Spring 5-10-2017

Processing Differences in Reading Alliteration and Rhyme: An Eye-Movement Study

Keiko Bridwell

PROCESSING DIFFERENCES IN READING ALLITERATION AND RHYME: AN EYE-MOVEMENT STUDY

By

Keiko Bridwell

Submitted in Partial Fulfillment
of the Requirements for
Graduation with Honors from the
South Carolina Honors College

May 2017

Approved:

Robin Morris, Ph.D.
Director of Thesis

Amanda Dalola, Ph.D.
Second Reader

Steve Lynn, Dean
For South Carolina Honors College

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THESIS SUMMARY

When people read written text, they not only process the visual shapes of words and letters, but the sound patterns that these words would have if spoken aloud. These mental representations of sounds serve as a pathway toward word recognition. One interesting consequence of this is that sentences with repeated initial sounds (also known as "tongue twisters") are read more slowly and less accurately than normal sentences. While this effect has been widely attested, previous research has largely dealt with the repetition of initial sounds, or alliteration. Very few studies have looked at the effect that the repetition of final sounds (rhyme) would have on reading patterns, and even fewer have compared alliteration and rhyme. There is evidence that the first letter of a word is the most important contributor to word recognition, but it is unclear whether this extends to the "tongue twister effect". This thesis seeks to fill this gap in the literature.

In this study, participants read sentences containing three-word phrases that exhibited alliteration, rhyme, or no repetition. Their eye movements were monitored and reading times were measured on various regions within the sentence to determine the time-courses of the "tongue twister effect" caused by alliteration and a potentially parallel effect caused by rhyme.

Results from this study showed that, consistent with previous studies, alliteration produced increased reading times on the third word in the phrase. However, diverging from previous studies, differences were observed between alliteration and rhyme, with rhyme having a much stronger effect that emerged earlier and lasted longer. These results suggest that rhyme creates stronger perceptual sound cues than alliteration, despite the importance of the initial letter in word recognition. This finding, which is the first to

provide evidence that rhyme and alliteration are processed differently in reading, offers up several intriguing possibilities for future research, which may be used to determine the source of their differences and provide a deeper understanding of the mechanisms that underlie the reading process.

ABSTRACT

In studies of silent reading, it is well-attested that the phonological content of a word, and not only its visual shape, contributes to the reading process. One of the most widely-observed phenomena in this field is the "tongue twister effect": the tendency for words with repeated initial phonemes to be read more slowly and comprehended more poorly than words without phonological repetition. This effect has been well-documented over decades of research; however, it has overwhelmingly dealt with word-initial overlap, or alliteration. Very few studies have looked at the impact that word-final overlap, or rhyme, might have on reading. In the current study, participants silently read sentences containing three-word alliterative, rhyming, or control phrases while their eye movements were monitored. Sentences were also controlled for orthographic overlap, with some phrases exhibiting both phonological and orthographic overlap (P+O+) and some exhibiting phonological overlap alone (P+O-). Results revealed that both alliteration and rhyme created longer processing times in early measures, but the effect of rhyme was far more robust and persisted into late measures. The P+O- condition also tended to elicit longer reading times than P+O+. These results suggest that rhyme exerts a stronger phonological cue than alliteration, despite previous studies suggesting that the initial letter of a word is the most important in word recognition.

INTRODUCTION

PHONOLOGICAL ACTIVATION IN READING

During the process of silent reading, readers experience the impression of mentally hearing the text in their heads. This phenomenon, known as inner voice, creates a sensation that is in many ways similar to hearing or producing overt speech. For example, silently reading rhyming poetry produces a subjectively similar experience to hearing it read aloud, and confusion results when one of the words is replaced with one that does not rhyme (Filik & Barber, 2011). Even more strikingly, "tongue twisters", which are difficult to pronounce aloud, are also read more slowly than ordinary sentences. This effect has been widely attested, and will be discussed in more detail below.

The properties of inner voice are thought to result from the recoding of orthographic information into phonological information (Leinenger, 2014), but its precise nature and its role in the reading process are still not completely understood. However, it is clear that the phonological content of text does have an impact on the reading process, a point which can be clearly elicited through the use of phonological repetition. Numerous studies have shown that the presence of phonologically similar words affects lexical access at an early stage. One of the most prominent methodologies used to demonstrate this has been the fast-priming paradigm, in which a target word is replaced with a random letter string until the reader's eyes cross an invisible boundary. Once this boundary is crossed, the letter string is briefly replaced with a prime word, and then replaced again by the target word for the remainder of the trial. Fast-priming studies have consistently demonstrated that readers spend less time reading a target word when it

is primed with a phonologically similar word, as opposed to an unrelated control word, and that this phonological processing takes place during the first 50 ms of fixation (for an overview, see Leinenger, 2014).

In the past, most phonological repetition studies have focused on alliteration (McCutchen & Perfetti, 1982; Hanson et al., 1991; McCutchen et al., 1991; Zhang & Perfetti, 1993; Robinson & Katayama, 1997; Kennison, 2004; Yan & Morris, 2012, 2013), or on "neighboring" words that differ by a single phoneme, regardless of its place in the word (Paterson et al., 2009; Yan, 2016). Very little has been done to specifically target the effects of rhyme, or to differentiate the effects of rhyme and alliteration in the reading process. There is some evidence to suggest that the two may be processed differently; for example, research using transposed and/or substituted letters has shown that letter identity is more important for exterior letters, and that the initial letter makes the largest contribution to word recognition (Rayner et al., 2006). However, few studies have explored this contrast. The present study seeks to fill this gap in the literature.

ALLITERATION

In studies utilizing sentence-reading under normal conditions, readers are slower and less accurate to read and comprehend sentences that contain repeated word-initial phonemes (McCutchen & Perfetti, 1982; Hanson et al., 1991; McCutchen et al., 1991; Zhang & Perfetti, 1993; Kennison, 2004; Yan & Morris, 2012, 2013). This phenomenon is known as the "tongue-twister effect", or TTE. One of the earliest studies demonstrating TTE was conducted by McCutchen and Perfetti (1982), which showed that readers took longer to classify sentences with repeated initial letters as acceptable or

unacceptable. More recent studies, using eye-tracking methods, have found that phonemic similarity tends to slow reading, resulting in longer fixations and more re-reading (Paterson, 2009; Yan & Morris, 2012, 2013; Frisson et al., 2014; Yan, 2016).

Previous studies have largely focused on late stages of sentence processing, such as text integration and comprehension (McCutchen & Perfetti, 1982; Hanson et al., 1991; McCutchen et al., 1991; Kennison, 2004). However, early effects have also been observed. Robinson and Katayama (1997) provided subjects with tongue-twister (i.e. alliterative) word-lists and control word-lists and found that they were slower to make lexical decisions on the alliterative words; they also had better memory for the control lists. This confirmed earlier studies indicating that TTE elicits a cost in working memory, but provided evidence that it also occurs early in processing, at lexical access. Similarly, in eye-tracking experiments performed by Yan & Morris (2012, 2013), TTE processing costs emerged by the third word in a tongue-twister phrase, and continued on to the end of the phrase, affecting both early and late reading measures. These results indicate that phonological forms are active and sensitive to repetition effects at lexical access, and persist into working memory during text integration.

RHYME

In contrast to alliteration, the effects of which are well-attested in the literature, rhyme has rarely been studied on its own. In studies using a phonological priming paradigm, there are findings showing that auditory recognition of a word occurs more quickly when preceded by a word with final overlap, while initial overlap tends to slow the response (for an overview, see Dufour, 2008). However, these results deal with

auditory recognition, and may not transfer over to visual processing. In fact, if the increased reading times produced by overlapping letters and/or phonemes are due to competition for word-recognition between similar lexical items, then both alliteration and rhyme should create confusion between these items during normal reading; neither should have a facilitatory effect.

That rhyme creates a TTE-like effect has been borne out by the few studies that have dealt with the effects of rhyme on sentence processing, either directly or indirectly. Shankweiler et al. (1979) found that among second-grade school children, recall of rhyming non-words was poorer than for non-rhyming non-words, especially among good readers (who, it should be noted, would approximate adult-like reading more closely than their less advanced peers). In a study by Acheson and MacDonald (2011), which investigated the effects of phonological overlap on sentence comprehension, the second word in a phonologically similar pair had a longer reading time. The pairs in this study contained both rhymes (e.g. *sought/bought*) and words with a level of overlap similar to rhyme (e.g. *baker/banker*). These studies, along with those that treat initial and final overlap as a single generic-overlap condition, provide evidence that rhyme creates a processing cost.

Comparison

Despite the evidence that both alliteration and rhyme produce temporal costs in silent reading, it does not necessarily follow that the strength and time-course of the two effects are identical. Yet the relative strength of the effects of alliteration and rhyme has been even less studied than that of rhyme alone. As mentioned above, a study by Rayner

et al. (2006) may suggest a special status for the initial letter of a word. Studies have found that beginning readers rely heavily on initial letters for word-identification (Williams, Blumberg, & Williams, 1970), and in adult reading, it has been suggested that the first few letters in a word may be the most important in determining word recognition, since readers gain greater parafoveal preview benefit from word initial letters (Rayner, McConkie, & Zola, 1980). In view of this, alliteration may be more disruptive to the reading process than rhyme.

One of the few studies to address the alliteration vs. rhyme issue was conducted by Frisson et al. (2014). In this study, phonological and orthographic neighbors (ex. *strain/strait*) were presented within the same sentence, with fixation times measured on the second word. Two experiments were included in the study, and showed slightly different results. In the first experiment, word-final overlap produced significant increases in gaze duration, an early measure, while word-initial overlap did not. Instead, it caused non-significant increases in gaze duration and in first-pass regressions (the number of times readers left the word to look backwards in the text). However, the regression-path measure, which combines the two previous measures, did show significant results. This would indicate a slightly later effect for alliteration (or in this case, word-initial overlap) than for rhyme. Frisson et al. suggested that these results could have been due to greater phonological cues exerted by rhyme. However, in a second experiment involving multi-clausal sentences, the shortest sentences showed increased times for gaze duration in both word-initial and word-final overlap. The different results between the two experiments go unexplained in the paper, but may

suggest a potential difference in the processing of alliteration and rhyme when the prime and target occur in close succession.

PRESENT STUDY

Since alliteration and rhyme seem to both elicit processing costs in silent reading, any distinction between them will likely be a difference in the magnitude of their effects, which cannot be determined from looking at either in isolation, as has been frequently done in the literature. The data obtained by Frisson et al. suggest that there is, in fact, a difference in the processing of alliteration and rhyme, but that this difference is subtle and needs strong phonological cues to be elicited. This study will attempt to tease apart the differences in alliteration and rhyme by strengthening the phonological repetition effect in relation to previous studies. In order to obtain a sensitive measure of initial effects, and to most naturally simulate the natural reading process, the present study uses online eye-tracking methods, which can capture both early and late effects in reading.

In eye-tracking studies, participants' eye movements are unobtrusively monitored by projecting an infrared light onto the eye and tracking the corneal reflection, which indicates where a subject's gaze is pointing. Since an eye-tracking setup directly records the reading process, silent reading can be studied without any secondary task (e.g. lexical decision, semantic categorization, etc.). These tasks require participants to not only read the text, but to plan and execute a response, by which time both early and late processing has already taken place. In contrast, eye-tracking allows early and late effects to be differentiated by providing a moment-by-moment record of a reader's fixations, so that

total reading time can be broken down by individual word and compared. For these reasons, the present study uses eye-movement monitoring for data collection.

In the paradigm used by Frisson et al. (2014), Paterson & Liversedge (2009), and Yan (2016), the target word occurred several words after the prime. However, in studies conducted by Yan & Morris (2012, 2013), which used a four-word string of alliterative words (e.g. *Brad's burned bran buns*), TTE did not consistently occur until word 3. Thus, having only two words with phonological overlap may not present a strong enough stimulus in some instances to create a repetition effect. Furthermore, separating the prime and target by several words may provide time for a decay of the phonological encoding of the prime. Given these findings, the stimuli in this study will consist of three consecutive words exhibiting either alliteration or rhyme, in order to increase the phonological load and create a strong effect by the third word.

Finally, it has been suggested that what has been called a phonological repetition effect is actually an orthographic repetition effect. Studies investigating this have shown contradictory results. Zhang & Perfetti (1993) presented readers with tongue twisters in Chinese that contained initial alveolar stops, and found that the participants read these alliterative sentences more slowly than their matched controls. As the writing system of Chinese is not alphabetic, the variable of orthographic repetition was not present for these stimuli, indicating that the tongue twister effect is created by the phonological representation of words in inner speech, and not by confusion caused by visual repetition. On the other hand, Hanson et al. (1991) found that both deaf and hearing readers were affected by the presence of alliteration in sentences. Since the deaf readers did not have access to an auditory phonological code, this would seem to suggest that the effect was

orthographic; however, both groups made more errors when tongue-twister sentences and memory-load numbers were phonologically similar. Hanson et al. suggest that this indicates that deaf readers have access to a phonological code in non-auditory form, but that TTE is still phonologically based. Current studies are similarly inconclusive. Frisson et al. (2014) observed that effects only emerged when phonological and orthographic overlap were combined, as opposed to either alone. However, Yan (2016) found similar gains in reading time for both phonological + orthographic overlap and phonological overlap alone, suggesting that the effect is driven by phonological encoding. The present study will not attempt to investigate phonological and orthographic overlap as separate phenomena, but will control for possible orthographic effects by including a condition with both phonological and orthographic overlap (P+O+) and a condition with phonological overlap alone (P+O-).

To summarize, the present study aims to directly examine the different effects of alliteration vs. rhyme on processing in silent reading, a distinction which has largely gone ignored in the literature. By creating stronger phonological cues than have been used in previous studies, the current experiment should be able to magnify any differential effects in the overlap types and use inferential statistics to analyze the results. It will then be possible to determine whether the well-attested "tongue twister effect" is specific to alliteration on any level, or if it is driven by generic phonological repetition that has mainly been tested on word-initial phonemes in the past. Finally, this study will provide a detailed look at rhyme, which has rarely been studied alone, and make it possible to create a moment-by-moment record of its effect on the initial reading process.

METHODS

PARTICIPANTS

58 undergraduate volunteers, (age: 17-38, mean 20.7; 9 males; 9 left-handed) were recruited using the SONA systems participant pool from the University of South Carolina. All participants were given informed consent prior to the IRB-approved experiment and had normal or corrected to normal vision. Participants were compensated with extra credit.

APPARATUS

Eye movements were recorded using an SR Research Eyelink 1000 eye tracker (spatial resolution 0.01°) sampling at 1000Hz. Participants were seated 60 cm away from a 45cm Viewsonic G225f CRT monitor, raised 22.5 cm above the table. Head movements were minimized with chin and forehead rests. Using a table-mounted camera, eye movements were recorded from the right eye, although viewing was binocular. The experiment was programmed with SR Research Experiment Builder software.

MATERIALS

The materials for this study consisted of 64 experimental sentences, each with a corresponding control item, and 54 filler sentences. The experimental and control sentences each consisted of introductory material, a three-word critical phrase, and a post-target prepositional phrase. In the critical phrase, the final word functioned as the target word for the sentence, while the previous two words served as primes in the

experimental conditions. The final word in this phrase was always a noun; the first two words were most often adjectives, but could also be modifying nouns or possessive nouns.

The critical phrases were constructed along two factors: phrase type and phonological overlap. Phrase type was divided into alliteration and rhyme. Each of these conditions contained 32 sentence pairs. Phonological overlap was divided into two conditions: phonological and orthographic overlap (P+O+) and phonological overlap alone (P+O-). Each of these levels contained 32 sentence pairs (16 per phrase type).

For the alliteration condition, each word in the critical phrase began with the same initial phoneme, while for the rhyme condition, each word ended with the same phoneme string, according to the pronunciation of Standard American English. Words in the rhyme condition were limited to one syllable in order to preserve the quality of the rhyme. In the no-orthographic-overlap condition (P+O-), each word in the critical phrase phonologically overlapped with the others, but the spelling pattern of each word differed. In the orthographic-overlap condition (P+O+), all of the words both phonologically and orthographically overlapped with each other. Therefore, the structure of the critical phrases could fall into one of four types, as shown below:

	Alliteration	Rhyme
P+O-	psyched city scene	new blue shoe
P+O+	last lava lamp	old cold mold

To form control sentences, words 1 and 2 from each critical phrase were removed from each sentence and replaced with words that had no overlap of any type with word 3. These new words were controlled for length (± 1 letter) and for token word frequency according to the SUBTLEXUS corpus. Examples of experimental-control pairs are shown below. A complete list of the stimuli, as well as the word length and frequency for each condition, can be found in Appendix I.

Alliteration

*The clerk sold the **large lava lamp** to the customer.*

*The clerk sold the **cheap rosy lamp** to the customer.*

Rhyme

*Zane wiped lots of **old cold mold** out of the fridge.*

*Zane wiped lots of **bad food mold** out of the fridge.*

54 additional sentences served as filler items. These were designed to closely match the test sentences in length and to have informative or narrative content that avoided controversial current issues. 18 of these sentences were followed by yes-no comprehension questions.

All of the sentences were divided into two counterbalances, with 32 experimental sentences (divided evenly among phrase type and phonological overlap type) in each counterbalance, and 32 controls, so that each participant would see one sentence from each experimental-control pair. Steps were taken to ensure that none of the words used in

a critical region appeared more than once in a single counterbalance. All of the fillers (54) appeared in both counterbalances.

PROCEDURES

After signing a consent form and filling out a brief questionnaire for demographic purposes, participants were seated in a chair in front of a computer and instructed to place their head comfortably in the eye tracker's headrest. Several introductory screens were shown to familiarize participants with the layout of the screen and the buttons that they would be using to answer comprehension questions. Following these screens, adjustments were made to the camera for optimal pupil recognition, and the camera was calibrated to the participant's eye movements.

Following calibration, a black fixation marker appeared at the middle of the left side of a white background. Participants were told that this marker would appear before each trial, and that they should look at this circle in order to begin each new sentence. They were instructed to read for comprehension at their natural reading rate, and to look toward a gray circle at the bottom right corner to end each trial.

Once a stable fixation was detected on the fixation marker, a sentence would appear on the screen until the participant ended the trial by looking at a gray circle at the bottom right corner. For each trial, sentences were displayed on the screen in single lines of Courier font, size 18, so that approximately 3 characters subtended 1° of visual angle. 32 experimental sentences, 32 controls, and 54 fillers appeared to each participant, pseudo-randomized with the constraint that no more than two items from the same condition would appear consecutively. Comprehension questions followed 18 of the

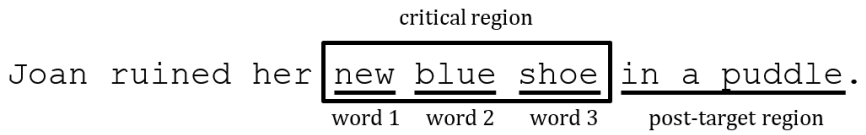
filler sentences, occurring at random intervals throughout the task, in order to ensure that participants were reading for comprehension for the duration of the task. Participants indicated their response to a question by pressing one of two buttons with the right hand.

Following each trial, the screen would be blank for 500 ms and the next fixation start screen would appear. The reading task took approximately 20 minutes.

RESULTS

Processing times were examined in three critical regions of the sentence. As shown below, the target phrases were made up of three words. In this paper, "word 2" and "word 3" refer to the second and third word of the target phrase respectively. Each of these one-word regions was analyzed separately to access early processing effects on lexical access. The words after the target phrase were grouped into a single "post-target region" and analyzed for text integration effects. In addition, the entire three-word target phrase was analyzed as a single word region for text integration effects.

Figure 1. Example stimuli sentence



Each measure was analyzed using a 2x2x2 repeated measures analysis of variance (ANOVA). In addition, four 2x2 ANOVAS were analyzed. A 2x2 ANOVA within the alliteration condition was compared with a 2x2 ANOVA for the rhyme condition, in order to compare how the measures differed according to phrase type. Another 2x2 ANOVA was conducted for items in the phonological + orthographic overlap condition (P+O+), and compared to the 2x2 ANOVA for phonological overlap alone (P+O-).

EARLY PROCESSING MEASURES

Data for 54 of the 58 tested participants was examined for this study. The remaining four were eliminated due to eye movement monitoring problems. Four items

were dropped from the stimuli prior to analyses due to problems in their construction, and a matched number was removed from each condition, leaving 128 stimuli sentences (16 per condition). No data were examined for filler sentences.

In order to examine lexical processing, initial processing times were measured on words 2 and 3 within the critical region. Initial processing was measured by gaze duration, calculated as the sum of all consecutive forward fixations on a word or region, beginning with a reader's first fixation on a word and ending with their last fixation before moving on to another word. Any gaze duration less than 120 ms or greater than 1000 ms was eliminated from the analyses. Less than 2% of the data were lost due to these cutoffs, or to trials eliminated due to faulty tracking.

If no fixation was made on a target word, then that trial was excluded from the analyses. Due to the nature of the study, trials were only included if the participant fixated on both word 2 and word 3. Less than 5% of the data were lost due to lack of fixations on the necessary words. Any condition mean made up of less than 3 data points was considered to have insufficient data, and was replaced with the participant's grand mean for that phrase type (rhyme/alliteration combined with experimental/control), as representative of that participant's reading pattern. This was data loss due to error, and amounted to less than 1% of the total data.

The first region analyzed was word 3 in the critical region. Mean gaze durations across participants are displayed below in Table 1. In the 2x2x2 ANOVA, there was a main effect of target phrase (experimental versus control) such that readers spent longer on the final word of a phrase containing phonological repetition than on a phrase of the same form that did not ($F(1,53)=21.17$, $MSE=2649$, $p<.001$). There was also a main

effect of phonological overlap (P+O+ versus P+O-) such that readers spent more time on phrases in which there was phonological overlap with varied orthography than on phrases that had both phonological and orthographic overlap ($F(1,53)=18.36$, $MSE=2223$, $p<.001$). Notably, there were clear differences in the effect of phonological overlap in rhyming phrases compared to alliterative phrases ($F(1,53)=4.58$, $MSE=1838$, $p=.037$). Readers spent more time on P+O- phrases in both alliteration and rhyme, but to a greater extent in rhyme. In addition, the main effect of phrase type (alliteration versus rhyme) approached significance ($F(1,53)=3.75$, $MSE=1851$, $p=.058$), such that readers spent less time on the final word of an alliterative phrase than on the final word of a rhyme phrase. The interaction between phrase type and target phrase (target versus control) also approached significance ($F(1,53)=3.29$, $MSE=2653$, $p=.075$): readers spent more time on the target phrase than the control phrase in both alliteration and rhyme, but the differences were more marked in rhyme.

Given that there were interactions involving phrase type, further analyses were conducted on the alliteration conditions alone and on the rhyme conditions alone. For the 2x2 ANOVA for the alliteration condition, there was a main effect of target phrase, such that readers spent longer on experimental phrases than their matched controls ($F(1,53)=4.27$, $MSE=2407$, $p=.044$). Similarly, the 2x2 ANOVA for the rhyme condition showed the same effect of target phrase, though the effect appeared to be more robust ($F(1,53)=18.83$, $MSE=2896$, $p<.001$). This analysis of the rhyme items also showed a main effect of phonological overlap, such that P+O+ items were read more quickly than P+O- items in the rhyme condition ($F(1,53)=21.68$, $MSE=1990$, $p<.001$).

Given the interaction between phrase type and phonological overlap, further analyses were conducted on the P+O+ items alone and the P+O- items alone. According to the 2x2 ANOVA for the P+O+ condition, there was no effect of phrase type. However, in the 2x2 ANOVA for the P+O- condition, an effect of phrase type was present, such that alliteration items were read more quickly than rhyme items when there was no orthographic overlap ($F(1,53)=9.67$, $MSE=1583.6$, $p=.003$).

Table 1
Mean gaze duration (in ms) on word 3 in the critical region

	P+O+	P+O-
Alliteration	296 (SD=63)	308 (SD=62)
Control	284 (SD=68)	293 (SD=60)
Difference	*12*	*16*

	P+O+	P+O-
Rhyme	306 (SD=59)	333 (SD=74)
Control	272 (SD=60)	302 (SD=54)
Difference	*33*	*30*

The next region analyzed was word 2 in the critical region (Table 2). In the 2x2x2 ANOVA, there was a main effect of phrase type, such that readers spent longer on the second word of a phrase in the alliteration condition than the rhyme condition ($F(1,53)=41.87$, $MSE=3334$, $p<.001$). There was also a main effect of phonological overlap ($F(1,53)=4.09$, $MSE=2936$, $p=.048$), such that readers spent more time on phrases in the P+O- condition than on phrases in the P+O+ condition. Although there was no main effect of target phrase, the interaction between phrase type and target phrase

approached significance ($F(1,53)=3.90$, $MSE=2787$, $p=.054$). In light of this, analyses were conducted on the alliteration items alone and the rhyme items alone.

In the 2x2 ANOVA for the rhyme condition, a main effect of target phrase was present, such that readers spent longer on experimental phrases than their matched controls ($F(1,53)=8.08$, $MSE=1595$, $p<.001$). In the 2x2 ANOVA for the alliteration condition, there was no effect of target phrase, but there was an effect of phonological overlap ($F(1,53)=5.322$, $MSE=2700$, $p=.025$), such that P+O+ items were read more quickly than P+O- items.

In the 2x2 ANOVA for P+O-, there was a significant effect of phrase type, such that readers spent longer on items in the alliteration conditions than on rhyme ($F(1,53)=28.43$, $MSE=3305$, $p<.001$). In the 2x2 ANOVA for P+O+, there was a significant effect of phrase type in the same direction ($F(1,53)=19.91$, $MSE=2471$, $p<.001$). These conditions also showed an interaction between target phrase and phrase type, such that rhymes took longer to read than their matched control counterparts, while alliterative items did not ($F(1,53)=6.062$, $MSE=2466$, $p=.017$)

Table 2
Mean gaze duration (in ms) on word 2 in the critical region

	P+O+	P+O-
Alliteration	325 (SD=75)	348 (SD=70)
Control	337 (SD=72)	345 (SD=79)
Difference	*-12*	*3*

	P+O+	P+O-
Rhyme	311 (SD=58)	310 (SD=62)
Control	290 (SD=72)	300 (SD=62)
Difference	*21*	*10*

LATE PROCESSING MEASURES

Later effects associated with text comprehension and working memory were examined using gaze duration on the post-target region and total dwell time on the critical region. Only those trials which were used in the initial processing analyses were included in the late processing analyses. Reading times of less than 100 ms were again eliminated from the analyses for both measures, and times over 2000 ms were eliminated for the post-target region. No upper cutoff was placed on total time, which reflects the total amount of time spent in a region over the course of a trial.

Gaze duration on the post-target region are shown in Table 3. In the 2x2x2 ANOVA, there was a main effect of phrase type, such that readers spent longer on the spillover region after the critical phrase in the rhyme condition than in the alliteration condition ($F(1,53)=21.89$, $MSE=11922$, $p<.001$). There was also an interaction between phrase type and phonological overlap ($F(1,53)=5.19$, $MSE=10993$, $p=.027$). As a result, analyses were conducted on the alliteration conditions alone and the rhyme conditions alone, and on the P+O+ items alone and the P+O- items alone.

In the 2x2 ANOVA for alliteration, there was a trending effect of phonological overlap in alliteration ($F(1,53)=2.70$, $MSE=8395$, $p=.090$), such that P+O- items were read more quickly than P+O+ items. No significant effects were seen in the 2x2 ANOVA for rhyme.

In the 2x2 ANOVA for P+O-, there was a main effect of phrase type ($F(1,53)=20.84$, $MSE=13483$, $p<.001$), such that readers spent longer on items in the rhyme condition than alliteration. In the 2x2 ANOVA for P+O+, there was a trending effect of phrase type in the same direction ($F(1,53)=3.92$, $MSE=9432$, $p=.053$). Most

notably, this analysis showed a significant interaction between phrase type and target phrase, such that rhyme items took longer to read than their matched control counterparts when orthographic overlap was present ($F(1,53)=4.49$, $MSE=6807$, $p=.039$).

Table 3
Mean gaze duration (in ms) on the post-target region

	P+O+	P+O-
Alliteration	529 (SD=178)	518 (SD=175)
Control	542 (SD=183)	510 (SD=179)
Difference	*-13*	*8*

	P+O+	P+O-
Rhyme	579 (SD=213)	594
Control	544 (SD=175)	578
Difference	*34*	*15*

Finally, total reading time was examined for the entire critical region (Table 4). In the 2x2x2 ANOVA, there was a main effect of target phrase, such that readers spent more time on experimental items than their controls ($F(1,53)=11.74$, $MSE=34878$, $p<.001$). There was also a main effect of phrase type, such that readers spent more time on items in the alliteration condition than rhyme ($F(1,53)=5.837$, $MSE=32797$, $p=.019$). There was also a main effect of phonological overlap, such that readers spent more time P+O- items than P+O+ ($F(1,53)=43.27$, $MSE=34278$, $p<.001$). In addition, there was a significant interaction between phrase type and target phrase ($F(1,53)=11.88$, $MSE=28312$, $p=.001$), which will be discussed below. There was also a significant interaction between target phrase and phonological overlap ($F(1,53)=6.61$, $MSE=31424$, $p=.013$).

Given that there were differences in the effect of target phrase in rhyming phrases compared to alliterative phrases, analyses were conducted on the alliteration items alone and on the rhyme items alone. In the 2x2 ANOVA for alliteration, there was no effect of target phrase. However, in the 2x2 ANOVA for rhyme, experimental items were read more slowly than their matched controls ($F(1,53)=18.31$, $MSE=41255$, $p<.001$). Interestingly, this analysis also showed an interaction between target phrase and phonological overlap in the rhyme condition, such that P+O- phrases had a larger increase relative to their matched controls than P+O+ items ($F(1,53)=6.76$, $MSE=34296$, $p=.012$).

Given the interaction between target phrase and phonological overlap, further analyses were conducted on the P+O+ items alone and the P+O- items alone. In the 2x2 ANOVA for P+O+, there were no significant effects. In the 2x2 ANOVA for P+O-, both target phrase and phrase type were significant ($F(1,53)=12.70$, $MSE=48040$, $p=.001$; $F(1,53)=6.788$, $MSE=32065$, $p=.012$). The most striking part of this data was the interaction between phrase type and target phrase, such that rhyme items had a larger increase relative to their matched controls than alliteration items, when there was no orthographic overlap ($F(1,53)=9.20$, $MSE=35258$, $p=.004$).

A summary of the differences in the time-courses of alliteration and rhyme are displayed below, in Figure 2. Each bar represents the mean reading time in the experimental condition for that measure, minus the mean reading time of the matched controls. The dark bars represent the gaze duration/first-pass on each interest area, while the light bar represents total time on the critical region. Statistically significant differences are marked with an asterisk (*).

Table 4
Mean total time (in ms) on the critical region

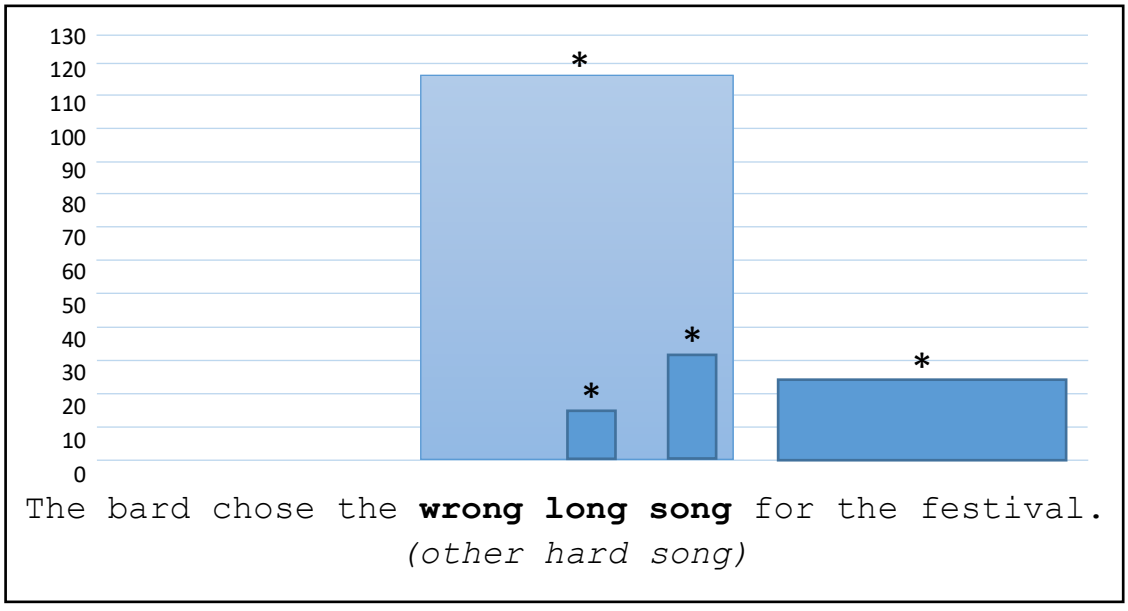
	P+O+	P+O-
Alliteration	1224 (SD=376)	1385 (SD=363)
Control	1239 (SD=388)	1356 (SD=388)
Difference	*-15*	*29*

	P+O+	P+O-
Rhyme	1237 (SD=333)	1399 (SD=456)
Control	1185 (SD=299)	1215 (SD=325)
Difference	*52*	*184*

Figure 2. Differences in mean reading times (Experimental – Control), combined across P+O+ and P+O-

Alliteration

Rhyme



DISCUSSION

PHONOLOGICAL REPETITION

Processing measures revealed clear effects of phonological repetition, both early and late. In gaze duration measures on word 3, increased reading times were observed on experimental items for all conditions, indicating that the presence of phonological repetition created a disruption at lexical access. Later processing measures, taken to represent text integration processes, revealed a similar pattern of results, but only in the rhyme conditions. In the total time measure on the critical region, phonological effects were seen in rhyme, and on the post-target region, a phonological effect was present for rhyme when both phonological and orthographic overlap were present.

The results from the alliteration condition are consistent with previous findings from TTE studies, and confirm the time-course determined by Yan & Morris (2012, 2013): alliteration effects emerge at the third word. Unlike previous studies, however, which have typically treated TTE and rhyme effects as part of the same phenomenon, this experiment found diverging results for alliteration and rhyme, both in magnitude and in the order in which they emerge.

ALLITERATION VERSUS RHYME

Across all measures, there is a significant effect of phrase type, and a closer look at the data reveals that this is because the phonological repetition effect produced by rhyme is more robust than that produced by alliteration at every stage. This is most apparent when looking at the data chronologically. In the rhyme condition, the phonological effect arises at word 2, at which point there is no trace of an effect in

alliteration. The alliteration effect emerges at word 3, yet still elicits smaller time costs than rhyme. In the post-target region, the phonological effect is already absent in alliteration, but is still present in rhyme for the P+O+ condition. Finally, in the total time measure, there is no phonological effect in alliteration. Since the total time included both the first and subsequent readings, and alliteration did have a significant phonological effect on the first pass, this indicates that total time is an effective measure of re-reading, and that alliteration triggered no more re-reading than the control conditions. In the total time measure for rhyme, however, there is still a strong phonological effect. These data suggest that while alliteration primarily affected lexical access, rhyme required additional processing from readers at both lexical access and later text integration processes.

It is interesting to compare this data to the first experiment in the Frisson et al. (2014) study, which found significant increases in gaze duration for rhyme, but not for word-initial overlap, where the effect was slightly delayed. In the current study, alliteration effects were present, but did not emerge until word 3, so Frisson et al.'s results may indicate that the phonological cue of only one overlapping word did not provide a strong enough environment to have a significant effect on lexical access.

ORTHOGRAPHY

In this study, the relationship between phonological overlap and orthographic overlap was not studied directly, but was treated as a potential confounding factor. Sentences with no orthographic overlap were provided in order to control for the possibility that results indicating a phonological effect might in fact be measuring an orthographic effect. According to the results for this study, the presence or absence of

orthographic overlap did have an effect on reading times in every measure, usually such that sentences without orthographic overlap took longer to read. However, readers spent longer on experimental phrases relative to their matched controls, both when orthographic overlap was present (P+O+) and when it was not (P+O-). This indicates that while the presence or absence of orthographic overlap was relevant to processing times, it did not account for the phonological effects observed; the effects of spelling and sound are distinct.

Typically in the literature, orthographic and phonological overlap are treated as having similar effects on the reading process; overlap of either type creates confusion between word forms that disrupts lexical access. It might be expected, therefore, that the P+O+ conditions would be read more slowly than the P+O- ones. However, the opposite proved to be true. In the word 3 and total time measures, gaze duration times were lower when there was orthographic overlap, for both alliteration and rhyme. This phenomenon emerged earlier for alliteration than for rhyme; at word 2, P+O+ gaze durations are significantly lower than P+O- for alliteration.

This surprising result could possibly be explained as the result of a lack of consistent mapping between phonology and orthography. According to the Triangle model, word-recognition is determined by phonology, orthography, and semantics, all of which are interconnected and feed each other (Plaut, 1996). It may be possible that the P+O- items created confusion within this system because of the conflict between overlapping phonological forms, and different orthographic ones. However, it must also be noted that the controls showed the same pattern as the experimental items in this respect, which could point to a potential confound in the construction of the sentences. It

would be necessary to do more research on the acceptability of the items before drawing any conclusions from these results. Nevertheless, the differences in total time measure for experimental vs. control items was significantly higher in the P+O- condition, so the previous hypothesis may still hold for this result.

IMPLICATIONS

Phonological overlap

The results from this study allow several clear conclusions to be drawn. First, there is a clear effect of phonological repetition on both early and late processing. This supports the theory that phonological encoding contributes to lexical access, and that a disruption in this process can lead to confusion in working memory.

Next, this study found marked differences in the phonological effects elicited by alliteration and rhyme respectively. Given that the initial letter of a word is thought to be more salient in the reading process (Williams, Blumburg, & Williams, 1970; Rayner, McConkie, & Zola, 1980; Rayner et al. 2006), it was expected that alliteration would be more costly than rhyme in terms of processing time. Interestingly, although no data was collected on readers' perceptions of the sentences, more than one participant voluntarily commented after testing that they felt that the rhyming sentences were easier to read than the alliterative ones. When the results were examined, however, rhyme exhibited much more robust effects than alliteration, and did so at every stage in the time-course of reading the sentence. It is possible that because readers feel more "comfortable" with rhyme, a literary device that they are frequently exposed to from a young age, and that is associated with metrical order and finality, they are unaware of the difficulties that it

creates for mental processing. In fact, it may even be true that this association of rhyme with the end of a line of poetry creates confusion when it occurs in the middle of a sentence, as it did in the stimuli for this study. However, this explanation would most likely only account for late text integration effects, not the early measures of lexical access.

One possible explanation for the strong differences in alliteration and rhyme has not yet been discussed, but deserves attention. It is possible that rhyme exerted a stronger phonological cue not because of any special inherent characteristics, but simply because it contained a greater number of overlapping phonemes. I am unaware of any reading literature that has tied the strength of the phonological repetition effect to the number of phonemes/letters; however, auditory priming studies have occasionally shown that the number of overlapping phonemes is relevant to the amount of facilitation or inhibition shown (for an overview, see Dufour, 2008). On the other hand, Frisson et al. (2014) used stimuli that only differed by a single phoneme (e.g. *strait/strain*, *wings/kings*), and still found a slight difference between word-initial and word-final overlap. To completely eliminate this possibility, however, further research would need to be conducted, using stimuli where the number of overlapping phonemes was matched between rhyme and alliteration (in this case more properly termed word-initial overlap).

Orthographic overlap

The findings relating to orthographic overlap were intriguing, and raise questions that require additional research to address. It was expected that if the phonological effect was actually an orthographic one, P+O+ and P+O- would have the same results, but that

if there were a phonological effect, that P+O+ would create a greater processing cost. Instead, the greatest costs occurred in the P+O- condition. This paper suggested that this may have been due to a lack of consistent mapping between the phonology and orthography. In order to test this, one profitable next step would be to conduct a similar experiment with a P-O+ condition (orthographic overlap without phonological overlap, such as *bear/gear*). If the increased processing times were due to inconsistent mapping, then the P-O+ condition should show results similar to those for P+O-. This setup would also allow for a direct study of any orthographic effects by separating them entirely from phonology.

Another unexpected result in orthographic overlap was that the phonological overlap effect emerged earlier for alliteration than for rhyme. This was the only measure in which alliteration appeared to have an advantage over rhyme, in spite of the "special status" of the initial letter discussed earlier. One way to investigate this more deeply would be to create a third condition: "partial orthographic overlap", where words 1 and 2 are P+O+ and word 3 is P+O- (e.g. *qu<u>ite</u> wh<u>ite</u> s<u>ight</u>*). By looking at how alliteration and rhyme behave with respect to this pattern, it would be possible to answer some of the questions about the relationship between phonology and orthography. For example, based on the current data, we might expect to see inflation on word 3 reading times in rhyme relative to P+O+, but it is more difficult to predict how partial-P+O+ would relate to P+O-. Would partial-P+O+ show shorter reading times, due to the fewer number of words exhibiting a phonological/orthographic conflict, or longer times, because the first two words build an expectation of orthographic overlap that is then disrupted? Furthermore, the current data show increased processing times for P+O- at word 2 for

alliteration and word 3 for rhyme, and phonological effects at word 2 and 3 for rhyme and word 3 for alliteration. How would this time-course affect the results of a partial-overlap condition? These questions make partial orthographic overlap an intriguing candidate for future study.

Conclusion

The results from this study, indicating strong differences in the effects of alliteration and rhyme on both lexical access and text integration, reveal a pattern that is new to the literature on phonological repetition in reading. Contrary to expectations, rhyme proved to exert a far stronger phonological cue than alliteration on the reading process. The reasons for this are unclear and will require further research, with possible explanations ranging from a low-level effect of the quantity of overlap, to readers' real-world attitudes toward rhyme. Findings related to orthographic overlap also showed interesting patterns that not only confirmed the effects of phonological overlap, but suggested that the presence of one predisposes the mind to expect the other; a result which, if confirmed, could have extremely interesting implications for reading models. In conclusion, although the differential results in alliteration and rhyme indicate that TTE studies are justified in not including rhyme, investigations into the nature of this contrast could be even more informative.

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APPENDICES

APPENDIX I:
STIMULI

Alliteration

Phrase Type	Phon. Overlap	Target Phrase	Sentence	Word 1		Word 2		Word 3	
				Freq	Length	Freq	Length	Freq	Length
Allit	P+O+	Expmt	The sailors washed the **damp dirty dock** after the voyage.	3	4	66	5	10	4
		Ctrl	**oily river dock**	1	4	55	5		
Allit	P+O+	Expmt	Mona opened the **jammed juice jars** with effort.	14	6	27	5	8	4
		Ctrl	**sealed bread jars**	15	5	28	5		
Allit	P+O+	Expmt	The doctor cured the **aged aide's aches** with pills.	79	4	2	5	2	5
		Ctrl	**rich heir's aches**	80	4	5	5		
Allit	P+O+	Expmt	The porter opened the **grand gold gates** for the travelers.	63	5	79	4	32	5
		Ctrl	**round west gates**	67	5	61	4		
Allit	P+O+	Expmt	Cody dodged the **horse's huge hooves at** the rodeo.	93	6	48	4	2	6
		Ctrl	**bull's wild hooves**	28	5	57	4		
Allit	P+O+	Expmt	We sailed **your yellow yacht** in the harbor.	6445	4	34	6	8	5
		Ctrl	**this silver yacht**	7979	4	32	6		
Allit	P+O+	Expmt	The travelers ate **coarse corn cakes** on the journey.	1	6	14	4	45	5
		Ctrl	**scarce bean cakes**	2	6	7	4		
Allit	P+O+	Expmt	The clerk sold the **large lava lamp** to the customer.	41	4	3	4	13	4
		Ctrl	**cheap rosy lamp**	36	5	3	4		
Allit	P+O+	Expmt	The child refused **more milk mush** at breakfast.	1299	4	43	4	3	4
		Ctrl	**some warm mush**	1727	4	52	4		
Allit	P+O+	Expmt	The drinks revived the **numb nerved nurse** after work.	5	4	23	6	45	5
		Ctrl	**grim scared nurse**	5	4	34	6		
Allit	P+O+	Expmt	The candidate gave a **poorly planned poll** to the voters.	3	6	146	6	2	4
		Ctrl	**neatly counted poll**	1	6	90	7		
Allit	P+O+	Expmt	The doctor tended the **poor pale prince** with a fever.	129	4	8	4	45	6
		Ctrl	**sick lame prince**	165	4	11	4		
Allit	P+O+	Expmt	Agnes placed the **raw rump roast** on the stove.	10	3	1	4	10	5
		Ctrl	**odd loin roast**	24	3	0	4		
Allit	P+O+	Expmt	The farmer sold his **short sheared sheep** in March.	86	5	0	7	13	5
		Ctrl	**eight trimmed sheep**	98	5	4	7		
Allit	P+O+	Expmt	The lady wore a **vain velvet veil** to the opera.	7	4	6	6	3	4
		Ctrl	**pale cotton veil**	8	4	14	6		
Allit	P+O+	Expmt	The man asked his **wise wary wife** for advice.	28	4	1	4	349	4
		Ctrl	**tall prim wife**	32	4	0	4		
Allit	P+O-	Expmt	The servants arranged the **elder heir's airing** each day.	7	5	5	5	1	6
		Ctrl	**eager chap's airing**	7	5	6	5		
Allit	P+O-	Expmt	The landlord pressured the **irked urban earl** for payment.	0	5	5	5	20	4
		Ctrl	**duped needy earl**	1	5	3	5		
Allit	P+O-	Expmt	The attack prompted an **early irked urge** to fight.	108	5	0	5	7	4
		Ctrl	**awful rabid urge**	63	5	1	5		
Allit	P+O-	Expmt	The director chased the **quick choir kids** around the stage.	109	5	5	5	339	4
		Ctrl	**smart noisy kids**	96	5	5	5		
Allit	P+O-	Expmt	The ship had a **quaint carved keel** of wood.	2	6	3	6	1	4
		Ctrl	**sloped ribbed keel**	3	6	6	6		
Allit	P+O-	Expmt	Jake replaced the **quaint chrome keys** to the cupboard.	2	6	1	6	87	4
		Ctrl	**flawed jagged keys**	3	6	2	6		
Allit	P+O-	Expmt	The noble received the **coy queen's kiss** at the ball.	2	3	55	6	121	4
		Ctrl	**sly madam's kiss**	3	3	44	6		
Allit	P+O-	Expmt	The host served the **cooked killed quail** at the dinner.	46	6	453	6	1	5
		Ctrl	**warmed choice quail**	52	6	98	6		
Allit	P+O-	Expmt	The seer foretold the **king's cursed quest** years ago.	129	5	18	6	6	5
		Ctrl	**lord's fourth quest**	138	5	26	6		
Allit	P+O-	Expmt	The vet cured the **knobby necked gnus** at the zoo.	0	6	60	6	1	4
		Ctrl	**wobbly legged gnus**	1	6	57	6		
Allit	P+O-	Expmt	The decorater painted the **ninth gnome's knee** with a brush.	7	5	1	6	15	4
		Ctrl	**goofy troll's knee**	5	5	3	6		
Allit	P+O-	Expmt	The healer bound the **knave's gnawed nail** with a bandage.	0	6	0	6	19	4
		Ctrl	**crone's grazed nail**	0	6	1	6		
Allit	P+O-	Expmt	The sculptor formed the **gnome's knobby nose** from putty.	1	6	0	6	7	4
		Ctrl	**troll's blobby nose**	3	6	0	6		
Allit	P+O-	Expmt	Walter smoked a **safe pseudo cigar** at the club.	143	4	0	6	13	5
		Ctrl	**free jaunty cigar**	178	4	0	6		
Allit	P+O-	Expmt	Lynne bought a **six cent psalm** for chapel.	200	3	9	4	1	5
		Ctrl	**ten dime psalm**	145	3	12	4		
Allit	P+O-	Expmt	The mayor watched the **psyched city scene** before the event.	7	7	169	4	75	5
		Ctrl	**crammed town scene**	2	7	248	4		

Rhyme

Phrase Type	Phon. Overlap	Target Phrase	Sentence	Word 1		Word 2		Word 3	
				Freq	Length	Freq	Length	Freq	Length
Rhyme	P+O+	Expmt	The tour group examined the **last vast mast** on the ship.	723	4	6	4	2	4
		Ctrl	**only bare mast**	1084	4	8	4		
Rhyme	P+O+	Expmt	The farmer sold his **nine fine swine** at the market.	67	4	598	4	4	5
		Ctrl	**near dead swine**	42	5	266	4		
Rhyme	P+O+	Expmt	The children exploited the **blind kind mind** of their aunt.	46	5	591	4	485	4
		Ctrl	**loose easy mind**	83	4	449	4		
Rhyme	P+O+	Expmt	Jan found a **nice rice price** at the stall.	650	4	15	4	53	5
		Ctrl	**high corn price**	195	4	14	4		
Rhyme	P+O+	Expmt	The bard chose the **wrong long song** for the festival.	523	5	675	4	94	4
		Ctrl	**other hard song**	735	5	308	4		
Rhyme	P+O+	Expmt	The hostess chose a **gray clay tray** for breakfast.	21	4	12	4	8	4
		Ctrl	**rare slim tray**	21	4	12	4		
Rhyme	P+O+	Expmt	The children played the **same tame game** every year.	417	4	3	4	234	4
		Ctrl	**most daft game**	351	4	1	4		
Rhyme	P+O+	Expmt	We heard a **bleak weak squeak** from the mousetrap.	1	5	32	4	2	6
		Ctrl	**frail rat's squeak**	2	5	33	4		
Rhyme	P+O+	Expmt	The protester threw a **thick slick brick** at the window.	14	5	7	5	10	5
		Ctrl	**gross messy brick**	15	5	7	5		
Rhyme	P+O+	Expmt	The magician performed a **quick slick trick** at the circus.	109	5	7	5	47	5
		Ctrl	**quite swift trick**	203	5	4	5		
Rhyme	P+O+	Expmt	The cafeteria offered a **real meal deal** at lunchtime.	443	4	29	4	261	4
		Ctrl	**free milk deal**	178	4	43	4		
Rhyme	P+O+	Expmt	The students feared the **mean lean dean** of the college.	1244	4	10	4	39	4
		Ctrl	**very bald dean**	1241	4	10	4		
Rhyme	P+O+	Expmt	Bob cut his **thin chin skin** on a rock.	20	4	13	4	44	4
		Ctrl	**torn heel skin**	11	4	7	4		
Rhyme	P+O+	Expmt	Everyone hated the **low slow flow** of the faucet.	59	3	76	4	14	4
		Ctrl	**sad thin flow**	63	3	20	4		
Rhyme	P+O+	Expmt	The exterminator filled the **sole mole hole** in the garden.	5	4	8	4	58	4
		Ctrl	**lone worm hole**	5	4	10	4		
Rhyme	P+O+	Expmt	Zane wiped lots of **old cold mold** out of the fridge.	609	3	130	4	4	4
		Ctrl	**bad food mold**	545	3	154	4		
Rhyme	P+O-	Expmt	The tanner displayed the **tied dyed hide** on the wall.	44	4	1	4	70	4
		Ctrl	**fake board hide**	36	4	2	4		
Rhyme	P+O-	Expmt	Donna mopped the **tile style aisle** of the store.	2	4	30	5	7	5
		Ctrl	**tidy bread aisle**	3	4	28	5		
Rhyme	P+O-	Expmt	The prisoner passed the **hard scarred guard** near the wall.	308	4	8	7	58	5
		Ctrl	**hurt bruised guard**	246	4	3	7		
Rhyme	P+O-	Expmt	The detective exposed a **broad flawed fraud** in the company.	15	5	3	6	10	5
		Ctrl	**sixth doomed fraud**	11	5	6	6		
Rhyme	P+O-	Expmt	Lina gave her teddy bear a **small doll shawl** for the tea party.	125	5	25	4	1	5
		Ctrl	**clean pink shawl**	121	5	28	4		
Rhyme	P+O-	Expmt	The subjects liked the **plain sane reign** of their king.	22	5	6	4	3	5
		Ctrl	**brief dull reign**	14	5	12	4		
Rhyme	P+O-	Expmt	The barber wore a **weird sheared beard** during the summer.	101	5	0	7	13	5
		Ctrl	**green flecked beard**	72	5	0	7		
Rhyme	P+O-	Expmt	Jenna smoothed the **fleece piece crease** with an iron.	1	6	124	5	1	6
		Ctrl	**frayed dress crease**	1	6	87	5		
Rhyme	P+O-	Expmt	Jordan ate the **whole roll bowl** at the restaurant.	385	5	63	4	21	4
		Ctrl	**first meat bowl**	841	5	44	4		
Rhyme	P+O-	Expmt	Mary completed her **whole droll goal** by Tuesday.	385	5	0	5	17	4
		Ctrl	**least swift goal**	208	5	4	5		
Rhyme	P+O-	Expmt	The settlers ate from their **stored gourd hoard** during the winter.	82	6	0	5	0	5
		Ctrl	**secret grain hoard**	110	6	5	5		
Rhyme	P+O-	Expmt	The storm frightened **those crows' foes** away from them.	753	5	3	5	2	4
		Ctrl	**these hares' foes**	904	5	4	5		
Rhyme	P+O-	Expmt	Joan ruined her **new blue shoe** in a puddle.	724	3	102	4	30	4
		Ctrl	**own cute shoe**	459	3	88	4		
Rhyme	P+O-	Expmt	The clans fought a **shrewd rude feud** for decades.	1	6	22	4	1	4
		Ctrl	**crazed gene feud**	1	6	15	4		
Rhyme	P+O-	Expmt	The principal announced a **cruel school rule** against talking.	18	5	333	6	48	4
		Ctrl	**basic course rule**	16	5	487	6		
Rhyme	P+O-	Expmt	Everyone was frightened by the **first worst burst** of the bomb.	841	5	56	5	9	5
		Ctrl	**great large burst**	821	5	41	5		

Fillers and Questions

Filler Sentence	Question	Answer
Tim fixed himself a dish of chocolate ice cream.		
Lightning struck the oak tree on the hill.		
The primary diet of the panda is bamboo.		
The traffic lights on that road went out yesterday.		
Jane rode her bicycle for a mile every day.	Does Jane bike regularly?	YES
Marge hung her linen curtains in the dining room.	Does Marge have satin curtains?	NO
The weather satellite orbited Earth twelve times a day.		
Jacob's professor gave the class three projects in a row.		
My sister likes to draw abstract designs as a hobby.		
A group of dolphins followed the cruise ship.		
The scientists measured the depth of the Arctic ice.	Did scientists measure the depth of the water?	NO
Basket weaving is a popular art form in many cultures.		
Ethan set the teapot on the stove to brew.	Is Ethan making coffee?	NO
Pam found several arrowheads under the bridge.		
Pluto's status as a planet has been debated recently.		
The yearbook editor removed several photos from the page.		
The flute and drum were invented in prehistoric times.	Is the flute an ancient instrument?	YES
Tess folded the sheets for the bedroom.		
Rita checked an armful of books out of the library.	Did Rita borrow multiple books?	YES
Paula overslept when her alarm clock ran out of power.	Did Paula wake up on time?	NO
Olives were an important dish in ancient Greek culture.		
Corey played hockey with his friends at the rink.		
Bees can communicate the location of nectar by dancing.	Can bees dance?	YES
Joey slipped on a banana peel and fell.		
Lois received a mysterious package in the mail.		
Exercise and a balanced diet contribute to a healthy life.		
The thief snatched the woman's purse and fled.	Did the thief take a man's wallet?	NO
Anne's grandparents grew peaches when they were children.	Did Anne's grandparents grow apples?	NO
Luis sprained his arm while playing football.		
Heather bought colored paints for a still life.		
My shelves do not have room for another book.		
Eliza wants to be an actress in Hollywood.	Does Eliza want to be a dancer?	NO
John's umbrella flipped inside out in the wind.		
The child ran away when the dog barked.		
Erica performed her gymnastics routine for the judges.		
The sleeping bear woke up from his winter nap.	Did the bear sleep during the winter?	YES
The official dance of the Carolinas is the shag.		
Australia is home to many unique species.		
Will grabbed a tissue just before he sneezed.		
Alex enjoyed the salsa served at the party.	Was there salsa at the event?	YES
Richard inherited an expensive watch from his father.	Did Richard receive a clock?	NO
Conch shells can be blown to make a sound like a trumpet.		
Shaking hands is a common greeting in American society.		
Barb decorated her couch with several pillows.		
Susan chose to wear a tank top to the barbecue.	Did Susan go to a barbecue?	YES
Brian got soaked when he fell off the pier.		
The mosaic was produced from thousands of glass fragments.	Was the mosaic made of glass?	YES
Kathy saved a special flower from her wedding.	Is Kathy married?	YES
The cave paintings depicted a mammoth hunt.		
Pacific societies made canoes by hollowing out logs.		
Zach delayed writing his essay until it was too late.	Did Zach finish his essay on time?	NO
Jeff and his friends played checkers to relax.		
The pirate ship sank off the coast of Bermuda.		
Nick found a mysterious drawer at the back of his desk.		

APPENDIX II:
WORD FREQUENCIES AND LENGTHS

Word Frequency

Word 1

	Alliteration		Rhyme	
Phon. Overlap	Experimental	Control	Experimental	Control
P+O+	μ: 519* σ: 1561	μ: 642* σ: 1938	μ: 309 σ: 353	μ: 298 σ: 385
P+O-	μ: 48 σ: 64	μ: 44 σ: 60	μ: 238 σ: 287	μ: 242 σ: 318

*The unusually large values for alliteration P+O+ are mainly due to one item pair, *this* vs. *your*. If this word is left out of the calculation, the experimental and control means become 124 and 153 respectively, with standard deviations of 316 and 423.

Word 2

	Alliteration		Rhyme	
Phon. Overlap	Experimental	Control	Experimental	Control
P+O+	μ: 31 σ: 38	μ: 28 σ: 27	μ: 138 σ: 235	μ: 84 σ: 133
P+O-	μ: 49 σ: 112	μ: 32 σ: 62	μ: 49 σ: 82	μ: 53 σ: 115

Word 3

	Alliteration	Rhyme
Phon. Overlap	Expt/Ctrl	Expt/Ctrl
P+O+	μ: 37 σ: 82	μ: 85 σ: 128
P+O-	μ: 45 σ: 84	μ: 18 σ: 21

Word Length

Word 1

	Alliteration		Rhyme	
Phon. Overlap	Experimental	Control	Experimental	Control
P+O+	μ: 4.6 σ: 0.9	μ: 4.5 σ: 0.8	μ: 4.2 σ: 0.63	μ: 4.2 σ: 0.6
P+O-	μ: 5.2 σ: 1.1	μ: 5.2 σ: 1.1	μ: 4.9 σ: 0.8	μ: 4.9 σ: 0.8

Word 2

	Alliteration		Rhyme	
Phon. Overlap	Experimental	Control	Experimental	Control
P+O+	μ: 4.9 σ: 1.1	μ: 4.9 σ: 1.1	μ: 4.1 σ: 0.3	μ: 4.1 σ: 0.3
P+O-	μ: 5.5 σ: 0.7	μ: 5.5 σ: 0.7	μ: 5.0 σ: 1.0	μ: 5.0 σ: 1.0

Word 3

	Alliteration	Rhyme
Phon. Overlap	Experimental	Experimental
P+O+	μ: 4.7 σ: 0.7	μ: 4.4 σ: 0.6
P+O-	μ: 4.4 σ: 0.6	μ: 4.8 σ: 0.6