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Working memory capacity and mind-wandering during low-demand cognitive tasks☆

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A B S T R A C T

Individual differences in working memory capacity (WMC) typically predict reduced rates of mind-wandering during laboratory tasks (Randall, Oswald, & Beier, 2014). However, some studies have shown a positive relationship between WMC and mind-wandering during particularly low-demand tasks (Levinson, Smallwood, & Davidson, 2012; Rummel & Boywitt, 2014; Zavagnin, Borella, & De Beni, 2014). More specifically, Baird, Smallwood, and Schooler (2011) found that when individuals with greater WMC do mind-wander, they tend entertain more future-oriented thoughts. This piece of evidence is frequently used to support the context-regulation hypothesis, which states that using spare capacity to think productively (e.g. plan) during relatively simple tasks is indicative of a cognitive system that is functioning in an adaptive manner (Smallwood & Andrews-Hanna, 2013). The present investigation failed to replicate the finding that WMC is positively related to future-oriented off-task thought, which has implications for several theoretical viewpoints.

1. Introduction

Recently, cognitive psychology has experienced a surge of interest into mind-wandering (Callard, Smallwood, Golchert, & Margulies, 2013; Smallwood & Schooler, 2006, 2015). The field has attempted to answer questions about how mind-wandering occurs, for whom and when it most often occurs, and what effects it has on behavior. Several hypotheses have been developed to explain empirical findings. The hypotheses addressed in the present study are the context-regulation hypothesis (Smallwood & Andrews-Hanna, 2013), the cognitive flexibility hypothesis (Rummel & Boywitt, 2014) and the executive failure hypothesis (McVay & Kane, 2009, 2010, 2012a, 2012b). In the present study, we address two unresolved issues within the field. Specifically, how do individual differences in working memory capacity (WMC) relate to tendencies to mind-wander during tasks that make relatively low demands on attention? And, when individuals with high WMC mind-wander, do they tend to use their excess mental capacity to engage in future-oriented thought?

Typically, research has shown that individuals with greater WMC, and thus a greater ability to maintain task goals and to restrict their attention to currently relevant information, show a lower tendency to mind-wander (Kane et al., 2016; McVay & Kane, 2009, 2012a, 2012b; McVay, Unsworth, McMillan, & Kane, 2013; Mrazek et al., 2012; Robison, Gath, & Unsworth, 2017; Robison & Unsworth, 2015; Unsworth & McMillan, 2013, 2014; Unsworth & Robison, 2016). This set of findings is largely consistent with the executive failure hypothesis (McVay & Kane, 2009, 2010, 2012a; McVay & Kane, 2012b), which argues that individuals with

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low WMC experience more frequent failures of goal maintenance, which sometimes manifest as mind-wandering. Individuals with greater WMC maintain task goals in mind, avoid the intrusion of irrelevant internal thoughts, and proceed with the task more consistently. The oft-observed negative correlation between WMC and mind-wandering supports this idea. Indeed a recent meta-analysis of the relationship between cognitive abilities and mind-wandering found that the bulk of existing evidence supported this hypothesis (Randall, Oswald, & Beier, 2014).

Despite this typical finding, some studies have shown null relationships between WMC and mind-wandering during certain tasks. For example, Smeekens and Kane (2016) showed a null relation between WMC and mind-wandering during several versions of a divergent thinking task, as well as the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). McVay and Kane (2012a) also showed a null relation between WMC and mind-wandering during a vigilance version of the SART. So there may be instances in which the general negative relationship does not hold. Furthermore, some studies have shown that when the demands of a task are particularly low, WMC and mind-wandering tendencies actually show a positive relationship (Levinson, Smallwood, & Davidson, 2012; Rummel & Boywitt, 2014). In these situations, it is hypothesized that individuals with high WMC have sufficient mental capacity both to mind-wander and to complete the task successfully. Leveraging the finding that people mind-wander more during tasks with low perceptual load (Forster & Lavie, 2009), Levinson et al. (2012) gave participants a visual search task with two conditions: high and low perceptual load. Under the low-load conditions, WMC positively correlated with mind-wandering rate. Under the high-load conditions, there was a null relationship between WMC and mind-wandering rate. Further, a second experiment asked participants to simply count their breaths and to report both self-caught and probe-caught instances of mind-wandering. During this task, WMC again positively correlated with probe-caught mind-wandering (Levinson et al., 2012). From these findings, Levinson et al. (2012) argue that working memory resources are actually necessary for mind-wandering, and those with greater WMC can actually mind-wander more when their resources are not consumed by external task demands. Additionally, Zavagnin, Borella, and De Beni (2014) gave participants two versions of the SART, the classic perceptual version and a more difficult semantic version. They found that individuals with greater WMC who reported more cognitive failures in their daily lives showed more frequent mind-wandering during the perceptual SART.

In another recent study, Rummel and Boywitt (2014) compared the relationship between WMC and mind-wandering in a relatively non-demanding task (1-back) versus a more demanding version of the task (3-back). They found a negative relationship between WMC and mind-wandering during the 3-back version and a positive relation during the 1-back version. From these findings, Rummel and Boywitt (2014) proposed the cognitive flexibility hypothesis, which argues that the relationship between WMC and mind-wandering depends on task demands. When task demands are low, high-WMC individuals may actually mind-wander more than low-WMC individuals because they have the capacity to do so. But when task demands are high, high-WMC individuals will flexibly adjust their attention to focus on the task, avoiding mind-wandering.

Finally, the context-regulation hypothesis (Smallwood, 2013; Smallwood & Andrews-Hanna, 2013) argues that a high-functioning cognitive system (as is presumably present in high-WMC individuals) regulates the occurrence of self-generated thoughts in a manner that reduces mind-wandering when it can hamper task performance. But during situations in which demands on attention are relatively low, self-generated thoughts play a functional role in planning, creativity, and patience (Baird, Smallwood, & Schooler, 2011; Baird et al., 2012; Smallwood, Ruby, & Singer, 2013). Specifically, Baird et al. (2011) found that when individuals with higher WMC mind-wander, they tend to think about the future, and this form of mind-wandering can be functional autobiographical planning. Baird et al. (2011) had participants complete a choice reaction time task in which participants indicated whether rare target digits (10%) were even or odd. This task had previously been used to study mind-wandering specifically because it made little demands on working memory resources and induces more mind-wandering than tasks that make greater demands on working memory (Smallwood, Nind, & O'Connor, 2009). So at least in some situations, high-WMC individuals may be able to adjust their attention-regulation to meet the external demands of the environment.

Given the evidence addressed above, the bulk of findings that support the executive failure hypothesis may actually mask the complex relationships among WMC, mind-wandering, and task demands because of their exclusive use of highly demanding tasks (Kane & McVay, 2012). These studies have used tasks that make relatively high demands on attention and cognitive processing, such as the Stroop task (Kane et al., 2016; McVay et al., 2013; Robison et al., 2017; Unsworth & McMillan, 2014), the SART (Kane et al., 2016; McVay & Kane, 2009, 2012a; McVay et al., 2013; Unsworth & McMillan, 2014), the antisaccade task (Kane et al., 2016; Robison et al., 2017; Unsworth & McMillan, 2014), flanker tasks (Kane et al., 2016; Unsworth & McMillan, 2014), psychomotor vigilance tasks (Robison et al., 2017; Unsworth & McMillan, 2014), reading comprehension tasks (McVay & Kane, 2012b; Robison & Unsworth, 2015; Unsworth & McMillan, 2013), and working memory tasks (Mrazek et al., 2012; Unsworth & Robison, 2016). All of these tasks can be considered highly demanding, and thus these studies may only find a negative relationship between WMC and mind-wandering because of the conditions under which mind-wandering tendencies were measured. Further, attempts to replicate the finding that high-WMC individuals tend to mind-wander about the future have failed to do so (McVay et al., 2013). However, in both studies analyzed by McVay et al. (2013), mind-wandering was measured during the course of relatively demanding tasks like reading comprehension, Stroop, and SART, which are more demanding than the choice reaction time task employed by Baird et al. (2011). Therefore, their indirect attempt to replicate the WMC-future thought relationship may have been hindered by the exclusive use of attention-demanding measures.

To reconcile these discrepancies, the present study attempted to replicate Baird et al. (2011), both directly and conceptually. To accomplish this, we gave participants three complex span tasks to measure WMC and two low-demand choice reaction time tasks, one of which replicated that used by Baird et al. (2011). The digit reaction time task has previously been used to study mind-wandering because it makes little demand on working memory resources (Smallwood et al., 2009). For this reason we have characterized it as "low-demand." The other low-demand task was a similar choice reaction time task in which few working memory resources are