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Mind-wandering and task stimuli: Stimulus-dependent thoughts influence performance on memory tasks and are more often past-versus future-oriented

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ABSTRACT

Although many studies have indicated that participants frequently mind-wander during experimental tasks, relatively little research has examined the extent to which such thoughts are triggered by task stimuli (stimulus-dependent thoughts; SDTs) versus internally triggered (stimulus-independent thoughts; SITs). In the current experiment, we assessed differences in the frequency and characteristics of SDTs and SITs, as well as their associations with subsequent memory in young adults. Whereas frequency of SDTs (but not SITs) increased in a task with more meaningful stimuli, frequency of SITs (but not SDTs) increased in an easier task. Furthermore, only SDTs were more likely to be past- versus future-oriented. Finally, frequency and vividness of SDTs during a shallow, but not a deep, incidental encoding task both correlated with later memory performance for word stimuli. These results suggest that SDTs differ from SITs in several important ways.

1. Introduction

Participants experience a variety of thoughts that are not directly relevant to performing an ongoing experimental task (mind-wandering; Smallwood & Schooler, 2015). Many studies have now examined the frequency and cognitive consequences of mind-wandering during numerous tasks, such as those indexing episodic encoding, sustained attention, and reading comprehension (for reviews, see Mooneyham & Schooler, 2013; Randall, Oswald, & Beier, 2014; Smallwood & Schooler, 2015). In the current experiment, we focus on one aspect of mind-wandering that has received relatively little attention in the literature: whether it is triggered by a task stimulus (stimulus-dependent thought; SDT; e.g. the word "apple" triggering a thought about going to the supermarket) or internally-triggered (stimulus-independent thought; SIT). Note that our use of the terms SDT and SIT differs another usage of these terms as specifying whether a thought is about immediate perceptual input or not (e.g., Teasdale et al., 1995). That is, in the current paper, an SDT is defined as a thought that was cued by a task stimulus, irrespective of whether that stimulus is still present in the environment when a participant is having it.

Whether defined with respect to its relation to current perceptual input or cueing, mind-wandering is primarily thought of as reflecting SIT. For instance, Stawarczyk, Majerus, Maj, Van der Linden, and D'Argembeau (2011) defined mind-wandering as thoughts whose content is decoupled from stimuli present in the environment and unrelated to the activity being carried out at the moment of its occurrence. Similarly, Smallwood and Schooler (2015) defined mind-wandering as a shift in the contents of thought away from an ongoing task and/or from events in the external environment to self-generated thoughts and feelings, where self-

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generated thoughts refer to thoughts that arise from intrinsic changes within an individual rather than extrinsic changes cued from perceptual events in the external environment. Moreover, mind-wandering is often studied using tasks devoid of meaningful stimuli. For instance, the sustained attention to response task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), one of the most commonly used tasks in the mind-wandering literature, uses the digits 1–9 as stimuli. Because digits are relatively meaningless stimuli, they are unlikely to themselves trigger thoughts, and it is thus a safe assumption that most mind-wandering episodes measured in this task are SITs.

Although many theoretical accounts of mind-wandering emphasize its independence from the environment, other authors such as Klinger (2013) have put more emphasis on the importance of external cues in triggering mind-wandering episodes. Specifically, Klinger (2013) argued that an individual's current goals/concerns sensitize them to respond to cues associated with those concerns. Concern-related cues receive automatic priority for cognitive processing, and these cues may in turn trigger concern-related though segments.

Several studies have provided evidence consistent with the idea that environmental stimuli can trigger mind-wandering episodes. For instance, McVay and Kane (2013) had participants complete a questionnaire in which they described their personal goals and concerns across several life domains. In a second session, participants performed a modified version of the SART, during which they had to respond to lowercase words and withhold their response to uppercase words. Unbeknownst to the participants, some words in the SART were designed by the experimenter to reflect the participants' previously reported concerns (e.g. the words INCREASE – FACIAL – HAIR for the concern "I want to grow a beard"). The authors observed a small increase in self-reported mind-wandering episodes following concern-related versus concern-unrelated words, suggesting that concern-related task stimuli can increase mind-wandering episodes (see Klinger, 1978 for similar results). In another study (Plimpton, Patel, & Kvavilashvili, 2015), dysphoric and non-dysphoric controls performed a vigilance task in which they had to respond to slides depicting arrangements of black vertical lines and withhold their response to slides depicting black horizontal lines. The slides also included short phrases (e.g., "friendly boss", "missed opportunity", "crossing the road") that participants were told to ignore. Eighty-six percent of task-unrelated thoughts in controls (83% in dysphorics) were reported to have identifiable triggers. Of these, 85% percent in controls (and 89% in dysphorics) were judged as having been triggered by the word cues, suggesting a strong influence of task stimuli on task-unrelated thought content (see Mazzoni, Vannucci, & Batool, 2014 for similar results). Moreover, task-unrelated thoughts were more likely to be past-oriented than present-oriented or future-oriented in this study. Lastly, in a daily-life experience sampling study (Song & Wang, 2012), 88% of mind-wandering episodes were reported to have an identifiable trigger: 49% were internally triggered whereas 51% were externally triggered. Collectively, these studies suggest that environmental stimuli regularly trigger mind-wandering episodes.

Although the aforementioned studies suggest that a large number of mind-wandering episodes are SDTs, these studies did not assess whether SDTs differ in any meaningful way from SITs. We addressed this gap in one of our recent studies (Maillet & Schacter, 2016). Specifically, we reasoned that one of the main differences between SDTs and SITs may lie in the extent to which they benefit later memory for incidentally encoded task stimuli. That is, because SDTs are thoughts that are triggered by specific stimuli, these thoughts may sometimes improve people's memory for the stimuli that elicited the thoughts in the first place (e.g. "I remember seeing the word 'elephant' because, when I initially saw it, I had a thought about the last time I saw one at the zoo") (Gardiner, Ramponi, & Richardson-Klavehn, 1998; Selmeczy & Dobbins, 2014). On the other hand, because SITs are thoughts that are unrelated to (i.e., were not triggered by) encoding stimuli, they may have either no effect, or be detrimental to later retrieval decisions. For example, many studies have indicated that greater mind-wandering during intentional encoding tasks (which presumably primarily reflected SITs) is negatively related to retrieval performance (e.g., Maillet & Rajah, 2013, 2016; Smallwood, Baracaia, Lowe, & Obonsawin, 2003; Thomson, Smilek, & Besner, 2014).

To test these hypotheses, Maillet and Schacter (2016) measured the frequency of SDTs and SITs during an incidental encoding task for word-picture pairs in young and older adults. Older adults experienced an increase in SDTs, but a decrease in SITs compared with young adults. Moreover, in older adults only, the frequency of SDTs during incidental encoding was positively correlated with later memory performance. SIT frequency was not correlated with memory performance in either age group. Thus, consistent with the notion that SDTs may facilitate the ability to remember stimuli that were responsible for eliciting the SDTs, we found a positive correlation between encoding SDTs and memory performance in older adults. However, this finding was not observed in young adults. This result suggests that memory retrieval in older adults, relative to young adults, may rely more heavily on thoughts and feelings elicited during encoding than on other features such as perceptual details, as previously established in studies examining the characteristics of retrieved memories (Hashtroudi, Johnson, & Chrosniak, 1990; Hashtroudi, Johnson, Vnek, & Ferguson, 1994). In addition to observing differences in how SDTs and SITs relate to later memory as a function of age, we found that, across age groups, SDTs and SITs differed in their temporal orientation: whereas SITs were more likely to be future-oriented relative to SDTs, SDTs were more likely to be past-oriented than SITs.

In summary, the findings from Maillet and Schacter (2016) suggest three ways in which SDTs and SITs differ. First, the frequency of SDTs and SITs is differentially associated with age. Second, some of the characteristics of SDTs and SITs may differ (e.g. the temporal nature of the thoughts). Third, SDTs and SITs may differentially affect later memory for triggering stimuli (i.e. in older, but not young, adults, SDTs correlated with memory performance). Although the foregoing research has shed some light on SDTs and SITs, our current knowledge of the nature and the characteristics of SDTs and SITs, the ways in which they are modulated by task conditions, and how they impact subsequent memory, remains modest. In the current experiment, we expand on this initial research examining SDTs and SITs in young adults. Specifically, in Experiment 1, we assess how a manipulation of stimulus meaningfulness affects the frequency of SDTs and SITs, and whether SDTs and SITs differ in characteristics other than temporality (i.e., their relation to current concerns, meta-awareness, and vividness). In Experiment 2, we assess the association between the frequency of SDTs and SITs and subsequent memory performance for words encoded in a shallow and deep encoding condition.

1.1. Factors modulating frequency of SDT and SITs

We think that one factor that is especially important to study to gain a better understanding of the nature and function of SDTs and SITs is the meaningfulness of task stimuli. When using a task with words, pictures, or short phrases, most task-unrelated thoughts were reported to have been triggered by task stimuli (SDTs) rather than being SITs (Maillet & Schacter, 2016; Mazzoni et al., 2014; Plimpton et al., 2015), suggesting that meaningful task stimuli have a strong influence on the content of task-unrelated thoughts. In contrast, it is possible that in a task using less meaningful stimuli (e.g., number stimuli), such stimuli would have little impact on the content of task-unrelated thoughts, such that majority of them would be SITs. For instance, one of the most commonly used tasks in the mind-wandering literature, the SART, typically uses relatively meaningless digits (1–9) as stimuli. In such a task, most task-unrelated thoughts experienced are likely to be SITs. In the current experiment, we manipulated stimulus meaningfulness using word stimuli versus number stimuli to directly test the hypothesis that SDTs would be more frequent in a task with more meaningful stimuli, whereas SITs would be more frequent in a task with less meaningful stimuli. We aimed to distinguish between two possibilities that need to be disentangled: (1) that meaningful stimuli boost the overall frequency of off-task thoughts experienced during an experimental task through an increase in SDTs and no change in SITs, or (2) that meaningful stimuli bias ongoing thoughts away from SITs towards SDTs, with no change in frequency of off-task thoughts.

In an experiment relevant to this question, Smallwood, O'Connor, Sudberry, Haskell, and Ballantyne (2004) measured rates of task-unrelated thoughts during (1) intentional encoding of words, (2) intentional encoding of non-words and (3) a SART (go stimulus: “XXXXX”; no-go stimulus: “OOOOO”). Thus, similar to the current experiment, this study assessed task-unrelated thoughts during tasks that varied in the meaningfulness of task stimuli (words for non-words). Task-unrelated thoughts were measured using open-ended thought probes asking participants to describe what was going through their minds. Thoughts were classified into task-unrelated (matters unrelated to the task at hand) and non-task related (all other thoughts reflecting some degree of attention to the current environment or the task at hand). The only task-related difference in rates of task-unrelated thoughts was that encoding words was associated with a reduction in task-unrelated thoughts compared to the SART. Although informative, the results of this experiment do not address the question of interest in the current experiment because task-unrelated thoughts were not separated into SDT and SIT categories (if anything, SDT may have been grouped with on-task thoughts in that experiment). Also in this experiment, it is hard to determine whether the differences in rates of task-unrelated thoughts between intentional encoding and the SART were due to differences in meaningfulness of task stimuli, or to other factors that differed between the two tasks (such as task difficulty). In the current experiment, we aimed to assess whether rates of SDT and SIT differ during tasks in which the only factor distinguishing the tasks is the presence versus absence of meaningful stimuli.

1.2. Characteristics of SDTs and SITs

The second goal of Experiment 1 was to broaden our understanding of the characteristics that distinguish SDTs and SITs; little is known about this issue beyond the aforementioned finding that SDTs are more past-oriented than SITs, whereas SITs are more future-oriented (Maillet & Schacter, 2016). In addition to attempting to replicate this finding, we tested three other thought characteristics that we think are central to understanding the relation between SDTs and SITs: their relevance to current concerns, their level of meta-awareness, and their vividness.

First, we were interested in determining whether SDTs and SITs differ in their relevance to current concerns. The current concerns hypothesis of mind-wandering (Klinger, 2013) emphasizes the importance of both external and internal cues in triggering mind-wandering episodes. As noted earlier, this theory suggests that current goals/concerns sensitize individuals to concern-related stimuli in the environment that may in turn trigger concern-related mind-wandering episodes. Furthermore, in the absence of salient external events, individuals may shift their attention inwards to goal/concern-related SITs. In other words, this theory suggests that individuals’ attention may primarily be drawn to goal/concern-related events, whether they be elicited externally or internally. Based on this theory, one could make the argument that SDTs and SITs should not differ in their relations to current concerns. However, another view is that a stimulus may capture one’s attention and trigger thoughts without the stimuli/thoughts necessarily being goal-/concern-related. For example, the presentation of the word “baseball” could trigger a memory of a high-school friend who loved baseball, without baseball or this friend being related to one’s current goals/concerns. Thus, an alternative hypothesis is that SDTs may be less relevant to one’s concerns than SITs because most stimuli presented in experimental studies (words, numbers) may not be related to participants’ current concerns and hence, the SDTs that are triggered by these stimuli may not be concern-related thoughts.

Another prominent characteristic of mind-wandering is that it often occurs without awareness of its occurrence, or, without “meta-awareness” (Schooler, Reichle, & Halpern, 2004). For example, consider the scenario in which you are reading, but your attention has wandered away from your task. Although you are aware of the contents of your mind wandering, you nonetheless fail to recognize that your attention has wandered from the text, and this is evidenced by the fact that you continue to scan the page without processing the material being scanned. Because participants need to be aware of task stimuli to perform the ongoing task, we expected that participants may also often be aware of the thoughts triggered by these stimuli (i.e., SDTs). In contrast, because SITs reflect a state of greater disengagement from the task than SDTs, they may also more often occur without meta-awareness. Thus, we predicted that SITs may occur with meta-awareness less often than SITs.

The last characteristic we measured was vividness. If, as hypothesized, SITs more frequently occur without meta-awareness than SDTs, then SITs may also be less vivid (under the assumption that one is more likely to be meta-aware of a highly vivid thought). Another reason to predict that SDTs may be more vivid than SITs is based on findings regarding “direct retrieval” (Uzer, Lee, & Brown, 2012) and "involuntary autobiographical memories" (Berntsen, 1996), both of which may be similar to SDTs. On the one hand, direct retrieval refers to instances where participants are asked to intentionally retrieve an autobiographical memory in response to a word cue and this memory comes to mind automatically without any memory search (Uzer et al., 2012). On the other hand, involuntary autobiographical memories refer to memories that pop into mind without any intention to do so (Berntsen, 1996). Importantly, the majority of involuntary memories are reported to have an identifiable external trigger (Berntsen, 1996, 1998; Mace, 2004; Schlagman, Kvavilashvili, & Schulz, 2007; Schlagman, Schulz, & Kvavilashvili, 2006). Thus, direct retrieval, involuntary retrieval, and SDTs all appear to be thoughts triggered in a relatively effortlessly manner by an external stimulus. Relevant to the current experiment, both direct retrieval and involuntary autobiographical memories have been described as being fairly to highly vivid (e.g., Barzykowski & Staugaard, 2016; Berntsen & Jacobsen, 2008). We hypothesised that this finding may extend to SDTs, which may be rated as more vivid than SITs.

2. Method

2.1. Participants

40 young adults (aged 18–30, mean age = 23, SD = 3.37; 23 females) were recruited through the Harvard psychology subject pool.

2.2. Stimuli

376 words were selected from the MRC psycholinguistics database (http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm) for the word task, and 376 numbers between 1 and 10,000 were randomly selected for the number task.

2.3. Procedure

Participants performed two tasks in a counterbalanced order. The only difference between the two tasks was that one used word stimuli and the other used number stimuli. 90% of stimuli were presented in orange and 10% were presented in blue. Participants were asked to press the spacebar as quickly as possible when an orange stimulus appeared, but to withhold their response for a blue stimulus. Stimuli were presented for 750 ms each, in a random order. An empty screen lasting 3250 ms appeared in between stimuli.

Approximately once every minute, a thought probe asked participants about the type of thought they had just been experiencing. Participants chose between (1) on-task, (2) a thought triggered by a task stimulus (SDT), (3) a thought related to the task that was not triggered by a task stimulus (task-related interference) and (4) a thought that was unrelated to the task and not triggered by any task stimulus (SIT). Of primary interest in the current experiment were response options 2 and 4 (SDT and SIT) – option 3 was included to allow us to separate task-related interferences (e.g. "I wonder what this task is about", "I wonder how many orange stimuli there are", "this task is boring") from the other categories. Furthermore, TRIs were not included in any analysis in the current paper, except for an exploratory analysis comparing the characteristics of SDTs and TRIs reported in Supplementary materials. If participants reported that they were experiencing a SDT, they were asked to type which word triggered the thought so that we could verify that participants could indeed specify a triggering stimulus. Additionally, if participants chose any option except being on-task, they were asked to answer four additional questions. First, whether they were aware of having the thought before the thought probe appeared (yes or no; meta-awareness index). Second, how vivid was the thought on a scale of 1–7 (vividness index). Third, was the thought about (a) the present, (b) the past, (c) the future or (d) atemporal (temporality index). "Present" was defined as a thought pertaining to something happening in the current task. "Past" and "Future" were defined as thoughts pertaining to something that happened/could happen before and after the task, respectively. "Atemporal" was to be selected for thoughts without a specific temporal orientation. Finally, participants were asked to rate the extent to which the thought was relevant to their everyday goals, concerns and worries on a 1–7 scale (current concerns index). There were 25 thought probes per task.

3. Results

3.1. Accuracy and response time

Accuracy and mean response time (RT) are presented in Table 1. A one-way within-group ANOVA indicated that there was no significant difference between the word and the number task in RT for go-trials (orange stimuli), $F(1,39) = 0.83$, $p = 0.37$, $\eta_p^2 = 0.02$. Additionally, there were no task-related differences in omission errors (failing to respond to orange trials), $F(1,39) = 1.15$, $p = 0.29$, $\eta_p^2 = 0.03$, or commission errors (failing to withhold response to blue trials), $F(1,39) = 0.10$, $p = 0.76$, $\eta_p^2 = 0.002$. Thus, any differences in thought proportions are unlikely to be attributable to differences in task demands. Also, task order had no effect on omission errors, commission errors or RT (all $ps > 0.1$).

3.2. Thought proportions

Thought proportions are depicted in Fig. 1. A task (word/number) by thought type (On-task, SDT, SIT) ANOVA revealed a significant main effect of thought type $F(2,78) = 13.12$, $p < 0.001$, $\eta_p^2 = 0.25$, and a thought type by task interaction, $F(2,78)$

Table 1
Ongoing task accuracy and RT (mean, SD).

Experiment 1 – Word/number manipulation		
	Word task	Number task
Omission errors	0.01 (0.02)	0.02 (0.04)
Commission errors	0.14 (0.09)	0.14 (0.12)
RT for correct trials	485.78 (136)	480 (148)
Experiment 2 – Deep/shallow encoding manipulation		
	Deep encoding	Shallow encoding
Accuracy	0.92 (0.07)	0.95 (0.06)
RT total	1017.28 (324)	643.98 (137)

Note: Omission errors, commission errors and accuracy and presented as proportions. RT is presented in milliseconds.

$= 26.83, p < 0.001, \eta_p^2 = 0.41$. Post-hoc tests indicated that this interaction arose because, in the word relative to the number task, individuals exhibited an increase in SDTs, $F(1,39) = 47.30, p < 0.001, \eta_p^2 = 0.55$, and a decrease in SITs $F(1,39) = 29.68, p < 0.001, \eta_p^2 = 0.43$. There were no task differences in the proportion of on-task thoughts ($p = 0.77$). Thus, a task with word stimuli versus number stimuli was associated with a reduction in the number of SITs and an increase in the proportion of SDTs, but not an increase the total proportion of off-task thoughts experienced.

3.3. Thought characteristics

We assessed whether SDTs and SITs differ in terms of their temporal orientation, relevance to current concerns, vividness and meta-awareness using linear and logistic mixed models. Descriptive statistics for current concerns and vividness are presented in Table 2, and descriptive statistics for temporality and meta-awareness are presented in Table 3. We used mixed models because they allowed us to include data from all participants in the analyses, even those with missing data (not all participants reported at least one SDT and one SIT). Analyses were run using the lme4 package in R. For each model, thought type (SDTs/SITs), task (word/number), and the thought type by task interaction were entered as fixed effects. For random effects, we had intercepts for subjects and we also included subjects as a random slope by the interaction of thought type and task. For all 4 of the dependent variables, a model using maximal random effects structure failed to converge. Thus, we used a model with uncorrelated intercepts and slopes in all cases.

For temporality, although participants chose between "present", "past", "future" and "atemporal", our main interest was in replicating our prior findings that SDTs are more past-oriented compared to SITs, whereas SITs are more future-oriented (Maillet & Schacter, 2016). Thus, we only analyzed "past" and "future" responses using a logistic mixed model (with "past" responses coded as 0 and "future" coded as 1). An initial model indicated that there was no task by thought type interaction ($p = 0.25$). Thus, we re-ran the model with only the two main effects. This model revealed a significant main effect of thought type on temporality ($b = 1.21$, $SE = 0.29$, $Z = 4.13$, $p < 0.001$). The odds ratio indicated that the odds of SITs being about the future versus the past were 3.45 higher than it was for SDTs. Predicted probabilities indicated that SDTs had a 0.29 probability (95% CI = [0.18, 0.43], SE = 0.31) of being about the future versus the past, whereas this probability for SITs was 0.59 (95% CI = [0.47, 0.69], SE = 0.24). Thus, whereas SDTs had a past- versus future-oriented bias, there was a trend for SITs in the opposite direction.

For current concerns, there was a thought type by task interaction ($b = -0.83$, $SE = 0.31$, $t = -2.71, p = 0.01$). The interaction was due to SDTs being rated as more relevant to current concerns in the word task versus the number task ($b = 0.66$, $SE = 0.24$, $t = 2.7$, $p < 0.01$), whereas there was no difference for SITs ($b = 0.15$, $SE = 0.16$, $t = 0.96$, $p = 0.34$). Additionally, SITs were rated as more relevant to current concerns compared to SDTs in both the number task ($b = 1.37$, $SE = 0.27$, $t = 5.05$, $p < 0.001$) and the word task ($b = 0.56$, $SE = 0.22$, $t = 2.57$, $p = 0.01$). These results support the hypothesis that stimuli, and particularly numbers, may trigger thoughts that are not as concern-related as SITs.

We predicted that SDTs would be rated as more vivid and as being associated with higher levels of meta-awareness than SITs. For vividness, there was a thought type by task interaction ($b = -0.79$, $SE = 0.23$, $t = -3.41$, $p = 0.001$). Inconsistent with our hypothesis, the interaction was due to SDTs being rated as *less* vivid than SITs in the number task ($b = 0.78$, $SE = 0.21$, $t = 3.72$,

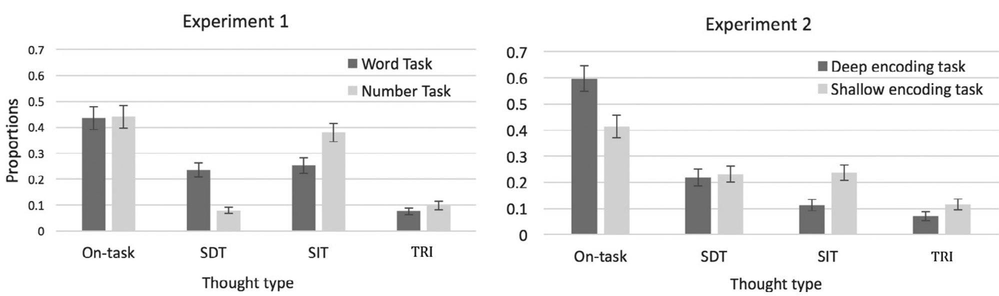

Fig. 1. Proportion of responses on the thought probes (with standard error). SDT = stimulus-dependent thought, SIT = stimulus independent thought, TRI = task-related interference.

Table 2
Mean (standard deviation) ratings for current concerns and vividness.

	Current concerns	Vividness
Experiment 1		
Word Task – SDT	3.09 (1.88)	4.03 (1.66)
Word Task – SIT	3.73 (2.04)	4.09 (1.72)
Number Task – SDT	2.43 (1.77)	3.47 (1.49)
Number Task – SIT	3.83 (2.03)	4.39 (1.65)
Experiment 2		
Deep Encoding – SDT	3.27 (2.02)	4.09 (1.56)
Deep Encoding – SIT	3.46 (1.96)	3.32 (1.62)
Shallow Encoding – SDT	3.40 (2.23)	4.04 (1.85)
Shallow Encoding – SIT	3.88 (1.92)	4.19 (1.68)

SDT = stimulus-dependent thought, SIT = stimulus-independent thought.

$p < 0.001$) but not in the word task (b = 0.04, SE = 0.17, t = 0.24, $p = 0.81$). Also, SITs were rated as more vivid in the number versus the word task (b = 0.33, SE = 0.14, t = 2.27, $p = 0.03$), whereas SDTs were rated as more vivid in the word versus the number task (b = 0.48, SE = 0.21, t = 2.23, $p = 0.02$). For meta-awareness, there were no significant main effects or interactions (all $p > 0.5$).

4. Discussion

Experiment 1 had two main goals. First, we were interested in whether the presence of meaningful stimuli (1) causes an increase in off-task thoughts, through an increase in frequency of SDTs and no change in SITs or (2) biases thoughts away from SITs and towards SDTs, with no change in overall frequency of off-task thoughts. We found support for the latter hypothesis. Second, we were interested in comparing the characteristics of SDTs and SITs. First, replicating our prior work (Maillet & Schacter, 2016), SDTs and SITs differed in temporal orientation, such that SDTs were more past- versus future-oriented whereas SITs trended in the opposite direction. We also found differences between SDTs and SITs in relation to current concerns and vividness. Across tasks, SDTs were rated as less relevant to current concerns than SITs. In addition, SDTs were rated as less relevant to current concerns in the number versus the word task. The lower relevance to current concerns for SDTs versus SITs is consistent with the hypothesis that, because word and number stimuli may not be related to participants' current concerns, the SDTs that are triggered by these stimuli are not concern-related thoughts. Moreover, number stimuli may be even less related to participants' current concerns compared to word stimuli. SDTs were also rated as more vivid in the word versus the number task, whereas SITs showed the opposite pattern. Thus, in general, SDTs in the number task may have been superficial thoughts: neither vivid nor related to participants' concerns. The finding that SITs were more vivid in the number versus the word task may be related to the finding that frequency of SITs was also higher in the number versus the word task. Speculatively, participants may experience more vivid thoughts in a task in which the frequency of that thought type is higher.

5. Experiment 2

One possibility as to why SDTs are more past-oriented compared with SITs (both in Maillet & Schacter, 2016, and in Experiment 1 of the current manuscript) is that the triggering stimulus occurred "in the past" in the experiment (i.e. a few seconds ago). That is, participants may be responding "past" because the triggering stimulus was seen a few seconds ago, and not because they are having a

Table 3
Number (and percentage) of responses for the temporality and meta-awareness characteristics.

	Temporality				Meta-awareness	
	Present	Past	Future	Atemporal	Yes	No
Experiment 1						
Word Task – SDT	20 (9%)	85 (36%)	46 (20%)	84 (36%)	141 (60%)	94 (40%)
Word Task – SIT	39 (15%)	58 (22%)	73 (28%)	89 (34%)	156 (60%)	103 (40%)
Number Task – SDT	11 (14%)	26 (32%)	11 (14%)	33 (41%)	45 (56%)	36 (44%)
Number Task – SIT	59 (16%)	80 (21%)	117 (31%)	118 (32%)	212 (57%)	162 (43%)
Experiment 2						
Deep Encoding – SDT	23 (14%)	55 (34%)	32 (20%)	54 (33%)	94 (57%)	70 (43%)
Deep Encoding – SIT	4 (5%)	24 (28%)	19 (22%)	38 (45%)	41 (48%)	44 (52%)
Shallow Encoding – SDT	7 (4%)	79 (45%)	29 (17%)	59 (34%)	98 (56%)	76 (44%)
Shallow Encoding – SIT	14 (8%)	41 (23%)	76 (43%)	47 (26%)	92 (52%)	86 (48%)

SDT = stimulus-dependent thought, SIT = stimulus-independent thought.

thought pertaining to something that happened prior to the beginning of the experiment (as stated in the instructions for all these studies). Thus, the first goal of Experiment 2 was to provide evidence against this possibility by changing the wording of the thought probes to minimize this concern (see below).

The second goal of Experiment 2 was to assess the relationship between the (1) frequency of SDTs during encoding and (2) subsequent recognition performance. In an old/new recognition task involving deep encoding of word-picture pairs, Maillet and Schacter (2016) found a positive correlation between SDT frequency (at encoding) and retrieval performance in older adults, but not in young adults. One possible explanation of this finding is that, unlike older adults, young adults may not rely so heavily on SDTs to aid recognition performance, and may instead rely on other features, such as perceptual details of the stimuli (e.g., "I remember that the elephant had a big trunk") or the semantic analysis required to make a deep incidental-encoding judgement (e.g., "I remember responding that the elephant was a living thing"). The availability of these other features in the task used in Maillet and Schacter (2016) may have minimized the importance of the extra elaboration provided by SDTs in young adults. If this was indeed the case, then a correlation between SDT frequency at encoding and retrieval performance should be found in young adults in a memory task in which the presence of these other features is minimized.

To assess this possibility, we used word stimuli rather than word-picture pairs (as in Maillet and Schacter (2016), which reduces the number of perceptual details for young adults to rely upon to aid recognition performance. In addition, the current experiment included a depth of processing manipulation: half the participants performed a deep encoding judgement, whereas the other half performed a shallow encoding judgement. Unlike the deep-encoding judgement, the shallow encoding judgement does not require semantic analysis of encoding stimuli, so the young adults in this condition should not be afforded the opportunity to rely on semantic analysis to aid memory performance.

Because shallow encoding of word stimuli is an impoverished encoding condition with few features to rely on for successful encoding performance, we expected that young adults would rely on SDTs in this condition, leading to a positive correlation between SDT frequency and memory performance. In contrast, we expected no relationship (or a weaker relationship) between SDT frequency and memory performance in the deep encoding condition, in which participants may rely on semantic analysis to aid memory performance. Furthermore, in addition to *frequency* of SDTs, it is possible that certain *characteristics* of SDTs also predict later memory performance. For instance, a word triggering an SDT that is very relevant to one's concerns may be more likely to be remembered than one triggering an SDT that is unrelated to one's concerns. We expected that increased relation to current concerns, meta-awareness, and vividness of SDTs would positively predict later memory, above-and-beyond SDT frequency.

6. Method

6.1. Participants

60 participants were recruited through the Harvard psychology subject pool. Thirty participants (aged 18–36, mean age = 23.23, SD = 4.42; 19 females) were randomly assigned to the shallow encoding condition, and 30 (aged 19–34, mean age = 24.17, SD = 4.15; 21 females) were assigned to the deep encoding condition. The groups did not differ in age ($p = 0.40$) or gender ratio ($p = 0.58$).

6.2. Stimuli

Five-hundred and sixty-four words were selected from the MRC psycholinguistics database. 376 encoding words were used during encoding, and 188 were used as novel lures on the recognition task. The assignment of words to retrieval lures was counterbalanced. Words were presented in a random order. Half of the words were abstract (e.g. friendship, love) and half were concrete (e.g., table, car).

6.3. Procedure

Participants were randomly assigned to either a deep or a shallow encoding task of 376 words. Half of the words were presented in blue, and half in orange. Participants in the shallow encoding condition judged whether words were presented in blue or orange. Participants in the deep encoding condition judged whether words were abstract or concrete. Rate of presentation of stimuli and thought probes were identical to those in Experiment 1, except for a slight change in the wording of the temporality question. This change was implemented to minimize the concern that participants may be responding "past" because the triggering stimulus was seen a few seconds ago, and not because they are having a thought pertaining to something that happened prior to the beginning of the experiment. The wording for the temporality component of the thought probes used in Experiment 2 was, "The thought was about:", and the response options were: (1) something happening in the current experiment, (2) something that happened in the past (before the start of the experiment), (3) something that could happen in the future and (4) something with no specific temporal orientation. Thus, although the pre-task instructions were the same in Experiments 1 and 2, the thought probes in Experiment 2 were designed to further remove any ambiguity about the meaning of "past".

Following encoding, participants filled out the daydreaming frequency scale (Giambra, 1993), which was intended to act as a delay between encoding and retrieval, and the results of which are not presented here. Next, participants performed a surprise recognition task. The 376 encoding words were presented along with 188 novel lures, one at a time, in a random order. Participants responded (1) Sure old, (2) Probably old, (3) Probably new or (4) Sure new. Henceforth, "sure" responses are referred to as high confidence responses, and "probably" responses are referred to as low confidence responses.

7. Results

7.1. Incidental encoding accuracy and reaction time

Encoding accuracy and RT data are presented in Table 1. One-way between-group ANOVAs indicated that, when making the incidental encoding judgement, participants in the deep encoding condition produced significantly longer RTs, $F(1,58) = 33.77$, $p < 0.001$, $\eta_p^2 = 0.37$, and reduced accuracy, $F(1,58) = 4.55$, $p = 0.04$, $\eta_p^2 = 0.07$, than did participants in the shallow-encoding condition.

7.2. Thought proportions

Thought proportions are depicted in Fig. 1. An encoding judgement (deep/shallow) by thought type (On-task, SDT, SIT) ANOVA revealed a significant interaction, $F(2,116) = 6.60$, $p = 0.002$, $\eta_p^2 = 0.10$. Post-hoc tests indicated that this interaction arose because, in the deep relative to the shallow task, participants reported an increase in on-task thoughts, $F(1,58) = 7.79$, $p = 0.007$, $\eta_p^2 = 0.12$, and a decrease in SITs, $F(1,58) = 11.45$, $p = 0.001$, $\eta_p^2 = 0.17$. Frequency of SDTs did not differ between the two tasks, $F(1,58) = 0.09$, $p = 0.76$, $\eta_p^2 = 0.002$.

We had not predicted any differences in thought proportions between the deep and shallow encoding tasks. However, previous studies in the mind-wandering literature have indicated that participants exhibit less mind-wandering during relatively difficult tasks (e.g., Mason et al., 2007; Smallwood, Davies, et al., 2004; Smallwood, Nind, & O'Connor, 2009). In the current experiment, the deep encoding task appeared to be more difficult than the shallow encoding task, as suggested by increased RT and reduced accuracy. Thus, it is possible that the observed difference in on-task thoughts was attributable to the differences in task difficulty between the two tasks. To examine whether task difficulty (indexed by increased RTs in the deep relative to the shallow encoding) accounted for the differences in thought types, we again conducted the encoding judgement (deep/shallow) by thought type (On-task, SDT, SIT) ANOVA, but this time, controlling for RT. There was no significant interaction, $F(2,114) = 2.47$, $p = 0.09$, $\eta_p^2 = 0.04$, indicating that differences in task difficulty accounted for thought-type differences in this experiment.

7.3. Thought characteristics

As in Experiment 1, we assessed whether SDTs and SITs differed in terms of their temporal orientation, relation to current concerns, vividness, and meta-awareness using linear and logistic mixed models. Descriptive statistics for current concerns and vividness are presented in Table 2, and descriptive statistics for temporality and meta-awareness are presented in Table 3. For each model, thought type (SDTs/SITs), task (word/number) and the thought type by task interaction were entered as fixed effects. For random effects, we had intercepts for participants and we also included participants as a random slope by the main effect of thought type. Models with a maximal random effect structure were used in all cases.

For temporality, as in Experiment 1, we focused on past and future responses. There was a significant main effect of temporality (b = 1.30, SE = 0.32, Z = 4.04, $p < 0.001$), which was qualified by a marginal temporality by task interaction (b = 1.18, SE = 0.62, Z = 1.91, $p = 0.06$). The interaction was due to SITs being more likely to be about the future versus the past compared to SDTs only in the shallow encoding task (b = −1.70, SE = 0.38, Z = −4.49, $p < 0.001$), which replicates the results from Experiment 1 (which also included a task requiring a color judgement on word stimuli), but not in the deep encoding task (which is unique to Experiment 2; b = 0.53, SE = 0.49, Z = 1.06, $p = 0.29$). In the shallow-encoding task, the odds ratio indicated that SITs were 3.65 times more likely to be about the future versus the past than were SDTs, whereas in the deep-encoding task, SITs were 1.69 times more likely to be about the future versus the past than were SDTs. Predicted probabilities indicated that, in the shallow encoding task, SDTs had a 0.28 chance of being about the future versus the past (SE = 0.27, 95% CI = [0.18, 0.38]) whereas SITs had a 0.67 chance (SE = 0.28, 95% CI = [0.54, 0.78]). In the deep encoding task, the probabilities were 0.35 (SE = 0.28, 95% CI = [0.24, 0.49]) for SDTs and 0.48 for SITs (SE = 0.41, 95% CI = [0.29, 0.67]). Thus, whereas SDTs were more likely to be past- than future-oriented across tasks, SITs were more future- than- past-oriented only in the shallow-encoding task.

In Experiment 1, we found that SITs were rated as more relevant to current concerns compared to SDTs, both in the word and the number task. Although SITs were again numerically rated as more relevant to current concerns compared to SDTs in Experiment 2, this difference was not statistically significant (all $ps > 0.1$).

In Experiment 1, SDTs were more vivid in a task with word versus number stimuli, whereas SITs showed the opposite pattern. In Experiment 2, we also found task-related differences in vividness ratings. That is, there was a task by thought type interaction (b = 0.91, SE = 0.35, t = 2.61, $p = 0.01$), which was due to SITs being rated as less vivid in the deep versus the shallow encoding task (b = −0.75, SE = 0.37, t = −2.04, $p = 0.05$), whereas there was no such difference for SDTs (b = −0.16, SE = 0.32, t = −0.51, $p = 0.62$). Also, SDTs were rated as more vivid than SITs in the deep encoding task (b = 0.76, SE = 0.27, t = 2.81, $p < 0.01$), but not in the shallow encoding task (b = 0.15, SE = 0.22, t = 0.69, $p = 0.49$). For meta-awareness, as was the case in Experiment 1, there were no significant main effects or interactions (all $ps > 0.5$).

Table 4
Proportion of hits, misses and false alarms (mean, SD), separated by confidence level in deep and shallow encoding.

	Deep encoding	Shallow encoding
Old words		
High confidence hit	0.60 (0.19)	0.29 (0.17)
Low confidence hit	0.20 (0.14)	0.24 (0.14)
Low confidence miss	0.15 (0.09)	0.32 (0.21)
High confidence miss	0.05 (0.05)	0.15 (0.17)
New words		
High confidence false alarm	0.25 (0.19)	0.17 (0.18)
Low confidence false alarm	0.24 (0.16)	0.24 (0.16)
Low confidence correct rejection	0.36 (0.18)	0.40 (0.25)
High confidence correct rejection	0.15 (0.11)	0.19 (0.22)
Hits-False alarms		
High confidence hits – High confidence false alarm	0.35 (0.17)	0.12 (0.09)
Low confidence hits – Low confidence false alarm	−0.04 (0.11)	0.01 (0.05)

7.4. Recognition performance

Participants performed a surprise recognition task for the words studied in the first part of the experiment. When asked whether they were aware that a memory test would follow, none of the participants responded positively. Consistent with our prior methods (Maillet & Schacter, 2016), for all analyses involving retrieval data, we removed words that participants had reported having an SDT about at encoding. This was done because participants were asked to type these words when responding to the thought probes, and to rate SDTs related to each of the words (on meta-awareness, vividness, temporal orientation, relation to current concerns). Thus, one would expect recognition of these words to be especially strong, not because participants experienced SDTs about them, per se, but because these words received extra exposure compared to other words. Recognition data are presented in Table 4.

As in Maillet and Schacter (2016), our measure of recognition performance was % High confidence Hits –% High confidence False alarms. Consistent with typical levels of processing manipulations (Craik & Lockhart, 1972), participants in the deep encoding condition performed at a higher level than did participants in the shallow encoding condition, $F(1,58) = 43.51$, $p < 0.001$, $\eta_p^2 = 0.43$.

Using stepwise multiple regressions, separately for each encoding condition, we assessed whether thought type proportion (on-task, SDT, SIT) and SDT characteristics (vividness, meta-awareness, relation to current concerns) were related to recognition performance. Twenty-five participants in the deep encoding condition and 29 participants in the shallow encoding condition had at least one SDT and were included in this analysis. Correlations among all variables of interest are presented in Table 5. A significant regression equation was found only in the shallow encoding condition, $F(2,26) = 8.67$, $p = 0.001$, with an adjusted R^2 of 0.35. Participants' predicted recognition score was equal to −0.04 + 0.09 (SDT proportion) + 0.03 (SDT vividness). On-task proportion, SIT proportion, SDT meta-awareness, and SDT relation to current concerns were not significant predictors of recognition performance (all $ps > 0.1$).

Table 5
Correlations between variables of interest.

	1	2	3	4	5	6	7
Deep encoding task							
1. High confidence hits – false alarms	1						
2. SDT proportion	0.20	1					
3. On-task proportion	−0.26	−0.78*	1				
4. SIT proportion	0.03	0.04	−0.55*	1			
5. SDT meta-awareness	0.14	0.06	−0.22	0.19	1		
6. SDT Vividness	−0.10	0.03	0.15	−0.029	0.158	1	
7. SDT Current Concerns	−0.16	0.18	−0.25	0.258	0.097	0.331	1
Shallow encoding task							
1. High confidence hits – false alarms	1						
2. SDT proportion	0.532*	1					
3. On-task proportion	−0.307	−0.512*	1				
4. SIT proportion	−0.146	−0.225	−0.566*	1			
5. SDT meta-awareness	0.176	−0.083	−0.183	0.152	1		
6. SDT Vividness	0.508*	0.352	−0.301	0.071	−0.067	1	
7. SDT Current Concerns	0.273	0.254	−0.09	−0.059	−0.298	0.578*	1

* $p < 0.05$. In deep encoding task, n = 25. In shallow encoding task, n = 29.

8. Discussion

Three key results emerged from Experiment 2. First, although not predicted, the deep/shallow manipulation in Experiment 2 affected thought proportions. Specifically, the shallow encoding task was associated with more SITs and fewer on-task responses compared with the deep encoding task, with no change in SDTs. However, the shallow encoding task was also associated with shorter RT compared with the deep encoding task, and task differences in thought frequency were no longer significant when controlling for RT. This suggests that the increase in SIT in the shallow versus the deep encoding task may have been due to the former task being easier, which would have in turn allowed more time for SITs to occur. This interpretation is in line with many studies in the mind-wandering literature indicating that mind-wandering frequency is reduced with increasing task difficulty (e.g., Mason et al., 2007; Smallwood, Davies, et al., 2004; Smallwood, Nind, & O'Connor, 2009, but see Feng, D'Mello, & Graesser, 2013).

Second, SDTs were again more likely to be past- versus-future oriented across tasks after changing the wording of the thought probes (which was done to minimize the possibility that this finding was attributable to participants' misunderstanding of the instructions). In contrast, SITs were more future- versus past-oriented in shallow encoding (which replicates Experiment 1), but not in the deep encoding task, which is unique to Experiment 2. If, as suggested above, differences in the types of thoughts experienced during the shallow versus deep encoding task can best be understood in terms of differences in task difficulty, then it is possible that SITs were only more future- versus past-oriented during shallow, but not deep encoding, because the latter task was more difficult. Indeed, a previous study also found that mind-wandering was more future- versus past-oriented only in an easy, but not in a more difficult task (Smallwood, Nind, & O'Connor, 2009). It was suggested that, compared to past thoughts, future thoughts are more likely to rely on controlled processing because they require a novel recombination of previous experiences (e.g., Addis, Wong, & Schacter, 2007). The extent to which participants can rely on such controlled processing may be reduced during a more difficult task, reducing the proportion of future thoughts.

Third, the frequency of SDTs and their vividness predicted later recognition memory performance, but only in a shallow encoding task. This is consistent with the hypothesis that, in young adults, SDTs aid later memory performance primarily under impoverished encoding conditions. In the general discussion, we discuss each of these findings in greater detail.

9. General discussion

Two experiments were conducted to further our understanding of SDTs and SITs. We were interested in (1) how a manipulation of the meaningfulness of task stimuli would affect rates of SDTs and SITs (Experiment 1), (2) whether SDTs and SITs differ in characteristics including temporality, their relevance to current concerns, vividness, and meta-awareness (Experiments 1 and 2) and (3) how SDT and SIT impact subsequent memory (Experiment 2). Each of these questions is addressed in more detail below.

9.1. SDTs, SITs and on-task responses are differentially modulated by task manipulations

In Experiment 1, we found that, compared to a task with number stimuli (non-meaningful stimuli), a task with word stimuli (meaningful stimuli) was associated with an increase in SDTs and a decrease in SITs, with no differences in the overall number of off-thoughts across the two tasks. In Experiment 2, we found that, compared with a deep encoding task, a shallow encoding task (an easier task) was associated with an increase in SIT and a reduction in on-task thought, with no change in SDT. Taken together, the results of the two experiments suggest that proportions of on-task thoughts, SDTs, and SITs are affected by different factors. On-task proportion increased with increasing task difficulty (Experiment 2) but was not affected by stimulus meaningfulness (Experiment 1). Thus, on-task responses may track the extent to which participants are focused on performing the ongoing task (and this may increase in more difficult tasks). SDT proportion was increased in a task with more meaningful stimuli, but was unaffected by task difficulty. Thus, SDT frequency may indicate the extent to which an ongoing task contains stimuli that spontaneously trigger thoughts. Finally, SIT proportion was reduced both when task stimuli were more meaningful and when the task was more difficult. One possibility is that participants engage in SITs by default, and that SIT proportion can be reduced by multiple factors such as task difficulty and the presence of meaningful stimuli.

9.2. Unlike SITs, SDTs are more likely to be past- versus future-oriented

Both in Experiments 1 and 2, SITs were more future- versus-past oriented in a task in which participants had to judge the colors of word stimuli. However, SITs were no longer associated with a future-oriented bias in the deep encoding condition in Experiment 2, perhaps because deep encoding condition was more difficult than the shallow encoding condition (Smallwood, Nind, & O'Connor, 2009). In contrast, in both experiments, we found that SDTs were more likely to be past- versus future-oriented. In Experiment 2, we used thought probes that placed extra emphasis on only choosing "past" if participants' thoughts pertained to something that happened before the beginning of the experiment (as noted earlier, this was done to minimize the concern that participants misunderstood instructions in Experiment 1 and selected this option because the triggering word was seen a few seconds ago, "in the past"). Other experiments have also found evidence suggestive of a past-oriented bias in thoughts triggered by environmental stimuli. In a vigilance task with task-irrelevant phrases (e.g. "going on holiday"), Plimpton et al. (2015) found a past-oriented bias in task-unrelated thoughts (the vast majority of which were reported to have been triggered by these phrases). In a reading task, Smallwood et al. (2009) found that participants with low interest and little experience with the topic they were reading about had a prospective bias in mind-wandering, whereas low interest and high experience participants had a retrospective bias. The authors suggested that the temporality of mind-wandering could be partially determined by an individual's associations with stimuli in the external environment (i.e. perhaps participants with greater knowledge had more past associations). In an unpublished dataset, we found that, when presented with individual words and asked to intentionally think of either a past or future event related to each word, participants were significantly more likely to choose a past event. Collectively, these results suggest that a variety of task stimuli are more likely to trigger past versus future thoughts.

However, the precise reason for this effect remains unclear. In the current experiment, the probability that participants spontaneously experience future thoughts that are associated with words such as "pen" and "painting" may be relatively low. Such spontaneous future thoughts may occur if participants already have plans relevant to these words. For instance, the word "painting" may trigger a future reminding (e.g., a thought related to remembering to carry out a future intention of going to an art exhibit this weekend; Ellis & Nimmo-Smith, 1993; Kvavilashvili & Fisher, 2007; Plimpton et al., 2015; Reese & Cherry, 2002; Sellen, Louie, Harris, & Wilkins, 1997; Szarras & Niedzwienska, 2011), or a memory for the content of a future simulation (remembering a future thought of being at the museum with a friend; Ingvar, 1985; Szpunar, Addis, McLelland, & Schacter, 2013). It is also possible that the presentation of the word could spontaneously trigger a novel thought about the future (Jeunehomme & D'Argembeau, 2016). However, on average, the probability that a given task stimulus will trigger a future thought may be lower than the probability that the same stimulus will trigger a past-oriented thought, perhaps because participants have likely encountered most of these stimuli in their daily lives. Thus, whereas only a few stimuli may have the potential to trigger participants' future plans, a majority of stimuli may have the potential to trigger memories because they have been previously encountered. However, this account is admittedly speculative, and further research will be required to better understand the past versus future bias in SDT.

We found no support for our hypothesis that SDTs would be rated as more vivid than SITs. Instead, differences in vividness were primarily caused by task-related differences. In Experiment 1, SDTs were rated as more vivid in the word versus the number task, whereas SITs were rated as more vivid in the number versus the word task. In Experiment 2, SITs were rated as more vivid in the shallow versus deep encoding task. These task-related differences in vividness seem to match the task-related differences in thought frequency discussed earlier. That is, in Experiment 1, SDTs were more frequent in the word versus the number task, whereas SITs showed the reverse pattern In Experiment 2, SITs were more frequent in the shallow versus the deep encoding task, with no task-related differences in SDT. Thus, one possibility is that people experience more vivid thoughts in a task in which they have more of a given thought type.

Lastly, we found that SDTs were rated as less relevant to current concerns compared to SITs in Experiment 1, but this was not replicated in Experiment 2. We thus advise that the reader cautiously interprets this result until future studies clarify this issue.

9.3. SDTs can benefit later memory for the triggering stimuli

Maillet and Schacter (2016) failed to observe a relationship between frequency of SDTs and retrieval performance in young adults in a task involving word-picture pairs and a deep encoding judgement. In the current experiment, we likewise failed to find a significant association between SDT frequency and retrieval performance in a task involving deep encoding of words. However, SDT frequency and vividness positively predicted retrieval performance during shallow encoding of words. Taken together, these results suggest that, during incidental encoding, SDTs likely do not contribute to old/new recognition performance as much as other features, such as the incidental encoding judgement and perceptual features in young adults. Instead, SDTs only contributed significantly to performance in an impoverished encoding condition with poor overall memory performance (shallow encoding of word stimuli) where perceptual features and semantic analysis were not available.

Interestingly, although the frequency of SDTs correlated with memory performance only in the shallow encoding condition, the frequency of SDTs did not differ between the shallow and the deep encoding condition. Thus, although SDTs were equally likely to occur, there seems to have been increased reliance on them in the retrieval task for words encoded in the shallow encoding task. Relatedly, in Maillet and Schacter (2016), when participants responded that a word was old (during a recognition test), they were asked to specify the extent to which they could remember any thoughts they were having when they had initially seen the word at encoding. In that experiment, the frequency of SDTs at encoding positively correlated with retrieval ratings for thoughts in both young and older adults; however, a significant positive correlation between SDT frequency and memory performance was observed only in older adults. Collectively, the results of both studies suggest that, even if SDTs are available, young adults do not primarily rely on SDTs when making old/new judgments if other features are available. Relatedly, it has been previously shown that individuals who focus on thoughts/feelings tend to perform poorly on memory tasks, perhaps because these thoughts/feelings are not as reliable an indicator that events occurred as is perceptual and contextual information (Hashtroudi et al., 1990, 1994).

It is important to emphasize that the usefulness of thoughts/feelings at encoding on later memory performance likely depends on several factors, including whether encoding is incidental or intentional. During intentional encoding, people have the opportunity to generate personally meaningful associations that are specific to individual words. In contrast, the types of thoughts that people spontaneously experience when they are unaware that they will later be tested may not always be as specific or efficient at promoting memory. For example, an SDT triggered by a food item (e.g., "I have to go grocery shopping tonight," or "I'm hungry") may have limited usefulness in a task that contains dozens of food items because such SDTs are not specific to one item. Note also that our results are based on a single kind of memory test, old/new recognition. Given the well-established finding that the usefulness of different kinds of encoding activities depends on the nature of subsequent retrieval conditions (e.g., Roediger, 2008), future studies should attempt to elucidate the impact of SDTs and SITs on a broader range of memory tasks.

A limitation of the current experiments is that we did not ask participants whether their thoughts were spontaneous or deliberate (Seli, Risko, Smilek, & Schacter, 2016). Thus, the thoughts in the current experiments likely reflect a mixture of the two. However, in a previous study (Maillet & Schacter, 2016), we reported that the majority of SDTs and SITs were spontaneous and that SDTs and SITs did not differ in terms of the extent to which they were engaged deliberately or spontaneously. Importantly, this finding suggests that it is unlikely that the differences in characteristics of SDTs and SITs reported here were attributable to differences in rates of spontaneity across the two thought types. Another limitation of the current experiments is that we did not include open-ended thought probes which could have allowed more insight into the content of SDTs and SITs. This avenue should be explored in future research.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2017.04.014.

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