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What Mind Wandering Reveals About Executive-Control Abilities and Failures

Michael J. Kane and Jennifer C. McVay
University of North Carolina at Greensboro

Abstract

People's minds sometimes wander from ongoing activities. Although these experiences can be pleasant and useful, they are often unintentional and precipitate mistakes. In this article, we adopt an individual-differences perspective in considering unwanted mind wandering as an indicator of both momentary failures of and enduring deficiencies in executive-control functions. We describe research that associates normal variation in working memory capacity (WMC)—a cognitive ability that broadly predicts intellectual capabilities and accomplishments—with off-task thinking. In laboratory and daily-life assessments, people with lower WMC mind wander more frequently than do those with higher WMC, at least during demanding tasks. Moreover, the error-proneness of lower-WMC subjects seems to arise partly from their vulnerability to mind wandering. Executive control over one's thoughts therefore seems to contribute to the effective regulation of behavior.

Keywords

mind wandering, executive control, working memory, individual differences

When comedian Steven Wright quipped, "I was trying to daydream, but my mind kept wandering," he wasn't simply being witty. He was also identifying a tension driving current research on mind wandering. On one hand, people sometimes find it desirable to allow their thoughts to flow freely—even fancifully—away from their current activity. Mentally fleeing the confines of present circumstances may help people persevere through tedious or unpleasant tasks and may allow them to simulate solutions to personal problems, unrealized goals, or creative projects (e.g., Baird et al., in press; Klinger, 1971; Singer, 1975). The human capacity for mind wandering therefore seems adaptive. On the other hand, sometimes people must focus attention on what they are doing, yet, despite their efforts to concentrate, their thoughts drift. Such unintended task-unrelated thoughts (TUTs) may lead to costly performance errors and even psychological distress (e.g., Schooler et al., 2011; Schupak & Rosenthal, 2009). We suggest that these involuntary mind wanderings can provide theorists of executive functioning with a unique window into aspects of the mind's cognitive-control mechanisms, including how, when, and for whom they tend to fail.

Mind Wandering, Goal Neglect, and Working Memory Capacity

Our wading into the stream of thought was motivated by individual-differences research on working memory capacity (WMC). Psychologists are interested in WMC because it is a strong, domain-general predictor of important intellectual abilities, such as learning, reasoning, and comprehending (see Conway, Jarrold, Kane, Miyake, & Towse, 2007). In adults, WMC is typically measured with *complex memory span* tasks, in which people must immediately recall short lists of items (e.g., letters, visuospatial locations) in serial order, with the memory items interpolated with an unrelated task (involving, e.g., verifying equations or judging the symmetry of patterns). These tasks thus require subjects to keep information accessible while only intermittently attending to it, and to withstand considerable memory interference from previously encountered items.

Of central importance here is our argument that normal variation in WMC—and its co-variation with complex cognitive ability—is influenced by attention processes that regulate thought and action (e.g., Engle & Kane, 2004). That is, even though WMC is measured with tasks requiring memorization, what may be foundational to the performance of these tasks is an executive-control ability to keep one's goals (and goal-relevant representations) mentally active and accessible enough to influence ongoing behavior. Indeed, a hallmark of the laboratory performance of lower-WMC subjects is *goal neglect*, or the occasional failure to act according to current goals and to respond instead according to long-standing habits. In the Stroop task, for example, in which color words

Corresponding Author:
Michael J. Kane, Department of Psychology, University of North Carolina at Greensboro, Eberhart Bldg., 321 McIver St., Greensboro, NC 27412
E-mail: mjkane@uncg.edu

appear in incongruent hues (e.g., "GREEN" displayed in red type), subjects must respond in a nonautomatic way by naming the font color of each word ("red") rather than reading the word. Kane and Engle (2003) created a Stroop-task environment that undermined the novel color-naming goal by presenting mostly congruent stimuli (e.g., "GREEN" displayed in green type and "RED" displayed in red type), which allow for "accurate" responding on the basis of habitual (but inappropriate) word reading. Despite exhortations to subjects to ignore the words and respond only to their color, this permissive task context left lower-WMC subjects especially prone to overt word-reading errors on the rare, but critical, trials on which the color names and font colors were incongruent (see also Meier & Kane, in press).

The high-congruency Stroop context is like a traffic light that cues us daily to turn right toward our neighborhood, but that stands at an intersection where—only today—we should turn left to buy a bouquet from the florist. Nothing about the light urges today's novel action. Instead, in the absence of adequate goal maintenance, the light's familiarity should trigger our routine but inappropriate behavior, leading us home, flowerless. Moreover, like a long, tedious Stroop task, an everyday drive invites frequent TUTs that may be so absorbing that we are surprised when we eventually "come to" in our driveway. Personal experience, then, as well as laboratory and field research on absentminded mistakes (e.g., Reason & Mycielska, 1982), suggests that TUTs can disrupt our goals' influences on ongoing behavior. Thus, the straightforward question that drives our research on mind wandering is whether people who are lower in WMC experience goal neglect, and generally perform poorly on intellectual tasks, because their executive-control systems more frequently fail to keep thoughts task-focused.

Executive Control and Mind Wandering in Daily Life

Executive-attention theories argue that WMC reflects, in part, an ability to control thought (e.g., Engle & Kane, 2004). Accordingly, WMC should affect not only performance in academic and laboratory contexts, but also everyday outcomes: People who vary in WMC should experience life differently, especially in their vulnerability to distraction and absentminded mistakes (Unsworth, Brewer, & Spillers, 2012). Therefore, if we assess people's thoughts during daily life, we should find that WMC influences their experience of involuntary TUTs, especially in activities that are as cognitively demanding as the formal intellectual tasks that regularly elicit WMC-related differences in performance.

We tested this prediction by first assessing undergraduates' WMC with complex span tasks; we then equipped the students with personal digital assistants (PDAs) that beeped 50 to 60 times over seven days to prompt the students to report their ongoing thoughts and activities (Kane et al., 2007). Following each beep, the PDA presented an electronic questionnaire asking subjects whether their immediately preceding thoughts had wandered from their activity. Subjects then rated aspects of their current context and activities.

Figure 1 presents our central findings. During activities reported to be challenging, effortful, or requiring concentration, lower-WMC subjects experienced more TUTs and less on-task thinking than did higher-WMC subjects. Notably, only these cognitive-demand variables moderated the association between WMC and mind wandering. Noncognitive variables did not. That is, WMC-related differences in mind wandering did not arise with increased boredom, stress, or sleepiness, or with decreased happiness, task enjoyment, or feelings of

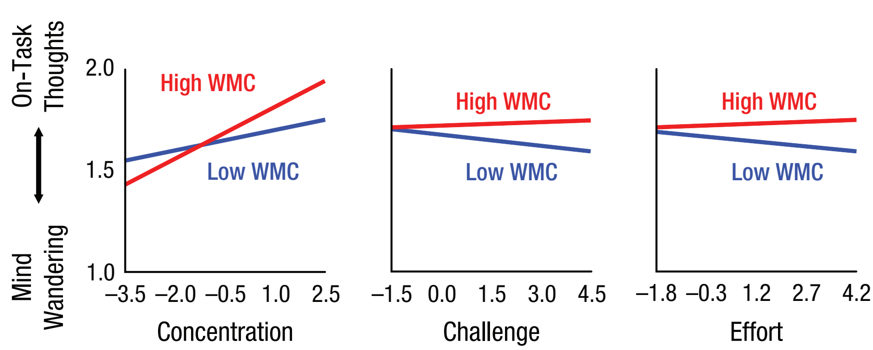

Fig. 1. The relation between mind wandering and self-reported cognitive-demand variables for undergraduates with low (bottom 25%) versus high (top 25%) working memory capacity (WMC) scores. Values on the *y*-axis represent the mind-wandering outcome variable, scored as either 1 (for mind wandering) or 2 (for on-task thoughts); lower values thus indicate more mind wandering. Values on the *x*-axes represent group-centered self-report ratings for concentration ("I had been trying to concentrate on what I was doing"), challenge ("What I'm doing right now is challenging"), and effort ("It takes a lot of effort to do this activity"); group centering means that higher and lower scores were always relative to each subject's own average. Adapted from "For Whom the Mind Wanders, and When: An Experience-Sampling Study of Working Memory and Executive Control in Daily Life," by M. J. Kane, L. E. Brown, J. C. McVay, P. J. Silvia, I. Myin-Germeys, and T. R. Kwapil, 2007, *Psychological Science, 18*, p. 619. Copyright 2007, Association for Psychological Science. Adapted with permission.

competence, although each of these variables predicted mind wandering overall. The variability in mind wandering that was specifically associated with WMC, then, did not reflect motivational influences or subjects' pre-existing folk theories about how consciousness works. Instead, objectively measured WMC predicted subjectively experienced TUTs only when people needed, or attempted, to keep thoughts focused on cognitively demanding activities.

We subsequently investigated the reliability of mind-wandering reports and tested the connection between TUTs and absentminded mistakes in daily life (McVay, Kane, & Kwapil, 2009). Subjects first performed a laboratory choice-reaction-time task while intermittently responding to thought probes that assessed their TUTs. They later completed a week-long, PDA-based assessment of thoughts and contexts in daily life; along with other measures similar to those from Kane et al. (2007), they rated their performance of activities and indicated whether, if they had been mind wandering, they were aware of doing so before the PDA beeped. Mind-wandering propensity was reliable: Subjects with more frequent TUTs in the laboratory also reported more TUTs in daily life. Furthermore, TUT experiences predicted success in everyday activities. Subjects reported their ongoing performance to be worse during TUTs than during on-task thinking; they further indicated that their performance was worse still when they had been mind wandering without realizing it (i.e., without prior "metaconsciousness" of their own mental state; Schooler et al., 2011).

Executive Control and Mind Wandering During Reading

Our experience-sampling research provisionally confirmed the executive-attention theory's claimed association between WMC and TUTs during demanding tasks. Moreover, our finding that TUTs predict, if not affect, people's performance of everyday activities suggests that vulnerability to mind wandering may contribute to WMC's power to predict cognitive performance and abilities. Reading comprehension, in particular, has been consistently linked to WMC (see Daneman & Merikle, 1996). Recent research has also suggested that reading elicits frequent TUTs that disrupt comprehension (e.g., Smallwood, McSpadden, & Schooler, 2008). We therefore asked whether WMC predicts normal variation in comprehension in part because of its association with TUTs (McVay & Kane, 2012b).

Approximately 250 undergraduates completed three WMC tests and seven reading-comprehension tests across a breadth of materials, including *Current Directions* articles, expository texts, short stories, and chapters from a novel. Thought probes appeared in two reading tasks and two attention-control tasks (e.g., a numerical Stroop task). We assessed TUTs beyond just the reading context in order to test causal claims about TUTs' relation to comprehension. That is, TUTs might correlate with comprehension because mind wandering causes reading impairment or, conversely, because difficulties with comprehension cause thoughts to wander. We attempted to disambiguate the correlation by assessing TUTs during reading *and nonreading* tasks. If people who mind wander frequently while reading also do so in nonreading tasks, then their overall TUT rate cannot be driven by reading skill. Poor reading doesn't cause TUTs during Stroop-task performance, so any TUT–reading association would most likely reflect the influence of TUTs on comprehension.

Figure 2 presents the main findings from our latent-variable analyses, which allowed us to leverage several tests to measure each underlying ("latent") construct of interest, such as WMC. When multiple tests assess the construct in slightly different ways, latent-variable techniques can statistically isolate what is shared among the tests' outcomes; the idea is that whatever these tests measure in common reflects the construct better than does any single, multidetermined measure. (Imagine a Venn diagram with three overlapping circles. Each represents the performance variability across subjects on one test; the region where all three circles overlap—the latent variable—represents the performance variability that all the tests capture in common; the nonoverlapping regions reflect measurement error.) Latent-variable methods also allow statistical tests of whether the associations hypothesized among these underlying factors are actually reflected by the data. In fact, the model fit our data well (see Fig. 2).

Note, first, the single TUTs factor, which indicates that students' TUT rates during reading closely tracked those during attention tasks, thereby suggesting a stable, general mind-wandering propensity: People who mind wandered a lot while reading short stories also mind wandered a lot while performing the Stroop task. We also found that WMC correlated negatively with TUTs (lower WMC = more TUTs) and positively with comprehension scores (lower WMC = worse comprehension). More specifically, WMC had a significant direct effect on comprehension (the WMC → Reading link), meaning that above and beyond the influence of TUTs, lower WMC predicted worse comprehension-test performance. At the same time, WMC also correlated indirectly with reading comprehension, through its association with mind wandering, as shown by a significant indirect effect (WMC → TUTs → Reading) and statistical evidence for partial mediation. Partial mediation signifies that an intermediary variable, such as TUTs, provides a significant associational route between two variables, such as WMC and reading ability (e.g., low WMC predicts more mind wandering, which then predicts poorer comprehension). Our findings therefore suggested that the association between WMC and reading comprehension arises partly because WMC reflects an executive ability to regulate thought while reading.

Executive Control and Mind Wandering During Goal Neglect

Might mind wandering also influence goal neglect? To find out, we tested hundreds of undergraduates who varied in

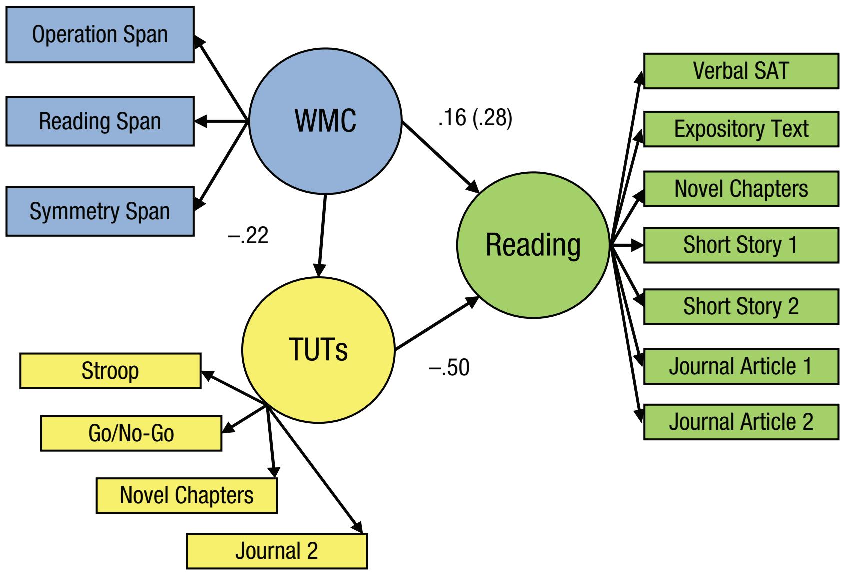

Fig. 2. A latent-variable model depicting the relation between working memory capacity (WMC) and reading-comprehension test performance (Reading), with mind wandering (i.e., task-unrelated thoughts, or TUTs) as a partial mediator. Latent factors are depicted in circles. Values represent the strength of the paths, or associations, between latent variables (all are statistically significant); the value in parentheses reflects the strength of the association between WMC and reading comprehension without the mediating effect of TUTs. Observed variables contributing to each factor are depicted in rectangles. Arrows between latent factors represent the modeled direction of their associations. The observed variables in blue rectangles represent scores on an operation span task (a measure of verbal WMC), a reading span task (a measure of verbal WMC), and a symmetry span task (a measure of visuospatial WMC). The observed variables in yellow rectangles represent TUT rates during a numerical Stroop task, a go/no-go attention task, a novel-chapters reading task, and a second journal-article reading task. The observed variables in green rectangles represent verbal SAT score, accuracy on inference-based tests about two brief expository texts, accuracy on comprehension questions during the novel-chapters reading task, and accuracy on comprehension questions following two short-story reading tasks and two journal-article reading tasks. Adapted from "Why Does Working Memory Capacity Predict Variation in Reading Comprehension? On the Influence of Mind Wandering and Executive Attention," by J. C. McVay and M. J. Kane, 2012, *Journal of Experimental Psychology: General, 141*, p. 312. Copyright 2012, American Psychological Association. Adapted with permission.

WMC (measured using complex span tasks) on a long-duration go/no-go task that included thought probes (McVay & Kane, 2009, 2012a). The task required subjects to press a key for most words appearing on-screen (e.g., animal names; 89% of trials) and to withhold from responding only rarely (e.g., food names; 11% of trials). Like the Stroop task, this task assessed control over habitual responding (*animal, press the key . . . animal, press the key*) in favor of a novel, or infrequently implemented, goal (*food, don't press now!*). Consistent with our reading-comprehension findings, WMC correlated negatively with TUTs and positively with accuracy. Moreover, TUT rate partially mediated the association between WMC and performance, again suggesting that WMC predicts goal neglect partly via TUT vulnerability.

To further explore the influence of TUTs on executive-task performance, we considered subjects' response times (RTs) on "go" trials (McVay & Kane, 2012a). We reasoned that drifting between on- and off-task thinking should produce subtle—but observable—variability in individual subjects' RTs. That is, during TUTs, people should process task stimuli superficially (Schooler et al., 2011) and thus occasionally fail to initiate timely decision processes, leading to occasionally slow responses. Moreover, because the go/no-go task encouraged habitual ("go") responding, TUTs might also precede unusually fast responses made on "autopilot" rather than on consideration of the actual stimulus (Cheyne, Solman, Carriere, & Smilek, 2009). We therefore expected subjects' TUT rates to predict inconsistency in RTs (more TUTs = more RT variability) and quantitatively assessed each subject's RT variability in several ways. We found that all of these variability assessments correlated negatively with WMC and positively with TUTs. Further analyses indicated that TUT rate partially mediated WMC's associations with all of our measures of RT variability (see Fig. 3 for latent-variable analyses of one such measure, a tau (τ) estimate, which reflects each subject's propensity to make occasional responses that were much slower

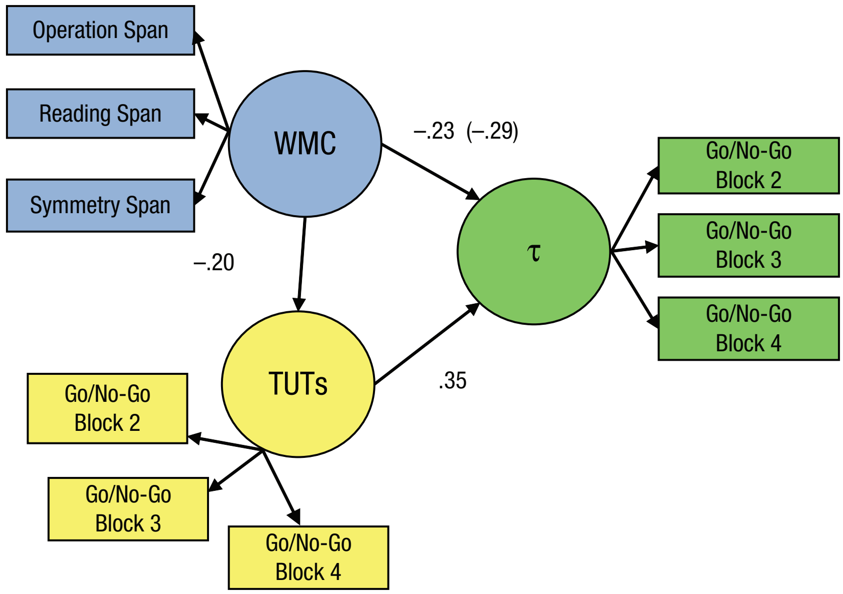

Fig. 3. A latent-variable model depicting the relation between working memory capacity (WMC) and a derived measure of response-time (RT) variability (tau, τ) from a go/no-go task, with mind wandering (i.e., task-unrelated thoughts, or TUTs) as a partial mediator. Latent factors are depicted in circles. Values represent the strength of the paths, or associations, between latent variables (all are statistically significant); the value in parentheses reflects the strength of the association between WMC and RT variability without the mediating effect of TUTs. Observed variables contributing to each factor are depicted in rectangles. Arrows between latent factors represent the modeled direction of their associations. Observed variables in blue rectangles represent scores on an operation span task (a measure of verbal WMC), a reading span task (a measure of verbal WMC), and a symmetry span task (a measure of visuospatial WMC). Observed variables in yellow rectangles represent TUT rates during the second, third, and fourth blocks of trials (of four) in a go/no-go task. Observed variables in green rectangles represent τ values calculated from go-trial RTs during the second, third, and fourth blocks in the go/no-go task. Adapted from "Drifting From Slow to "D'oh!": Working Memory Capacity and Mind Wandering Predict Extreme Reaction Times and Executive Control Errors," by J. C. McVay and M. J. Kane, 2012, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, p. 536. Copyright 2012, American Psychological Association. Adapted with permission.

than their average; higher τ values reflect a greater number of especially slow responses). First, these findings reinforced the idea that WMC predicts effective action partly because it predicts effective thought control. Second, they demonstrated that associations between WMC and TUTs don't arise simply from subjects' beliefs about mind wandering. Subjects are not aware of their own RT variability, so they cannot use these self-assessments to alter their TUT reporting to match expectations (as they might after committing overt errors). WMC genuinely predicts people's vulnerability to off-task thinking and its apparent consequences.

Caveats, Causality, and Conclusions

WMC consistently predicts TUT rates during cognitively demanding activities (Kane et al., 2007; McVay & Kane, 2009, 2012a, 2012b). Moreover, TUT variability partially mediates WMC's associations with task performance in multiple domains (McVay & Kane, 2009, 2012a, 2012b). We therefore suggest that TUT assessments during cognitive tasks can inform theoretical claims regarding executive-control constructs and their measures. With that said, we emphasize that objective WMC scores predict subjective mind-wandering reports only modestly, with correlations typically around –.20 (negative correlations range from –.01 to –1.00, with larger absolute values indicating stronger associations). Such low correlations indicate that WMC accounts for only about 5% of the variability in TUT rates (and vice versa).[1] In addition, WMC predicts substantial variation in task performance directly, beyond its association with TUTs. Thus, even though WMC tasks themselves may be vulnerable to mind-wandering experiences and disruptions (Mrazek et al., in press), WMC can tell only part of the story of TUT variability, which has numerable determinants, such as boredom, stress, task importance, arousal, mood, mindfulness, conscientiousness, and everyday personal concerns (e.g., Jackson & Balota, 2012; Kane et al., 2007; Klinger, 1971; Mrazek, Smallwood, & Schooler, 2012). Conversely, TUTs can tell only part of the story of WMC variation and its covariation with complex cognition.

Regarding questions of causation, it is important to note that statistical mediation models like the ones we discuss here require the paths between latent variables to be directional (e.g., the arrows from WMC to TUTs to Reading in Fig. 2), which implies a particular chain of causation (i.e., that WMC causes TUT vulnerability, which then causes success or failure in comprehension). However, our data are correlational: People arrived at the laboratory with a particular WM capability, which was out of our experimental control, and they happened to mind wander at particular times and at particular rates, which was also beyond our control. Given that our data are correlational, the latent-variable models we present here would fit the data just as well if the paths' causal directions were changed (e.g., TUTs → WMC → Reading).

Fortunately, in the case of our primary questions, inferences about causal chains don't actually matter much. According to the central claims of executive-attention theory (e.g., Engle & Kane, 2004), the causal direction between WMC and TUT rate is irrelevant, because one's score on a WMC task and one's rate of unintentional TUTs are both of a piece—in other words, they are both partly a product of one's domain-general attention-control system. That is, rather than arguing that WMC accounts for TUTs, or that TUTs account for WMC, our view is that both are accounted for by the third variable of attention-control capability (along with other influences, of course). It is, accordingly, the variance that is *shared* between WMC and TUT rate that has the primary power to predict variation in consequential cognitive and behavioral outcomes, such as reading comprehension and goal neglect.

In closing, we suggest that, although the WMC–TUT association is of circumscribed strength and its direction (if it even has a direction) is ambiguous, it still poses a theoretically important, unanswered question: Under what particular conditions does WMC predict TUTs? WMC is not associated with all varieties of top-down control over performance (e.g., null WMC effects arise in many demanding visual-search tasks; e.g., Kane, Poole, Tuholski, & Engle, 2006), which indicates that executive functions are not entirely unitary (e.g., Miyake & Friedman, 2012). Indeed, we (McVay & Kane, 2012a) found that WMC did not predict either performance or TUTs in a task that flipped the go/no-go into no-go/go requirements—such that most trials required no response, and only rare trials required responding. By removing the "go" prepotency (and thus the no-go inhibitory requirement) from the task, we changed its cognitive-control demands and also the exaggerated vulnerability of low-WMC subjects to mind wandering (see also Levinson, Smallwood, & Davidson, 2012, for null WMC–TUT correlations during visual search). WMC may, sometimes, even correlate *positively* with TUTs. Levinson et al. (2012) demonstrated that in tasks that are particularly undemanding (e.g., pressing a key in time with one's breaths), higher-WMC subjects mind wander *more* than do lower-WMC subjects. Such findings suggest that the executive-control mechanisms associated with WMC may not only suppress TUTs when tasks demand concentration—as our work has emphasized—but may also support TUTs when control processes are not engaged by ongoing tasks. Thus, WMC research may eventually confirm that mind wandering sometimes reflects executive "function" as well as dysfunction (Baird et al., in press; Schooler et al., 2011).

Recommended Reading

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Declaration of Conflicting Interests

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Note

1. In part, the low correlations with TUTs reflect the fact that we primarily measured WMC and executive attention narrowly, with only a few complex span tasks. When we conducted a latent-variable analysis that broadened the assessment of executive attention as the shared variance among complex span, go/no-go, and Stroop-type tasks, the correlation with TUT rate was closer to –.40 (lower executive attention = higher TUT rate; McVay & Kane, 2012b). Of course, this correlation did not equal –1.00, so it still left much of the

variance in mind-wandering propensity unexplained, but it was a significantly stronger correlation than the typical −.20 value that we have otherwise seen.

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