2002

# Consistency effects : the role of friends and enemies in reading.

Brett Miller
*University of Massachusetts Amherst*

# CONSISTENCY EFFECTS: THE ROLE OF FRIENDS AND ENEMIES IN READING

A Thesis Presented

by

BRETT MILLER

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

Master of Science

February 2002

Department of Psychology

# CONSISTENCY EFFECTS: THE ROLE OF FRIENDS AND ENEMIES IN READING

A Thesis Presented

by

BRETT MILLER

Approved as to style and content by:

Keith Rayner, Chair

Alexander Pollatsek, Member

James M. Royer, Member

Melinda Novak, Department Head
Department of Psychology

ACKNOWLEDGEMENTS

I would like to thank my advisor, Keith Rayner, for his invaluable guidance throughout my master's project. I would also like to thank Alexander Pollatsek and James M. Royer for their help and feedback during my formulation of the experimental design and throughout the project. Thanks also to Charles Clifton, Jr. for his help implementing the running programs for both experiments on the eyetracking equipment.

I would like to especially thank my fiancé Laura for her patience and support over the past few years.

TABLE OF CONTENTS

# CHAPTER 1

# RIME PATTERN CONSISTENCY BACKGROUND

## A. Frequency by Regularity Interaction

The role of phonological activation in reading has been an issue of much debate and has sometimes yielded conflicting results. One way in which phonology influences reading is that the regularity of a word's pronunciation affects the processing time for the word. A general finding is that words which have a regular pronunciation according to grapheme-to-phoneme correspondences (GPC) take less time either to pronounce or to identify as a word in a lexical decision task (LDT) than words with an irregular pronunciation. However, this regularity effect interacts with the frequency with which the word has been encountered: effects are more robust for low frequency words than high frequency words (e.g., Baron & Strawson, 1976; Stanovich & Bauer, 1978; Taraban & McClelland, 1987).

To try to explain this finding, advocates of dual route models (e.g., Carr & Pollatsek, 1985; Coltheart, 1978) proposed that regular words would be accessed faster than irregular words because the correct output would be consistent with both the direct (lexical) route and the indirect or assembled route for the regular words, but only the lexical route would produce the correct output for irregular words. On the indirect pathway, a word's abstract phonological information would be computed via GPC rules. In these models, irregular words can only be correctly accessed by the direct route because the output generated from the indirect route would be inconsistent with the information stored at the lexical level for the particular word. Hence, the reason for the regularity effect has generally been explained in two ways. First, the lexical route could be assumed to be faster on average than the indirect route as reading becomes more skilled. Presumably, the fastest items would be composed of items that have been most frequently encountered by the reader. Second, competition between the lexical and indirect routes slows down naming, together generating this interaction. This competition should be strongest for words that are accessed relatively slowly via the direct route. To illustrate this, remember that irregular words were correctly identified from the lexical route (direct lookup), but an incorrect pronunciation would be generated by the indirect route (regularization error). The mismatch in the outputs from the two routes might require some kind of a "check" process resulting in a delayed response, compared to regular words (Rayner & Pollatsek, 1989).

For connectionist models that specify a phonological mechanism (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989), this pattern of data has been represented by a distributed representation produced by the pattern of connection weights between units in the model. The Seidenberg and McClelland (1989) model produces the regularity effect as a result of its sensitivity to the frequency of occurrence for a particular pronunciation in the model's training corpus. If a word was presented frequently, the word would have had a greater opportunity to have enough of an impact on the weights to speed responses for this item. However, if the item is rarely presented in the training corpus, the response generated by the model may be more reliant upon other words with similar patterns leading to a decrease in speed and accuracy, replicating the frequency by regularity interaction reported in the literature (Seidenberg & McClelland, 1989; Taraban & McClelland, 1987).

The frequency by regularity interaction has also been investigated within the context of reading. Inhoff and Topolski (1994, Experiment 2) recorded eye movements to examine whether the frequency by regularity interaction that had been found in both the naming and LDT literature could be obtained during normal reading. They examined regular and irregular words and varied the frequency of the target. Only an effect for frequency was found: low frequency words were fixated longer than high frequency words consistent with previous findings (e.g., Just & Carpenter, 1980; Inhoff & Rayner, 1986; Rayner & Duffy, 1986). There are, however, a few potential reasons for their inability to replicate the findings from the naming and LDT literature. Inhoff and Topolski did not place the target words being compared in the same sentence frame leading to potentially greater variability, which may have led to the null result. It appears unlikely that the frequency by regularity interaction was an artifact of the task here due to the robustness across tasks and evidence suggesting that naming, LDT, and eye movements all appear to be tapping some of the same underlying processes in lexical access (Schilling, Rayner, & Chumbley, 1998). However, it is important to note that the effect size for eye movements was more similar to naming than to LDT.

Sereno and Rayner (2000) monitored eye movements while reading and used a preview paradigm to examine the frequency by regularity interaction. In this paradigm, participants are presented a sentence with a target word embedded in it. This target is replaced by another word or letter string of the same length until the reader crosses an imaginary boundary before the target region and the display is changed to the target during the initial saccade crossing the boundary (Rayner, 1975). It is important to note that the display change is completed before the end of the saccade, ensuring that the reader does not notice the change. Sereno and Rayner (1992) presented two types of previews: valid and invalid. The valid preview was the target word, while in the invalid preview was a random letter string.

The results for the invalid preview condition are a bit complex, probably because there was some inconsistency in the types of invalid previews. That is, some of the previews in the invalid condition were possible to pronounce. Sereno and Rayner found that the frequency by regularity interaction only occurred for the invalid previews that were not pronounceable. However, in the valid condition the frequency by regularity interaction was clearer as first fixation duration (the amount of time spent on the initial fixation on a target word) and gaze duration (the sum of all the fixations on the target word before exiting the word to the left or to the right) were shorter for regular than for irregular words, but only when the target word was low frequency. This demonstrates that under appropriate conditions the frequency by regularity interaction can be obtained.

Findings of a frequency by regularity interaction have not been without critiques (e.g., Seidenberg & McClelland, 1989; Taraban & McClelland, 1987). Possibly, the categories of “regular” versus “irregular” (exception) may not fully encompass the relevant dimensions. For example, part of the effect may be due to the expertise of the reader. Seidenberg (1985) placed his readers into three categories based upon their naming latencies: fast, medium, and slow readers. He found that fast readers did not show a regularity effect and claimed that the lack of a regularity effect may result from the familiarity of the stimuli for this set of readers. For instance, fast readers may actually treat what could be considered low-frequency words for slow readers as high frequency words, because they have encountered these words more frequently.

## B. Consistency Effects

There has also been the suggestion that regularity should be viewed not only in terms of the regular/irregular distinction defined using GPC rules but also in terms of the consistency of a word's body or rime. For example, take a word such as *gave* which has a regular pronunciation according to GPC rules, but has multiple possible pronunciations for the word's rime body _*ave* (vowel & coda): e.g., *cave, have, pave, rave, save,* & *wave*. Since the body portion _*ave* has multiple pronunciations (such as in *gave* and *have*), this word would be considered regular-inconsistent because not all of the words that share the same body as *gave* have the same pronunciation pattern for the rime body. In support of the claim that there is more to regularity than GPC rules, Glushko (1979) found that regular-consistent words were pronounced more rapidly than regular-inconsistent words even though they both fall under the same heading of 'regular' (emphasizing the importance of units larger than phonemes in visual word recognition). He also found that nonwords derived from words with consistent rime body pronunciations were named more quickly than those derived from words with inconsistent body pronunciations.

Consistent with Glushko's finding of an effect for rime pattern consistency, Seidenberg, Waters, Barnes, and Tanenhaus (1984) replicated the finding that regular-inconsistent words take longer to name than regular-consistent words, but only for low-frequency words. Furthermore, Taraban and McClelland (1987, Experiment 1) found an effect for exception words in naming for both intact and degraded stimuli presentations. However, for regular-inconsistent words, when the stimuli were intact, the difference in latency between regular-inconsistent and the controls was significant only by participants with no suggestion of an effect in the error data. When the stimuli were degraded, the effect in latencies disappeared, but a suggestion of an effect was present in the error data with the inconsistent words producing more pronunciation errors than the controls. As noted above, although an effect for consistency had been replicated, the question still remains as to what are the precise conditions for observing a consistency effect for low and high frequency words.

Attempts have been made to clarify the conditions that will generate a consistency effect. Kay and Bishop (1987, Experiment 2) investigated how the number of body neighbors (i.e., words with the same body as the target) with a consistent pronunciation affects the naming times for regular-consistent, regular-inconsistent, and exception words, while keeping the number of neighbors with conflicting pronunciation roughly controlled. For low frequency words, both regular-inconsistent and exception words that have many consistently pronounced neighbors were named more quickly than those with few consistently pronounced neighbors. This suggests that the makeup of the body pattern "neighborhood" affects the processing time on the target word.

To clarify, Jared, McRae, and Seidenberg (1990) suggested that the size of the consistency effect might be due to the degree of the inconsistency. They found that the difference in the frequency of the neighbors mediated the consistency effect. Two types of body neighbors were examined: body neighbors that have the same body pronunciation as the target word (friends) and body neighbors that have a different body pronunciation then the target word (enemies). Here, naming latency for target words that had a lower mean summed frequency for friends than for enemies was longer than for those which had a lower summed frequency for their enemies than their friends. Jared et al. (1990) examined this relationship for a set of words that had been used in prior experiments examining consistency. They found that regular-inconsistent words typically possessed higher-frequency friends and higher-frequency enemies while exception words generally possessed lower-frequency friends and higher frequency enemies. They suggested that this confound may explain why a consistency effect is not always found in naming studies.

Jared (1997) followed up on the idea that the summed frequency of the friends and enemies of a word dictated whether or not a consistency effect would be found. This time she attempted to extend her earlier findings to the realm of higher-frequency words. Jared found that participants in the naming task pronounced consistent words more quickly and accurately than inconsistent words. One potential problem with the results from her study was that orthographic familiarity could have been responsible for her findings. That is, the size of a word's neighborhood could have potentially affected processing of the word. Even though the number and frequency of friends were equated across the two conditions (regular-consistent and regular-inconsistent), only regular-inconsistent words possess enemies. The implication here is that it still could be the case that the regular-inconsistent words could have larger neighborhoods and a higher, overall summed neighborhood frequency than regular-consistent words. The logic here is that regular-inconsistent words have both friends and enemies and regular-consistent words only have friends that, on average, given this were the case, it is possible that the overall neighborhood size would be larger for this class of words. If this were the case, then the differences in neighborhood size could be generating the effect here that has been posited as resulting from the consistency of a word's rime pattern.

To argue against this interpretation, Jared (1997) conducted a LDT using the same words from Experiment 1 with an equal number of pseudoword foils. She argued that participants make decisions in a LDT based on orthographic characteristics of the words when the words and nonwords are adequately different. In fact, some models of word recognition make the same prediction. For example, Johnson and Pugh's (1994) cohort model of visual word recognition suggests that when individuals make judgments in a LDT they are able to evaluate how orthographically similar a target is to a word and use this sense of "word-likeness" to make a LDT judgment. Therefore, it follows that when examining the LDT one might expect any difference due to orthographic familiarity to be reflected in the reaction latencies. As Jared (1997) expected, she did not find a difference between regular-consistent and regular-inconsistent words. Although this finding is consistent with her expectations, a bit of caution needs to be applied whenever an argument rests upon a finding of a null effect in an experiment. Jared went on to replicate her findings of a consistency effect for high frequency words. Consistent with her argument that the ratio of the summed frequency of the friends and enemies of a word affects the reliability of generating a consistency effect, she found that words possessing lower frequency friends than enemies yielded a reliable effect for consistency while words that possessed a higher frequency friend than enemy was only reliable by participants. Hence, it appears that not only is consistency a relevant dimension to be examined, but the nature of the body neighbors also needs to be controlled.

Both dual route models (e.g., Carr & Pollatsek) and connectionist models (e.g., Seidenberg & McClelland, 1989) can accommodate for an effect of consistency. Dual route models can account for this finding by presuming that through analogy to other lexical items a phonological code for an item can be produced. With this logic, if an item's rime pattern was inconsistent over the entire neighborhood of words that possess the same pattern, then multiple phonological codes would be generated and the reader would need to resolve which pronunciation to accept, which could take time. However, when the rime pattern is consistent, only one pronunciation would be generated and no resolution would be needed. Also, one could assume that this type of analogical process would be more likely for lower frequency words than high frequency words which could be accessed via the direct route, presumably more quickly (see Van Orden, Pennington, & Stone, 1990 for a review).

Consistency effects can naturally fall out of most connectionist models also. Similar to the explanation given for the frequency by regularity interaction, here the frequency that a particular word is encountered will affect the amount of influence that this particular item applies to the model. If there is an inconsistency in the rime over the course of training items, this will affect the strength of the relationship between the spelling and associated sound pattern for the rime. Consistent with Jared and colleagues' results (Jared, 1997; Jared et al., 1990), if there was a rime pattern with multiple pronunciations and the words that possess an irregular pronunciation for the rime have a relatively high frequency, then these words will have more of a chance to modify the connection weights exerting a larger influence over the spelling-sound association. However, if the relative frequencies of any irregularly pronounced rime is relatively low, then this inconsistency would not exert much of an influence on the weight settings leading to a prediction of little or no consistency effect here.

The consistency effect has also been examined using eye movements (Inhoff & Topolski, 1994, Experiment 3). Inhoff and Topolski manipulated the frequency and consistency of targets within normal reading. They found a main effect for frequency with low frequency words yielding longer first fixations and gaze durations on the target word. A marginal effect for consistency on gaze duration was observed but in the opposite direction as predicted with regular-consistent words resulting in longer fixations on the target than for regular-inconsistent; this finding did not approach significance by items.

Although Inhoff and Topolski (1994) were unable to find a hint of a consistency effect comparable to that found in the naming and lexical decision literature, there remain a number of reasons that the conclusion that consistency effects are not present in reading may be spurious. First, their results are not consistent with the naming literature that seems to be converging on the conditions necessary to generate a consistency effect within a study. For example, Inhoff and Topolski did not maximize the probability of generating a consistency effect by taking into account the number of friends and enemies (Jared, 1997; Jared et al., 1990). Second, as noted above, the targets were not embedded in the same sentence frame leading to potentially greater variability in their study. These potential problems leave open the question of what led to their inability to obtain the expected effect for consistency.

## C. Phonological Processing in the Parafovea

Consistent with this claim that consistency may play a role during reading, there have been successful demonstrations of phonology's role in reading on other fronts. Pollatsek, Lesch, Morris, and Rayner (1992) used homophones, within the context of a boundary experiment, to examine the time course of phonological activation in reading. As noted earlier, during a boundary experiment, a particular word is replaced with another word or string of characters (the preview) until the person passes an invisible boundary, just before the target region. After crossing this boundary with his/her eyes, the target changes from the preview to the target word and remains the target word for the remainder of the trial. In the critical manipulation for Pollatsek et al. (1992), two types of previews were presented. Participants read a sentence where either the homophone of the target word or an orthographically similar word served as the preview. So for example, if the target word was *beach* the homophone and the orthographically similar preview would be *beech* and *bench*, respectively. They found that the homophone preview condition resulted in shorter fixation times on the target word than the orthographic control suggesting that phonological information extracted in the parafovea can aid in lexical access of that word. In a similar vain, Folk and Morris (1995) also attributed an early role to phonology when examining differences between homographic homophones, heterographic homophones, and homographic heterophones within an eye movement paradigm. The contrast of primary interest is the difference between homographic heterophones (e.g., tear) and homographic homophones (e.g. calf). It is important to keep in mind that both words have multiple meanings, but only the heterophones have multiple phonological codes associated with the word. As predicted, gaze durations on the target for the homographic heterophony condition were longer than for the homographic homophones' targets. This evidence is consistent with an early role for phonological processing in reading.

In addition, Henderson, Dixon, Petersen, Twilley, and Ferreira (1995) presented data suggesting that examining regularity even for smaller units than rime patterns can give insight into processing during reading. Henderson et al. examined the effect of the regularity of a word's initial trigram. They presented a preview of a word with the same initial trigram with either an identical or differing pronunciation. In their task, participants fixated on a point and were instructed to move their eyes to the location of the word in the periphery after it was displayed on the screen and to make a lexical decision judgment at that time. Regularity of the first trigram was indexed by examining the pronunciation of the initial trigram in isolation. If the pronunciation was the same as the pronunciation of the trigram in isolation, then the pronunciation would be considered regular. So for example, if the target pair was *button* and *butane*, the initial trigram in *button* would be regular because the pronunciation is consistent with the pronunciation of 'but' in isolation. A larger preview benefit occurred when the pronunciation of the trigram for the preview was consistent with the pronunciation of the trigram in isolation than if the pronunciation of the initial trigram preview was irregular, suggesting that phonological information was extracted in the parafoveal region.

The time course for the activation of phonological information has also been investigated. Rayner, Sereno, Lesch, and Pollatsek (1995) used a fast priming paradigm, originally developed by Sereno and Rayner (1992), to investigate when phonological information is utilized for phonological information. In the fast priming paradigm, a prime is presented for a short duration at the onset of the first fixation on the target region and is later replaced by the target. In this study, either a word or pseudoword prime occurred in one of four prime conditions: identical word, homophone, visually similar, and visually dissimilar to the target. At a 36 ms prime duration, Rayner et al. (1995) found that, for the word prime condition, homophone primes led to shorter gaze durations (370 ms) on the target than for visually similar words (400 ms) consistent with an early and automatic role for phonology (see also Lee, Rayner, & Pollatsek, 1999; Lee, Binder, Kim, Pollatsek, & Rayner, 1999 for similar results).

There has, however, been some suggestion that phonological information is not activated early but rather is activated during a post-lexical, verification stage (Daneman & Reingold, 1993; Daneman, Reingold, & Davidson, 1995). In the Daneman and Reingold (1993) study, participants read text containing both homophone and non-homophone errors. Contrary to an assignment of an early role for phonology, they did not find a difference between homophones and visually similar errors, but rather the amount of time spent *rereading* the homophony errors was shorter than for orthographically similar words. However, this only occurred for homophone errors that were visually similar to the appropriate word (e.g., *bored* in place of *board*) (see Daneman et al., 1995 for similar conclusions).

Rayner, Pollatsek, and Binder (1998) attempted to replicate and extend the findings of Daneman and colleagues (Daneman & Reingold, 1993: Daneman et al., 1995). In contrast to the earlier findings (Daneman & Reingold, 1993: Daneman et al., 1995), Rayner et al. (1998) found evidence for early phonological processing using materials similar to those used by Daneman and Reingold (1993) containing homophone errors. However, this time contextual constraint was manipulated. Rayner et al. (1998) examined the probability of either a skip of a target region or a single fixation and no regression back into the target region (i.e., trials on which readers did not seem to ever notice that the target was incorrect). In these cases when the target shared one or two letters with the contextually appropriate word, approximately 40% of the trials were of this type in Experiment 2 and 73% of the time in Experiment 3, suggesting that readers were not fully processing the target word on a considerable number of trials. In addition, for high constraint words that shared 2 initial letters in common with the contextually appropriate word, the first fixation duration for the correct and incorrect homophone did not differ, but they did differ from the orthographic control. Consistent with these findings, Jared, Levy, and Rayner (1999) examined the performance of good and poor readers in detecting homophone errors in a proofreading task while monitoring readers' eye movements (Experiments 4-6). In general, their findings suggested that phonology was used to access word meaning primarily for poor readers. Poor readers' fixations on homophone errors were shorter than for the orthographic controls on the first-pass measures. Again, phonology appears to play an early role in visual word recognition.

# CHAPTER 2

## EXPERIMENT 1

### A. Motivation for Experiment 1

Of particular interest is whether the Jared et al. (1990) and Jared (1997) findings that the frequency of a word's friends and enemies influence whether one finds a consistency effect will mediate performance during normal reading. Although Jared (1997) found a consistency effect for high frequency words in the naming task, as a consistency effect has not been shown during reading, it seemed prudent to test whether a consistency effect could be found for low-frequency words first because the success rate has been highest for this set of words (see Jared, 1997). It is important to note that the work of Stone, Vanhoy, and Van Orden (1997) has suggested that the traditional view of consistency may also be an oversimplification. Stone et al. posited that there are potentially two types of consistency effects: feedforward and feedback consistency. Feedforward consistency involves the consistency of the pronunciation for the spelling pattern for the rime or body of a word, which earlier in the paper was referred simply as 'rime pattern consistency' or simply 'consistency'. Feedback consistency has to do with whether there are multiple spellings for a particular pronunciation for a word's body. Initially, however, it seems more prudent to manipulate only feedforward consistency given that this type of consistency has been more widely examined. I expected the regular-consistent words to yield shorter fixation times than either the regular-consistent or exception words. In addition, the regular-inconsistent words were expected to perform more similarly to the irregular words than to the regular-consistent words.

## B. Experimental Design

*Participants*. The participants were 42 University of Massachusetts undergraduate psychology students. All participants were native speakers of American English and received course credit or $8 for participation.

*Apparatus*. Participants were asked to read individual sentences on a 17" ViewSonic 17PS monitor attached to a Pentium 166 Compaq Presario computer. During the experiment, participants' eye movements were monitored using an SMI video based eyetracking unit which samples the participants' eye every 4 ms by means of a light-weight helmet with attached IR (infrared) cameras. The position and duration of each fixation were recorded for the right eye although viewing was binocular. Participants were seated approximately 85 cm from the monitor during the experiment and were allowed unrestricted head movement. All sentences were displayed on a single line with a maximum length of 80 characters.

*Procedure*. Upon arrival, participants were familiarized with the eyetracker, and directions concerning the experiment were given. Participants were informed that single sentences would appear on the screen in front of them and were instructed to read each sentence silently to themselves as if they were reading normal text. To insure that individuals were reading the sentences, comprehension question were asked after approximately 15% of the items where a simple "no" or "yes" vocal response was required.

*Stimuli.* The target words were composed of three groups: 21 Regular-consistent (e.g., fern), 21 regular-inconsistent (e.g. wreath), and 21 exception words (e.g., wand). These words varied in length from 4-7 characters and average length was controlled over the list. Frequency was controlled on average over the three lists (Francis & Kucera, 1982), however the exception words were of slightly higher frequency (See Table 1). I tried to optimize the number of friends and enemies as suggested by Jared (1990) to increase the likelihood of generating the expected pattern of data. For the regular-inconsistent and exception words, the words selected had a relatively high ratio for the summed frequency of enemies to friends, whereas for the regular-consistent items, the attempt was to obtain as high a summed frequency for the friends as possible (See Table 1). All target words were monosyllabic with the noun as the dominant or only meaning of the word. These words were imbedded in triads (regular-consistent, regular-inconsistent, and exception words) into the same 21 sentence frames. For example, participants would have read the following sentence with one of the three target words imbedded in the sentence frame: *Jack's doctor stated that the (phase, mood, brace) would only be temporary.* To insure that the words were not predictable and of approximately equal naturalness in the sentence frames, they were normed by individuals in the same population as tested.

*Normative Data:* Normative data were collected to investigate whether there might have been any differences in processing time attributable to differences in the predictability of target items imbedded in the experimental sentences or to how natural the target items fit into each sentence context. After the data were collected for Experiment 1, nine participants completed a word completion task to examine the predictability of the items in the sentence context. Participants were asked to fill in the next word in the sentence fragment with a noun. The target words were not predictable in the sentence context: target word was filled in only 0.5% of the time. For the naturalness judgments, 35 participants from the same population as used for the experiment made naturalness judgments to gauge whether the items used fit equally naturally into the sentence context. Three versions of a norming study were composed. In each version, participants evaluated whether the two words were presented fit equally well into the sentence fragment up through the target word. These two words were selected from the set of three words that were grouped together in each sentence frame. So to use the example from before, participants might have seen sentence frames with *mood* and *brace* in one version, *mood and phase* in another, and finally *phase* and *brace* in the last version of the norming study. Essentially, the selection of the pairs of words to be evaluated was counterbalanced over the three different versions of the norming task. From these results, participants rated items in one sentence frame as not equally naturally when using a 1.8 standard deviation cutoff[1]. All the analyses presented below are means calculated after this item was removed. Also, trials were removed from consideration due to track-losses on with the eye tracker. Participants were excluded from the analyses if more than 20% of their trials contained track-losses.

## C. Results from Experiment 1

Before discussing the analyses conducted, the operational definitions of the most common eye movement measures will be discussed. First fixation duration corresponds to the duration of the first fixation on the target word, not including regressive fixations to the word if the target word was initially skipped. Gaze duration is the sum of the fixation durations on a word before the eyes leave the word to move either to the left or to the right. Total time consists of the total amount of time spent fixating the target word over the entire trial including regressive fixations back to the word. There are also two indices at the time spent on the region immediately following the target word; this region normally consists of the next 2-3 words. Spillover1 is the duration of the first fixation in this post-target region, only including forward movements of the eye into this region, while Spillover2 is the duration of the first fixation in this post-target region regardless of whether the eye is moving forward in the sentence or regressing back to this region. Other measures are defined where appropriate.

A 1-way (consistency) repeated measures ANOVA was conducted on the data in Experiment 1. A variety of eye movement measures were examined to elucidate the time course that an effect for rime pattern consistency develops. For FFD, the main effect for consistency did not approach significance with ($Fs<1$). However, a non-significant trend in the predicted direction did occur with the regular-consistent words (258 ms) yielding shorter fixations than either the regular-inconsistent (264 ms) or the exception words (266 ms). Similar patterns resulted for both gaze duration and total time ($Fs<1$) (See Table 2). For total time, regular-consistent words yielding shorter fixation durations by 10-13 ms than for the other two word types. However, for gaze duration, the means for regular-consistent (276 ms), regular-inconsistent (284 ms) and exception words (279 ms) were very similar.

The expected consistency pattern was significant when the first fixation in the post-target region was evaluated (spillover2), $F_1(2,82)=4.493$, $p<0.05$; $F_2(2,38)= 4.066$, $p<0.05$. Here, spillover2 durations were fastest for regular-consistent words. Regular-inconsistent words took 15 ms longer and exception words took 23 ms longer on spillover2 than regular-consistent words. Planned comparisons yielded significantly shorter spillover2 durations for regular-consistent than for exception words, $t_1(37)=3.308$, $p<0.01$; $t_2(19)=2.911$, $p<0.009$, and also for regular-consistent than regular-inconsistent words, $t_1(37)=2.258$, $p=0.029$; $t_2(19)=0.048$ (See Table 2). When examining the more restrictive definition of spillover (spillover1), the main effect of consistency was not significant, $F_1(2,82)=1.552$, $p=0.218$; $F_2(2,38)= 2.083$, $p=0.138$. When examining the planned comparisons between different conditions, regular-consistent words were marginally faster than regular-inconsistent words yielding a 15 ms difference in spillover1, $t_1(41)=1.728$, $p=0.092$; $t_2(19)=1.931$, $p=0.069$. However, the contrast between regular-consistent and exception words was not significant by participants despite the mean difference of 13 ms, $t_1(41)=1.505$, $p=0.140$, and was marginally significant by items, $t_2(19)=1.786$, $p=0.09$ (See Table 2).

Generally, effects whose locus is lexical appear in earlier time course measures such as gaze duration or first fixation duration. However, this does not necessarily need to be the case; some models of reading posit that lexical processing spills over into the post-target measures (Reichle et al., 1998). In this study, it seems reasonable to suggest that spillover1 and perhaps to a somewhat lesser degree spillover2 reflects some later remaining lexical processing; since spillover2 includes regressive movements into the post-target region, these durations most likely also reflect some post-lexical processing of the target.

One source of evidence consistent with this claim that spillover1 may reflect lexical processing is that the average number of first-pass fixations is less than 1 fixation (Table 2), due presumably in part to the relatively short length of the targets (Rayner & McConkie, 1976; Rayner, Sereno, & Raney, 1996). The above also suggests that one would expect a differential pattern of data depending on the quality of parafoveal information that is provided to the reader. There is evidence to suggest that the distance between a prior fixation and the target word affects the time course of processing on the target word. For cases where the fixation immediately prior to fixating the target was farther away, effects appeared later in processing (gaze duration rather than first fixation duration) (Pollatsek, Rayner, & Balota, 1986). In this experiment, due to the relatively low first-pass refixation rate on the target, the next fixation frequently would fall in the spillover region, which perhaps more closely corresponds to gaze duration in the Pollatsek et al. (1986) study. To examine this possibility, a repeated measure ANOVA was conducted contingent upon the reader fixating within a region 6 characters in size before the target region. For cases where there was a fixation in this pre-target region, the main effect of consistency on

FFDs did not approach significance, $F_1(2,76)=1.927$, $p=0.153$; $F_2<1$. However, when examining the contrast between exception words and regular-consistent, FFDs for regular-consistent words (251 ms) were marginally faster than for exception words (267 ms) by participants, $t_1(39)=1.922$, $p=062$, but did not approach significance by items, $t_2(19)=1.058$, $p=0.303$. For spillover2, the main effect of consistency remains with durations decreasing as the rime pattern becomes more consistent, $F_1(2,82)=6.985$, $p<0.01$; $F_2(2,38)=4.057$, $p<0.05$ (see Table 3). Here, both regular-consistent and regular-inconsistent words had shorter times in spillover2 than exception words, $t_1(41)=3.589$, $p<0.01$; $t_2(19)=2.910$, $p<0.01$ (regular-consistent); $t_1(41)=2.469$, $p<0.05$; $t_2(19)=2.125$, $p<0.05$ (regular-inconsistent). In addition, for spillover1, the planned comparisons yielded no difference by participants amongst the three groups, however, in numerically terms, regular-consistent items were 15 ms faster than the exception words, $t_2(19)=1.803$, $p<0.067$, and 13 ms faster than the regular-inconsistent items, $t_2(19)=1.945$, $p<0.087$, identical to the robust analyses. It seems that although the effect for consistency does appear to be emerging early in FFD when people presumably obtain a better preview of the item, the effect in the spillover region remains at approximately the same magnitude.

## D. Discussion for Experiment 1

The effects of rime pattern consistency were investigated using eye movements as an indication of any underlying cognitive processes that may be involved in processing this pattern. Similar to Inhoff and Topolski, no effect for consistency was found when examining FFD and gaze duration. However, when looking at spillover2, a robust effect for rime pattern consistency was found with regular-consistent words yielding shorter reading times than both regular-inconsistent and exception words; when examining spillover1, regular-consistent words yielded marginally shorter fixation durations than regular-inconsistent words, but the difference between regular-consistent and exception words was not significant. It is important to note that this is not simply a regularity effect because otherwise you would expect regular-inconsistent words to be read significantly faster than exception words and approximately the same duration on average as the regular-consistent words, which was not the case.

Contrary to initial expectation, the effect for consistency was found in the post-target region rather than on the target word itself. Keep in mind that under some circumstances the initial fixation in this region could reflect remaining lexical processing and has even been built into a prominent model of eye movement control during reading (Reichle et al., 1998). Consistent with this argument, participants did not tend to refixate the target word during first-pass reading and skipped it relatively frequently. In addition, participants may have received relatively little information in the parafovea on the fixation prior to landing on the target, which could have delayed some processing until the next fixation (which was frequently in the post-target region). If one considers the pattern of means for FFD when participants fixate near the target on the previous fixation, the pattern of means was very similar to that which was found for the spillover2 with regular-consistent words being fixated for shorter durations than exception words. A note of caution needs to applied because the amount of preview was not actively manipulated in this case and the items analyses did not obtain significance.

# CHAPTER 3

# EXPERIMENT 2

## A. Motivation for Experiment 2

In Experiment 1, contrary to expectation, an effect for consistency was found not on the target word itself but rather on the first fixation in the spillover region, which consisted of the next two to three words following the target. In order to better determine whether this earlier spillover2 finding can be attributed to processes involved in lexical access, a couple of the potential problems in Experiment 1 were corrected. One possible reason that the locus for the effect was in the post-target region rather than on the target might be that participants were only able to obtain a limited amount of information about the target when they were fixating on the pre-target word, resulting in the inability to find an effect for consistency on the target item itself.

To resolve this potential problem, the pre-target word was lengthened to increase the likelihood of a fixation on this word. Given an appropriate preview of the target, one would expect the effects of the consistency of a word's body to appear in an early measure (e.g., first fixation or gaze duration), assuming the skipping rate is not too high. In addition, to increase the likelihood of finding a consistency effect, readers saw a preview of a body neighbor of the target word using the boundary paradigm (Rayner, 1975). In this paradigm, the preview word appears until the reader crosses an invisible boundary, usually within 3 characters before the target word. The display changes during a reader's saccade past this prespecified boundary ensuring that the reader is unaware of any change. Of primary interest was the level of disruption for regular-inconsistent and exception words. For these words, the preview word had a different pronunciation for the rime body. If the consistency of a body neighbor affects lexical processing, the body neighbor preview could indicate this. In the past, preview experiments have successfully provided evidence of early phonological and orthographic processing (e.g., Dore & Beauvillain, 1997; Henderson et al., 1995; Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, 1975).

## B. Experimental Design

*Participants*. The participants were 36 University of Massachusetts undergraduate psychology students. All participants were native speakers of American English and received course credit or $8 for participation.

*Apparatus*. The target sentences were presented on a NEC MultiSync 15FG monitor controlled by an SVGA card. The text was displayed using the "simple" font provided with the Borland C compilation program. Participants were seated 62 cm from the display and 4 characters subtended 1° of visual angle. Eye movements were monitored using a Fourward Technologies Generation V Dual Purkinje Eyetracker that has a resolution of less than 10 min of arc. The eyetracker was interfaced with a 486 IBM compatible PC and was sampled every millisecond. Viewing was binocular, however, only eye movements for the right eye were recorded.

*Stimuli*. The target words were classified into three groups: 18 regular-consistent (e.g., wand), 18 regular-inconsistent (e.g., wreath), and 18 exception words (e.g., lamp). Most of the target words from Experiment 1 were again used here. 18 sets of triads consisting of one regular-consistent, regular-inconsistent, and exception word were included in each. Three sets of sentence frames were constructed to fit with each triad for a total of 54 sentence frames. Each participant read each sentence frame (54 total) only once and each word once. This design maximizes the number of observations per condition, which is especially important given the constraint on the number of items. So for example, participants would have read the following sentence with one of the target words embedded: 'The stage hand dropped the heavy *(wand, wreath, lamp)* on the ground after changing the scene'.

Three different preview conditions were used: Identical, Body Neighbor, & No Preview. For the Identical condition, the target word functioned as it own preview. For the Body Neighbor condition, a body neighbor of the same length was presented as the preview. These words naturally differed in the initial consonant or consonant cluster. In addition, for the regular-inconsistent and exception words, the body neighbor had a different pronunciation for the body pattern then the target (keep in mind that by definition the regular-consistent words can only have a preview with an identical pronunciation for the word's body). For example in the regular-consistent category, a participant could have seen *sage* as a preview for *cage*. In the No Preview condition, a string of visually dissimilar letters and unpronounceable letters were presented; here the reader might have seen *tlmc* as a preview for *cage*. So this yields nine possible conditions: three levels for consistency (Exception, Regular-Inconsistent, &

Regular-Consistent) and three levels for the preview manipulation (No Preview, Body Neighbor Preview, & Identical Preview).

*Procedure.* Upon arrival into the lab, a bite bar was prepared to eliminate head movements during the experiment. Participants were instructed to read the sentences for meaning and told that their eye movements would be recorded while they completed the task. Occasionally (approximately 15% of the trials) a content question was asked about the sentence that they had just read, participants simply responded yes/no to the comprehension question by making a key press (left key for "no" and right key for "yes"). After these instructions have been given, participants began the initial calibration routine, to establish and later verify the accuracy of the calibration. If the calibration was found to be inaccurate during the initial calibration or at any point during the experiment, the participant was recalibrated. A series of practice trials were given for each person.

For this experiment, an invisible boundary was located after the last letter of the pre-target word (see Rayner, 1975 for full description of technique). When the participant crossed this boundary during a saccade, the preview was replaced by the target word and remained for the remainder of the trial. It is important to keep in mind that this change should not have been detected by the participant (Rayner, 1975).

*Normative Data.* Again, normative data were collected to investigate whether there might have been any differences in processing time attributable to differences in the predictability of target items imbedded in the experimental sentences used here or to how natural the target items fit into each sentence context. Concurrent with the collection of data for Experiment 2, predictability ratings were gathered from 8 participants. These individuals completed a word completion task similar in format to that in Experiment 1. The target words were not predictable in the sentence context: a target words were predicted less than 0.5% of the time. Normative data were also collected on how natural a particular target item fit into the sentence context using the same format as the norms collected for Experiment 1. Items that were rated as 1.8 standard deviations or more away from the overall mean on the naturalness ratings were excluded from the analyses reported below; this amounted to a net loss of four items per participant[2]. Trials were also excluded if a track-loss was detected. A participant's data was excluded if 20% or more of the trials contained a track-loss.

## C. Results for Experiment 2

A 3 (consistency) X 3 (preview) repeated measures ANOVA was conducted on the data. Initially, effects of consistency and preview manipulation were examined for first-pass eye movement measures. For FFD, no effect of consistency was found, Fs<1. In terms of preview benefit, consistent with prior findings, a main effect for preview was found with the Identical Preview condition (263 ms) yielding shorter fixation durations than the Body Neighbor Preview (275 ms) or the No Preview condition (284 ms), $F_1(2,70)=7.773$, $\underline{p}<0.01$; $F_2(2,34)=7.920$, $\underline{p}<0.01$ (see Table 4). The interaction between consistency and preview was not significant, $F_1(2,70)=1.198$, $\underline{p}=0.314$; $F_2<1$. For gaze duration, again no effect for consistency was found, Fs<1. A preview effect emerged in the same direction as for FFD, which was marginal by participants, $F_1(2,70)=2.713$, $p=0.073$; and significant by items $F_2(2,34)=4.134$, $p<0.05$. Again the interaction did not approach significance, both Fs<1.

For words that received a single fixation, only a main effect for preview condition was found with durations increasing in the following order: identical, body neighbor, and no preview, $F_1(2,68)=10.004$, $p<0.01$; $F_2(2,34)=7.909$, $p<0.01$. Contrary to prediction, no main effect for consistency was found, $F_1<1$; $F_2(2,34)=1.651$, $p=0.207$. The interaction also did not approach significance, $F_1(4,140)=1.132$, $p=0.344$, $F_2(4,68)=1.118$, $p=0.355$. Examination of the number of first-pass fixations and skipping also did not hint at any effect of consistency, all Fs<1. Although an effect for preview obtained significance for FFD and gaze, it did not obtain significance for number of fixations, $F_1(2,70)=2.107$, $p=0.129$; F<1. However, for skipping, in the participants' analyses, there was a marginally significant effect for the quality of the preview with the identical condition yielding the highest skipping rate (approximately 40%) versus the preview denied and body neighbor preview (approximately 34%), which were skipped at approximately the same rate, $F_1(2,70)=2.516$, $p=0.088$, but the effect did not obtain significance by items, F<1. The interaction between preview and consistency for skipping also did not obtain significance, $F_1(4,140)=1.132$, $p=0.344$; $F_2(4,68)=1.421$, $p=0.236$, nor did the number of fixations, both Fs<1. Hence, the early measures of processing did not indicate that the regularity of the rime pattern exhibits any effect on processing. However, the quality of the preview did affect the processing times on the target word with identical previews yielding greater preview benefit than either the body neighbor or no preview conditions.

To view whether consistency and preview affect processing slightly later in time course, measures examining processing on the spillover region and measures on the target that include regressive saccades into the target were analyzed. The interaction between rime pattern consistency and preview condition did not approach significance on any of the measure discussed below unless otherwise noted and will not be discussed otherwise, both Fs<1. For the total time spent on the target region including regressive saccades back to the target, the main effect for rime pattern consistency did not approach significance, $F_1<1$, $F_2(2,34)=1.047$, $p=0.362$, nor did any affect for the type of preview remain, $F_1(2,70)=2.292$, $p=0.109$, $F_2(2,34)=1.218$, $p=0.308$. For spillover1, the main effect for consistency did not reach significance, $F_1(2,70)=1.849$, $p=0.165$, $F_2(2,34)=2.249$, $p=0.121$, however, the planned comparison between regular-consistent words and regular-inconsistent words did obtain significance by items with regular-consistent words (268 ms) yielding shorter fixation durations on spillover1 than regular-inconsistent words (281 ms), $t_2(17)=2.683$, $p<0.05$, but not by participants, $t_1(33)=1.516$, $p=0.139$. The overall trend was as predicted with longer spillover1 times for regular-inconsistent and exception words than for regular-consistent words, but this trend was driven by the performance of the regular-consistent words in the no preview condition (See Table 5). It appears that readers were able to take advantage of the extra processing time that they had on the target item itself resulting in shorter fixation times on the fixation in the spillover region. Note that for first fixation duration this condition was inflated approximately 17 ms over the exception words and 24 ms over the regular-inconsistent words in the same preview condition and that the average number of first pass fixations on the target was relatively low with an average of just over 0.7 fixations. The quality of the parafoveal preview affected spillover1 times with previews that were more consistent with the target yielding faster reading time, $F_1(2,66)=5.148$, $p\leq0.01$, but did not obtain significance by items, $F_2(2,34)=2.132$, $p=0.134$. The interaction between consistency and preview did not approach significance, $F_1(4,132)=1.311$, $p=0.269$; $F_2(4,68)=1.545$, $p=0.199$.

The pattern for spillover2 was somewhat different than for spillover1. Here, a marginally significant effect for consistency yielded shorter durations for regular-consistent words versus regular-inconsistent or exception words by participants and by items, $F_1(2,70)=2.934$, $p<0.06$; $F_2(2,34)=3.055$, $p<0.06$. Here, regular-consistent words were marginally faster than exception words by participants, $t_1(35)=1.884$, $p=0.068$, but not by items $t_2(17)=1.451$, $p=0.165$, and significantly faster than the regular-inconsistent words, $t_1(35)=2.134$, $p<0.05$; $t_2(17)=3.991$, $p<0.01$. A marginal effect for preview was present for subjects, $F_1(2,70)=2.386$, $p=0.099$, but not by items, $F_2(2,34)=1.904$, $p=0.164$. In addition, the interaction between consistency and preview was marginally significance, $F_1(4,140)=2.152$, $p=0.078$; $F_2(4,68)=2.248$, $p=0.073$. This interaction appears to be driven by the apparent tradeoff for regular-consistent words in the no preview condition, where they are substantially faster (approximately 20 ms) than the other two conditions. For both regular-inconsistent and exception words, the exception words yielded similar fixation times to the regular-inconsistent items. The consistency effects for spillover1 and spillover2 need to be interpreted with caution due to the performance of the regular-consistent items in the no preview condition reflected in the interaction obtaining significance for spillover2.

Perhaps, the attempt to encourage parafoveal preview of the target by increasing the length of the pre-target word was unsuccessful. Therefore, analyzing occurrences where the reader fixated a region within six characters of the target region was again justified. If the reader did fixation in this pre-target region, one might expect that a similar pattern on first fixation duration would occur. However, the pattern of means for the main effect of consistency closely reflects the mean from the robust analyses with the regular-consistent items actually yielding slightly longer reading times than the other word types, both $Fs<1$ (Table 6). The same pattern appears when examining single fixation durations for the cases where the pre-target region was fixated with regular-consistent words yielding numerically longer reading times than the other two groups, $F_1<1$. Hence, there was little evidence even with the preview manipulations that consistency exerted much of an effect on first-pass measures of processing.

## D. Discussion for Experiment 2

In Experiment 2, rime pattern consistency and parafoveal information were manipulated. Effects for parafoveal preview were found for the preview manipulation with first fixation duration and gaze duration decreasing when given full preview of the target versus either the body neighbor or a string of unpronounceable characters. However, consistent with Experiment 1, effects for consistency in the direction predicted were only found when examining the spillover region. Unfortunately, there appears to have been a tradeoff for one class of items; for the regular-consistent words on FFD, reading times were slower by approximately 20 ms for the no preview condition over the other two conditions, opposite in the direction to that predicted with regular-consistent items yielding the slowest reading times overall. However, when spillover2 was examined, this condition was faster by approximately (27 ms) over the exception with the no preview condition driving the effect for consistency in the spillover region. Although the potentially spurious pattern for consistency was found in the spillover region, a trend in the opposite direction resulted when examining only fixations in the target region, regardless of whether they fixated the area immediately preceding the target region.

Why might the lack of a consistency effect on these first-pass measures have occurred? Perhaps, the body neighbor preview was unsuccessful at priming the target word due to the inconsistency of the target and preview onset. By definition in this study, a body neighbor differs from the target only in its onset. Preview benefit usually occurs when the initial pair of letters in the target is consistent with the target. Here the onsets ranged from 1-3 letters yielding potential interference not only from the phonological difference but also from the orthographic difference working against the attempted rime pattern priming (find citation!!!). It did not appear to be the case that the phonological consistency of the rime used for the preview of the target resulted in any differences in processing times. Keep in mind that only the regular-consistent items possessed a body neighbor preview whose rime pattern was pronounced identically to the target. In addition, some of the Body Neighbor previews were a different part of speech than that of the target. Unfortunately, in order to conduct a preview experiment, the preview must be of the same length as the target otherwise every word following the target will appear to move after the change. This gross change is quite perceptible to the participant and thus was avoided by using only body neighbors of the same length. This, however, made it impossible to control the part of speech of the preview, whenever possible the target was replaced with a word of the same part of speech.

Another possible problem results from lengthening the pre-target word. In Experiment 1, the pre-target word was short and frequently an article, which contains less meaning content than the relatively long and content rich adjectives that were used in the second experiment. Potentially, this may have consumed more of the attentional resources available when fixating the pre-target region. If this were the case, readers would not obtain as much of a preview benefit as intended of the target item (although participants did obtain some benefit as seen from the main effect for preview on FFD).

# CHAPTER 4

## GENERAL DISCUSSION

Consistency of a word's rime pattern has been shown to effect processing of individual words in isolation (e.g., Glushko, 1979; Jared, 1997; Jared et al., 1990). The present studies tried to extend these results and examine under what circumstances one might obtain these effects during the course of normal reading and provide additional evidence regarding the role that phonology plays in this process. The only prior eyetracking experiment (Inhoff & Topolski, 1994) that investigated the effect of rime pattern during reading did not find any evidence supporting the role of consistency in visual word recognition during reading. Consistent with their results, FFD and gaze duration did not yield a significant effect for consistency over either experiment. In Experiment 1, if however, reader's fixated relatively close to the target word, a consistency effect to emerged on FFD with regular-consistent words yielding shorter durations than exception words. However, both experiments' data yielded reliable effects for consistency in the spillover region although the data from Experiment 2 was equivocal as to the cause of this difference.

Unfortunately, Inhoff and Topolski did not report any analyses of fixations in the spillover region nor did they examine the pattern of fixations contingent upon fixating within a region relatively close to the target to see whether under this circumstance the pattern of means might resemble those obtained in the first experiment here where there was the suggestion that with greater preview one might obtain a significantly faster reading times for regular-consistent words than regular-inconsistent or exception words. Also, the stimuli were unavailable to categorize the length of the pre-target word to try to obtain a sense of the probability of fixating this region.

The results from the second experiment that were intended to elucidate the nature of any effect for rime pattern consistency unfortunately were equivocal. The regular-consistent words presented in the no preview condition appeared inflated in FFD over the regular-inconsistent and exception words in this preview condition. There was no a priori reason to expect that this class of words would have longer fixation durations on average. In part, this apparent slow down on first fixation duration appears to yield a speed tradeoff when the person fixates the post-target region resulting in a relative speed up compared to the other conditions of around 20 ms on this fixation. It remains unclear why readers would require longer initial fixations on FFD over the two other word classes, presumably there is no way for the reader to be aware that there may be a difference in the consistency of the rime pattern given that the only preview they obtain before initially fixating on this word is a string of non-visually similar letters. What does appear clear is that this initial slow down does yield easier processing slightly later down stream, generally on the next fixation. This potential tradeoff makes a strong interpretation of the spillover data in Experiment 2 hazardous.

This apparent tradeoff makes comparison between Experiment 1 and 2 difficult. Experiment 1's data suggested that under appropriate conditions consistency effects do seem to emerge on FFD suggesting that the nature of the effect would most likely be lexical even if it is still significant over the spillover measures. Perhaps though, consistency effects can influence both lexical and post-lexical processing on the target. It was unclear whether the inability to find clear consistency effects in Experiment 2 was due to the tenuous nature of the effect or if some of the potential problems mentioned earlier might have occluded any effect present.

Although there has been strong evidence supporting the role that phonology plays in other preview studies (e.g., Henderson et al., 1995; Pollatsek et al., 1992), the results here suggest that at least under these limited circumstances phonological priming did not occur. This is not to suggest that phonological priming is not possible, only that the initial phonological and orthographic inconsistency between the preview and the target was perhaps too much to overcome. Supportive of this argument, Rayner, McConkie, and Zola (1980) obtained a significant preview benefit only for words that had two or more initial letters in common with the target.

The time course of phonological activation appears most consistent with Rayner et al. (1998) explanation that phonological is used relatively early rather than a post-lexical check as suggested by Daneman and colleagues (Daneman & Reingold, 1993; Daneman et al., 1995). If phonological activation was strictly a post-lexical phenomenon, then one would expect the pattern of activation to occur in later measures such as both spillover measures and regressions. Although the data here suggest that effect may appear only in the spillover region, when taken into consideration with the pattern of means for Experiment 1 (contingent upon a fixation in the region immediately preceding the target) where the results suggested that one could find significant differences at minimum between regular-consistent items and exception words, the evidence was more suggestive that the time course unfolds earlier than would be suggested by a post-lexical process.

In order to be less equivocal about the nature of rime pattern consistency's role in visual word recognition, one might try to expand the focus beyond monosyllabic words to disyllabic and other polysyllabic words. One way one might attempt this is to use words with an initial syllable only composed of a rime, specifically not possessing an onset. In this case, this would allow one to work around two of the problems that plagued the experiments here. It would lengthen the target region increasing the probability of a second fixation onto the target (citation for fixation stuff). Also, the inconsistency between the onset of the target and preview would be eliminated with the use of this class of words, such as *average*, where the initial syllable *ave* is pronounced inconsistently when considering the neighborhood of monosyllabic words with that rime pattern. Since the 1$^{st}$ syllable in *average* does not contain an onset, there would be no inconsistency if one were interested in providing preview of only the rime for the first syllable. Hence, one could manipulate the consistency of the rime of the initial syllable when compared with the population of monosyllabic words with identical rime patterns, avoid the problem of potential interference from the inconsistent onset, and increase the likelihood of a second fixation on the word by increasing the length of the item. This could perhaps yield more easily interpretable data and better resolve the nature of consistency effects during reading.

Endnotes

[1]Participants rated the following item as not equally natural amongst the three potential target words. Here, *freak* was rated as less natural than *choir* in this sentence context.

1. The school children watched the *(choir, freak, stunt)* from across the way.

[2]Participants rated the following items as not equally natural amongst the three potential target words.

1. Timmy asked what the recommended (dose, cleat, fern) would be for his needs.
2. The worker didn't notice the unsightly (soot, fork, rust) before the final inspection.
3. Barry was hopeful that Samantha's (phase, mood, trance) would be very short-lived.
4. The baby tried to put the nearby (dough, leaf, spade) into his little mouth.

Table 1

Frequency Counts for Experiment 1 and Experiment 2

Experiment 1

| | EXCEPTION | REGULAR-INCONSISTENT | REGULAR-CONSISTENT |
|---|---|---|---|
| Average Overall Frequency | 24 | 14 | 13 |
| Average Summed Frequency of Friends | 28 | 290 | 706 |
| Average Summed Frequency of Enemies | 2038 | 1458 | |

Experiment 2

| | EXCEPTION | REGULAR-INCONSISTENT | REGULAR-CONSISTENT |
|---|---|---|---|
| Overall Average Frequency | 20 | 16 | 11 |
| Average Summed Frequency of Friends | 32 | 220 | 746 |
| Average Summed Frequency of Enemies | 2378 | 1561 | |

Table 2

Participants' Means for Experiment 1 Robust ANOVA

| | EXCEPTION | REGULAR-INCONSISTENT | REGULAR-CONSISTENT |
|---|---|---|---|
| *FIRST FIXATION DURATION* | 266 | 264 | 258 |
| *GAZE DURATION* | 279 | 284 | 276 |
| *TOTAL TIME* | 317 | 314 | 304 |
| *SPILLOVER1* | 268 | 270 | 256 |
| *SPILLOVER2* | 274 | 266 | 251 |
| *PROBABILITY OF A FIRST-PASS FIXATION* | 79.6% | 78.5% | 82.9% |
| *NUMBER OF FIRST-PASS FIXATIONS* | 0.864 | 0.879 | 0.91 |
| *REGRESSION INTO TARGET REGION* | 10.86% | 9.95% | 10.07% |

Note. All values for FFD, gaze duration, total time, spillover1 and spillover2 are in ms.

Table 3

Participants' Means for Experiment 1 -- Fixating the Pretarget Region

| | EXCEPTION | REGULAR-INCONSISTENT | REGULAR-CONSISTENT |
|---|---|---|---|
| *FIRST FIXATION DURATION* | 267 | 262 | 251 |
| *GAZE DURATION* | 276 | 278 | 268 |
| *TOTAL TIME* | 315 | 312 | 304 |
| *SPILLOVER1* | 270 | 269 | 260 |
| *SPILLOVER2* | 280 | 270 | 248 |
| *PROBABILITY OF A FIRST-PASS FIXATION* | 72.5% | 73.6% | 80.4% |

Note. All values for FFD, gaze duration, total time, spillover1 and spillover2 are in ms.

Table 4

Participants' Means for Experiment 2 Robust ANOVA – First-Pass Measures

First Fixation Duration

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 281 | 274 | 264 |
| regular-inconsistent | 274 | 279 | 264 |
| regular-consistent | 298 | 273 | 260 |

Gaze Duration

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 303 | 293 | 289 |
| regular-inconsistent | 306 | 303 | 293 |
| regular-consistent | 323 | 298 | 290 |

Total Time

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 355 | 314 | 318 |
| regular-inconsistent | 333 | 342 | 319 |
| regular-consistent | 345 | 331 | 333 |

Single Fixation Duration

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 284 | 275 | 265 |
| regular-inconsistent | 285 | 282 | 266 |
| regular-consistent | 311 | 278 | 264 |

*Skipping*

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 30.1% | 36.8% | 32.6% |
| regular-inconsistent | 37.2% | 32.8% | 31.0% |
| regular-consistent | 35.9% | 41.6% | 37.4% |

Note. All values for FFD, gaze duration, total time, and single fixation duration are in ms.

Table 5

Participants' Means for Experiment 2 Robust ANOVA – Post-Target Measures and Regressions

*Spillover1*

| *Consistency* | *Preview* | | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 282 | 284 | 262 |
| regular-inconsistent | 284 | 280 | 259 |
| regular-consistent | 253 | 280 | 262 |

*Spillover2*

| *Consistency* | *Preview* | | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 285 | 277 | 265 |
| regular-inconsistent | 283 | 284 | 265 |
| regular-consistent | 258 | 270 | 270 |

*Regressions*

| *Consistency* | *Preview* | | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 8.33% | 10.00% | 9.54% |
| regular-inconsistent | 5.74% | 8.29% | 7.22% |
| regular-consistent | 7.64% | 8.75% | 10.37% |

Note. All values for spillover1 and spillover2 are in ms.

Table 6

Participants' Means for Experiment 2 ANOVA (Contingent upon Fixating Pre-Target Region)

First Fixation Duration

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 285 | 269 | 249 |
| regular-inconsistent | 269 | 257 | 258 |
| regular-consistent | 296 | 260 | 268 |

Gaze Duration

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 305 | 283 | 262 |
| regular-inconsistent | 296 | 285 | 294 |
| regular-consistent | 332 | 279 | 303 |

Total Time

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 355 | 314 | 318 |
| regular-inconsistent | 333 | 342 | 319 |
| regular-consistent | 345 | 331 | 333 |

Spillover1

| *Consistency* | | *Preview* | |
|---|---|---|---|
| | No Preview | Body Neighbor | Identical |
| exception | 367 | 313 | 289 |
| regular-inconsistent | 327 | 320 | 294 |
| regular-consistent | 343 | 319 | 334 |

Note. All values for FFD, gaze duration, total time, and spillover1 are in ms.

## BIBLIOGRAPHY


Balota, D., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. Cognitive Psychology, 17, 364-390.

Baron, J. & Strawon, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. Journal of Experimental Psychology: Human Perception and Performance, 2, 386-393.

Carr, T. & Pollatsek, A. (1985). Recognizing printed words: A look at current models. In D. Besner, T. G. Walker, and G. E. MacKinnon (eds.), Reading research: Advances in theory and practice (Vol. 5). Orlando, FL: Academic Press.

Daneman, M. & Reingold, E. (1993). What eye fixations tell us about phonological recoding during reading. Canadian Journal of Experimental Psychology: Learning, Memory, and Cognition, 47, 153-178.

Daneman, M., Reingold, E., & Davidson, M. (1995). Time course of phonological activation during reading: Evidence from eye fixations. . Journal of Experimental Psychology: Learning, Memory, and Cognition, 21(4), 884-898.

Dore, K. & Beauvillain, C. (1997). Latency dependency of word-initial letter integration by the saccadic system. Perception & Psychophysics, 59(4), 523-533.

Folk, J. & Morris, R. (1995). Multiple lexical codes in reading: Evidence from eye movements, naming time, and oral reading. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21(6), 1412-1429.

Francis, W. & Kucera, H. (1982). Frequency analysis of English usage: Lexicon and grammar. Boston: Houghton Mifflin.

Glushko, R. (1979). The organization and activation of orthographic knowledge in reading aloud. Journal of Experimental Psychology: Human Perception and Performance, 5, 674-691.

Henderson, J., Dixon, P., Petersen, A., Twilley, L., & Ferreira, F. (1995). Evidence for the use of phonological representations during transsaccadic word recognition. Journal of Experimental Psychology: Human Perception and Performance, 21, 82-97.

Inhoff, A. & Rayner, K. (1986). Parafoveal word processing during eye fixations in reading: Effects of word frequency. Perception & Psychophysics, 40(6), 431-439.

Inhoff, A. & Topolski, R. (1994). Use of phonological codes during eye fixations in reading and in on-line and delayed naming task. Journal of Memory & Language, 33, 689-713.

Jared, D. (1997). Spelling-sound consistency affects the naming of high-frequency words. Journal of Memory & Language, 36, 505-529.

Jared, D., Levy, B., & Rayner, K. (1999). The role of phonology in the activation of word meanings during reading: Evidence from proofreading and eye movements. Journal of Experimental Psychology: General, 128(3), 219-264.

Jared, D., McRae, K., & Seidenberg, M. (1990). The basis of consistency effects in word naming. Journal of Memory & Language, 29, 687-715.

Johnson, N. & Pugh, K. (1994). A cohort model of visual word recognition. Cognitive Psychology, 26(3), 240-346.

Kay, J. & Bishop D. (1987). Anatomical differences between nose, palm, and foot, or the body in question: Further dissection of the processes of sub-lexical spelling-sound translation. In M. Coltheart (Ed.), Attention and performance XII: The psychology of reading. Hillsdale, NJ: Erlbaum.

Lee, H., Rayner, K., & Pollatsek, A. (1999). The time course of phonological, semantic, and orthographic coding in reading: Evidence from the fast-priming technique. Psychonomic Bulletin & Review, 6(4), 624-634.

Lee, Y., Binder, K., Kim, J., Pollatsek, A., & Rayner, K. (1999). Activation of Phonological codes during eye fixations in reading. Journal of Experimental Psychology: Human Perception and Performance, 25(4), 948-964.

Plaut, D., McClelland, J., Seidenberg, M., Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. Psychological Review, 103(1), 56-115.

Pollatsek, A., Lesch, M., Morris, R., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. Journal of Experimental Psychology: Human Perception and Performance, 18, 148-162.

Pollatsek, A., Rayner, K., & Balota, D. (1986). Inferences about eye movement control from the perceptual span in reading. Perception & Psychophysics, 40(2), 123-130.

Rayner, K. (1975). The perceptual span and peripheral cues in reading. Cognitive Psychology, 7, 65-81.

Rayner, K. & Duffy, S. (1986). Lexical complexity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity. Memory & Cognition, 14(3), 191-201.

Rayner, K. & McConkie, G. (1976). What guides a reader's eye movements? Vision Research, 16, 829-837.

Rayner, K., McConkie, G., & Zola, D. (1980) Integrating information across eye movements. Cognitive Psychology, 12(2), 206-226.

Rayner, K. & Pollatsek, A. (1989). The psychology of reading. Englewood Cliffs, NJ: Prentice-Hall.

Rayner, K., Pollatsek, A., & Binder, K. (1998). Phonological codes and eye movements in reading. Journal of Experimental Psychology: Learning, Memory, and Cognition, 24(2), 476-497.

Rayner, K., Sereno, S., Lesch, M., & Pollatsek, A. (1995). Phonological codes are automatically activated in reading: Evidence from an eye movement priming paradigm. Psychological Science, 6(1), 26-32.

Rayner, K., Sereno, S., & Raney, G. (1996). Eye movement control in reading: A Comparison of two types of models. Journal of Experimental Psychology: Human Perception and Performance, 22(5), 1188-1200.

Reichle, E., Pollatsek, A., Fisher, D., & Rayner, K. (1998). Toward a model of eye movement control in reading. Psychological Review, 105(1), 125-157.

Schilling, H., Rayner, K., & Chumbley, J. (1998). Comparing naming, lexical decision, and eye fixation times: Word frequency effects and individual differences. Memory & Cognition, 26 (6), 1270-1281.

Seidenberg, M. (1985). The time course of phonological activation in two writing system. Cognition, 19, 1-30.

Seidenberg, M. & McClelland, J. (1989). A distributed, developmental model of word recognition and naming. Psychological Review, 96, 523-568.

Seidenberg, M., Waters, G., Barnes, M. & Tanenhaus, M. (1984). When does irregular spelling or pronunciation influence word recognition: Facilitory or inhibitory? Memory & Cognition, 21, 247-266.

Sereno, S. & Rayner, K. (1992). Fast priming during eye fixation in reading. Journal of Experimental Psychology: Human Perception and Performance, 18, 173-184.

Sereno, S. & Rayner, K. (2000). Spelling-sound regularity effects on eye fixations in reading. Perception & Psychophysics, 62 (2), 402-409.

Stanovich, K. & Bauer, D. (1978). Experiments on the spelling-to-sound regularity effect in word recognition. Memory & Cognition, 6, 410-415.

Stone, G., Vanhoy, M., & Van Orden, G. (1997). Perception is a two-way street: Feedforward and feedback phonology in visual word recognition. Journal of Memory and Language, 36, 337-359.

Taraban, R. & McClelland, J. (1987). Conspiracy effects in word pronunciation. Journal of Memory & Language, 26, 608-631.

Van Orden, G., Pennington, B., & Stone, G. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics. Psychological Review, 97 (4), 488-522.