

## Dealing with prospective memory demands while performing an ongoing task: Shared processing, increased on-task focus, or both?

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### **Abstract:**

Prospective memory (PM) is the cognitive ability to remember to fulfill intended action plans at the appropriate future moment. Current theories assume that PM fulfillment draws on attentional processes. Accordingly, pending PM intentions interfere with other ongoing tasks to the extent to which both tasks rely on the same processes. How do people manage the competition between PM and ongoing-task demands? Based on research relating mind wandering and attentional control (Kane & McVay, 2012), we argue that people may not only change the way they process ongoing-task stimuli when given a PM intention, but they may also engage in less off-task thinking than they otherwise would. That is, people focus more strongly on the tasks at hand and dedicate considerable conscious thought to the PM goal. We tested this hypothesis by asking subjects to periodically report on their thoughts during prototypical PM (and control) tasks. Task-unrelated thought rates dropped when participants performed an ongoing task while holding a PM intention versus performing the ongoing task alone (Experiment 1), even when PM demands were minimized (Experiment 2) and more so when PM execution was especially rewarded (Experiment 3). Our findings suggest that PM demands not only elicit a cost to ongoing-task processing, but they also induce a stronger on-task focus and promote conscious thoughts about the PM intention.

**Keywords:** prospective memory | mind wandering | attentional control | event-based intention

### **Article:**

Event-based PM refers to the host of cognitive processes that enable us to remember to fulfill an intention under appropriate future circumstances, such as giving a friend a message the next time one sees her or stopping to run an errand on the way to work (cf., McDaniel & Einstein, 2007). In the laboratory, event-based PM tasks are typically embedded in an ongoing task that requires some attention and keeps participants busy. The PM task may be to respond to certain stimuli

from the ongoing task (PM targets) with a special key. PM targets occur infrequently—usually on less than 10% of all trials (McDaniel & Einstein, 2007)—and so the PM task mimics the common situation of having to remember to perform an action at a certain moment while being actively engaged in other activities.

As the PM/ongoing-task ensemble comprises two tasks—the *ongoing task* and the *PM task*—it appears similar to traditional divided attention paradigms where two tasks have to be performed simultaneously ( Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; McDowd & Craik, 1988). However, the PM ensemble differs from traditional dual-task situations in some important respects (Ellis & Kvavilashvili, 2000). First, the PM intention is executed after a delay and thus is likely to be retrieved from long-term memory when needed, rather than being actively sustained in working memory. Second, the PM task is executed much less frequently than the ongoing task (usually on not more than 10% of all trials), which prioritizes the ongoing task over the PM task. Third, the PM task is executed in response to PM targets without an explicit reminder.

A core question in PM research is how people manage to fulfill their intentions, self-initiated and at the appropriate moment, under these conditions. Building on the divided-attention literature (Craik et al., 1996), a straightforward assumption would be that attentional processes are distributed between tasks, allowing both the ongoing and the PM task to be fulfilled simultaneously (Smith, 2003). But what is the nature of this process sharing? Will engaging the PM task only occupy mechanisms that would otherwise optimize ongoing-task performance? Recent research on mind wandering indicates that, even while performing attention-demanding tasks, people's attention sometimes drifts away from the currently to-be-performed tasks to task-unrelated thoughts (TUTs; Kane & McVay, 2012; Smallwood, 2013; Smallwood & Schooler, 2015). We therefore argue that when holding a PM intention, people may not only recruit executive control mechanisms for the PM task that they would have used to perform the ongoing task otherwise. They may, additionally, think more about the current task goals (ongoing-task and PM intention) instead, thereby reducing their engagement in TUTs. This reduction of TUTs may happen consciously (Smallwood & Schooler, 2015) or as a byproduct of a stronger attentional focus on the tasks at hand (Kane & McVay, 2012). Relating this general idea to the PM field may imply that, in addition to engaging in PM processing at a cost to ongoing-task processing (e.g., Hicks, Marsh, & Cook, 2005), individuals also generally focus more on the entire PM/ongoing-task ensemble. Before we describe the studies we conducted to test this hypothesis in detail, we will first review existing PM theories and further elaborate on how the consideration of research on TUTs may increase our understanding of PM.

### *Attention-Demanding PM Processing*

Current theories assume that PM performance relies more or less heavily on attentional processes that are also required to perform the ongoing task. One prominent attentional account of PM is the preparatory attention and memory theory (PAM; Smith, 2003, 2010, 2016), according to which, controlled preparatory processing (i.e., rehearsal and monitoring processes) must be engaged to identify PM targets as cues for intention fulfillment. Similarly, the two-process model of strategic monitoring (2PSM; Guynn, 2003; see also Horn & Bayen, 2015, for a recent model-

based test of this theory) suggests that controlled processing is required to actively maintain the intention and to regularly check the environment for PM targets. Finally, the multiprocess theory (MPT; McDaniel & Einstein, 2000; McDaniel, Umanath, Einstein, & Waldum, 2015) assumes some controlled attentional monitoring of the environment for PM targets, but also that PM can sometimes rely on spontaneous processes that are not attention demanding (McDaniel & Einstein, 2000; McDaniel et al., 2015). That is, when PM targets fall naturally in the focus of attention while performing an ongoing task (i.e., focal PM targets), the PM targets will be spontaneously noticed, even without engagement in attentional monitoring (Einstein & McDaniel, 2005; Harrison & Einstein, 2010); note, however, that some evidence indicates that even PM tasks that comprise focal targets elicit some levels of attentional monitoring (Harrison, Mullet, Whiffen, Ousterhout, & Einstein, 2014; Smith, Hunt, McVay, & McConnell, 2007). A recent extension of MPT has further emphasized the role of attentional monitoring by assuming that a spontaneous PM-retrieval encounter can subsequently initiate attentional monitoring (Scullin, McDaniel, & Shelton, 2013). In line with the assumption that executive attentional processes underlie PM performance, Schnitzspahn, Stahl, Zeintl, Kaller, and Kliegel (2013) showed that individual differences in executive control (i.e., inhibition and shifting) are associated with age-related PM declines and predict PM performance (see also Zuber, Kliegel, & Ihle, 2016).

In sum, the conceptualization of attentional PM processes differs across theories, but all current views generally agree that PM must often rely on attentional processing. In line with this assumption, considerable evidence demonstrates that holding a (nonfocal) PM intention slows ongoing-task responses compared to performing the ongoing task alone (e.g., A.-L. Cohen, Jaudas, & Gollwitzer, 2008; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003). This robust finding has been termed the PM-induced interference or cost effect (Hicks et al., 2005; Marsh et al., 2003; Smith, 2003) and is usually interpreted as evidence that attentional processes are recruited for PM processing at a cost to performing one's ongoing tasks (but see Heathcote, Loft, & Remington, 2015).

Whereas PM-induced costs indicate that participants sacrifice their ongoing-task processing to some extent in order to maintain the PM task, they do not necessarily imply that this is the only strategy that people use to avoid PM failures. In fact, people may solve the problem of balancing PM and ongoing-task performance in a number of ways: for example, by adhering to contextual or stimulus-specific information that is indicative of PM target occurrence (A. L. Cohen, Jaudas, Hirschhorn, Sobin, & Gollwitzer, 2012; Kuhlmann & Rummel, 2014; Lourenço, White, & Maylor, 2013; Marsh, Cook, & Hicks, 2006) or by strategically allocating additional attention away from the ongoing task to the PM task due to actual (Hicks et al., 2005) or anticipated (Boywitt & Rummel, 2012; Lourenço, Hill, & Maylor, 2015; Rummel & Meiser, 2013) PM demands. In the present research, we go a step further by arguing that people holding an intention do not simply strategically distribute their attention between their ongoing and PM tasks. Additionally, they also focus more on the entire PM/ongoing-task ensemble and thus engage less in thoughts that are unrelated to their current tasks in order to allow for performing both tasks.

### *TUTs and Their Relation to PM*

Extensive laboratory research demonstrates that people experience TUTs frequently while performing a broad range of cognitive tasks (McVay & Kane, 2010; Mooneyham & Schooler, 2013; Schooler et al., 2011; Smallwood & Schooler, 2006, 2015). TUTs are typically assessed via the unpredictable presentation of thought probes throughout ongoing tasks, and these elicited TUT reports have been validated, in part, by correspondences to objective measures, such as executive-control errors, extreme response times (RTs; and modeled parameters thereof), eye-movement and blinking patterns, and neuroimaging signatures (e.g., Baird, Smallwood, Lutz, & Schooler, 2014; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Frank, Nara, Zavagnin, Touron, & Kane, 2015; Kucyi & Davis, 2014; McVay & Kane, 2012a; Reichle, Reineberg, & Schooler, 2010; Schooler & Schreiber, 2004; Smilek, Carriere, & Cheyne, 2010). TUTs might be more or less functional for the individual in the long run (Klinger, 2013; McMillan, Kaufman, & Singer, 2013; Mooneyham & Schooler, 2013), but they clearly interfere with performance of concurrent tasks. Disengagement from TUTs also appears to be under some degree of willful control, as subjects with stronger cognitive abilities tend to mind-wander less during demanding tasks than do those with weaker abilities (e.g., Kane et al., 2016; McVay & Kane, 2009, 2012b; Randall, Oswald, & Beier, 2014; Unsworth & McMillan, 2013, 2014). Furthermore, TUT rates also tend to change with context: When current cognitive tasks become more complex, fewer TUTs are observed (Antrobus, Singer, & Greenberg, 1966; Kane et al., 2007; Randall et al., 2014; Rummel & Boywitt, 2014; Teasdale et al., 1995; Teasdale, Proctor, Lloyd, & Baddeley, 1993).

Importantly, a controlled disengagement from mind wandering offers an additional degree of freedom for the adjustment of attentional processing within the PM/ongoing-task ensemble. On the one hand, people holding a PM intention could engage in attentional PM processing at a cost to their ongoing task, as argued by existing PM theories (Einstein & McDaniel, 2010; Smith, 2010) and shown in previous studies (Marsh et al., 2003; Smith, 2003). On the other hand, they could also decide to engage more in PM-task related thoughts instead of allowing their minds to wander. That is, in the light of additional demands from the PM task, people may decide to focus to a greater extent on the current complement of tasks. This latter idea has not yet been systematically tested so far, but Marsh, Hicks, and Cook (2005) raised a similar idea in their General Discussion section; namely, that people likely engage in stimulus-independent thoughts in addition to thoughts about the PM/ongoing-task set. Drawing from this idea, Cook, Rummel, and Dummel (2015) recently suggested that reward-induced PM improvements without a concomitant increase in PM-induced costs might be caused by the reward motivating participants to focus more on the overall PM/ongoing-task ensemble. Therefore, in the present research we assessed participants' thought content while they performed an ongoing task with or without an embedded PM task to test whether the addition of a PM task would affect TUT engagement.

To our best knowledge, only two previous studies have investigated participants' thought content while performing a laboratory PM/ongoing-task ensemble (but see Kvavilashvili & Fisher, 2007, for a collection of thought self-reports in a naturalistic PM setting). Anderson and Einstein (2016) collected open thought report in a task participants performed after the PM task was

finished and found that the presentation of PM targets in this task still triggered PM-related thoughts. This finding suggests that the PM intention was not completely deactivated but does not address the present question of whether an active PM intention changes the engagement in TUTs. Reese and Cherry (2002) had older and younger adults perform a short-term memory (STM) task. On each trial, participants saw 4–9 words for immediate recall. Furthermore, as a PM task, they had to press a special key in response to one specific target word. TUTs (i.e., thoughts that did not refer to either task) were assessed while participants performed the ongoing task by asking them to classify their thoughts as being off- or on-task and further report on them. Younger adults reported higher TUT rates than did older adults, but PM-related thoughts did not predict PM performance. However, as this study focused primarily on age differences, the investigators did not include a control group in their design that performed the ongoing task alone. Therefore, their study also does not speak to whether participants' on-task focus changes with the addition of a PM task to an ongoing task.

Like Reese and Cherry (2002), we consider thoughts about a PM task within an ongoing-task context, in which the PM intention might have to be executed, as “task-related thoughts” because these thoughts directly refer to one of the task goals in the current context. According to the executive-failure view of mind wandering (Kane & McVay, 2012), TUTs are conceptualized as thoughts that interfere with current task goals and thus PM-task thoughts would not be considered TUTs according to this view (see the General Discussion section for alternative views). This conceptualization also jibes with views from the PM literature, that maintaining a PM intention becomes an integral part of the ongoing-task processing. For example, Smith (2010) argues that people continuously engage in preparatory PM processing as part of their regular ongoing-task processing, in order to retrieve the PM intention at the appropriate moment. Similarly, Guynn (2003) argues that people with pending intentions will put themselves in a retrieval mode while performing their ongoing task. Note, however, that considering PM-related thoughts as task-related does not necessarily contradict the alternative view that intention retrieval can occur spontaneously and is stimulus driven (McDaniel et al., 2015; Scullin et al., 2013). Although such views would probably predict PM-related thoughts to occur rather infrequently in the absence of a PM target, they do not deny that the PM-task goal may be reactivated and conscious from time to time.

Others have argued that thoughts about a PM intention, which occur while performing an ongoing task, can be considered a distinct form of goal-driven mind-wandering (A.-L. Cohen, 2013). Although we believe that any conscious thought about an active (i.e., potentially relevant) task goal should rather be classified as task-related than as task-unrelated, we generally sympathize with the consideration of PM-related thoughts as being distinct from both task-unrelated mind wandering and (ongoing-) task-related thoughts. Therefore, we combined a forced-choice thought probe procedure with additional open reports in order to subdivide the task-related thoughts as explicitly ongoing task or PM task related. We describe this procedure in the following section.

### *General Method*

We conducted three experiments to test our hypothesis that people holding an intention will not only sacrifice their ongoing-task performance in favor of the PM task, but will also increase their conscious on-task focus.

In all experiments, we presented groups of subjects (in the PM conditions) with a typical PM/ongoing-task ensemble, using a lexical-decision task as the ongoing task, and the intention to respond to members of the animal category or to specific words with a special key, as the PM task. Another group (no-PM condition) performed the ongoing task alone. From time to time, we asked subjects of all groups to report on their thought contents. For this purpose, we used binary forced-choice thought probes that asked subjects to indicate whether their immediately preceding thoughts had been on task or off task (with instructions to consider thoughts about the ongoing task or PM task to be “on task”). We paired these forced-choice probes with subsequent open thought reports. In doing so, we were able to assess thought contents and classify them as either ongoing-task related, PM-task related, or task unrelated without explicitly reminding participants of the PM task (cf., Reese & Cherry, 2002). By comparing thought contents between PM and no-PM conditions, we aimed to evaluate how the addition of a PM task to an ongoing task changes the engagement in on-task and off-task thoughts. Furthermore, by comparing ongoing-task performances under PM and no-PM conditions, we aimed to replicate the PM-induced costs effect (Marsh et al., 2003; Smith, 2003). Finally, we applied the ex-Gaussian model to the ongoing-task RT data. According to previous research, this approach can be useful to differentiate between more sustained and more transient PM-induced cost effects, because the former should be reflected by changes in the  $\mu$  and the latter by changes in the  $\tau$  parameter of the model (Abney, McBride, & Petrella, 2013; Ball, Brewer, Loft, & Bowden, 2015; Brewer, 2011; Loft, Bowden, Ball, & Brewer, 2014). Inasmuch as participants continuously maintain their PM intentions (Guynn, 2003; Smith, 2003, 2010), we would expect to observe PM-related changes in  $\mu$ , whereas more periodical checking (Guynn, 2003; Scullin et al., 2013) should be reflected by PM-related changes in  $\tau$ . That is, we expected the ex-Gaussian parameters to be informative regarding the relation between ongoing task and PM processing.

### *Experiment 1*

The aim of the first experiment was to test whether holding a PM intention results in attentional costs to an ongoing task and also in a disengagement from TUTs and thus in a stronger on-task conscious focus. Across subsequent Method and Results sections, we report how we determined our sample size and all data exclusions, manipulations, and measures in the study (Simmons, Nelson, & Simonsohn, 2012).

## **Method**

### **Participants and design**

One hundred and four university students (19–36 years,  $M_{age} = 22$ ; 78% female), who were all native speakers of German, participated for course credit or payment. Sample size was determined with the software G\*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to detect medium-sized effects ( $d = .5$ ) in the predicted direction with good statistical power (i.e.,  $1 - \beta <$

.80). We excluded the data from one subject from all analyses who never pressed the PM key and was unable to recall the PM task at the end of the experiment.

We randomly assigned subjects to one of two experimental groups. One group performed the ongoing task alone (no-PM condition;  $n = 51$ ); the other performed the ongoing task while additionally holding a PM intention (PM condition;  $n = 52$ ).

## Materials and procedure

For the ongoing lexical-decision task, we selected 316 words of medium frequency and length from a German word norm database (Heister et al., 2011). We converted half the words to nonwords by swapping 2–4 letters. For the PM task, we selected the German words for the animal names, “sheep,” “zebra,” “rabbit,” “elk,” “giraffe,” “elephant,” “goat,” and “badger” as PM targets. These were the only animal names that appeared during the task.

The experiment started with instructions for the ongoing lexical-decision task, to press the J-key for words and the F-key for nonwords as quickly and as accurately as possible. Subjects then practiced with 20 trials (half words, half nonwords; randomly intermixed). On each practice trial, subjects saw a fixation cross of varying duration (250–750 ms) followed by a letter string that was either a word or nonword. Letter strings remained on the screen until response. After a 500-ms interstimulus interval, subjects received performance feedback on accuracy and speed. After this practice phase, we provided PM-task subjects with the additional PM instructions to press the hyphen key on a QWERTZ keyboard (which is at the same location as the “/” key on a QWERTY keyboard), instead of the J-key, for any animal names they saw in the lexical-decision task. We also informed subjects that pressing the PM key after having pressed an ongoing-task response key first would still count as an accurate PM response.

Next, we presented thought-report instructions to all subjects. We first told subjects that we were interested in the thoughts that people have while performing cognitive tasks and that we would ask them about their current thoughts on several occasions during the lexical-decision task. Subjects learned that thought probes would be presented in white font on a green screen and that they should report only on their thoughts occurring in the instant before the thought probe appeared (i.e., just before the screen turned green). To increase compliance and reduce subjective bias, we told subjects that it is common that thoughts are sometimes on task and sometimes off task, and that they should respond honestly (Vinski & Watter, 2012). Note that we explicitly instructed subjects in the PM condition that thoughts about the additional PM task should be considered as being “on task” (see also Reese & Cherry, 2002).

For illustration purposes, all subjects then performed another four ongoing-task practice trials (half word, half nonword; without performance feedback) with a thought-probe trial embedded after the second trial. Thought-probe trials comprised two questions—a forced-choice thought probe followed by an open thought report. Forced-choice probes presented the question, “What were you thinking in the previous moment?” in white font on a green background. Subjects chose between two options presented on-screen: (1) I thought about the task(s) I just performed, or (2) I thought about other stuff, which had nothing to do with the task(s) I just performed, using the numbers 1 and 2 on the number pad. Note that we did *not* mention the PM task in the thought



Experiment 1								
No PM			.93(.04)		655(102)		735(127)	
PM		.74(.28)	.94(.03)		738(113)		807(144)	
Experiment 2								
No-PM			.93(.06)	.93(.05)	644(112)	625(101)	743(181)	706(133)
High demands		.35(.37)	.94(.03)	.93(.04)	702(128)	673(117)	803(183)	751(158)
Low demands		.77(.27)	.94(.04)	.94(.04)	707(146)	667(112)	825(214)	763(141)
Experiment 3								
No PM			.93(.04)	.93(.04)	633(113)	620(104)	707(151)	690(137)
No-reward		.43(.40)	.95(.04)	.94(.03)	669(94)	653(89)	767(129)	725(112)
PM								
Reward PM		.71(.37)	.95(.03)	.94(.04)	672(106)	671(102)	758(142)	742(130)

*Note.* PM = prospective memory; OT = ongoing task; MRTs = mean response times in milliseconds. In the PM condition of Experiment 1, eight PM targets occurred in the course of the ongoing task. In the PM conditions of Experiments 2 and 3, the ongoing task was divided into two phases. Phase 1 comprises the first half of ongoing-task trials where no-PM targets occurred; Phase 2 comprises the second half of ongoing trials with four embedded PM targets.

### Ongoing-task performance

We used ongoing-task accuracy rates and RTs (in milliseconds) to assess ongoing-task performance (see Table 1 for means in both conditions). PM trials, as well as their analogous

trials in the no-PM control condition, were discarded from the ongoing-task analyses. As in previous studies, lexical-decision accuracy was not affected by the presence versus absence of an additional PM intention,  $t(101) = 1.36, p = .177, d = .28$ .

For RT analyses, we included only ongoing-task trials with accurate responses. We also discarded RTs on the two trials following a PM target trial or a thought probe, to control for task-switching costs potentially associated with these trials (cf., Brewer, 2011; Meier & Rey-Mermet, 2012). As in our previous studies, we trimmed RTs separately for words and nonwords, retaining for analyses only RTs slower than 300 ms and faster than two standard deviations above the individual subject's mean. As PM targets were always words, word RTs should better reflect PM processes (Brewer, 2011; A. L. Cohen et al., 2012) and so we focused analyses on word RTs. Including nonword RTs as an additional factor level, however, yielded the same pattern of results.

Subjects made significantly faster lexical decisions in the no-PM control condition than in the PM condition,  $t(101) = 3.89, p < .001, d = .77$ . Thus, as in previous studies (Marsh et al., 2003; Smith, 2003), the additional PM intention interfered with ongoing-task RTs. To further investigate the nature of PM-induced costs, we modeled the word RT distributions separately for both experimental conditions using an ex-Gaussian analysis. Table 2 presents the mean parameter estimates from these analyses. In line with several previous studies (Abney et al., 2013; Loft et al., 2014; McBride & Abney, 2012), the RT differences between the no-PM and the PM condition were reflected by differences in the  $\mu$  parameter,  $t(101) = 3.97, p < .001, d = .77$  and the  $\tau$  parameter,  $t(101) = 2.18, p = .032, d = .43$  (but see Brewer, 2011, for an isolated effect on tau). Further, there was a nonsignificant trend for a difference in the  $\sigma$  parameter,  $t(101) = 1.96, p = .053, d = .39$ .

Table 2. Mean (Standard Deviation) Ex-Gaussian Parameter Estimates and Thought Rates (Assessed Via Forced-Choice Probes)

Experimental condition	$\mu$		$\sigma$		$\tau$		TUT rates	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Experiment 1								
No PM	525(58)		.93(.04)		655(102)		735(127)	
PM	572(63)		.94(.03)		738(113)		807(144)	

Experiment 2								
No-PM	537(64)	527(63)	60(29)	52(36)	110(68)	103(75)	.36(.21)	.38(.24)
High demands	566(71)	556(85)	70(41)	65(59)	142(86)	118(75)	.27(.23)	.30(.23)
Low demands	550(66)	532(60)	61(41)	52(32)	159(120)	137(80)	.27(.22)	.30(.21)
Experiment 3								
No PM	529(64)	520(64)	46(35)	49(34)	110(77)	102(66)	.31(.21)	.40(.25)
No-reward	559(68)	535(52)	62(41)	51(40)	116(70)	125(76)	.26(.22)	.30(.24)
Reward PM	569(72)	569(79)	65(36)	57(42)	108(76)	106(68)	.14(.18)	.25(.21)

*Note.* PM = prospective memory; TUT = task-unrelated thoughts. Phase 1 comprises the first half of ongoing-task trials of Experiment 2 where no-PM targets occurred; Phase 2 comprises the second half of ongoing trials with four embedded PM targets.

### **Task-unrelated thoughts**

We assessed TUTs in two ways, via forced-choice and via open thought reports. Table 2 presents the mean TUT rates assessed via forced-choice probes in the two experimental conditions. As the forced-choice probes had a binary format (on-task, off-task thoughts), we calculated TUT rates by dividing the number of off-task responses by the total number of responses. Subjects reported significantly higher TUT rates in the no-PM ( $M = .32$ ;  $SD = .20$ ) than in the PM condition ( $M = .23$ ;  $SD = .20$ ),  $t(101) = 2.12$ ,  $p = .037$ ,  $d = .40$ , indicating that engagement in TUTs decreases when holding a PM intention. Open thought reports were coded by two independent raters, blinded to the hypothesis and experimental conditions. The raters were given a list of all the reported thought contents (13 per subject), without any identifying information. The raters decided for each thought whether it was generally task-related or not. They were then asked to code each thought content into one of four categories—ongoing-task related, PM-task related, unspecifically task related, or task unrelated. The first category, ongoing-task related, was assigned to thought contents that were clearly about the ongoing lexical-decision task, such as “Was the last string a word?” or “Damn, I miss-classified the word ‘concrete.’” The second category, PM-task related, was assigned to thought responses that were clearly about the PM

task, such as “Finally, there was an animal word” or “ZEBRA, strike!” The third category, unspecifically task related, was used for responses that were definitely on task, but it was unclear whether they were about the ongoing lexical-decision task or the PM task, specifically. For example, we classified responses such as these as unspecifically task related, “Pressing the wrong key nearly feels like a slap in the face” or “I have to concentrate more.” The fourth and final category, task unrelated, was used for thoughts that were clearly off task, such as “I was thinking about the guy who is cheating on my friend” or “I should learn more about politics.” Because the raters were condition blinded, on-task thoughts could be classified as being unspecifically-task-related in the no-PM control condition; we later reclassified these as ongoing-task related. Only few thoughts did not fit into one of the four categories and they remained unclassified (0.8% of all ratings). We calculated Cohen’s kappa (J. Cohen, 1960) to assess interrater reliability,  $\kappa = .80$ ,  $SE = .01$ ,  $p < .001$ . According to Altman (1991),  $\kappa > .60$  indicates a high level of agreement between raters and so our interrater reliability was good. Whenever the raters disagreed, the first author (while blinded to condition) decided which rating was more appropriate. Figure 1 displays the mean proportions of on-task and off-task thoughts by open thought reports. An independent samples  $t$  test for off-task open-reports revealed significantly higher TUT engagement in the no-PM condition ( $M = .39$ ;  $SD = .23$ ) than in the PM condition, ( $M = .28$ ;  $SD = .21$ ),  $t(101) = 2.47$ ,  $p = .015$ ,  $d = .49$ . Thus, the open-thought-report results mirrored the forced-choice-probe results. We finally note that in the PM condition, the proportion of thoughts classified as PM-related was significantly higher than zero,  $t(51) = 8.06$ ,  $p < .001$ ,  $d = .63$ , indicating that, for those individuals holding a PM intention, a substantial amount of conscious thinking was focused on the PM task.

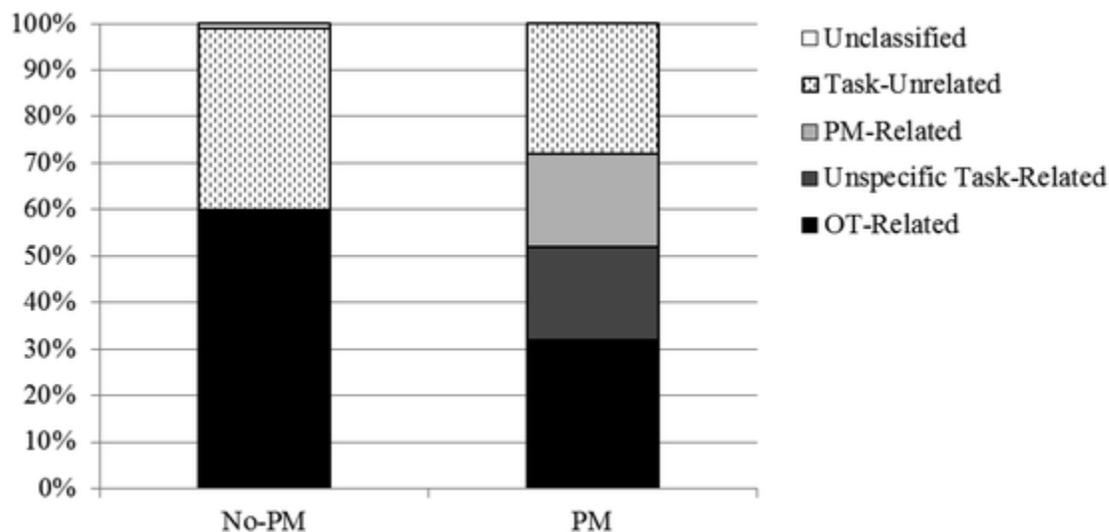


Figure 1. Proportions of task-related and task-unrelated thoughts assessed via open thought reports in Experiment 1. In the prospective memory (PM) condition, task-related thoughts were further classified as being ongoing-task (OT) related, unspecifically task related, or PM related.

## Discussion

In line with previous research (e.g., A.-L. Cohen et al., 2008; Marsh et al., 2003; Smith, 2003), we found substantial PM-induced costs in terms of slower ongoing-task responses in the presence versus absence of a PM intention. Ex-Gaussian modeling further showed that the  $\mu$  and  $\tau$  parameters best reflected PM-induced changes in response speed (Abney et al., 2013; Loft et al., 2014). Acknowledging that ex-Gaussian parameters do not necessarily map cleanly onto underlying processes (Matzke & Wagenmakers, 2009), Loft et al. argued that PM-induced costs have a rather continuous component (increase in  $\mu$ ) as well as a more transient (increase in  $\tau$ ) component and that these two components reflect different types of attentional PM processing. Whereas changes in  $\mu$  may reflect continuous monitoring, changes in  $\tau$  may reflect periodical reactivations of the intention (cf., Guynn, 2003). If so, both types of attentional processes may have been recruited by our participants to perform the present PM task. We will further discuss implications of the ex-Gaussian modeling results in the General Discussion section.

Our thought-probe results further indicate that the PM intention not only interfered with ongoing-task processing but also led to a reduction in TUTs. Open-thought-report results further corroborated that holding a PM intention reduces TUTs. In the context of substantial rates of PM thoughts and PM-induced slowing to the ongoing task, we conclude that people who hold a PM intention tend to engage in PM processing that comes at a cost to their ongoing task. Critically, however, they also tend to focus more on the entire PM/ongoing-task ensemble (as indexed by fewer TUTs)—probably, in part, via conscious thinking about the PM goal.

We must note one alternative interpretation for the present findings, however. Perhaps the increase in PM-task-related thoughts was not due to a proactive engagement in PM processing, but rather to a reactive activation of PM-task-related thoughts caused by the presentation of PM targets in the course of the ongoing task (cf., Scullin et al., 2013). To rule out this alternative explanation, Experiment 2 included a task condition in which PM targets did not occur until the second half of the ongoing-task phase. Further aims of Experiment 2 were to replicate the Experiment 1 findings and to extend them to another PM task that imposed lower attentional demands.

### *Experiment 2*

Experiment 2 comprised three between-subjects conditions: two PM conditions and a no-PM control condition. In one PM condition, subjects responded to any members of a particular semantic category with the PM key (as in Experiment 1). Because the PM targets are not well specified in this PM task (i.e., subjects do not know which exemplars to expect), target detection requires a category decision in addition to the word/nonword decision required for performing the ongoing task. Because of these extra processing requirements, this task is considered to be “nonfocal” to the ongoing task and thus rather demanding (Einstein & McDaniel, 2005; Knight et al., 2011; Marsh et al., 2003). In the other PM condition, subjects received two specific words as PM targets. Because two words are relatively easily to actively maintain in working memory, and especially because identifying these words does not interfere with making lexical decisions (A.-L. Cohen et al., 2008), this PM task can be considered “focal” to the ongoing task. It should therefore impose little attentional demand on subjects (Marsh et al., 2003; Rummel, Kuhlmann, & Touron, 2013). Based on previous research, we expected less continuous monitoring (and an

attendant decrease in  $\mu$ ) in the low- versus the high-demands condition. We were further interested in whether the PM-task-induced reduction in TUTs observed in the first experiment would also be influenced by variation in task demands across these PM conditions. Finally, we also aimed to rule out the alternative explanation, that the reduction in TUTs observed in the Experiment-1 PM condition was due to a reactive effect of PM targets triggering PM-task-related thoughts. For this purpose, we did not present any PM targets during the first half of the ongoing task. We could therefore test, in the absence of PM target cues, whether PM-related thoughts would still occur at substantial rates and whether TUTs would still be reduced in the PM conditions versus the control condition.

## **Method**

### **Participants and design**

One hundred forty-one students (17–51 years, mean age = 22; 82% female), who were all native speakers of German, participated for course credit or monetary compensation. We aimed to collect data from 159 subjects in order to test for medium-sized ( $f = .25$ ) group differences with a statistical power of .80, but we were forced to stop data collection at the end of the semester. Therefore, the achieved power for medium-sized group differences was satisfactory but lower than targeted (i.e.,  $1 - \beta = .74$ ). We excluded from analyses one participant who did not follow task instructions, and two subjects who never pressed the PM key and were additionally unable to recall the PM task at the end of the experiment.

We randomly assigned subjects to one of three experimental groups. Subjects in the no-PM condition performed the ongoing task alone ( $n = 48$ ). Those in the high-demand PM condition performed the ongoing task and pressed the PM key for members of the animal category ( $n = 44$ ). Finally, subjects in the low-demand PM condition performed the ongoing task and pressed the PM key for two specific words ( $n = 46$ ). In both PM conditions, PM targets appeared only in the second half of the ongoing-task phase. Therefore, we had a 3 (condition)  $\times$  2 (task phase) mixed design. The statistical power to detect a medium-sized interaction between condition and task phase was very good,  $1 - \beta > .99$ .

### *Materials and procedure*

Materials and procedure mirrored Experiment 1, with the following exceptions. In addition to the no-PM condition and the (high-demand) PM condition that used animal names as PM targets, a (low-demand) PM condition required participants to press the PM key in response to either of two specific words (i.e., the German words for “sheep” and “crown”). Furthermore, PM targets did not appear during the first two blocks (of four) of the ongoing task. Instead, four new words from the same word database were presented. This allowed us to investigate whether on-task thought rates would be higher for those individuals who hold a PM intention, as in Experiment 1, even during a task phase where thoughts are not cued by the prior occurrence of PM targets. In both PM conditions here, then, only Trials 180, 219, 252, and 276 presented PM targets. Thought probes occurred at the same positions as in Experiment 1. For analyses, we considered the first two ongoing-task blocks as Phase 1 (i.e., phase without PM-target presentation) and the second two blocks as Phase 2 (i.e., phase with PM-target presentation).

## Results

### Prospective-memory performance

PM performance was worse in the high ( $M = .35$ ;  $SD = .37$ ) than in the low-demand PM condition ( $M = .77$ ;  $SD = .27$ ),  $t(88) = 6.15$ ,  $p < .001$ ,  $d = 1.30$ , indicating a successful manipulation of PM task demands. Notably, PM performance in the high-demand condition was substantially worse than in Experiment 1, which used the same PM-task instructions. Experiment 2 presented the first PM target quite late in the course of the ongoing task and it presented only four (rather than 8) PM targets. Prior empirical evidence suggests that both delayed presentation of the first target (Martin, Brown, & Hicks, 2011; McBride, Beckner, & Abney, 2011) and infrequent target occurrence (Czernochowski, Horn, & Bayen, 2012) hamper PM performance, and so this likely explains the lower PM performance with category targets in Experiment 2 versus Experiment 1. False PM responses were not considered because they were rare ( $M = .001$ ;  $SD = .002$ ) and did not vary between the two PM groups,  $t < 1$ .

### Ongoing-task performance

Table 1 presents the mean ongoing-task accuracy rates and RTs. A  $3 \times 2$  mixed-factorial analysis of variance (ANOVA) with the between-subjects factor condition (no-PM, high-demand PM, low-demand PM) and the within-subjects factor task phase (first, second) for ongoing-task accuracy did not indicate a significant main effect or interaction, with all  $F$ s  $< 1$ .

The same  $3 \times 2$  ANOVA for word RTs (trimmed as in Experiment 1, and for each task phase separately) indicated that subjects were significantly slower in the first ( $M = 683$ ;  $SD = 132$ ) than in the second phase ( $M = 654$ ;  $SD = 111$ ),  $F(1, 135) = 46.36$ ,  $p < .001$ ,  $f = 0.43$ . This finding may reflect a general ongoing-task practice effect but could be also be due to the fact that PM costs decrease over time, especially when no targets occur (Loft, Kearney, & Remington, 2008). However, because the interaction with condition was not significant,  $F(2, 135) = 2.13$ ,  $p = .123$ ,  $f = 0.18$ , there was no evidence for a stronger decrease in RTs in the PM than in the no-PM conditions, rendering the practice-effect explanation more likely. There was a significant main effect of condition,  $F(2, 135) = 3.17$ ,  $p = .045$ ,  $f = 0.22$ . Pairwise comparisons indicated that RTs were faster in the no-PM condition ( $M = 634$ ;  $SD = 105$ ) than in either the high-demand ( $M = 687$ ;  $SD = 120$ ) or low-demand PM condition ( $M = 687$ ;  $SD = 126$ ), both  $p$ s  $< .05$ . RTs in the two PM conditions did not differ,  $p = .981$ .

We submitted the three ex-Gaussian parameters to the same  $3 \times 2$  ANOVA (see Table 2 for mean estimates). For the parameter  $\mu$ , this analysis indicated a main (practice) effect of task phase,  $F(1, 135) = 7.56$ ,  $p = .007$ ,  $f = 0.24$ , that was not further qualified by an interaction,  $F < 1$ . Further, there was a nonsignificant trend of condition,  $F(2, 135) = 2.48$ ,  $p = .088$ ,  $f = 0.19$ . Pairwise comparisons showed that the  $\mu$ -parameter estimates were lower in the no-PM ( $M = 561$ ;  $SD = 58$ ) than in the high-demand PM condition ( $M = 561$ ;  $SD = 72$ ),  $p = .030$ , which is in line with the findings of Experiment 1. However,  $\mu$ -parameter estimates in the no-PM condition did not differ from those in the low-demand PM condition ( $M = 541$ ;  $SD = 59$ ),  $p = .49$ ; the two-PM condition also did not differ,  $p = .139$ . We found no effects or trends for the  $\sigma$  parameter (all  $F$ s  $< 2.50$ ; all  $p$ s  $> .120$ ). For the  $\tau$  parameter, there was a main effect of task phase,  $F(1, 135)$

= 7.98,  $p = .005$ ,  $f = 0.24$ , and no interaction,  $F < 1$ , but a main effect of condition,  $F(2, 135) = 3.35$ ,  $p = .038$ ,  $f = 0.22$ . Pairwise comparisons further showed that the  $\tau$  parameter was lower in the no-PM ( $M = 107$ ;  $SD = 65$ ) than in the low-demand PM condition ( $M = 148$ ;  $SD = 71$ ),  $p = .011$ . The  $\tau$  parameter in the high-demand PM condition ( $M = 141$ ;  $SD = 93$ ) did not differ from either the no-PM condition,  $p = .155$ , or the low-demand PM condition,  $p = .269$ .

### **Task-unrelated thoughts**

Table 2 displays mean TUT rates, assessed via forced-choice probes, in the three experimental conditions.

Again, we conducted a  $3 \times 2$  ANOVA with the between-subjects factor, condition (no-PM, high-demand PM, low-demand PM), and the within-subjects factor, task phase (first, second), for TUT rates. Despite high power, this analysis did not reveal a main effect of task phase,  $F(1, 135) = 2.15$ ,  $p = .145$ ,  $f = 0.13$ , or an interaction between condition and task phase,  $F < 1$ . However, there was a significant main effect of condition,  $F(2, 135) = 3.23$ ,  $p = .043$ ,  $f = 0.22$ . Pairwise comparisons further showed that the TUT rates were significantly higher in the no-PM condition ( $M = .37$ ;  $SD = .19$ ) than in both the high-demand ( $M = .28$ ;  $SD = .19$ ),  $p = .029$ , and the low-demand PM conditions ( $M = .29$ ;  $SD = .18$ ),  $p = .033$ . The two PM conditions did not differ in TUT rates,  $p = .947$ . This finding replicates the results of Experiment 1 and provides further support for the idea that the likelihood of thoughts being off task decreases in the presence of a pending intention. Importantly, TUTs decreased for both the high-demand and the low-demand PM condition to a similar extent.

The same two raters as in Experiment 1 coded the open thought contents. Interrater reliability was again good,  $\kappa = .80$ ,  $SE = .01$ ,  $p < .001$  (Altman, 1991). The first author adjudicated between discrepant ratings. Only a few thoughts were coded as unclassifiable (1.2% of all ratings). The open-report results were similar to those of the forced-choice probes. Figure 2 displays the means across conditions.

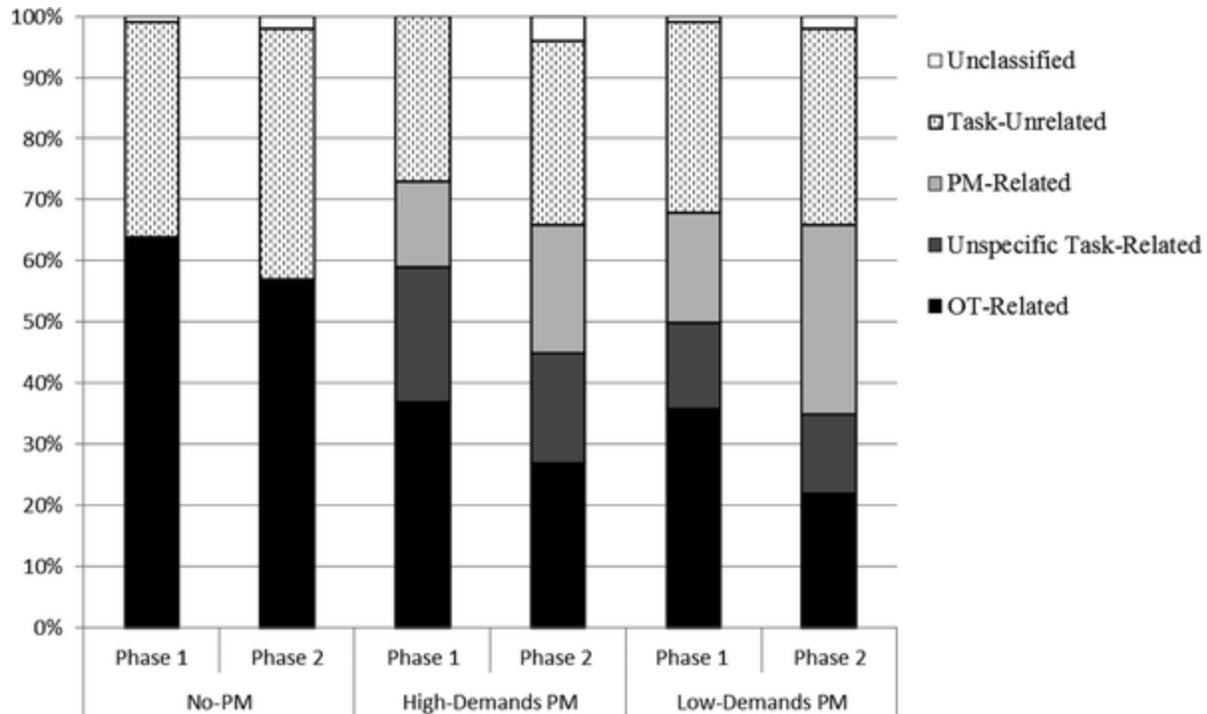


Figure 2. Proportions of task-related and task-unrelated thoughts assessed via open thought reports in Experiment 2. Phase 1 = task phase without PM targets; Phase 2 = task phase with prospective memory (PM) targets. In the two PM conditions, task-related thoughts were further classified as being ongoing-task (OT) related, unspecifically task related, or PM related.

The  $3 \times 2$  ANOVA for open-report TUT rates showed a trending effect of task phase,  $F(1, 135) = 3.51, p = .063, f = 0.16$ , but no interaction,  $F < 1$ . Importantly, there was a main effect of condition,  $F(2, 135) = 3.46, p = .034, f = 0.22$ , replicating the findings from the forced-choice probes. Follow-up pairwise comparisons indicated that open-report TUT rates in the no-PM condition ( $M = .38; SD = .20$ ) were significantly higher than in the high-demand PM condition ( $M = .29; SD = .20$ ),  $p = .012$ , but only marginally higher than in the low-demand PM condition ( $M = .32; SD = .18$ ),  $p = .075$ ; again, the two PM conditions did not differ,  $p = .442$ .

The proportions of thoughts classified as explicitly PM-task related were significantly higher than zero in each block of both PM conditions, all  $t_s > 5.00, p_s < .001$  and increased from the first ( $M = .16; SD = .16$ ) to the second block ( $M = .26; SD = .22$ ),  $t(89) = 4.92, p < .001, d = 0.97$ . Thus, subjects holding a PM intention—regardless of the PM task demands and even in the absence of PM targets—experienced a substantial rate of conscious thoughts about the PM intention but more so in the presence of PM targets.

## Discussion

Experiment 2 replicated the central findings of Experiment 1, that people not only maintain pending intentions at a processing cost to their ongoing task, but that they also disengage from TUTs in order to focus more on their intentions. Importantly, despite the very good statistical power for the interaction test, there was no evidence that the reliable condition differences in reported TUTs changed from the first to the second ongoing-task phase (i.e., there was no

interaction of condition with task phase). Therefore, it seems unlikely that the decrease in TUTs observed in Experiment 1 resulted from a reactive increase in PM-task-related thoughts after PM target presentation. However, the increase of open-report thoughts that were rated as being explicitly PM-task related from the first to the second task phase also indicates that the presentation of PM targets may trigger some additional conscious PM thoughts (cf., Anderson & Einstein, 2016; Kvavilashvili & Fisher, 2007). Interestingly, the strength of the general on-task focus did not vary between the two PM-task conditions, perhaps because subjects were not consciously aware of the actual demands until late in the task (i.e., not until after they had experienced the first PM target; see Rummel & Meiser, 2013). In line with this finding, the mean-RT results also suggest that subjects in Experiment 2 were not sensitive to the variation of PM task demands. However, ex-Gaussian modeling results suggest that attentional PM processing might have been of different quality in the two PM conditions. Whereas the significant increase in the parameter  $\mu$  in the high-demand PM condition may reflect a more continuous monitoring process (Loft et al., 2014), the increase in the parameter  $\tau$  in the low-demand PM condition monitoring may reflect a more transient attentional process (e.g., more periodically target checking; Ball et al., 2015). Notably, in Experiment 1 we observed PM-induced changes in both  $\mu$  and  $\tau$  with the more demanding PM task. This might have been due to the more frequent presentation of PM targets that may have encouraged subjects to engage in more periodical target checking. Further research varying PM-task demands on a more fine-grained level should further investigate this possibility. It is possible, for example, that the on-task focus will change according to the nature of the PM task in a more idiosyncratic way, depending on the personal value of successful intention fulfillment (Brandimonte, Ferrante, Bianco, & Villani, 2010; Cook et al., 2015). In the third experiment, then, we examined whether subjects for whom the PM task goal had a high personal relevance would be motivated to focus more on the current task setting than would other subjects who held the same PM intention but for whom the PM task was of less personal relevance.

### *Experiment 3*

Experiment 3 comprised three between-subjects conditions: two PM conditions and a no-PM control condition. Both PM conditions used a categorical (nonfocal, high-demand) PM task, but PM performance in one condition was additionally associated with a monetary reward. Similar manipulations have rendered the PM task goal particularly important and thus increased motivation to execute the intention (Cook et al., 2015). We hypothesized that higher personal relevance of the PM-task goal would result in a stronger on-task focus and fewer TUTs compared with a condition where the PM intention comes with no additional rewards. In order to prevent subjects in the reward condition from sacrificing their ongoing-task performance for the PM-task goal, we made the reward also contingent upon ongoing-task performance. As in Experiment 2, we only presented PM targets in the second task phase to investigate TUTs and PM-related thoughts in the presence and absence of PM targets.

## **Method**

### **Participants and design**

One hundred forty-nine German-speaking students (18–34 years, mean age = 23; 86% female) participated for monetary compensation. We excluded from analyses two participants who did not follow task instructions, and one who never pressed the PM key and did not remember the PM task in the final memory test.

We randomly assigned subjects to one of three experimental groups. Subjects in the no-PM condition performed the ongoing task alone ( $n = 49$ ). Those in the no-reward PM condition performed the ongoing task and pressed the PM key for members of the animal category ( $n = 50$ ). Subjects in the reward PM condition ( $n = 47$ ) performed the same tasks as those in the no-reward PM condition, but received additional money for every correct PM response. In both PM conditions, PM targets appeared only in the second half of the ongoing-task phase. Therefore, we had a 3 (condition)  $\times$  2 (task phase) mixed-factorial design. We determined our sample size so that the statistical power for medium-sized group differences in a planned comparison analysis ( $1 - \beta = .85$ ) as well as for a medium-sized effect of task phase or an interaction between condition and task phase ( $1 - \beta > .99$ ) were good.

## Materials and procedure

Materials and procedure were the same as in Experiment 2. Both PM conditions used the animal category as PM targets. All participants were paid 5 euros for their participation. Participants in the reward PM condition were informed with PM instructions that they could receive up to 2 euros in addition when they detected all animal names and responded to them with the PM key. They were informed that, in case they missed some of the animal names, they would receive a portion of the 2 euros in accordance with the proportion of correct responses to animal names (see Cook et al., 2015, Exp. 2 for a similar manipulation). Furthermore, they were told that they would only receive the additional payment if their ongoing-task accuracy and speed would be average or better. In doing so, we aimed to prevent participants from sacrificing their ongoing-task performance in order to gain higher payments but, in fact, we paid participants contingent on their PM performance only. Thought probes occurred at the same positions as in Experiments 1 and 2. PM targets occurred at the same positions as in Experiment 2 (i.e., only in the second task phase).

## Results

### Prospective-memory performance

PM performance was worse in the no-reward ( $M = .42$ ;  $SD = .40$ ) than in the reward PM condition ( $M = .71$ ;  $SD = .37$ ),  $t(95) = 3.58$ ,  $p = .001$ ,  $d = 0.73$ . PM performance in the no-reward condition was similar to the one observed in the category PM condition of Experiment 2, suggesting that the rather low PM performance observed there was reliable. False PM responses were not considered because they were rare ( $M = .001$ ;  $SD = .002$ ) and did not vary between the two PM conditions,  $t < 1.2$ .

### Ongoing-task performance

Table 1 shows the mean ongoing-task accuracy rates and RTs. A 3  $\times$  2 ANOVA with the between-subjects factor condition (no-PM, no-reward PM, reward PM) and the within-subjects

factor task phase (first, second) for ongoing-task accuracy did not indicate a significant main effect or interaction, with all  $F$ s  $< 2.6$ ,  $p$ s  $> .116$ .

The  $3 \times 2$  ANOVA for word RTs (trimmed as in Experiment 2) indicated that subjects were significantly slower in the first ( $M = 658$ ;  $SD = 105$ ) than in the second phase ( $M = 648$ ;  $SD = 100$ ),  $F(1, 143) = 6.64$ ,  $p = .011$ ,  $f = 0.21$ . There was no interaction,  $F < 1.3$ , but a trending condition effect,  $F(2, 143) = 2.81$ ,  $p = .064$ ,  $f = 0.20$ . We used planned Helmert contrasts to test our hypotheses with maximal power (Rosenthal & Rosnow, 1985). That is, the first contrast compared the no-PM with the two PM conditions to test for PM-induced effects. The second contrast compared the no-reward with the reward PM condition to test for additional reward-induced effects. The Helmert contrasts revealed that participants were generally faster in the no-PM condition than in the PM conditions,  $F(1, 143) = 5.37$ ,  $p = .022$ ,  $f = 0.19$ , whereas RTs in the two PM conditions did not differ,  $F < 1$ .

We next submitted the three ex-Gaussian parameters to the  $3 \times 2$  ANOVA (see Table 2 for mean estimates). For the parameter  $\mu$ , this analysis showed a task-phase main effect,  $F(1, 143) = 6.19$ ,  $p = .014$ ,  $f = 0.21$ , no interaction,  $F(2, 143) = 2.41$ ,  $p = .093$ ,  $f = 0.18$ , but a significant condition main effect,  $F(2, 143) = 6.12$ ,  $p = .003$ ,  $f = 0.29$ . Planned contrasts revealed that, as predicted with the rather demanding PM task,  $\mu$ -parameter estimates were higher in the presence versus absence of a PM intention,  $F(1, 143) = 9.30$ ,  $p = .003$ ,  $f = 0.25$ . This finding is in line with Experiment 2. There was also a nonsignificant trend for higher  $\mu$ -parameter estimates in the presence versus absence of a reward,  $F(1, 143) = 3.13$ ,  $p = .079$ ,  $f = 0.15$ . We did not find any significant effects for the  $\sigma$  estimates (all  $F$ s  $< 1.70$ ; all  $p$ s  $> .190$ ) except for a trending main effect of condition,  $F(2, 143) = 2.62$ ,  $p = .076$ ,  $f = 0.19$ . Planned contrasts suggested that  $\sigma$  estimates were higher in the presence versus absence of a PM intention,  $F(1, 143) = 4.54$ ,  $p = .035$ ,  $f = 0.18$ , but unaffected by the reward manipulation,  $F < 1$ . Because we did not observe any effects on  $\sigma$  in the other two experiments, however, we did not interpret this result any further. For the  $\tau$  parameter, we did not observe any significant main effects or interaction this time, all  $F$ s  $< 1$ . This is also in line with results from Experiment 2 regarding the demanding PM condition.

### **Task-unrelated thoughts**

Table 2 displays mean TUT rates, assessed via forced-choice probes, in the three experimental conditions.

A  $3 \times 2$  ANOVA with the between-subjects factor, condition (no-PM, no-reward PM, reward PM), and the within-subjects factor, task phase (first, second), for TUT rates revealed a main effect of task phase,  $F(1, 143) = 18.82$ ,  $p < .001$ ,  $f = 0.36$ , with lower TUT rates in the first ( $M = .24$ ;  $SD = .22$ ) rather than in the second ( $M = .32$ ;  $SD = .24$ ) phase. There was no significant interaction,  $F < 1.3$ , but a significant main effect of condition,  $F(2, 143) = 7.80$ ,  $p = .001$ ,  $f = 0.33$ . In line with the previous experiments, planned comparisons revealed that TUTs were generally reduced in the presence versus absence of a PM intention,  $F(1, 143) = 11.71$ ,  $p = .001$ ,  $f = 0.29$ . Additionally, TUTs decreased further in the presence versus absence of a

reward,  $F(1, 143) = 4.14, p = .044, f = 0.17$ . This result is the first evidence that subjects engage in an even stronger on-task focus when PM intention execution is of high personal value.

Two new raters coded the open-report thought contents. An additional thought category (thinking about the study payment) was introduced, which should account for thoughts potentially induced by the reward manipulation. As such thoughts occurred very infrequently (<1%) we did not analyze them further. Interrater reliability was again good,  $\kappa = .82, SE = .01, p < .001$ , and the first author adjudicated between discrepant ratings. Only 2.1% of all ratings were unclassifiable. Figure 3 displays the means across conditions.

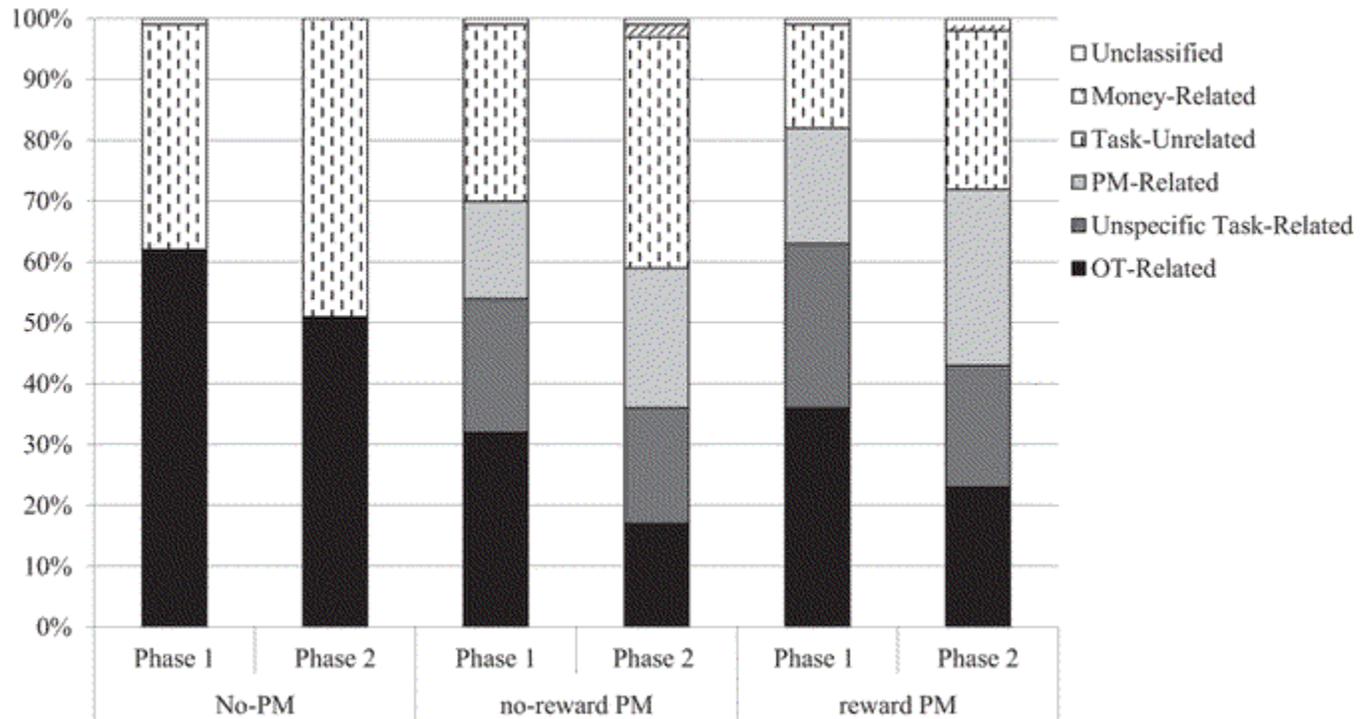


Figure 3. Proportions of task-related and task-unrelated thoughts assessed via open thought reports in Experiment 3. Phase 1 = task phase without PM targets; Phase 2 = task phase with PM targets. In the two prospective memory (PM) conditions, task-related thoughts were further classified as being ongoing-task (OT) related, unspecifically task related, or PM related.

The  $3 \times 2$  ANOVA for open-report TUT rates showed a main effect of task phase,  $F(1, 143) = 28.69, p < .001, f = 0.45$ , but no interaction,  $F < 1$ . Additionally, there was a main effect of condition,  $F(2, 143) = 14.20, p < .001, f = 0.45$ , planned contrasts further showed that TUTs decreased in the presence versus absence of a PM intention,  $F(1, 143) = 20.00, p < .001, f = 0.37$  and further decreased in the presence versus absence of a reward,  $F(1, 143) = 8.94, p = .003, f = 0.25$ . Thus, the open-report TUT results mirrored the results from the forced-choice probes and replicated the results from Experiment 2 regarding the demanding PM condition.

The proportions of thoughts classified as explicitly PM-task related were significantly higher than zero in each block of both PM conditions, all  $t_s > 5.00, p_s < .001$  and increased from the first ( $M = .18; SD = .18$ ) to the second block ( $M = .26; SD = .22$ ),  $F(1, 143) = 15.00, p < .001, f =$

0.40. We did not observe more explicitly PM-related thoughts in the reward than in the no-reward condition,  $F < 1.5$ . Thus, all subjects holding a PM intention experienced a substantial rate of conscious thoughts about the PM intention and, in line with Experiment 2, more so in the presence of PM targets. Subjects of the reward PM condition had a generally stronger on-task focus than those of the no-reward PM condition but did not report more explicitly PM-task-related thoughts. It may well be, however, that differences in PM-related thoughts were present but not discovered because they fell in the unspecifically task-related thought category.

### Exploratory correlational analyses for Experiments 1 to 3

We did not design our experiments to rigorously assess individual differences, and so they are underpowered to detect medium effects. Nonetheless, in an exploratory vein, we asked two theoretically inspired questions: (a) does the rate of PM-related thoughts positively predict ongoing-task RTs, as one would expect if monitoring was, at least in part, a conscious process?, and (b) does the rate of either off-task thoughts (negatively) or PM-related thoughts (positively) predict the accuracy of fulfilling the PM intention? Table 3 presents correlations among the variables of interest for the PM conditions from each experiment. With respect to our first question, in none of the three experiments did PM thought rate correlate with ongoing-task RTs, perhaps suggesting that monitoring processes are not subjectively experienced. With respect to our second question, in Experiment 1 and in the low PM-demand condition of Experiment 2, PM-target detection accuracy did not correlate with either TUT rates or PM-related thoughts (see also Reese & Cherry, 2002, for a similar result with a PM task that can be considered low-demanding). However, in the high PM-demand condition from Experiment 2 and the no-reward condition from Experiment 3 (both presented above the diagonals in Table 3), subjects' rate of PM thoughts positively predicted rate of PM accuracy ( $r = .57$  and  $r = .47$ ). Additionally, TUTs negatively predicted PM accuracy in the high PM-demand condition from Experiment 2 ( $r = -.39$ ) and the no-reward ( $r = -.31$ ) as well as the reward ( $r = -.34$ ) conditions from Experiment 3. These are suggestive results—potentially indicating that a stronger on-task focus, and conscious thoughts about more challenging and infrequently cued PM intentions, may facilitate their completion—but these findings require further replication in larger samples.

Table 3. *Correlations Among Performance and Thought-Reports in Prospective Memory Conditions*

Experimental conditions	1	2	3	4	5
Experiment 1					
1. OT word MRT					
2. PM hit rate	.11				
3. TUT rate (forced-choice)	-.01	-.11			
4. TUT rate (open report)	-.05	-.15	.62**		
5. PM thought rate (open report)	-.14	.02	.04	-.12	
Experiment 2					

1. OT word MRT		.11	.20	.11	-.15
2. PM hit rate	-.25		-.34*	-.39**	.57**
3. TUT rate (forced-choice)	.02	.20		.77**	-.42**
4. TUT rate (open report)	.09	.23	.74**		-.39**
5. PM thought rate (open report)	-.10	-.13	-.23	-.38*	
Experiment 3					
1. OT word MRT		-.05	.11	.12	.05
2. PM hit rate	.22		-.17	-.31*	.47**
3. TUT rate (forced-choice)	-.16	-.37*		.55**	-.21
4. TUT rate (open report)	-.25	-.34*	.75**		-.54**
5. PM thought rate (open report)	.15	.23	-.31*	-.44*	

*Note.* OT = ongoing task; MRTs = mean response times in milliseconds; PM = prospective memory; TUT = task-unrelated thoughts. Correlations for Experiments 2 and 3 refer to the second task phase. The low-demand and the reward conditions are presented below the diagonal and the high-demand and the no-reward conditions above. \*  $p < .01$ . \*\* $p < .01$ .

## Discussion

Experiment 3 replicated the central findings of the previous experiments that people with pending intentions engage in a stronger on-task focus than those without. This on-task focus was even further increased when the PM-task goal was associated with a monetary reward, suggesting that people focus especially on their current tasks while PM goals of higher personal relevance are active. In line with previous research (Cook et al., 2015), associating PM execution with a monetary reward resulted in better PM performance that was not accompanied by significantly higher levels of PM-induced costs. Furthermore, we again observed PM-induced costs in terms of slowed ongoing-task responding that were best reflected by changes in the ex-Gaussian parameter  $\mu$ . These results suggest that the categorical PM task causes subjects to monitor relatively continuously for PM targets while performing the ongoing task (Ball et al., 2015).

In sum, the results from Experiment 3 provide strong evidence that people who are motivated to adhere to their current task goals engage in a stronger on-task focus (as indexed by fewer TUTs).

### *General Discussion*

The primary aim of the present research was to gain a better understanding of how people deal with the attentional demands from pending intentions by asking them about the thoughts they have while performing the PM/ongoing-task ensemble. In three experiments, we replicated previous research showing that holding a PM intention interferes with ongoing-task processing (e.g., A.-L. Cohen, 2013; A.-L. Cohen et al., 2008; Marsh et al., 2003; Smith, 2003). Moreover,

the present thought-report results also demonstrated that the addition of a PM task to an ongoing task not only interferes with ongoing-task processing but also changes the engagement in TUTs, implying a generally stronger attentional focus on the task ensemble. Whereas the former finding is in line with numerous previous empirical studies, the latter finding is novel and has implications for PM theorizing.

Most existing theories of PM assume (implicitly or explicitly) that attentional capacities or mechanisms are shared between pending PM intentions and a currently ongoing task (Guynn, 2003; McDaniel et al., 2015; Scullin et al., 2013; Smith, 2010) and they do not consider the possibility that there may be a third draw on attentional processes, namely, the engagement in TUTs. Most explicitly, Marsh, Hicks, and colleagues suggested that, when forming an intention, people also decide how they distribute their attention between the ongoing task and the PM intention (Hicks et al., 2005; Marsh et al., 2003). The present findings are in line with this general idea. More specifically, we assume that the PM-induced costs stem from the fact that both the ongoing task and the PM task require basic executive (top-down) processes to some extent and thus PM processing interferes with ongoing-task processing (see also McDaniel, Lamontagne, Beck, Scullin, & Braver, 2013).

Recent PM research has shown that the level of PM-induced costs to an ongoing task depends not only on actual PM task demands, but also on people's expectancies regarding those demands (Lourenço et al., 2015; Rummel & Meiser, 2013). The level of engagement in attentional PM processing therefore seems to lie under personal (metacognitive) control. Findings that attentional PM processing is adjusted in line with information regarding the context in which a PM target will occur (Ball et al., 2015; Kuhlmann & Rummel, 2014; Lourenço et al., 2013; Marsh, Hicks, & Cook, 2006) further speaks to the flexible adjustment of PM processing. If attentional PM processing indeed reflects strategic decisions about how to succeed in an ongoing task without forgetting one's intentions, it is plausible that, when holding intentions, people not only shift attention between the ongoing task and the PM task, but also become more consciously focused on the overall PM/ongoing-task ensemble. This idea is also well in line with the idea from the mind-wandering literature that TUTs interfere with most concurrent tasks, especially when these are demanding, and that task engagement is thus adjusted to current cognitive demands (Casner & Schooler, 2014; Kane et al., 2007; Rummel & Boywitt, 2014). The present finding of a stronger on-task focus (i.e., fewer TUTs) in the presence of a pending intention renders the first empirical support for this idea: people's minds seem to wander less while holding a PM intention in addition to engaging in their ongoing activities. When the current PM and ongoing-task goals are of high personal relevance, moreover, mind wandering occurs on even fewer occasions and the preliminary correlative pattern suggest that the reduction in mind wandering may come with improved PM performance. Thus, engaging a stronger on-task focus (with "task" referring to the entire ensemble of ongoing and PM tasks) seems to be an effective strategy to improve PM.

The present findings seem consistent with two prominent mind-wandering theories. On the one hand, the context-regulation theory (Smallwood & Schooler, 2015) predicts that mind wandering will be actively reduced in situations where demands from ongoing tasks require attention. On

the other hand, the executive-failure theory (Kane & McVay, 2012; McVay & Kane, 2009) predicts that less mind wandering will occur when task demands increase, not necessarily due to an active resource withdrawal from TUTs, but also potentially due to a stronger on-task focus (i.e., a stronger maintenance of task goals). From the present findings, unfortunately, we cannot determine whether participants consciously reallocated attentional resources from TUTs or consciously focused more on their current task goals and reduced their TUT engagement in doing so; this may be an interesting question for future research.

That being said, future studies might profitably address the extent to which PM-induced reductions in TUTs are strategic, or the result of metacognitive assessments of the task context and demands. Recent evidence from Seli, Smilek, and their colleagues suggests that mind wandering is sometimes intentional and sometimes unintentional. That is, if you ask subjects why they were mind wandering at a particular moment, they usually report doing so unintentionally but they also report intentional mind wandering at nonnegligible rates (Seli, Carriere, & Smilek, 2015; Seli, Risko, Smilek, & Schacter, 2016; see also Forster & Lavie, 2009; Grodsky & Giambra, 1990-91). We did not assess the intentionality of participants' mind wandering experiences here, but it might be fruitful to do so in future work. If the PM-related reduction in TUTs selectively reduced intentional rather than unintentional mind wandering, it would be probably more in line with the idea that an active reallocation of attentional resources underlies the observable reduction in TUTs.

What we can conclude is that people *do* show fewer TUTs when they hold unfulfilled intentions. This new insight may help refine current theories on the role of attentional processing in PM because it can explain some puzzling results. For example, manipulations that affect the motivation to perform well in a PM task, like associating intention failures with monetary rewards (current Experiment 3; Cook et al., 2015; Kliegel, Brandenberger, & Aberle, 2010) or social consequences (Altgassen, Kliegel, Brandimonte, & Filippello, 2010; Brandimonte et al., 2010), often improve PM performance without substantially increasing ongoing-task costs. Any PM theory that considers only two mental "tasks" (i.e., the ongoing task and the PM task) that engage attentional processes has difficulties explaining these findings. By taking into account a third form of mental activity—mind wandering—from which people may disengage in order to focus more strongly on the current PM and ongoing-task goals (as empirically shown in Experiment 3), attentional-processing theories of PM remain candidates for explaining such PM improvements in the absence of additional ongoing-task costs.

Notably, in line with most current PM theories—that is, PAM theory (Smith, 2010; Smith & Loft, 2014), 2PSM theory (Guynn, 2003; Horn & Bayen, 2015), and MPT (Einstein & McDaniel, 2010; McDaniel et al., 2013; Scullin et al., 2013)—we assumed that ongoing and PM tasks of a typical PM ensemble both rely on the same attentional processes (likely inhibition and shifting processes; cf., Schnitzspahn et al., 2013) to be executed and that this is the reason why holding a PM intention slows down ongoing-task responding. This view was recently challenged by Heathcote et al. (2015), who proposed a *delay theory* of PM. These scholars argue that PM-induced costs to an ongoing task reflects a strategic slowing of ongoing-task responding to gain more time for PM responding, rather than an attentional process. They used a diffusion modeling

approach to test this idea and found that PM-induced costs are mostly due to a more careful response-criterion setting rather than changes in information accumulation. Due to suboptimal data structure for this purpose (cf., Heathcote et al., 2015), we did not apply a diffusion model to the present data. However, the ex-Gaussian modeling of RTs showed that especially the  $\mu$  parameter (and sometimes also  $\tau$ ) mirrored the PM-induced costs. These results suggest that the addition of the PM task may cause processing changes of different kinds. That is, people may perform their ongoing tasks generally more carefully to ensure that they do not miss any PM targets, at least in the case of rather demanding PM tasks like the category target task we used, but they may also sometimes engage in additional attentional processing, such as rehearsing the PM intention and a strategic search for the targets (cf., Loft et al., 2014). This idea is also tentatively supported by our exploratory finding that individual differences in PM-related thoughts predict PM performance under some conditions.

On a conceptual level, neither the classic attentional processing views (Gynn, 2003; McDaniel et al., 2015; Smith, 2003, 2016) nor delay theory's assumption of more thoughtful ongoing-task performance (Heathcote et al., 2015) yet incorporate the present idea that the addition of a PM task causes—in addition to any strategic changes within the PM/ongoing-task setting—a generally stronger attentional focus on the overall PM/ongoing-task ensemble. Both theories could, however, easily be updated to account for such a process. We hope that this new approach will help to broaden our understanding of attentional PM processing and inspire new research in this area.

#### Footnotes

1 One student was 51, all others were 35 and younger.

2 An anonymous reviewer pointed out that an alternative mechanism that could explain the simultaneous observation of faster ongoing-task performance in combination with higher PM-hit rates would be the establishment of a more lenient criterion for PM responses. We agree with this idea, but as the reviewer also argued, such a more lenient PM response criterion would also result in more false PM responses. We would thus not consider this a simultaneous improvement of performances in both the ongoing and the PM task. Nevertheless, we acknowledge that there may be potential mechanisms other than the reduction of TUTs that may result in simultaneous performance improvements in both tasks of the PM ensemble.

#### References

Abney, D. H., McBride, D. M., & Petrella, S. N. (2013). Interactive effects in transfer-appropriate processing for event-based prospective memory: The roles of effort, ongoing task, and PM cue properties. *Memory & Cognition*, *41*, 1032–1045. 10.3758/s13421-013-0324-7

Altgassen, M., Kliegel, M., Brandimonte, M., & Filippello, P. (2010). Are older adults more social than younger adults? Social importance increases older adults' prospective memory performance. *Aging, Neuropsychology, and Cognition*, *17*, 312–328. 10.1080/13825580903281308

Altman, D. G. (1991). *Practical statistics for medical research*. London, UK: Chapman and Hall.

- Anderson, F. T., & Einstein, G. O. (2016). The fate of completed intentions. *Memory*. Advance online publication. 10.1080/09658211.2016.1187756
- Antrobus, J. S., Singer, J. L., & Greenberg, S. (1966). Studies in stream of consciousness: Experimental enhancement and suppression of spontaneous cognitive processes. *Perceptual and Motor Skills*, 23, 399–417. 10.2466/pms.1966.23.2.399
- Baird, B., Smallwood, J., Lutz, A., & Schooler, J. W. (2014). The decoupled mind: Mind-wandering disrupts cortical phase-locking to perceptual events. *Journal of Cognitive Neuroscience*, 26, 2596–2607. 10.1162/jocn\_a\_00656
- Ball, B. H., Brewer, G. A., Loft, S., & Bowden, V. (2015). Uncovering continuous and transient monitoring profiles in event-based prospective memory. *Psychonomic Bulletin & Review*, 22, 492–499.
- Boywitt, C. D., & Rummel, J. (2012). A diffusion model analysis of task interference effects in prospective memory. *Memory & Cognition*, 40, 70–82. 10.3758/s13421-011-0128-6
- Brandimonte, M. A., Ferrante, D., Bianco, C., & Villani, M. G. (2010). Memory for pro-social intentions: When competing motives collide. *Cognition*, 114, 436–441. 10.1016/j.cognition.2009.10.011
- Brewer, G. A. (2011). Analyzing response time distributions methodological and theoretical suggestions for prospective memory researchers. *Zeitschrift für Psychologie/Journal of Psychology*, 219, 117–124.
- Casner, S. M., & Schooler, J. W. (2014). Thoughts in flight: Automation use and pilots' task-related and task-unrelated thought. *Human Factors*, 56, 433–442. 10.1177/0018720813501550
- Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 8719–8724. 10.1073/pnas.0900234106
- Cohen, A.-L. (2013). Attentional decoupling while pursuing intentions: A form of mind wandering? *Frontiers in Psychology*, 4, 693. 10.3389/fpsyg.2013.00693
- Cohen, A.-L., Jaudas, A., & Gollwitzer, P. M. (2008). Number of cues influences the cost of remembering to remember. *Memory & Cognition*, 36, 149–156. 10.3758/MC.36.1.149
- Cohen, A. L., Jaudas, A., Hirschhorn, E., Sobin, Y., & Gollwitzer, P. M. (2012). The specificity of prospective memory costs. *Memory*, 20, 848–864. 10.1080/09658211.2012.710637
- Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20, 37–46. 10.1177/001316446002000104
- Cook, G. I., Rummel, J., & Dummel, S. (2015). Toward an understanding of motivational influences on prospective memory using value-added intentions. *Frontiers in Human Neuroscience*, 9, 278. 10.3389/fnhum.2015.00278

- Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General*, *125*, 159–180. 10.1037/0096-3445.125.2.159
- Czernochowski, D., Horn, S., & Bayen, U. J. (2012). Does frequency matter? ERP and behavioral correlates of monitoring for rare and frequent prospective memory targets. *Neuropsychologia*, *50*, 67–76. 10.1016/j.neuropsychologia.2011.10.023
- Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science*, *14*, 286–290. 10.1111/j.0963-7214.2005.00382.x
- Einstein, G. O., & McDaniel, M. A. (2010). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1082–1088. 10.1037/a0019184
- Ellis, J. A., & Kvavilashvili, L. (2000). Prospective memory in 2000: Past, present, and future directions. *Applied Cognitive Psychology*, *14*, S1–S9. 10.1002/acp.767
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G\*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. 10.3758/BF03193146
- Forster, S., & Lavie, N. (2009). Harnessing the wandering mind: The role of perceptual load. *Cognition*, *111*, 345–355. 10.1016/j.cognition.2009.02.006
- Frank, D. J., Nara, B., Zavagnin, M., Tournon, D. R., & Kane, M. J. (2015). Validating older adults' reports of less mind-wandering: An examination of eye movements and dispositional influences. *Psychology and Aging*, *30*, 266–278. 10.1037/pag0000031
- Grodsky, A., & Giambra, L. M. (1990). The consistency across vigilance and reading tasks of individual differences in the occurrence of task-unrelated and task-related images and thoughts. *Imagination, Cognition and Personality*, *10*, 39–52. 10.2190/6QG5-CXVV-4XUR-7P3K
- Guynn, M. J. (2003). A two-process model of strategic monitoring in event-based prospective memory: Activation/retrieval mode and checking. *International Journal of Psychology*, *38*, 245–256. 10.1080/00207590344000178
- Harrison, T. L., & Einstein, G. O. (2010). Prospective memory: Are preparatory attentional processes necessary for a single focal cue? *Memory & Cognition*, *38*, 860–867. 10.3758/MC.38.7.860
- Harrison, T. L., Mullet, H. G., Whiffen, K. N., Ousterhout, H., & Einstein, G. O. (2014). Prospective memory: Effects of divided attention on spontaneous retrieval. *Memory & Cognition*, *42*, 212–224.

- Heathcote, A., Loft, S., & Remington, R. W. (2015). Slow down and remember to remember! A delay theory of prospective memory costs. *Psychological Review*, *122*, 376–410. 10.1037/a0038952
- Heister, J., Würzner, K. M., Bubenzer, J., Pohl, E., Hanneforth, T., Geyken, A., & Kliegl, R. (2011). dlexDB—eine lexikalische Datenbank für die psychologische und linguistische Forschung [dlexDB—A lexical database for the psychological and linguistic research]. *Psychologische Rundschau*, *62*, 10–20. 10.1026/0033-3042/a000029
- Hicks, J. L., Marsh, R. L., & Cook, G. I. (2005). Task interference in time-based, event-based, and dual intention prospective memory conditions. *Journal of Memory and Language*, *53*, 430–444. 10.1016/j.jml.2005.04.001
- Horn, S. S., & Bayen, U. J. (2015). Modeling criterion shifts and target checking in prospective memory monitoring. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*, 95–117. 10.1037/a0037676
- Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, *18*, 614–621. 10.1111/j.1467-9280.2007.01948.x
- Kane, M. J., & McVay, J. C. (2012). What mind wandering reveals about executive-control abilities and failures. *Current Directions in Psychological Science*, *21*, 348–354. 10.1177/0963721412454875
- Kane, M. J., Meier, M. E., Smeekens, B. A., Gross, G. M., Chun, C. A., Silvia, P. J., & Kwapil, T. R. (2016). Individual differences in the executive control of attention, memory, and thought, and their associations with schizotypy. *Journal of Experimental Psychology: General*, *145*, 1017–1048. 10.1037/xge0000184
- Kliegel, M., Brandenberger, M., & Aberle, I. (2010). Effect of motivational incentives on prospective memory performance in preschoolers. *European Journal of Developmental Psychology*, *7*, 223–232. 10.1080/17405620802025643
- Klinger, E. (2013). Goal commitments and the content of thoughts and dreams: Basic principles. *Frontiers in Psychology*, *4*, 415. 10.3389/fpsyg.2013.00415
- Knight, J. B., Meeks, J. T., Marsh, R. L., Cook, G. I., Brewer, G. A., & Hicks, J. L. (2011). An observation on the spontaneous noticing of prospective memory event-based cues. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 298–307. 10.1037/a0021969
- Kucyi, A., & Davis, K. D. (2014). Dynamic functional connectivity of the default mode network tracks daydreaming. *NeuroImage*, *100*, 471–480. 10.1016/j.neuroimage.2014.06.044
- Kuhlmann, B. G., & Rummel, J. (2014). Context-specific prospective-memory processing: Evidence for flexible attention allocation adjustments after intention encoding. *Memory & Cognition*, *42*, 943–949. 10.3758/s13421-014-0405-2

- Kvavilashvili, L., & Fisher, L. (2007). Is time-based prospective remembering mediated by self-initiated rehearsals? Role of incidental cues, ongoing activity, age, and motivation. *Journal of Experimental Psychology: General*, *136*, 112–132. 10.1037/0096-3445.136.1.112
- Loft, S., Bowden, V. K., Ball, B. H., & Brewer, G. A. (2014). Fitting an ex-Gaussian function to examine costs in event-based prospective memory: Evidence for a continuous monitoring profile. *Acta Psychologica*, *152*, 177–182. 10.1016/j.actpsy.2014.08.010
- Loft, S., Kearney, R., & Remington, R. (2008). Is task interference in event-based prospective memory dependent on cue presentation? *Memory & Cognition*, *36*, 139–148. 10.3758/MC.36.1.139
- Lourenço, J. S., Hill, J. H., & Maylor, E. A. (2015). Too easy? The influence of task demands conveyed tacitly on prospective memory. *Frontiers in Human Neuroscience*, *9*, 242. 10.3389/fnhum.2015.00242
- Lourenço, J. S., White, K., & Maylor, E. A. (2013). Target context specification can reduce costs in nonfocal prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*, 1757–1764. 10.1037/a0033702
- Marsh, R. L., Cook, G. I., & Hicks, J. L. (2006). Task interference from event-based intentions. *Memory & Cognition*, *34*, 1636–1643. 10.3758/BF03195926
- Marsh, R. L., Hicks, J. L., & Cook, G. I. (2005). On the relationship between effort toward an ongoing task and cue detection in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*, 68–75. 10.1037/0278-7393.31.1.68
- Marsh, R. L., Hicks, J. L., & Cook, G. I. (2006). Task interference from prospective memories covaries with contextual associations of fulfilling them. *Memory & Cognition*, *34*, 1037–1045. 10.3758/BF03193250
- Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 861–870. 10.1037/0278-7393.29.5.861
- Martin, B. A., Brown, N. L., & Hicks, J. L. (2011). Ongoing task delays affect prospective memory more powerfully than filler task delays. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *65*, 48–56. 10.1037/a0022872
- Matzke, D., & Wagenmakers, E. J. (2009). Psychological interpretation of the ex-Gaussian and shifted Wald parameters: A diffusion model analysis. *Psychonomic Bulletin & Review*, *16*, 798–817. 10.3758/PBR.16.5.798
- McBride, D. M., & Abney, D. H. (2012). A comparison of transfer-appropriate processing and multi-process frameworks for prospective memory performance. *Experimental Psychology*, *59*, 190–198. 10.1027/1618-3169/a000143

- McBride, D. M., Beckner, J. K., & Abney, D. H. (2011). Effects of delay of prospective memory cues in an ongoing task on prospective memory task performance. *Memory & Cognition*, *39*, 1222–1231. 10.3758/s13421-011-0105-0
- McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*, 127–144. 10.1002/acp.775
- McDaniel, M. A., & Einstein, G. O. (2007). *Prospective memory: An overview and synthesis of an emerging field*. Los Angeles, CA: Sage.
- McDaniel, M. A., Lamontagne, P., Beck, S. M., Scullin, M. K., & Braver, T. S. (2013). Dissociable neural routes to successful prospective memory. *Psychological Science*, *24*, 1791–1800. 10.1177/0956797613481233
- McDaniel, M. A., Umanath, S., Einstein, G. O., & Waldum, E. R. (2015). Dual pathways to prospective remembering. *Frontiers in Human Neuroscience*, *9*, 392. 10.3389/fnhum.2015.00392
- McDowd, J. M., & Craik, F. I. M. (1988). Effects of aging and task difficulty on divided attention performance. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 267–280. 10.1037/0096-1523.14.2.267
- McMillan, R. L., Kaufman, S. B., & Singer, J. L. (2013). Ode to positive constructive daydreaming. *Frontiers in Psychology*, *4*, 626. 10.3389/fpsyg.2013.00626
- McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 196–204. 10.1037/a0014104
- McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006). and Watkins (2008). *Psychological Bulletin*, *136*, 188–197. 10.1037/a0018298
- McVay, J. C., & Kane, M. J. (2012a). Drifting from slow to “D’oh!”: Working memory capacity and mind wandering predict extreme reaction times and executive control errors. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 525–549. 10.1037/a0025896
- McVay, J. C., & Kane, M. J. (2012b). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General*, *141*, 302–320. 10.1037/a0025250
- Meier, B., & Rey-Mermet, A. (2012). Beyond monitoring: After-effects of responding to prospective memory targets. *Consciousness and Cognition: An International Journal*, *21*, 1644–1653. 10.1016/j.concog.2012.09.003
- Mooneyham, B. W., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: A review. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *67*, 11–18. 10.1037/a0031569

- Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin*, *140*, 1411–1431. 10.1037/a0037428
- Reese, C. M., & Cherry, K. E. (2002). The effects of age, ability, and memory monitoring on prospective memory task performance. *Aging, Neuropsychology, and Cognition*, *9*, 98–113. 10.1076/anec.9.2.98.9546
- Reichle, E. D., Reineberg, A. E., & Schooler, J. W. (2010). Eye movements during mindless reading. *Psychological Science*, *21*, 1300–1310. 10.1177/0956797610378686
- Rosenthal, R., & Rosnow, R. (1985). *Contrast analysis: Focused comparisons in the analysis of variance*. Cambridge, UK: Cambridge University Press.
- Rummel, J., & Boywitt, C. D. (2014). Controlling the stream of thought: Working memory capacity predicts adjustment of mind-wandering to situational demands. *Psychonomic Bulletin & Review*, *21*, 1309–1315. 10.3758/s13423-013-0580-3
- Rummel, J., Kuhlmann, B. G., & Touron, D. R. (2013). Performance predictions affect attentional processes of event-based prospective memory. *Consciousness and Cognition: An International Journal*, *22*, 729–741. 10.1016/j.concog.2013.04.012
- Rummel, J., & Meiser, T. (2013). The role of metacognition in prospective memory: Anticipated task demands influence attention allocation strategies. *Consciousness and Cognition: An International Journal*, *22*, 931–943. 10.1016/j.concog.2013.06.006
- Schnitzspahn, K. M., Stahl, C., Zeintl, M., Kaller, C. P., & Kliegel, M. (2013). The role of shifting, updating, and inhibition in prospective memory performance in young and older adults. *Developmental Psychology*, *49*, 1544–1553. 10.1037/a0030579
- Schooler, J. W., & Schreiber, C. A. (2004). Experience, meta-consciousness, and the paradox of introspection. *Journal of Consciousness Studies*, *11*, 17–39.
- Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*, 319–326.
- Scullin, M. K., McDaniel, M. A., & Shelton, J. T. (2013). The dynamic multiprocess framework: Evidence from prospective memory with contextual variability. *Cognitive Psychology*, *67*, 55–71. 10.1016/j.cogpsych.2013.07.001
- Seli, P., Carriere, J. S. A., & Smilek, D. (2015). Not all mind wandering is created equal: Dissociating deliberate from spontaneous mind wandering. *Psychological Research*, *79*, 750–758. 10.1007/s00426-014-0617-x
- Seli, P., Risko, E. F., Smilek, D., & Schacter, D. L. (2016). Mind-wandering with and without intention. *Trends in Cognitive Sciences*, *20*, 605–617. 10.1016/j.tics.2016.05.010

- Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. *Dialogue: The Official Newsletter of the Society for Personality and Social Psychology*, 26, 4–7.
- Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process-occurrence framework for self-generated mental activity. *Psychological Bulletin*, 139, 519–535. 10.1037/a0030010
- Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, 132, 946–958. 10.1037/0033-2909.132.6.946
- Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology*, 66, 487–518. 10.1146/annurev-psych-010814-015331
- Smilek, D., Carriere, J. S., & Cheyne, J. A. (2010). Out of mind, out of sight: Eye blinking as indicator and embodiment of mind wandering. *Psychological Science*, 21, 786–789. 10.1177/0956797610368063
- Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 347–361. 10.1037/0278-7393.29.3.347
- Smith, R. E. (2010). What costs do reveal and moving beyond the cost debate: Reply to Einstein and McDaniel (2010). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36, 1089–1095. 10.1037/a0019183
- Smith, R. E. (2016). Prospective memory: A framework for research on metaintentions. In J. Dunlosky & S. K. Tauber (Eds.), *The Oxford handbook on metamemory* (pp. 217–244). New York, NY: Oxford University Press.
- Smith, R. E., Hunt, R. R., McVay, J. C., & McConnell, M. D. (2007). The cost of event-based prospective memory: Salient target events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33, 734–746. 10.1037/0278-7393.33.4.734
- Smith, R. E., & Loft, S. (2014). Investigating the cost to ongoing tasks not associated with prospective memory task requirements. *Consciousness and Cognition: An International Journal*, 27, 1–13. 10.1016/j.concog.2014.04.002
- Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I., & Baddeley, A. D. (1995). Stimulus-independent thought depends on central executive resources. *Memory & Cognition*, 23, 551–559. 10.3758/BF03197257
- Teasdale, J. D., Proctor, L., Lloyd, C. A., & Baddeley, A. D. (1993). Working-memory and stimulus-independent thought: Effects of memory load and presentation rate. *European Journal of Cognitive Psychology*, 5, 417–433. 10.1080/09541449308520128
- Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: Examining the roles of working memory capacity, interest, motivation, and topic

experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 39, 832–842. 10.1037/a0029669

Unsworth, N., & McMillan, B. D. (2014). Similarities and differences between mind-wandering and external distraction: A latent variable analysis of lapses of attention and their relation to cognitive abilities. *Acta Psychologica*, 150, 14–25. 10.1016/j.actpsy.2014.04.001

Vinski, M. T., & Watter, S. (2012). Priming honesty reduces subjective bias in self-report measures of mind wandering. *Consciousness and Cognition: An International Journal*, 21, 451–455. 10.1016/j.concog.2011.11.001

Zuber, S., Kliegel, M., & Ihle, A. (2016). An individual difference perspective on focal versus nonfocal prospective memory. *Memory & Cognition*, 44, 1192–1203. 10.3758/s13421-016-0628-5