

Mind wandering while reading easy and difficult texts

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Author Note

This research was supported by the National Science Foundation (NSF) (ITR 0325428, HCC 0834847, DRL 1235958). Any opinions, findings and conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of NSF. Our special gratitude goes to Debra Long for her guidance in the development of the current experimental design.

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Abstract

Mind wandering is a phenomenon in which attention drifts away from the primary task to task-unrelated thoughts. Previous studies have used self-report methods to measure the frequency of mind wandering and its effect on task performance. Many of these studies have investigated mind wandering in simple perceptual and memory tasks such as recognition memory, sustained attention, and choice reaction time. Manipulations of task difficulty have revealed that mind wandering occurs more frequently in easy than difficult conditions, but has a greater negative impact on performance in the difficult conditions. The goal of this study was to examine the relation between mind wandering and task difficulty in a high level cognitive task, namely reading comprehension of standardized texts. We hypothesize that reading comprehension may yield a different relation between mind wandering and task difficulty than has been observed previously. Participants read easy or difficult versions of eight passages and then answered comprehension questions after reading each passage. Mind wandering was reported using the probe-caught method used in several previous studies. Contradictory to the previous results, but consistent with our hypothesis, mind wandering occurred more frequently when participants read difficult compared to easy texts. However, mind wandering had a more negative influence on comprehension for the difficult texts, which is consistent with previous data. The results are interpreted from the perspectives of executive resources and control-failure theories of mind wandering and situational models of text comprehension.

Keywords: Mind wandering, reading comprehension, text difficulty

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Mind wandering is an attentional shift away from the processing of external, task-related information to the processing of internal, task-unrelated information (Smallwood & Schooler, 2006). Mind wandering involves controlled processing that can occur without intention or even awareness (Schooler, 2002). Recent studies have shown that mind wandering is linked to both default and executive networks and of the brain, thereby suggesting that mind wandering utilizes central executive resources to some extent (Baird, Smallwood, & Schooler, 2011; Barron, Riby, Greer, & Smallwood 2011; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). In line with this, Smallwood, Schooler, and colleagues have proposed an *executive-resource hypothesis*, which posits that both task-related and task-unrelated thoughts compete for limited executive resources. When the primary task is difficult and resource demanding, little or no resources are available for mind wandering to occur. On the other hand, mind wandering is more likely to occur when the primary task is easy or its execution has been automated, because it utilizes unused executive resources from the primary task (Smallwood & Schooler, 2006).

There is considerable empirical evidence to support the executive-resource hypothesis that predicts that mind wandering is less prominent in difficult compared to easy tasks. For example, Smallwood, Obonsawin, and Reid (2003) had participants perform a fluency task, a verbal encoding task, or a lottery task. They found that mind wandering increased as a function of block duration in both the verbal encoding task and the lottery task, but not in the fluency task. Smallwood et al. (2003) argued that the fluency task required more attentional resources than the other tasks, so there was less attentional “space” for mind wandering to occur. Similarly, Smallwood, Davies, Heim, et al. (2004) found that in a Sustained Attention to Response Task (SART, Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), mind wandering was less likely

to occur in the first half of the task than in the second, which suggests that mind wandering increased when the task became easier due to practice effects.

As an alternative to the executive-resource hypothesis, the *control-failure hypothesis* (McVay & Kane, 2010) suggests that mind wandering is the result of executive maintenance failures. According to this view, task-related and task-unrelated thoughts frequently compete under executive control, and mind wandering occurs when executive control fails to maintain task-related thoughts by suppressing task-unrelated thoughts. Difficult tasks that require considerable controlled processing to meet task demands should minimize mind wandering, but only if there are enough cognitive resources and skills to handle the difficult task and there are minimal interfering activities. Individuals with weaker attentional-control abilities are predicted to mind wander due to interfering thoughts unrelated to the primary task than those with stronger attentional-control abilities (McVay & Kane, 2012a; 2012b).

In support of this view, McVay and Kane cite studies that show that working memory capacity (WMC) is largely associated with executive-control capabilities (e.g. Kane & Engle, 2003). Kane, Brown, McVay, Silvia, et al. (2007) found that people with high WMC were less likely to report mind wandering during attention-demanding activities than low WMC individuals. McVay and Kane (2010) hypothesize that if mind wandering competes for working memory resources, as would be predicted by the executive resource hypothesis, people with high WMC should mind wander more frequently than people with low WMC because the high WMC individuals will have more executive resources available for mind wandering. They cite empirical data that support an opposite view, and instead characterize unintended mind wandering as occurring due to a lapse of attentional control rather than executive resource availability.

To counter this argument, Levinson, Smallwood, and Davidson's (2012) recently conducted a visual-span search study with varying task load. They found that higher WMC individuals reported more mind wandering during low task load, but mind wandering did not depend on WMC during high task load. Levinson et al. interpreted this finding as a challenge to McVay and Kane's (2010) claims because their model cannot easily explain why participants with more WM resources, although better at focusing attention, nonetheless mind-wandered more during the low perceptual-load task.

As evident from the discussion above, there is considerable debate as to the underlying cognitive processes that give rise to mind wandering. The current study investigates mind wandering in a higher level cognitive task, namely reading comprehension. The few studies on mind wandering during reading have shown that mind wandering negatively impacts reading comprehension and that comprehension is negatively correlated with probe-caught mind wandering, but not with self-caught mind wandering (Reichle, Morales, Laurent, et al., 2009; Smallwood, McSpadden, & Schooler, 2008).

One unsatisfactorily addressed aspect is the effect of text difficulty on mind wandering. Giambra and Grodsky tracked mind wandering during reading by obtaining human-provided ratings of passage difficulty and asked readers to rate interest in the passages (Giambra & Grodsky, 1989; Grodsky & Giambra, 1990/1991). They found that mind wandering was not related to passage difficulty but was related to readers' interest. However, an important limitation of these two studies is that it did not use objective measures of text difficulty and the texts varied in content between the difficult and easy passages, which is a potential confound. Giambra and Grodsky also did not report any results linking mind wandering to reading comprehension or whether mind wandering interacted with text difficulty to predict reading comprehension.

The goal of the current study was to investigate mind wandering during the reading of texts that were equated content but varied in difficulty. It is generally acknowledged that reading texts involves the construction of a *situation model* that represents the most up-to-date interpretation of the text meaning (both explicit information and inferences) and links the past and present segments of the text (Graesser & McNamara, 2011; Zwaan, Langston, & Graesser, 1995). The situation model exerts top-down influence in reading by providing a global context in which a reader interprets the explicit text content and associated inferences. Difficult texts have more discontinuities in cohesion which may make it more challenging to maintain sustained control and attention on the comprehension activities. In line with this, we expect that mind wandering will occur when a reader has difficulty in constructing a *situational model* of the text (Smallwood, 2011; Smallwood et al., 2008) due to failure of executive processing, be it control failure (McVay and Kane's view) or insufficient executive resources (Smallwood and colleagues' view). Furthermore, mind wandering may disrupt comprehension as a result of the reader's inability to construct a well-formulated situational model of the text (Smallwood, 2011).

Text difficulty in our study was manipulated by creating two versions of a set of texts instead of having humans to rate the difficulty of texts as was the case in the Giambra and Grodsky (Giambra & Grodsky, 1989; Grodsky & Giambra, 1990/1991) studies. One goal of this study was to investigate how text difficulty impacts mind wandering. The second goal was to investigate if text difficulty moderates the impact of mind wandering on reading comprehension.

If mind wandering is affected by difficulty during reading, as it is in the other tasks discussed above, then mind wandering should be systematically influenced by text difficulty. One hypothesis predicts that mind wandering should be more frequent in the easy text condition than in the difficult text condition. This is compatible with Smallwood and Schooler's executive-

resource hypothesis: difficult tasks utilize more attentional resources, thereby yielding less resources for mind wandering to occur. An alternative hypothesis predicts that mind wandering should be more prominent while reading difficult texts compared to easy texts because readers are likely to experience more difficulty in constructing situation models for the difficult texts.

Method

Participants

Participants were 80 undergraduate students, from a large U.S. University who received course credit for their participation.

Materials

The texts were 8 passages from the Nelson-Denny Reading Comprehension test, version E (Brown, Bennett, & Hanna, 1981). These 8 passages were used in the difficult text condition. Each passage was modified to create an easier version. This was done by simplifying the syntactic structure of sentences and substituting low frequency words with higher frequency ones. The average Flesch-Kincaid Grade level scores for the difficult and easy sentences in the texts were 10.9 and 8.9, respectively ($t(243) = 3.706, p < .001$). The average numbers of sentences in the difficult and easy versions of the texts were 13.4 ($SD = 6.89$) and 17.0 ($SD = 10.64$), respectively, ($t(14) = .809, p = .432$). The mean numbers of words in the difficult and easy versions of the passages were 261.3 ($SD = 152.2$) and 255.3 ($SD = 163.7$), respectively, ($t(14) = .076, p = .941$). These results suggest that our text difficulty manipulation was successful because it lowered readability while preserving verbosity.

The 8 passages and their content were ordered in the same manner as in the Nelson-Denny Reading Comprehension Test for all participants (passages 1 through 8). There were two sets that counterbalanced whether a text was easy or difficulty. For Set 1 the difficult passages

were the odd number passages (passages 1, 3, 5, and 7) and the easy passages were the even number passages (passages 2, 4, 6, and 8). The opposite assignment of passage difficulty occurred for Set 2. All subjects read 4 difficult and 4 easy passages and were randomly assigned to either Set 1 or Set 2.

Multiple-choice comprehension questions from the Nelson-Denny test followed every passage. Passage 1 was approximately 3 times as long as the other passages and had 8 comprehension questions. The remaining 7 passages had 4 comprehension questions, thereby yielding a total of 36 comprehension questions. Each text was analyzed to identify information in the text that corresponded to an answer to one of the comprehension questions and thought probes were inserted at these text positions. The number of probes per text varied from 2 to 7 and was determined by the number and nature of the Nelson-Denny reading comprehension questions. Whole passage comprehension questions (e.g. “the purpose of this passage is to?”) had no thought probes since answers to these questions could not be linked to a single position in the text. Set 1 had a total of 28 thought probes and Set 2 had a total of 27 thought probes. The difference in the number of thought probes between the two sets was due to how the sentences were split when creating the easy different versions of the texts; this discrepancy is addressed in the Results Section.

Procedure

Experimental instructions and passages were presented on a computer monitor. Participants first read a definition of mind wandering that was largely taken from previous studies (see Smallwood & Schooler, 2006 for review): “Mind wandering is a term used to describe what occurs when your attention wanders from a task. Sometimes when your mind wanders, you begin thinking about personal events or concerns rather than your task. At other

times, your mind can wander because you are bored or tired and you don't really know what you're thinking about; all you know is that you are no longer thinking about your task." They were then instructed to read each passage one sentence at a time using the spacebar to advance sentences. Participants could not go back to re-read a sentence once they had advanced to the next sentence. Participants were periodically interrupted during reading to respond to a thought probe that read "were you mind wandering when you read the previous sentence." They reported whether they were thinking about the task or were having thoughts that were unrelated to the task by pressing keys labeled "yes" and "no." Reading times were recorded for each sentence. The comprehension questions were presented after each passage.

Results

The present analysis focused on sentences in the text that had thought probes that corresponded to comprehension questions. There were 2,200 original sentences that matched this criterion across all participants. Two probes were removed from each participant assigned to Set 1 and one probe was removed from each participant assigned to Set 2 for Passage 6 due to uneven counterbalancing and ambiguity of the reading comprehension question that corresponded to them. This yielded a set of 2,080 probes after probe removal. The primary dependent measures for each sentence were reading time, mind wandering response (0 for no and 1 for yes) and performance on the comprehension question (0 for incorrect and 1 for correct) for that sentence.

An examination of the sentence reading time distributions signaled the presence of some outliers that could potentially skew the results. To address this, the shortest 1% (RTs < 395 ms) and longest 1% (RTs > 24640 ms) reading times were replaced with values corresponding to the lowest (395 ms) and highest (24640) one percentile, respectively. A total of 41 RTs, 30 from the

difficult and 11 from the easy texts, were replaced by this procedure. Analysis of the RT data both with and without outlier replacement yielded the same results.

A mixed-effects modeling approach was adopted to analyze the data because of the repeated and nested nature of the design. The lme4 package in R (Bates & Maechler, 2010) was used to perform the requisite computation. The unit of analysis was an individual sentence, so there were 2,080 cases in the data set. Linear or logistic models were constructed on the basis of whether the dependent variable was continuous (reading times) or binary (mind wandering and reading comprehension), respectively. The random effects were: *subject* (80 levels), and *sentence*, which had a unique number to identify each sentence with a thought probe (26 levels). *Condition* was a two-level (*difficult* and *easy*) categorical fixed effect with the easy condition set as the reference group. An alpha value of .05 was adopted for all significance testing and two-tailed tests were used.

Reading Times

A mixed-effects linear regression model using text difficulty to predict sentence reading times was significant, $F(1, 2078) = 150, p < .001$. There was a 1544 ms (i.e., $B = 1544, SE = 126, p < .001$) increase in reading time when participant's read the difficult ($M = 7164, SD = 2719$) vs. easy ($M = 5625, SD = 1914$) versions of the sentences. This provides some additional evidence in support of our text difficulty manipulation.

Mind Wandering Frequency

A mixed-effects logistic regression model that detected the presence (coded as a 1) or absence (coded as a 0) of mind wandering with text difficulty as a fixed effect yielded a significantly better fit than a model with only the random effects but without the fixed effect, $\chi^2(1) = 4.49, p < .05$. The coefficient was .212 ($SE = .098, p = .031$), which indicates that

participants were 1.24 ($e^{0.212}$) times more likely to mind wander when reading a difficult sentence compared to an easy sentence. Mean proportion of mind wandering was .423 for the difficult texts and .362 for the easy texts.

There was the concern that the increased mind wandering in the difficult condition might be confounded by the longer reading times for the probe sentences in the difficult texts because longer tasks provide more opportunities for mind wandering than easier tasks. Fortunately, overall reading times (in minutes) for the four difficult texts ($M = 5.50, SD = 2.26$) were not statistically different from overall reading times for the four easy texts ($M = 5.25, SD = 2.14$), $t(79) = .727, p = .470$). In addition, Spearman's correlations between overall reading times and the proportion of mind wandering were very small and not significant ($\rho = -.053, p = .640$ for the difficult texts; $\rho = .108, p = .341$ for the easy texts), suggesting that overall reading time was not related to mind wandering.

Additionally, our findings cannot be attributed to simple fatigue effects because (a) easy and difficult texts were interleaved, (b) average task time was 18 minutes and 13 seconds ($SD = 4$ minutes and 23 seconds) which is quite short, and (c) text order (i.e., first, second, third, etc.) did not correlate with the proportion of mind wandering (Spearman's $\rho = .038, p = .337$).

Reading Comprehension

On average, participants answered 61.9 % of the questions correctly for the easy texts and 56.2% for the difficult texts. A mixed-effects logistic regression model that detected a correct (coded as a 1) or incorrect (coded as a 0) response on the comprehension test was not significant, $\chi^2(1) = 3.16, p = .075$. Participants were 1.20 times ($B = -.185, SE = .103, p = .075$) less likely to answer correctly on a comprehension test item when they read the difficult vs. easy version of

the texts. This effect was not statistically significant with respect to an alpha of .05 and therefore should be taken as a tentative finding.

Mind Wandering, Reading Times, and Reading Comprehension

We investigated if mind wandering predicted reading times by regressing sentence reading time on the presence or absence of mind wandering (for that sentence). The resultant mixed-effects linear regression model was significant, $F(1, 2078) = 41.4, p < .001$. Reading times increased by 958 ms when participants were mind wandering compared to when they were on task ($B = 958, SE = 149, p < .001$). Mind wandering also predicted reading times after controlling for condition (i.e., including condition as a fixed effect, $F(1, 2077) = 36.9, p < .001, B = 875, SE = 144$). We also investigated if mind wandering moderated the effect of text difficulty on reading times by including the *mind wandering* \times *text difficulty* interaction term as a fixed effect. However, this did not yield a significant model, $B = -34.89, SE = 40.92, F(1, 2076) = .727, p = .394$.

A logistic regression model that regressed response correctness for comprehension questions on mind wandering was significant, $\chi^2(1) = 11.3, p < 0.001$. Participants were 1.5 times less likely ($B = -.387, SE = .113, p < .001$) to respond correctly to a comprehension question on a sentence if they mind wandered while reading that sentence.

Finally, we investigated if mind wandering moderated the effect of text difficulty on comprehension scores by including the *mind wandering* \times *text difficulty* interaction term as a fixed effect. The interaction was significant ($B = .110, SE = .039, F(1, 2076) = 7.716, p < .01$) and is depicted in Figure 1. The interaction was probed by regression comprehension scores on mind wandering separately for the easy vs. difficult texts. The results indicated that mind wandering did not negatively influence reading comprehension for the easy texts ($B = -.143, SE$

= .160, $p = .373$) but had a substantial negative influence for the difficult texts ($B = -.625$, $SE = .158$, $p < .001$). Indeed, participants were 1.87 times less likely to answer correctly on an item on the comprehension test if they mind wandered while reading a difficult text on that item.

General Discussion

The goal of this experiment was to examine text comprehension as a function of mind wandering and text difficulty. In this section, we align the findings with our hypotheses, discuss limitations, and consider extensions of future research.

Major Findings

The results indicated that mind wandering interacted with text difficulty in predicting reading comprehension. Specifically, mind wandering had a substantial negative effect on comprehension when the text was difficult to comprehend. This finding is consistent with Smallwood and Schooler's (2006) executive-resource hypothesis which posits that mind wandering impairs performance more when the primary task is difficult. However, the present study indicated that mind wandering was more frequent in the difficult than in the easy condition, which is inconsistent with previous studies that have found that task difficulty is associated with a reduction in the frequency of mind wandering. It is also contrary to Grodsky and Giambra's (Giambra & Grodsky, 1989; Grodsky & Giambra, 1990/1991) finding that passage difficulty was not related to mind wandering.

The finding that there was more mind wandering in the difficult condition can be best explained by the situation model view which posits that mind wandering increases when readers have difficulty constructing a situational model from the text (Smallwood, 2011; Smallwood et al., 2008). Specifically, when a text affords the construction of a situation model, attentional resources and text comprehension processes work in tandem. Attentional resources that attend to

the primary task can suppress off-task thoughts that are competing for attention. The longer reading times, and lower, albeit not significant ($p = .075$), comprehension scores associated with the difficult text provide some tentative evidence that participants were less successful in constructing situation models when reading these texts, which might lead to more mind wandering.

Our study also showed that reading time was longer when subjects mind wandered than when they were on task. Previous research involving low-level perceptual tasks have found that reaction times are often faster when participants mind wander than when they are on-task (e.g. Smallwood, et al., 2004). However, reaction times are often slow when participants mind wander in actively engaging tasks such as word encoding (Smallwood, Obonsawin, & Heim, 2003a; Smallwood, Baraciaia, Lowe, & Obonsawin, 2003b) and, in our study, a high-level processing task of reading.

Limitations and Future Directions

There are some potential limitations in our study that warrant further investigation. First, the role of interest was not investigated. The lack of a measure of interest might be a limitation because previous studies have shown that interest is negatively related to mind wandering (Giambra & Grodsky, 1989; Grodsky & Giambra, 1990/1991; Smallwood, Nind, & O'Connor, 2009). It might be the case that interest in the text has a compensatory effect on the relation between text difficulty and mind wandering. Mind wandering may occur more often while reading difficult texts, but only among disinterested participants. The question of whether interest moderates the effect of text difficulty on mind wandering awaits future research.

Another consideration is that our task was a sentence-by-sentence self-paced task, which may deviate from normal reading tasks in which the reader has the entire referential context in

view during reading. For future studies it would be helpful to assess whether text difficulty predicts mind wandering after controlling for differences in the style of text presentation. Reading tasks that are timed versus self-paced may also impact mind wandering. When participants are pressed on time, they may make more effort to comprehend the difficult texts than if they are reading at their own pace. Experimenter-paced presentations of text may reduce mind wandering because readers would need to allocate more attentional resources to successfully comprehend the texts due to time constraints. In future experiments it would be interesting to investigate whether the data would show the same pattern with timed tasks.

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Figure 1. Mind wandering and comprehension as a function of text difficulty.

