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BRIEF REPORT

The role of offloading intentions on future-oriented thinking

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Abstract
Offloading (e.g., using Google calendar reminders) has been shown to improve prospective memory (PM). One unstudied aspect of PM offloading is whether having reminders reduces our future-oriented thinking about PM intentions in contexts in which the intention cannot be fulfilled. In the current study, participants were given two blocks of an ongoing lexical decision task. Prior to beginning the task, participants formed an intention to make a special response to PM targets only in block 2. Participants in the reminder condition had the PM intention displayed at the top of the screen in block 2, whereas those in the no-reminder condition did not. To assess activation of the intention out of context, PM lures (Experiment 1) or thought probes (Experiments 2 and 3) were presented in block 1. Results showed that reminders improved PM performance in block 2 but did not reduce lure interference or PM-related thoughts in block 1. These findings suggest that offloaded memory representations remain as activated and accessible as non-offloaded representations outside the context in which intentions can be fulfilled.

Keywords Prospective memory · Offloading · Future-oriented thinking · Mind-wandering

Introduction

Prospective memory (PM) refers to our ability to remember to fulfill an action in the future, and includes three fundamental stages: (1) *intention formation,* the period in which the intention is formed (e.g., take medication at dinner), (2) *intention retention,* the delay interval between encoding and retrieval (e.g., busy workday) in which the intention is stored in long-term memory, and (3) *intention retrieval,* the period in which the intention should be fulfilled (e.g., dinner). Research shows that our everyday thoughts show a prospective bias, meaning that thoughts unrelated to the current task at hand tend to be future-oriented compared to past-oriented (see Kvavilashvili & Rummel, 2020, for a review). Thinking about our PM intentions may be adaptive in nature, serving to keep them at higher baseline levels of activation to increase the likelihood of successfully fulfilling these plans later (Goshke & Kuhl, 1993; Marsh et al., 1998). However, actively maintaining intentions throughout the day can have detrimental effects to ongoing activities (Smith, 2003) and can be particularly burdensome when these thoughts become ruminative (Beaty et al., 2019; Miranda et al., 2017, 2023). To reduce these demands while improving goal completion, intentions can be offloaded onto the environment (e.g., setting an electronic calendar reminder; for reviews, see Risko & Gilbert, 2016; Gilbert et al., 2023). But what becomes of the fate of these offloaded memory representations during the retention interval? The current study was designed to examine whether offloading reduces our thinking about PM intentions in contexts in which the intention cannot be fulfilled.

The different stages of PM can be examined in laboratory settings by having participants complete two blocks of an ongoing lexical decision task. Prior to beginning the task, participants may form the intention to press the "7" key any time they encounter PM target words (e.g., any animal word starting with the letter "C", such as *cheetah*), but *only* during the second lexical decision block. Thus, block 1 serves as the retention interval whereas block 2 serves as the retrieval phase. The majority of PM research is aimed at examining the factors underlying intention retrieval, as measured by the proportion of targets that participants correctly respond to with the "7" key in block 2. Growing research suggests that offloading (e.g., reminders) can improve performance (Gilbert et al., 2023). For example,

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Peper et al. (2023) had participants remember to respond to either one (e.g., c-animals) or four categories (e.g., c-animals, fruits, sports, gems). In the reminder condition, participants were shown the PM categories at the top of the screen throughout the retrieval phase, whereas in the no-reminder condition, no categories were presented. Perhaps unsurprisingly, PM was better with reminders and especially so under high load. A potentially more theoretically interesting question concerns the nature of these offloaded intentions during the retention interval (i.e., block 1), a question that has currently been unexplored. If a memory is externalized, does its representation still need to be maintained? If so, there should be some evidence of residual activation during the retention interval.

Residual activation of (non-offloaded) intentions has been explored in different ways. Using the two-block paradigm just described, Knight et al. (2011) unexpectedly embedded c-animal words during block 1. These words are considered PM "lures" since PM targets should only be responded to in block 2. Results showed that participants took longer to make lexical decisions to lure word than to control (non-"c-animal") words matched for lexical characteristics, referred to as *lure interference*. Slower responding to PM lures suggests that participants spontaneously retrieved the intention, had to verify that the context was inappropriate for making a PM response, and then had to inhibit the PM response to instead make a lexical decision (Marsh et al., 2003). Using a slightly different procedure,[1] Anderson and Einstein (2017) periodically included thought probes that asked participants about what they were thinking, which showed that participants were more likely to report thinking about the intention immediately following lure items than control items. These findings suggest that intentions can remain at a heightened level of activation and be retrieved outside the context in which intentions should be fulfilled (i.e., block 1). We use the term "future-oriented thinking" to refer to PM-related thoughts occurring in the retention interval (rather than the retrieval interval).

One issue with the lure interference paradigm is that thought probes occur following lure trials, meaning that any reports of future-oriented thinking could simply reflect reactive activation of the intention following presentation of the first lure. Ideally, probes could be assessed during the retention interval without presentation of lure items to determine whether the intention is activated. Research in naturalistic settings has demonstrated that participants do spontaneously rehearse intentions during the retention interval and that the frequency of these rehearsals is positively correlated with subsequent intention fulfillment (e.g., Kvavilashvili & Fisher, 2007). Participants even report thinking about their real-world future intentions in laboratory settings using non-PM tasks (e.g., n-back task; Smallwood et al., 2009). However, much of the laboratory studies examining intention activation during the retention interval (without the presentation of PM targets) has assessed it either indirectly (Hicks et al., 2000) or during the retrieval interval (Rummel et al., 2017). Importantly, no research has examined how externalizing these memory representations influences future-oriented thinking.

Current study

To examine how reminders influence future-oriented thinking, we used the two-block paradigm to assess lure interference (Experiment 1) and reports of PM-related thoughts (without lures) in response to thought probes (Experiments 2 and 3) during block 1. Following intention encoding, participants in the reminder condition were instructed that the contents of the intention would be displayed at the top of the screen during the retrieval phase (i.e., block 2). Because the reminder serves as an external repository for the memory representation (Risko & Gilbert, 2016), this should eliminate the need to maintain the intention in an activated state over the retention interval (i.e., block 1). Because participants in the no-reminder condition must represent the intention internally, we anticipated that they would show more lure interference (Experiment 1) and PM-related thoughts (Experiments 2 and 3) in block 1 than those in the reminder condition.

Experiment 1

Method

Pre-registration and ethics statement

For each experiment, all hypotheses, methods, and analyses were preregistered prior to data collection. Any deviations from preregistered analyses are explicitly mentioned in the text. Data for all experiments are available via the Open Science Framework (OSF) at https://osf.io/zg8ph/. The OSF preregistration for Experiment 1 can be found at https://osf.io/rfktn. All research reported herein was conducted using appropriate ethical guidelines and was approved by the Institutional Review Board at the University of Texas at Arlington.

[1] Anderson and Einstein (2017) actually told participants to make a PM response only during block 1 and presented lures in block 2. They were interested in the persistence of activation following suspension or cancellation of an intention following block 1. However, for ease of exposition, we describe using the methodology from Knight et al. (2011), which is most similar to the paradigm used in the present study.

Participants and design

A two-level (reminder vs. no reminder) between-subjects design was employed. A G*Power a priori power analysis effect size ($n_p^2 = .06$) with an alpha of .05 and a power of .90 recommended we use 88 participants (44 participants per condition). We opted to stop at 50 participants per condition. A total of 112 undergraduates from the University of Texas at Arlington participated and received credit towards course requirements. Following participant exclusions (described below), there were 44 participants in the reminder condition and 48 in the no-reminder condition. The task was completed in-person using E-Prime in approximately 25 min.

Materials

The materials were similar to those used by Peper et al. (2023). Ongoing task stimuli were selected from the English Lexicon Project (Balota et al., 2007). These consisted of 130 words and 140 nonwords that were four to eight letters in length. An additional four c-animal words were selected to serve as PM targets and another four c-animal words were selected to serve as PM lures. There were also four control-matched words that were similar in lexical length, frequency, and latency to the c-animal lures. The ongoing task stimuli were presented in uppercase black font at the center of the screen on a gray background.

Procedure

The procedure was similar to that used by Peper et al. (2023). The experiment involved participants performing a lexical decision ongoing task with PM targets embedded. Participants practiced the ongoing task and then received the general intention instructions (and were quizzed). They learned the intention, then performed the blocks of the task (i.e., lexical decision task 1, demographics, lexical decision task 2). Finally, participants completed a post-experimental questionnaire. For the ongoing lexical decision task, participants were required to make word versus non-word judgements about English words presented on a computer. They pressed the "F" key for the word being a valid English word (e.g., AXLE) and the "J" key for the word being a non-valid word (e.g., KEND). After each judgement, a brief (500 ms) fixation cross appeared before another word stimulus was presented.

Practice block After reading instructions for the ongoing task, participants completed a 20-trial practice block and received accuracy feedback after each trial. Participants were only allowed to proceed after achieving 75% accuracy or greater on the practice. Afterward, participants performed another practice block (40 trials) without feedback.

Intention instruction block Upon completing the practice block, participants received instructions for the upcoming PM task. Participants were instructed that they were going to learn a category of words that were to later appear during the lexical decision task. The PM intention was to make a special response (press the "7" key) whenever they encountered exemplars from the category (i.e., PM targets). They were to press the "7" key *instead* of making their ongoing task response and *only* in block 2. Participants were informed that the first and second blocks would clearly be demarcated by an intervening demographics questionnaire and that their primary objective was still to perform the ongoing task as quickly but as accurately as possible.

A brief instructions quiz was then presented to each participant with four questions. The first question asked about what their primary task consisted of (i.e., making word vs. non-word string judgements). The second question asked about their PM task (i.e., look for category exemplar words). The third question asked about their PM response (i.e., press the "7" key). The fourth question asked when they should perform the PM task (i.e., second ongoing string judgment block). Participants had to get every question correct before proceeding. If they answered a question wrong, they had to reread the instructions to ensure proper encoding of the PM task.

PM encoding block After the instructions quiz, participants then proceeded to encode the PM task wherein they studied a category of words. Participants were instructed that they will have 15 s to try and memorize this category. Additionally, it was reaffirmed that their response of pressing the "7" key should occur if they see a word from this category instead of making their normal response to the lexical decision task. Participants in the no-reminder control were given a summary of the instructions that they had just previously been tested on, outlining both their ongoing task and the PM task. Participants in the reminder condition were additionally told that they would have a reminder at the top of their screen in block 2 that displayed the category and PM response (i.e., "7" key for c-animal words) and were shown a visual depiction of what the reminder would look like during the task.

Distractor block Participants completed arithmetic problems involving multi-digit multiplication for 2 min before the PM task.

Block 1 Before beginning the PM task, participants received instructions that reiterated only the ongoing task instructions. The ongoing task consisted of 112 trials with word type (word vs. non-word) randomly presented. Every 20 trials a control-matched word was presented and every 24 trials a PM lure was presented.

Demographic questionnaire After block 1, participants answered demographic questions. Questions included age, years of education, native language, gender, ethnicity, and proficiencies in speaking, understanding, and reading English.

Block 2 The procedure for block 2 was nearly identical to block 1, with PM targets (different from those in block 1) presented every 24 trials. The primary difference was that those in the reminder condition were presented with a reminder in yellow text at the top of the screen that read: "Press '7' when you see any animals that start with the letter 'C'."

Attention checks Following the demographic questionnaire and the completion of block 2, participants were required to correctly respond to an attention check (e.g., "press 3 if you are paying attention").

Post-experimental questionnaire block After block 2, participants completed post-experimental questions assessing their retrospective memory for the PM task. They were first asked if they remembered having a secondary task in addition to their lexical decision task, and if so, what were they supposed to do for this secondary task and when. They were then given two Likert scales ranging from 1 to 7 (1 being not at all important, 7 being extremely important) regarding their perception of importance for the lexical decision task and secondary PM task, respectively. They were also asked if they ever pressed the "7" key during the first block, and if so, to explain why.

Recognition test After the post-experimental questionnaire, participants were presented with 16 words, one at a time. They were instructed that some words were seen in the first block of the ongoing task, and other words were not seen in the experiment at all. If they see a word that appeared in the first block of the ongoing task, they were instructed to press the "1" key for "old." If they believed they had never seen the word before, they were instructed to press the "2" key for "new." The recognition items consisted of four PM lures and control-matched words from block 1, along with four new c-animal words and four new control-matched words.

Preregistered dependent variables

Lure interference Lure interference in block 1 was measured by averaging the mean response times to the lure trials and trials immediately following lures (i.e., lure + 1) and comparing that to the average mean responses time to control trials and trials immediately following controls (i.e., control + 1). This variable reflects that spontaneous retrieval might be most evident on the trial immediately *following* the lure trial (Anderson & Einstein, 2017; Rummel et al., 2012). Response time measures were only calculated for trials in which a correct lexical decision was made. Preregistered analyses for only lure and control-matched words (excluding the subsequent trials) can be found in the Online Supplemental Materials (OSM).

PM performance PM performance was measured by calculating the proportion of PM targets (out of four) correctly responded to with the "7" key in block 2. A target not responded to with the "7" key was counted as incorrect (i.e., miss). Late responses within two trials of the target were infrequent and counted as incorrect.

Supplemental analyses

Recognition memory Although preregistered, analyses for recognition memory are presented in the OSM because they are not directly relevant to the purpose of the current study.

Ongoing task performance Analyses for ongoing lexical decision task performance (speed and accuracy) were not preregistered and are presented in the OSM.

Exclusionary criteria

Participants who met any of the following preregistered exclusionary criteria were excluded from analyses: failed either attention check (N = 5), both failed to detect any PM targets and failed to remember the prospective memory task (N = 9), performed below 50% on a math distractor task (N = 3), achieved below 60% accuracy on the ongoing task in block 2 (N = 2), ongoing task response times greater/less than 3 SDs from the group mean in block 2 (N = 1).

Results

Descriptive statistics for Experiment 1 can be found in Table 1 and visual depiction of lure interference can be found in Fig. 1. Although not pre-registered, we also provide exploratory Bayes factor estimates to examine differences across conditions during Block 1. A BF_{10} less than .33 is considered moderate evidence in favor of the null hypothesis (i.e., that the two conditions do not differ) and a BF_{10} greater than 3.0 is considered moderate evidence in favor of the alternative hypothesis (i.e., that the two conditions do differ).

Table 1 Descriptive statistics (standard errors) for Experiment 1

Condition	Block 1		Block 2	
	Lure +1 RT	Control +1 RT	Interference	PM Performance
Reminder	1090 (59)	946 (55)	143 (61)	0.65 (0.03)
No Reminder	1056 (68)	950 (39)	106 (50)	0.47 (0.05)

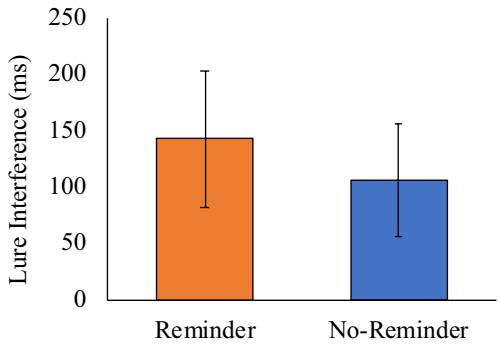

Fig. 1 Lure interference during block 1 of Experiment 1. Error bars reflect standard errors

Lure interference

Response times[2] were submitted to a 2 (Trial Type: lure vs. control; *within-subjects*) × 2 (Condition: reminder vs. no reminder; *between-subjects*) mixed-level ANOVA. There was a main effect of trial type [$F(1, 83) = 9.846$, $p = .002$, $\eta_p^2 = .106$;], meaning that participants slowed down on lure trials relative to control trials (i.e., there was lure interference). There was no effect of condition [$F(1, 83) = .046$, $p = .830$, $\eta_p^2 = .001$] and no interaction between the two [$F(1, 83) = .217$, $p = .643$, $\eta_p^2 = .003$]. Bayesian analyses revealed that there was moderate evidence in favor of the null hypothesis that lure interference did not differ between conditions ($BF_{10} = .184$)**.**

PM performance

Mean performance was submitted to a two-level (*Condition*: reminder vs. no-reminder) between-subjects ANOVA. This analysis revealed that participants in the reminder condition had higher performance than those in the no-reminder condition [*Condition*: $F(1, 90) = 6.975$, $p = .010$, $\eta_p^2 = .072$].

[2] Because response times were only collected on trials in which a correct lexical decision was made, seven participants were excluded from this analysis for not having values for both the lure and the control items.

Discussion

Experiment 1 tested the hypothesis that offloaded intentions would be less likely to be retrieved during the retention interval due to lower levels of residual activation. Although we found that participants were slower to make lexical decisions for PM lures than they were for control-matched words, the amount of slowing (i.e., lure interference) did not differ between reminder and no-reminder conditions. This suggests that the intention was equally active across conditions. Notably, participants in the reminder condition had better PM performance than those in the no-reminder condition (Peper et al., 2023). Together these findings suggest reminders improve PM performance but do not reduce future-oriented thinking. However, because lure interference is an indirect measure of thinking about the intention, Experiment 2 was designed to explicitly measure of future-oriented thinking using thought probes.

Experiment 2

Rummel et al. (2017) periodically inserted thought probes during the retrieval phase that asked participants to indicate if they were just previously thinking about the ongoing task (i.e., ongoing task-related), the PM task (i.e., PM task-related), or things unrelated to the either the ongoing or PM task (i.e., task-unrelated). It was found that task-unrelated thoughts (i.e., mind-wandering) were reduced when participants had an intention in mind compared to when they performed the ongoing task alone, suggesting that participants focus more on task goals when possessing an intention. To explore how offloading influences future-oriented thinking, we randomly inserted thought probes (without lures) in block 1. To increase memory load, participants learned five specific words to respond to during block 2 rather than having a single categorical intention. If reminders reduce future-oriented thinking, we expected participants in the reminder condition would have fewer PM-related thoughts in block 1.

Method

Participants and design

A two-level (reminder vs. no reminder) between-subjects design was employed. A G*Power a priori power analysis

Table 2 Descriptive statistics (standard errors) for Experiments 2 and 3

Experiment	Importance	Reminders	Block 1			Block 2	Post Experimental
			PM Task - Related	Ongoing Task - Related	Task - Unrelated	PM Performance	Perceived PM Importance
2	-	Reminder	0.10 (0.02)	0.79 (0.03)	0.11 (0.02)	0.76 (0.03)	-
	-	No Reminder	0.13 (0.02)	0.76 (0.03)	0.10 (0.02)	0.39 (0.04)	-
3	Ongoing Task	Reminder	0.13 (0.03)	0.77 (0.03)	0.10 (0.02)	0.64 (0.04)	5.27 (0.19)
		No Reminder	0.18 (0.04)	0.68 (0.05)	0.14 (0.03)	0.39 (0.05)	4.97 (0.25)
	PM Task	Reminder	0.25 (0.04)	0.68 (0.04)	0.07 (0.02)	0.73 (0.04)	5.97 (0.16)
		No Reminder	0.22 (0.04)	0.66 (0.05)	0.12 (0.03)	0.36 (0.05)	5.50 (0.23)

effect size ($n_p^2 = .05$) with an alpha of .05 and a power of .80 recommended we use 128 participants (64 participants per condition). A total of 122 undergraduates from the University of Texas at Arlington received credit towards course requirements. Data collection was stopped six participants short of our target goal due to the semester ending. Following participant exclusions (N = 16, described below), there were 52 participants in the reminder condition and 54 in the no-reminder condition. The task was completed in-person in approximately 25 min. The OSF preregistration for Experiment 2 can be found at https://osf.io/xh8d2.

Materials

The materials were similar to those used in Experiment 1. The primary difference was that rather than using c-animal words as PM targets, participants studied five specific words (cove, guild, jargon, slipper, and tincture). Blocks 1 and 2 were also lengthened, so the ongoing task stimuli consisted of 204 words and 204 nonwords.

Procedure

The procedure was similar to Experiment 1. The primary difference was the instructions prior to beginning the PM block. Participants were instructed that they would learn five PM targets and should study each target word for five seconds each. Participants in the reminder condition were aware that all five PM targets would be present at the top of the screen and saw a visual depiction of the reminder presentation prior to beginning block 1. Participants were also instructed that there would be thought probes in block 1 and were shown an example. The thought probes asked participants what they were just thinking about, to which they could choose one of three responses: (1) "I was thinking about making word/nonword judgments" (i.e., *ongoing task-related*), (2) "I was thinking about the studied words or the secondary task" (i.e., *PM-related*), or (3) "I was thinking about things unrelated to the experiment" (i.e., *task-unrelated*). A total of eight thought probes were presented in block 1. In all other regards, the procedure was identical.

Preregistered dependent variables

Thought probes Thought probe measures in block 1 were calculated as the proportional score of each response option (e.g., three PM-related, four ongoing task-related, one task-unrelated) divided by the total number of probes (i.e., eight probes overall). Although we only preregistered analyses for PM-related thoughts, we report all categories for sake of completion.

PM performance PM performance was measured by calculating the proportion of PM targets (out of five) correctly responded to with the "7" key in block 2.

Supplemental analyses

Ongoing task performance Although not preregistered, analyses for ongoing lexical decision task performance (speed and accuracy) are presented in the OSM.

Participant exclusions

Preregistered participant exclusions included: failed attention checks (N = 9), both failed to detect any PM targets and failed to remember the prospective memory task (N = 5), achieved below 60% accuracy in block 2 (N = 1), ongoing task response times greater/less than 3 SDs from the group mean in block 2 (N = 1).

Results

The primary dependent variables were submitted to a two-level (*Condition*: reminder vs. no-reminder) between-subjects ANOVA. Descriptive statistics for Experiment 2 can

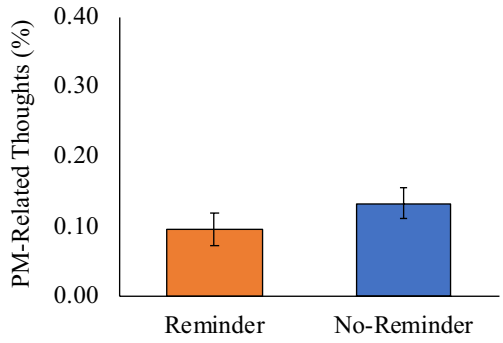

Fig. 2 Prospective memory (PM)-related thinking assessed by thought probes during block 1 of Experiment 2. Error bars reflect standard errors

be found in top half of Table 2 and visual depiction of the frequency of PM-related thoughts can be found in Fig. 2. We also provide exploratory Bayes factor estimates to quantify evidence in favor of the null hypothesis during Block 1.

Thought probes

PM-related There was no difference in PM-related thoughts between conditions [$F(1, 104) = 1.341$, $p = .250$, $\eta_p^2 = .013$]. There was moderate evidence in favor of the null hypothesis ($BF_{10} = .281$).

Ongoing task-related There was no difference in the proportion of ongoing task-related thoughts between conditions [$F(1, 104) = .358$, $p = .551$, $\eta_p^2 = .003$]. There was moderate evidence in favor of the null hypothesis ($BF_{10} = .177$).

Task-unrelated There was no difference in the proportion of task-unrelated thoughts between conditions [$F(1, 104) = .149$, $p = .700$, $\eta_p^2 = .001$]. There was moderate evidence in favor of the null hypothesis ($BF_{10} = .161$).

PM performance

PM performance was significantly higher in the reminder condition than in the no-reminder condition [$F(1, 104) = 57.167$, $p < .001$, $\eta_p^2 = .355$].

Discussion

The hypothesis that offloading would reduce future-oriented thinking was not supported, as reports of PM-related thoughts was similar between conditions. We did, however, replicate the finding from Experiment 1 showing that reminders improve PM performance. One issue with the current procedure was that participants only reported thinking about the PM intentions 10–15% of the time in each condition. Experiment 3 emphasized the importance of the PM intention to see if doing so increased the frequency of future-oriented thinking.

Experiment 3

The purpose of Experiment 3 was to examine the interaction of offloading and task importance on future-oriented thinking. We used the same paradigm as Experiment 2, but participants were either instructed to focus primarily on the ongoing lexical decision task (ongoing task importance) or on remembering the words they encoded (PM task importance; Ball & Aschenbrenner, 2018). Rummel et al. (2017) showed that increasing motivation to fulfill PM intentions by providing monetary rewards for each PM target detected increased PM-related thoughts during the retrieval phase. Accordingly, without reminders, we expected greater PM-related thoughts in the retention interval (i.e., block 1) when the importance of the PM intention was emphasized compared to when the ongoing task emphasized. With reminders, however, we expected little to no difference in PM-related thoughts between the two importance conditions if reminders reduce the need to represent the intention.

Method

Participants and design

A 2 (*Reminders*: reminder vs. no reminder) × 2 (*Importance*: ongoing task vs. PM task) between-subjects design was employed. A power analysis to detect a medium-sized interaction effect at alpha = 0.05 and power = 0.80 requires 32 participants per condition. To probe the critical interaction based on large effect size between two independent factors at alpha = 0.025 and power = 0.80, the power analysis recommended 31 participants in each group. We chose to run 40 participants in each condition. A total of 168 undergraduates from the University of Texas at Arlington received credit towards course requirements. The final sample following exclusions (N = 15, described below) in each condition included 36 in the ongoing task no-reminder, 40 in the ongoing task reminder, 40 in the PM task no-reminder, and 37 in the PM task reminder conditions. The task was completed in-person in approximately 25 min. The OSF preregistration for Experiment 3 can be found at https://osf.io/k62e9.

Materials

The materials were identical to those used in Experiment 2.

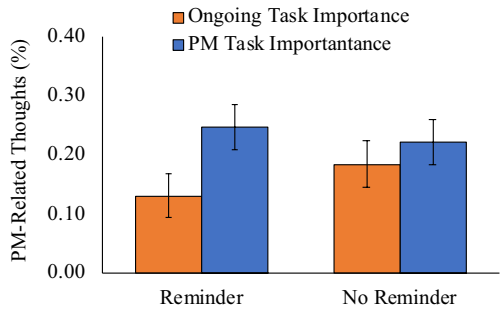

Fig. 3 Prospective memory (PM)-related thinking assessed by thought probes during block 2 of Experiment 3. Error bars reflect standard errors

Procedure

The procedure was similar to Experiment 2. The primary difference was the instructions prior to forming the PM intention. Participants were either instructed that it was more important to perform the ongoing task as quickly/accurately as possible than it was to detect PM targets (ongoing task importance condition) or that it was more important to detect PM targets than to do well on the ongoing task (PM task importance condition). In all other regards, the procedure was identical.

Preregistered dependent variables and supplemental analyses

Dependent variables and analyses were identical to those of Experiment 2, with the addition of the perceived PM task importance rating.

Perceived PM importance At the end of the task, participants were asked to rate how important they perceived completing the PM task was (1 = not at all important, 7 = very important). Although not preregistered, we analyze these results below.

Participant exclusions

Preregistered participant exclusions included: failed attention checks (N = 8), both failed to detect any PM targets and failed to remember the prospective memory task (N = 2), achieved below 60% accuracy in Block 2 (N = 3), ongoing task response times greater/less than 3 SDs from the group mean in Block 2 (N = 2).

Results

The primary dependent variables were submitted to a 2 (*Reminders*: reminder vs. no reminder) × 2 (*Importance*: ongoing task vs. PM task) between-subjects ANOVA. Descriptive statistics for Experiment 3 can be found in the bottom half of Table 2 and visual depiction of the frequency of PM-related thoughts can be found in Fig. 3.

Thought probes

PM-related There were marginally more PM-related thoughts in the PM task importance condition than the ongoing task importance condition [*Importance:* $F(1, 149) = 3.892$, $p = .050$, $\eta_p^2 = .025$]. There was no effect of reminders [*Reminders:* $F(1, 149) = .130$, $p = .719$, $\eta_p^2 = .001$] and no interaction between the two [*Reminders*Importance:* $F(1, 149) = .996$, $p = .320$, $\eta_p^2 = .007$]. There was moderate evidence in favor of the null hypothesis that PM-related thoughts did not differ between reminder conditions ($BF_{10} = .138$).

Ongoing task-related For ongoing task-related thoughts, there was no effect of reminders [*Reminders:* $F(1, 149) = 1.465$, $p = .228$, $\eta_p^2 = .010$], no effect of importance [*Importance:* $F(1, 149) = 1.190$, $p = .277$, $\eta_p^2 = .008$], and no interaction between the two [*Reminders*Importance:* $F(1, 149) = .586$, $p = .445$, $\eta_p^2 = .004$]. There was moderate evidence in favor of the null hypothesis that ongoing task-related thoughts did not differ between reminder conditions ($BF_{10} = .268$).

Task-unrelated For task-unrelated thoughts, there was no effect of reminders [*Reminders:* $F(1, 149) = 2.050$, $p = .154$, $\eta_p^2 = .014$], no effect of importance [*Importance:* $F(1, 149) = .974$, $p = .325$, $\eta_p^2 = .006$], and no interaction between the two [*Reminders*Importance:* $F(1, 149) = .025$, $p = .874$, $\eta_p^2 = .000$]. There was moderate evidence in favor of the null hypothesis that task-unrelated thoughts did not differ between reminder conditions ($BF_{10} = .318$).

PM performance

PM performance was higher with reminders than without [*Reminders*: $F(1, 149) = 42.631$, $p < .001$, $\eta_p^2 = .222$]. However, there was no effect of importance [*Importance:* $F(1, 149) = .280$, $p = .579$, $\eta_p^2 = .002$] and no interaction between the two [*Reminders*Importance:* $F(1, 149) = 1.849$, $p = .176$, $\eta_p^2 = .012$].

Manipulation check

Perceived PM importance ratings at the end of the experiment were higher in the PM task importance condition than the ongoing task importance condition [*Importance:* $F(1, 149) = 8.470$, $p = .004$, $\eta_p^2 = .054$]. There was no effect or reminders [*Reminders:* $F(1, 149) = 3.396$, $p = .067$, $\eta_p^2 = .022$] and no interaction between the two [*Reminders*Importance* $F(1, 149) = 0.163$, $p = .687$, $\eta_p^2 = .001$].

Discussion

Results showed that emphasizing the importance of the PM task increased the frequency of PM-related thoughts in block 1 (albeit marginally, $p = .05$) and perceived importance of the PM task in the post-experimental questionnaire. Despite these findings, we did not see the anticipated difference between reminder conditions in the frequency of future-oriented thinking in block 1. We reasoned that if offloading reduced the need to represent the intention during the retention interval, we would only see an effect of importance in the no-reminder condition, which was not the case. These findings are, however, consistent with the results of Experiment 2 showing that reminders do not influence PM-related thinking.

We did not find the anticipated improvements to PM performance when the intention was emphasized. Notably, prior studies showing an influence of importance do not typically include a retention interval (block 1) and have either used monetary incentives (e.g., Rummel et al., 2017) or similar instructions but with an attentional demanding nonfocal intention (e.g., Kliegel et al., 2004). Future research is needed to determine whether the type of intention and/or the nature of the importance instructions differentially influences performance. Critically, we replicate Experiment 2 in that reminders do not influence future-oriented thinking in block 1 but do improve PM target detection in block 2.

General discussion

The current study was designed to assess how offloading influences future-oriented thinking outside the context in which the intention can be fulfilled. If the memory representation is externalized, this should reduce the need to periodically refresh or rehearse the intention (Risko & Gilbert, 2016). For example, writing down a list of plans for the following day before going to bed should reduce the need to ruminate on those thoughts prior to falling asleep or setting a calendar reminder in the morning about needing to study in the afternoon should reduce the need to rehearse the intention throughout the day (Scullin et al., 2018). To test this idea, participants formed an intention associated with a future context (block 2) and we assessed lure interference (Experiment 1) and thought probe responses (Experiments 2 and 3)[3] during the intervening context (block 1). The results showed that the intention was indeed activated to some degree during block 1, with slower responding to PM lures suggesting that the intention was retrieved (Knight et al., 2011) and reports of PM-related thoughts on ~20% of the probes. However, there was no evidence that this activation differed between conditions in which the memory representation was or was not offloaded. That said, reminders consistently produced better PM performance in block 2, suggesting that offloading is an effective means for ensuring intention fulfillment (Gilbert et al., 2023).

There are several possibilities for why we did not find significant differences in future-oriented thinking between conditions. One important thing to consider is the nature of the PM representation, which consists of two components. The *prospective* component of PM refers to the attention processes involved in becoming aware that an intended action should be initiated (i.e., remember *to* remember), whereas the *retrospective* component refers to the memory processes involved in remembering the contents of the intention (i.e., remembering *what* to remember; Einstein & McDaniel, 1990). Landsiedel and Gilbert (2015) had participants complete a PM task with or without the use of reminders while brain activity was measured in the scanner during the retrieval phase. Interestingly, they found that reminders reduced activation in brain regions associated with remembering *what* to remember (i.e., retrospective component), but not in areas associated with remembering that *something* needed to be done (i.e., prospective component). In the current study, participants may have offloaded the contents of the intention yet still maintained the prospective component[4] throughout the retention interval, meaning that the intention was in an equally accessible state in both conditions.

Another important thing to consider is the intentionality of the memory maintenance during the retention interval. The intention superiority effect refers to the finding that PM intentions reside in memory at a higher level of activation than retrospective memories (Goschke & Kuhl, 1993). Although this is largely considered to be automatic, some research has found that participants use the storage interval to rehearse the intention (Hicks et al., 2000). Lure interference likely reflects automatic thinking of the intention, as

[3] Although not preregistered, we combined the data from Experiments 2 and 3 to analyze thought probe responses and found the same pattern of results (see OSM).

[4] Maintenance of the prospective component is sometimes referred to as a *prospective retrieval mode* (Guynn, 2003).

it has been suggested to reflect the automatic retrieval of an intention following discrepant processing associated with encountering lures (Anderson & Einstein, 2017; Knight et al., 2011). In contrast, thought probe response could reflect either unintentional (e.g., spontaneous retrieval) or intentional (e.g., strategic rehearsal) processes. Notably, previous research on episodic future thinking and mind-wandering suggests that much of our future-oriented thinking occurs unintentionally (for a review, see Kvavilashvilli & Rummel, 2020). One possibility is that reminders only reduce intentional thinking about the PM task, while unintentional activation of the intention occurs automatically, perhaps as a functional backup in case that reminders fail (Peper & Ball, *submitted*). Future work exploring the intentionality of these thoughts might provide greater insights into the role of offloading on future-oriented thinking (Rummel et al., 2017).

Lastly, previous research shows that participants encode information less effortfully when they know that reminders will subsequently be available (Kelly & Risko, 2019, 2022; Peper, & Ball, *submitted*). To ensure equal initial encoding between conditions in the current study, it was not until the intention had already been formed that the reminder condition was made aware of the fact that reminders would be available later (see also Peper et al., 2023). However, many everyday intentions are likely formed knowing that they will be offloaded, in which case, they may be less frequently retrieved during the retention interval. However, this could reflect a difference in initial storage strength due to less effortful encoding rather than offloading per se. It is also possible that some participants in the reminder conditions planned to maintain the intention internally rather than relying on reminders (Ball & Peper, *submitted*), which would reduce the likelihood of finding differences in future-oriented thinking between the reminder and no reminder conditions. Future studies should explicitly query participants on whether they had planned to use reminders after forming the intention and whether this differs for different types of reminders.

Conclusions

We often have multiple things to remember, which can interfere with ongoing activities. The results from the current study show that offloading does not necessarily influence future-oriented thinking during the retrieval interval, yet it is still effective at improving PM target detection during the retrieval phase. Although we did not find differences here, future research may further explore different paradigms for assessing the effect of offloading on the intentionality of future-oriented thoughts and how offloading interventions may be used to reduce ruminative thoughts.

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Preregistered documents can be found at https://osf.io/rfktn (Exp 1), https://osf.io/xh8d2 (Exp 2) and https://osf.io/k62e9 (Exp 3). Data for all experiments can be found at https://osf.io/zg8ph/.

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