently in print.

Bowers, Davis and Hanley (2005) further investigated the influence of orthographic neighborhood size on word identification. They designed their study in response to research suggesting that large orthographic neighborhood sizes do not greatly inhibit word identification. Competitive network models such as the self-organising lexical acquisition and recognition (SOLAR) model of visual word recognition contend that the interference caused by orthographic neighborhood size is apparent when comparing words that have no orthographic neighbors with words that have at least one neighbor (see Bowers et al., 2005). In order to examine this idea, the researchers chose words with no orthographic neighbors (e.g., banana) and changed one internal letter to create nonwords (e.g., banara). Over the course of two days, participants engaged in tasks that repeatedly exposed them to the nonwords. Several times during the study, the researchers administered a semantic categorization task that tested the participants' ability to successfully classify the familiar words as either natural (e.g., tomato) or an artefact (e.g., violin). It was found that participants had more difficulty categorizing the familiar words after learning the visually similar nonwords. This suggests that orthographic neighbors interfere with word identification by creating competition with the similarly spelled words (Bowers, et. al., 2005).

An important factor to consider when studying the effects of orthographic neighborhood size is neighborhood frequency. This issue is one reason for the inconsistency of results in this area of research. It is not clear what the best method is for controlling for frequency, and different results have been obtained depending on the procedure used. For example, in a study by Sears, Hino, and Lupker (1995), it was found that large neighborhood size has a facilitative effect on processing for low frequency words. Because of the disagreement among researchers, further research on the topic of neighborhood size would be beneficial to understanding how orthography influences word processing.

Differences between Skilled and Less Skilled Readers

In addition to research focusing on the effects of orthography, some studies have examined orthographic and phonological skills in both skilled and less skilled readers. A number of studies have found that skilled readers frequently rely on phonological coding while less skilled readers do not make as much use of phonological coding. For example, in a study conducted by Majeres (2005), participants were shown pairs of words and asked which word either looks or sounds most like a real word. An analysis of response times found that the highly skilled readers relied heavily on phonological skills. Less skilled readers were not efficient at phonological coding and they were not as successful at the word recognition task.

A study by Unsworth and Pexman (2003) had a similar finding for phonological activation among skilled readers. A task that is often used by researchers examining word identification is the lexical decision task. This involves displaying a string of letters and instructing the participant to give a "yes" or "no" response depending upon whether or not it is a real word. The phonological lexical decision task also involves showing participants a letter string, and requires participants to decide whether each string of letters sounds like a word or not. Through the use of these two tasks, Unsworth and Pexman found that highly skilled readers tend to rely on phonological coding.

Researchers have also investigated the differences in orthographic coding between groups of skilled and less skilled readers. Booth, Perfetti and MacWhinney (1999) conducted a study examining the roles of both orthographic and phonological coding in readers from grades two through six. In the word identification task, a nonword prime was briefly displayed on a computer screen, followed by a brief display of the target word. A pattern mask was then presented for a longer period of time in order to make it more difficult for participants to process the target word. The researchers used three types of nonword primes. The pseudohomophone primes sounded like their corresponding target words but had a different spelling (e.g., tume-tomb). The orthographic primes were visually similar to the target word but did not share a similar pronunciation (e.g., tams-tomb). The control primes did not share any letters with the corresponding target words (e.g., usan-tomb). After viewing each nonword prime, target word and pattern mask, participants were instructed to write the target word. The researchers found that skilled readers experienced orthographic and phonological priming effects after being presented with the items for 30 ms and 60 ms. Because these effects occurred at such brief exposure durations, the researchers concluded that phonological and orthographic coding are both utilized early during word recognition. It was also found that skilled readers showed more effects from orthographic priming for both exposure durations than did the less skilled readers. Skilled readers showed more phonological priming effects than less skilled readers during the short exposure duration. This suggests that skilled readers are more efficient at using both orthographic and phonological information.

The Present Experiment

This experiment investigated the processes involved in acquiring meanings of nonwords during silent reading for skilled readers. The methodology was similar to the study by Chaffin et al. (2001). However, instead of manipulating word frequency, the phonological and orthographic properties of nonwords were varied. This made it possible to examine whether phonological and orthographic properties facilitate or inhibit vocabulary acquisition for skilled readers. Participants read pairs of sentences containing either a familiar word or a nonword. The nonwords had three conditions: letter strings that did not resemble any English word (neutral condition); pseudohomophones, which sounded like actual words but were spelled differently (phonological condition); and orthographically similar words, which had a spelling similar to an actual word but did not sound similar to the word (orthographic condition). Eye movement data were collected during the experiment, and a vocabulary test was administered after the sentences were shown.

It was hypothesized that the pseudohomophones would be most difficult for skilled readers to process because seeing them would activate the similar sounding words. For example, seeing the nonword "klawk" in the sentence, "Joe picked up the klawk and began to strum a tune," would cause activation of the word "clock." This phonological similarity would cause interference and make it more difficult to learn the meaning of the pseudohomophone. It was also hypothesized that there would be interference for the orthographically similar nonwords compared to the neutral nonwords, but this was predicted to be less than for the pseudohomophones. An eye tracker was used to monitor participants' eye movements while they read. This allowed for measurement of processing times and provided us with data concerning the number of regressions a participant made to a previous area of the text. In addition to the eye movement data, a vocabulary test was given to participants after they read all of the sentences. The vocabulary test provided information on which nonwords were comprehended and which were not. This information was used in conjunction with the eye movement data and helped to determine how the orthographic and phonological properties of the nonwords affected word processing and comprehension.

METHOD

Participants

Twenty-two students from Mount Holyoke College were recruited to participate in the eye tracking task in exchange for credit toward the research participation requirement of their psychology courses. Students not enrolled in a psychology course that grants this credit were offered $10 to participate. Participants were recruited through sign-up sheets, flyers, email, and word-of-mouth. All participants had normal or corrected-to-normal vision. Seventeen of the participants reported English as their first language, while 5 participants did not.

In addition to the eye tracking task, 55 students from Mount Holyoke College completed a lexical decision task. These participants were recruited and rewarded in the same manner as the participants in the eye tracking task. Of these participants, 41 indicated that English was their first language, 13 reported that it was not, and 1 participant reported learning English simultaneously with another language.

Stimulus

Thirty-six four-to-nine-letter nonwords were selected for each of the three nonword conditions (see Appendix A). In addition, 54 familiar words were selected. Participants were shown either a nonword or a familiar word for each sentence frame. There were three conditions for the nonwords: orthographic, phonological, and neutral. Some of the nonwords were adapted from Booth, Perfetti and MacWhinney (1999), Hooper and Paap (1997), and Unsworth and Pexman (2003). Nonwords not taken from previous research studies were created using the criteria stated below.

The orthographic nonwords were letter strings that shared all but one letter with an English word, such as choit (from "choir"). The phonological nonwords sounded like an English word but had a different spelling, such as foane (from "phone"). The neutral condition consisted of words that did not resemble actual words in either spelling or pronunciation, such as asdor.

All target words were concrete nouns, which are nouns that signify a material object (e.g., "table"). Also, only nonwords whose source word did not have multiple meanings were chosen (words such as "pitcher" were not used). In addition, target words were four to nine letters long, and they only consisted of letter strings with legal English spellings. For example, the pattern "jj" was not used in a nonword because the letter combination does not occur in English.

For thirty-six sentence frames, letter strings were created for the four conditions (orthographic, phonological, neutral and familiar). The orthographic and phonological nonwords in each grouping were derived from the same source word. For example, from the word "doll," a phonological nonword, "dawl" and an orthographic nonword, "dold," were created. In addition, bigram and trigram frequencies were manipulated. These refer to how frequently two or three letters (such as "ea" or "ear") occur together in the English language. For example, the bigram frequency of "dold" is the sum of the frequencies for "do," "ol," and "ld." The trigram frequency for "dold" is the sum of the frequencies for "dol" and "old." Bigram frequencies were higher for the orthographic nonwords (M = 979.80) than the phonological nonwords (M = 379.25), $t(35) = 6.42$, $p < .001$. Trigram frequencies were also higher for the orthographic nonwords (M = 125.05) than the phonological nonwords (M = 12.95), $t(35) = 7.34$, $p < .001$. These measurements ensured that the orthographic nonwords had spellings that are frequent in the English language and that the phonological words did not have frequently occurring spellings.

Orthographic neighborhood size was higher for the orthographic nonwords (M = 2.33) than the phonological nonwords (M = .06), $t(35) = 6.07$, $p < .001$. Neighborhood size was also higher for the orthographic nonwords than the neutral nonwords (M = 0), $t(35) = 6.24$, $p < .001$. Word frequency, as measured by Kucera and Francis (1967), was similar for the familiar words (M = 60.53) and the source words from which the orthographic and phonological nonwords were derived (M = 68.06), $t(35) = 1.49$, $p > .05$. In addition, the items in each grouping were matched by word length; the items in each group did not differ by more than 2 letters. Overall, word length was longer for the phonological condition (M = 6.08) than the orthographic condition (M = 5.72), $t(35) = -2.71$, $p < .05$. Word length was also longer for the phonological condition than the neutral condition (M = 5.78), $t(35) = 2.33$, $p < .05$.

The lexical measures were determined using the N-Watch database, which is an online database that provides information such as word frequency from the CELEX Lexical Database (1995) and Kucera and Francis (1967) as well as neighborhood size and other lexical measures (Davis, 2004). Information on homophones is provided for some nonwords. Independent ratings were acquired in order to ensure that the nonwords met our criteria.

A phonological norming task was administered to 40 independent raters in order to determine if participants agreed that the items in the phonological condition were pseudohomophones. Mount Holyoke College students were presented with a list of 41 word-nonword pairs (e.g., "stomach" and "stumik") and were instructed to indicate whether each set of items sounded the same. On the basis of this task, 39 phonological nonwords were selected. The selected nonwords had a rate of agreement of at least 50% (M = 71.73%).

A second norming task was conducted to determine the orthographic and neutral nonwords. Eighty-three nonwords were presented in random order to 40 Mount Holyoke students. The participants were asked to look at each item and write down the first word that came to their mind. Items were classified as orthographic if 30% of the participants wrote down the intended real word (e.g., "shoulder" for "shoumder"). Items were classified as neutral if less than 30% of the participants wrote down the same word. From the 41 items that were originally thought to be orthographic, 26 had at least 30% agreement with the intended word, with a mean of 67.79%. From the 42 items that were thought to be neutral, 20 nonwords had less than 30% agreement with any one word, with a mean of 19.75%. In addition, one orthographic item was not used because it was a real word, and one neutral item was not chosen because it was orthographically similar to a real word.

Because an adequate set of nonword groupings could not be compiled from the results of these tasks, a third norming task was created and administered to 15 Mount Holyoke College students. This task consisted of two sections. The first section consisted of 54 orthographic and neutral items, and the second section consisted of 10 phonological items. The format and instructions of these sections were the same as in the previous norming tasks. From the 24 items that were originally thought to be orthographic, 15 were selected for the orthographic condition. From the 30 items thought to be neutral, 18 met the criteria for the neutral condition. From the phonological task, 4 of the 10 items were classified as pseudohomophones.

Based on the results of these norming tasks, 36 sets of nonwords were created. The mean rate of agreement with the intended real words was 67% for the orthographic nonwords and 71% for the phonological nonwords.

Sentence Frames

The structure of the sentence frames was taken from Chaffin et al. (2001) and Chaffin (1997). For each sentence pair, the first sentence began with neutral context, which is context that does not predict any word. This was followed by the target word and informative context, which enabled the reader to infer the meaning of the target word. An example is, "Joe picked up the ploje and began to strum a tune," which was adapted from Chaffin (1997, Experiment 5). The phrase "began to strum a tune" allowed the reader to infer the category that the nonword fits. The second sentence of the pair contained a superordinate or synonym of the target word that directly stated this category. This associate word was placed near the middle of the sentence (see Appendix B and Appendix C). For example, the corresponding sentence for this example was, "He played the instrument to relax" (Chaffin et al., 2001).

Vocabulary Test

A vocabulary test was given to participants to determine whether they learned the meanings of the nonwords. The test was administered on the computer using the website http://www.formsite.com, and it had a format similar to the vocabulary test used by Williams and Morris (2004). The test included all of the nonwords that the participant read in the experiment. The items were multiple-choice and each question had four answer choices. One of these contained the correct answer while the others were choices that were dissimilar to the correct one. For example, for the phonological nonword "kwire," which was embedded into a sentence with context referring to flowers, the choices were as follows:

A: table

B: part of the body

C: musical group

D: flower

The correct choice was the word that was presented as the synonym in the second sentence of the pair during the experiment. For example, the choice "flower" was taken from the sentence, "That flower smelled so nice." For approximately 30% of the items, a phonologically or orthographically similar choice was included as a possible answer. For example, "musical group" was an answer choice for "kwire" and “thoir” because the source word for these items was "choir." The phonological and orthographic lures were expected to cause interference for the readers because these nonwords should activate real words. If the nonwords “kwire” and “thoir” activated the word “choir,” then having a word or phrase related to “choir” as an answer choice on the vocabulary test should have caused confusion for the participants. Because it was expected that the phonological nonwords would create the most interference for skilled readers, it was expected that participants would be more likely to choose the lure (e.g., “musical group”) when presented with a phonological item than an orthographic item.

Nelson Denny Reading Test

Participants were also administered a Nelson Denny Reading Test. This allowed us to assess their reading skill. The test included questions designed to assess vocabulary knowledge and reading comprehension skills. The vocabulary portion consisted of 80 multiple choice questions, which required the participant to identify the meaning of a particular word. The comprehension portion of the test required the participant to read seven passages and answer 38 multiple choice comprehension questions. It was completed using the test booklet and a pen or pencil. The participants were allowed 15 minutes for the first section and 20 minutes for the second section.

Questionnaire

A questionnaire provided information on participants' age, whether English was their first language, what other languages they speak, whether they regularly use an Instant Messenger program, what form of instruction was used to teach them to read, and whether they are right or left handed (see Appendix D).

Apparatus

Eye movements were measured using a Fourward Technologies Dual Purkinje Image Eyetracker. Participants had binocular viewing, and eye movements were recorded from the participant's right eye. The system was interfaced with a computer that controlled the display of the sentences and stored data. The sentence frames were presented in a double-spaced format with up to 72 characters per line and four character spaces per degree of visual angle. The eye tracker sampled the position of the participant's eye every millisecond with a resolution of 10 min. of arc. The measures that were employed will be defined in the Results section.

Procedure

The participants were told that they would be reading pairs of sentences while their eye movements were recorded. Before beginning the experiment, participants were asked to read and sign an informed consent form. Following this, a bite bar was prepared in order to restrain head movement. The eye tracker was calibrated, and participants engaged in a practice session that involved reading six sentences. When the trial began, five boxes appeared on the screen, and the participant was told to look at the box farthest left when she was ready to begin the experiment. Each participant was shown fifty-four sentence frames. The participants were shown nine orthographic nonwords, nine phonological nonwords, nine neutral nonwords, and 27 familiar words. The items were presented in a different order for each participant. Participants were instructed to press a button after reading each sentence pair in order to signal that they were finished with that trial. After completing all of the trials, the participants were given a vocabulary test on all of the nonwords that they viewed.

It was not always possible to collect eye movement data from participants for several reasons. The eye tracker did not work correctly for participants with long eyelashes, droopy eyelids, or corrective lenses that did not stay in place. Furthermore, if participants were tired, their pupils contracted and dilated, which interfered with the study. In addition to these situations, the eye tracker would not track the eye movements of some participants for unknown reasons. If it was not possible to track a participant's eye movements, the participant was instead administered a lexical decision task.

In the lexical decision task, participants were asked to view a series of words and nonwords on a computer screen and identify whether or not each item was an English word. All of the stimulus items used in the eye tracking task were used in this task. Additional familiar words were created in order to have the same number of nonwords and real words. The items were presented in random order. Participants viewed 240 items in total: 40 orthographic nonwords, 40 phonological nonwords, 40 neutral nonwords, and 120 familiar words. After the practice session was completed, the word "Ready" appeared on the screen, and participants were instructed to press the space bar when they were ready to begin. A fixation cross appeared on the screen for 750 ms followed by the first stimulus item. Participants pressed one of two designated keys to indicate "yes" if the letter string was a real word, or "no" if it was not a real word. After the participant pressed a key, the next stimulus item appeared on the screen. The participant continued in this way until all stimulus items had been shown.

After the completion of the eye tracking task or the lexical decision task, participants were asked to complete the Nelson Denny Reading Test. Participants were given 15 minutes to complete the vocabulary subtest and 20 minutes to complete the comprehension subtest.

After the completion of the reading test, participants were asked to fill out the questionnaire (see Appendix D). After this was finished, the participants were debriefed and thanked for their participation.

RESULTS

For the eye movement data, three regions were analyzed: the target word, the informative context in Sentence 1, and the definitional associate of the target word in Sentence 2. Data from one of the twenty-two participants were not analyzed due to track losses. The data were analyzed using SPSS 12.0. The design was a one-way ANOVA, and the levels of the independent variable were the orthographic, phonological, neutral and familiar word conditions. An alpha level of .05 was used for all statistical tests. For each measure with a significant effect, an LSD post-hoc test was conducted. Appendix E contains ANOVA tables for all of the measures.

Initial processing of the target word

Initial processing time was measured by examining first fixation duration and gaze duration. First fixation refers to how long the participant spends in the first fixation on the word; it does not matter how many times the participant has fixated the word. Gaze duration is the total amount of time spent fixating on a target word spanning from when the participant first set her gaze on that word or region to when she first leaves it. This is called first pass reading time when referring to a region with multiple words.

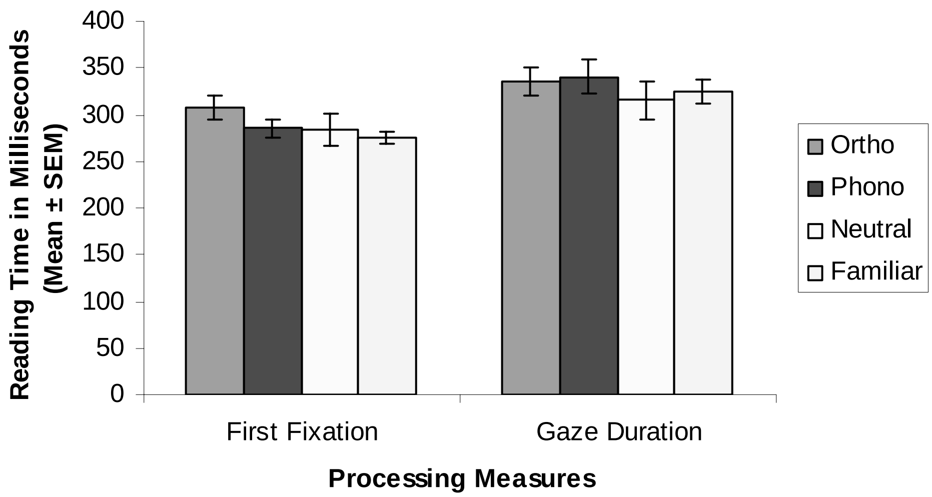
As shown in Figure 1, the mean first fixation duration is highest for the orthographic target words, followed by the phonological, neutral, and familiar targets. However, no main effect was found for first fixation, $F(3, 60) = 1.33$, $MSE = 2{,}375$, $p > .05$.

Also shown in Figure 1, the mean gaze duration is highest for the phonological target words, followed by the orthographic, familiar and neutral target words. There was no main effect for gaze duration, $F(3, 60) = .51$, $MSE = 6{,}160$, $p > .05$ (see Table 2). The failure to find significance for the first fixation and gaze duration measures indicates that participants did not differ significantly in the initial time they spent on the target words. This is inconsistent with past research that has found longer initial processing times for nonwords than for high-familiar words (e.g., Chaffin et al., 2001; Williams, 2004; Williams & Morris, 2004).

Reanalysis of the Target Word

Total time, spill over, second pass time, and regressions were used as rereading measures. The total time includes the amount of time spent on all fixations in the region, including the time spent rereading. Spill over is the amount of time spent on the fixation that comes directly after the participant stops looking at the word. This is believed to reflect post-access processes. If the item is more difficult to process, the spill over time should be longer. Second pass time refers to how long the reader spends looking at the word after leaving it and coming back to it a second time. Regressions out of the target region were measured by the number of times a fixation in the target word region was followed by a fixation to an earlier point in the sentence. Regressions into the

Figure 1. The mean initial processing times in milliseconds for the target word region of the sentence. Vertical lines represent standard error for means.



Reading Time in Milliseconds (Mean ± SEM)
400
350
300
250
200
150
100
50
0
First Fixation
Gaze Duration
Processing Measures
Ortho
Phono
Neutral
Familiar

target word were calculated by the number of times a participant looked back to the target word after her first fixation on the target word had ended. As illustrated in Figure 2, the mean total time was highest for the phonological target words, followed by the orthographic, neutral and familiar items. There was a main effect for total time, $F(3, 60) = 3.68$, $MSE = 17{,}021$, $p < .05$. Post hoc comparisons revealed that participants spent a significantly longer amount of time processing the orthographic target words when compared to the familiar target words. Participants also spent longer processing the phonological items than the familiar and neutral items. Contrary to the hypothesis, there was no difference between the total time spent on the orthographic and phonological conditions. There was also no difference between the orthographic and neutral conditions. No difference was found between the neutral and familiar conditions. While it was hypothesized that the phonological items would be most difficult to process, the findings from this measure suggest that both the orthographic and phonological target words caused processing difficulties when compared to the familiar words.

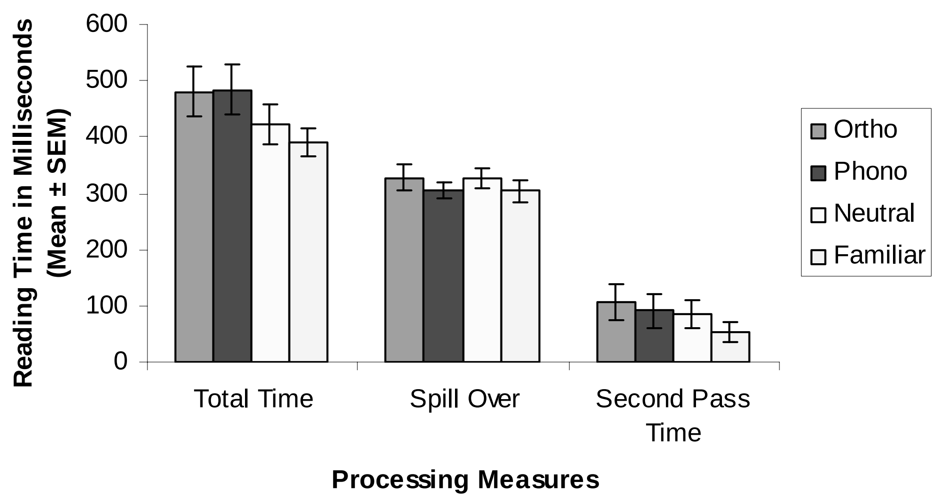
The mean spill over time was highest for the orthographic target words, followed by the neutral, phonological and familiar target words (see Figure 2). There was no main effect for spill over, $F(3, 60) = .55$, $MSE = 8853$, $p > .05$. This is inconsistent with the hypothesis since it was predicted that spill over time would be longest for the phonological items followed by the orthographic, neutral and familiar items. The finding is also inconsistent with past research in which spill over time was found to be shorter for familiar items when compared to nonwords (e.g., Chaffin et al., 2001).

For second pass time, the mean reading time was highest for the orthographic target words, followed by the phonological, neutral and familiar items (see Figure 2). There was a main effect for second pass time, $F(3, 60) = 3.00$, $MSE = 5482$, $p < .05$. Post hoc comparisons indicated that participants spent a significantly longer time on the orthographic target words than the familiar target words. This finding is consistent with the hypothesis since it was expected that participants would have more difficulty processing the orthographic items than the familiar items. However, no other differences were found. This is inconsistent with the prediction that readers would spend a longer time on the phonological items when compared to the other conditions.

As shown in Figure 3, the mean number of regressions out of the target word was highest for the orthographic condition followed by the neutral, phonological and familiar conditions. However, no significant main effect was found, $F(3, 60) = 2.12$, $MSE = 126$, $p > .05$.

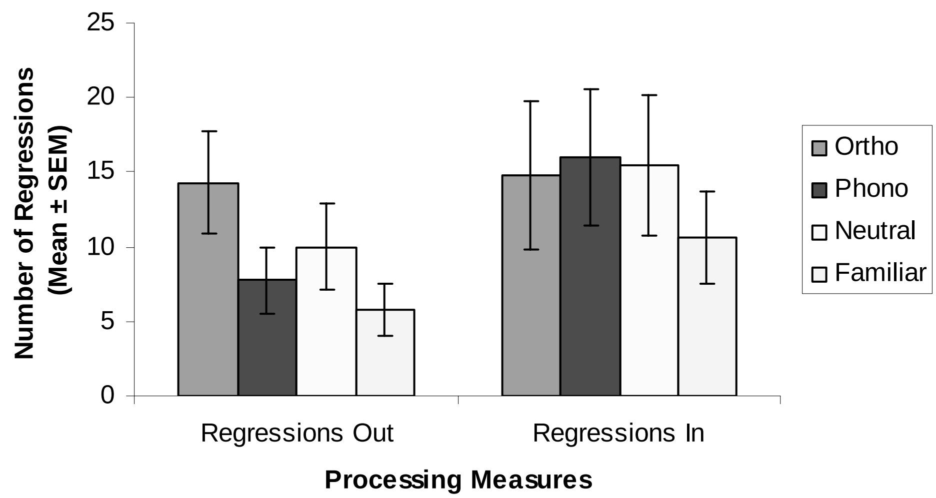
The mean number of regressions into the target word was highest for the phonological condition followed by the neutral, orthographic and familiar conditions (see Figure 3). There was no significant main effect, $F(3, 60) = .70$, $MSE = 244$, $p > .05$. The failure to find any differences in the number of regressions into and out of the target word region is inconsistent with the hypothesis. It was predicted that readers would experience the most difficulty acquiring the meaning of the phonological target words. However, the participants

Figure 2. The mean total time, spill over time, and second pass time in milliseconds for the target word region of the sentence. Vertical lines represent standard error for means.



Reading Time in Milliseconds
(Mean ± SEM)
600
500
400
300
200
100
0
Total Time
Spill Over
Second Pass Time
Processing Measures
Ortho
Phono
Neutral
Familiar

Figure 3. The mean number of regressions for the target word region of the sentence. Vertical lines represent standard error for means.



Number of Regressions
(Mean ± SEM)
25
20
15
10
5
0
Regressions Out
Regressions In
Processing Measures
Ortho
Phono
Neutral
Familiar

did not reread the phonological target words more frequently than the other conditions.

Initial processing of the informative context

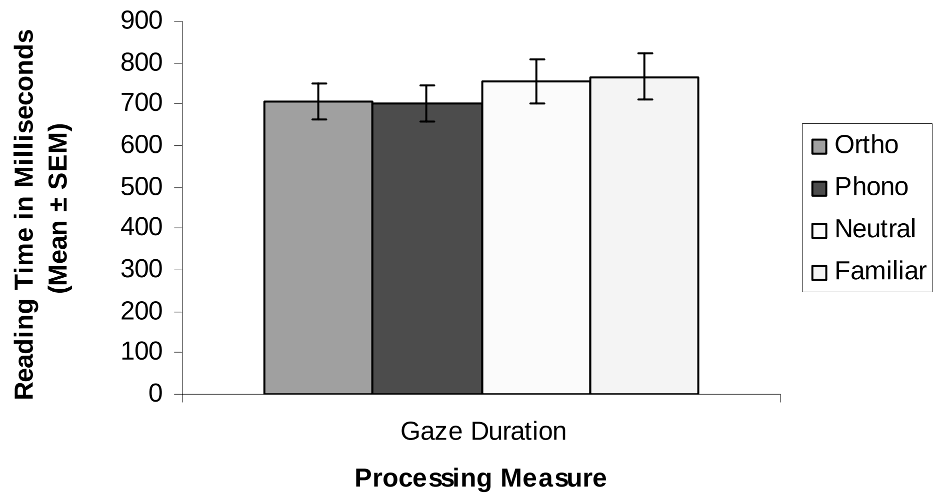
Initial processing time was examined for the informative context region in order to determine if participants had more difficulty processing context when it was followed by a phonological target word than an orthographic, neutral or familiar target word. Gaze duration was used to analyze the initial processing time for this region. First fixation duration was not analyzed for the informative context because this measure is only useful for single-word regions. As seen in Figure 4, the mean gaze duration for the informative context region was highest for the neutral condition followed by the familiar, phonological and orthographic conditions. However, no significant main effect was found, $F(3, 51) = 1.78$, $MSE = 51{,}754$, $p > .05$. This finding indicates that the amount of time spent fixating on the informative context region of the sentence did not depend on the type of target word.

Reanalysis of the informative context

As indicated in Figure 5, the mean total time for the informative context region was highest for the phonological condition followed by the familiar, orthographic and neutral conditions. There was no significant main effect, $F(3, 60) = .05$, $MSE = 46{,}291$, $p > .05$.

The mean spill over time was highest for the phonological condition followed by the orthographic, familiar and neutral conditions (see Figure 5).

Figure 4. The mean initial processing times in milliseconds for the informative context region of the sentence. Vertical lines represent standard error for means.



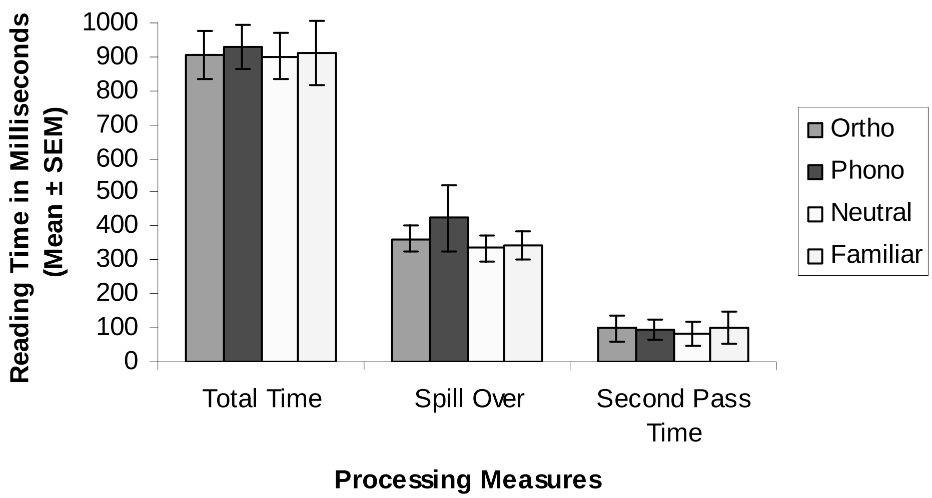
Reading Time in Milliseconds
(Mean ± SEM)
900
800
700
600
500
400
300
200
100
0
Gaze Duration
Processing Measure
Ortho
Phono
Neutral
Familiar

There was no main effect for spill over in the informative context region, $F(3, 60) = .62$, $MSE = 17,091$, $p > .05$.

For second pass time, the mean processing time was highest in the familiar condition followed by the orthographic, phonological and neutral conditions (see Figure 5). No significant main effect was found for second pass time in the informative context region, $F(3, 60) = .14$, $MSE = 4,934$, $p > .05$. The results from these reanalysis measures indicate that the amount of time spent on post-access processing did not differ depending on the condition. While it was expected that participants would have the most difficulty processing the informative context in the phonological condition, this hypothesis was not supported.

As seen in Figure 6, the mean number of regressions out of the informative context region was highest in the phonological condition followed by the orthographic, neutral and familiar conditions. There was a significant main effect for this measure, $F(3, 60) = 3.51$, $MSE = 310$, $p < .05$. Post hoc comparisons indicated that participants made more regressions in the phonological and neutral conditions than the familiar word condition. Contrary to the hypothesis, there was no significant difference between the orthographic and phonological conditions. There was also no difference between the orthographic and neutral conditions, as well as between the orthographic and familiar conditions. No significant difference was found between the phonological and neutral conditions. The high number of regressions for the phonological condition suggests that participants had more difficulty processing the meanings

Figure 5. The mean total times, spill over times, and second pass times in milliseconds for the informative context region of the sentence. Vertical lines represent standard error for means.


Reading Time in Milliseconds (Mean ± SEM)
1000
900
800
700
600
500
400
300
200
100
0
Total Time
Spill Over
Second Pass Time
Processing Measures
Ortho
Phono
Neutral
Familiar

of the phonological nonwords compared to the familiar word condition, which is consistent with the hypothesis.

The mean number of regressions into the informative context region was highest for the phonological condition followed by the neutral, familiar and orthographic conditions (see Figure 6). There was no significant main effect, $F(3, 60) = 1.34$, $MSE = 69.50$, $p > .05$. This indicates that the target word type did not influence how many times a participant looked back to the informative context.

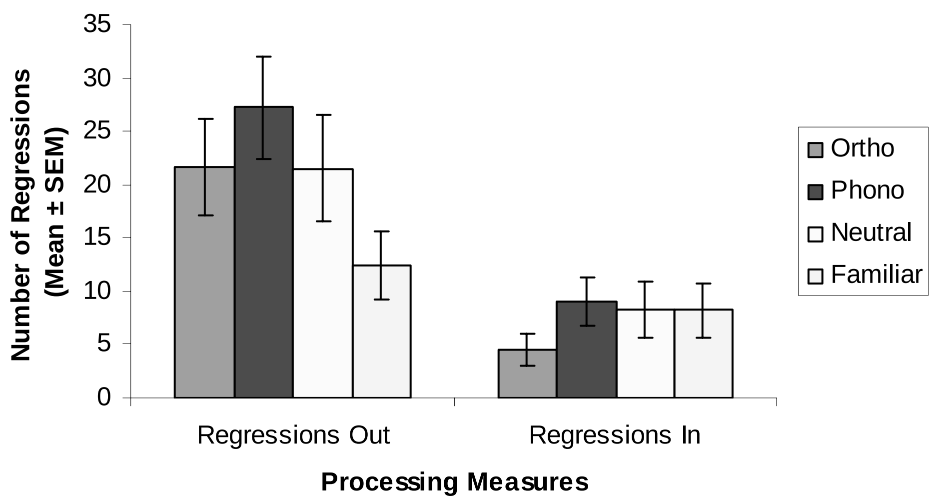
Initial processing of the category word

The third region that was examined was the category word in the second sentence of each sentence frame. Because the category word provided the reader with information about the target word, it was important to analyze the processing times and regressions for this region. If there was no difference in the way the category word was processed for the four conditions, it could be inferred that the readers had already determined the meaning of the target word before beginning the second sentence. This result was found in Chaffin et al.'s (2001) study, in which the researchers manipulated the familiarity of the target word.

In the current study it was hypothesized that there would be a difference in processing and regressions for the category word because the orthographic and phonological properties of the target words were manipulated. The orthographic and phonological similarities to real words were expected to cause difficulties in processing in both sentences of the sentence frame.

To examine the initial processing of the category word, first fixation

Figure 6. The number of regressions for the informative context region of the sentence. Vertical lines represent standard error for means.



Number of Regressions (Mean ± SEM)
35
30
25
20
15
10
5
0
Regressions Out
Regressions In
Processing Measures
Ortho
Phono
Neutral
Familiar

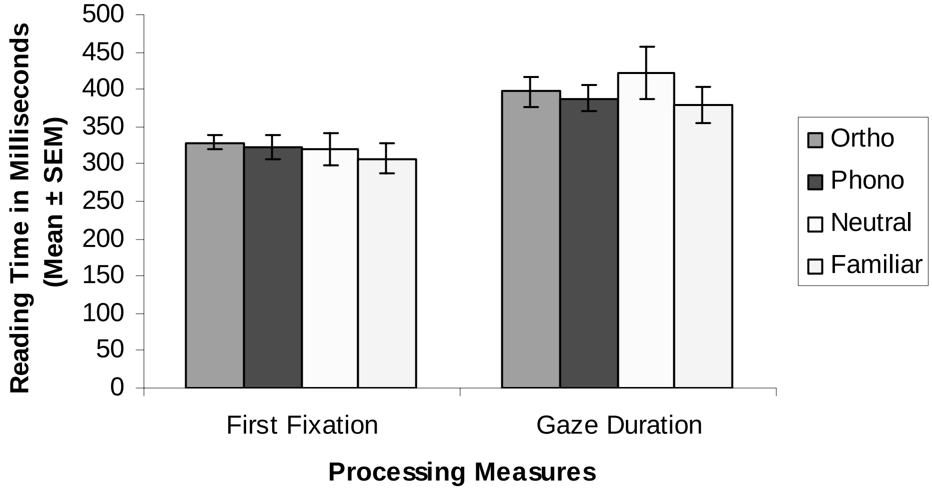
duration and gaze duration times were analyzed. As indicated in Figure 7, the mean first fixation duration for the category word in Sentence 2 was highest for the orthographic condition, followed by the phonological, neutral and familiar word conditions. However, no significant main effect was found for first fixation duration, $F(3, 60) = .26$, $MSE = 2{,}418$, $p > .05$.

The mean gaze duration for the category word was highest for the neutral condition followed by the orthographic, phonological, and familiar conditions (see Figure 7). There was no significant main effect, $F(3, 60) = .52$, $MSE = 7{,}311$, $p > .05$. The failure to find significant differences for these measures indicates that the orthographic and phonological properties of the target words did not influence the initial processing of the category word.

Reanalysis of the category word

Figure 8 illustrates the mean processing times for the reanalysis measures for the category word. The mean total time was highest for the neutral condition followed by the phonological, orthographic and familiar word conditions. There was a significant main effect for total time, $F(3, 60) = 3.86$, $MSE = 9{,}512$, $p < .05$. Post hoc comparisons revealed that participants spent more time on the category word in the neutral condition than in the orthographic, phonological, and familiar word conditions. However, there was no difference between the orthographic and familiar word conditions, and no difference between the phonological and familiar word conditions. There was also no significant difference between the

Figure 7. The mean initial processing times in milliseconds for the category word region of the sentence. Vertical lines represent standard error for means.



Reading Time in Milliseconds (Mean ± SEM)
500
450
400
350
300
250
200
150
100
50
0
First Fixation
Gaze Duration
Processing Measures
Ortho
Phono
Neutral
Familiar

orthographic and phonological conditions. These findings suggest that participants had the most difficulty processing the category word in the neutral condition, which is inconsistent with the expected results. It was also unexpected that the total time spent in the familiar condition was not significantly different from the time spent on the category word in the orthographic and phonological conditions. Furthermore, it was surprising that the total times did not differ for the orthographic and phonological conditions.

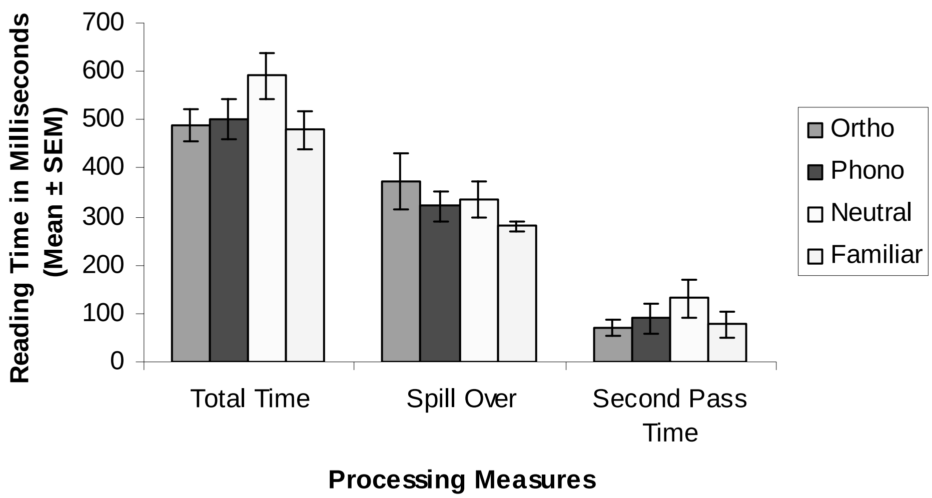
As seen in Figure 8, the mean spill over time was highest for the orthographic condition followed by the neutral, phonological and familiar word conditions. However, there was no significant main effect for spill over time on the category word region, $F(3, 60) = 1.17$, $MSE = 23{,}562$, $p > .05$. This suggests that post-access processing did not differ significantly for the four conditions.

The mean second pass time for the category word was highest for the neutral condition followed by the phonological, familiar, and orthographic conditions (see Figure 8). There was no significant main effect, $F(3, 60) = 2.48$, $MSE = 4{,}442$, $p > .05$. This finding suggests that participants did not differ significantly in the time spent rereading the category word in the four conditions.

As shown in Figure 9, the mean number of regressions out of the category word was highest for the orthographic condition followed by the phonological, neutral and familiar word conditions. There was no significant main effect, $F(3, 60) = .19$, $MSE = 310$, $p > .05$.

The mean number of regressions into the category word was highest for

Figure 8. The mean total times, spill over times, and second pass times in milliseconds for the category word region of the sentence. Vertical lines represent standard error for means.



Reading Time in Milliseconds (Mean ± SEM)
700
600
500
400
300
200
100
0
Total Time
Spill Over
Second Pass Time
Processing Measures
Ortho
Phono
Neutral
Familiar

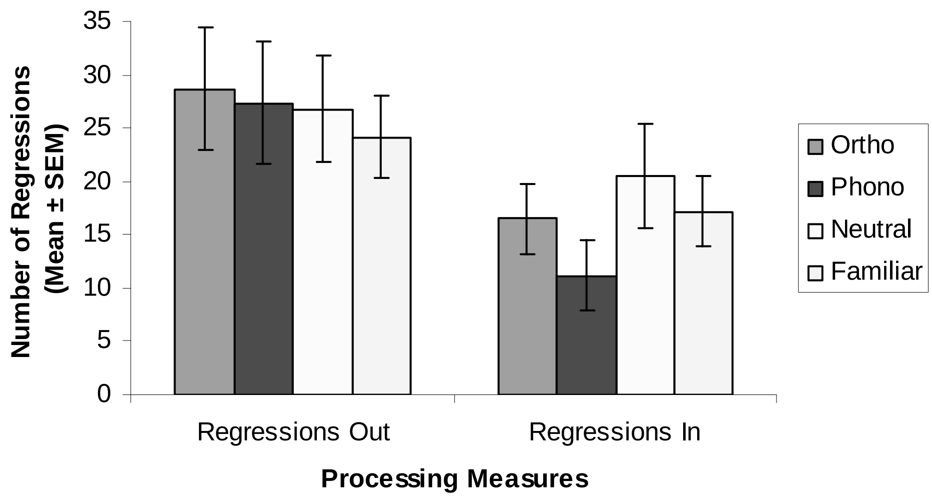
the neutral condition followed by the familiar, orthographic and phonological conditions (see Figure 9). No significant main effect was found, $F(3, 60) = 1.24$, $MSE = 138$, $p > .05$. The failure to find a significant difference for regressions into and out of the category word region indicates that participants were not more likely to look back to earlier segments of the text in the orthographic and phonological conditions.

Vocabulary Test Scores

In addition to the eye movement data, the vocabulary test scores were analyzed in order to determine if the participants were able to acquire and retain the meanings of the nonwords. As shown in Figure 10, the mean number of correct items was highest for the phonological condition followed by the orthographic and neutral conditions. However, no main effect was found, $F(2, 38) = .91$, $MSE = 2.71$, $p > .05$. This finding is inconsistent with the hypothesis, which stated that participants would have the most difficulty retaining the meanings of the phonological nonwords followed by the orthographic and neutral nonwords. The results indicate that the scores did not significantly differ for the three conditions.

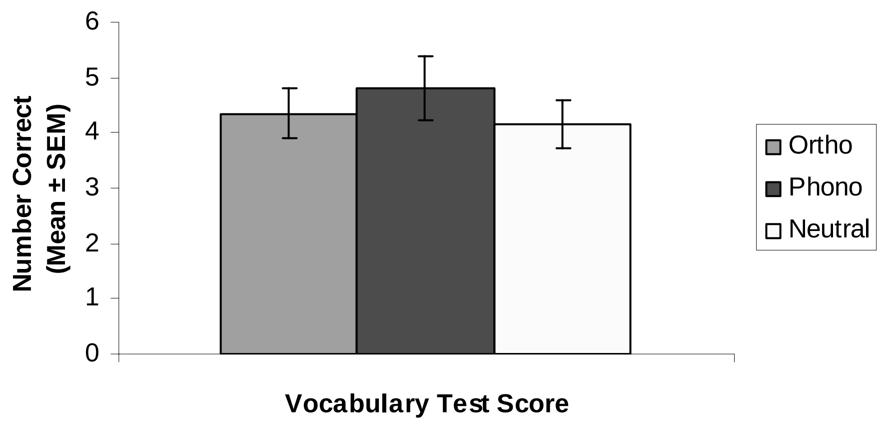
Data were also analyzed for the lure conditions in order to determine if participants were more likely to indicate that the phonological lures were the correct definitions when compared to the orthographic lures. The mean number of correct answers was higher for the orthographic lures than the phonological lures (see Figure 11). However, there was no significant main effect, $F(1, 19) = .073$,

Figure 9. The mean number of regressions for the category word region of the sentence. Vertical lines represent standard error for means.



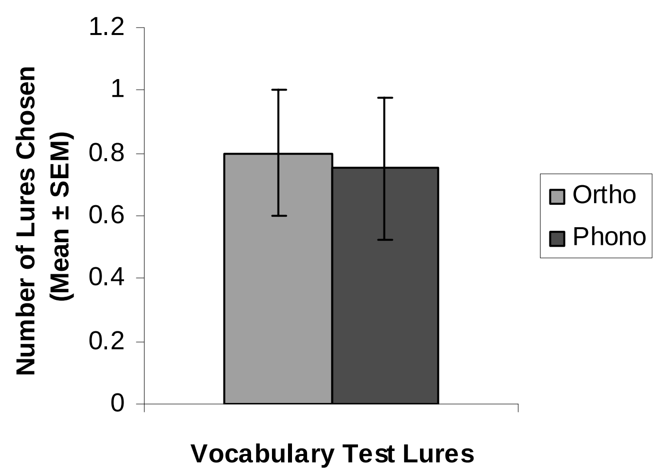
Number of Regressions (Mean ± SEM)
35
30
25
20
15
10
5
0
Regressions Out
Regressions In
Processing Measures
Ortho
Phono
Neutral
Familiar

Figure 10. The mean number of correct scores for the vocabulary test. Vertical lines represent standard error for means.



6
5
4
3
2
1
0
Number Correct
(Mean ± SEM)
Ortho
Phono
Neutral
Vocabulary Test Score

Figure 11. The mean number of orthographic and phonological lures chosen as correct answers in the vocabulary test. Vertical lines represent standard error for means.


1.2
1
0.8
0.6
0.4
0.2
0
Number of Lures Chosen (Mean ± SEM)
Vocabulary Test Lures
Ortho
Phono

MSE = .34, *p* > .05. This suggests that the interference created by including these lures in the answer choices did not significantly differ between the orthographic and phonological conditions.

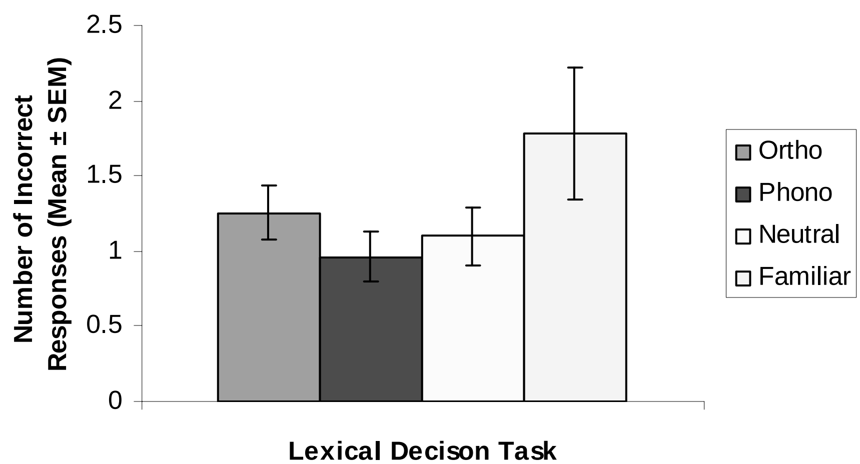
Lexical Decision Task

The lexical decision task data were examined in order to discover whether there were differences in processing when the stimuli items were viewed in isolation as opposed to being embedded into sentences. Data were eliminated from three participants because the task was not completed correctly. In addition, the data were lost for one participant. Data from 51 participants were analyzed using a one-way ANOVA to determine if there were any differences in accuracy and reaction times among the four conditions.

As seen in Figure 12, the mean number of incorrect responses in the lexical decision task was highest for the familiar word condition followed by the orthographic, neutral and phonological conditions. However, there was no significant main effect for accuracy, $F(3, 150) = 2.11$, $MSE = 4.45$, $p > .05$. While it was predicted that participants would have the highest number of incorrect responses for the phonological nonwords, the results indicate that the number of incorrect responses did not significantly differ among the conditions.

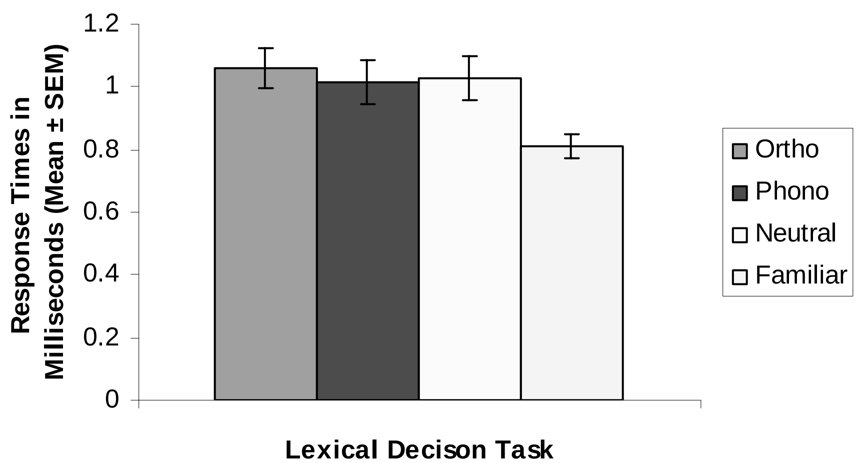
Figure 13 illustrates the mean response times for the four conditions. The mean was highest for the orthographic condition followed by the neutral, phonological and familiar conditions. There was a significant main effect for reaction times, $F(3, 150) = 15.40$, $MSE = .05$, $p < .05$. Post hoc comparisons

Figure 12. The mean number of incorrect responses for the lexical decision task. Vertical lines represent standard error for means.



Number of Incorrect Responses (Mean ± SEM)
2.5
2
1.5
1
0.5
0
Lexical Decison Task
Ortho
Phono
Neutral
Familiar

Figure 13. The mean response times for the lexical decision task. Vertical lines represent standard error for means.



Response Times in Milliseconds (Mean ± SEM)
1.2
1
0.8
0.6
0.4
0.2
0
Ortho
Phono
Neutral
Familiar
Lexical Decison Task

indicated that response times were significantly shorter for the familiar words than for the orthographic, phonological and neutral nonwords. However, no other differences among the conditions were found. While it was expected that participants would have shorter response times for the familiar words, it had also been predicted that participants would be quicker to respond to neutral nonwords than to orthographic and phonological nonwords. It was also hypothesized that participants would have shorter response times for orthographic nonwords than for phonological nonwords. The findings indicate that there were no significant differences in response times among the three nonword conditions.

DISCUSSION

The present study examined whether the orthographic and phonological properties of nonwords facilitate or inhibit vocabulary acquisition. Participants' eye movements were monitored as they read fifty-four sentences, each containing a familiar word or an orthographic, phonological, or neutral nonword. The phonological nonwords were expected to cause the most difficulty for skilled readers. The neutral nonwords were predicted to be less difficult than the orthographic and phonological items because seeing them should not activate any real words. To determine if the hypothesis was supported, three regions of the items were examined: the target word, the informative context, and the category word. The results were not entirely consistent with our hypothesis. No significant differences were found in the initial processing of the three regions, which does not support our prediction that phonology is activated early in word processing. However, evidence for both phonological and orthographic processing was found in some of the reanalysis measures.

Present Results Compared to Predicted Outcome

Participants spent more total time on the orthographic and phonological target words than on the familiar target words. The total time was also higher for the phonological target words compared to the neutral items. These findings suggest that the orthographic and phonological items caused interference for the readers, while the neutral and familiar words were processed more easily. This is consistent with the prediction that viewing the orthographic and phonological nonwords causes activation of real words while the neutral nonwords do not activate any real words.

Second pass time was also found to be longer for the orthographic nonwords than the familiar words, although no such difference was found for the phonological target words. This is consistent with the horse-race model of word recognition (see Rayner & Pollatsek, 1989), in which the orthographic and phonological routes compete against each other to find the correct meaning for the word. Whichever route is quickest is employed by the reader. As Rayner and Pollatsek (1989) explain, this model is similar to the direct-access route because the visual-orthographic route is fastest in most cases. However, the horse-race model differs from the direct-access model because both sources of information are competing simultaneously. For words with a regular spelling, the orthographic and phonological routes are in agreement and competition is not necessary. However, for irregular words (e.g., island), both routes work to provide the reader with the correct meaning. In the direct-access model, the visual-orthographic route plays a central role and the phonological route is only accessed under limited circumstances.

The results of this study also indicated that readers made more regressions out of the informative context region following the phonological and neutral nonwords than the familiar words. This is somewhat consistent with the hypothesis, since it was predicted that readers would have the most difficulty processing the phonological items. This finding is also supported by the horse-race theory, which suggests that readers should have slower processing times and a lower rate of accuracy for pseudohomophones because these items will activate the similar sounding real words in the lexicon. However, it was surprising that readers did not make more regressions back to the orthographic nonwords than to the neutral and familiar items. It was also unexpected that there was no significant difference between the phonological and neutral condition. The finding that the familiar words are easiest to process is consistent with past research.

As with the target word and informative context, there were no differences in the initial processing of the category word in Sentence 2. However, the amount of total time spent on the category word was longer for the neutral condition than the other three conditions. No differences were found for the orthographic and phonological conditions. This is somewhat consistent with the findings from Chaffin et al.'s (2001) study. Chaffin et al. did not find any differences in initial or total time for the Sentence 2 associate word. They explained this by suggesting that the readers determined the meaning of the novel word by the time they finished reading Sentence 1. Therefore, they did not need to spend any more time than necessary to process the associate word in Sentence 2.

While this could explain the lack of differences for the orthographic and phonological condition in the present study, it does not explain the higher processing time for the neutral condition. Perhaps participants spent less time on the category word in the orthographic and phonological conditions because the interference created by these nonwords caused readers to spend a longer amount of time processing the first sentence. By the time readers reached the second sentence, they did not need to spend as much time processing the category word because the difficulties had been resolved. Because readers did not face as much difficulty when presented with the neutral nonwords, they processed the first sentence more quickly for the neutral condition. When they read the category word in the second sentence they may have needed to spend more time processing it because they had not yet successfully inferred the meaning of the neutral nonword.

The results from the vocabulary test indicate that readers successfully learned the meanings of approximately 50% of the nonwords. Contrary to what was predicted, no significant differences were found for vocabulary test scores among the three nonword conditions. This indicates that the participants did not have more difficulty retaining the meanings of the phonological and orthographic nonwords compared to the neutral nonwords. This is inconsistent with past studies by researchers such as Van Orden (1987), who suggested that skilled readers have more difficulty processing pseudohomophones than other nonwords. The results from this study suggest that while participants experienced greater difficulty processing the orthographic and phonological nonwords in some of the reanalysis measures, the orthographic and phonological conditions did not interfere with their ability to learn the meanings of the nonwords.

Also, no significant differences were found for accuracy among the orthographic, phonological, neutral and familiar word conditions in the lexical decision task. This was inconsistent with the hypothesis, since it was predicted that participants would make more errors in the phonological condition, followed by the orthographic and neutral conditions. It was also expected that participants would have the highest rate of accuracy for the familiar words compared to the nonword conditions. The failure to find a significant main effect may have been due to the small sample size. While researchers such as Unsworth and Pexman (2003) conducted lexical decision tasks with 75 participants, the present study only included data from 51 participants. This suggests that significant results may be obtained with a larger number of participants.

There was however, a significant main effect for response times in the lexical decision task. The finding that participants had the shortest response times for the familiar words is consistent with the hypothesis. It is also consistent with past research suggesting that familiar words are easier to process than unfamiliar words (e.g., Chaffin et al., 2001).

Directions for Future Research

Evidence from vocabulary acquisition studies can be valuable in explaining how readers process words. Since the results from the present experiment were not consistent with the hypothesis, further research into this area of study may provide clearer insight into the roles of orthography and phonology in vocabulary acquisition. It would be beneficial to examine readers' long term retention of the orthographic, phonological and neutral nonwords. While evidence from the vocabulary test scores showed that participants were able to retain the meanings of many of the nonwords, it was unclear whether this effect was long-term. A future study could involve administering a vocabulary test to participants a week or more after the eye tracking task. A study such as this could provide insight about whether or not participants are able to retain the meanings of the nonwords after a significant amount of time has passed. In addition to determining whether the retention effects are long term, it would also be possible to discover whether the ability of participants to remember the nonword meanings over a long period of time differs among the nonwords conditions.

It would also be interesting to conduct this study with a different population to examine whether less skilled readers rely on different sources of information than more skilled readers. Because it is likely that all of the participants in the present study are skilled readers, it was hypothesized that the readers would rely upon phonological coding. According to past studies conducted by researchers such as Majeres (2005) and Unsworth and Pexman (2003), less skilled readers rely more heavily on orthographic skills. By conducting a study that incorporates younger and less skilled adult readers as well as skilled adult readers, it would be possible to investigate the differences among readers of different ages and skill levels.

Conclusion

By expanding on the present study, it would be possible to gain more insight into how readers acquire the meanings of unfamiliar words. Research on the orthographic and phonological properties of words can provide valuable information as to how readers process words and could be used to further our knowledge of the differences between skilled and less skilled readers. Knowledge of differences in reading may be especially beneficial to illiterate adults since it could inform the instructional approaches employed in adult basic education programs. It is essential for the problem of adult illiteracy to be addressed due to the importance placed on effective reading and writing skills in this society. Further research examining the differences in word processing among different populations may be valuable in determining effective methods of instruction for readers of different backgrounds and skill levels.

Appendix A

Orthographic, Phonological, Neutral and Familiar Conditions

Source Words	**Orthographic**	**Phonological**	**Neutral**	**Familiar**
ballroom	ballkoom	bawlrume	quintrod	champagne
brain	brair	brayne	asdor	salt
broccoli	broscoli	brockalee	spocheld	apricots
broom	broam	bruume	swurp	onions
camera	cameda	kamarah	lathlar	pistol
choir	thoir	kwire	troig	roses
city	oity	sitee	nilb	house
clerk	clerf	klurck	ginta	hymn
clock	closk	klawk	ploje	guitar
coffee	cogfee	kophy	quetic	knife
cousin	comsin	kuhzen	zithen	baseball
disk	disp	dihsk	keth	chairs
doctor	dootor	dahktur	klendop	radio
dollar	dollan	dawlur	crauth	dress
friend	friond	phrynd	joart	leather
fruit	frult	phroot	mugro	wrench
garden	gamden	gaurdyn	brensot	cocktail
human	humak	huemyn	noalt	church
kitten	kiften	kyttin	seloip	yacht
lawyer	mawyer	loyur	cudram	needle
milk	misk	mihlck	phup	taxi
mirror	mirsor	meerur	secain	hawk
money	motey	munnee	pexim	water
ocean	ocead	oshun	plarp	waltz
oxygen	oxylen	ocksijen	rickep	cabbage
paper	paped	paypur	hulto	rolls
phone	plone	foane	sodet	salmon
picture	picqure	pikshir	flipins	science
pocket	pecket	pawkit	burvet	clip
sauce	saice	sawse	lodim	basil

scissors	stissors	sizzurz	cynthors	cholera
shoulder	shoumder	sholdir	clostern	chocolate
skunk	skund	scunck	octem	seltzer
soccer	soccep	sawkur	pramit	leopard
stomach	storach	stumik	stisher	otters
urine	urone	yuren	micog	holly

Appendix B

Experimental Sentences with Orthographic, Phonological, Neutral and Familiar Target Words

(1)
Annette bought *ballkoom* for Jason and Natalie because their wedding was in two weeks.
She hoped the wedding gift would be well received.

Annette bought *bawlrume* for Jason and Natalie because their wedding was in two weeks.
She hoped the wedding gift would be well received.

Annette bought *quintrod* for Jason and Natalie because their wedding was in two weeks.
She hoped the wedding gift would be well received.

Annette bought *champagne* for Jason and Natalie because their wedding was in two weeks.
She hoped the wedding gift would be well received.

(2)
Jack wondered if the *brair* would taste good in coffee.
The seasoning added a new flavor.

Jack wondered if the *brayne* would taste good in coffee.
The seasoning added a new flavor.

Jack wondered if the *asdor* would taste good in coffee.
The seasoning added a new flavor.

Jack wondered if the *salt* would taste good in coffee.
The seasoning added a new flavor.

(3)
There were *broscoli* ready to pick for making jam.
The fruit looked ripe and delicious.

There were *brockalee* ready to pick for making jam.
The fruit looked ripe and delicious.

There were *spocheld* ready to pick for making jam.
The fruit looked ripe and delicious.

There were *apricots* ready to pick for making jam.
The fruit looked ripe and delicious.

(4)
Ingrid chopped the *broam* to put in the soup.
She wanted to add a lot of ingredients to bring out the soup's flavor.

Ingrid chopped the *bruume* to put in the soup.
She wanted to add a lot of ingredients to bring out the soup's flavor.

Ingrid chopped the *swurp* to put in the soup.
She wanted to add a lot of ingredients to bring out the soup's flavor.

Ingrid chopped the *onions* to put in the soup.
She wanted to add a lot of ingredients to bring out the soup's flavor.

(5)
After the *cameda* was fired at the sheriff, the gambler ran off.
While running off he dropped his weapon and fumbled.

After the *kamarah* was fired at the sheriff, the gambler ran off.
While running off he dropped his weapon and fumbled.

After the *lathlar* was fired at the sheriff, the gambler ran off.
While running off he dropped his weapon and fumbled.

After the *pistol* was fired at the sheriff, the gambler ran off.
While running off he dropped his weapon and fumbled.

(6)
Sabrina was sad that the *thoir* did not bloom this year.
That flower smelled so nice.

Sabrina was sad that the *kwire* did not bloom this year.
That flower smelled so nice.

Sabrina was sad that the *troig* did not bloom this year.
That flower smelled so nice.

Sabrina was sad that the *roses* did not bloom this year.
That flower smelled so nice.

(7)
After her *oity* was burglarized, Gloria always bolted the door.

She was worried the dwelling would be broken into again.

After her *sitee* was burglarized, Gloria always bolted the door.
She was worried the dwelling would be broken into again.

After her *nilb* was burglarized, Gloria always bolted the door.
She was worried the dwelling would be broken into again.

After her *house* was burglarized, Gloria always bolted the door.
She was worried the dwelling would be broken into again.

(8)
Last night the *clerf* was performed beautifully by the organist.
The song resounded through the hall.

Last night the *klurck* was performed beautifully by the organist.
The song resounded through the hall.

Last night the *ginta* was performed beautifully by the organist.
The song resounded through the hall.

Last night the *hymn* was performed beautifully by the organist.
The song resounded through the hall.

(9)
Joe picked up the *closk* and began to strum a tune.
He played the instrument to relax.

Joe picked up the *klawk* and began to strum a tune.
He played the instrument to relax.

Joe picked up the *ploje* and began to strum a tune.
He played the instrument to relax.

Joe picked up the *guitar* and began to strum a tune.
He played the instrument to relax.

(10)
The *cogfee* was used to cut the material in many parts.
The utensil was sharp so it was very useful.

The *kophy* was used to cut the material in many parts.
The utensil was sharp so it was very useful.

The *quetic* was used to cut the material in many parts.
The utensil was sharp so it was very useful.

The *knife* was used to cut the material in many parts.
The utensil was sharp so it was very useful.

(11)
Jackie loved *comsin* because her team always won.
She decided to play the sport again next year.

Jackie loved *kuhzen* because her team always won.
She decided to play the sport again next year.

Jackie loved *zithen* because her team always won.
She decided to play the sport again next year.

Jackie loved *baseball* because her team always won.
She decided to play the sport again next year.

(12)
Sharon needed *disp* for her apartment because there was no place to sit.
She bought the furniture that was most comfortable.

Sharon needed *dihsk* for her apartment because there was no place to sit.
She bought the furniture that was most comfortable.

Sharon needed *keth* for her apartment because there was no place to sit.
She bought the furniture that was most comfortable.

Sharon needed *chairs* for her apartment because there was no place to sit.
She bought the furniture that was most comfortable.

(13)
Nathan used the *dootor* to talk to Jennifer.
The communication device was very inexpensive.

Nathan used the *dahktur* to talk to Jennifer.
The communication device was very inexpensive.

Nathan used the *klendop* to talk to Jennifer.
The communication device was very inexpensive.

Nathan used the *radio* to talk to Jennifer.
The communication device was very inexpensive.

(14)
There was the *dollan* that Ann’s seamstress had made for the party.
The clothing looked just as she had imagined.

There was the *dawlur* that Ann’s seamstress had made for the party.
The clothing looked just as she had imagined.

There was the *crauth* that Ann’s seamstress had made for the party.
The clothing looked just as she had imagined.

There was the *dress* that Ann’s seamstress had made for the party.
The clothing looked just as she had imagined.

(15)
Carol decided that the *friond* could not be used to make a lovely skirt.
The texture of the fabric wasn't right.

Carol decided that the *phrynd* could not be used to make a lovely skirt.
The texture of the fabric wasn't right.

Carol decided that the *joart* could not be used to make a lovely skirt.
The texture of the fabric wasn't right.

Carol decided that the *leather* could not be used to make a lovely skirt.
The texture of the fabric wasn't right.

(16)
Kim realized she didn’t have a *frult* to fix her motorcycle.
She searched for the tool in the garage.

Kim realized she didn’t have a *phroot* to fix her motorcycle.
She searched for the tool in the garage.

Kim realized she didn’t have a *mugro* to fix her motorcycle.
She searched for the tool in the garage.

Kim realized she didn’t have a *wrench* to fix her motorcycle.
She searched for the tool in the garage.

(17)
Nancy finished her *gamden* and asked the bartender for another.
This was her third drink of the night.

Nancy finished her *gaurdyn* and asked the bartender for another.

This was her third drink of the night.

Nancy finished her *brensot* and asked the bartender for another.
This was her third drink of the night.

Nancy finished her *cocktail* and asked the bartender for another.
This was her third drink of the night.

(18)
There was a *humak* in the center of the city.
The building was built in the eighteenth century.

There was a *huemyn* in the center of the city.
The building was built in the eighteenth century.

There was a *noalt* in the center of the city.
The building was built in the eighteenth century.

There was a *church* in the center of the city.
The building was built in the eighteenth century.

(19)
Kyle had seen the *kiften* in the harbor when he visited the captain.
He was surprised the boat was so gigantic.

Kyle had seen the *kyttin* in the harbor when he visited the captain.
He was surprised the boat was so gigantic.

Kyle had seen the *seloip* in the harbor when he visited the captain.
He was surprised the boat was so gigantic.

Kyle had seen the *yacht* in the harbor when he visited the captain.
He was surprised the boat was so gigantic.

(20)
First the *mawyer* was used to make holes in the leather.
John found the implement in the sewing kit.

First the *loyur* was used to make holes in the leather.
John found the implement in the sewing kit.

First the *cudram* was used to make holes in the leather.
John found the implement in the sewing kit.

First the *needle* was used to make holes in the leather.
John found the implement in the sewing kit.

(21)
That day the *misk* carried the tourists through the city streets.
The tourists hoped the vehicle was safe.

That day the *mihlck* carried the tourists through the city streets.
The tourists hoped the vehicle was safe.

That day the *phup* carried the tourists through the city streets.
The tourists hoped the vehicle was safe.

That day the *taxi* carried the tourists through the city streets.
The tourists hoped the vehicle was safe.

(22)
There was a single *mirsor* perched in the tree this morning.
It seemed like an odd season for birds to be around.

There was a single *meerur* perched in the tree this morning.
It seemed like an odd season for birds to be around.

There was a single *secain* perched in the tree this morning.
It seemed like an odd season for birds to be around.

There was a single *hawk* perched in the tree this morning.
It seemed like an odd season for birds to be around.

(23)
Aaron took the *motey* and poured it on his head.
The liquid was refreshing since it was a very hot day.

Aaron took the *munnee* and poured it on his head.
The liquid was refreshing since it was a very hot day.

Aaron took the *pexim* and poured it on his head.
The liquid was refreshing since it was a very hot day.

Aaron took the *water* and poured it on his head.
The liquid was refreshing since it was a very hot day.

(24)
Kay knew that the *ocead* would be performed to Spanish music.
Last night the dance was slower.

Kay knew that the *oshun* would be performed to Spanish music.
Last night the dance was slower.

Kay knew that the *plarp* would be performed to Spanish music.
Last night the dance was slower.

Kay knew that the *waltz* would be performed to Spanish music.
Last night the dance was slower.

(25)
Mike was surprised that the *oxylen* was boiled for dinner.
He had hoped to have the vegetable steamed.

Mike was surprised that the *ocksijen* was boiled for dinner.
He had hoped to have the vegetable steamed.

Mike was surprised that the *rickep* was boiled for dinner.
He had hoped to have the vegetable steamed.

Mike was surprised that the *cabbage* was boiled for dinner.
He had hoped to have the vegetable steamed.

(26)
Ben bought a lot of *paped* at the bakery.
He enjoyed the bread because it was fresh.

Ben bought a lot of *paypur* at the bakery.
He enjoyed the bread because it was fresh.

Ben bought a lot of *hulto* at the bakery.
He enjoyed the bread because it was fresh.

Ben bought a lot of *rolls* at the bakery.
He enjoyed the bread because it was fresh.

(27)
Even before the *plone* was reeled in, the sportsman held the record.
The squirming fish was difficult to catch.

Even before the *foane* was reeled in, the sportsman held the record.

The squirming fish was difficult to catch.

Even before the *sodet* was reeled in, the sportsman held the record.
The squirming fish was difficult to catch.

Even before the *salmon* was reeled in, the sportsman held the record.
The squirming fish was difficult to catch.

(28)
Jake disliked *picqure* because he did badly on the tests.
He thought the subject was boring.

Jake disliked *pikshir* because he did badly on the tests.
He thought the subject was boring.

Jake disliked *flipins* because he did badly on the tests.
He thought the subject was boring.

Jake disliked *science* because he did badly on the tests.
He thought the subject was boring.

(29)
Julie bought a *pecket* to wear in her hair.
She chose the accessory because it matched her dress.

Julie bought a *pawkit* to wear in her hair.
She chose the accessory because it matched her dress.

Julie bought a *burvet* to wear in her hair.
She chose the accessory because it matched her dress.

Julie bought a *clip* to wear in her hair.
She chose the accessory because it matched her dress.

(30)
Tom put *saice* in his pasta to add more flavor.
He enjoyed trying new herbs in his food.

Tom put *sawse* in his pasta to add more flavor.
He enjoyed trying new herbs in his food.

Tom put *lodim* in his pasta to add more flavor.
He enjoyed trying new herbs in his food.

Tom put *basil* in his pasta to add more flavor.
He enjoyed trying new herbs in his food.

(31)
When the *stissors* was diagnosed, the boy was placed in the hospital.
The boy's disease was dangerous.

When the *sizzurz* was diagnosed, the boy was placed in the hospital.
The boy's disease was dangerous.

When the *cynthors* was diagnosed, the boy was placed in the hospital.
The boy's disease was dangerous.

When the *cholera* was diagnosed, the boy was placed in the hospital.
The boy's disease was dangerous.

(32)
Brian bought *shoumder* to give to children on Halloween.
He saved the candy that was left over.

Brian bought *sholdir* to give to children on Halloween.
He saved the candy that was left over.

Brian bought *clostern* to give to children on Halloween.
He saved the candy that was left over.

Brian bought *chocolate* to give to children on Halloween.
He saved the candy that was left over.

(33)
Jill bought the *skund* and sipped it with a straw.
The drink was ice cold.

Jill bought the *scunck* and sipped it with a straw.
The drink was ice cold.

Jill bought the *octem* and sipped it with a straw.
The drink was ice cold.

Jill bought the *seltzer* and sipped it with a straw.
The drink was ice cold.

(34)
Yesterday the *soccep* stalked its prey and moved in for the kill.

The animal’s tactic was swift.

Yesterday the *sawkur* stalked its prey and moved in for the kill.
The animal’s tactic was swift.

Yesterday the *pramit* stalked its prey and moved in for the kill.
The animal’s tactic was swift.

Yesterday the *leopard* stalked its prey and moved in for the kill.
The animal’s tactic was swift.

(35)
There were many *storach* at the zoo.
The animals were in the water the whole day.

There were many *stumik* at the zoo.
The animals were in the water the whole day.

There were many *stisher* at the zoo.
The animals were in the water the whole day.

There were many *otters* at the zoo.
The animals were in the water the whole day.

(36)
It is clear that the *urone* along the driveway need trimming.
The unkempt plants are unappealing.

It is clear that the *yuren* along the driveway need trimming.
The unkempt plants are unappealing.

It is clear that the *micog* along the driveway need trimming.
The unkempt plants are unappealing.

It is clear that the *holly* along the driveway need trimming.
The unkempt plants are unappealing.

Appendix C

Filler Sentences

Elisa thought the painting was very thought provoking.
She saw the artwork in a museum in her town.

Paul bought the figurine for his cousin.
The toy was very popular.

The thunderstorm frightened the children.
They waited until the storm was over to go to sleep.

Henry used watercolors for his design.
He used the paint for many of his projects.

Lindsey found waiters to work in her restaurant.
She was pleased to find that the employees were diligent.

Taylor decided to enter the marathon this June.
He started training for the race last week.

There was a rattlesnake slithering along the rocky ledge.
It was time for the reptile to hibernate.

Dean enjoyed archeology because ancient history fascinated him.
He found his career to be very rewarding.

Cindy wanted the fable to be read to her one more time.
She listened eagerly because the story was her favorite.

The group spotted a scorpion in the desert.
They were careful of the arachnid since it was venomous.

The students were given poetry to read.
They found the writing very interesting.

As a snowboarder, Leah participated in many competitions.
It was hard for the athlete to cope with her injury.

The tour guide described the statue to interested passerby.
The monument was a popular attraction.

Myra discovered that quartz was abundant in the area.
She was not surprised since the mineral is extremely common.

Greg searched for the manuscript in the library.
He was interested in the document due to its rarity.

Maggie inspected the cabinet and added it to her collection.
She wanted to know how much the antique was worth.

Becky offered pecans to her guests while they waited for dinner.
She had bought the nuts at the grocery store.

Susan had breakfast every morning before work.
It was her favorite meal of the day.

Appendix D

Questionnaire

Age: ____

Was English your first language? Yes No

If no, how long have you been speaking English?

____

Please list any languages you speak besides English. Include how long you have been speaking each and your level of fluency on a scale of 1 to 5 (1=not at all, 5=very fluent).

Language Years spoken Level of Fluency (scale of 1-5)

____

____

____

What instructional approach was used to teach you how to read? (Leave blank if you are unsure.) ____________________________

Are you right or left handed? ____________________________

Do you regularly use an Instant Messenger program? Yes No

How often do you use shortcut spellings (i.e. fone instead of phone) when typing?

Frequently Sometimes Never

Appendix E

ANOVA Tables

Table 1

First Fixation Duration for Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	11868.857	3	3956.286	1.326	.274
	Greenhouse-Geisser	11868.857	1.933	6139.982	1.326	.277
	Huynh-Feldt	11868.857	2.136	5556.162	1.326	.277
	Lower-bound	11868.857	1.000	11868.857	1.326	.263
Error(target)	Sphericity Assumed	178996.643	60	2983.277		
	Greenhouse-Geisser	178996.643	38.661	4629.916		
	Huynh-Feldt	178996.643	42.723	4189.680		
	Lower-bound	178996.643	20.000	8949.832		

Table 2

Gaze Duration for Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	8113.381	3	2704.460	.511	.676
	Greenhouse-Geisser	8113.381	2.523	3216.366	.511	.645
	Huynh-Feldt	8113.381	2.917	2781.884	.511	.671
	Lower-bound	8113.381	1.000	8113.381	.511	.483
Error(target)	Sphericity Assumed	317798.619	60	5296.644		
	Greenhouse-Geisser	317798.619	50.451	6299.202		
	Huynh-Feldt	317798.619	58.330	5448.276		
	Lower-bound	317798.619	20.000	15889.931		

Table 3

Total Time for Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	133747.083	3	44582.361	3.675	.017
	Greenhouse-Geisser	133747.083	2.569	52065.908	3.675	.023
	Huynh-Feldt	133747.083	2.980	44881.652	3.675	.017
	Lower-bound	133747.083	1.000	133747.083	3.675	.070
Error(target)	Sphericity Assumed	727833.167	60	12130.553		
	Greenhouse-Geisser	727833.167	51.376	14166.774		
	Huynh-Feldt	727833.167	59.600	12211.988		
	Lower-bound	727833.167	20.000	36391.658		

Table 4

Spill Over for Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	10217.274	3	3405.758	.545	.654
	Greenhouse-Geisser	10217.274	2.263	4515.474	.545	.605
	Huynh-Feldt	10217.274	2.566	3981.496	.545	.627
	Lower-bound	10217.274	1.000	10217.274	.545	.469
Error(target)	Sphericity Assumed	375044.976	60	6250.750		
	Greenhouse-Geisser	375044.976	45.254	8287.464		
	Huynh-Feldt	375044.976	51.324	7307.429		
	Lower-bound	375044.976	20.000	18752.249		

Table 5

Second Pass Time for Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	31990.226	3	10663.409	2.995	.038
	Greenhouse-Geisser	31990.226	2.534	12622.361	2.995	.047
	Huynh-Feldt	31990.226	2.933	10907.847	2.995	.039
	Lower-bound	31990.226	1.000	31990.226	2.995	.099
Error(target)	Sphericity Assumed	213626.024	60	3560.434		
	Greenhouse-Geisser	213626.024	50.688	4214.513		
	Huynh-Feldt	213626.024	58.655	3642.050		
	Lower-bound	213626.024	20.000	10681.301		

Table 6

Regressions out of Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	842.905	3	280.968	2.119	.107
	Greenhouse-Geisser	842.905	2.662	316.670	2.119	.115
	Huynh-Feldt	842.905	3.000	280.968	2.119	.107
	Lower-bound	842.905	1.000	842.905	2.119	.161
Error(target)	Sphericity Assumed	7954.095	60	132.568		
	Greenhouse-Geisser	7954.095	53.236	149.413		
	Huynh-Feldt	7954.095	60.000	132.568		
	Lower-bound	7954.095	20.000	397.705		

Table 7

Regressions into Target Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
target	Sphericity Assumed	376.810	3	125.603	.696	.558
	Greenhouse-Geisser	376.810	2.188	172.244	.696	.516
	Huynh-Feldt	376.810	2.467	152.748	.696	.532
	Lower-bound	376.810	1.000	376.810	.696	.414
Error(target)	Sphericity Assumed	10831.690	60	180.528		
	Greenhouse-Geisser	10831.690	43.753	247.564		
	Huynh-Feldt	10831.690	49.337	219.544		
	Lower-bound	10831.690	20.000	541.585		

Table 8

Gaze Duration for Informative Context

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	71303.143	3	23767.714	.691	.561
	Greenhouse-Geisser	71303.143	2.391	29819.174	.691	.531
	Huynh-Feldt	71303.143	2.738	26041.009	.691	.549
	Lower-bound	71303.143	1.000	71303.143	.691	.416
Error(context)	Sphericity Assumed	2064282.857	60	34404.714		
	Greenhouse-Geisser	2064282.857	47.824	43164.444		
	Huynh-Feldt	2064282.857	54.762	37695.399		
	Lower-bound	2064282.857	20.000	103214.143		

Table 9

Total Time for Informative Context

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	8703.845	3	2901.282	.050	.985
	Greenhouse-Geisser	8703.845	2.120	4105.849	.050	.958
	Huynh-Feldt	8703.845	2.378	3660.309	.050	.969
	Lower-bound	8703.845	1.000	8703.845	.050	.826
Error(context)	Sphericity Assumed	3493573.405	60	58226.223		
	Greenhouse-Geisser	3493573.405	42.397	82400.858		
	Huynh-Feldt	3493573.405	47.558	73459.242		
	Lower-bound	3493573.405	20.000	174678.670		

Table 10

Spill Over Time for Informative Context

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	97689.560	3	32563.187	.618	.606
	Greenhouse-Geisser	97689.560	1.256	77787.910	.618	.474
	Huynh-Feldt	97689.560	1.300	75129.339	.618	.480
	Lower-bound	97689.560	1.000	97689.560	.618	.441
Error(context)	Sphericity Assumed	3161072.690	60	52684.545		
	Greenhouse-Geisser	3161072.690	25.117	125854.411		
	Huynh-Feldt	3161072.690	26.006	121553.062		
	Lower-bound	3161072.690	20.000	158053.635		

Table 11

Second Pass Time for Informative Context

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	3193.560	3	1064.520	.136	.938
	Greenhouse-Geisser	3193.560	1.951	1636.487	.136	.868
	Huynh-Feldt	3193.560	2.160	1478.648	.136	.887
	Lower-bound	3193.560	1.000	3193.560	.136	.716
Error(context)	Sphericity Assumed	469470.190	60	7824.503		
	Greenhouse-Geisser	469470.190	39.029	12028.616		
	Huynh-Feldt	469470.190	43.196	10868.454		
	Lower-bound	469470.190	20.000	23473.510		

Table 12

Regressions out of Informative Context

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	2349.905	3	783.302	3.513	.020
	Greenhouse-Geisser	2349.905	2.378	988.020	3.513	.031
	Huynh-Feldt	2349.905	2.721	863.655	3.513	.024
	Lower-bound	2349.905	1.000	2349.905	3.513	.076
Error(context)	Sphericity Assumed	13376.595	60	222.943		
	Greenhouse-Geisser	13376.595	47.568	281.210		
	Huynh-Feldt	13376.595	54.418	245.813		
	Lower-bound	13376.595	20.000	668.830		

Table 13

Regressions into Informative Context

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
context	Sphericity Assumed	247.381	3	82.460	1.337	.271
	Greenhouse-Geisser	247.381	2.732	90.558	1.337	.272
	Huynh-Feldt	247.381	3.000	82.460	1.337	.271
	Lower-bound	247.381	1.000	247.381	1.337	.261
Error(context)	Sphericity Assumed	3700.119	60	61.669		
	Greenhouse-Geisser	3700.119	54.635	67.725		
	Huynh-Feldt	3700.119	60.000	61.669		
	Lower-bound	3700.119	20.000	185.006		

Table 14

First Fixation Duration for Category Word

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	5366.952	3	1788.984	.255	.858
	Greenhouse-Geisser	5366.952	1.434	3741.832	.255	.702
	Huynh-Feldt	5366.952	1.515	3543.359	.255	.715
	Lower-bound	5366.952	1.000	5366.952	.255	.619
Error(category)	Sphericity Assumed	421289.548	60	7021.492		
	Greenhouse-Geisser	421289.548	28.686	14686.125		
	Huynh-Feldt	421289.548	30.293	13907.148		
	Lower-bound	421289.548	20.000	21064.477		

Table 15

Gaze Duration for Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	21962.893	3	7320.964	.515	.674
	Greenhouse-Geisser	21962.893	1.584	13869.392	.515	.560
	Huynh-Feldt	21962.893	1.697	12941.417	.515	.573
	Lower-bound	21962.893	1.000	21962.893	.515	.481
Error(category)	Sphericity Assumed	853106.857	60	14218.448		
	Greenhouse-Geisser	853106.857	31.671	26936.510		
	Huynh-Feldt	853106.857	33.942	25134.238		
	Lower-bound	853106.857	20.000	42655.343		

Table 16

Total Time for Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	165357.560	3	55119.187	3.864	.014
	Greenhouse-Geisser	165357.560	2.117	78123.499	3.864	.027
	Huynh-Feldt	165357.560	2.374	69663.711	3.864	.022
	Lower-bound	165357.560	1.000	165357.560	3.864	.063
Error(category)	Sphericity Assumed	855860.190	60	14264.337		
	Greenhouse-Geisser	855860.190	42.332	20217.640		
	Huynh-Feldt	855860.190	47.473	18028.325		
	Lower-bound	855860.190	20.000	42793.010		

Table 17

Spill Over Time for Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	90958.607	3	30319.536	1.170	.329
	Greenhouse-Geisser	90958.607	1.894	48027.680	1.170	.319
	Huynh-Feldt	90958.607	2.086	43601.909	1.170	.322
	Lower-bound	90958.607	1.000	90958.607	1.170	.292
Error(category)	Sphericity Assumed	1554606.643	60	25910.111		
	Greenhouse-Geisser	1554606.643	37.878	41042.928		
	Huynh-Feldt	1554606.643	41.722	37260.804		
	Lower-bound	1554606.643	20.000	77730.332		

Table 18

Second Pass Time for Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Category	Sphericity Assumed	47805.905	3	15935.302	2.483	.069
	Greenhouse-Geisser	47805.905	1.994	23970.298	2.483	.096
	Huynh-Feldt	47805.905	2.215	21583.044	2.483	.090
	Lower-bound	47805.905	1.000	47805.905	2.483	.131
Error(category)	Sphericity Assumed	385123.595	60	6418.727		
	Greenhouse-Geisser	385123.595	39.888	9655.217		
	Huynh-Feldt	385123.595	44.300	8693.632		
	Lower-bound	385123.595	20.000	19256.180		

Table 19

Regressions out of Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	226.988	3	75.663	.192	.901
	Greenhouse-Geisser	226.988	2.448	92.732	.192	.866
	Huynh-Feldt	226.988	2.815	80.645	.192	.891
	Lower-bound	226.988	1.000	226.988	.192	.666
Error(category)	Sphericity Assumed	23595.262	60	393.254		
	Greenhouse-Geisser	23595.262	48.956	481.972		
	Huynh-Feldt	23595.262	56.293	419.150		
	Lower-bound	23595.262	20.000	1179.763		

Table 20

Regressions into Category Word

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
category	Sphericity Assumed	940.333	3	313.444	1.241	.303
	Greenhouse-Geisser	940.333	2.114	444.798	1.241	.301
	Huynh-Feldt	940.333	2.370	396.711	1.241	.302
	Lower-bound	940.333	1.000	940.333	1.241	.279
Error(category)	Sphericity Assumed	15155.667	60	252.594		
	Greenhouse-Geisser	15155.667	42.281	358.448		
	Huynh-Feldt	15155.667	47.406	319.696		
	Lower-bound	15155.667	20.000	757.783		

Table 21

Vocabulary Test Scores

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
vocab	Sphericity Assumed	4.433	2	2.217	.907	.412
	Greenhouse-Geisser	4.433	1.964	2.258	.907	.411
	Huynh-Feldt	4.433	2.000	2.217	.907	.412
	Lower-bound	4.433	1.000	4.433	.907	.353
Error(vocab)	Sphericity Assumed	92.900	38	2.445		
	Greenhouse-Geisser	92.900	37.307	2.490		
	Huynh-Feldt	92.900	38.000	2.445		
	Lower-bound	92.900	19.000	4.889		

Table 22

Orthographic and Phonological Lures Chosen as Correct Answers in Vocabulary Test

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Vocab	Sphericity Assumed	.025	1	.025	.073	.789
	Greenhouse-Geisser	.025	1.000	.025	.073	.789
	Huynh-Feldt	.025	1.000	.025	.073	.789
	Lower-bound	.025	1.000	.025	.073	.789
Error(vocab)	Sphericity Assumed	6.475	19	.341		
	Greenhouse-Geisser	6.475	19.000	.341		
	Huynh-Feldt	6.475	19.000	.341		
	Lower-bound	6.475	19.000	.341		

Table 23

Incorrect Responses in Lexical Decision Task

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Ldt	Sphericity Assumed	19.882	3	6.627	2.110	.101
	Greenhouse-Geisser	19.882	1.489	13.349	2.110	.141
	Huynh-Feldt	19.882	1.525	13.041	2.110	.140
	Lower-bound	19.882	1.000	19.882	2.110	.153
Error(ldt)	Sphericity Assumed	471.118	150	3.141		
	Greenhouse-Geisser	471.118	74.469	6.326		
	Huynh-Feldt	471.118	76.230	6.180		
	Lower-bound	471.118	50.000	9.422		

Table 24

Lexical Decision Response Times

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Ldt	Sphericity Assumed	2.002	3	.667	15.395	.000
	Greenhouse-Geisser	2.002	2.432	.823	15.395	.000
	Huynh-Feldt	2.002	2.565	.780	15.395	.000
	Lower-bound	2.002	1.000	2.002	15.395	.000
Error(ldt)	Sphericity Assumed	6.501	150	.043		
	Greenhouse-Geisser	6.501	121.576	.053		
	Huynh-Feldt	6.501	128.244	.051		
	Lower-bound	6.501	50.000	.130		

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