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Back to the future: Autobiographical planning and the functionality of mind-wandering

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ABSTRACT

Given that as much as half of human thought arises in a stimulus independent fashion, it would seem unlikely that such thoughts would play no functional role in our lives. However, evidence linking the mind-wandering state to performance decrement has led to the notion that mind-wandering primarily represents a form of cognitive failure. Based on previous work showing a prospective bias to mind-wandering, the current study explores the hypothesis that one potential function of spontaneous thought is to plan and anticipate personally relevant future goals, a process referred to as autobiographical planning. The results confirm that the content of mind-wandering is predominantly future-focused, demonstrate that individuals with high working memory capacity are more likely to engage in prospective mind-wandering, and show that prospective mind-wandering frequently involves autobiographical planning. Together this evidence suggests that mind-wandering can enable prospective cognitive operations that are likely to be useful to the individual as they navigate through their daily lives.

1. Introduction

The capacity of consciousness to engage in mentation that is unrelated to the demands of the moment confers a great amount of mental freedom, enabling the individual to go beyond the information contained in the immediate perceptual environment (Frith & Frith, 2006; Smallwood, Obonsawin, & Heim, 2003). Given that as much as half of human thought arises in this stimulus independent fashion (Killingsworth & Gilbert, 2010; Klinger, 1999), it would seem intuitive that such thoughts would play some functional role in our lives (Schooler et al., 2011). However, evidence linking the attentional decoupling that occurs during mind-wandering to performance decrements (Smallwood, 2011; Smallwood & Schooler, 2006) has led to the suggestion that stimulus independent thought represents a form of cognitive failure that interferes with rather than contributes to accomplishing the goals of daily life (McVay & Kane, 2010).

While mind-wandering can undoubtedly derail the goals associated with accomplishing one's current task (McVay & Kane, 2009; Reichle, Reineberg, & Schooler, 2010; Smallwood, Beach, Schooler, & Handy, 2008; Smallwood, Mcspadden, & Schooler, 2008; Smallwood, O'Connor, Sudberry, & Ballantyre, 2004), the functional value of stimulus independent thought may be found in the service of more general socio-cognitive goals (Baars, 2010; Baumeister & Masicampo, 2010). Indeed, the close coupling between spontaneous thought and an individual's current concerns (Klinger, 1999; McVay & Kane, 2010; Smallwood, O'Connor, et al., 2004) led to the suggestion that the mind-wandering state is often goal-directed (Smallwood & Schooler, 2006). Furthermore, in terms of frequency, a significant proportion of the imaginative opportunities afforded

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by the mind-wandering state are devoted to prospection (D'Argembeau, Renaud, & Van der Linden, 2009; Smallwood, Nind, & O'Connor, 2009). If mind-wandering is in part goal oriented, then such properties may be best served by prospective thought (Smallwood, 2010). Therefore, one functional value of mind-wandering could be its role in enabling the anticipation and planning of personally relevant future goals, a process referred to as autobiographical planning.

Consistent with the notion that future thinking during the mind wandering state involves autobiographical planning, Smallwood et al. (2011) found that a period of self-reflection increased the frequency of prospective mind-wandering. This finding is consistent with evidence showing that the process of imagining personal future events depends heavily upon the autobiographical memory system (Buckner, 2010; Schacter, Addis, & Buckner, 2007; Spreng & Grady, 2010; Suddendorf & Corballis, 2007; Tulving, 2005). Lesion studies, for example, indicate that problems in autobiographical memory retrieval are accompanied by deficits in future related thought (e.g., Klein, Loftus, & Kihlstrom, 2002; Williams, 1996) and neuroimaging studies show overlapping brain activation when individuals remember events from the past and imagine experiences that have yet to occur (Addis, Wong, & Schacter, 2007). Thus it is hypothesized that the autobiographical memory system provides key aspects of the content of prospective thought in general, and specifically in the mind wandering state. In the current context, we propose that this autobiographical information may primarily be invoked in the service of processing personal goals.

While autobiographical memory contributes to thought content, executive mechanisms are likely to be important in transforming self-memory into detailed, structured trains of thought, particularly thoughts that involve planning for the future. At a process level, future orientated thought entails a strong control component because situations that involve a working memory load reduce the frequency of future related thinking to a greater extent than thoughts of the past (Smallwood, Brown, Baird, & Schooler, 2011; Smallwood et al., 2009; Smallwood et al., 2011). Likewise, neuroimaging evidence indicates that, similar to mind wandering (e.g. Christoff, Smith, Gordon, Smallwood, & Schooler, 2009), experimenter induced future planning engages neural substrates of working memory, including the dorsolateral prefrontal cortex (Gerlach, Spreng, Gilmore, & Schacter, 2011; Spreng, Stevens, Chamberlain, Gilmore, & Schacter, 2010). Together these lines of evidence lead to the suggestion that autobiographical planning in the mind-wandering state is supported by a cooperation between the autobiographical memory system (providing the content) and executive control processes (allowing buffering and co-ordination of information) (Smallwood, Brown, et al., 2011).

2. Current study

During completion of a choice reaction time task known to be conducive to prospective mind-wandering (Smallwood et al., 2009; Smallwood et al., 2011; Smallwood, Brown, et al., 2011), participants were intermittently interrupted and asked to enter any thoughts they were having directly into an on-screen text box with the keyboard. After the conclusion of the testing session, these free-response experience sampling reports were coded by a panel of independent judges for task focus (*on task*, *off task*), temporal focus (*past, present*, *future*) and the cognitive dimensions under empirical investigation (*self-related*, *goal-directed*) using a method closely linked to previous studies (e.g. Smallwood et al., 2003).

There were three aims to the current study. Our first aim was to evaluate whether the content of off-task thought would be predominantly future-focused, as previous forced-choice experience sampling studies have suggested (e.g. Smallwood et al., 2009). Second, based on the fact that future thinking is suppressed by situations requiring attentional control (Smallwood et al., 2009), we examined whether greater working memory capacity allows for greater future thought during the mind-wandering state. Finally, our primary aim was to examine the content of experience sampling reports to assess the extent to which mind-wandering about the future involves autobiographical planning. We hypothesized that off-task future thoughts would entail a form of autobiographical planning in which goal-directed operations were executed on personally relevant content. Several predictions follow from this hypothesis: (1) individual differences in self-related thought should not account for unique variance in prospective mind-wandering when controlling for individual differences in goal-directed thought, and (2) experience sampling reports of prospective mind-wandering should involve the combination of goal-directed and self-related content.

3. Methods

3.1. Participants

Forty-seven participants completed this experiment (age range 17–32 years). All participants had normal or corrected to normal vision.

3.2. Procedure

In a counterbalanced order, participants completed a Choice Reaction Time Task (Smallwood et al., 2009) and an automated version of the Operation Span (OSPAN) task (Turner & Engle, 1989; Unsworth, Heitz, Schrock, & Engle, 2005).

3.2.1. Choice Reaction Time Task

Stimuli for this task were numeric digits, 1–9. Stimulus presentation rate was 1 item every 1750 ms (followed by 1250 ms fixation cross) and the stimuli were presented in five blocks each with a quasi-random order of presentation. Non-targets

($n = 260$) were black digits, while targets ($n = 30$) were colored green. Frequent non-targets required no response; targets required participants to determine whether the stimulus was even or odd. Responses were made with the mouse. Participants were instructed to click the left mouse button if the target was an odd number and the right mouse button if the target was an even number. The testing session for this task lasted approximately 30 min.

3.2.2. Thought probes

At 20 different occasions throughout the task, a prompt screen suddenly appeared asking participants to report the contents of their mental state. These probes were presented pseudo-randomly with a minimum gap size of 5 non-targets and a maximum gap size of 18 non-target stimuli. At each thought probe, participants were asked to "Please describe anything in your stream of consciousness in the moments prior to the probe." Responses were entered directly into a text box on the thought probe screen using the keyboard. Four independent judges rated the thoughts for task focus (*on task, off task*), temporal focus (*past, present, future*) and cognitive dimension (*self-related, goal-directed*). Each category was rated independently, and with the exception of the on/off task distinction the categories were not considered mutually exclusive. The judges coded each thought report on a categorical 0–1 basis (e.g., a thought was considered to be future oriented (1) or it was not (0)). Judges were instructed that to receive an off task classification a thought report must explicitly include content that is not related to the task. In the current study, judges were instructed to classify task related interference (Smallwood, Riby, Heim, & Davies, 2006) or participant's thoughts about their performance (e.g., "I'm worried I am forgetting the numbers") as on task. Judges were instructed to classify the temporal focus of the thought samples according to whether the participant mentioned or implied a past, present or future episode. Finally, thought samples were classified as self-related if they included specific mention of an individual's self, and were classified as goal-directed if they included an indication of a specific goal (defined as an objective or desired result that an individual endeavors to achieve). These guidelines were provided to judges in a text document that included examples for each category. The inter-rater classification for on and off task was found to be highly reliable ($\alpha = .95$). Experience sampling reports were coded for past focus ($\alpha = .77$), present focus ($\alpha = .79$), future focus ($\alpha = .88$), self-related ($\alpha = .69$) and goal-directed ($\alpha = .64$). For the purpose of analysis, inter-rater averages were calculated for each category for each individual.

3.2.3. Operation span task

Participants completed a 25 min automated version of the Operation Span (OSPAN) task (Unsworth et al., 2005). This task requires participants to remember a series of stimuli (letters) while engaging in an alternating processing task (verifying the accuracy of math equations). In the Automated OSPAN, participants complete three practice blocks and one experimental block. In the first practice block, participants practice the letter portion of the task. A sequence of letter stimuli are presented serially in the center of the monitor and participants are required to recall the letters in the order in which they are presented. In the second practice block, participants practice the math portion of the task by solving a series of 15 math problems. The program automatically calculates the average time participants take to solve the math equations and uses this mean time plus 2.5 SD as a response deadline for the math problems in the experimental block. In the third practice block, participants perform the letter recall and math equations in alternation, as is required in the experimental block. In the experimental block, participants complete 15 trials of a standardized sequence of set sizes (which varied from 3 to 7). In each trial, letter stimuli (presented at a central location for 800 ms) are interposed between math question and answer screens. At the end of each trial, participants are instructed to select all the letter stimuli from the current set in the correct serial order in which they were presented. If participants take longer than the response deadline (their average response latency plus 2 SD for the 15 practice math problems) to solve the math equation, the program automatically counts the trial as an error. This processing deadline serves to prevent participants from pausing to rehearse the letters instead of solving the math problems. Following standard procedure (Conway et al., 2005), we imposed an 85% accuracy criterion for math errors to exclude participants that did not abide by the processing deadline. However, all participants had accuracy above 85%, so no participants were excluded from analysis. OSPAN scores were calculated as the total number of letter stimuli recalled in the correct serial position over all trials (Conway et al., 2005).

4. Results

Our first analysis examined the temporal focus of thinking during on and off task states. The experience sampling data were analyzed using a mixed-model analysis of variance (ANOVA) with the repeated measures factors of Temporal Focus [*past, present and future*] and Task Focus [*on or off*]. Results are summarized in Fig. 1. A Temporal Focus × Task Focus interaction emerged [$F(2,46) = 128.97$, $p < .001$, $\eta^2 = .74$]. To further explore this effect we analyzed the temporal focus specific to off task cognition. Repeated measures ANOVA revealed a main effect of temporal focus in off task cognition [$F(2,46) = 25.98$, $p < .001$, $\eta^2 = .36$], post-hoc LSD tests indicated that off-task thought was primarily prospective ($M = .43$, $SD = .25$) [$p < .01$] while thoughts of the present ($M = .28$, $SD = .16$) were more common than past-related ($M = .12$, $SD = .14$) thoughts [$p < .01$]. As expected, relative to both future ($M = .03$, $SD = .05$) and past ($M = .02$, $SD = .04$) thought, on-task thoughts were overwhelmingly associated with the here and now ($M = .73$, $SD = .23$) [$p < .01$]. This analysis replicates the prospective bias to off-task thought observed previously (Smallwood et al., 2009) in a context where experience sampling reports were collected in a non-directed manner.

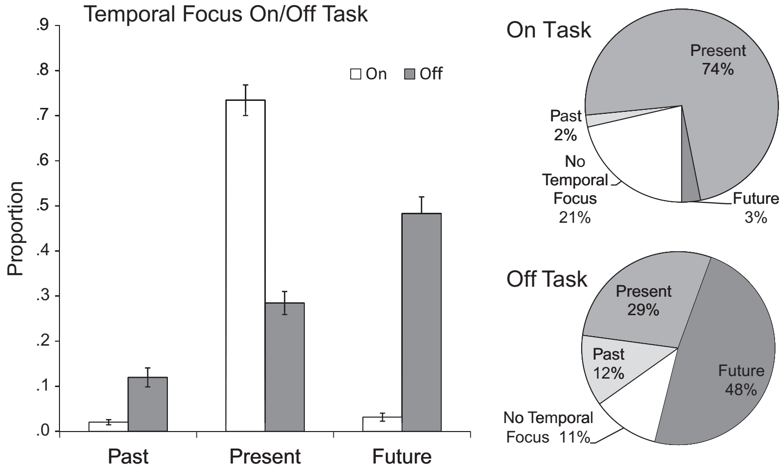

Fig. 1. Off task cognition exhibits a strong prospective bias while on task cognition is focused on the present.

Next we explored the relationship between participants' working memory capacity (as measured by performance on the OSPAN) and the tendency to engage in on and off task thoughts of different temporal foci. Overall, no significant correlation was observed between OSPAN Score and the general tendency to engage in off task thought during the task [$r(47) = .18$, $p = .43$], contrary to the predictions of executive failure theory (McVay & Kane, 2010). We used a mixed-model analysis of variance (ANOVA) with the repeated measures factors of Temporal Focus [*past, present and future*] and Task Focus [*on or off*] with OSPAN entered as a continuous between participant variable to explore the relationship between participants' working memory capacity and different categories of on and off task thought. We found a three way interaction of Temporal Focus × Task Focus × OSPAN Score [$F(2,46) = 3.01$, $p = .05$, $\eta^2 = .06$]. To further explore this effect we analyzed the temporal focus specific to on and off task cognition while co-varying OSPAN Score. Results revealed that there was no significant interaction between the temporal focus of on task thoughts and OSPAN [$F(2,45) = .02$, $p = .98$, $\eta^2 = .001$], while there was a significant interaction between the temporal focus of off task thoughts and OSPAN [$F(2,45) = 5.43$, $p < .01$, $\eta^2 = .11$]. Further analysis showed that OSPAN was positively correlated with off task future thoughts [$r(47) = .36$, $p < .05$, 95% CI [.08, .59]], negatively correlated with off task thoughts of the present [$r(47) = -.29$, $p = .05$, 95% CI [−.53, −.004]] and showed no relationship to off task thoughts of the past [$r(47) = .06$, $p = .68$, 95% CI [−.23,.34]]. Fig. 2 shows the correlations between OSPAN score and prospective, present focused and retrospective mind-wandering.

Our next analysis examined the relationship between individual differences in prospective mind-wandering and individual differences in the tendency to engage in self-related and goal-directed thought. If prospective mind-wandering involves autobiographical planning, then future thinking should be best predicted by a combination of self and goal directed thought. Using a parallel hierarchical multiple regression model, we evaluated the extent to which *self-related* and *goal-directed* uniquely predicted future off task cognition (see Table 1). In the first model, *self-related* was entered on the first step of the

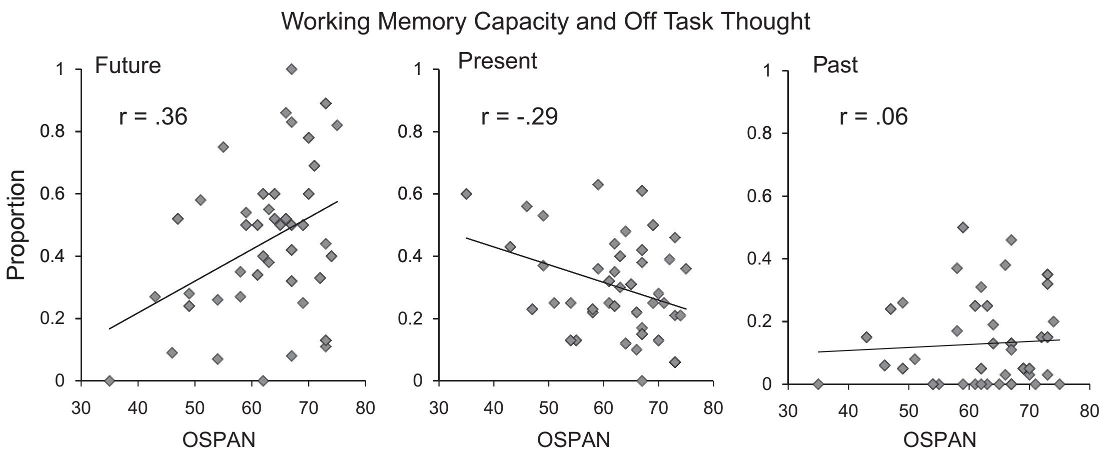

Fig. 2. Participants who more frequently engaged in spontaneous future thought and less frequently engaged in spontaneous thoughts of the present had higher OSPAN scores, while there was no relationship between spontaneous past thought and OSPAN.

regression equation, *goal-directed* was entered in the second step and the interaction term *self-related x goal-directed* was entered in the third step. In the second model, *goal-directed* was entered on the first step of the regression equation, *self-related* was entered in the second step and the interaction term *goal-directed x self-related* was entered in the third step. As indicated in Table 1, overall the model accounted for 55% of the variance in prospective thought [$F(3,46) = 17.49$, $p < .001$]. *Model 1*: On Step 1, *self-related* explained 28% of the variance in prospective thought [$F(1,46) = 17.85$, $p < .001$]. On Step 2, *goal-directed* accounted for 17% of the variance in prospective thought beyond self-directedness [$F(1,44) = 13.57$, $p < .001$]. On Step 3, *goal-directed x self-related* accounted for an additional 9.7% of the variance in future thought beyond the main effects [$F(1,43) = 9.24$, $p < .001$]. *Model 2*: On Step 1, *goal-directed* explained 41% of the variance in prospective thought [$F(1,45) = 32.13$, $p < .001$]. On Step 2, *self-directed* accounted for a non-significant 3% additional variance [$F(1,44) = 2.91$, $p = .095$]. As before, on Step 3 *goal-directed* × *self-related* accounted for an additional 9.7% of the variance in future thought [$F(1,43) = 9.24$, $p < .001$]. This analysis indicates that individual differences in future thinking were best explained by the tendency to engage in autobiographical planning (e.g. the application of goal-directed processes to self relevant information). Finally, we also examined the predictive capacity of individual differences in *self-related* and *goal-directed* thought to individual differences in off task thoughts of the past. Together the predictor variables explained approximately 20% of the variance in past off task cognition [$R^2 = .199$; $F(2,46) = 5.48$, $p < .01$]. Unconstrained thoughts of the past were more frequent for individuals who reported greater *self-related* thought ($\beta = .52$, $p < .01$, $sr^2 = .42$) and who reported less *goal-directed* thought ($\beta = -.45$, $p < .01$, $sr^2 = .42$).

Finally, we examined the associations between *self-related* and *goal-directed* content to on and off task thought as well as the temporal focus of mind-wandering reports. First, we examined the relationship between *self-related* and *goal-directed* cognition to on and off task thoughts. The proportion of *self-related* thought was significantly greater for off task ($M = .66$, $SD = .27$) than for on task reports [($M = .46$, $SD = .27$), $t(45) = 3.424$, $p < .001$, $\eta^2 = .23$]. Correspondingly, the proportion of *goal-directed* thought was greater for off task [$M = .26$, $SD = .16$] than on task reports [($M = .04$, $SD = .08$), $t(45) = 7.921$, $p < .001$, $\eta^2 = .49$]. See Fig. 3, lower panel. Repeated measures ANOVA was then used to compare the relative proportion of *self-related*, *goal-directed* and both self-related and goal-directed (*goal-directed x self-related*) off task thoughts of the past, present and future. This analysis compared, for example, the proportion of past self-related thoughts to present self-related thoughts to future self-related thoughts. For each participant, proportion scores were calculated that reflected the proportion of thoughts that were simultaneously classified as having *self-related*, *goal-directed* or self-related and goal-directed (*goal-directed x self-related*) content and also a temporal focus. ANOVA revealed that goal-directed thought was more frequently future focused ($M = .40$, $SD = .27$) than present focused ($M = .06$, $SD = .12$) or past focused [($M = .03$, $SD = .07$), $F(2,45) = 58.20$, $p < .001$, $\eta^2 = .58$]. Correspondingly, self-related thought was more frequently future focused ($M = .48$, $SD = .30$), than present focused ($M = .20$, $SD = .24$), and more frequently present focused than past focused [($M = .12$, $SD = .16$), $F(2,45) = 23.16$, $p < .001$, $\eta^2 = .52$]. Finally, and most importantly, thoughts that involved a combination of both goal-directed and self-related content were more frequently future focused ($M = .39$, $SD = .27$) than present focused ($M = .06$, $SD = .12$) or past focused [($M = .03$, $SD = .07$), $F(2,45) = 33.95$, $p < .001$, $\eta^2 = .62$]. This analysis indicates that reports of prospective mind-wandering most frequently involved the combination of goal-directed and self-related content, providing evidence that the thoughts involve autobiographical planning. The percentage of past and future thoughts comprised by each content category (*self, goal, and self* × *goal*) across all thought probe responses is illustrated by Fig. 3. Complementing our individual differences analysis, the examination of the momentary occurrence of thoughts that were both self-related and goal-directed indicated that such experiences were overwhelming associated with a prospective focus.

5. Discussion

Through content analysis of experience sampling protocols, this study revealed that a significant part of the mind-wandering state involves thoughts of the future, confirming previous observations made using forced choice experience sam-

Table 1
Hierarchical regression analyses predicting prospective mind-wandering.

	B	*SE*	β	R^2	ΔR^2
Predictors: self, goal, self × goal					
Step 1: Self	0.502	0.119	0.533***	0.284***	0.284***
Step 2: Self, goal	0.770	0.209	0.507***	0.453***	0.169***
Step 3: Self, goal, self × goal	2.096	0.690	1.283**	0.550***	0.097**
Predictors: goal, self, goal × self					
Step 1: Goal	0.980	0.051	0.645***	0.417***	0.417***
Step 2: Goal, self	0.222	0.130	0.235	0.453***	0.036
Step 3: Goal, self, goal × self	2.096	0.690	1.283**	0.550***	0.097**

Note: $N = 47$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

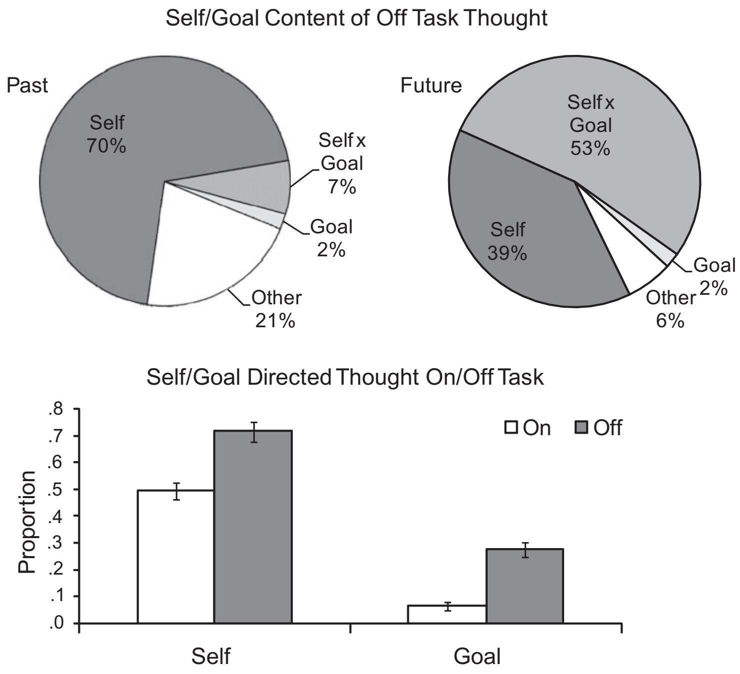

Fig. 3. While both the past and future involve the self, future thought involves goal-directed operations on self-relevant information or *autobiographical planning*. The proportion of goal-related and self-directed thought is significantly higher for off task compared to on task experience sampling reports.

pling methods (Smallwood et al., 2009). In addition, those individuals who engaged in the greatest future off task thought had advantages in their executive processing skills. The fact that individuals with higher working memory capacity engaged in greater future thought is the corollary finding of the observation that when working memory resources are not required for task performance, participants engage in greater amounts of future related thought (Smallwood et al., 2009). In tandem, these observations suggest that the availability of idle working memory resources is particularly important in the generation of future related cognition during mind-wandering.[2]

Building on the finding that self-memory is a core component of future thinking during mind-wandering (Smallwood et al., 2011), we propose that this autobiographical information may primarily be invoked in the service of anticipating and planning personally relevant future goals. In support of this hypothesis, the results of our hierarchical multiple regression model show that individual differences in self-related thought did not account for unique variance in prospective mind-wandering when controlling for individual differences in goal-directed thought. Furthermore, a detailed analysis of the subjective reports of the content of off task thought indicated that prospective mind-wandering frequently involves a combination of self-relevant and goal-directed content. Together these findings suggest that the observed connection between the self and future thinking in mind-wandering may be attributed in large part to the fact that prospective mind-wandering often involves planning for the future goals of the individual.

While the majority of spontaneous cognition is future oriented, a smaller but significant proportion of off task thoughts were directed to the past. Thoughts of the past, unlike prospection, tended not to be associated with goal-directed processing. The observation that goal-related content was associated with mind-wandering about the future but not the past is consistent with the idea that spontaneous prospective thought is particularly likely to be functional, i.e. to aid in carrying out future plans (Suddendorf & Corballis, 2007). While cognitive neuroscience studies of future and past episodic thought show overlap in neural activation (Bar, 2007; Buckner & Carroll, 2007), the current data suggests that there are important differences that govern the occurrence of these states in spontaneous thought. Given the overlap of goal-directed and future thoughts demonstrated by the current study, one interesting possibility is that prospective thought could differ on the involvement of the fronto-parietal system, given that this region shows enhanced default mode connectivity when individuals engage in autobiographical planning (Smallwood, Brown, et al., 2011; Spreng et al., 2010).

Recent work indicates that inducing a negative mood increases retrospective focus during the mind-wandering state (Smallwood & O'Connor, 2011). In this context, perhaps the low level of goal-related operations during retrospection are one reason why depressive ruminative thought is typically unproductive (Watkins, 2008). On the other hand, a focus on the past could reflect a process of reminiscence in which individuals benefit from reliving pleasant past experiences. Given

[2] Additionally, the fact that OSPAN scores significantly predicted future thinking provides an important source of external corroboration for the judge's ratings of the content of thoughts in this study.

the close ties between mind-wandering and mood (Killingsworth & Gilbert, 2010; Smallwood et al., 2009), future studies investigating how the content of mind-wandering episodes relate to the affective functioning of the individual would be valuable.

In combination with recent results, the current data provide converging evidence that the mind-wandering state often involves autobiographical planning and that executive control processes support this thought. Not only is greater working memory capacity associated with more future thought during mind-wandering, but tasks that require the engagement of working memory selectively decrease prospective thought (Smallwood et al., 2009, 2011; Smallwood, Brown, et al., 2011). Furthermore, both mind-wandering (Christoff et al., 2009) and experimenter induced autobiographical planning (Gerlach et al., 2011; Spreng et al., 2010) engage elements of both the default mode (such as the medial prefrontal cortex and the posterior parietal cortex) and the executive system (e.g. dorsolateral prefrontal cortex). Such converging evidence supports the decoupling hypothesis of spontaneous thought: executive resources may be required to coordinate an internal train of thought (particularly thoughts that involve planning for or anticipating the future) and to insulate the experience from the disruptive influence of external events (Barron, Riby, Greene, & Smallwood, 2011; Schooler et al., 2011; Smallwood, 2010; Smallwood & Schooler, 2006; Smallwood et al., 2003, 2011; Smallwood, Brown, et al., 2011).

It is important to note, however, that the relationship between individual differences in executive processes and mind-wandering is likely to be influenced by the context within which they occur (Smallwood, 2010). This *context x resource* view suggests that while mind-wandering at the wrong time can undoubtedly involve a lapse in executive control of task relevant information (McVay & Kane, 2009; Smallwood et al., 2004, 2008), in other circumstances, particularly when the demands of the primary task are low, executive resources can be beneficially deployed in the mind-wandering state (e.g. to prepare for future events). Thus, under circumstances of minimal attentional demands, the application of control processes during spontaneous thought may serve to help balance the goals of the present with the more general current concerns of the individual (Klinger, 1999; McVay & Kane, 2010; Smallwood, 2010; Smallwood, O'Connor, et al., 2004; Smallwood & Schooler, 2006). Rather than simply mitigating against mind-wandering, the possession of sufficient working memory capacity enables individuals to take full advantage of these underutilized resources and return to their favored mental destination: back to the future.

Acknowledgments

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