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Letter Detection and Reading Aloud

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LETTER DETECTION AND READING ALOUD

Letter Detection and Reading Aloud

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Abstract

Subjects were asked either to circle all the e’s in a passage or to read a passage aloud. There were four different passages, which included either the word the in prose, one in prose, the in scrambled text, or one in scrambled text. Some subjects silently read a passage viewed on paper and performed letter detection by circling all the e’s they noticed (letter detection). Other subjects read aloud a passage viewed on a computer screen (reading aloud). In the reading aloud task, the words the and one were repeated in some of the sentences of the passage. The number of missed e’s or missed repeated words was recorded. We expected letter detection and reading aloud to be explained by different processes within the Guidance Organization (GO) Model of reading (Greenberg, Healy, Koriat, & Kreiner, 2004). Specifically, we expected letter detection to be explained more by unitization processes (Healy, 1994) and predicted slightly more misses on the frequent word the than the less frequent word one (both words are relatively common) and no difference between prose and scrambled text. Alternately, we expected reading aloud to be explained more by structural processes (Koriat & Greenberg, 1994) and predicted more errors on the function word the than the content word one and more errors on prose than scrambled text.

Our results are consistent with our predictions and an overall analysis of task, word, and text type indicates that there are significantly different patterns of misses for letter detection and reading aloud.
Previous Study (Healy, A.F. 1983)

This study is based on a former study conducted by Dr. Alice Healy in 1983. We replicated that study because Dr. Healy was unable to find some materials for the experiment, the reading aloud data were not recorded, and the letter detection and reading aloud tasks were done separately. However, the computer program code, data tabulation, statistical analyses, and letter detection protocols were available. To address the concerns of the past experiment, we recorded reading aloud data using QuickTime and used a fixed rotation procedure for assigning subjects to the reading aloud and letter detection conditions. Most important, this study is an attempt to put the results in a modern theoretical context assuming replication (which occurred).
Acknowledgements

I would like to thank Dr. Alice Healy, my thesis advisor, for offering ideas for my research project, helping to design the experiments, meeting with me weekly, helping with data analysis and aiding with the writing process of my thesis. This project would not have been possible without Dr. Healy’s guidance, advice and encouragement.

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Reading Aloud

The experiment reported here uses two tasks. One of them is a new task illustrated below:

Did you read the above image as “Paris in the spring?” If so, look again and notice that the image actually says “Paris in the the spring.” There are two instances of the word the. This demonstration is found in numerous locations on the web and illustrates what we have termed the “missing word effect.” Although it is extensive on the Internet and laypeople admit to not being able to detect the additional the, this phenomenon has been largely ignored in experimental
psychology research. We will address this phenomenon and compare it to a related phenomenon in the experiment reported here.

**Letter Detection and the Missing Letter Effect (MLE)**

The second, related phenomenon involves the task of letter detection. The letter detection task and the missing letter effect (MLE) was introduced in an experiment done by D. W. J. Corcoran (1966) and has since been and replicated numerous times. Corcoran’s experiment consisted of subjects reading passages and cancelling every e they noticed in the passage. The results demonstrated that subjects made more errors identifying the e in the word *the* than in words where the e was silent and in words where the e was pronounced. More broadly, the MLE is the phenomenon in which subjects make more letter detection errors on common function words than uncommon content words (e.g., Healy, 1976; Healy & Cunningham, 2014).

The missing letter effect has been explained by several hypotheses. The most prominent are the unitization hypothesis (Healy, 1976, 1994) and the structural hypothesis (Koriat & Greenberg, 1991, 1994). These two hypotheses have been integrated into the Guidance Organization (GO) Model (Greenberg, Healy, Koriat, & Kreiner, 2004). Other important hypotheses that have also been proposed to explain the missing letter effect include the processing time hypothesis (Moravcsik & Healy, 1995, 1998) and the attentional disengagement
model (Roy-Charland, Saint-Aubin, Klein, & Lawrence, 2007). These alternative are considered in the General Discussion.

**Unitization Hypothesis (Healy, 1976, 1994)**

To explain the missing letter effect in letter detection, Healy (1976, 1994) proposed the unitization hypothesis. Specifically, this hypothesis posits that subjects make a disproportionately larger number of errors on common words like *the* than on less frequent words (e.g., Drewnoswki & Healy, 1977).

The rationale behind the unitization hypothesis is that readers identify units of various sizes before and during lexical access. For example, readers identify units like syllables, words, or phrases as well as individual letter units when reading. The size of the units used depends on the familiarity of the words because common words can be identified on the basis of their familiar visual configuration. Conversely, rare words are read in smaller units like individual letters. Furthermore, it is assumed that once readers identify a unit they move on to the next portion of text even if the individual subcomponent pieces of the unit (e.g., letters) have not been identified. This process results in a larger number of letter detection errors on more familiar words than on rare words.
Structural Hypothesis (Koriat & Greenberg, 1991, 1994)

The structural hypothesis proposed by Koriat and Greenberg (1994) asserts that processing of structure comes before meaning and that initial structural processing is key to assigning meaning to the text. More simply, readers view text and assign a structural frame to the text to help with processing of the sentences in the text. Once identified, these structural words recede into the background and readers then focus on the content words and semantic processing, assigning meaning to the text. This process explains why letter detection errors are more common on function words than content words.

The structural frame of text arises from the identification of function and content words. Functions words are defined as those that lack content but give structure to text including prepositions, articles, pronouns and conjunctions (Aaronson & Ferres, 1983). Function words are the precursor to understanding the meaning of the text and act as superficial cues that signal the construction of a new phrase (Kimball, 1973) and create a structural frame. They guide the reader through the text and are in predictable locations that allow the reader to build such a structural frame. Once this structure is established, the “slots” in the sentence are filled by appropriate lexical units. From this structural frame, function words recede into the background and the reader can move onto the content words of the text and understand the overall meaning (Koriat & Greenberg, 1994).
Studies on function words have provided support for the structural hypothesis. For example, Inhoff, Topolski, Vitu, and O’Regan (1993) found that the syntactic role is the main contributor to processing because subjects skipped more function words than nonfunction words of the same length and structure. Moreover, Rayner, Carlson, and Frazier (1983) showed that text processing relies initially on structural frames and precedes the semantic processing of text in an experiment that analyzed time spent on each character in obscurely written text.

In terms of processing, Koriat and Greenberg (1994) posit that reading requires attention to both the structure and meaning of the text. Unlike the unitization hypothesis, processing in the structural hypothesis occurs after lexical access. However, processing of meaning is secondary to the processing of the structure and is achieved by attending to content words. In essence, the reader creates a structural framework, which then helps with the interpretation of the individual units, and this framework then recedes into the background to allow content words to be attended so that meaning can be drawn from the text.

Guidance Organization (GO) Model (Greenberg et al., 2004)

To explain the missing-letter effect (MLE) Healy (1994) focused on the identification of reading units–proposing the unitization hypothesis–whereas Koriat and Greenberg (1994) focused on the identification of sentence structure–proposing the structural hypothesis
By unitization (Healy, 1976), letter detection errors occur before and during lexical access and relate to perceptual processing. Highly familiar words are read in units larger than the individual letters and once processed, the reader moves on to the next portion of text, resulting in many letter detection errors on familiar words. According to Koriat and Greenberg’s (1991) structural hypothesis, letter detection errors occur after lexical access is finished. After function words help to define the structural component of the text, they recede into the background and content words come to the forefront allowing for interpretation of the text. This process results in more errors on function words and fewer on content words that contribute to the meaning of the text.

Both the unitization hypothesis and structural hypothesis are valuable contributions to understanding letter detection. Thus, Greenberg et al. (2004) proposed a model that suggests an integration of both views. This guidance-organization (GO) model proposes that the MLE comes “from a hierarchical nature of text processing” (Greenberg et al., 2004, p. 428). The processes that underlie unitization—being able to identify words based on perceptual familiarity—guides readers to function words that allow the reader to create a structural frame for the text, enables the readers to identify content words, and thus, “enables on-line semantic analysis and integration” (Greenberg et al., 2004, p. 428). They further propose that the structure of text guides eye movements to “important” but rare words (Greenberg et al., 2004).
The GO Model makes five assumptions about how letter detection errors occur: (1) unitization, (2) parafoveal processing, (3) contextual constraints, (4) structural precedence, and (5) guidance. The unitization and parafoveal assumptions (1 and 2) state that familiar units are processed in the parafovea, which cannot process individual letters but aids in identifying overall structures. The structural precedence and guidance assumptions (4 and 5) state that the structure of text leads the readers to focus on meaningful parts of text while skipping those that contribute only to the text structure. The contextual constraint assumption (3) states that readers are able to identify function words because they are predictable from the surrounding text.

An essential component of the GO Model relies on the fact that both hypotheses (unitization and structural) contribute to the missing-letter effect (MLE), but the distinction lies in the stage at which function words are processed. Unitization asserts that the processing leading to letter detection errors occurs at the prelexical and lexical stages (i.e., during the course of word identification) because readers recognize words on the basis of perceptual familiarity. The structural hypothesis asserts instead that the processing leading to letter detection errors occurs at postlexical stages (i.e., after words have been identified).

As mentioned previously in the structural hypothesis, readers use cues as forerunners to establish structural frames which are then used to establish meaning in the text. Central to the structural hypothesis is that words are interpreted as function words after a superficial initial
viewing of the text. However, what the structural hypothesis is unable to explain is how these function words are analyzed so quickly and categorized as function words. The unitization hypothesis comes in at this point to explain that the perceptual properties of these forerunners facilitate identification, particularly in the parafoveal region (Hadley & Healy 1991). Once identified, these forerunners allow the reader to make a superficial analysis of the newly added syntactic units which helps determine the overall structure of a given sentence.

**Current Study**

In the present experiment, we compared two tasks–letter detection and reading aloud–in several conditions and recorded the number of errors subjects made on words or letters. In the letter detection task, we asked subjects to encircle all of the *e*’s they saw in a passage and compared the number of missed *e*’s in the different conditions. In the reading aloud task, we recorded the number of repeated words subjects missed in each of the conditions. We then determined if there was a difference in the error rate when the passages had a different text type (prose vs. scrambled) or a different test word (*the* vs. *one*).

We chose to compare prose text and scrambled text because scrambled text reduces the cohesiveness of sentences and the predictability of the words in the sentences. Furthermore, we chose to compare the words *one* and *the* for two reasons: First, *the* is the most common word in
the English language whereas the word *one* is the 32nd most common word in the English language. Second, *the* is a function word, whereas *one* is a content word, even though the two words are used in the same text locations.

**Hypotheses**

We analyzed both tasks–letter detection and reading aloud–in reference to the GO Model. Although the GO model was proposed to account for the task of letter detection, we propose that it can also account for the task of word reading. However, we postulate that the two component processes in the GO model–unitization and structural–are weighted differently in the two tasks. Specifically, we believe that the unitization processes are weighted more heavily in the task of letter detection whereas structural processes are weighted more heavily in the task of reading aloud.

In terms of letter detection, we hypothesize that unitization processes will be more prominent than structural processes and will lead to more errors on common words than rare words. Thus, we predict somewhat more misses on the frequent word *the* than the less frequent word *one* (both words are relatively common). Furthermore, we hypothesize that the number of missed *e’s* will not depend on text type (prose vs. scrambled) because as long as units are intact (in this case, words), then reducing sentence cohesion should not affect the number of missed *e’s.*
In terms of reading aloud, we hypothesize that structural processes will be more prominent than unitization processes leading to more errors on function words than on content words. Because the word *the* is a function word and the word *one* is a content word, we expect more errors on the word *the*. Furthermore, we hypothesize that the number of errors made on reading aloud will be influenced by text type (scrambled vs. prose) because the structural role of a word (whether it is a function word or a content word) depends on the context of the sentence. Thus, we expect more errors in prose than in scrambled text.
Method

Subjects

The subjects in this experiment were one hundred and four undergraduate students enrolled in general psychology (PSYC 1001) at the University of Colorado at Boulder. Subjects received research credit that affected their overall grade in the course in exchange for participating in the experiment. Fifty-three of the subjects were men, and fifty-one of the subjects were women. An additional nine subjects were tested, but their data were excluded from analyses because they were not native English speakers. Of the one hundred and four subjects, four had participated in a letter detection experiment in the past.

Design

A 2x2x2x2 mixed factorial design was used. There were three between-subjects variables including task (computer, letter), word (the, one), and text type (prose, scrambled). In addition, there was one within-subjects variable, which was word type (critical, noncritical). The dependent variable was proportion of detection errors.

Materials and Procedure

Letter detection
Subjects assigned to the letter detection task were given a packet containing a consent form, questionnaire (asking if they had previously participated in a letter detection experiment, their first language, and their gender), instructions (see Appendix A), and the letter detection passage. There were four conditions for the letter detection task: prose the, prose one, scrambled the, and scrambled one (see Appendices C, D, E, F, respectively). There was a fixed rotation between letter detection and reading aloud and among the four conditions as exemplified in Table 1.

These passages are composed of 40 sentences, each containing one instance of either the word the or the word one. We considered 20 of the sentences to have critical thes or ones and 20 to have noncritical thes or ones. The passages were the same for both the and one conditions except for the word used (the, one).

In addition, the passages differed in terms of whether they were prose or scrambled. The prose passages were written in a coherent manner, and the scrambled passages were meant to reduce the coherence of the passages. The words one and the were in the same position in the prose and scrambled versions of the passages; the only difference concerned the positions of the other words.

Subjects were placed alone in a room and were told to read and sign the consent form, fill out the questionnaire, and then alert the experimenter when ready to begin. The experimenter
asked if the subjects had any questions, answered any questions, and then the subjects began the letter detection task.

Subjects were given as much time as they needed to complete the task. The experimenter did not provide any instructions other than what was given in the packet.

Subjects were given a letter detection task and were instructed to circle all of the es they saw in the passage. They were told to move at their normal reading speed and not to go back if they realized they missed an e (see Appendix A).

Once finished, the experimenter retrieved the packets, gave the subjects a debriefing form and a course credit slip, and asked if the subjects had any questions. In addition, the experimenter asked the subjects not to disclose any information about the study to their classmates in order to ensure that they would not bias future subjects.

Reading aloud

Subjects assigned to the reading aloud task were given a packet containing a consent form and the same questionnaire as used in the letter detection task (asking if they had ever participated in a letter detection experiment, their first language, and their gender). After completing the packet, subjects were taken into a lab room containing an Apple iMac desktop computer that had each of the four conditions coded in the program PsychoPy. Similarly to the
letter detection task (see above), the four conditions were prose the, prose one, scrambled the, and scrambled one (see Appendices H, I, J, K, respectively).

These passages were the same as those used in the letter detection task except that each line had only two words on it. In addition, we repeated the critical words (same as letter detection, the or one, depending on the condition. There were a total of 20 critical repeated words (one per sentence) in a total of 40 sentences. We positioned the critical repeated words so that they were never on the same line or in the same position (first word or second word); instead each repeated word occurred in the second position of one line and then in the first position of the following line. This constraint ensured that the subjects would not see repeated words on the same line, which might suggest to the subjects the purpose of the study.

Subjects were told to read instructions on the computer (see Appendix G), ask any questions they had and listen to the experimenter’s answers, then press the “space” bar to continue. Pressing “space” took a subject from one sentence to the next. The experimenter did not provide any other instructions than what was shown on the computer. In addition, the subjects were recorded using QuickTime to ensure that all responses were accurately collected and scored.

The experimenter monitored the experiment and recorded – on a separate sheet of paper – how many of the critical and noncritical words subjects missed, corrected, or read correctly.
Once the subjects completed reading the sentences, the computer program notified them that they were finished with the experiment. The subjects were then given a debriefing form, a voucher ensuring credit, and were asked if they had any questions. In addition, the experimenter asked the subjects not to disclose any information about the study to their classmates in order to ensure that they would not bias future subjects.

**Tabulation**

**Letter detection**

To score the letter detection portion, we counted the total number of e’s missed in the passage. In addition, we further classified the missed e’s by whether they were critical or not critical. Critical letters are e's in the words the or one that were repeated in the reading aloud task and are highlighted in Appendices C, D, E, F. We then counted the e’s missed in those critical words. There are 20 total critical e’s. We then counted the total number of missed noncritical e's – e's in the word one or the that are not in the critical sentences.

**Reading aloud**

Subjects in the reading aloud condition were monitored by an experimenter. The experimenter had a copy of the sentences that the subjects read and marked missed repeated
words, other instances of the and one and accurately read sentences and noted any other errors.

After completion of the task, the experimenter counted the total number of missed repeated (critical) words, missed noncritical words, corrected words, and sentences read correctly. The corrected words were considered to be errors for the purpose of the data analysis. There were 20 total critical words and 20 noncritical words out of 40 sentences.

To ensure that the experimenter did not miss any of the subject’s answers, we implemented the application QuickTime, which recorded the subjects’ vocalizations. We then reviewed these dictations to ensure that the data collected were accurate.
Results

Reading Aloud

To analyze the reading aloud task, we performed a 2 x 2 factorial ANOVA examining the factors of word (the vs. one), text type (prose vs. scrambled) and the interaction between word x text type on the proportion of word misses (i.e., subjects missed reading aloud the second of the two instances of the or one in a sentence). We included only critical test words in the analysis (i.e., only the instances of the or one in the sentences that included repeated words in the reading aloud task). The results for the reading aloud task are shown in Figure 1.

Word (the vs. one) had an overall impact on number of missed critical test words for reading aloud with the mean proportion of misses for the being much higher (.413) than the mean proportion of misses for one (.052), $F(1, 48) = 53.97, MSE = .031, p < .001$, which demonstrates that the very common function word the is missed more than the less common content word one.

Text type (prose vs. scrambled) had an overall impact, with the critical test words in the prose passages being missed more (.354) than target words in scrambled passages (.112), $F(1, 48) = 24.24, MSE = .031, p < .001$. This effect shows that readers made more errors on prose passages in the reading aloud task than on scrambled passages.
The interaction of Word (the vs. one) x Text Type (prose vs. scrambled) was significant, with the effect of text type larger for the than for one, $F(1, 48) = 15.27, MSE = .031, p < .001$.

**Letter Detection**

To analyze letter detection, we performed a 2 x 2 factorial ANOVA examining word (the vs. one), text type (prose vs. scrambled), and the interaction of word x text type on the proportion of target letter misses (i.e., subjects missed circling an $e$ in a sentence). We included only critical test words in the analysis (i.e., only the instances of the or one in the sentences that included repeated words in the reading aloud task). The results of the letter detection task are shown in Figure 2.

The main effect of word (the vs. one) in letter detection was not significant, but readers did show the expected tendency to miss more target letters in the (.392) than in one (.287), $F(1, 48) = 2.13, MSE = .068, p = .151$.

The main effect of text type was not significant, with readers missing very similar numbers of target letters in the prose (.338) and scrambled (.340) conditions, $F(1, 48) < 1$.

The interaction of word x text type was also not significant in letter detection, although the most errors were made in the prose, followed by the scrambled, followed by one scrambled, followed by one prose, $F(1, 48) < 1$. 
Overall

To analyze our overall results, we used a 2 x 2 x 2 factorial ANOVA examining task (reading aloud vs. letter detection), text type (prose vs. scrambled), word (the vs. one), interaction of task x word, interaction of task x text type, interaction of word x text type, and three-way interaction of task x word x text type on the proportion of misses (i.e. subjects missed circling an e in a sentence or missed reading aloud the second of the two instances of the or one in a sentence). We included only critical test words in the analysis (i.e., only the instances of the or one in the sentences that included repeated words in the reading aloud task). The results are shown in Figure 3.

The main effect of task was significant, with more errors made on the letter detection task (.339) than the reading aloud task (.233), $F(1, 96) = 5.94, MSE = .050, p = .017$.

The main effect of word was significant, with many more errors made on the word the (.403) than on the word one (.169), $F(1, 96) = 28.46, MSE = .050, p < .001$.

The main effect of text type was significant, with more errors made on prose (.346) than on scrambled text (.226), $F(1, 96) = 7.53, MSE = .050, p = .007$.

The interaction of task x word was significant, with a larger difference between the and one in reading aloud than in letter detection, $F(1, 96) = 8.53, MSE = .050, p = .004$. 
The interaction of task x text type was significant, with the difference between prose and scrambled only found for reading aloud not for letter detection, \( F(1, 96) = 7.77, \text{MSE} = .050, p = .006. \)

The interaction of word x text type was also significant, with the difference between prose and scrambled only evident for the word *the* not for the word *one*, \( F(1, 96) = 5.73, \text{MSE} = .050, p = .019. \)

The three-way interaction of task x word x text type was significant; the effects of text type and word much larger for reading aloud than for letter detection, \( F(1, 96) = 3.99, \text{MSE} = .050, p = .049. \)
Discussion

Reading Aloud

In the reading aloud task, the main effects of word, text type, and the interaction of Word x Text Type were found to be significant. In other words, subjects made many more mistakes on the word *the* than the word *one*. This finding is consistent with our initial expectation that was based on the structural hypothesis. We noted that in the structural hypothesis, function words are more likely to be skipped than content words. Given that the word *the* is a function word and serves in a structural role, it is logical to expect that the word *the* would be skipped more than the word *one*.

In terms of text type, we predicted that there would be more errors made on prose passages than scrambled passages in conjunction with the structural hypothesis. The structural hypothesis posits that the structure of the sentence determines which words are function or content. Ergo, scrambling the sentences may influence whether a word is perceived as a function or content word. Breaking up these sentences with scrambling reduces the likelihood that function words will be easily recognized as contributing to the sentence structure and results in fewer errors than in a prose passage in which the function and content words are clear to the reader.
The most errors were made in the prose, followed by the scrambled, followed by one prose, followed by one scrambled. This finding demonstrates that there were more errors in the the condition and the prose condition which is consistent with our predictions. The fact that the fewest errors were made on one scrambled is also consistent with our hypothesis.

Letter Detection

In the letter detection task, word was not found to be significant which was consistent with our hypothesis. In consideration of the unitization hypothesis, we proposed that there would be more letter detection errors made on the word the than the word one because the unitization hypothesis posits that letters in more common words will be detected less often than letters in less common words simply because of the common words’ perceptual familiarity. However, we also expected that this difference might not be significant given that even though the word the is the most common word in the English language the word one is the 32nd most common, which led us to conjecture that there would not be a large difference because both words are extremely frequent in the English language.

In terms of text type, we predicted that there would be no difference between errors in prose and scrambled text. We made this prediction based upon the conjecture, consistent with the unitization hypothesis, that readers fail to detect letters because of the overall perceptual
familiarity of a word, which enables it to be identified without necessarily identifying all of its component letters. Thus, unless we rearrange or disrupt the configuration of a word, we should not see a difference between scrambled text and prose. The perceptual units (words) were not disrupted, so readers have the same perceptual familiarity and will continue to fail to detect letters in common words unless an alteration is made to the units themselves.

The most errors in letter detection were made on the prose, followed by the scrambled, followed by one scrambled, followed by one prose. This ordering demonstrates that our predictions regarding the word one were consistent with our findings. Furthermore, our predictions regarding text type were also correct; about the same number of errors were made on prose and scrambled forms which is a significantly different pattern than that found in the reading aloud task.

Overall

Overall, there were significant main effects for task (reading aloud vs. letter detection), which indicates that the two tasks had a significantly different number of errors. We expected this difference because we predicted a different pattern for the two tasks that could be explained by two different dominant processes (unitization and structural). In addition, there was a significant main effect for word. Overall, there were more errors made on the word the than one
in both of the tasks. This is consistent with our predictions because the word *the* is a common function word, whereas the word *one* is a less common content word. Furthermore, there was a significant main effect for text type (scrambled vs. prose). In reading aloud, there were more errors on prose passages, which is consistent with our hypothesis. However, within letter detection, the pattern was reversed and there were slightly more errors on scrambled passages than prose passages.

A significant interaction was Task x Word which indicated that between the two tasks (reading aloud and letter detection), there was a larger difference between *the* and *one* for reading aloud. This is consistent with our expectations because unitization processes (which dominate letter detection) rely on how common words are and the words *the* and *one* are both common whereas structural processes (which dominate reading aloud) rely on function words vs. content words (*the* is a function word, *one* is a content word).

A second significant interaction was Task x Text Type, which indicates that there was a large difference in the number of errors between prose and scrambled forms of text in the reading aloud task but not the letter detection task. This is also consistent with our expectations in that we predicted text type to affect errors in reading aloud but not to affect errors in letter detection. Unitization processes should not be affected by changing the context of a sentence whereas structural processes are affected by changing the sentence context.
Another significant interaction is between Word x Text Type. Between the two forms of text (prose and scrambled), there was only a difference for the word *the* not for the word *one*. The word *one* did not have different error rates for prose and scrambled passages whereas the word *the* did. *The* is a common function word, which explains this result, because structural processes (which are disrupted by scrambling the text) should affect function words, not content words.

Lastly, there was a three-way interaction among Task x Word x Text Type. This result demonstrates that the effects of text type and word and their combination were larger for reading aloud.

Overall, these results point to a difference between reading aloud and letter detection that is consistent with our hypotheses. We predicted different processes to dominate the different tasks and yield results that indicate different patterns for each of the tasks. Structural processes seem to be responsible for the results of reading aloud, and unitization processes seem to be responsible for the results of letter detection.
Other Models

Other hypotheses and models considered in explaining our letter detection and reading aloud results include the processing time hypothesis and the attentional disengagement model.

Processing Time Hypothesis (Moravcsik & Healy, 1995, 1998)

The processing time hypothesis proposed by Moravcsik and Healy (1995, 1998) suggests that a major indicator of targets missed in letter detection stems from the amount of time spent processing words. The more time spent processing a word, the fewer letter detection errors a reader will make on that word. Furthermore, the more common a word is, the more errors a reader will make because they will spend less time processing the word.

Attentional Disengagement Model

The attentional disengagement model proposed by Roy-Charland et al. (2007) attempts to explain why there are more errors on function words than content words. This model is similar to the structural hypothesis in that it predicts more errors in function words than content words. Furthermore, it also has components of the processing time hypothesis in that it asserts that there
will be more errors on frequent words than on less frequent words. Roy-Charland et al. explain the high error rates for the frequent words in that “any factors causing a word to be rapidly identified (including word frequency, expectancy, or structure) will lead to more rapid attentional disengagement and thus a great omission rate” (Healy & Cunningham, 2014, p. 283). Common function words are missed more often because readers spend less time focusing their attention on these words than less common content words.

**Attentional Disengagement Model vs. GO Model**

The main difference between the attentional disengagement model and the GO Model lies in the fact that the GO Model includes the unitization hypothesis and the attentional disengagement model does not. To determine which model was more relevant, a study by Healy and Cunningham (2014) examined (a) detection of letters (i.e., the letter *h*) and letter sequences (i.e., the letter sequence *the*), (b) errors made on the word *the* alone vs. “the definite article,” (c) text in which the word *the* was a subject vs. an object, (d) passages in regular or all capital letters. These experiments resulted in a large number of missed target letters and fewer missed target letter sequences, which provides support for the unitization hypothesis because readers identified whole words and often ignored the individual components (letters). Thus, the current experiment
used the GO Model as our guiding model because unitization is instrumental in explaining letter
detection.
References


<table>
<thead>
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<th>Condition</th>
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<tr>
<td>1</td>
<td>Letter prose <em>the</em> (LT)</td>
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<td>2</td>
<td>Letter prose <em>one</em> (LO)</td>
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<tr>
<td>3</td>
<td>Letter scrambled <em>the</em> (LST)</td>
</tr>
<tr>
<td>4</td>
<td>Letter scrambled <em>one</em> (LSO)</td>
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<td>5</td>
<td>Computer prose <em>the</em> (CT)</td>
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<td>6</td>
<td>Computer prose <em>one</em> (CO)</td>
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</tr>
<tr>
<td>8</td>
<td>Computer scrambled <em>one</em> (CST)</td>
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</table>

*Table 1.* Fixed rotation schedule for subjects.
Figure 1. Proportion of misses of critical words (the vs. one) for reading aloud task in prose vs. scrambled form.
Figure 2. Proportion of misses of critical words (the vs. one) for letter detection task in prose vs. scrambled form.
Figure 3. Proportion of critical misses for task (reading aloud vs. letter detection), word (the vs. one) and text type (prose vs. scrambled).
Appendix A

Instructions for Letter Detection

Instructions to Subjects – E Circling

On the following sheet is a prose passage. Please do not look at it until you are told to do so. Your task will be to read the passage at your normal reading speed, but whenever you come to the letter e (typed as e or E), encircle it with your pen or pencil. If at any time you realize that you missed an e in a previous word, do not retrace your steps to encircle the e. You are not expected to get every e, so do not slow down your reading speed in order to be overcautious about getting each e.

If you have any questions, please ask them now.
Appendix B

Key to Letter Detection/Reading Aloud

Critical

Noncritical
Appendix C

Prose The

Clarifying three tablespoons of butter will be the way to begin. Two different men were arrested for stealing the car. Trout were being released in the mountain stream. Our papers include the copy to be sent to our office. We expected them to find the buried treasure. They decided to wait for the story. Summer vacation is the period we all look forward to. Lipton tea is the drink to serve at parties. Some intoxicating aroma came from the hot apple pie. According to our new procedure the step could be eliminated. Many different kinds of wild flowers covered the meadow. However, to change the class would be ineffectual. I would say unscrupulous was the word to describe him. Two cougars stalked the prairie dog. NBC network ran the program on sharks. Merlin cast his spell in the dungeon out West. Students flock to the popular ski resort during winter. Both fawns were resting under the tree. His hunting dog had located the rabbit. It took almost the whole day to complete our project. Reading the novel can be relaxing. This boy found the shoe in tall grass. Citation ran in the Kentucky Derby. Our head production manager is the man to see to solve your problem. We continued to work on the series for several days. We decided not to paint the room blue. There were three famous people in Room 310 at the time. Beginning in winter, the dauntless knight went forth. Working overtime is the reason for stress. Being hasty caused the mistake on his test. They stayed for the musical performance. According to some officials, this woman committed the homicide. Extreme dizziness is the side effect to watch for. Many organizations are being formed to protect the group of wild animals. Dining out was the treat we enjoyed. Space travel will soon become available for the trip. Two overzealous athletes knocked the hurdle down. We will begin the chapter on Monday. His radical group called Red Raiders killed the hostage. Some ice was added to the bowl of punch.
Appendix D

Prose One

Clarifying three tablespoons of butter will be one way to begin. Two different men were arrested for stealing one car. Trout were being released in one mountain stream. Our papers include one copy to be sent to our office. We expected them to find one buried treasure. They decided to wait for one story. Summer vacation is one period we all look forward to. Lipton tea is one drink to serve at parties. Some intoxicating aroma came from one hot apple pie. According to our new procedure one step could be eliminated. Many different kinds of wild flowers covered one meadow. However, to change one class would be ineffectual. I would say unscrupulous was one word to describe him. Two cougars stalked one prairie dog. NBC network ran one program on sharks. Merlin cast his spell in one dungeon out West. Students flock to one popular ski resort during winter. Both fawns were resting under one tree. His hunting dog had located one rabbit. It took almost one whole day to complete our project. Reading one novel can be relaxing. This boy found one shoe in tall grass. Citation ran in one Kentucky Derby. Our head production manager is one man to see to solve your problem. We continued to work on one series for several days. We decided not to paint one room blue. There were three famous people in Room 310 at one time. Beginning in winter, one dauntless knight went forth. Working overtime is one reason for stress. Being hasty caused one mistake on his test. They stayed for one musical performance. According to some officials, this woman committed one homicide. Extreme dizziness is one side effect to watch for. Many organizations are being formed to protect one group of wild animals. Dining out was one treat we enjoyed. Space travel will soon become available for one trip. Two over zealous athletes knocked one hurdle down. We will begin one chapter on Monday. His radical group called Red Raiders killed one hostage. Some ice was added to one bowl of punch.
Appendix E

Scrambled The

Way of tablespoons butter clarifying to will be three. Arrested two men different were stealing car for. Mountain were being in released the trout stream. To sent copy the our papers include our office be to. Buried find we treasure expected them to. To story decided for wait they. Is period forward the summer all vacation look we to. Lipton to tea the parties is at serve drink. From apple hot pie aroma intoxicating the some came. Eliminated new could to be the according procedure our step. Wild different many of meadow flowers covered the kinds. Change, be class the would ineffectual however to. Would unscrupulous word was describe the him to I say. Prairie stalked cougars the dog two. Program on NBC the sharks ran network. Merlin cast West spell out the his in dungeon. Ski popular winter the flock students resort during to. Both fawns under tree were the resting. His located hunting had dog the rabbit. Day complete project the whole took it to almost our. Novel the can relaxing be reading. Tall this in the grass boy shoe found. Ran Citation Derby the Kentucky in. Solve head to man our the to problem see is your manager production. For days continued work series the several on we to. Not blue to we room the decided paint. There famous time at were in room three people the 310. Dauntless forth winter, the beginning knight went in. Overtime working is the stress for reason. Test mistake caused the his on being hasty. For stayed musical the they performance. Committed to woman homicide, officials according some the this. Dizziness extreme to the for effect side watch is. To protect many of animals organizations formed the being wild are group. Treat dining enjoyed the out we was. Space travel soon for become will trip the available. Zealous knocked hurdle over two the athletes down. Begin on chapter the will Monday we. Hostage called killed group his radical Red the Raiders. Was of bowl some to the added punch ice.
Appendix F

Scrambled One

Way of tablespoons butter clarifying to will on begin be three. Arrested two men different were stealing car one for. Mountain were being in released one trout stream. To sent copy one our papers include our office be to. Buried find we treasure expected one them to. To story decided for wait on they. Is period forward on summer all vacation look we to. Lipton to tea one parties is at serve drink. From apple hot pie aroma intoxicating on some came. Eliminated new could to be one according procedure our step. Wild different many of meadow flowers covered on kinds. Change, be class one would ineffectual however to. Would unscrupulous word was describe on him to I say. Prairie stalked cougars one dog two. Program on NBC one sharks ran network. Merlin cast West spell out one his in dungeon. Ski popular winter one flock students resort during to. Both fawns under tree were one resting. His located hunting had dog one rabbit. Day complete project one whole took it to almost our. Novel one can relaxing be reading. Tall this in one grass boy shoe found. Ran Citation Derby one Kentucky in. Solve head to man our one to problem see is your manager production. For days continued work series on several on we to. Not blue to we room one decided paint. There famous time at were in room three people on 310. Dauntless forth winter, one beginning knight went in. Overtime working is on stress for reason. Test mistake caused one his on being hasty. For stayed musical one they performance. Committed to woman homicide, officials according some one this. Dizziness extreme to one for effect side watch is. To protect many of animals organizations formed one being wild are group. Treat dining enjoyed on out we was. Space travel soon for become will trip one available. Zealous knocked hurdle over two one athletes down. Begin on chapter one will Monday we. Hostage called killed group his radical Red one Raiders. Was of bowl some to one added punch ice.
Appendix G

Instructions for Reading Aloud

In this experiment you will be shown several sentences to read aloud. Each sentence will be shown individually. Please read each word in the sentence aloud. When you are done reading the sentence, press the space bar to move on to the next sentence. You will be instructed to stop when you have read all of the sentences.
Appendix H

Prose The

1.) Clarifying three tablespoons of butter will be the way to begin.
2.) Two different men were arrested for stealing the car.
3.) Trout were being released in the mountain stream.
4.) Our papers include the copy to be sent to our office.
5.) We expected them to find the buried treasure.
6.) They decided to wait for the story.
7.) Summer vacation is the period we all look forward to.
8.) Lipton tea is the drink to serve at parties.
9.) Some intoxicating aroma came from the hot apple pie.
10.) According to our new procedure the step could be eliminated.
11.) Many different kinds of wild flowers covered the meadow.
12.) However, to change the class would be ineffectual.
13.) I would say unscrupulous was the word to describe him.
14.) Two cougars stalked the prairie dog.
15.) NBC network ran the program on sharks.
16.) Merlin cast his spell in the dungeon out West.
17.) Students flock to the popular ski resort during winter.
18.) Both fawns were resting under the tree.
19.) His hunting dog had located the rabbit.
20.) It took almost the whole day to complete our project.
21.) Reading the novel can be relaxing.
22.) This boy found the shoe in tall grass.
23.) Citation ran
24.) Our head production manager is the man to see to solve your problem.

25.) We continued to work on the series for several days.

26.) We decided not to paint the room blue.

27.) There were three famous people in Room 310 at the time.

28.) Beginning in winter, the dauntless knight went forth.

29.) Working overtime is the reason for stress.

30.) Being hasty caused the mistake on his test.

31.) They stayed for the musical performance.

32.) According to some officials, this woman committed the homicide.

33.) Extreme dizziness is the side effect to watch for.

34.) Many organizations are being formed to protect the group of wild animals.

35.) Dining out was the treat we enjoyed.

36.) Space travel will soon become available for the trip.

37.) Two overzealous athletes knocked the hurdle down.

38.) We will begin the chapter on Monday.

39.) His radical group called Red Raiders killed the hostage.

40.) Some ice was added to the bowl of punch.
Appendix I

Prose One

1.) Clarifying three tablespoons of butter will be one way to begin.
2.) Two different men were arrested for stealing one car.
3.) Trout were being released in one mountain stream.
4.) Our papers include one copy to be sent to our office.
5.) We expected them to find one buried treasure.
6.) They decided to wait for one story.
7.) Summer vacation is one period we all look forward to.
8.) Lipton tea is one drink to serve at parties.
9.) Some intoxicating aroma came from one hot apple pie.
10.) According to our new procedure one step could be eliminated.
11.) Many different kinds of wild flowers covered one meadow.
12.) However, to change one class would be ineffectual.
13.) I would say unscrupulous was one word to describe him.
14.) Two cougars stalked one prairie dog.
15.) NBC network ran one program on sharks.
16.) Merlin cast his spell in one dungeon out West.
17.) Students flock to one popular ski resort during winter.
18.) Both fawns were resting under one tree.
19.) His hunting dog had located one rabbit.
20.) It took almost one whole day to complete our project.
21.) Reading one novel can be relaxing.
22.) This boy found one shoe in tall grass.
23.) Citation ran
in one
one Kentucky
Derby.
24.) Our head
production manager
is one
one man
to see
to solve
your problem.
25.) We continued
to work
on one
series for
several days.
26.) We decided
not to
paint one
one room
blue.
27.) There were
three famous
people in
Room 310
at one
one time.
28.) Beginning in
winter, one
one dauntless
knight went
forth.
29.) Working overtime
is one
reason for
stress.
30.) Being hasty
caused one
mistake on
his test.
31.) They stayed
for one
musical performance.
32.) According to
some officials,
this woman
committed one
one homicide.
33.) Extreme dizziness
is one
one side
effect to
watch for.
34.) Many organizations
are being
formed to
protect one
group of
wild animals.
35.) Dining out
was one
treat we
enjoyed.
36.) Space travel
will soon
become available
for one
trip.
37.) Two over
zealous athletes
knocked one
one hurdle
down.
38.) We will
begin one
chapter on
Monday.
39.) His radical
group called
Red Raiders
killed one
one hostage.
40.) Some ice
was added
to one
one bowl
of punch.
Appendix J

Scrambled The

1. Way of tablespoons butter clarifying to will the the begin be three.
2. Arrested two men different were stealing car the the for.
3. Mountain were being in released the trout stream.
4. To sent copy the the our papers include our office be to.
5. Buried find we treasure expected the them to.
6. To story decided for wait the they.
7. Is period forward the the summer all vacation look we to.
8. Lipton to tea the the parties is at serve drink.
9. From apple hot pie aroma the intoxicating some came.
10. Eliminated new could to be the according procedure our step.
11. Wild different many of meadow flowers covered the kinds.
12. Change, be class the the would ineffectual however to.
13. Would unscrupulous word was describe the the him to I say.
14. Prairie stalked cougars the the dog two.
15. Program on NBC the sharks ran network.
16. Merlin cast West spell out the the his in dungeon.
17. Ski popular winter the flock students resort during to.
18. Both fawns under tree were the the resting.
19. His located hunting had dog the rabbit.
20. Day complete project the the whole took it to almost our.
21. Novel the can relaxing be reading.
22. Tall this in the the grass boy shoe found.
23. Ran Citation
Derby the
the Kentucky in.

24.) Solve head
to man
our the
the to
problem see
is your
manager production.

25.) For days
continued work
series the
several on
we to.

26.) Not blue
to we
room the
the decided
paint.

27.) There famous
time at
were in
room three
people the
the 310.

28.) Dauntless forth
winter, the
the beginning
knight went
in.

29.) Overtime working
is the
stress for
reason.

30.) Test mistake
caused the
his on
being hasty.

31.) For stayed
musical the
they performance.

32.) Committed to

woman homicide,
officials according
some the
the this.

33.) Dizziness extreme
to the
the for
effect side
watch is.

34.) To protect
many of
animals organizations
formed the
being wild
are group.

35.) Treat dining
enjoyed the
out we
was.

36.) Space travel
soon for
become will
trip the
available.

37.) Zealous knocked
hurdle over
two the
the athletes
down.

38.) Begin on
chapter the
will Monday
we.

39.) Hostage called
killed group
his radical
Red the
the Raiders.

40.) Was of
bowl some
to the
the added
punch ice.
Appendix K

Scrambled One

1.) Way of tablespoons butter clarifying to will one one begin be three.
2.) Arrested two men different were stealing car one one for.
3.) Mountain were being in released one trout stream.
4.) To sent copy one one our papers include our office be to.
5.) Buried find we treasure expected one them to.
6.) To story decided for wait one they.
7.) Is period forward one summer all vacation look we to.
8.) Lipton to tea one one parties is at serve drink.
9.) From apple hot pie aroma one intoxicating some came.
10.) Eliminated new could to be one according procedure our step.
11.) Wild different many of meadow flowers covered one kinds.
12.) Change, be class one one would ineffectual however to.
13.) Would unscrupulous word was describe one one him to I say.
14.) Prairie stalked cougars one one dog two.
15.) Program on NBC one sharks ran network.
16.) Merlin cast West spell out one one his in dungeon.
17.) Ski popular winter one flock students resort during to.
18.) Both fawns under tree were one resting.
19.) His located hunting had dog one rabbit.
20.) Day complete project one one whole took it to almost our.
21.) Novel one can relaxing be reading.
22.) Tall this in one one grass boy shoe found.
23.) Ran Citation
Derby one
one Kentucky in.
24.) Solve head to man one our one one to problem see is your manager production.
25.) For days continued work series one several on we to.
26.) Not blue to we room one one decided paint.
27.) There famous time at were in room three people one one 310.
28.) Dauntless forth winter, one one beginning knight went in.
29.) Overtime working is one stress for reason.
30.) Test mistake caused one his on being hasty.
31.) For stayed musical one they performance.
32.) Committed to woman homicide, officials according some one one this.
33.) Dizziness extreme to one one for effect side watch is.
34.) To protect many of animals organizations formed one being wild are group.
35.) Treat dining enjoyed one out we was.
36.) Space travel soon for become will trip one available.
37.) Zealous knocked hurdle over two one one athletes down.
38.) Begin on chapter one one will Monday we.
39.) Hostage called killed group his radical Red one one Raiders.
40.) Was of bowl some to one one added punch ice.