Chapter 19
Adrift in the Stream of Thought: The Effects of Mind Wandering on Executive Control and Working Memory Capacity

Jennifer C. McVay and Michael J. Kane

Our minds wander. Sometimes, that’s good – we can ponder scientific questions, practice important conversations, or just plan daily events while we engage in routine or dull tasks. Sometimes, that’s bad – we may worry excessively, reexperience traumatic events repeatedly, or (most relevant to present purposes) simply become distracted by thoughts, images, or fantasies that interfere with our ongoing activities. Such interference is especially likely to become problematic during tasks that are cognitively demanding.

Despite its ubiquity in human mental life, and its frequently disruptive effects, mind wandering has garnered only scant attention from cognitive psychology (e.g., Giambra, 1995; Schooler, 2002; Smallwood & Schooler, 2006; Wegner, 1997). This is unfortunate but understandable. If one considers the fantastical content of some mind-wandering episodes (those we might call “daydreams”), the phenomenon seems to be more central to the concerns of clinical or personality psychology if not the humanities (e.g., Bowling, 1950). Moreover, the covert mental processes that cognitive psychology regularly studies leave a behavioral residue that can be measured objectively, such as accuracy rate or response latency. The stream of thought, in contrast, leaves no overt behavior in its wake other than retrospective self-reports, and our field has learned to be skeptical of these (Nisbett & Wilson, 1977). We agree that a healthy skepticism is always warranted regarding people’s reports of their own objective experiences, including those about thought content (e.g., Schwartzgebel, 2008). At the same time, our chapter will argue (from robust empirical data) for the general validity of subjects’ mind-wandering reports, at least under particular conditions. Moreover, we will contend that mind-wandering reports are useful as measures of failed executive control in the moment, and of normal variation in executive-control capabilities within and among healthy adults. Our research, and others’, demonstrates that mind-wandering experiences tend to precede executive-control errors, and that people who experience more mind-wandering episodes also commit more performance errors. We will thus argue for a causal role for conscious thought in the willful control of action.

Our Approach to Executive Control: Variation in Working Memory Capacity

"Executive control" is a broad term that is used differently by different subfields in psychology and neuroscience and even by different investigators within these subfields. When we refer to executive control, we mean the collection of cognitive processes that allow for volitional, goal-directed behavior,
particularly in contexts where that behavior is challenged by environmental or mental distractors, or by learned habitual responses that are currently inappropriate. Our research, which we will describe in more detail below, has illuminated several functions to be especially important to performing well in the face of distraction and response conflict: goal maintenance and competition resolution (for more thorough treatments, see Engle & Kane, 2004; Kane, Conway, Hambrick, & Engle, 2007; for a related view, see Braver, Gray, & Burgess, 2007). Goal maintenance refers to processes that actively sustain ready access to goal-relevant information, either within or outside conscious awareness, which proactively biases downstream information-processing in accordance with intentions. Competition resolution refers to mechanisms that, in the face of cognitive conflict (e.g., memory interference, stimulus-response incompatibility, elicited-but-incorrect responses), reactively facilitate goal-relevant memory representations or response tendencies, inhibit goal-irrelevant memory representations or response tendencies, or both.

Our general empirical strategy for studying these executive-control functions has been to assess individual differences in working memory capacity (WMC), via “complex span” tasks, and then to observe how these WM-related differences play themselves out in lower-level attention tasks that are thought to engage controlled processing (or not). In doing so, we follow Cronbach’s (1957) recommendation of testing for individual-by-treatment interactions as a way of harnessing the combined strengths of experimental and correlational methods, here to learn more about the broad constructs we are interested in (e.g., WMC, executive control) and the specific tasks we use to measure those constructs (e.g., complex span, Stroop tasks). Like Cronbach (and like other contributors to this volume), we believe that the experimentalist’s study of variation among treatments can be effectively combined with the psychometrician’s study of variation among people, and this combination will result in a more complete view of human behavior, generally, and of executive control, in particular, than will either of these methods in isolation (Kane & Miyake, 2008).

We have focused our Cronbachian efforts on WMC because a large literature, based on a variety of tasks and subject populations, demonstrates complex-span measures to predict individual differences in a broad range of higher-order cognitive abilities, such as language comprehension, complex learning, and reasoning through novel problems (e.g., Daneman & Merikle, 1996; Engle, Tuholski, Laughlin, & Conway, 1999; Gathercole & Pickering, 2000; Kyllonen & Christal, 1990; Kyllonen & Stephens, 1990). WMC thus appears to be an important contributor to general fluid intelligence beyond any particular domain-specific skills or strategies that it may also be associated with. Moreover, at a theoretical level, WMC measures were developed to assess specifically the “central executive” functions of Baddeley’s (1986, 2000, 2007) working memory model (Daneman & Carpenter, 1980). They do so by requiring subjects to keep items accessible in memory while also engaging in a demanding secondary processing task, and so they seem to require attentional along with memorial processes.

To be more concrete, complex span tasks present short lists of to-be-remembered items, such as individual words, letters, digits, or visuospatial patterns, interspersed with an unrelated processing task, such as judging sentences, verifying equations, or mentally rotating objects. Most researchers require serial-order recall of the item lists, which usually vary in length from a minimum of two items to a maximum of five or six items; although subjects must maintain some criterion level of accuracy in the processing task, scores typically reflect only the recall rates for the memory items (for a methodological review, see Conway et al., 2005). In our laboratory, we often create a composite score from at least three different complex span tasks that have been developed for fully automated testing (Unsworth, Heitz, Schrock, & Engle, 2005): (1) operation span (OSPAN), which tests memory for words or letters embedded within an equation-verification task (is the provided answer to each equation correct?) (2) reading span (RSPAN), which tests memory for words or letters embedded within a sentence-judgment task (is each sentence sensible or nonsensical?), and; (3) spatial span (SSPAN), which tests memory for spatial locations within a matrix in alternation with a symmetry-judgment task (is each novel pattern vertically symmetrical?). The key advantage to
Combining multiple WMC measures from the same subjects is that it reduces the impact of task-specific error variance that is unrelated to the latent WMC construct (e.g., arithmetic knowledge in OSPAN; mental-rotation skill in SSPAN). Individual differences in such a composite measure from complex span tasks are therefore more likely to reflect primarily individual differences in WMC rather than individual differences in some other skills or abilities.

**Variation in Working Memory Capacity as Variation in Executive Attention**

Our theoretical perspective, which we have described as a "controlled attention" or "executive attention" view of WMC, holds that the robust empirical association between measures of complex span and tests of higher-order cognitive abilities is due to their both drawing upon, in part, domain-general, attentional-control mechanisms (Engle & Kane, 2004; Kane, Hambrick, & Conway, 2005; Kane, Conway et al., 2007). Indirect evidence for this view comes from investigating the performance of complex-span tasks themselves. For example, recent work by Unsworth and Engle (2006, 2007; see Ilkowska & Engle, this volume) indicates that complex span—and its relation to complex cognition—is dually driven by mechanisms that actively maintain a limited number of representations in the focus of attention and, perhaps primarily, by cue-driven retrieval processes that recover inactive representations from long-term memory (LTM). In fact, traditional LTM-retrieval tasks, such as immediate free recall, appear to measure the WMC construct (and account for variation in higher-order cognition) just as well as complex span tasks do (Ilkowska & Engle, this volume). We do not yet know the extent to which executive-attention mechanisms are involved in such cue-driven retrieval. Previous research, however, indicates that LTM retrieval is attention demanding, at least in interference-rich contexts that characterize complex span tasks (e.g., Conway & Engle, 1996; Kane & Engle, 2000; Rosen & Engle, 1997).

More direct evidence for a link between WMC and executive attention comes from studies that examine WMC-related individual differences in the performance of attention-control tasks that make little or no demand on LTM-retrieval processes. Instead, these tasks seem to elicit WMC-related variation in the goal-maintenance and competition-resolution functions we described earlier. In the antisaccade task, for example, subjects are asked to move their eyes and attention away from a visual-onset cue; if a cue flashes on the right, subjects should look to the left, and if a cue flashes on the left, they should look to the right. WMC predicts two aspects of antisaccade performance (Kane, Bleckley, Conway, & Engle, 2001; Unsworth, Schrock, & Engle, 2004). First, lower-WMC subjects make more eye-movement errors than do higher-WMC subjects, by looking at rather than away from the stimulus. These overt action errors suggest that lower-WMC subjects fail more than higher-WMC subjects to maintain sufficient access to task goals, in the moment, to control their behavior. We refer to such failures as "goal neglect" (see Duncan, 1995). Second, lower-WMC subjects are slower to initiate their accurately directed eye movements than are higher-WMC subjects. These slow responses suggest that lower-WMC subjects have particular difficulty resolving the competition between habitual and goal-appropriate responses on a trial-by-trial basis, even when the goal is sufficiently maintained to produce the desired action.

Our subsequent investigation of the Stroop task (Kane & Engle, 2003) replicated these basic findings while demonstrating more clearly the independence of goal-neglect and competition-resolution functions of executive control. Using a computerized color-word Stroop task in four experiments, we manipulated the proportion of congruent trials as a means to vary the importance of goal maintenance to success. Low-congruent conditions presented color words that matched the hues on only 0–20% of trials (e.g., RED appearing in red), whereas high-congruent conditions presented word-hue matches on 75–80% of trials (see Logan & Zbrodoff, 1979). All conditions included critical incongruent trials, where the words and hues were in conflict (BLUE appearing in
red), and some conditions also presented occasional neutral stimuli (*JKM* in red). Our idea was that, in the low-congruent task, the color-naming goal is externally and repeatedly reinforced by the context because most trials present color-word conflict; control in low-congruent conditions is thus supported by the environment. In contrast, in the high-congruent task, the color-naming goal is not reinforced because most trials present color-word matches rather than mismatches; here, then, subjects must endogenously maintain goal activation throughout the task. If subjects lose access to the goal and begin to read words rather than name colors, accuracy will remain generally high (from the experimenter’s perspective) because the colors and words require the same overt response. However, on the rare trials that present color-word conflict, goal neglect will be evident in erroneous word-reading responses.

Kane and Engle (2003) found that low-congruent conditions produced modest WMC-related differences in response time (RT) interference, but not in errors, with lower-WMC subjects naming colors on incongruent trials a bit more slowly than higher-WMC subjects. As in the antisaccade task, then, lower-WMC subjects had greater difficulty resolving competition between color and word dimensions, even when responding was goal directed. In contrast, high-congruent conditions elicited dramatic accuracy differences related to WMC. Lower-WMC subjects committed 50–100% more color-naming errors than did higher-WMC subjects, with most reflecting overt word reading. As well, lower-WMC subjects responded more quickly here to the congruent trials than did higher-WMC subjects, suggesting that lower-WMC subjects more often read the word aloud (a faster, more habitual response than color naming) than did higher-WMC subjects. Both high error rates and fast congruent responses are signatures of lower-WMC subjects failing to maintain adequate access to goal representations during the high-congruent Stroop task, and thus experiencing more frequent goal neglect.

**Mind Wandering as an Executive-Control Failure**

If competition-resolution and goal-maintenance mechanisms both contribute to successful executive control, then we must consider at least two sources of control failures. The source of the conflict that competition-resolution processes must contend with is often a shared cue to both a habitual (erroneous) and an intended (correct) response. For example, the color word in the Stroop task cues the dominant reading response; the visual flash in the antisaccade task cues the dominant orienting response. In both situations, even when the task goal is being maintained, the interference from competing responses may temporarily impede appropriate action. By analogy, we may also consider what competes with goal maintenance in contexts that tend to produce goal neglect. Why do people sometimes fail to maintain sufficient goal access to control behavior?

When goal maintenance fails, we observe the correct response being replaced by the dominant-but-inappropriate response. This may suggest that the dominant response goal (e.g., “read the words”) actually replaces the intention (e.g., “name the colors”) in working memory. Or, it may be that something else elicits the loss of goal activation that then causes the system to default to an automatic action schema. We propose that the latter is more likely. Specifically, we suggest that goal maintenance is often hijacked by task-unrelated thought (TUT), resulting in both the subjective experience of mind wandering and habit-based errors.

The experience of TUT, or mind wandering, represents a failure to maintain focal attention on the task at hand. It seems noteworthy, then, that mainstream cognitive research on attention largely ignores the contribution of on-versus off-task thoughts to performance, emphasizing instead the stimulus, context, and expectancy factors that contribute to attentional selection, set, and orienting. Our claim, in contrast, is that conscious thoughts actually matter. It bears reminding that human research subjects do not exist in the vacuum of the experimental laboratory, and that the extraexperimental goals, interests,
thoughts that subjects bring into the testing room may represent a tremendously important
difference and situational variable in the expression of attention-control capabilities. If we
are right, it would seem irresponsible to ignore the potential contributions of off-task thoughts to
executive functions and their variation. Goal-appropriate actions may depend, at least in part, on
conscious thought being directed at those very actions.

The Measurement of Mind Wandering

A challenge arises, then, regarding the objective and reliable measurement of inherently subjective
on- and off-task thoughts. Antrobus, Singer, and Greenberg (1966) introduced a measurement to
tackle the challenge of assessing mind wandering during ongoing activities. During a vigilance
task, they asked subject to indicate, at the end of each trial block, whether they had experienced any
TUTs. This block-by-block assessment of mind wandering provided a new tool, the “thought
probe,” to the field. Many versions of thought probes are now used in the literature. Some exper­
mencers ask their subjects to verbalize their thought content at various points during the task and
subsequently code them for task-relatedness (e.g., Smallwood, Baracia, Lowe, & Obonsawin, 2003;
Smallwood, Davies et al., 2004); others employ a rating scale indicating the frequency of off-task
thinking during a given period (e.g., Antrobus et al.; McGuire, Paulesu, Frackowiak, & Frith, 1996).

We argue that the best and most objective type of probe requires only a simple binary or categorical
choice response (e.g., TUT vs. on-task thought) in order to minimize both the interruption to the task
and the potential translation problems between an idiosyncratic thought or image and the language
required to convey conscious states to the experimenter. Probes can also either be experimenter­
scheduled or self-initiated. Self-initiated reports rely on meta-awareness of the mind wandering
episode as it occurs and, therefore, are a less reliable measure of mind wandering as it relates to task
performance (for a review, see Smallwood & Schooler, 2006).

A potential criticism of any particular thought-probe technique is that social desirability and
thought monitoring might reactively change the frequency of mind-wandering episodes. For example,
Filler and Giambra (1973) predicted that the expectation of thought probes would increase reports
of mind wandering during a vigilance task. Instead of warning subjects before the experiment that
they would have to report their thoughts, the authors waited until part of the task was complete to
ask subjects about TUTs (i.e., after the first, second, or third block of the ongoing task). Contrary
to predictions, Filler and Giambra found fewer TUTs when subjects knew earlier about the thought
probes, suggesting that subjects’ awareness of their mind wandering in the first block caused
them to exert more control during the second. Expected thought probes may therefore under­
estimate TUTs.

Despite any potential biases inherent in probed thought reports, they have effectively established
some basic, replicable characteristics of mind wandering. For example, its frequency decreases with
task complexity (Grodsky & Giambra, 1990–1991; Teasdale et al., 1995), with task difficulty
Antrobus, Singer, Goldstein, & Fortgang, 1970; Filler & Giambra, 1973; Grodsky & Giambra,
1990–1991; McGuire et al., 1996; McKiernan, D’Angelo, Kaufman, & Binder, 2006; Smallwood,
Obonsawin, & Reid, 2002–2003; Teasdale, Proctor, Lloyd, & Baddeley, 1993) and with heightened
task motivation (Antrobus et al., 1966). Conversely, mind wandering increases with time on
coherent) tasks (Antrobus, Coleman, & Singer, 1967; Antrobus et al., 1966; Smallwood, Davies,
2004; Smallwood, Heim, Riby, & Davies, 2006, Smallwood et al., 2002–2003; Teasdale et al.,
35) and with experimental manipulations designed to prime subjects’ personal concerns unrelated to
ongoing task (Antrobus et al., 1966). We will say more about the validity of thought reports later
(see also Smallwood & Schooler, 2006), but we note here that such systematic variation in TUT
reports, along similar variables across different studies, provides supportive evidence for validity.
Also, individual differences in the propensity to experience TUTs appear stable over time and reliable across a variety of primary tasks. For example, Grodsky and Giambra (1990–1991) found that, while TUT rates were lower during a complex reading task than during a vigilance task, people with higher TUT rates in one task also had higher rates in the other \( r=0.51 \). Giambra (1995) also demonstrated the test-retest reliability of the thought-probe procedure during vigilance tasks. Mind-wandering reports correlated at \( r=0.77 \) for tests conducted 1–14 days apart and \( r=0.81 \) for tests conducted 12 months apart. Furthermore, recent work from our lab finds that TUT rates during a laboratory go/no-go task predict probed TUT rates (via experience-sampling methodology) during daily life activities \( b=1.29, SE=0.607, t(68)=2.12; \) McVay, Kane, & Kwapil, 2009). Whatever mechanisms are responsible for lapses of attention, then, they appear to be stable across people, tasks, contexts, and time. Moreover, variation in mind-wandering rates is predicted by other stable individual-difference variables, such as psychopathology: TUT rates are higher for people diagnosed with AD/HD than for controls (McVay et al., 2008; Shaw & Giambra, 1993) and higher for more, than for less, dysphoric subjects (Smallwood, O’Connor, & Heim, 2004–2005), while TUT rates are lower for clinically depressed people than for controls (Giambra, Grodsky, Jelonlme, Rosenberg, 1994–1995) and lower for ruminators than for nonruminators (Smallwood et al., 2004–2005).

**Brain Wandering and Goal Directed Behavior**

Neuroimaging studies have now identified several regions of the brain, labeled the “default mode network” (Raichle et al., 2001), which consistently show deactivations in activity when subjects shift from a passive resting state (in which thoughts tend to drift) to an attention-demanding, goal-driven, activity; they are considered “default” because they represent the spontaneous cognitive activity that people engage in when they have no particular goal, or task to complete. These brain regions (including medial frontal cortex, lateral and medial parietal cortex, and medial temporal cortex) have thus been implicated in mind-wandering experiences, which decrease during attention-demanding tasks (e.g., Antrobus et al., 1966). McGuire et al. (1996) first proposed the connection between mind-wandering and activation in specific regions of the brain. Using positron emission tomography (PET), they found that individual differences in TUT rates were significantly correlated with default network activation during rest and several cognitive tasks (in the latter case, such mind-wandering/default-activation should have interfered with task performance).

In an fMRI study, McKiernan et al. (2006) manipulated the difficulty of processing required by an auditory target-detection task, expecting to find both TUT-rate and default-network differences between difficulty conditions. Subjects first responded to unpredictable thought probes (for on-task vs. off-task thoughts) during the tone-detection task and during “rest” in a sham fMRI scanner; they subsequently performed tone detection in alternation with rest during neuroimaging. As predicted, as task difficulty increased, TUTs increased and task-induced deactivations (TIDs) decreased (i.e., the default network was less active as the task became more difficult). More importantly, the authors report an association between the average TUT frequency at each difficulty level and the average TID at the same difficulty level \( r=-0.90 \) suggesting that the observed TID reflected reductions in off-task thinking. Mason et al. (2007) also demonstrated the relation between TUT rate (measured during the task) and changes in fMRI-assessed activity in the default-mode network \( rs>0.50 \). TUT rates were lower, and default-mode deactivations were greater, during an unpracticed visuospatial WM task than during a practiced task, indicating that the (mind-wandering) processes occurring during rest continued to a greater degree during more automated tasks. As well, individual differences in these deactivations correlated with a retrospective questionnaire about mind-wandering experiences, the Imaginal Processes Inventory \( rs=0.60 \).
Mind Wandering and Goal Neglect

We conceive ongoing conscious cognition as reflecting a balance between task-related and task-unrelated images and thoughts (or between default-network and task-network brain regions). There are times in life when it is not necessary to devote attention to the immediate external environment, such as on a long bus ride or when one’s current task is largely automatic. These occasions provide the opportunity for a person to willfully turn attention toward TUTs. For example, during a bus ride, you might write a mental grocery list or consider a recent interaction with a colleague. In these situations, TUTs are not likely to interfere with the task goal (i.e., getting home) and, therefore, an appropriate balance is maintained. If, however, you are so engaged in thought that you miss your bus stop, the balance is off and TUTs have become detrimental. It is this situation—where off-task cognitions interfere with the ongoing task goals and produce goal-neglect errors—that is of primary interest to us.

Indirect evidence for a causal connection between off-task thoughts and performance errors comes from diary studies of action slips (e.g., Reason, 1990; Reason & Mycielska, 1982), where absent-minded mistakes (e.g., pouring coffee into a bowl of cereal instead of milk; driving home the normal route instead of stopping at the store) are frequently reported while subjects are preoccupied by TUTs. In the famous quote from James (1890), absent-minded people are known to go into their bedrooms to change clothes for dinner, only to subsequently find themselves in bed. During such complex, but erroneous, action sequences, a person’s mind seems to be “elsewhere,” apparently allowing a habitual, but inappropriate, action schema to control behavior. But does mind-wandering self actually cause such action slips?

Unfortunately, most empirical mind-wandering studies have focused on vigilance tasks that elicit ceiling-level performance, and so these studies cannot help us evaluate an ostensible link between mind wandering and performance error. Fortunately, a few studies have used more complex, attention-demanding tasks, and these have shown clear evidence for mind wandering’s disruptive effects. Schooler, Reichle, and Halpern (2004) assessed the impact of TUTs on reading by administering a comprehension test immediately after a TUT was reported; the test items addressed the portion of the text that had just been “read.” When compared to midpassage tests given to control subjects who were not probed for TUTs, comprehension accuracy was worse on passages following a TUT report (M = 78% vs. 54%). Teasdale et al. (1995) also observed deficits in a more traditional executive-control task, random number generation, in trial blocks during which subjects reported a TUT. Subjects were asked to generate a series of random numbers, one per second for 100-120 s, and to report their thought contents at the end of a block (recorded verbatim and coded for task-relatedness). The digit series generated in blocks without TUT reports were significantly more random (and so, conforming to the demanding task goals) than those accompanied by a TUT report. We discuss further evidence for a causal role of conscious thought on performance, from our own laboratory, below.

Mind Wandering, Goal Neglect, and WMC

The executive-attention theory of WMC (e.g., Engle & Kane, 2004; Kane, Brown et al., 2007) states that WMC tasks capture, in part, the goal-maintenance function of executive control and, therefore, they should predict individual differences in the subjective experience of mind wandering. We first demonstrated this relation in daily life using the experience-sampling method (Kane, Brown et al., 2007). One hundred and twenty-six subjects, having previously completed WMC screening, used Palm Pilot PDAs, which beeped them randomly throughout the day for 7 days. At the beep, subjects completed an electronic questionnaire that first asked whether their mind had wandered to something other than what they were doing (whatever that was). Subjects then
answered additional questions about their thought content, their perceived control over their thoughts, and about their current activity. We predicted that during cognitively demanding activities (as in laboratory tasks, such as Stroop and antisaccade), lower-WMC subjects would suffer more off-task thoughts than would higher-WMC subjects. However, during routine, everyday activities that required little in the way of cognitive control, we predicted little or no WMC-related variation; when there is little need to focus attention, there is little reason to expect WMC to matter.

Indeed, when averaged across all daily life contexts, many of which were not cognitively demanding, WMC had no effect on mind-wandering rates. Only cognitively demanding contexts discriminated the higher from lower-WMC subjects: During self-reported concentration attempts and high-effort/high-challenge tasks – where lapses should hurt performance – lower-WMC subjects mind-wandered more frequently than did higher-WMC subjects (as assessed via multilevel modeling; $b=0.022$, SE=0.006, $t(122)=3.98$). These findings provide powerful, ecologically valid evidence for our attentional view of WMC, and for the notion that some of the attentional difficulties demonstrated by lower-WMC subjects may be linked to off-task thinking.

At the same time, our experience-sampling protocol did not allow us to examine how (or whether) off-task thoughts affected our subjects’ performance of their daily life activities. Although we intend to address this question in a future protocol, such a performance assessment will necessarily rely on subjects’ monitoring their own behavior and such assessments may be error prone and subject to bias. We have therefore conducted a laboratory investigation of executive control and thought content, in which performance accuracy could be assessed objectively and subjects’ thoughts could be probed at critical times (McVay & Kane, 2009). We expected WMC to predict both mind-wandering rates and performance errors. As well, we hypothesized that some (if not most) of the performance variance accounted for by WMC variation would be shared with mind-wandering rate. That is, task errors attributable to deficits in goal maintenance, which lower-WMC subjects commit more than do higher-WMC subjects, should largely be the result of mind wandering.

We conducted our study using the Sustained Attention to Response Task (SART; Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), a task that elicits high error rates and that was previously shown to correlate with global self-report measures of cognitive failures (Robertson et al., 1997) and end-of-block thought reports (Smallwood, Davies et al., 2004). The SART is a go/no-go task in which stimuli are presented rapidly (250 ms; 900 ms mask) and subjects respond to all stimuli expect infrequent (11%) targets. In the original SART, the stimuli were digits 1–9 and the target was “3”; we presented stimulus words that required a perceptual response (upper vs. lowercase letters) or a semantic response (animal vs. food exemplar) as a between-subjects processing-demand manipulation. Subjects responded to every instance of one category (e.g., animals) and withheld responding to the rare instances of the other category (e.g., foods). The processing-demand manipulation did not produce any important effects and so we will not discuss it further.

We administered numerous thought probes to assess mind wandering during the SART. After 60% of the no-go target trials, a screen appeared that asked subjects to indicate what they had been thinking in the moment before the probe. The probes presented seven categories of thought, determined through our pilot testing; subjects were trained on the categories prior to the start of the task.

1. The task – Select this number if your thoughts were about the word you saw or its meaning or if you were thinking about pressing the space bar.
2. Task performance – Select this number if your thoughts were about how well you are doing on the task, how many you are getting right, or frustrations with the task.
3. Everyday stuff – Select this number if your thoughts were about what you did recently, what you are going to do later, or casual, everyday, routine things.
4. Current state of being – Select this number if you were thinking about being sleepy, hungry, bored, or any other current state.
5. Personal worries – Select this number if your thoughts were about life concerns such as a test coming up or a fight with a friend.
6. Daydreams – Select this number for fantasy or thoughts disconnected from reality.
7. Other – Select "other" ONLY if your thoughts do not fit into any of the other category options.

Only the numbers and names of the categories appeared on the subsequent thought probes. We used categories here rather than asking subjects to report their thoughts aloud, in order to eliminate discomfort in verbalizing personal thoughts (Smallwood, Davies et al., 2004; Smallwood et al., 2002–2003; Smallwood et al., 2003; Teasdale et al., 1993; 1995) and to minimize the interruption to the ongoing task to collect thought reports (probe response time $M=2,300$ ms). The first two categories were coded as on-task thinking and as task-related interference (TR1; Smallwood et al., 2006), respectively. The rest were coded as TUTs. We inserted thought probes following target trials in order to directly connect reports of mind-wandering to errors.

Our findings indicated that mind-wandering contributes to goal neglect errors in the SART. Subjects had a lower accuracy rate on target trials where they reported off-task thinking ($M=0.42$) than when they were on-task ($M=0.66$) and their overall accuracy correlated negatively with TUT rate ($r=-0.37$). Moreover, intrasubject variation in RT to the frequent nontarget trials, which provides an index of general fluctuations in attention to the task, correlated significantly with TUT rate ($r=0.40$).

Of primary importance, we predicted a mediating role for mind wandering between WMC and goal neglect. WMC variation did significantly predict SART accuracy ($r=0.29$), RT variability ($r=-0.35$), and TUT rate ($r=-0.22$). Critically, hierarchical regression also indicated that TUT rate accounted for about half of WMC’s shared variance with performance (accuracy and RT variability), indicating that TUT experiences mediated, in part, the relation between WMC and goal neglect.

**Mind Wandering as Thought Interference: A Cause of Executive Control Failures**

Colloquially, a person may claim to “have a lot on her mind” as an excuse for a mistake or express need to “get her head in the game” when she feels she is inadequately focusing on the task at hand. These common phrases reflect the subjective experience of the relationship between off-task thinking and errors. Most people have experienced the less-than-optimal performance that accompanies interfering thoughts in stressful or worrisome situations. We reemphasize, here, that subjects’ “real world” concerns do not disappear when they enter the artificial world of our laboratory to complete experiments. Rather, these extralaboratory concerns may have a significant impact on subjects’ performance. That is, in the process of completing a task, TUTs about a worrisome situation, or about everyday things to do, may act as interference to the task goals in the same way that conflicting task stimuli interfere with attention to target stimuli. Klinger (1971, 1999) has defined the nature of this internal interference with his current concerns theory.

A **current concern** is a state of mind that is proposed to exist between the formation of an intention and its completion or abandonment. In other words, when someone forms an intention to achieve a goal sometime in the future, that intention exists as a current concern until the intention is satisfied or discarded. This language mirrors the definition of a prospective memory (Einstein & McDaniel, 2005; Smith, 2003; Smith & Bayen, 2004). Most of the time, however, prospective-memory researchers limit their focus to relatively simple intention–action associations that are, themselves, embedded in a simple ongoing task. For example, subjects may be asked to vocally state whenever a nonword appears in a sequence of words that they are categorizing as animate or inanimate via key-press. A current concern, in contrast, is not limited to simple actions to be related with event- or time-based cues. Although current concerns can be as simple as “buy milk
at the store tonight," they can also be as complex and abstract as “improve my relationship with my mother.” Likewise, “I must do well in school” may be a current concern that remains unsatisfied until graduation, even though many subgoals (which also exist as current concerns, such as “study for tomorrow’s quiz”) are completed along the way.

By Klinger’s (1971, 1999) view, current concerns are activated by relevant environmental or mental events and when active they compete for attention with external stimuli. The likelihood of a current concern “winning” such competition against ongoing thought, and thus entering consciousness, depends on its importance and imminence. Current concerns that are self-rated as more important, and those that require some action in the near future, are more likely to gain entrance into awareness (Klinger, Barta, & Maxeiner, 1980). One way to explore empirically the consequences of current-concern activation on concurrent cognitive performance is thus to manipulate exposure to concern-related cues. Antrobus et al. (1966) pioneered this technique by introducing a concern prior to administration of a vigilance task with mind-wandering probes. College-student subjects sat briefly in a waiting room before the critical part of the experiment where, for half the subjects, a realistic mock radio broadcast reported an escalation of the Vietnam War. Subjects exposed to this broadcast reported substantially more mind wandering during the subsequent vigilance task than did controls. Presumably, the experimental subjects became preoccupied with thoughts of the war (and implications for the draft) and were less able to maintain their attention on the task at hand. In 1966, the potential personal impact of the Vietnam War was certainly a concern for most young Americans. By cuing this concern prior to testing the attention of their subjects, Antrobus et al. (1966) demonstrated the dramatic impact that extralaboratory concerns can have on laboratory performance.

In a more recent study, McVay and Kane (2007) embedded cues to subjects’ personal concerns in the ongoing task. Our question was whether priming subjects’ personal goals would trigger TUTs and subsequent executive-control errors. If so, we would have compelling evidence for the causal impact of off-task thoughts on behavior, whereas previous laboratory studies of mind-wandering have all relied on correlations of thought reports with performance under various task contexts.

Our subjects first reported some of their personal goals and concerns on the Personal Concerns Inventory (Cox & Klinger, 2004), which was completed along with several other surveys. We used subjects’ ratings of importance and imminence to select two personal goals to cue in a separate session, 2 days later. These concerns were converted into word triplets designed to capture the idea of the goal while using as few of the subjects’ own words as possible. These goal triplets were then presented periodically, in sequence, during a SART task. For example, the goal, “pay my piano accompanist this week” might be converted to the word triplet: compensate-piano-helper. In the SART, words were presented one at a time and subjects responded to non targets (lowercase words) and withheld the response for target items (uppercase words). The concern-related word triplets were always presented as nontarget stimuli (lowercase words) and always appeared in the same order (always a few words before critical target trials and thought probes). Note that for successful task completion, subjects did not have to read any of the words for meaning but rather to make a simple perceptual judgment about them.

We compared subjects’ performance and thought reports on personal-goal-cued trials to two kinds of control events that occurred with equal frequency: Yoked goal triplets from another subject that did not match any of the current subject’s reported concerns, and nongoal-related word triplets that all subjects saw and that should not correspond to any subject’s concerns (e.g., close—wooden-doors). Thus, throughout the SART, subjects saw nongoal triplet cues, their own personal goal cues, and another subject’s goal cues, all followed soon after by target events and thought probes.

Based on current concerns theory and the Antrobus et al. (1966) study, we expected that subjects would report more mind wandering following cues to their own personal goals and concerns. Furthermore, we expected this interference to impair performance on the SART no-go targets. In fact, subjects reported significantly higher TUT rates and had significantly lower accuracy rates for
targets following personal-goal cues (44% TUTs; 64% errors) than those following nongoal control cues (38% TUTs; 48% errors). And, as predicted, mind wandering and errors were also numerically higher following personal-goal cues versus other-subject goal cues (42% TUTs; 61% errors), but these differences were not statistically significant. We suspect that the lack of significance here reflects the limited range of goals and concerns across our undergraduate subjects. Although we attempted to use other subjects’ cues that were unrelated to the personal goals and concerns reported by the subject, many of the academic, social, financial, and family-related concerns of our subjects were probably not unique. We are therefore encouraged by the raw pattern of data here, and for the next step in this line of research, we plan to better control the degree to which the control cues relate to each subject’s current concerns.

For now, however, we suggest that thoughts about personal concerns and goals are automatically and continuously generated (perhaps by the default-mode network of the brain) and compete for attention with on-task thoughts. When the interference is too great for the person’s executive-control system to block or inhibit (whether due to fatigue, stress, disorder/disease, or low WMC), these thoughts supplant task-related thoughts in conscious awareness. So, in some cases, it is the build-up of the interference from thoughts such as current concerns that overwhelm the control system and cause disruptions to conscious focus that may, in turn, cause performance failures. The finding that mind-wandering rates increase when current concerns are primed via pretask information (Antrobus et al., 1966) or via in-task cues (McVay & Kane, 2007) provides evidence that current concerns interfere with task-related thoughts. The in-the-moment connection between mind wandering and task performance suggests that thought-control failures may sometimes result in executive-control failures in performance.

Testing the Waters

Psychology has begun to wade, tentatively, back into the stream of thought flow in order to test important hypotheses about consciousness, attention, and executive control. After decades of standing on shore for fear of reviving historical controversies about introspective methods, we should ask whether today’s methods of assessing subjects’ subjective experience of off-task and on-task thought are generally valid and worthy of scientific consideration. We believe that the answer to this question is a provisional – but optimistic – “yes.” As we already noted above, the empirical literature on mind wandering demonstrates that TUT experiences vary systematically with particular experimental manipulations, replicated across multiple subject samples in different laboratories. As well, a consistent brain-activity signature, found in separate samples across multiple research groups, distinguishes self-reported TUT states from task-oriented states (and people who TUT frequently from people who TUT infrequently).

We argue, moreover, that our research provides additional – and particularly compelling – evidence for the validity of mind-wandering self-reports. First, our studies of mind wandering in the laboratory (McVay & Kane, 2009) and in daily life (Kane, Brown et al., 2007) both show that subjective, self-reported experiences of off-task thought are predicted by objective tests of WMC. Even though we assessed WMC and mind wandering in separate sessions (that actually appeared to subjects as completely separate studies), and even though our subjects had no basis on which to compare their own WMC to others’, people with lower-WMC reported mind wandering more often than did people with higher-WMC during a laboratory test of executive control and during cognitively demanding daily life activities. Moreover, the mind-wandering rates we measured in the laboratory varied systematically, not only with performance measures that were obvious to subjects (which, therefore, could reactively influence their thought reports), such as target accuracy, but also with measures that were unlikely be detected or monitored by subjects, such as overall RT variability. Finally, we have primed our subjects’ personal goals during executive-control tasks and found that
these primes elicit increased TUT reports and increased error rates, despite the fact that our subjects reported no awareness (when queried at the end of the experiment) that any of the task stimuli were related to their goals or concerns. Together, we argue that these findings suggest strongly that subjects accurately report their subjective experiences of off-task thought when probed during ongoing activities, and that contextual and individual variation in off-task thought reports are meaningfully related to important cognitive constructs such as WMC, executive control, and goals.

Conclusions

A broad theme of our mind-wandering research, and its implications for individual differences work in psychology and neuroscience, is that human subjects bring with them to the lab a plethora of experiences, memories, plans, and ongoing thoughts that influence their performance on cognitive tasks. In trying to understand individual or group differences in cognitive functioning, these extralaboratory concerns are usually considered noise and thus they represent within-group error in our statistical analyses. However, just as Cronbach (1957) called on experimental psychologists to embrace the interindividual variation that they regarded as measurement error, we suggest that researchers who study attention, working memory, executive control, and individual differences therein should consider how subjects’ extraexperimental goals and concerns might affect their stream of conscious experience during cognitive tasks, and how these experiences might lead systematically to particular varieties of attention and memory errors that are of theoretical and practical importance. Our findings suggest that at least some of the variance shared by WMC and executive-control tasks, for example, is explained by individual differences in propensity for mind-wandering. We therefore wonder about the extent to which other WMC- and attention-related findings, those discussed in the present volume, may also have mind wandering at their source.

References

Adrift in the Stream of Thought: The Effects of Mind Wandering on Executive Control and Working


