FINAL ACCEPTED VERSION

# Failure to detect function word repetitions and omissions in reading: Are eye movements to blame?


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Keywords: eye movements and reading; language comprehension

Word Count: 4610 (all text excluding title page, abstract, and figure captions)



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Acknowledgements: The authors thank Audrey O'Neill, Laurel Whitfield, Marcos Coli, and Serene Elbach for their assistance with data collection. This work was supported in part by a grant from the National Science Foundation (BCS 1732008) to the first author.

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## Abstract

We test whether failure to notice repetitions of function words during reading (e.g. *Amanda jumped off the the swing and landed on her feet*.) is due to the eyes' tendency to skip one of the instances of the word. Eye movements were recorded during reading of sentences with repetitions of the word *the* or repetitions of a noun, after which readers were asked whether an error was present. A repeated *the* was detected on 46% of trials overall. On trials when both instances of *the* were fixated, detection was still only 66%. A repeated noun was detected on 90% of trials, with no significant effect of eye-movement patterns. Detecting an omitted *the* also proved difficult, with eye-movement patterns having only a small effect. Readers frequently overlook function word errors even when their eye movements provide maximal opportunity for noticing such errors, but notice content word repetitions regardless of their eye-movement pattern. We propose that readers overlook function word errors because they attribute the apparent error to noise in the eye-movement control system.

## Introduction

In the HBO comedy series *Veep*, former President Selina Meyer finds, to her chagrin, that her published memoir begins, “From the moment I entered the the White House…” (Kenward, Iannuci, & Hall, 2017, June 18). Most readers can recall noticing a repeated function word only after initially failing to detect it, and such oversights seem to be especially common with the word *the*. A version of this phenomenon is often noted in introductory psychology textbooks (e.g., Coon & Mitterer, 2010; Eysenck & Keane, 2005), in which the phrase ‘Paris in the the Spring’ is presented in a triangle, with the two occurrences of *the* separated by a line break. Readers’ failure to notice the error is described as an example of top-down processing, but without any account of why this particular error is overlooked. Coon and Mitterer (2010, p. 167) attribute the phenomenon to readers’ “past experience with the English language,” while Eysenck and Keane (2005, p. 2) attribute it to “your expectation that it is the well-known phrase.”

In fact, no research has investigated how frequently readers fail to detect function word repetitions, or why such failures happen. The most closely related work may be that of Healy and colleagues (Healy, 1976, 1980; Healy & Drewnowski, 1983; Moravcsik and Healy, 1995). They found that function words are likely to be overlooked in a letter detection task (e.g., the letter *t* is often missed in the word *the*), and suggested that a function word is a ‘reading unit,’ which makes individual letters difficult to detect. Other related work by Drieghe, Pollatsek, Staub, and Rayner (2008) tested the idea that a short function word such as *the* is treated by the eye-movement control system as a single unit with the word that follows it. Drieghe et al. confirmed that *the* is very frequently skipped by the eyes (e.g., Angele & Rayner, 2013), but found that the pattern of fixations on *the* and on a subsequent noun was consistent with the saccade-targeting system treating each word as a separate unit.

In the present study, we test an explanation for the failure to notice function word repetitions based on eye-movement patterns. We assume that readers will rarely directly fixate both instances of a repeated function word. Moreover, in many of the cases in which they do not fixate both instances, the skipped instance may not be fully processed. It is clear that skipped words are usually processed to a relatively high level, as most word skipping occurs when the word has been identified during fixation on the previous word (e.g., Gordon, Plummer, & Choi, 2013). A substantial proportion of the skipping of short words (e.g., most function words), however, is likely to occur 'accidentally,' that is, because of oculomotor error in the programming and execution of saccades (Reichle & Drieghe, 2013).

This hypothesis makes the prediction that failure to notice repeated function words should be restricted to trials on which one of the instances was skipped; when both instances are fixated, the repetition should be noticed. By contrast, on the assumption that longer, lower-frequency content words are fully processed even if they are skipped, repeated content words should be noticed regardless of the fixation pattern. To test these predictions, we tracked readers' eye movements while they read sentences in which either the word *the* or the following noun was repeated, as well as grammatical control sentences. To investigate whether failure to notice function word repetitions may be part of a broader phenomenon related to detection of function word errors, we also included a condition in which the word *the* was omitted.

## Method

### *Subjects*

Fifty-one UMass Amherst students received course credit for participation. All were speakers of English as a first language. None reported any reading or language disorder.

*Materials*

Thirty-six items were created, with four versions, as shown in (1).[1]

(1) a. Amanda jumped off the swing and landed on her feet. (G)

b. Amanda jumped off the the swing and landed on her feet. (RT)

c. Amanda jumped off the swing swing and landed on her feet. (RN)

d. Amanda jumped off swing and landed on her feet. (OT)

In each item, a *grammatical* sentence (G) was modified with a *repeated the* (RT), a *repeated noun* (RN), or an *omitted the* (OT).[2] The repeated word in the RN condition ranged from 3 to 6 characters, with a mean of 4.25. The median frequency of this word in the Subtlex Corpus (Brysbaert & New, 2009) was 81.92 occurrences per million words, ranging from a low of 4.1 (*curb*) to a high of 1845.75 (*man*). In 12 items, the critical noun phrase was in direct object position, as in (1), while in 24 it was either the subject of an embedded clause (e.g., The girl decorated the cake while *the boy* baked cookies for the party) or a prepositional object (e.g., The teenagers went to *the beach* for the first time today).

Four lists were created from the 36 critical items; each subject read 9 items in each condition, and each version of each item was read by an approximately equal number of subjects. The 36 critical items were intermixed with 72 unrelated fillers with a wide variety of sentence

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1 All materials, data, and analysis scripts may be accessed at: https://osf.io/7x9uh/?view_only=a38db884be684242b6390b226eed7eb1

2 The OT condition may also be repaired by adding the indefinite article *a*, or by making the following noun plural (though this correction often would have been infelicitous). Our method does not allow a determination of what subjects took the error to be, when they did detect it. We also note that in three of the 36 items the word that followed the critical instance of *the*, and which was repeated in the RN condition, was actually an adjective. For convenience, we nevertheless refer to this condition as the RN condition.

structures, none of which contained grammatical errors. The order of the 108 items, presented after 8 practice sentences, was randomized for each subject.

*Procedure*

The movement of the subject's right eye was recorded using an EyeLink 1000 (SR Research, Toronto, ON, Canada) eyetracker. The sampling rate was 1000 Hz. Subjects were seated 55 cm from a CRT monitor, with 1024×768 resolution and a screen refresh rate of 120 Hz.

Sentences were displayed on a single line in 11-point Monaco font, with between 3 and 4 characters subtending 1º of visual angle. Subjects were instructed to read for comprehension. A three-point calibration procedure was performed at the start of the experiment and, as needed, between trials. The subject triggered the appearance of each sentence by fixating a box at the left edge of the monitor. After finishing the sentence, the subject removed it from the screen by pressing a button on a hand-held controller. A two-alternative forced-choice question then appeared. The subject responded by button press. For the critical trials, the question *Was there anything wrong with that sentence?* appeared with the options *NO* and *YES*, on the left and right respectively. The filler trials were followed by comprehension questions, some of which were Yes/No questions, and some of which had distinct response options; e.g., for the sentence, *When Dan went outside, he discovered that it was much colder than inside.*, the question was *What was colder?* with the response options *outside* and *inside*.

The experiment lasted approximately 30 minutes. The experiment was implemented with the EyeTrack software, and initial stages of data analysis were carried out with Robodoc and EyeDry (http://blogs.umass.edu/eyelab/software/). Because we were primarily concerned with patterns of fixations, rather than measures of reading time, we did not eliminate trials based on the presence of blinks. Thus, all results reported below are based on the full set of 459 trials per condition (51 subjects × 9 trials per condition).

## Results

The distribution of error detection performance is shown in Figure 1. Subjects made false alarms on only 3.1% of trials in the G condition. In the RN, OT, and RT conditions, subjects noticed the error on 90.2%, 67.5%, and 45.8% of trials, respectively. All pairwise comparisons of condition means were significant ($t$s > 4.4, $p$s < .001).

Accuracy on the comprehension questions following the filler trials was high (mean accuracy = .93, minimum = .79), and was not significantly correlated with performance in either the RT or OT conditions (RT $r = .17$, $p = .22$; OT $r = .16$, $p = .25$). Mean total sentence reading time on the fillers was substantially more variable (mean = 4.73 s, range = 2.76 s to 8.51 s), and its correlation with error detection in the RT condition was marginal ($r = .26$, $p = .07$). However, there was no correlation between this measure and error detection in the OT condition ($r = -.02$, $p = .86$). The correlation between subjects' performance in the RT and OT conditions themselves was marginally significant, $r = .264$, $p = .06$.

To summarize the behavioral results, although accuracy was near ceiling in the RN and G conditions, subjects detected the error in the RT condition less than half of the time, and in the OT condition about two-thirds of the time. Error detection in the RT and OT conditions was only weakly correlated, and in neither condition was error detection strongly predicted by comprehension accuracy or reading speed on the filler items. Because subjects were aware that they would be asked to detect occasional errors, the rate of detection may overestimate the detection rate in normal reading.

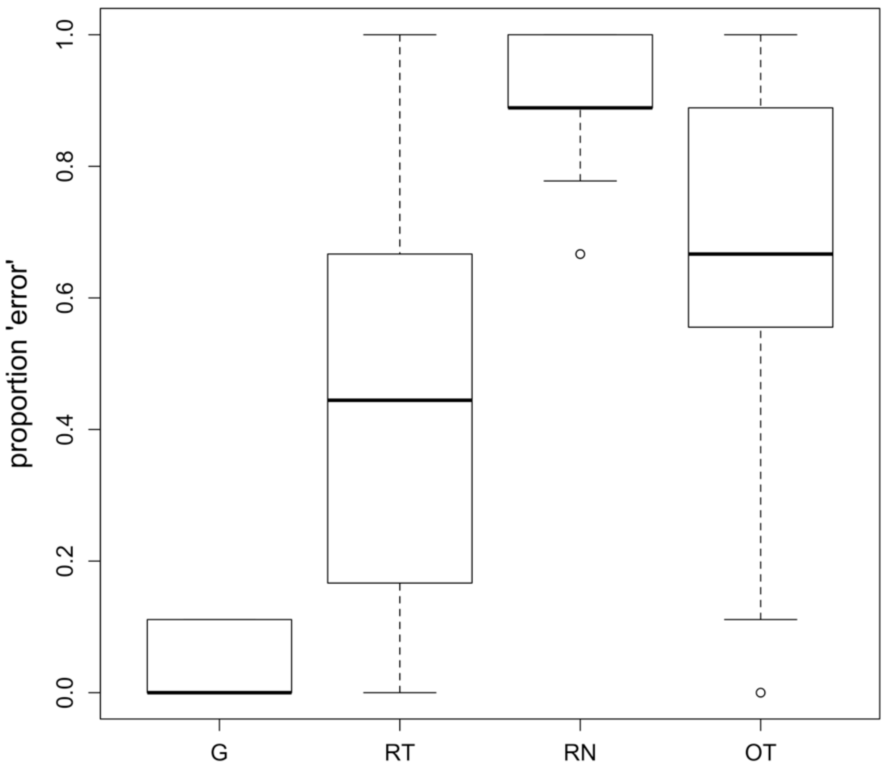


Figure 1. Distribution of proportion of ‘error’ responses in each experimental condition (G: grammatical; RT: repeated *the*; RN: repeated noun; OT: omitted *the*), by subject.

The main question addressed by this study is how patterns of eye fixations on the regions containing the errors, during first-pass reading, is related to error detection. Analyses that we do not present here show that error detection is associated with inflated reading times as reflected in both early (first-pass time) and late (regression-path duration) eye-movement measures. However, we do not emphasize this result, as the direction of causation underlying this relationship is uncertain; we assume that error detection itself is likely to increase reading time.

On the other hand, we assume that while error detection may *result from* a specific pattern of first-pass fixations, it is unlikely to *cause* changes in the pattern of first pass fixations on the critical words. This assumption is based on the previous evidence that saccade targeting is based mostly on low-level orthographic features (e.g., Reichle, Rayner, & Pollatsek, 2003), such as the length of the parafoveal word, and is much less sensitive than durational measures to lexical and higher-level factors. More specifically, there is evidence that the word *the* tends to be fixated at about the same rate regardless of whether it is a grammatical continuation of the sentence (Abbott, Angele, Ahn, & Rayner, 2015; Angele & Rayner, 2013). Below we provide evidence that first pass fixations on the critical words were not much (if at all) more likely in the ungrammatical conditions than in the grammatical control condition.

In the RT condition, the first instance of *the* was fixated during first-pass reading on 53.4% of trials. For comparison, the single instance of *the* in the G condition was fixated 49.5% of the time. When the first *the* was skipped in the RT condition, the second *the* was fixated 78.0% of the time, but when the first *the* was fixated, the second was fixated only 38.0% of the time. The fixation rate on the second instance of *the* when the first was fixated is similar to the fixation rate on the first instance of *the* when the previous word was fixated, which was 37.8% and 33.7% in the RT and G conditions, respectively. Thus, it appears, as suggested above, that the presence of the repetition error did not itself result in much, if any, increase in the probability of fixation on either instance of *the*.

The frequency of each of the four possible first-pass eye-movement patterns on *the the* is shown in Figure 2b: Fixating the first instance of *the* and skipping the second (33.1%); skipping the first and fixating the second (36.4%); fixating both instances (20.3%); or fixating neither (10.3%). For comparison, the frequency of each of the corresponding patterns in the G condition, on the word *the* and on the following noun, is shown in Figure 2a. Figure 2b also shows the rate of error detection following each of these fixation patterns: 34.2% when only the first *the* was fixated, 45.5% when only the second *the* was fixated, 65.6% when both were fixated, and 44.7% when neither was fixated.

In the RN condition, the first noun received a first-pass fixation on 75.8% of trials. For comparison, the single noun in the G condition was fixated 72.3% of the time. The second noun was fixated on 92.8% of trials on which the first was skipped, but 75.0% of trials on which the first was fixated. As shown in Figure 2c, readers fixated both instances of the noun on 56.9% of trials, compared to 19.0% on which only the first was fixated, 22.4% on which the only the second was fixated, and less than 2% (a total of 8 trials) on which neither was fixated. The error was detected at a similar rate when both were fixated (91.6%) and when only the first (89.7%) or only the second (89.3%) was fixated.

To assess these patterns statistically, we first computed separate mixed-effects logistic-regression models of error detection in the RT and RN conditions, using the lme4 package (version 1.1-7; Bates, Maechler, Bolker, & Walker, 2015) for the R statistical programming environment (version 3.1.2; R Core Team, 2014). For each model, the fixed effects were two orthogonal contrasts: (a) Fixation on both repeated instances vs. fixation on only one (both vs. one); and (b) fixation on only the first vs. fixation on only the second (first vs. second). The small number of trials on which neither instance was fixated were left out. Random subject and item intercepts and random subject slopes for each of the contrasts were included. Random item slopes were included for the model of the RT condition, but were removed from the model of the RN condition to obtain convergence. The model of the RT condition revealed an effect of fixation on both vs. one ($\beta = 1.53$, $SE = 0.39$, $z = 3.87$, $p < .001$). However, the first vs. second contrast was not significant ($\beta = 0.44$, $SE = 0.35$, $z = 1.28$, $p = .20$). The model of the RN data did not reveal significant effects of either contrast (both vs. one: $\beta = -0.09$, $SE = 0.56$, $z = -0.16$, $p = .88$; first vs. second: $\beta = -0.02$, $SE = 0.60$, $z = -0.05$, $p = .96$).

We then computed a model that directly compared the RT and RN conditions. This model included the data from both conditions, with (centered) condition and fixation on both vs. one as fixed effects, as well as their interaction. Random intercepts for subjects and items, and random by-subject slopes for the condition factor were included (models with more complete random effect structures didn't converge). This model revealed main effects of condition ($\beta = 2.72$, $SE = 0.36$, $z = 7.53$, $p < .001$) and both vs. one ($\beta = 0.71$, $SE = 0.25$, $z = 2.84$, $p < .01$), as well as an interaction between these factors ($\beta = -1.18$, $SE = 0.50$, $z = -2.35$, $p = .019$). The interaction reflects the fact that fixation on both instances of the repeated *the* did increase error detection, while fixation on both instances of the repeated noun did not do so.

We also consider the influence of first-pass fixation pattern on detection probability in the OT condition. We focus on fixation on the *lead-in* word immediately prior to the position of the omitted *the* (which could be a verb, preposition, complementizer, or subordinator such as *while*), and the noun that immediately followed the omitted *the* position. The lead-in word was fixated during first-pass reading on 64.9% of trials in the OT condition, compared to 63.4% in the G condition. When the lead-in word was skipped, the following noun was fixated on 96.9% of trials, but when the lead-in word was fixated, the following noun was fixated on only 71.1% of trials.

Figure 2d shows that fixation on both words occurred on 46.2% of trials, while fixation on only the lead-in word occurred on 18.7%, and fixation on only the noun occurred on 34.0%. Neither word was fixated on about 1% of trials. When both words were fixated, the error was detected 71.2% of the time, compared to 64.0% when only the lead-in word was fixated, and 64.1% when only the noun was fixated. A logistic regression model (with maximal random effect structure) reveals that the relatively small increase in error detection when both words were fixated was significant ($\beta = 0.63$, $SE = 0.28$, $z = 2.28$, $p = .023$). Trials on which only the lead-in word was fixated and trials on which only the noun was fixated did not differ ($\beta = 0.22$, $SE = 0.37$, $z = 0.59$, $p = .55$).

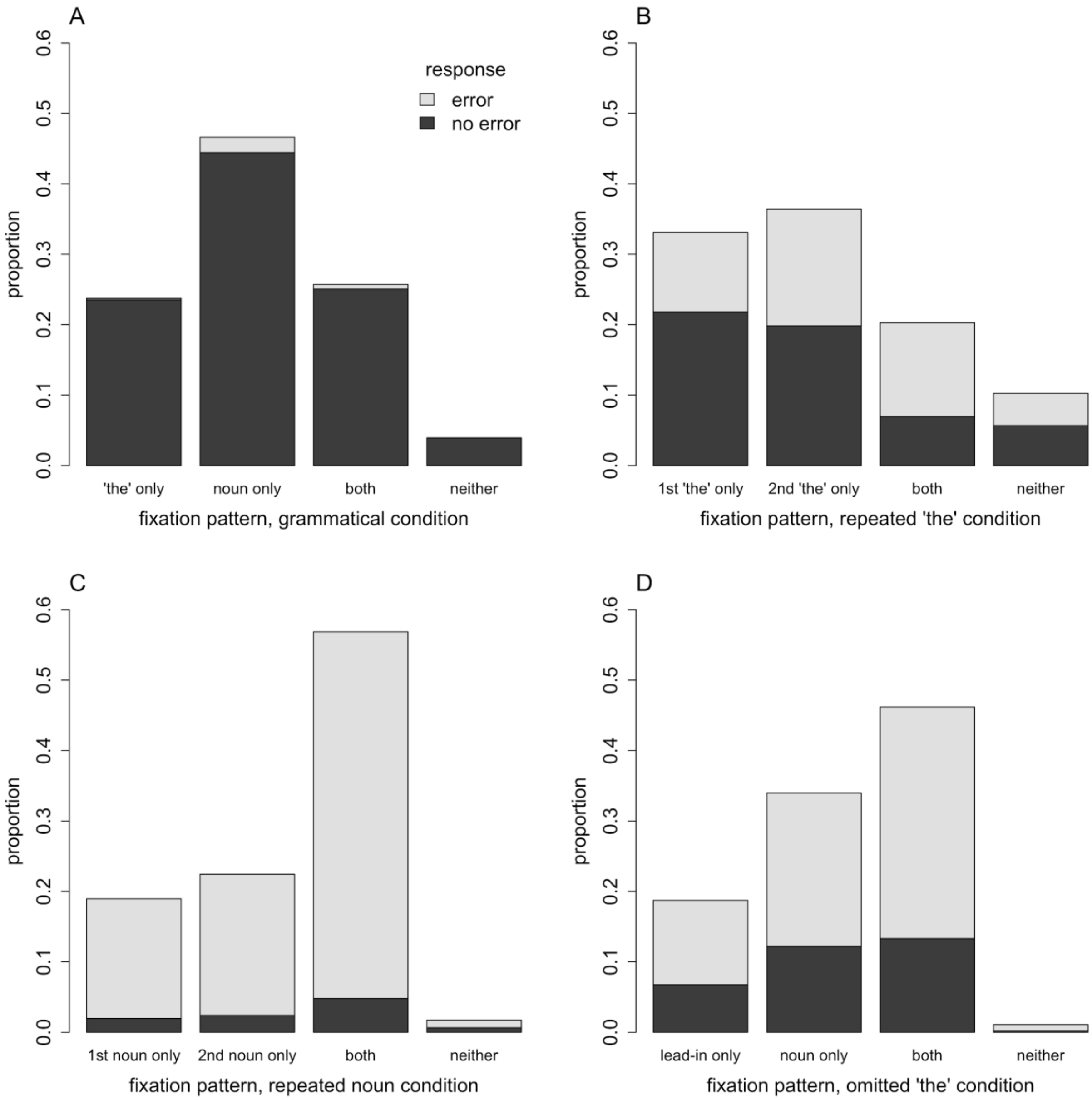


Figure 2. Proportion of trials by first-pass fixation pattern and ‘error’ vs. ‘no error’ response in (A) grammatical condition; (B) repeated *the* condition; (C) repeated noun condition, and (D) omitted *the* condition.

## Discussion

Contrary to the initial hypothesis that failure to detect function word repetitions is due to skipping of one of the instances, fixation on both instances was not sufficient for detection of the error. When readers fixated only one instance of a repeated *the*, about 40% of errors were detected; when both instances were fixated, detection increased, but only to about 66%. By contrast, readers detected a repeated noun 90% of the time, whether they fixated one or both instances. In other words, a reader who fixates only *one* instance of a repeated noun is much more likely to detect an error than is a reader who fixates *both* instances of a repeated *the*. While the eyes' tendency to skip one instance of a repeated *the* does make a contribution to their failure to notice that the repetition, the present experiment suggests that this is not the primary cause.

This phenomenon might be regarded as a form of *repetition blindness*, in which subjects fail to report two occurrences of a visual stimulus (e.g., words, letters, color patches) that are separated in time or space. A standard account (Kanwisher, 1987, 1991) holds that the stimulus *types* are recognized, but the subject fails to represent the two stimuli as separate *tokens*. In the present case, each instance of a function word might be recognized (e.g., as the word *the*), but the reader may fail to represent the two distinct instances. However, the notion of repetition blindness is more descriptive than explanatory in this case. It is not obvious why failure of token individuation should occur with *the*, and not with content words. Also, not only did readers frequently fail to notice a repeated *the*, they also frequently failed to notice an omitted *the*. Thus, the experiment reveals a broader tendency to fail to report errors involving the word *the*, whether repetitions or omissions.

Our preferred explanation is similar in spirit to the 'Noisy Channel' hypothesis proposed by Gibson and colleagues (Gibson, Bergen, & Piantadosi, 2013), which claims that readers make rapid, unconscious inferences, of a Bayesian nature, about the sequences of words they have encountered. In the present case, we make the specific proposal that these inferences rely, in part, on the reader's implicit knowledge of which apparent errors could easily have arisen due to errors in the eye-movement control system. Only apparent errors that are unlikely to have arisen from the eye-movement control system are inferred to be present.

In order for such an account to explain the current phenomena, we must claim that the evidence obtained from encountering two successive instances of the word *the*, or from a string in which the word *the* is absent, is particularly attributable to eye-movement control errors. This claim is supported as follows. First, given the sources of error in saccadic targeting and execution (McConkie, Kerr, Reddix, & Zola, 1988; Reilly & O'Regan, 1998), a relatively high proportion of the fixations on the word *the*, in normal reading, are likely to take place after the word has already been parafoveally processed. This can occur for two reasons: Either a saccade that was intended to skip the word *the* falls short of its target, due to oculomotor error (Drieghe, Rayner, & Pollatsek, 2008), or parafoveal identification of the word *the* happens too late to cancel a saccade targeting this word (a 'forced fixation'; Schotter, Leinenger, & von der Malsburg, in press). Both of these occurrences are likely to be particularly common with the word *the*, simply because this word is skipped so frequently and is so easily recognized. Thus, the reader may discount a repetition of *the* as only apparent, rather than real. Note that a longer, lower-frequency noun is much less likely to be 'accidentally' fixated after it has already been processed, and as a result, a reader is less likely to attribute an apparent repetition of a noun to an error in eye-movement control. Second, the eyes are also relatively likely to 'accidentally' skip a very short word such as *the*, i.e., skipping it when in fact it has not been parafoveally processed (Drieghe, Rayner, & Pollatsek, 2008; Reichle & Drieghe, 2013). While a short content word is also relatively likely to be accidentally skipped, a function word such as *the* is more easily inferred from context. Thus, the reader may attribute the apparent absence of the word *the*, when the grammar requires it, to such an accidental skip.

This account predicts that error detection should not be completely independent of the reader's eye-movement pattern, consistent with the results of the present experiment. The perceptual evidence from fixation on both instances of a repeated *the*, or on the words immediately preceding and following the location of an omitted *the*, is somewhat less easily attributed to errors in eye-movement control. Admittedly, this account does not make precise predictions about how frequently readers should detect each type of error, and does not directly predict, in the absence of additional assumptions, that failure to notice a repeated *the* should be more common than failure to notice an omitted *the*. Interestingly, this asymmetry goes in the opposite direction from that predicted by Gibson et al. (2013), who argue on Bayesian grounds that comprehenders should be more likely to 'correct' deletions than insertions of material.

Finally, we point out that this kind of meta-cognitive account is, as far as we know, novel in the eye movement literature. Our account does propose that failure to notice function word repetitions and omissions is due to a kind of top-down processing (e.g., Eysenck & Keane, 2005). However, we propose that the knowledge that interacts with bottom-up processing of the stimulus is not simply knowledge about the likely strings of words in the language. Rather, readers make use of implicit knowledge of the reliability of specific types of perceptual input, which is obtained through reading experience. This suggests that differences in reading experience (as opposed to language experience more generally) may give rise to differences in the tendency to 'correct' errors in the text. Whether this is the case is a question for future work.

*Conclusion*

This study has shown that readers tend to overlook both repetitions and omissions of the word *the*. Remarkably, they missed repetitions of *the* over half the time, despite task demands that are likely to have increased sensitivity to such repetitions. Furthermore, readers fail to notice these errors in novel sentences, and when the two instances of *the* are on the same line of text. Failure to fixate on the relevant words is not the chief cause of this phenomenon; remarkably, readers missed a repeated *the* 34% of the time even when they directly fixated both instances, and they missed a repeated noun only 10% of the time even when they fixated only one instance. We suggest that function word errors are often overlooked because readers attribute the apparent error to an error in control of their own eye movements, rather than to the text itself. More research is needed to fully test this hypothesis.

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