Can reading time predict mind wandering in expository text?

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Summary
Prior research has suggested that episodes of mind wandering not only negatively impact text comprehension but also are associated with fluctuations in reading behavior. However, these studies typically do not account for differences in the fundamental nature of the text itself, namely, whether it is narrative or expository in structure. As much research has supported the idea that these text genres are processed differently, it is of interest to determine whether similar changes in reading patterns are observed when mind wandering in an expository text. The present study examined whether fluctuations in sentence-by-sentence reading times were associated with periods of mindless reading during processing of an expository text. Results indicated that although mindless reading did negatively impact learning, probed reading time did not vary as a function of mind wandering. These results suggest that research aimed at studying mind wandering while reading may need to account for text genre.

1 | INTRODUCTION

Sometime during their formal schooling, nearly every individual has had the experience of reading “mindlessly” whereas their eyes move along the page but they cannot remember what they just read. This often disconcerting experience is commonly known as mind wandering and represents an attentional shift away from the task at hand (in this case reading) towards other unrelated, self-generated, thoughts. Unfortunately, such lapses are not innocuous, as the occurrence of such mind wandering episodes has been consistently linked to declines in performance in multiple areas such as sustained attention tasks (McVay & Kane, 2012b), learning from lectures (Risko, Anderson, Sarwal, Engelhardt, & Kingston, 2012; Szpunar, Khan, & Schacter, 2013), and reading comprehension (McVay & Kane, 2012a).

As there appears to be a strong connection between mind wandering and changes in performance, it is important to find accurate ways of identifying and predicting such lapses of attention. Multiple methodologies have been utilized in the past to capture mind wandering, ranging from the more explicit or obvious (e.g., probes and self-caught response; see Mooneyham & Schooler, 2013, for a review) to the more implicit or transparent to the participant (e.g., reading time and eye movements; Smallwood, McSpadden, & Schooler, 2008; Smallwood et al., 2011; Reichele, Reineberg, & Schooler, 2010). More explicit measures attempt to diagnose mind wandering by saliently querying participants on their current state of mind, whereas more implicit measures do not have this obvious or overt focus on mind wandering or even state of mind. In other words, more implicit measures such as reading time do not, in anyway, inform the participant regarding the nature of their measurement and thus minimize the effect that any subject reactivity could occur as they are functionally transparent to the participant.

However, these different methodologies do each have their own strengths and weaknesses. Although some argue that explicit probing is perhaps the best way to capture mind wandering behavior (Schooler, Reichele, & Halpern, 2005), a major criticism that could be levied against the use of explicit methods is that such noticeable breaks in the reading process could themselves produce reductions in comprehension that interact with (or perhaps are exacerbated by) mind wandering. Forcing participants to halt midtext to process unrelated information has been shown previously to negatively impact reading comprehension (Connelly, Hasher, & Zacks, 1991; Hakala & O’Brien, 1995). Even providing explicit, but secondary, distractions (e.g., music in the background) while reading can reduce learning from text (Martin, Wogalter & Forlano, 1988). These results suggest that inducing explicit breaks in attentional focus while reading (as is the case with an overt mind wandering probe) may in fact produce a demand characteristic that potentially interacts with mind wandering behaviors. At the very least, such findings caution that explicit probing may not be the standard by which other mind wandering metrics should be judged, and that conceivably other metrics might also be worth considering.

Perhaps because of such concerns and others, some researchers have turned to less invasive (and more implicit) measures to capture mind wandering, using metrics such as reading time (Franklin, Smallwood, & Schooler, 2011), eye movements (Reichele et al., 2010;
A long history of text-processing research has identified several differences in how different text genres are structured, processed, and subsequently learned (see Weaver & Kintsch, 1991). For example, not only do readers engage in different types of processing strategies across different text genres, but the availability of strategies is often a direct result of prior exposure to the expository genre, suggesting potential influences of prior knowledge or perspective (Best, Floyd & McNamara, 2008; Englert & Hiebert, 1984). Readers also tend to process expository texts faster (Zwaan, 1994), focus more on details (Einstein, McDaniel, Owen, & Cote, 1990; Mayer, 1996), and are sometimes less metacognitively aware of their learning (Weaver & Bryant, 1995) when compared with narrative texts. Eye movement studies have also demonstrated that readers make more regressions, shorter saccades, and longer fixations within expository texts (Hyönä, Lorch, & Kaakinen, 2002; Rayner, 1998). Finally, there is also some electrophysiological evidence to suggest that these texts even elicit differential brain activity (Baretta, Tomitch, MacNair, Lim, & Waldie, 2009).

Further, as the primary function of narrative text is to tell a story that is often closely tied to themes of everyday experience (of which the reader likely possesses a higher level of familiarity with), it is not surprising that narrative texts often also produce deep affective reactions within readers (Graesser, Singer, & Trabasso, 1994). This affective reaction is often not inspired in expository texts, which serve the unidimensional purpose of conveying conceptual and factual information to the reader. Given that expository texts often introduce unfamiliar key terms and concepts, do not follow the simple and well-known narrative structure, and also require readers to generate causal inferences not explicit in the text (Berman & Nir-Sagiv, 2007; Graesser, McNamara, & Louwerse, 2003), it is perhaps not surprising that readers do not feel a strong emotional connection to the material presented in these texts. However, this distinction is especially important relative to mind wandering as situational factors such as topic interest, motivation, and mood (McVay & Kane, 2010, 2013; Smallwood, Fitzgerald, Miles, Phillips, 2009; Unsworth & McMillan, 2013) have been shown to impact the likelihood of producing mind wandering behaviors. In one of the few studies of mind wandering that includes both narrative and expository texts, Kane and McVay (2012) found a positive relationship between mind wandering measures and narrative text comprehension, but this was not found consistently for expository text comprehension. This further highlights the need for studies examining metrics of mind wandering, including more implicit measures, and expository text comprehension.

For these reasons, it is of primary interest to understand whether previous findings from the study of mind wandering in narrative text reading transfer to expository applications. Thus, the current research seeks to address a critical theoretical shortcoming within the mind wandering literature, by expanding this investigation to academically relevant text that is not narrative in structure. Although it is naturally expected that the presence of mind wandering will negatively impact understanding of an expository text, it is not known whether implicit reading behaviors likewise vary as a result of mind wandering when reading or whether previously found reading differences are instead an artifact of narrative text processing. This question has serious implications for the accurate assessment of mind wandering behavior and the ability to develop interventions for academic settings to avoid some of the potential pitfalls of mind wandering and lower learning (Smallwood, Fishman & Schooer, 2007).

To evaluate these questions, a study was conducted in which participants were asked to read and learn an expository text. During reading, both implicit and explicit measures of mind wandering were captured. These measures were then related to subsequent comprehension of the text to examine the potential relationships between different mind wandering metrics and learning.

2 | METHOD

2.1 | Participants

A total of 104 undergraduates (78% female, 20% male, 2% declined to report gender) from a large public university in the United States were recruited for participation. All participants were native English speakers and compensated with course credit in an undergraduate psychology course.


2.2 | Materials

2.2.1 | Target text and reading time metrics

Participants read an expository text adapted from Sanchez and Goolsbee (2010), which provided information about the African country of Djibouti. This text contained information about the geographical location, topographical layout, climate, wildlife, economic stability, ethnic makeup, observed religion, transportation, and government of the country and was originally adapted from Encarta Online Encyclopedia (Microsoft, 2008). This text was 1,212 words long, and participants were allowed to read at their own pace. Participants were informed that they would be tested on the material afterwards. A sample of this text is available in the Appendix.

Importantly, this text was presented in a sentence-by-sentence format, and participants advanced to the next sentence by pressing the SPACEBAR. This methodology has been used previously to examine how mind wandering affects reading behavior in narrative texts such as War and Peace (Franklin et al., 2014). Reading times for each sentence were recorded for all sentences. These sentence reading times were then aggregated to provide a metric for the average time spent reading the text. Importantly, sentence reading times immediately before the administration of the thought probes (described below) were of particular interest. To evaluate reading times immediately preceding the probes, the reading time for the sentence preceding the probe was recorded (i.e., prior to the actual probe) and then divided by the number of words in this sentence. This averaging controls for any differences in the length of the sentence that preceded the probe and also allows comparisons with other studies that recorded word-by-word presentation times. To be clear, the probe reading times (PRT) discussed below represent the average reading time per word, for only the sentence immediately preceding the probe, averaged across all three probes.

2.2.2 | Training text

Prior to reading the Djibouti text, participants also read a control text (151 words) on the African country of Chad to acclimate themselves with the procedure of reading sentence-by-sentence. This was to ensure that any reading time differences observed were due to textual processing and not related to unfamiliarity with the sentence-by-sentence reading procedure.

2.2.3 | Text memory measure

To evaluate how well participants were able to learn the material presented in the text, participants were asked to complete 10 multiple-choice questions after they had finished reading the text. Example questions were “What is Djibouti’s main export?” and “What mammals can be found in Djibouti?” Participants were not allowed access to the Djibouti text while completing the learning measure.

2.2.4 | Thought probes

This measure was adapted from McVay and Kane (2012b). Roughly every 300 words (i.e., three times during reading), participants were prompted to respond to the following probe: “What were you just thinking about? Please be honest. Press the # that corresponds with your choice.” This probe occurred between sentences, after participants had pressed the spacebar. Participants were asked to select between seven different responses: (1) the text, (2) task performance, (3) everyday stuff, (4) current state of being, (5) personal worries, (6) daydreams, or (7) other. Responses 1 and 2 were coded as on-task thoughts and 3–7 were coded as task-unrelated thoughts (TUTs). After responding to a given probe, participants proceeded to read the remaining portion of the text.

The number of thought probes in which readers indicated mind wandering behavior was then aggregated into a measure of the frequency of TUTs, with higher scores indicating more mind wandering at the time of the probe.

2.2.5 | Posttask questionnaire

Immediately after completing the comprehension measure, participants were given the posttask questionnaire. Participants were first asked to provide ratings of perceived difficulty of learning the text on a scale of 1–6 (1 = not at all difficult, 6 = very difficult). This question was included to permit a consideration of perceived difficulty as an additional moderating factor related to mind wandering and performance (Feng, D’Mello, & Graesser, 2013). This questionnaire also included a second portion that contained eight questions drawn from both the Memory and Attention Lapses subscale of the Cognitive Failures Questionnaire (McVay & Kane, 2009) and the Mind Wandering Questionnaire (Mrazek, Phillips, Franklin, Broadway, & Schooler, 2013). As such, this questionnaire allowed participants to self-report both the degree to which they mind wandered during the current experiment and how often they normally experience such behavior in everyday life. Example questions were “I find myself running on automatic without much awareness of what I am doing” and “I mind wander during lectures and presentations” on a 6-point Likert scale (1 = not at all, 6 = almost always). The maximum score on the mind wandering portion of the questionnaire was 48.

2.2.6 | Operation span

A measure of working memory capacity (WMC) was included in the current study as it has been shown to be related to both reading comprehension (Daneman & Merikle, 1996) and frequency of mind wandering (Kane et al., 2007; McVay & Kane, 2012a). All participants completed a computerized measure of WMC, operation span (OSpan; Unsworth, Heitz, Schrock, & Engle, 2005). OSpan consists of several trials in which participants are required to evaluate the correctness of simple math equation and then remember a target letter (e.g., 2 * 1 + 1 = 4? F). Set sizes vary between two and five equations per sentences, and there are three instances of each trial size in this task (randomly ordered). Participants whose equation verification accuracy was below 85% were not retained for any further analyses (Conway et al., 2005).

2.3 | Procedure

The entire study took place over a single 1-hr session. Upon arriving, participants first completed the OSpan task. Participants then read the training text to familiarize themselves with the reading procedure. Once this was completed, participants then proceeded to read the target text and were probed for off-task thought during reading.
Immediately after they finished reading, participants then completed the text memory test and then the posttask questionnaire. When all tasks were completed, participants were debriefed and dismissed.

3 | RESULTS

Descriptive statistics for all measures are available in Table 1. To evaluate general patterns of relationships, simple correlations were computed between all measures. These correlations are presented in Table 2.

Several interesting patterns are visible in Table 2. To begin, more frequent TUTs were related to faster overall reading times, and these probe responses also correlated with posttest evaluation, again consistent with prior research (Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Smallwood & Schooler, 2006). Text memory was negatively correlated with both the number of TUTs and also the posttest mind wandering questionnaire. However, text memory was not correlated with PRT nor overall reading time. This suggests that although measures of mind wandering were related, only the more explicit measures of mind wandering used here demonstrated a relationship to text memory.

Although the number of TUTs was not significantly correlated with WMC in this sample ($r = -.18$, $p < .07$), the magnitude of this correlation is consistent with values found in prior research (Kane & McVay, 2012; McVay & Kane, 2012a). To better examine some of these complex relationships between variables, an additional analysis was then conducted.

In order to gain a better understanding of the various factors that might impact memory of expository text simultaneously, a hierarchical linear regression was conducted. WMC, frequency of TUTs, posttest mind wandering questionnaire, PRT, overall text reading time, and estimates of text difficulty were all entered into the first block of the model to predict learning of the text. To then examine whether the frequency of TUTs interacted with PRT, an interaction term between these factors was entered in the second block of the model.

Results indicated that the first block of the model predicted a significant portion of the text memory variance, $R^2 = .15$, $F(6, 97) = 2.95$, $p < .01$. However, only TUTs ($β = -.27$), PRT ($β = -.33$), and overall reading time ($β = .25$) significantly predicted text memory ($p < .05$). All other factors failed to approach statistical reliability. These results indicate not only that more frequent TUTs indicate poorer memory for text but also that longer PRTs likewise predicted lower remembering, which is perhaps evidence of a “zoning out” behavior. Interestingly, and consistent with a notion that more careful general patterns of reading produce better understanding of a text, higher overall reading time was also predictive of better memory for text details.

However, did the implicit PRT measure vary as a function of mind wandering? The interaction term between PRT and the frequency of TUTs was entered in the second block of the analysis. The addition of this interaction term failed to predict a significant portion of additional variance ($ΔR^2 = .008$, $p > .05$), suggesting that these factors do not interact to predict text memory. This suggests that more frequent mind wandering is not indicative of different reading patterns at the time of the probe, and PRTs are perhaps reflective of some other factor that is related to text memory. Although it is not clear what this factor might be, regardless, it does seem to cast doubt on whether reading times are a useful measure of diagnosing mind wandering behavior in expository texts.

4 | DISCUSSION

The current study sought to extend previously found results on reading behavior and mind wandering to expository text applications.

### Table 1 Descriptive statistics for all measures

<table>
<thead>
<tr>
<th>Measures</th>
<th>M (SD)</th>
<th>Skew</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation span</td>
<td>57.33 (8.85)</td>
<td>-0.43</td>
<td>-0.61</td>
</tr>
<tr>
<td>Frequency of task-unrelated thoughts</td>
<td>0.77 (0.93)</td>
<td>1.15</td>
<td>0.52</td>
</tr>
<tr>
<td>Posttest mind wandering questionnaire</td>
<td>4.06 (0.69)</td>
<td>-0.23</td>
<td>0.08</td>
</tr>
<tr>
<td>Text difficulty</td>
<td>3.16 (1.34)</td>
<td>-0.01</td>
<td>-0.99</td>
</tr>
<tr>
<td>Learning</td>
<td>7.10 (1.49)</td>
<td>-0.11</td>
<td>-0.90</td>
</tr>
<tr>
<td>Average probe reading time per word (ms)</td>
<td>433.15 (106.89)</td>
<td>0.43</td>
<td>-0.61</td>
</tr>
<tr>
<td>Overall reading time (ms)</td>
<td>475,544.04 (108,167.55)</td>
<td>0.30</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

### Table 2 Pearson correlation coefficients between all measures

<table>
<thead>
<tr>
<th>Measures</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Operation span</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Frequency of task-unrelated thoughts</td>
<td>-.18</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Posttest mind wandering questionnaire</td>
<td>-.20*</td>
<td>.37*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Text difficulty</td>
<td>.18</td>
<td>-.04</td>
<td>.04</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Learning</td>
<td>.08</td>
<td>-.30*</td>
<td>-.19*</td>
<td>-.01</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Average probe reading time per word (ms)</td>
<td>-.04</td>
<td>-.14</td>
<td>.05</td>
<td>.18</td>
<td>-.12</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7. Overall reading time (ms)</td>
<td>.02</td>
<td>-.22*</td>
<td>-.03</td>
<td>.14</td>
<td>.09</td>
<td>.68*</td>
<td>1</td>
</tr>
</tbody>
</table>

*p < .05.*
Overall, the pattern of results do largely replicate previous studies on mind wandering and narrative reading but do offer some key refinements. For example, consistent with past research, higher incidences of mind wandering (assessed both using explicit TUTs and a postreading mind wandering questionnaire) were associated with poorer reading comprehension in an expository text (Kane & McVay, 2012; McVay & Kane, 2012a, 2012b).

However, although mind wandering was associated with shorter overall reading times and lower learning, PRT behavior was not associated with any variation in mind wandering. However, PRT was associated with text memory, such that longer captured PRTs were indicative of less remembering overall. These results suggest that mind wandering during the reading of expository text does indeed reduce text understanding. However, this negative relationship was not directly connected to differences in PRT.

These results thus do stand in contrast to the findings of Franklin et al. (2011), who found that reading time behaviors like the PRT are indeed associated with explicit reports of mind wandering. Whereas they demonstrated that mindless reading could be predicted by faster reading times at specific times during narrative text comprehension, we found that the same is unfortunately not true for expository text. Given the large differences in the structure and usage of these different text genres, it is possible that expository text characteristics are somehow attenuating or eliminating these previously found reading differences. For example, overall faster reading times in expository texts might reduce the ability to detect faster reading as a result of mind wandering (Zwaan, 1994). Although the current study did not explicitly evaluate a matched narrative text, an interesting question for future research might be to explore what specific expository characteristics (if any) might obfuscate the detection of these reading time differences. Further, it must be noted that because of the potential for these kinds of cross-genre differences, it may also not be possible to identify an appropriately matched narrative text. At the very least, this perhaps emphasizes a major point of the current investigation, namely, the potential incommensurability that might exist across text genres related to measures designed to capture mind wandering behavior.

Finally, it must be noted that not all studies on mind wandering and reading narrative text do find probed reading time differences (Krawietz et al., 2012), and some also find that individuals who mind wander actually read longer at the time of probe (Foulsham et al., 2013). This again highlights the need to consider such pragmatic issues as text genre when deciding on the use of implicit measures such as the PRT. In short, researchers must realize that text-specific features might affect the utility of different metrics used to identify mind wandering, and they should plan accordingly based on task constraints.

Related to this point, the current pattern of results broadly suggests that some implicit measures of reading behavior might not be an ideal means of identifying mind wandering and that perhaps more explicit measures might provide more effective detection of mind wandering (consistent with Schooler et al., 2005). However, it is also entirely possible that other online reading metrics, not measured here, might be better predictors of expository text comprehension. For example, previous research that eye-tracked participants as they read narrative text has been able to identify very detailed and specific estimates of reading behavior relative to mind wandering (Reichle et al., 2010; Schad et al., 2012; Uzzaman & Joordens, 2011). Perhaps this more detailed (and complex) methodology might be likewise fruitful in applications to expository text. However, from an applied perspective, it must also be recognized that such investigations, although perhaps theoretically useful, are somewhat lacking in their practical utility for educational interventions, due to the cost and availability of eye-tracking equipment. For example, it is unfortunately just not feasible to measure eye movement behavior for entire classrooms of students simultaneously and thus provide interventions in real time in any kind of useful way. Simple reading times (such as those measured here), however, are simple low-cost metrics that could be easily measured by classroom computers and then leveraged to keep students focused while reading. As such, it may be worth exploring other simple reading behaviors in concert with these more advanced studies that also incorporate eye movements, with the ultimate goal of identifying not only accurate but also easy-to-implement measures of mind wandering.

In closing, mind wandering remains a fascinating topic of study due to its ubiquitous nature and the robust effects it has on human performance. Whereas recent work has sufficiently validated mind wandering as an important part of the human experience, our results suggest that it is important for researchers to also consider how the processing demands of a given text interact with this mind wandering behavior to shape reading and learning. Further refinement of these implicit metrics will certainly benefit the study of mind wandering by dismissing methodological criticisms and lead to innovative new strategies for improving comprehension and academic engagement in situ.

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REFERENCES
Example Djibouti text:

...Djibouti has an area of 8,960 square miles. It extends 120 miles from north to south and 140 miles from east to west. The country is bordered by Eritrea to the north; Ethiopia to the north, west, and south; and Somalia to the southeast. To its east lies the Gulf of Aden, an arm of the Indian Ocean. The Gulf of Tadjoura extends over 60 miles into Djibouti from the east coast. Plateaus and mountains rise above narrow coastal plains to the north and south of the gulf. The country’s highest point, Moussa Ali 6,768 feet, is on the northern border, at the junction of the Ethiopian and Eritrean boundaries. Western Djibouti is desert lowland with depressions containing several salt lakes. The largest, Lake Abbé, lies on the Ethiopian border. Another, Lake ‘Asal, is the lowest point in Africa at 502 feet below sea level. Djibouti has a potential for generating geothermal energy and limited deposits of gypsum, copper, and other ores, which are not exploited. Very little of the country’s land is arable, and there are no regularly flowing rivers or streams. Djibouti relies on an underground aquifer for fresh water.

The country has a climate that is hot and dry year-round, but it is especially hot and dry in the summer, when winds blow from the inland desert. In the capital, average daily temperatures range from 73° to 84°F in January and from 87° to 106°F in July. Annual rainfall ranges from 5 inches in the capital to 15 inches in the mountains. Djibouti lies in an earthquake.