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EXPLORING THE PAST AND IMPENDING FUTURE IN THE HERE AND NOW: MIND-WANDERING IN THE DEFAULT STATE

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ABSTRACT

Although mind-wandering is a ubiquitous psychological phenomenon, little is known about the neural operations that support this core feature of human cognition. Using a combination of behavioral and functional brain imaging (fMRI) methods, the current investigation demonstrates that recruitment of circumscribed regions of the default network – cortical areas that are active during unconstrained cognitive periods – depends on people's proclivity for reflecting on events from the distant past or impending future while mind-wandering. The present results reveal that whereas medial temporal regions (e.g., parahippocampal cortex) are recruited when the mind wanders to memories of past episodes, areas involved in propsection (e.g., frontal polar and hippocampal) are active when mind-wandering centers on future events. Consistent with recent findings, there is some overlap between the cortical regions involved in thinking about the past and the future. The significance of spontaneous self-projection in time is considered.

Key words: Mind-wandering, stimulus-independent thought, SIT, Default network, Default state, Prospective memory, medial temporal lobe, Prospection, Simulation, Self-Projection, Mental time travel, goals.

INTRODUCTION

Although most of us are all too familiar with the mind's proclivity for generating thought that is unbound to the "here and now" (e.g., "considering who to invite to a dinner party while walking to work"), surprisingly little is known about the extensive time periods in which people engage in stimulus-independent thought (SIT). In particular, precisely where does the mind tend to wander to and how does it spontaneously create thoughts that are unrelated to current sensory inputs? Present across cultures (Singer & McCraven, 1962), mind-wandering is hypothesized to constitute a psychological baseline to which people return when they "do nothing," or when they engage in activities that can be accomplished without conscious supervision (Klinger, 1971; Singer, 1966). Recent evidence indicates that a network of cortical regions that is active when people are resting or performing tasks with minimal processing demands – the *default network* (Raichle et al., 2001) – may support this cognitive capacity (Andreasen et al., 1995; Binder et al., 1999; Christoff, Ream, & Gabrieli, 2004; Maguire et al., 2001; Mason et al., 2007; Mazoyer et al., 2001; McGuire et al., 1996). Quite how activity in the default-network relates to mind-wandering content, however, has yet to be elucidated.

Several attempts at specifying where people's minds tend to wander to when they engage in SIT have previously been undertaken. In perhaps the most exhaustive effort to clarify the content of mind-wandering, Klinger and Cox (1987) analyzed more than 1,400 thought samples that were collected from 29 individuals over the course of several days (see also Klinger, 1999; Singer, 1966; Singer & McRaven, 1961). Based on their findings, they concluded that while people occasionally entertain thoughts about improbable events (i.e., they fantasize), the mind more frequently wanders to episodes from the past (e.g., remembering the last time one missed a meeting while brushing one's teeth) and to current practical concerns (e.g., pondering whether one has time to stop for coffee while dressing for work). While under certain circumstances this spontaneous self-projection is problematic, such as when it interferes with current processing goals, there is reason to suspect that it serves an adaptive function in cognition, facilitating problem-solving and planning when circumstances preclude doing something immediate about an existing goal (Bar, 2007; Buckner & Carroll, 2007; Dudai, 2005; Klinger, 1990; Schacter and Addis, 2007; Singer & Antrobus, 1972; Suddendorf & Corballis, 1997; Szpunar, Watson & McDermott, 2007).

As mind-wandering regularly involves these two types of thought (i.e., past vs. impending future), we anticipated that activity in specific regions of the default-network would be associated with these distinct mental contents. Although it would be reasonable to explore this possibility by measuring BOLD changes in the default network while participants respond to prompts that direct them to consider events and people from their past and to reflect on "unfinished business" (cf. Addis, Wong & Schacter, 2007), one would possibly be doing so at the expense of the hallmark features of this form of mentation: its relatively unbidden, undirected and unmonitored (e.g., "Am I still thinking about events from the past?") nature. In light of evidence that people have a "mind-wandering style" (cf. Singer & Antrobus, 1963; 1972) – a favored pattern of thought that they default to when the external environment ceases to pose challenging and variable processing demands – the approach taken in the present investigation was to develop a model of mind-wandering content by factor-analyzing participants' responses to the Imaginal Process Inventory (IPI; Singer & Antrobus, 1972), a questionnaire designed to measure aspects of inner thought, and then relate participants' mind-wandering content factor scores to the default network activity they exhibit during periods of frequent mind-wandering.

Given the high level of resting-state metabolism observed in the same medial temporal lobe regions that support episodic memory (Greicius, Kransow, Reiss & Menon, 2002; Greicius, Srivastava, Reiss & Menon, 2004), we expected that activity in this area during high incidence SIT periods would be greatest among individuals whose mind-wandering episodes tend to dwell on episodes and people of the past. In contrast, we expected that people with a proclivity for reflecting on impending events or "current concerns" (Klinger, 1971) while mind-wandering would exhibit significantly greater recruitment of both frontal regions that are implicated in such things as reflecting on intentions to act in the future (e.g., BA10; Okuda et al., 2003) and medial temporal regions implicated in retrieving details of past episodes. This latter hypothesis stems, in part, from recent evidence indicating that simulating possible future scenarios requires retrieving contextual details from past happenings (see Addis, Wong & Schacter, 2007; Bar, Aminoff, Mason & Fenske, 2007; Hassavis, Kumaran, Vann & Maguire, 2007; Okuda et al., 2003; Szpunar, Watson & McDermott, 2007).

MATERIALS AND METHODS

The approach taken in the current investigation was to obtain measures of impending future and past- oriented mind-wandering and then to relate these constructs to the activity observed in the default network when people engage in SIT. Prior to conducting the fMRI portion of the experiment, we administered a questionnaire that measures mind-wandering and then used factor analysis to identify dimensions related to mind-wandering content to regress against our functional imaging data. Identifying cortical regions associated with impending future and past-oriented mind-wandering involved a series of 3 experimental phases (see Mason et al., 2007 for a detailed description). In Phase 1, we established high incidence SIT periods by extensively training participants on a small set of working-memory sequences and then confirmed that people experience a greater incidence of SIT while performing the trained sequences relative to new sequences (Phase 2). In Phase 3, we identified cortical regions (with fMRI) that were more active during high relative to low incidence SIT periods (when participants performed 'trained' sequences relative to 'new' sequences) and then regressed participants' mind-wandering content scores against this pattern of cortical activity. To confirm that people have relatively stable mind-wandering styles, we administered the IPI on a second occasion, approximately 32 months later, and assessed the reliability of their responses over a period of several years.

OBTAINING MEASURES OF IMPENDING FUTURE AND PAST-ORIENTED MIND-WANDERING

Participants

A total of 194 individuals (127 female) participated in this portion of the experiment in exchange for course credit. All participants gave informed consent according to the procedures approved by the Committee for the Protection of Human Subjects (CPHS).

Design and Stimulus Materials

To confirm that the mind tends to wander to events from the past and to immediate future concerns, we administered portions of the IPI (Singer & Antrobus, 1972) and conducted a factor analysis on participants' responses. Participants were administered a total of 140 attitudinal statements (e.g., "*I sometimes daydream about people and places I was familiar with when young*") from 11 subscales related to daydreaming to which they were asked to indicate the extent to which they agreed or disagreed (1: *strongly uncharacteristic* to 5: *strongly characteristic*).

Procedure

Each participant completed an electronic version of the questionnaire. It was explained that the questionnaire pertained to mind-wandering, or their spontaneous thoughts and daydreams. Participants were told that, within the context of the present experiment, the term 'daydream' referred to the "shifting of attention away from an ongoing physical or mental task or from a perceptual response to some internal stimulus" and provided an example: "*thinking about an upcoming party while making a tuna sandwich*."

Factor analysis was conducted using principle component analysis followed by a varimax rotation (Goldberg & Digman, 1994). As we anticipated finding high correlations among the constructs measured by the IPI subscales (e.g., 'Present Oriented Thought' and 'Problem-Solving' in Daydreams) and because we were interested in how these higher-order factors related to cortical activity in the default network, the analyses were undertaken on the IPI subscale means. Results of Cronbach's reliability analyses confirmed that each of the eleven subscales was comprised of items related to a single uni-dimensional construct. Eight of the eleven subcales on the IPI had high internal consistency (Cronbach's Alpha > .80). The remaining three had adeqsuate alpha levels of .73, .74, and .72. Components were restricted to those with Eigenvalues > 1.

Results

Results indicated that 67% of the variance in participants' responses to the questionnaire was accounted for by four factors. Of particular interest to the present investigation were the two factors related exclusively to mind-wandering content (see Table 1 for factor loadings and example items). The first of these factors – *propensity for impending future thought* – accounted for 14% of the variance in participants' responses, with high positive loadings on scales measuring the tendency to reflect on immediate concerns and generate potential solutions to unresolved problems and negative loadings on the scale measuring improbable thinking while daydreaming. The second mind-wandering content factor – *propensity for past mind-wandering* – had high loading on the scale measuring the tendency to reflect on the past and accounted for 11% of the variance.[1] Having established these two factors, we then computed factor scores for participants in the fMRI portion of the experiment using the rotated loadings as weights.

Table 1.0 Varimax rotated component matrix displaying loadings greater than 0.5 and less than -0.5 for the factors related to mind-wandering content

Subscale	Sample Items	Impending Future	Past
'Present Orientation in Daydreams'	"My present day concerns are usually reflected in my daydreams"	.71	
'Problem Solving in Daydreams'	"Thoughts I have are often about different ways of finishing things I still have to do in my life"	.80	
'Bizzare/Improbable Daydreams'	"I often have thoughts about things that could rarely occur in real life"	-.57	
'Past Orientation in Daydreams'	"I sometimes think about people and places I was familiar with when I was young"		.87
	Variance Explained	***14%***	***11%***

ASSESSING THE STABILITY OF PEOPLE'S IMPENDING FUTURE AND PAST-ORIENTED MIND-WANDERING

To confirm that people have relatively stable mind-wandering styles, we administered the IPI on a second occasion, approximately 32 months later, and assessed the reliability of participants' responses over a period of several years.

Participants

Each of the 194 individuals who completed the IPI were contacted 32 months after the initial administration date and asked to complete the questionnaire in exchange for monetary compensation. Approximately 35% of the individuals (N=

69) completed and returned the electronic version of the questionnaire to the experimenter.

Design and Stimulus Materials

To assess the stability of people's mind-wandering experiences (i.e., to establish that people have a mind-wandering "style"), we computed participants' *propensity for impending future thought* and *propensity for past mind-wandering* factor scores. This was done by taking the standardized mean score for each scale, multiplying it by the corresponding factor loading of the variable for the given factor (from the factor model generated 32 months previously) and summing these products.

Results

As expected, results revealed a strong positive correlation between participants *propensity for impending future thought* factor scores computed after the initial administration (Time 1) and their *propensity for impending future thought* factor scores 32 months later (Time 2), $r(68) = .66$, $p < .0001$. Correlations between mean responses to the particular scales with high loadings ($x > .5$ and $x < -.5$) on the *propensity for impending future thought* factor scores at Time 1 and Time 2 were also computed. Results revealed a strong positive correlation between Time 1 and Time 2 for all three scales: 'Problem Solving in Daydreams', $r(68) = .51$, $p < .0001$; 'Present-Oriented Daydreams', $r(68) = .60$, $p < .0001$; and 'Bizarre and Improbable Daydreams' (which was negatively correlated with the factor), $r(68) = .71$, $p < .0001$. Similarly, results revealed a strong positive correlation between participants' Time 1 *propensity for past mind-wandering* and their Time 2 *propensity for past mind-wandering* factor scores, $r(68) = .60$, $p < .0001$. The correlation between mean responses to the one scale with high loadings on the *propensity for past mind-wandering* factor scores – 'Past-Oriented Daydreams' -- at Time 1 and Time 2 was also significant, $r(68) = .65$. $p < .0001$.

Having established that mind-wandering styles can be reliably characterized by the proclivity for considering past and impending future events, we then sought to relate these two dimensions to the activity observed in the default network when people engage in SIT. Identifying cortical regions associated with impending future and past-oriented mind-wandering involved a series of 3 experimental phases (see Mason et al., 2007 for a detailed description). In Phase 1, we established high incidence SIT periods by extensively training participants on a small set of working-memory sequences and then confirmed that people experience a greater incidence of SIT while performing the trained sequences relative to new sequences (Phase 2). In Phase 3, we identified cortical regions (with fMRI) that were more active during high relative to low incidence SIT periods (when participants performed 'trained' sequences relative to 'new' sequences) and then regressed participants mind-wandering content scores against this pattern of cortical activity.

PHASE 1: ESTABLISHING HIGH INCIDENCE MIND-WANDERING PERIODS

In Phase 1, we sought to establish high incidence SIT periods by extensively training participants on a small set of working-memory sequences (cf. Teasdale et al., 1995).

Participants

Nineteen individuals (12 female) who filled out the IPI also completed the training, thought-sampling and fMRI phases of the experiment in exchange for course credit. All participants were right-handed, native English speakers with no history of neurological problems. Participants gave informed consent according to the procedures approved by the CPHS.

Procedure

Training (Days 1-3)

During Phase 1, participants were trained on both a verbal and a motor working-memory task. The verbal working-memory task involved remembering and manipulating 4 four-letter sequences (e.g., 'R H V X'). A verbal working memory trial consisted of the following sequence of events. The target sequence appeared on the screen for a duration of 800ms, at which point it was replaced by an arrow which indicated the direction participants should reference the sequence (an arrow to the 'left' indicated the participant should think of the sequence in reverse – as 'X V H R' – while an arrow to the 'right' indicated that the string should be references in the forwards direction). Participants were then shown each of the letters contained in the string, to which they indicated, via a key-press, the position of the letter (e.g., if they saw 'R H V X' after a 'left' arrow the correct response would be '2'). The motor task involved remembering and manipulating 4 finger-tapping patterns. A motor trial consisted of the following sequence of events. Four boxes appeared at the center of the screen and illuminated, one at a time, in the target key sequence order. Eight hundred milliseconds later, an arrow indicating the direction in which they should repeat the target sequence appeared on the screen. An arrow to the right indicated that participants should repeat the sequence in the order just displayed, while an arrow to the left signaled that the key sequence should be repeated in the reverse order. All trials in both the verbal and motor working-memory task were self-paced, leaving no time in any of the block for participants to "do nothing". On three consecutive days, participants reported to the laboratory for 30 minutes of training with the 4 letter and 4 finger-tapping sequences.

PHASE 2: THOUGHT-SAMPLING (DAY 4)

The goal of Phase 2 was to confirm that people experience a greater incidence of SIT while performing the trained sequences relative to new sequences. Upon arrival on the fourth day of training, the 19 participants were informed that they again would be practicing the learned sequences in blocks but that, at random intervals, they would be interrupted and asked to indicate, via a binary key-press, whether they were experiencing SIT (defined for them as "thoughts that do not facilitate performance and are not immediate reactions to perceptual information gleaned over the course of a trial"). Participants were then informed of one additional procedural change. In addition to performing blocks of the working-memory task on the eight learned sequences (4 letter strings, 4 motor patterns), they would also be performing the task on sequences that they had not practiced previously. Each participant was then administered three 7-min runs of interleaved rest (i.e.,'+') and task blocks (i.e., verbal and motor working memory tasks). Data from one participant were not included in the analysis because of a computer malfunction

Results

Consistent with results of other studies (e.g., Teasdale et al., 1995), the propensity to mind wander was most pronounced when participants performed practiced sequences (i.e., when the task could be performed without conscious supervision) and during rest periods relative to periods in which novel sequences were performed [$F(2,34) = 81.49$, $p < .01$]. Participants reported a greater incidence of mind wandering during the baseline (i.e., rest) blocks ($M = .93$; $SD = .16$) than during both practiced blocks ($M = .32$, $SD = .20$), $t(17) = 9.22$, $p < .01$, and novel blocks ($M = .22$, $SD = .18$), $t(17) = 10.96$, $p < .01$. More importantly, however, participants reported a significantly greater incidence of mind wandering during the practiced blocks than during the novel blocks [$t(17) = 2.11$, $p < .05$], even though the tasks were identical.

PHASE 3: IDENTIFYING NEURAL CORRELATES OF PAST AND IMPENDING FUTURE MIND-WANDERING

In Phase 3, we identified cortical regions (with fMRI) that were more active during high relative to low incidence SIT periods (when participants performed 'trained' sequences relative to 'new' sequences) and then regressed participants mind-wandering content scores against this pattern of cortical activity.

Procedure

Functional MRI (Day 5)

On the fifth and final day of the experiment, participants were scanned (fMRI) while performing both working memory tasks on the practiced sequences, on novel sequences and while passively observing a centrally-presented fixation cross. The experiment consisted of 5 EPI scans, each lasting 6 minutes and 50 seconds. Each of the blocks (fixation, practiced sequences, novel sequences) within a single scan lasted between 20 and 40 seconds in duration.

Images were acquired using a 1.5 Tesla whole body scanner (GE Signa) with a standard head coil. Visual stimuli were generated with Presentation software (www.neuro-bs.com) on a Dell computer. Stimuli were projected to participants with an Epson (model ELP-7000) LCD projector onto a screen positioned at the head end of the bore. Participants viewed the screen through a mirror. Cushions were used to minimize head movement.

T1- weighted anatomical images were collected using a high-resolution 3-D sequence (SPGR; 128 sagital slices, TR = 7 ms, TE = 3 ms, prep time = 315 ms, flip angle = 15°, FOV = 24 cm, slice thickness = 1.2 mm, matrix = 256 x 192). Functional images were collected in runs using a gradient echo EPI sequence (each volume comprised 25 slices; 4.5 mm thick, 1 mm skip; TR = 2500 ms, TE = 35 ms, FOV = 24 cm, 64 x 64 matrix; 90° flip angle).

Image Analysis

Functional MRI data were analyzed using SPM99 (Friston et al., 1995). For each functional run, data were preprocessed to remove sources of noise and artifact. Functional data were corrected for differences in acquisition time between slices for each whole-brain volume, realigned within and across runs to correct for head movement, and co-registered with each participant's anatomical data. Functional data were then transformed into a standard anatomical space (3 mm isotropic voxels) based on the ICBM 152 brain template (MNI) which approximates Talairach and Tournoux's atlas space. Normalized data were then spatially smoothed using a Gaussian kernel (6 mm FWHM).

For each participant, a general linear model specifying task effects (modeled with a function for the hemodynamic response), runs (modeled as constants), and scanner drift (modeled with linear trends) was used to compute parameter estimates (β) and *t*-contrast images for each comparison at each voxel. These individual contrast images were then submitted to a second-level, random-effects analysis to obtain mean *t*-images (thresholded at p = .001, uncorrected; k = 10 mm^3). An automated peak-search algorithm identified the location of peak activations based on *z*-value and cluster size.

Results

Neural Correlates of Mind-wandering

The default-network was functionally defined by comparing the neural response associated with rest (i.e., baseline) to the response associated with all-task periods (i.e., novel and practiced blocks). This comparison revealed significantly greater recruitment in the: posterior cingulate and precuneus, posterior lateral cortices, bilateral insula, anterior cingulate, bilateral parahippocampal gyri, and aspects of ventral and dorsal MPFC (Mazoyer et al., 2001; Shulman et al., 1997). To identify default-network regions that were more active during periods of frequent relative to infrequent mind wandering, we compared neural activity when participants performed practiced blocks to activity during novel blocks using the 'baseline > task' contrast as an inclusive mask. As predicted, activity in nearly all default-network regions was significantly greater during frequent mind-wandering periods (Figure 1). Importantly, no default-network regions exhibited greater activity during periods of infrequent mind-wandering (i.e., ‘novel > practiced’, inclusively masked with ‘baseline > task’).

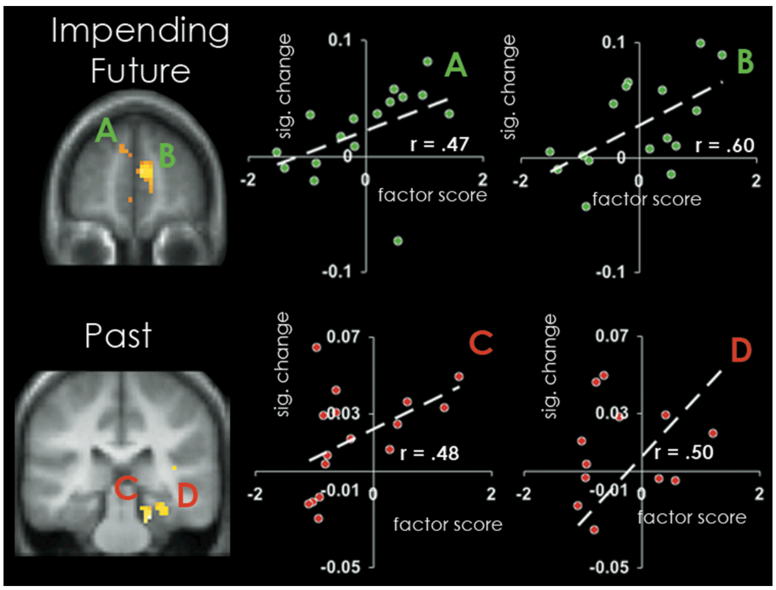

Figure 1. Default-network regions associated with thinking about the impending future (i.e., “concern-related” thought) and the past while mind-wandering. Depicted are regions within the default-network [i.e., areas that emerged from the contrast ‘rest > task’ (p<.05, k=10)] that exhibited greater activity during frequent relative to infrequent mind-wandering periods (p<.001, k=10) and that correlated positively with participants’ *propensity for impending future thought* scores (top) and *propensity for past mind-wandering* scores (bottom). Scatter-plots depict participants’ BOLD difference scores (practiced – novel) plotted against their factor scores. BOLD signal values for the two blocks were computed for each participant by averaging the signal in regions within 8 mm of the peak from 3 TRs (7.5 s) until 7 TRs (17.5 s) after the block onset. ‘A’= R. mPFC (BA9; -9,54,28; *p* = .003, uncorrected); ‘B’ = X (BA10; 6,53,13; *p* = .003, uncorrected); ‘C’ = R. parahippocampus (BA36; 21,-30,-19 *p* = .006, uncorrected); and ‘D’= R. parahippocampus (BA36; 30,-33,-14; *p* = .006, uncorrected).

Neural Correlates of Impending Future and Past-Oriented Mind-wandering

To assess the relationship between default-network activity and mind-wandering content, we computed participants' factor scores on the experimental dimensions of interest (i.e., *propensity for impending future thought* & *propensity for past thinking*). The resulting scores were then regressed against the pattern of activity participants exhibited during high incidence mind-wandering periods (i.e., 'practiced > novel', inclusively masked with 'baseline > task'; $p < .05$, k=15; see Table 2). Consistent with our predictions, the greater the self-reported tendency to mind-wander about impending events and unresolved matters, the greater the activity observed in a cluster that extended across bilateral medial frontal (BAs 10,8) and superior frontal (BA9) gyri, a cluster that extended across the left hippocampus and amygdala (BAs 24,28,36), and a cluster in the left parrahippocampal (BA36)/fusiform gyri (BA37). There were also significant positive correlations detected in the R. anterior cingulate (BAs 24,31), in the R. supramarginal gyrus (BA40) and the L. claustrum (BA37). No cortical regions exhibited a negative correlation with this factor. Furthermore, the stronger the tendency to mind wander about events from the past, the greater the activity observed in the R. parahippocampus (BA35,36), R. insula (BA13), and the R. cingulate (BA24). Significant negative correlations with *propensity for past thinking* were observed in bilateral medial frontal regions (BAs 9 and10) and in the posterior cingulate (BA31).

Discussion

Previous functional imaging and lesion studies suggest that the cued retrieval of episodes from the past and future involve overlapping and unique aspects of medial temporal lobe and frontal polar regions (Addis et al., 2007; Okuda et al., 2003; 2005; Szpunar, Watson & McDermott, 2007). Of particular interest is recent evidence revealing that imagining future events involves frontal polar areas that have been implicated in prospective memory tasks (e.g., Burgess, Quinn & Frith, 2001; Okuda et al., 2003) as well as areas, like the hippocampus, which are thought to support episodic memory (e.g., Hassabis, Kumaran, Vann & Maguire et al., 2007). This pattern of findings is interpreted as evidence that mentally envisioning the future involves retrieving memories of similar past episodes or contextually relevant information (Atance & O'Neill, 2001; 2005; Bar, Aminoff, Mason & Fenske, 2007; Tulving, 2002). Extending these findings, the current results show that the neural activity observed in these areas when people's thoughts are unconstrained (i.e., during high incidence mind-wandering periods) depends on their proclivity for thinking about the past and reflecting on current concerns.

Table 2. Regions of the default network that exhibited significant positive correlations with 'proclivity for past mind-wandering' and 'proclivity for future mind-wandering' factor scores. Coordinates are reported in Talairach space. The displayed *t*-values are associated with the area's peak hemodynamic response. All coordinates emerged with at a threshold of $p < .05$, k = 15.

			coordinates		
Anatomical Location	**BA**	**k**	**x**	**y**	**z**
Positive Correlations					
L. hippocampus	24/28	17	-20	-13	-17
L. fusiform/parahippocampal gyrus	37/36	29	-30	-43	16
B. medial frontal	10	114	6	54	14
R. supramarginal gyrus	40	30	48	-62	36
B. cingulate gyrus	31	142	6	-15	45
L. clausturm		65	-51	-3	-9
Negative Correlations					
None.					

			coordinates		
Anatomical Location	**BA**	**k**	**x**	**y**	**z**
Positive Correlations					
R. parahippicampal cortex	35/36	42	21	-30	-19
R. insula		21	36	-26	12
B. cingulate gyrus	24	22	9	-6	47
Negative Correlations					
B. medial frontal	9/10	127	-9	68	16
L. posterior cingulate	31	20	-9	-42	35

Although, at first glance, the mind's proclivity for wandering may be worrisome (Schooler, Reichle & Halpern, 2004; Smallwod & Schooler, 2006), it is important to note that the capacity to relive past events and imagine future scenarios may, on the contrary, be quite advantageous (see Buckner & Carrol, 2007; Mason et al., 2007). Through "mental time travel" (Tulving, 2001) – traveling backwards and forwards in subjective time – people can anticipate future events, reconsider past episodes, and formulate strategies and plans based on previous experiences (Bar, 2007; Buckner & Carroll, 2007; Gilbert & Wilson, 2007; Mason et al., 2007; Shallice & Burgess, 1991). This capacity enables humans to consider potential consequences prior to acting (i.e., to simulate), to maintain intentions to act in particular ways over long time periods, and to override momentary needs in pursuit of longer-term goals and objectives (Suddendorf & Corballis, 1997). From this perspective, allocating one's attention away from the present sensory environment to people, places, and events of the past or future (i.e., mind-wandering) is arguably the most adaptive way to use surplus processing resources.

One limitation of the approach taken in the present investigation – regressing participants' factor scores against the BOLD activity they exhibit during frequent SIT – is that it may lack the sensitivity to detect significant effects in regions that subserve future and past-oriented mind-wandering. Indeed, it is quite possible that the present analysis fails to implicate all of the regions involved in producing impending future and past-oriented thought because of a modest sample size, an inadequate range of factor scores or because of an imperfect mapping between the constructs represented by the factors and the functions subserved by the critical cortical areas. Although we believe the present approach provides insight into the process by which people travel back-and-forth in subjective time, by no means do we think it provides an exhaustive account of these mechanisms. For example, it is worth noting that some of the regions that appear to play a general role in introspectively-oriented mental activity (e.g., MPFC; Mason et al., 2007) did not correlate positively with *both* the experiential dimensions of interest (i.e., *propensity for impending future thought* & *propensity for past thinking*). Furthermore, the present investigation did not detect a relationship between participants' factor scores along the dimensions of interest and a couple of areas that would be expected to be involved, such as the *propensity for past thinking* and the hippocampus (cf. Andreasen et al., 1995; Maguire et al., 2001). We suspect that a more complete account of the process by which people divert their attention from the external sensory environment and consider events from their past or "unfinished business" will emerge only through a convergence of approaches.

In considering why the mind evolved the capacity to spontaneously fluctuate among the immediate sensory environment, events of the near and distant past, and possible future scenarios it is helpful to imagine what life would be like without this capacity. One need only reflect on the extensive time periods spent confined to endless business meetings, "on hold" with telephone customer service representatives, and at a stand-still in rush-hour traffic to appreciate the freedom this type of mentation affords. For better or worse, lacking this capacity, we would each be trapped in the present moment. Despite the popularity of "mental time travel" as a strategy for coping with invariable and impoverished settings, it is difficult to imagine that this type of thought *evolved* to serve a coping function. Instead, it seems more plausible that the adaptiveness of this capacity centers on the benefits conferred by engaging in simulation (for a discussion, see Buckner & Carroll, 2007). Whereas simulating past experiences reinforces learning, clarifies uncertainties and deepens one's understanding of previous episodes; through mentally exploring the future one can consider alternatives before acting and maintain intentions to act over quite extensive time periods (e.g., "I have to move my car on the third Thursday of the month for street cleaning"). While the relationship between these two forms of self-projection needs to be clarified, the results of the present study support the idea that, at any given moment in time, people allocate significant processing resources not just to their immediate surroundings but to episodes long past and yet to occur.

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FOOTNOTES

1. The other two factors, which accounted for 20% and 22% of the variability in participants' responses, were related to the general proclivity people have for producing and becoming absorbed by these thoughts (i.e., *propensity for mind-wandering*) and to participants' self-reported daydreaming phenomenology (e.g., whether their thoughts are accompanied by visual imagery; i.e., *imagery in mind-wandering*) respectively.