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THE RELATION BETWEEN WORKING MEMORY AND MIND WANDERING
HONORS THESIS

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Abstract

The purpose of this study was to examine the relation between working-memory capacity and mind wandering in light of two perspectives about how mind wandering should be conceptualized. The Resource Capacity view of mind wandering predicts a positive correlation between working-memory capacity and mind wandering, whereas the Executive Attention view of mind wandering predicts a negative correlation between the two. The results showed that the relation between working-memory capacity and mind wandering depended on how mind wandering was assessed. Working-memory capacity was positively related to self-caught mind wandering, but not related to probe-caught mind-wandering. In summary, the results of this study were consistent with the conceptualization of mind wandering as a resource-consuming phenomenon. An important question about the relation between working-memory capacity and mind wandering in this study is whether high working memory capacity is associated with more mind wandering or with better comprehension monitoring. Implications of the findings are discussed.

Key Words:
Cognitive resources, comprehension monitoring, executive attention, executive control, mind wandering, reading comprehension, task interest, task difficulty, working-memory.

Introduction

The Relation between Mind Wandering and Working Memory

Mind wandering is a pervasive cognitive phenomenon in which attention shifts away from a primary task toward task-unrelated thoughts and feelings (Smallwood, & Schooler, 2006; McVay & Kane, 2010). The frequency of mind wandering varies according to the type of task, occurring ~ 15% of the time in verbal fluency and memory encoding tasks (Smallwood, Obonsawin, & Heim, 2003), ~20% of the time during reading (Schooler, Reichle, & Halpern, 2005), and ~50% of the time during a simple signal detection task (Antrobus, 1968; Giambra, 1995; Smallwood, O'Connor, et al., 2004). Mind wandering in daily life constitutes between 30-40% of reported thoughts (Klinger & Cox, 1987).

Two self-report methods are commonly used to assess mind wandering. In probe-caught mind wandering, participants are asked to report their mind wandering experiences at pre-determined intervals in response to probes. In self-caught mind wandering, participants are asked to monitor their thoughts and to report mind wandering experiences whenever they are aware of them. Self-caught measures require participants' awareness of their own mind wandering (Schooler, Reichle, & Halpern, 2005). Self-caught measures may increase mind wandering frequency artificially due to task demands (Nisbett, & Wilson, 1977); however, they are useful in understanding how individuals monitor their on-task and off-task behavior (Smallwood, & Schooler, 2006).

The goal of the current study was to examine the relation between working-memory capacity and mind wandering. The issue is interesting in light of two different theories of the nature of mind wandering. In one theory, the Resource Capacity view, mind wandering is a mental activity that competes with on-task thoughts for limited cognitive resources. In the other theory, the Executive Attention view, mind wandering is a failure of top-down executive control. These theories make different predictions about the relation between working memory capacity and mind wandering as detailed below.

Mind Wandering from a Resource Capacity View

Working-memory resources are used for coordinating and maintaining task-relevant information in awareness. According to the Resource Capacity view (Smallwood & Schooler, 2006) of mind wandering, mind wandering competes for the same limited working-memory resources as does any task that relies on controlled processing. When processing is devoted to a resource-demanding task, mind wandering will diminish because too few resources can be devoted to off-task thinking. If mind wandering does occur, performance on the primary task will be impaired because mind wandering will consume resources needed for optimal performance on the primary task (Smallwood, & Schooler, 2006).

The Resource Capacity view has been supported in studies examining factors that influence the frequency of mind-wandering. For example, mind wandering decreases as task difficulty increases (Antrobus, Singer, & Greenberg, 1966; Filler & Giambra, 1973; Forster & Lavie, 2009; McKiernan, D'Angelo, Kaufman, & Binder, 2006; Stuvyen, & van der Gouten, 1995; Teasdale, Lloyd, Proctor, & Baddeley, 1993), suggesting that mind wandering does not occur when the primary task consumes the majority of cognitive resources. In contrast, mind wandering increases when a task is well-practiced (Antrobus, 1968; Cunningham et al., 2000; Giambra, 1995; Small wood, Obonsawin, & Reid, 2003; Smallwood, Baracaia, et al., 2003; Smallwood, Davies, et al., 2004; Teasdale, Dritschell, et al., 1995; Smallwood, O'Connor, et al., 2004). Mind wandering is also affected by cognitive load. For example, Teasdale et al. (1993) had participants perform a dichotic listening task in which they did or did not have to remember the shadowed material. Performance was significantly worse in the memory than in the no-memory condition.

Mind Wandering from an Executive Control View

McVay and Kane (2010) propose a view of mind wandering that is largely based on Watkins' elaborated control theory (Watkins, 2008). Watkins posits that the levels at which goals are construed regulate thought content. According to the theory, goals can be construed at either a concrete or abstract level. At a concrete level of construal, an individual is focused on the means of achieving a goal (e.g., focusing on what needs to be done in the primary task to perform well). At an abstract level of construal, an individual is focused on thoughts about higher order goals (e.g., performing a primary task "on autopilot" while thinking about task-unrelated concerns). When one wants to perform well on difficult or novel tasks, a concrete level of construal is desired. When one is performing an easy or well-practiced task, an abstract level of construal can occur without impairing task performance.

According to McVay and Kane (2010), executive control is used for implementing the right level of construal for a given task. They argue that mind wandering is likely to occur because an abstract level of construal is the default mode of processing and that construal at an abstract level increases task-unrelated thoughts by activating a large network of related concepts (McVay, & Kane, 2010). According to their view, executive control works to prevent task-unrelated thoughts that are generated from an abstract level of construal. The occurrence of mind wandering signifies a failure of executive control to prevent task unrelated thoughts from entering conscious awareness. Executive control has to be initiated proactively to suppress mind wandering in difficult or novel tasks. According to McVay and Kane (2010), task-unrelated thoughts themselves do not consume executive resources because the default state of mind involves the generation of thoughts continuously and unintentionally without consuming resources. Mind wandering is a failure of executive control to successfully inhibit off-task thoughts when attention is devoted to a task (McVay, & Kane, 2010, p.191).

In support of the Executive Control View, studies have shown that individuals who score high on working-memory capacity tests report more on-task thoughts and fewer off-task thoughts during attention-demanding activities than do individuals who score low (Kane, Brown, et al., 2007; McVay & Kane, 2009; Kane et al., 2007; Unsworth, Brewer, & Spillers, 2012; Unsworth, & McMillan, 2012). Kane et al. (2007) also found a relation between working-memory capacity and mind wandering in a study assessing participants' daily-life experiences of mind wandering. They found that higher working-memory capacity individuals had fewer off-task thoughts than did lower working-memory capacity individuals during challenging, attention-demanding, and effortful activities. Other studies have found similar negative correlations between working-memory capacity and mind wandering, such that low working-memory capacity individuals have more task-unrelated thoughts than higher working-memory capacity individuals (McVay, 2010; McVay, & Kane, 2010; McVay, & Kane, 2012; Unsworth, & McMillan, 2013).

The Current Study

The goal of the current study was to examine the relation between mind wandering and working-memory capacity in the context of reading comprehension. Reading provides a useful context for studying the relation for several reasons. First, reading is a sustained attention task (Brock, & Knapp, 1996; Stern, & Shalev, 2013); past research has shown that task duration is a factor that influences the frequency of mind wandering (Smallwood, Obonsawin, & Reid, 2003). Second, both mind wandering and working-memory capacity are related to comprehension; mind-wandering impairs comprehension (McVay et al., 2012; Smallwood, 2011), whereas comprehension increases as a function of scores on tests of working-memory capacity (Daneman, & Carpenter, 1980). Finally, comprehension monitoring, a meta-cognitive ability, is an important factor in the construction of accurate and complete discourse representations. Thus, asking participants to monitor their off-task thoughts during reading may be less artificial than it is in other tasks.

The Resource Capacity view of mind wandering predicts a positive relation between mind wandering and working-memory capacity. Participants who are high in working memory capacity, relative to those who are low in capacity, should have resources to simultaneously perform a primary task and engage in task-unrelated thought. In contrast, the Executive Control view of mind wandering predicts a negative relation between mind wandering and working-memory capacity. Participants who are high in working-memory capacity, relative to those who are low in capacity, should exhibit better cognitive control; thus, they should be better at remaining on-task.

Participants read the first five chapters of *War and Peace*. Mind wandering was assessed by self-monitoring and by probes that were presented periodically during reading. Working-memory capacity was assessed by the reading span and operation span tasks.

Methodology

Participants

Participants were eighty undergraduate students from the University of California, Davis who participated in the experiment in exchange for course credit. Data from three participants were lost due to computer failure.

Materials

The reading materials consisted of the first five chapters of *War and Peace* (Tolstoy, 1869). A 54-item sentence recognition test was constructed to assess reading comprehension, consisting of 25 sentences selected from the first five chapters of *War and Peace* and 29 sentences that were randomly chosen from unread chapters of the book. A 10-item questionnaire was created to assess readers' interest in the text and its perceived level of difficulty. The questionnaire is presented in the Appendix.

Procedure

The study was conducted in two sessions that were administered no more than one week apart. In the first session, participants read *War and Peace*. The text was presented page-by-page on a computer screen. Reading was self-paced and readers advanced through the text by pressing a key.

Self-caught and probe-caught mind-wandering measures were adapted from Smallwood et al. (2003) and Teasdale et al. (1995). For the self-caught measure, participants were instructed to press a designated key whenever they found that their thoughts had deviated from understanding the text. When they pressed the key, a screen appeared asking them to report the degree to which they were on-task or off-task using a 5-point scale from completely on-task to completely off-task. Participants were also probed intermittently over the course of the reading task (probe-caught measure). Probes were administered at intervals of 3 to 5 minutes since the last mind-wandering episode (i.e., either self-caught or probe-caught). Intervals were selected at random from a normally distributed sample of times. Participants used the same 5-point scale to report their degree of on-task/off-task thought. It should be noted that readers who self-reported frequent off-task episodes received few mind-wandering probes because probes were presented only after 3-5 minutes of uninterrupted reading. Thus, we expected the frequency of probe-caught mind wandering to be negatively correlated with the frequency of self-reported mind wandering.

After reading the text, participants took the recognition test and the difficulty-and-interest questionnaire. In the second session, participants received the working-memory capacity tests. The reading-span task (Daneman & Carpenter, 1980) was comprised of 60 unrelated sentences, arranged as 20 trials in variable sets of 3 to 7 sentences. Sentence length ranged from 13 to 16 words. Each sentence was presented on a computer screen and participants were asked to read the sentence and make a sense/nonsense judgment about it. After each sentence, a letter was presented and participants were asked to store it for later recall. After receiving all of the sentences in a set, an array of letters was presented on the computer screen. Participants were asked to recall the letters in the correct order by clicking letters in the array (Unsworth et al., 2009). Reading span was calculated as the number of letters that were recalled in the correct order. Scores were included only for participants who responded with at least 80% accuracy on the sentence-judgment task.

The operation-span task (Turner, & Engle, 1989; Engle, Tuholski, Laughlin, & Conway, 1999) was comprised of 84 arithmetic problems in variable sets of 3 to 7 problems. Each problem was presented alongside its solution followed by a to-be-remembered letter. Participants were asked to read the problem and solution, judge whether the solution was correct or incorrect, and to commit the following letter to memory. Once all of the problems in a set had been presented, a letter array was presented. Participants clicked on the to-be-remembered letters in the order in which they had been presented in the set. Operation span was calculated as the number of letters that were recalled in the correct order. Scores were included only for participants who responded with at least 80% accuracy on the problem-judgment task.

Results

Correlations among items on the questionnaire were examined. The reverse scored items appeared to be problematic (items 2, 4, 7, 8, and 9) in that they did not correlate with the other items. Thus, these items were deleted from the data. Difficulty and interest scores were calculated as the sum of the item ratings .

To measure reading comprehension, a d' prime score was calculated from performance on the sentence recognition test. The score was calculated as the hit rate (i.e., proportion of yes responses to old items) adjusted for the false alarm rate (Brophy, 1986). A working-memory capacity score was calculated as the sum of the reading span and operation span scores. Self-caught mind wandering was calculated as the number of self-caught mind wandering episodes with a rating of 2 or above ($M = 11.75$, $SD = 10.67$) as was done in Smallwood et al. (2003) and Teasdale et al. (1995). Probe-caught mind wandering was calculated as the number of probe-caught mind wandering episodes with a rating of 2 or above. Descriptive statistics for all measures can be found in Table 1.

Bivariate correlations for all measures are presented in Table 2. Reading comprehension was positively correlated with interest. Participants comprehended the text better the more interested they were in it. As expected, self-caught mind wandering was negatively correlated with probe-caught mind wandering. Of primary interest was the relation between working-memory capacity and mind wandering. High capacity readers caught themselves mind wandering more frequently than low capacity readers. In contrast, no relation was found between working-memory capacity and probe-caught mind wandering. Finally, task difficulty was negatively correlated with interest such that readers who found the text more difficult found it to be less interesting.

Three regression analyses were conducted with self-caught mind wandering, probe-caught mind wandering, and reading comprehension (d' prime scores) entered as the respective dependent variables. With respect to self-caught mind wandering, task difficulty, interest, working-memory capacity, and reading comprehension explained a significant proportion of variance in self-caught mind wandering, $R2 = .172$, $F(4, 61) = 3.16$, $p = .020$. Only task difficulty ($B = .644$, $t(61) = 1.97$, $p = .054$) and working-memory capacity ($B = .135$, $t(61) = 3.13$, $p = .003$) significantly predicted self-caught mind wandering. Increased difficulty and higher capacity scores were associated with increased self-caught mind wandering. With respect to probe-caught mind wandering, the variables did not explain a significant proportion of variance, $R2 = .072$, $F(4, 61) = 1.183$, $p = .327$, although interest was a marginally significant predictor, B = .292, t(61) = 1.76, p = .08. With respect to reading comprehension, the predictor variables did not explain a significant proportion of variance, R2 = .092, F(4, 61) = 1.22, p = .311, only interest was a significant predictor of reading comprehension, B = .106, t(61) = 2.24, p = .03.

Discussion

The purpose of this study was to examine the relation between working-memory capacity and mind wandering in light of two perspectives about how mind wandering should be conceptualized. McVay and Kane (2010) have proposed that mind wandering occurs when executive control fails to prevent task unrelated thoughts from entering into conscious awareness. Their view predicts a negative correlation between working-memory capacity and mind wandering—high capacity readers should be better able than low capacity readers to prevent off-task thoughts from interfering with comprehension. In contrast, Smallwood and Schooler (2006) have proposed that mind wandering is a resource-demanding phenomenon and competes with other controlled processes for working-memory resources. Their view predicts a positive relation between working-memory capacity and mind wandering—high capacity readers should have resources to engage in off-task thoughts and still do well on the comprehension task.

The results showed that the relation between working-memory capacity and mind wandering depended on how mind wandering was assessed. Working-memory capacity and self-caught mind wandering were positively related, whereas no relation was found between working-memory capacity and probe-caught mind-wandering. Higher working-memory capacity scores were associated with higher self-caught mind wandering during reading.

The positive relation between working-memory capacity and mind wandering in this study is inconsistent with previous studies that have found a negative relation between the two (McVay, 2010; McVay, & Kane, 2010; McVay, & Kane, 2012; Unsworth, & McMillan, 2013). What factors might account for the discrepancy in findings? One possibility is that the discrepancy may be due to differences in tasks across studies. Prior studies have used the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) as the primary task and mind wandering has often been measured using the probe-caught method. Either of these factors could be responsible for the difference in results. Further studies will be necessary to determine how the choice of tasks and mind-wandering measures influence the relation between working-memory capacity and mind wandering.

An important question about the relation between working-memory capacity and mind wandering in this study is whether high capacity is associated with more mind wandering or whether high capacity is associated with more “caught” mind wandering. In other words: do high-capacity readers have more resources available to mind wander or do they have more resources available to monitor their comprehension for thoughts that are off-task? Neither probe-caught nor self-caught measures directly assess the overall occurrence of mind wandering; both measures only provide information about conscious awareness of mind wandering. Nonetheless, the data do distinguish individuals who become aware of mind wandering on their own from individuals who become aware of mind wandering when they are prompted by a probe. Capacity was reliably associated with self-caught, but not probe caught, mind wandering. In other words, the primary finding of the study is specific to the relation between working memory capacity and the number of occurrences when mind wandering was accompanied by an awareness that thoughts had strayed from the primary task. Thus, high-capacity individuals appear to monitor their performance for off-task thought better than low-capacity individuals.

The failure to find a relation between working-memory capacity and probe-caught mind wandering may suggest that overall mind wandering does not differ as a function of working-memory capacity. Our failure to find a relation, however, should be interpreted cautiously. Individuals with high self-caught scores by necessity had low probe-caught scores since probes were never presented at intervals shorter than 3 minutes since the last reported mind wandering episode. A follow-up study should be conducted in which self-caught mind wandering is assessed separately from probe-caught mind wandering to determine whether the correlation with capacity remains dissociated.

Mind wandering was not correlated with reading comprehension in this study in contrast to previous studies that have found a negative correlation between the two (McVay, 2010; Unsworth, & McMillan, 2013). One possible explanation for the discrepancy in findings may be related to how the texts were presented in this study. After each mind-wandering episode (either self-caught or probe-caught), the text reappeared on the screen and participants had an opportunity to reread the text. This could have minimized the effect of mind wandering on comprehension.

Interest in the text was positively correlated with reading comprehension. This relation is both intuitive and consistent with previous research on the relation between interest and comprehension (Baldwin et al., 1985; Hidi, 2001; Schiefele & Krapp, 1996; Tobias, 1994; Hidi & Harackiewicz, 2000; Unsworth, & McMillan, 2013). In addition, interest had small negative correlation with probe-caught mind wandering. Readers who were interested in the text were reported having fewer off-task thoughts than those who did not find the text to be interesting, consistent with previous research (Unsworth, & McMillan, 2013).

In summary, the results of this study were consistent with Smallwood and Schooler's conceptualization of mind wandering as a resource-consuming phenomenon (Smallwood, & Schooler, 2006). An important question to be addressed by subsequent research is whether high-capacity readers mind wander more than low capacity readers or whether they are just better at monitoring their performance for off-task thoughts.

Appendix:

Questionnaire:

Please answer the following questions based on a 1 to 7 scale as honestly as possible (1 = Strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, and 7 = strongly agree).

1. ____ I thought the task/reading was difficulty.

2. ____ I cannot believe how easy the task/reading was (R).

3. ____ I had trouble comprehending what the task/reading was about.

4. ____ The task/reading was a piece of cake for me(R).

5. ____ The reading was hard for me.

6. ____ I loved the task/reading!

7. ____ That was the most boring task/reading ever (R)!

8. ____ I thought the task/reading was dull and uninteresting (R).

9. ____ I almost dozed off while doing the task/reading War and Peace (R).

10. ____ I cannot get enough of doing the task/reading War and Peace!

*(R) = reverse items.

Table 1. Descriptive Statistics of All the Measures.

	N	Range	Minimum	Maximum	Sum	Mean	SD
1. Difficulty	76	18	3	21	963	12.67	4.00
2. Interest	77	10	2	12	414	5.38	2.94
3. Self-caught episodes	69	49	1	50	811	11.75	10.67
4. Probe-caught episodes	69	13	0	13	321	4.65	3.77
5. Working-memory capacity	77	121	20	141	5829	75.70	28.86
6. Reading comprehension	77	5.533	-.239	5.294	128.815	1.67	1.04

Table 2. Pearson Correlations between difficulty, interest, self-caught and probe-caught mind wandering, working memory capacity, and reading comprehension.

	1	2	3	4	5	6
1. Difficulty	1					
2. Interest	.344**	1				
3. Self-caught episodes	.147	-.077	1			
4. Probe-caught episodes	.127	-.217	-.481**	1		
5. Working-memory capacity	-.214	.145	.322**	-.055	1	
6. Reading comprehension	-.10	.253*	-.123	.066	-.047	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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