Consciousness and Cognition 18 (2009) 118–125

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind

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ARTICLE INFO

Article history:
Received 22 April 2008
Available online 3 January 2009

Keywords:
Mental time travel
Experience sampling
Task unrelated thought
Mind wandering
Prospective/retrospective cognition
Spontaneous thought
Stimulus independent thought

ABSTRACT

Two experiments employed experience sampling to examine the factors associated with a prospective and retrospective focus during mind wandering. Experiment One explored the contribution of working memory and indicated that participants generally prospect when the task does not require continuous monitoring. Experiment Two demonstrated that in the context of reading, interest in what was read suppressed both past and future-related task-unrelated-thought. Moreover, in disinterested individuals the temporal focus during mind wandering depended on the amount of experience with the topic matter—less experienced individuals tended to prospect, while more experienced individuals tended to retrospect. Together these results suggest that during mind wandering participants' are inclined to prospect as long as the task does not require their undivided attention and raise the intriguing possibility that autobiographical associations with the current task environment have the potential to cue the disinterested mind.

1. Introduction

Remembering events from the past and imagining those that may yet occur are fundamental to the human condition (Lewin, 1935; Suddendorf & Busby, 2003). Both retrospective and prospective wonderings are postulated occur because of the minds ability to reconstruct or simulate episodes from the past (Tulving, 1985). Underpinning such 'mental time travel' is the ability to *simulate*—episodes from the past or future are constructed from elements retrieved from memory and combined to mimic the rich multi sensory nature of the event. In this way, prospective thought is seen as adaptive—future thoughts allow the individual to "envisage and mentally "try out" one or more versions of what might happen" (Schacter, Addis, & Buckner, 2008, p. 40).

In general, studies examining past and future cognitions use a paradigm in which participants generate future or past 'episodes' in response to a word cue. Using this approach the consensus view is that prospective cognition is common (Buckner & Carroll, 2007) and may be a marker of good mental health because specific deficits have been shown to increase suicide risk (O'Connor et al., 2007). Moreover, the ability to explicitly engage in prospective thought is argued to underpin many adaptive psychological phenomena because 'preparing for the future is a vital task in any domain of cognition or behaviour that is important for survival' (Schacter, Addis, & Buckner, 2007, p. 660).

Despite the importance of 'mental time travel' to humans, little is known about the factors which influence the different temporal focus that humans adopt in ongoing spontaneous thought. In this paper we readdress this oversight and examine

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doi:10.1016/j.concog.2008.11.004

the factors which influence whether participants consider past or future events in two of the most common task environments used to study ongoing thought. Experiment One considers how the availability of working memory resources influences prospective and retrospective thoughts. Experiment Two, considers the factors which influence past and future-related thoughts as the mind wanders during reading. In both experiments, *experience sampling* is used to identify whether participants are considering personal experiences from either their past or future.

2. Experiment one

Experiment One explores the role of working memory in past and future thoughts which are unrelated to the task in hand. Many contemporary cognitive and social theories, under the rubric of dual process theories (see Smith & Decoster, 2000), suggest that cognition results from two different processing modes—a quick and effortless mode based on associative processing and a slow, effortful, controlled or reflective mode. While both retrospective and prospective thoughts require simulation, future thoughts are likely to load more heavily on the controlled mode because future memories must be created by the *novel recombination* of previous episodes (Tulving, 1985). The additional resource demands placed by prospective cognition is further underlined by neuroimaging evidence. Studies in which participants construct an episode of past or future events in response to a word cue suggest that although there is a core network of brain regions—including pre-frontal and medial temporal lobe regions—which are recruited when participants both recall past and imagine future events (see Schacter et al., 2008 for a review), many of these regions are in fact more active in future than past-related thought (Addis, Wong, & Schacter, 2007; Okuda et al., 2003; Szpunar et al., 2007 see also Mason, Bar, & Macrae, in press, although see also Botzung, Denkova, & Manning, 2008). Schacter et al. (2008) interpret these differences as indicating that despite constructive processes being implicated in both retrospective and prospective cognition, only future thought "requires that events be flexibly recombined into a novel future event" (p45). Thus, the increased requirement for flexibility inherent in prospective cognition suggests that it may require a more vigorous deployment of working memory resources than does retrospection.

To explore the potentially greater role of working memory in past and future thought participants performed three tasks these tasks were chosen to illuminate the role of working memory which has been shown to be important to off task thinking (Teasdale, Proctor, Lloyd, & Baddeley, 1993). In the first (Choice Reaction Time) a decision is made about whether an infrequent target number (coloured green) is odd or even. In the second (Working Memory), participants must decide whether the stimulus preceding the infrequent target (a red '?') was odd or even. Broadly these tasks differ on the need to continuously monitor events in the task—the Choice Reaction Time task merely requiring we wait for an event to occur (such as waiting for traffic lights to turn to green) and the Working Memory Task requiring we keep the recent events in mind (such as knowing the sequence of driver arrival at a four way Stop sign). As an additional control, participants simply observed numeric stimuli and indicated their attentional focus at thought probes (Passive Viewing). Importantly, the Working Memory Load condition mimics the Choice RT task with the addition that for accurate response participants must continually rehearse the identity of the previous digit.

Studies suggest that tasks requiring working memory resources suppress the experience of TUT (Mason et al., 2007; Teasdale et al., 1993: Kane et al., 2007; see Smallwood & Schooler, 2006 for a review). Based on the assumption that future thoughts are amongst the more resource demanding examples of TUT, then working memory load should disproportionately reduce the opportunity for prospective cognition relative to retrospective cognition. In addition, if participants are generally inclined to prospect then future-related TUT should be more common in all situations except the working memory condition.

2.1. Methods

2.1.1. Participants

Seventy-six participants (21 Males) completed this experiment (age range 17–44 years). All participants had normal or corrected to normal vision. 66 participants were right handed.

2.1.2. Procedure

The study employed a within participants design with all participants completing all tasks. Task order was counterbalanced.

2.1.3. Materials

2.1.3.1. Stimuli. Stimuli for this experiment were numeric digits, 1–9. Across all conditions stimuli were presented on screen for two seconds and were separated by a one second fixation cross. In the Choice RT task, whenever a target occurred (coloured Green) participants were asked to determine whether the stimulus was odd or even. In the Working Memory task a question mark (coloured Red) appeared intermittently and participants were asked to indicate whether the previous number had been odd or even. Responses were made using the mouse buttons and approximately equal numbers of target stimuli occurred across tasks (Choice Reaction Time Non Targets = 145, Targets = 22, Working Memory, Non Targets = 146, Targets = 25). During Passive Viewing, participants merely watched numeric digits appear on the screen. The testing session lasted approximately twenty minutes.

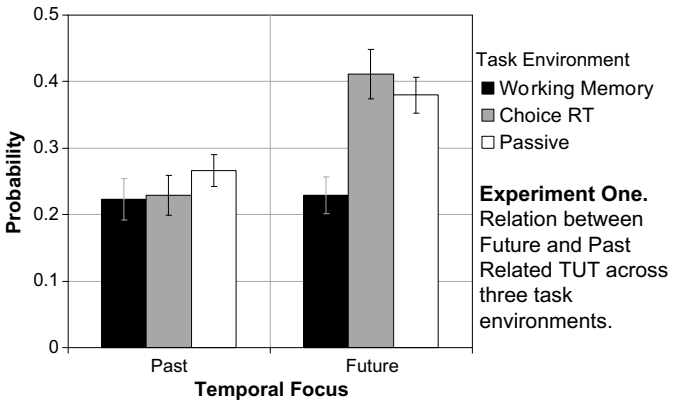

Fig. 1. The suppression of future-related TUT by a working memory load. Participants were more inclined to consider future events when the task did not make continuous demands on working memory.

2.1.4. Thought probes

Participants were asked to describe their mental state at thought probes on five occasions in each task. When the thought probe occurred the screen changed colour from white to blue, while text was presented in yellow ink. Participants were asked "Just prior to being asked was your attention directed to the task (here and now), or to a personal event from your past, or an upcoming personal event?" Participants responded to the thought probes using the computer keyboard with the first letter of each experience (T for the task/here and now, P for Past or F for Future). Prior to testing all participants indicated familiarity with the basic phenomenon of mind wandering and were asked to reserve the past and future categories for personal memories from outside the testing session.

2.2. Results

Participants maintained reasonable accuracy throughout both tasks, although performance was significantly worse under load [Choice RT, $M = .98$, ($SE = .01$), Working Memory = .87 (.01), $t\,(75) = 11.53$, $p < .001$]. Next, we considered how the task environment impacted upon the temporal focus of TUT. A 2 (Past/Future) $\times$ 3 (Working Memory, Choice RT and Passive Viewing) ANOVA yielded a main effect of temporal focus [$F\,(1,75) = 9.9$, $p < .005$, $\eta^2 = .12$] indicating that in general Future TUT [$M = .33$, (.02)] was more common than Past TUT [$M = .23$ (.02)]. In addition, a main effect of task environment [$F\,(2,150) = 14.57$, $p < .001$, $\eta^2 = .17$] indicated that, in general, TUT was lower in Working Memory [$M = .23$ (.01)] than in both Choice RT [$M = .32$ (.02), $p < .01$] and Passive Viewing [$M = .33$ (.02), $p < .01$]. Finally, a Task Environment X Temporal Focus Interaction was observed [$F\,(2,150) = 4.6$, $p < .01$, $\eta^2 = .06$, see Fig. 1]. Further analysis revealed that prospective thoughts varied across task environments [$F\,(2,150) = 12.2$, $p < .001$, $\eta^2 = .14$], while retrospective thoughts did not [$F\,(2,150) = 1.9$, $p = .15$, $\eta^2 = .02$[1]]. Post hoc LSD tests indicated prospective thoughts were more frequent in both the Passive Viewing [$p < .001$] and Choice RT [$p < .001$] than in the Working Memory condition. No difference was observed between the Passive and Choice RT conditions [$p = .3$]. Next, we compared the size of the prospective bias across task environments by subtracting the number of past-related from future-related cognitions. ANOVA indicated a significant effect of task environment [$F\,(2,150) = 4.6$, $p < .01$, $\eta^2 = .06$]. Post hoc LSD tests determined that the magnitude of the prospective bias in the Working Memory task ($M = .01$ ($SE = .04$) was significantly smaller than both Choice RT ($M = -.17$ ($SE = .06$), $p < .01$) and Passive conditions ($M = .11$ ($SE = .04$), $p < .05$). Finally, paired t-tests were employed to contrast the frequency of different forms of past and future-related TUT in each task. To control for the number of comparisons we applied the bonferoni correction yielding a new significance value of $p < .017$. These revealed that Future thoughts were more frequent in Choice RT [$t\,(75) = 3.2$, $p < .005$] and Passive Viewing [$t\,(75) = 2.6$, $p < .01$] but not in Working Memory [$t\,(75) = -.29$, $p = .77$].

2.3. Discussion of Experiment One

In Experiment One, participants showed a prospective bias to thought—considering the future whenever the task environment allowed them sufficient attentional resources to do so. By contrast, thoughts of the past were less frequent and varied less across task environments. It is important to recognise that that the lack of an effect of load on the rate of past-related TUT may be because the tasks were not sufficiently demanding. Nonetheless, it is clear that participants were inclined to consider the future and that this bias was curtailed by the requirement to continuously monitor the task.

[1] Despite the lack of a main effect in the ANOVA comparing retrospective TUT, post hoc LSD tests indicated that slightly more past related thoughts were reported in the Passive than the Working Memory Task ($p < .05$).

3. Experiment Two

In Experiment Two we adapted the mind wandering during reading paradigm (e.g. Grodsky & Giambra, 1989; Schooler et al., 2004) to examine the frequency of past and future thoughts during text comprehension. Similar to the Working Memory task employed in Experiment One, successful text comprehension requires that the participant must continuously monitor the task in order to follow the narrative, however, during reading the likelihood of TUT depends not upon difficulty but upon interest in what was being read (Grodsky & Giambra, 1989). In Experiment Two, participants are asked to report the experience of past and future TUT while they read an engaging work of non fiction—an expository scientific text. As a control, participants perform the same working memory task as Experiment One. The key aims of Experiment Two are to explore whether (a) more absorbing tasks such as reading influence the experience of past and future mind wandering equally and (b) whether such changes depend on interest to an equal extent. As participants naturally vary in terms of their experience with the topic matter, our analysis also considers whether experience influences the temporal focus of mind wandering (Schiefele & Krapp, 1996).

3.1. Methods

3.1.1. Participants

Seventy-seven participants (21 Males) completed the experiment (age range 17–41). All participants had normal or corrected to normal vision and all read English at a level sufficient for University. Sixty-six participants were right handed.

3.1.2. Procedure

Participants read one of three expository texts from an engaging work of popular science. Each text was selected so as to reflect one of the three main science subjects studied in school (biology, physics and chemistry). Participants also performed the same working memory task as in Experiment One. Both task order and text was counter balanced.

3.1.3. Materials

3.1.3.1. Reading. The text used in this experiment was selected from the Bill Bryson's *A Short History of Nearly Everything* (2005) which is a general science book written in non technical language. Three excerpts were selected for this experiment, each detailing a different aspect of science taught at school: biology, physics and chemistry. Each excerpt was edited to approximately 2500 words. Participants read the text a paragraph at a time using the key 'n' to move to the next page. For each passage 10 multiple choice questions were created, each with four options as answers. Questions related either to general knowledge contained in the text (e.g., chemistry—"How many different kinds of particles are there in the nucleus of an atom?" Answer—Three) or to the specific wording employed (e.g. biology—"The membrane is not, as most of us imagine it, a ..., rubbery casing", Answer—Durable).

Interest and experience with the subject matter were measured at the completion of the task. To measure retrospective interest we adapted the approach employed by Grodsky and Giambra (1989). Participants were asked "On a scale of 1 to 5 how interesting did you find the text?" (1—I had no interest in this text to 5—This was the most interesting text I have read recently). To measure experience participants were asked to indicate how far through school they had studied the three science subjects (biology, physics and chemistry). The five options presented (years in secondary education are in parentheses) were (a) before standard grades/O levels (2 years) (b) standard grade (4 years) (c) higher/A levels (5 or 6 years) (d) at university as an elective (6 or 7 years) (e) degree level (9 or 10 years).

3.1.4. Thought probes

During reading, probes were triggered using a quasi randomisation regime in which a probe was triggered if reading time exceeded a randomly selected elapsed time interval (range 13–30 s). On average this yielded 4.6 probes per individual. As thought probing could be confounded with reading time, we included median reading time as a co-variate in all analyses.

3.2. Results

Performance in the Working Memory task was comparable to Experiment One [Mean = .89 (*SE* = .01)]. Interest in the subject matter was close to the mid point of the scale [MEDIAN = 3, Range 1–5], while participants tended to have studied the subject matter of the text for four years at school [Range 2–6]. No participants had studied the topic beyond that of an elective at university. Accuracy on the comprehension questions was moderate [MEAN = .51, *SE* = .02] although was well above chance level (.25) indicating reasonably good attention to the text. Consistent with the assumption that the Interest was indicative of better engagement with the task, Interest was positively correlated with Comprehension ($r = .28$, $p < .05$). Finally, multivariate ANOVA indicated that participants assigned to a particular text did not differ on experience with any of the three science subjects [all *F*-values <2.5, all *p*-values > .1].

Table 1
Experiment Two. Probabilities of Future and Past-related TUT during reading and a working memory task.

Task	Temporal focus	Mean probability	Std. error
Working memory	Future	0.27	.03
	Past	0.20	.03
Reading	Future	0.10	.01
	Past	0.09	.02

Table 2
Experiment Two. Relation between Future and Past-Related TUT and retrospective reports of interest while reading.

Interest level	Future-related TUT	Past-related TUT
Low	0.16 (.03)	0.15 (.03)
Moderate	0.09 (.02)*	0.06 (.02)*
High	0.09 (.02)*	0.02 (.02)*

*Significantly different from the Low Interest Group at the $p < .05$ level (LSD)

Our first analysis considered the relationship between future and past-related thinking during reading and the working memory task (see Table 1)[2]. A 2 [Temporal Focus] × 2 [Task] ANOVA indicated that irrespective of temporal focus fewer off task thoughts were reported while reading than during the working memory task [$F(1,67) = 22.0$, $p < .001$, $\eta^2 = .25$]. No main effect of temporal focus nor the subsequent interaction were reliable [all F-values < 2, all p-values > .14]. Importantly, separate comparisons indicated that the likelihood of past and future thoughts did not differ in either task [Working Memory, $t(68) = 1.5$, $p = .15$, Reading Task, $t(76) = .53$, $p = .53$].

Next, we considered the relation between interest, experience and the temporal focus of mind-wandering during reading. Exploratory analysis indicated that Interest and Experience were uncorrelated [$r = .01$, $p = .91$]. Participants were divided into three approximately equal groups on the dimensions of interest and experience with the topic matter [Interest, Low $n = 22$, Moderate $n = 29$ and High $n = 26$; Experience Low $n = 27$, Moderate $n = 26$, High $n = 24$]. Using these grouping variables we examined the cumulative effects of Interest and Experience on the probability of reports of temporal focus during reading using a 2 (Past/Future) × 3 (Interest) × 3 (Experience) ANOVA. This analysis indicated a main effect of Interest Group [$F(2,66) = 9.6$, $p < .001$, $\eta^2 = .22$]. Post Hoc LSD tests showed that the Low Interest Group indicated a greater number of TUT than both other groups ($p < .001$). Separate comparisons on both Future and Past-related thoughts confirmed that Interest reduced both Past and Future thoughts to an equal amount [see Table 2].

In addition, ANOVA revealed an Interest × Experience × Temporal Focus interaction [$F(2,66) = 3.8$, $p < .01$, $\eta^2 = .18$, see Fig. 2]. Post hoc LSD tests indicated that retrospective off task thoughts were more frequent in the Low Interest High Experience condition than in any other group [$p < .025$ for all comparisons]. In addition, the Low Interest Moderate Experience Group reported more retrospective off task thoughts than the High Interest High Experience group [$p < .01$] and the Moderate Interest Low and High experience groups [$p < .05$]. No differences were reliable for prospective cognitions. Within the Low interest Group, those individuals with low experience with the topic had a prospective bias - reporting more future than past TUT ($p < .05$), while the opposite was true for the high experience group who showed a retrospective bias ($p < .01$).

To explore the reliability of this effect separate correlations between Experience and Past-related thinking were conducted in each of the three Interest Groups. To correct for the number of comparisons (3) we employed the bonferroni correction yielding an α of .016. Only in the Low Interest Group was the relation between experience and past-related thinking reliable [Low, $r = .43$, $p < .001$, Moderate $r = -.02$, $p = .90$, High $r = -.31$ $p = .12$]. Finally we explored the possibility that the association between experience, interest and past-related thought results from an underlying dispositional difference which decreases the likelihood that participants would be interested in a task *per se*, and which causes them to focus on the past. If correct, we reasoned that participants who reported greater past-related thoughts during reading would show a similar pattern in the Working Memory task. Contrary to this alternative hypothesis, no correlation was observed between retrospective thoughts [$r = -.15$, $p = .19$] despite a reliable association being observed for prospective thought [$r = .34$, $p < .005$].

3.3. Discussion of Experiment Two

Thoughts of the past and future were equally suppressed by the task of reading relative to the Working Memory task and by the interest in what was read. Thus, unlike the manipulations of attentional resources in Experiment One, the engagement of the more absorbing task of reading led to a reduction in both prospective and retrospective TUT. Additionally, we observed that the temporal focus adopted during TUT depended upon experience with what was read—a prospective bias to TUT was

[2] Due to a computer error the Working Memory data from eight participants was lost and so the comparison between tasks was limited to sixty nine individuals completing both tasks.

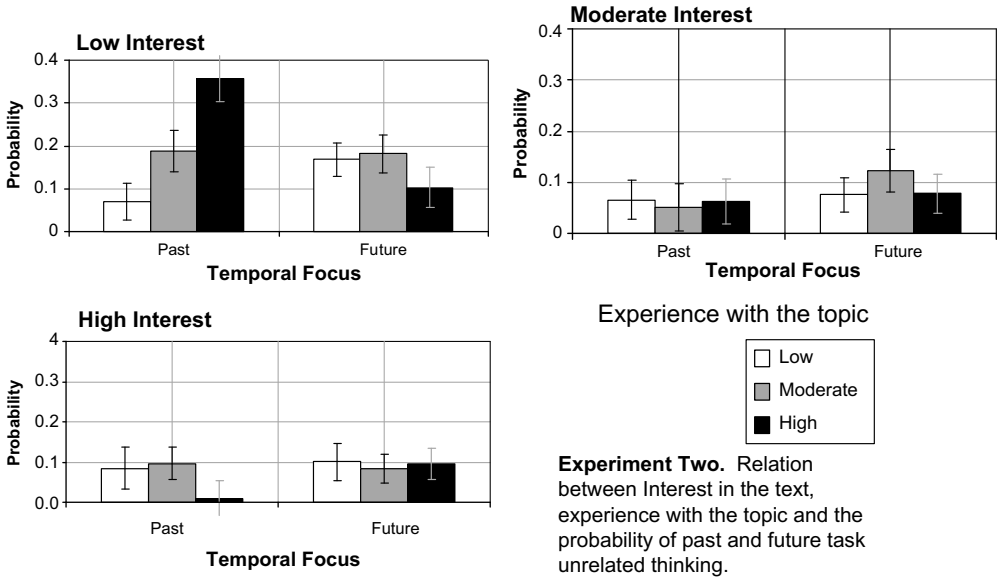

Fig. 2. The relations between interest in what was read, experience with the topic matter and the probability of past and future-related TUT. Disinterested participants with less experience with the topic matter, showed a prospective bias to TUT. By contrast, participants with greater experience with the subject matter and yet lacked interest in what was read tended to focus retrospectively.

observed for individuals low on both interest and experience with the topic, while participants who lacked interest and yet had greater experience with the subject matter showed a retrospective bias.

4. General discussion

When deprived of a task, or when engaged in a concurrent task that either did not make significant demands on working memory, individuals were inclined to devote their spare resources to thoughts about the future. A strategic 'prospective bias' to ongoing thought supports the contention that in humans prospective thought is both common (e.g. Buckner & Carroll, 2007) and of particular significance to the individual (e.g. Schacter et al., 2007). Additionally, the inhibition of prospective thought by working memory load underlines the additional resources necessary to engage in future orientated thought (Tulving, 1985). Presumably future thoughts have more salience than past thoughts (cf Klinger & Cox, 1987) because they allow the exploration of "possible mechanisms of change... and ... the potential outcomes of different actions" (Karniol & Ross, 1996, p. 601). Such a prospective bias to ongoing thought disappears when participants are given a more absorbing task, such as reading, or prevented from doing so because the task requires their undivided attention.

The manipulations of resources in Experiment One suggest that past thinking while a complex activity, is somewhat less resource demanding than prospective thought. While, it remains an open question whether increasing working memory resources required to perform the task (e.g. by utilising a 2 or 3 back procedure) would act to alter the likehood of retrospection, it is clear that reading an interesting text does reduce the likelihood of Past and Future TUT alike[3]. Even when provided with a task environment in which they had sufficient idle resources, however, participants generally failed to expend resources on the consideration of their past. The relative lack of preference for past-related thoughts in a healthy student population is perhaps unsurprising given that an over focus on the past at the expense of the future could be expected to be indicative of poor mental health. For example, studies have frequently documented that ruminating on the past has implications for mental health (e.g. Nolen-Hoeksemma & Morrow, 1991), while deficits in future thinking are a documented risk for suicide (O'Connor et al., 2007).

One unanticipated result of Experiment Two was that experience with the topic read influenced the temporal focus of mind wandering. In disinterested participants, low experience with the topic matter was associated with a prospective focus to TUT, while high levels of experience led them to retrospect. Such a result suggests that the inclination to engage with different temporal epochs of ones' life could depend in part upon the associations between events in the task environment and the individual's life history. More generally, this result implies that the idle or disinterested mind could be loosely primed to mind wander by a task environment rich in autobiographical associations. Such a notion is consistent with certain views of priming—for example, Bargh & Morsella (2008) suggest that cognitive impulses emerge from a multitude of influences

[3] While direct links between brain activations and behavioural studies should be made with caution, it is interesting that the assumption that past related thought involves less resource than do thoughts of the future is consistent with the neuroimaging work in this area (e.g. Schacter et al., 2008).

including evolution, cultural norms and *previous experience in similar circumstances*. While the interaction between experience and interest observed in Experiment Two was highly significant, firm conclusions on precisely how external events can prime the wandering mind should await further research. Nonetheless, it is an intriguing possibility that the direction that we mentally time travel when we mind wander could be partially cued by an individual's associations with events in the external environment and is a research question which is likely to reveal interesting aspects of the dynamics of our mental lives.

4.1. Limitations and future directions

In both experiments participants were offered a forced choice between thoughts related to the task and unrelated future or past events, and were asked to reserve these latter categories for personal events unrelated to the task. While useful in documenting the temporal focus to TUT, such an approach could lead participants to place off task episodes which are not directly related to any temporal period, such as creative musings, into the 'here and now' category. Moreover, it is possible, that this approach could bias participants to be more likely to engage in prospective or retrospective thought. This issue, however, is a general problem with thought sampling per se (see Smallwood & Schooler, 2006) rather than a specific limitation of this particular study, especially given that in both studies we replicated findings from previous work (e.g. Experiment One, Mason et al., 2007; Teasdale et al., 1993; Experiment Two, (Grodsky & Giambra, 1989). Finally, in the future, studies could supplement the categorical approach employed in these studies with information regarding the temporal epoch to which the thoughts relate (e.g. months, weeks or years).

A number of implications follow from the results of these experiments. First our data suggest that manipulations which have been shown to alter the frequency of TUT by changing resource availability (e.g. faster stimulus presentation rates, Antrobus, 1968) may elicit their effects primarily by denying participants the opportunity to engage in prospective thought. It is even possible that placing participants under even greater cognitive loads (e.g. a 2 or 3 back working memory load) could lead to the development of a retrospective bias to TUT—a possibility worthy of further research. Similarly, working memory span has been shown to determine mind wandering propensity (Kane et al., 2007) and so could possibly determine the balance between past and future thought. Second, the method developed in these studies reveals the occurrence of future and past-related cognitions in ongoing thought and so serves as a useful contrast to methods in which participants construct future scenarios in response to word cues. It would be useful to explicitly contrast the different techniques—for example by examining the prospective bias in explicit and naturally occurring thought in individuals with mental health problems (O'Connor et al., 2008). Finally, Experiment Two suggests that the contents of the task may be able to influence the wandering mind. Recognizing that the content of the idle mind can be loosely primed through associations with the external world could help explain why certain features of our mental lives are so difficult to escape (e.g. Najmi & Wegner, 2008). Perhaps it is the impact of our past life history on our ongoing thoughts and feelings that Nietzsche (1999) had in mind when he stated "Man... cannot learn to forget, but hangs on the past: however far or fast he runs, that chain runs with him." (p. 61).

Acknowledgments

Thanks to the comments of three anonymous reviewers, Jonathan Schooler, Derek Heim and Lynden Miles for their comments on this manuscript, and to Neil Macrae for his encouragement to explore this topic. Louise Nind was supported by a Nuffield Grant awarded to J. Smallwood.

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