AMERICAN PSYCHOLOGICAL ASSOCIATION

Journal of Experimental Psychology: Learning, Memory, and Cognition

ISSN: 0278-7393

https://doi.org/10.1037/xlm0001154

After-Effects of Responding to Activated and Deactivated Prospective Memory Target Events Differ Depending on Processing Overlaps

Beat Meier[1] and Milvia Cottini[2]

[1] Institute of Psychology, University of Bern

[2] Faculty of Education, Free University of Bolzano-Bozen

Responding to a prospective memory task in the course of an ongoing activity requires switching tasks, which typically comes at a cost in performing the ongoing activity. Similarly, when the prospective memory task is deactivated, a cost can occur when previously relevant prospective memory targets appear in the course of the ongoing activity. In three experiments with undergraduate student participants (N = 226), in which cue focality was manipulated as a function of processing overlaps, we investigated the after-effects of activated and deactivated prospective memory target events. We predicted that lower focality results in stronger after-effects when the prospective memory task is activated but in weaker after-effects when the prospective memory task is deactivated. In contrast, we predicted that higher focality results in weaker after-effects when the prospective memory task is activated but in stronger after-effects when the prospective memory task is deactivated. For activated prospective memory, the pattern of results conformed to the expectations. For deactivated prospective memory, after-effects occurred only under high process overlap situations in a zero-target condition, in which participants were instructed for the prospective memory task, but never had the opportunity to perform it, indicating the special representational status of uncompleted intentions. We discuss these findings within the process overlap framework, which allows more fine-grained distinctions than the focal versus nonfocal dichotomy.

Keywords: intention memory, unfulfiled intentions, parallel overlap, sequential overlap, bivalency

Prospective memory refers to the ability to plan an intention, to retain it while being engaged in other activities, to retrieve and execute it at the appropriate occasion, and to deactivate it when it is completed. A typical example of a prospective memory task is remembering to buy groceries on the way home from work in the evening after having formed this plan in the morning. In order to investigate prospective memory under controlled laboratory conditions, a prospective memory task is embedded in an ongoing task; for example, pressing a specific key on a computer keyboard when a particular word occurs during a lexical-decision task (LDT). Research has shown that having a prospective memory intention in mind can be costly to the ongoing task because participants are monitoring for prospective memory targets (Einstein & McDaniel, 2005; Smith, 2003). Monitoring costs have attracted a lot of attention in recent years, resulting in important hypotheses and theoretical advances about the nature of the retrieval processes involved in prospective memory (Anderson et al., 2019; Einstein & McDaniel, 2010; Heathcote et al., 2015; Smith, 2003; Smith et al., 2007; Strickland et al., 2018).

Importantly, other kinds of costs can occur in prospective memory tasks. For example, a cost can occur because the execution of the prospective memory task requires switching from the ongoing task to the prospective memory task and back to the ongoing task, resulting in costly after-effects of responding to the prospective memory task (Meier & Rey-Mermet, 2012, 2018). Moreover, a cost can occur after the prospective memory task is finished. If participants are instructed that it is no longer relevant to perform the intention, former prospective memory targets tend still to affect performance (Bugg & Scullin, 2013; Scullin et al., 2009, 2011; Walser et al., 2012, 2014). These kinds of costly after-effects are the focus of the present study. We specifically test whether after-effects of responding to activated intentions and after-effects of responding to deactivated intentions are expressed differently depending on the degree of processing overlaps between the prospective memory task and the ongoing task.

So far, the impact of processing overlaps has been mainly investigated in relation to prospective memory performance and to monitoring costs. When the overlap between the processing operations required for noticing the target event and for performing the ongoing task is high—for example, when the prospective memory target is defined as the word "CAT" in an ongoing LDT—prospective memory performance is high, but costs are low. In contrast, when the overlap between processing operations required for the

Beat Meier https://orcid.org/0000-0003-3303-6854
Milvia Cottini https://orcid.org/0000-0003-4906-9407

We thank Sabine Lehmann for recruiting and testing the participants. The data of the study are available on https://osf.io/kgtsb/?view_only=d62a0e251d6e47a89e096d46ec170d18.

Correspondence concerning this article should be addressed to Beat Meier, Institute of Psychology, University of Bern, Fabrikstr. 8, 3012 Bern, Switzerland. Email: beat.meier@unibe.ch

target event and the ongoing task is low—for example, when the prospective memory target is defined as a word containing the syllable "ENT" in an ongoing LDT—costly monitoring is required for prospective memory target detection, expressed as a slowing in ongoing LDT performance (Anderson et al., 2019; Einstein & McDaniel, 2005). According to the multiple process view, monitoring is necessary in situations of low overlap, while spontaneous retrieval occurs in high overlap situations such that no cost occurs at all in the ongoing task (McDaniel & Einstein, 2000; Scullin et al., 2013; Shelton & Scullin, 2017). In contrast, the monitoring view argues that after intention formation, effortful preparatory monitoring processes are always required for successful prospective memory target performance (Smith, 2003) and according to the delay view, ongoing task costs represent a strategic adjustment to participants' response caution (Heathcote et al., 2015; Loft & Remington, 2013; Strickland et al., 2018, 2021). Investigating after-effects of responding to activated and to deactivated intentions allows for a more fine-grained assessment of costs that occur in prospective memory tasks and thus contributes to understanding the processes involved in prospective memory. Specifically, after-effects represent a cost that is stimulus-driven rather than due to a proactive adjustment to the prospective memory requirements such as monitoring costs.

So far, only very few studies have looked into the after-effects of responding to prospective memory target events. Meier and Rey-Mermet (2012, 2018) used a task-switching paradigm as an ongoing task and tested whether prospective memory targets would result in similar costs as bivalent stimuli that are more typically used in task-switching research (cf. Grundy & Shedden, 2014; Meier et al., 2009; Metzak et al., 2013; Woodward et al., 2003). Bivalent stimuli are stimuli that carry features relevant for more than one task. In a typical prospective memory experiment for example, the word "CAT" can be used as a stimulus for an ongoing LDT requiring a "word" response, or as a prospective memory target requiring a prospective memory response. The results of Meier and Rey-Mermet (2012, 2018) showed substantial slowing immediately after responding to a prospective memory target indicating their bivalent nature. Moreover, the endurance of the slowing increased with the amount of features that were shared between the prospective memory targets and the ongoing task stimuli, that is, with the number of tasks that were activated by the particular prospective memory targets. In the most difficult condition, the ongoing task slowing was lingering for several subsequent trials, up to 30 seconds after performing the prospective memory task (Meier & Rey-Mermet, 2018). These results indicate that when more cognitive resources are required to switch between the ongoing task and the prospective memory task, the after-effects of responding to a prospective memory task become larger. Notably, however, even in the least demanding situation after-effects occurred, most likely due to the bivalent nature of the prospective memory target. In line with these results, we hypothesized that after-effects of responding to a prospective memory task with a high processing overlap (e.g., focal cues) should be small due to low resource demands to switch tasks. In contrast, after-effects of responding to nonoverlapping prospective memory targets (e.g., nonfocal cues) should result in larger after-effects.

Compared to the small number of studies that have addressed after-effects of responding to activated prospective memory tasks, a larger body of research has looked into the after-effects of deactivated prospective memory tasks (see Möschl et al., 2020; Streeper & Bugg, 2021; for recent reviews). In general, two different paradigms are typically used. In the *finished paradigm*, participants are first instructed for a prospective memory task. After performing some ongoing task trials that may or may not have included prospective memory target events, participants are informed that the prospective memory task is over. Then they have to perform further ongoing task trials with some of them containing "deactivated" prospective memory targets (Scullin et al., 2009, 2012). In situations of high process overlaps and with salient cues, commission errors can occur, that is participants still perform erroneously the prospective memory task (Bugg & Scullin, 2013; Scullin et al., 2012). Interestingly, this tendency is even higher for participants who did not have the opportunity for performing the prospective memory task at all (Bugg et al., 2016; Scullin & Bugg, 2013; Streeper & Bugg, 2021). Moreover, older adults and children, but not young adults, perform slower on deactivated prospective memory targets (Cottini & Meier, 2020; Scullin et al., 2011, 2012). Notably, after-effects do not seem to materialize when processing overlaps are low (e.g., nonfocal cues; Cohen et al., 2017). As low processing overlap situations require monitoring for target detection, and monitoring is not functional after the prospective memory task is finished, this is indirect evidence that in high overlap situations, after-effects are due to spontaneous retrieval of the intention. In the *repeated cycles paradigm*, a series of prospective memory tasks is given across several blocks such that in each block a formerly relevant (i.e., deactivated) prospective memory target and/or a new prospective memory target is presented (Walser et al., 2012, 2014, 2017). With this paradigm, the results show that responding to the deactivated prospective memory target is slowed, but commission errors occur very seldom. Due to the regular refreshing of the prospective memory task, monitoring is repeatedly functional and thus the slowing is likely due to both monitoring and spontaneous retrieval of the intention. In the present study, we are interested in the effects of spontaneous retrieval of deactivated intentions rather than in the effects of monitoring, thus we focus on the finished paradigm.

Spontaneous retrieval is stimulus-triggered and occurs without intention (Einstein & McDaniel, 2005; McDaniel & Einstein, 2000; Meier et al., 2006). It is assumed that under situations of high processing overlap, encountering the prospective memory target reflexively brings to mind the associated prospective memory intention (reflexive-associative hypothesis; see McDaniel et al., 2004). Importantly, it is possible that this retrieval process is initiated only after an ongoing task response has already been given, which would result in a somewhat delayed ongoing task slowing, that is, an after-effect of after-effect (cf. Rummel et al., 2012). Phenomenological reports indicate that participants sometimes respond to the ongoing task before realizing the nature of the deactivated prospective memory target and thus intention-related thoughts may occur somewhat delayed (Anderson & Einstein, 2017). Delayed rather than immediate slowing would also explain why correctly responding to deactivated prospective memory targets (i.e., prospective memory lures) is typically not slowed in the finished paradigm (Cottini & Meier, 2020; Scullin et al., 2011; but see Anderson & Einstein, 2017, for an exception). Moreover, delayed slowing provides a direct link to the lingering after-effects of responding to activated prospective memory targets, which has been related to an adjustment of cognitive control after experiencing a cognitive conflict due to the bivalent nature of the prospective memory targets (Meier & Rey-Mermet, 2012, 2018).

As deactivated prospective memory targets may still carry bivalency, we hypothesized that they may still be costly for subsequent performance. However, in contrast to the expected pattern of after-effects of responding to activated prospective memory targets, we predicted that after-effects of deactivated prospective memory targets would be larger when processing overlaps are high (e.g., for focal cues) rather than when processing overlaps are low. This expectation is based on the idea that when processing overlaps are low, costly monitoring is necessary for target detection. Because after the deactivation of the intention, monitoring is not functional anymore, the likelihood of detection of deactivated targets is lower, and in consequence, the likelihood of after-effects is reduced. In contrast, when processing overlaps are high, reflexive-associative processes are triggered, and this should result in after-effects of responding to deactivated targets through spontaneous retrieval of the intention.

The Present Study

We conducted three experiments, which differed in the amount of processing overlap between the ongoing task and the prospective memory task. The series of activities for each experiment is listed in Table 1. Each experiment consisted of three conditions: In the ProM condition, participants were given prospective memory task instructions and later, in the active phase prospective memory targets appeared. This phase is critical for the analysis of after-effects of responding to activated prospective memory targets. After the active phase, participants were instructed that the prospective memory task is finished and that another block of the ongoing task is administrated. Critically, in this block (i.e., the deactivation phase), formerly relevant prospective memory targets appeared as lures. This phase is relevant for the analysis of after-effects of correctly responding to deactivated prospective memory targets. In a second condition, the zero-target condition, participants were given prospective memory task instructions but in the active phase, no prospective memory targets appeared. However, in the deactivation phase, the formerly relevant prospective memory targets appeared as lures in the exact same manner as in the ProM condition. The zero-target condition is the critical condition to test after-effects of correctly responding to deactivated prospective memory targets as it has been demonstrated that these kinds of after-effects are stronger after never having performed the prospective memory task (e.g., Bugg & Scullin, 2013). In the third condition, the control condition, participants were not given prospective memory task instructions but the same stimuli appeared as in the ProM condition. This control condition is informative regarding monitoring costs and it also serves as a control for unspecific stimulus-related after-effects that are not due to the prospective memory instructions.

Table 1
Ordering of Activities and Use of Materials for Each Experiment (ProM Condition)

Activity	# of trials
Ongoing task instruction	
Practice	10 Trials
Block 1: Baseline	100 Trials
Prospective Memory task instruction (active phase)	
Block 2: Ongoing task	100 Trials
Block 3: Ongoing task with 6 embedded targets	106 Trials
Block 4: Ongoing task	100 Trials
Deactivation instruction (deactivated phase)	
Block 5: Ongoing task with 6 embedded lures	106 Trials

In each experiment, the prospective memory task was embedded in an ongoing lexical-decision task. In Experiment 1, the prospective memory targets were defined as letter strings containing the syllable *ENT*. As ongoing task processing requires semantic processing of the letter string in order to make a word/nonword decision and the extraction of the syllable ENT requires perceptual processes this condition is considered as a nonoverlap or low overlap processing condition (i.e., with nonfocal targets). In Experiment 2, the prospective memory targets were defined as words belonging to the category of animals. As both the lexical decision and the prospective memory task require semantic processing, this condition is a high process overlap condition, containing parallel overlap (also termed "task-appropriate processing," Marsh et al., 2000; Maylor, 1996; McBride & Abney, 2012; Meier & Graf, 2000; Meiser & Schult, 2008). In Experiment 3, the prospective memory targets were defined as the word CAT. Because this specific word was presented already in the instructions, this kind of prospective memory target contains a sequential overlap (Meier & Graf, 2000). Moreover, as both the lexical decision and the prospective memory task require semantic processing, this condition also involves a parallel overlap between the ongoing task and the prospective memory task. Thus, compared to Experiment 2, Experiment 3 represents even a higher processing overlap (i.e., with focal targets).

Experiment 1

Method

Participants

Eighty students from the University of Bern participated in Experiment 1. They were recruited from the subject pool of the institute and consisted of undergraduate psychology students (*M* age 21.9 years; 68.8% female, 18.8% male, 12.5% not specified). They received credit for participating, which is part of the requirement of the curriculum. They were pseudorandomly assigned to one of three conditions, the ProM condition ($n = 40$), the zero-target condition ($n = 20$), or the control condition ($n = 20$). Sample size is based on our previous studies on after-effects of responding to activated intentions (Meier & Rey-Mermet, 2012, 2018), in which we tested 20 participants per condition. As the ProM condition is crucial for the analysis of after-effects of responding to prospective memory targets, and because based on previous experiments we expected that not all participants would perform the prospective memory task, particularly with nonoverlapping prospective memory targets, we doubled the number of participants in this condition. The study was approved from the ethics commission of the faculty.

Materials

For the ongoing lexical-decision task 255 German medium- to high-frequency words were selected from the CELEX-database, each consisting of five to eight letters (Baayen et al., 1993). Two hundred and 55 nonwords were created by keeping the first and the last letter of a word while randomizing the other letters. Two additional lists of six words were used as prospective memory targets and as placeholders. The prospective memory targets were defined as letter strings containing the syllable ENT. Specifically, the following stimuli were used: EIGENTUM, MENTOR, AGENTUR, GENTSAG, FLENTOE, SDENTU, with the first three targets representing words and the other three representing nonwords. For the zero-target condition, these stimuli were replaced in the active phase with the following six prospective memory placeholders: GEIGE, HORN, GITARRE, POSAUNE, KLAVIER, TROMPETE (English: violin, horn, guitar, trombone, piano, trumpet). For the control condition, the same stimuli were used as for the ProM condition.

Procedure

Participants were tested individually. After arrival in the laboratory, they were seated in front of a computer and gave informed consent. The ordering of experimental activities is outlined in Table 1. First, participants received the instructions for the lexical-decision task, that is, they were asked to press the *B*–key for a word and the *N*–key for a nonword with their left and right index fingers on the computer keyboard. Next, a brief practice phase consisting of 10 lexical decision trials was given. For each trial of the lexical-decision task, a fixation point was presented for 500 ms, followed by a word or a nonword. Each stimulus was selected randomly and remained on the screen for 5 seconds or until the participant responded by pressing one of the designated keys.

After a screen with the question "Are you ready to continue?," the ongoing task baseline was administered (100 trials; see Table 1). For the ProM condition and the zero-target condition, the prospective memory task instruction was given next. Specifically, participants were instructed to press the *Q*-key whenever a word containing the syllable ENT appeared on the screen. The instruction emphasized to press the *Q*-key immediately, that is, instead of performing the ongoing task. An example was shown and the participants were asked to repeat back the instructions in their own words to make sure they understood. For the control condition, another screen with the question "Are you ready to continue?" appeared. The next phase consisted of a series of 306 ongoing task trials. This phase contained three blocks of 100 ongoing task trials, with an additional six trials in the middle block. For the ProM condition, in the middle block a total of six prospective memory targets appeared while these stimuli were replaced with six other stimuli (i.e., placeholders) for the zero-target condition. Between two subsequent prospective memory targets (and their placeholders), between 15 and 20 ongoing task trials were interspersed. There was no break between the three blocks (see Table 1). After this phase, participants in the ProM condition and the zero-target condition were informed that the prospective memory task was finished and that next another series of the lexical-decision task has to be performed. The specific instructions were as follows: "Now, we proceed to the last part of this experiment. The additional task is not relevant anymore, that is, you should not press the Q-key anymore when a word containing the syllable ENT appears on the screen. As at the very beginning, your only task is to decide, as quickly as possible, whether the letter string is a word or not by pressing the *B*-key for a word and the *N*-key for a nonword." For the control condition, another screen with the question "Are you ready to continue?" appeared. In this phase, the same six prospective memory targets were embedded in another series of 106 lexical-decision task trials except for the zero-target condition for which these prospective memory lures occurred for the first time. At the end of the experiment, a manipulation check interview was conducted. Participants were asked to describe what they were supposed to do. We specifically assessed whether participants in the ProM condition and in the zero-target condition remembered the prospective memory task. All the participants remembered the instructions correctly. The whole experiment lasted about 25 minutes.

Data Analyses

Prospective memory performance was calculated as the proportion of correct prospective memory responses (out of six). In line with the previous studies, we focused on after-effects on the five trials following a prospective memory response (Meier & Rey-Mermet, 2012, 2018). After-effects of responding to activated prospective memory target events were calculated as the reaction time (RT) difference between the first five trials after a correct prospective memory response and the mean of the five trials before presentation of the prospective memory target. This allowed taking into account individual differences in response time. Moreover, it also allowed calculating after-effects of responding to prospective memory placeholders in the zero-target condition and in the control condition accordingly. Performance on deactivated prospective memory target events was assessed in terms of accuracy (commission errors) and response times. After-effects of correctly responding to deactivated prospective memory targets was calculated as the difference between the RTs of the first five trials after a correct response to deactivated prospective memory targets and the mean of the five trials before presentation of the deactivated prospective memory target for both the ProM condition and the zero-target condition. Again, this allowed taking into account individual differences in response time and it allowed calculating after-effects of responding to prospective memory placeholders in the control condition in order to rule out any unspecific stimulus effects. For the sake of completeness, the response times on which the calculation of these after-effects is based are presented in the Appendix.

Across all blocks, ongoing task performance was assessed in terms of accuracy and reaction times (RTs) to lexical decisions. For RT analysis, only correct responses were used. We elected not to trim responses in order to avoid exacerbating the problem of having a low number of observations to calculate after-effects. For the sake of comparability, we also used untrimmed data for all other RT means. Monitoring costs were calculated as the difference between Block 2 (i.e., after the prospective memory instructions, but before the occurrence of any prospective memory target) and Block 1 (i.e., before the prospective memory instructions were given; see Table 1).

For all statistical analyses, an alpha level of .05 was used, η_p^2 values are reported as effect sizes. Bonferroni corrections were used for post-hoc comparisons; *p*-values for which the Bonferroni-corrected alpha level applies are denoted as *p**. Greenhouse-Geisser adjustments are used where appropriate. The data of the study are available on https://osf.io/kgtsb/?view_only=d62a0e251d6e47a89e096d46ec170d18.

Results

Prospective Memory Performance and After-Effects of Responding to Activated Prospective Memory Targets

Proportion of correct prospective memory responses (out of 6) was .33 (*SD* = .29). Two participants responded correctly to all six targets, one responded to five targets, six responded to four targets, five responded to three targets, nine responded to two targets, six responded to one target and 11 did not respond to any prospective memory target. Thus, for the analysis of after-effects of responding, 29 out of 40 participants in the ProM condition could be included. Trajectory of after-effects was compared to the zero-target condition and the control condition with 20 participants each.

After-effects of responding to activated prospective memory targets were calculated as difference between mean performance on the five ongoing task trials before each prospective memory target and the five ongoing task trials following each prospective memory target. For the zero-target and the control condition after-effects of responding to prospective memory placeholders were calculated accordingly. The results are depicted in Figure 1A. A positive value denotes a cost of having responded to the prospective memory target, a value around zero indicates similar response times throughout. A visual inspection indicates a strong after-effect for the ProM condition, in particular for the first trial after responding to the prospective memory target (ProM + 1, $M = 477$ ms) and a lingering after-effect on the following trials (ProM + 1 and ProM + 3). An analysis of variance (ANOVA) with the between-subjects factor condition (ProM, zero-target, control) and the within-subjects factor position (ProM + 1, ProM + 2, ProM + 3, ProM + 4, and ProM + 5) revealed a Condition × Position interaction $F(4.94, 163.04) = 3.46$, $p = .006$, $\eta_p^2 = .10$. The effect of condition was also significant, $F(2, 66) = 10.77$, $p < .001$, $\eta_p^2 = .25$, while the effect of position was not, $F(2.47, 163.04) = 2.23$, $p = .10$, $\eta_p^2 = .03$. The main effect of condition was due to a difference in after-effects between the ProM condition and both the zero-target condition, $t(47) = 4.36$, $p^* < .001$, and the control condition, $t(47) = 3.14$, $p^* =. 013$, while the latter two conditions did not differ, $t(38) = –2.65$, $p^* = .518$.

To follow up on the significant Condition × Position interaction, we compared the after-effects for each position separately. The one-way ANOVA revealed a significant after-effect on ProM + 1, $F(2, 66) = 13.62$, $p < .001$, $\eta_p^2 = .29$. The after-effect differed between the ProM condition and both the zero-target condition, $t(47) = 4.01$, $p^* < .001$, and the control condition, $t(47) = 3.34$, $p^* = .001$, whereas the latter two conditions did not differ, $t(38) = –2.06$, $p^* = 1.00$. The ANOVA on ProM + 2 gave a marginal significant effect, $F(2, 66) = 3.13$, $p = .05$, $\eta_p^2 = .09$, and posthoc tests revealed a significant difference between the ProM condition and the zero-target condition, $t(47) = 2.17$, $p^* = .045$. The differences between the ProM condition and the control condition and between the zero-target and the control condition were not significant, $t(47) = 1.10$, $p^* = .71$, and $t(38) = –1.90$, $p^* = .71$, respectively. The ANOVAs on the following positions (ProM + 3, ProM + 4, ProM + 5) showed no significant effects (all *F*s < 1.48, all *p*s > .10).

After-Effects of Responding to Deactivated Prospective Memory Targets

Proportion of correct responses to deactivated prospective memory targets (out of 6) was .96 (*SD* = .08) for the ProM condition, .98 (.08) for the zero-target condition, and .97 (*SD* = .07) for the control condition. Participants did not make any commission errors. To test for a potential slowing effect (intention interference) in correctly responding to the deactivated prospective memory targets (i.e., ProM lures), we carried out an analysis of covariance (ANCOVA) with the mean ongoing task reaction times of deactivated Block 5 as a covariate. The covariate was significantly related to response times for deactivated prospective memory targets (and their placeholders in the control condition, respectively), $F(1, 76) = 251.66$, $p < .001$, $\eta_p^2 = .77$. However, there was no difference between the three experimental conditions (ProM, zero-target, control condition), $F(2, 76) = 1.11$, $p = .335$, $\eta_p^2 = .03$. The specific values for the estimated deactivated prospective memory target RTs after controlling for mean block performance were 724 ms, 704 ms, and 683 ms, for the ProM condition, zero-target condition, and control condition, respectively.

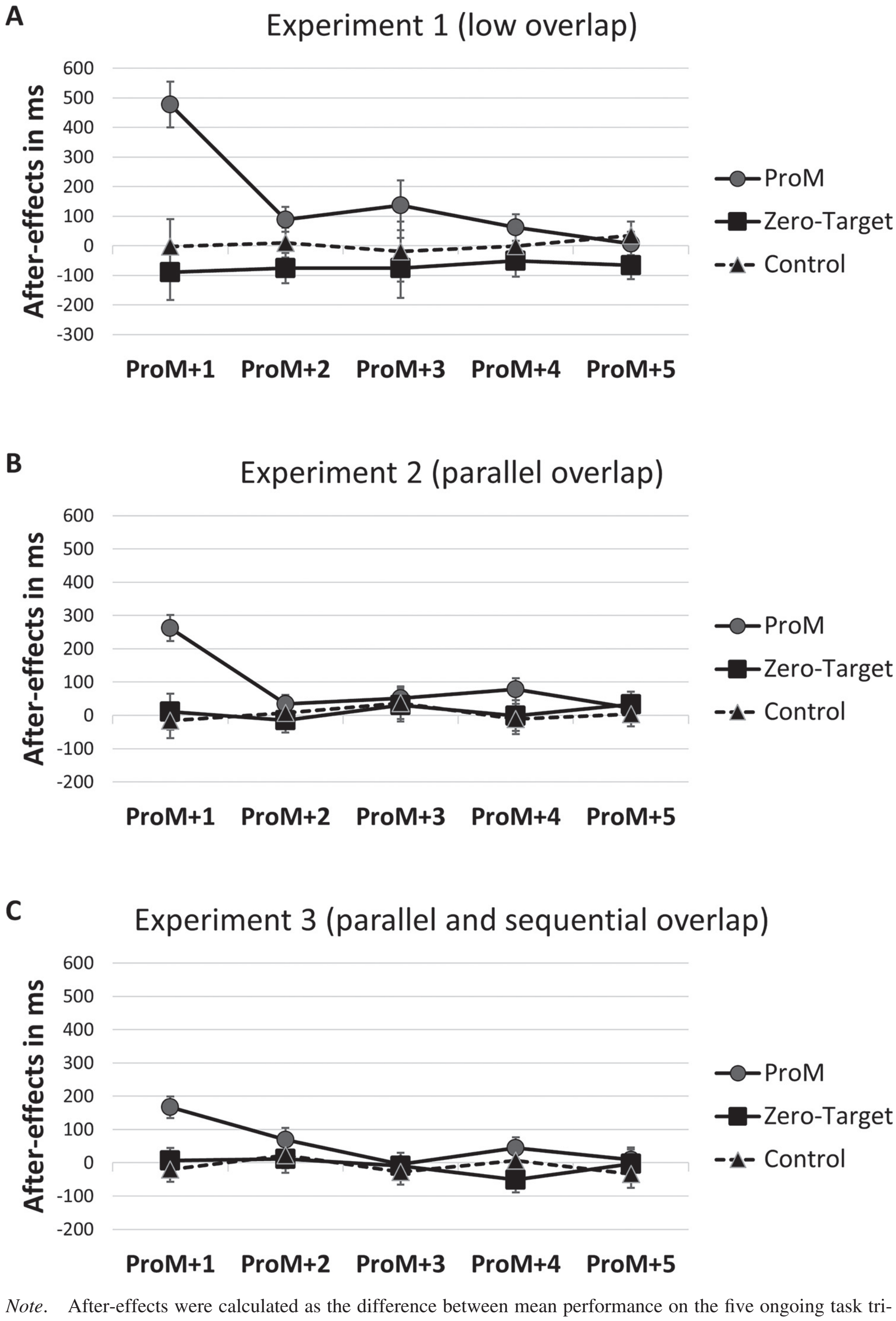
After-effects of correctly responding to deactivated prospective memory targets (i.e., lures) were calculated as the difference between the mean performance on the five ongoing task trials before each deactivated prospective memory target and each of the five ongoing task trials following the prospective memory lure for each condition. For the control condition, after-effects were calculated accordingly. The results are depicted in Figure 2A. A positive value denotes a cost of having encountered a lure, a value around zero indicates similar response times throughout. The ANOVA with the between-subjects factor condition (ProM, zero-target, control) and the within-subjects factor position (Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5) revealed no significant effects, $F(4, 308) = .34$, $p = .85$, $\eta_p^2 = .01$, $F(2, 77) = 2.03$, $p = .14$, $\eta_p^2 = .05$, and $F(8, 308) = 1.69$, $p = .10$, $\eta_p^2 = .04$, for position, condition, and their interaction, respectively. Against our hypothesis, there were no significant after-effects of correctly responding to deactivated prospective memory targets. In order to quantify the evidence for the null hypothesis, we conducted a Bayesian analysis (Dienes, 2014; Wagenmakers et al., 2015). The Bayes factor (BF) represents a ratio between the likelihood of the null and the alternative hypotheses. A BF of above 3 indicates evidence for the alternative hypothesis and a BF below 1/3 indicates evidence for the null hypothesis; values between 1/3 and 3 are considered inconclusive. We compared after-effects on each position with a Bayesian *t*-test against zero, separately for the ProM condition and the zero-target condition. For the ProM condition, the BFs were .125, .206, .133, .186, and .249 for Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5, respectively, thus providing evidence for the null hypothesis. For the zero-target condition, the respective BFs were .171, .208, .437, .913 and .574 for Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5, respectively, providing also evidence for the null, particularly when considering that numerically, the results suggest a benefit rather than a cost of responding correctly to deactivated prospective memory targets (cf. Figure 2A).

Monitoring Costs and Ongoing Task Performance

Table 2 shows ongoing task performance (RTs for correct responses and proportion of correct responses) across all blocks and conditions, as well as monitoring costs. Most important are the monitoring costs which were calculated as the difference between Block 2 (i.e., after the prospective memory instructions, but before the occurrence of any prospective memory target) and

Figure 1

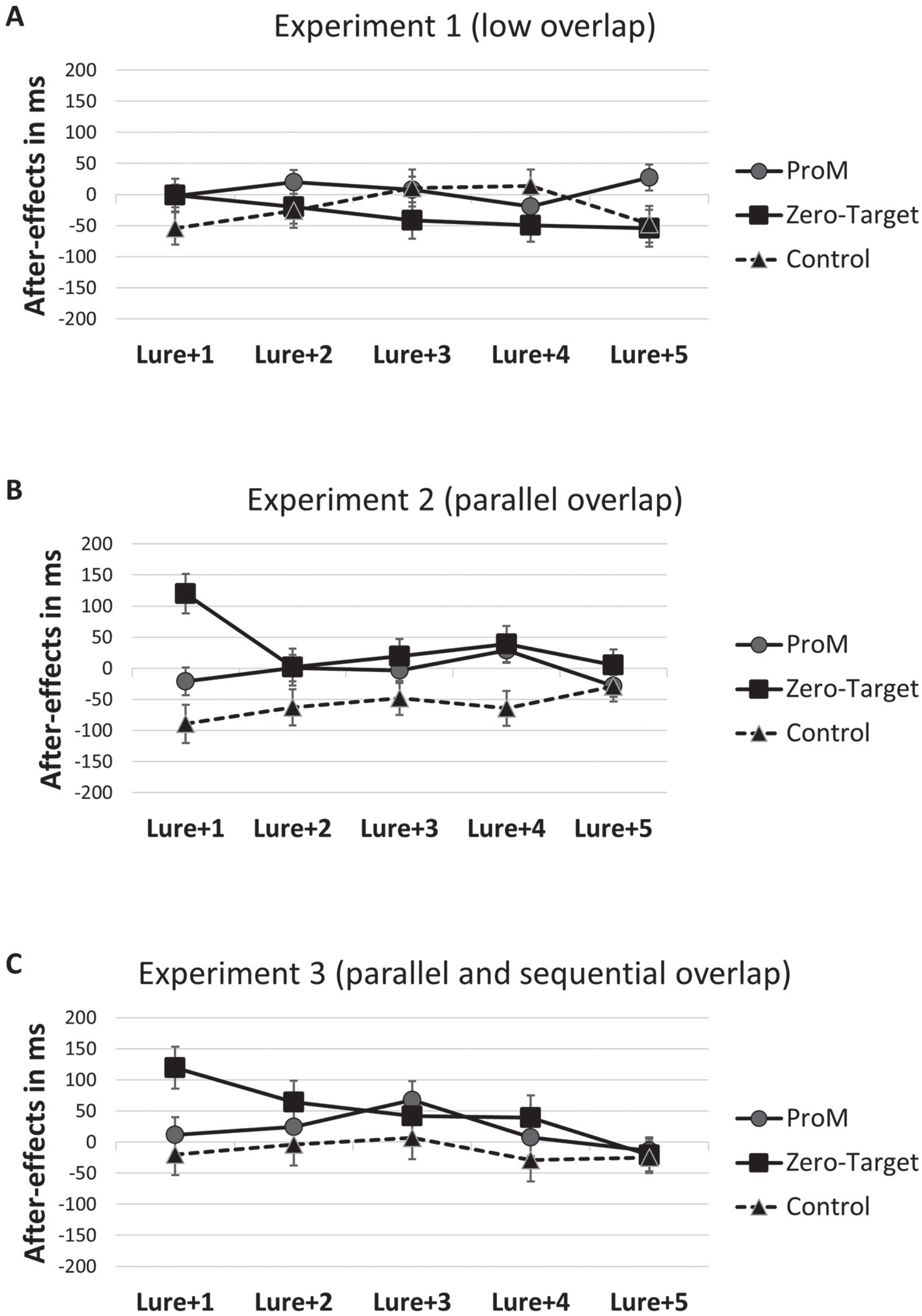
After-Effects of Responding to Activated Prospective Memory Targets (ProM) as a Function of Processing Overlap in Experiment 1 (A), Experiment 2 (B), and Experiment 3 (C)



Note. After-effects were calculated as the difference between mean performance on the five ongoing task trials before each prospective memory target and the five ongoing task trials following it (or the corresponding placeholders in the zero-target and the control condition). Error bars represent standard errors.

Figure 2

After-Effects of Responding to Deactivated Prospective Memory Targets (i.e., Lures) as a Function of Processing Overlap in Experiment 1 (A), Experiment 2 (B), and Experiment 3 (C)



Note. After-effects were calculated as the difference between mean performance on the five ongoing task trials before a correct response to a deactivated prospective memory target and the five ongoing task trials following it (or the corresponding placeholders in the zero-target and the control condition). Error bars represent standard errors.

Table 2
Means (and Standard Errors) of Ongoing Task Performance in Each Block and Condition in Experiment 1

Condition	Block 1	Block 2	Block 3	Block 4	Block 5	Monitoring costs
			Response times			
ProM condition	790 (28)	1,029 (42)	987 (39)	914 (39)	763 (28)	+239 (33)
Zero-target condition	811 (40)	1,050 (59)	902 (55)	856 (55)	773 (39)	+239 (43)
Control condition	744 (40)	699 (59)	718 (55)	708 (55)	731 (39)	–46 (10)
			Accuracy rates			
ProM condition	0.92 (0.01)	0.91 (0.01)	0.92 (0.01)	0.91 (0.01)	0.89 (0.01)	
Zero-target condition	0.94 (0.01)	0.93 (0.01)	0.93 (0.01)	0.91 (0.01)	0.90 (0.02)	
Control condition	0.94 (0.01)	0.93 (0.01)	0.92 (0.01)	0.92 (0.01)	0.92 (0.02)	

Note. Monitoring costs represent the mean difference between RTs in Block 1 and 2. Positive scores represent performance slowing from Block 1 to Block 2 whereas negative scores represent faster RTs in Block 2 compared to Block1.

baseline Block 1 (i.e., before the prospective memory instructions were given). Due to the nonoverlapping nature of the prospective memory task, we expected substantial monitoring costs in the ProM condition and in the zero-target condition. A one-way ANOVA with the between-subjects factor condition confirmed this expectation. The effect of condition was significant, $F(2, 77) = 19.31$, $p < .001$, $\eta_p^2 = .33$. Posthoc tests revealed significant monitoring costs in the two conditions with prospective memory task instructions (ProM and zero-target condition) compared to the control condition, with significant differences between the ProM condition and the control condition, $t(58) = 6.03$, $p^* < .001$, the zero-target condition and the control condition, $t(58) = 6.46$, $p^* < .001$, and no differences between the ProM and the zero-target condition, $t(58) < .01$, $p^* = 1.00$.

Due to the theoretical relevance and as a kind of check whether participants complied with the instructions, we also tested for monitoring in the deactivated block. We conducted a one-way ANCOVA on ongoing task response times in the deactivated Block 5 with the between-subjects factor condition and the covariate Block 1 (baseline) to take into account a priori response time differences between groups. The covariate was significantly related to performance in the deactivated block, $F(1, 76) = 134.75$, $p < .001$, $\eta_p^2 = .64$. However, there was no difference between the three experimental conditions (ProM, zero-target, control), $F(2, 76) = .05$, $p = .951$, $\eta_p^2 = .01$. The specific values for the estimated Block 5 response times after controlling for baseline block performance were 758 ms, 751 ms, and 762 ms, for the ProM condition, zero-target condition, and the control condition, respectively. This result confirms that participants followed the deactivation instructions.

Discussion

The goal of Experiment 1 was to investigate after-effects of responding to activated as well as to deactivated nonoverlapping prospective memory targets within the same experiment. When the prospective memory task was activated, the results showed that after correctly responding to prospective memory targets a substantial slowing occurred on the first following trial and some subsequent lingering. This result is in line with previous findings and indicates that switching back from the prospective memory task to the ongoing task involves a cost that can result in a substantial slowing (Meier & Rey-Mermet, 2012, 2018). In addition to the strong after-effect of responding to activated prospective memory targets, the lack of an after-effect in the control condition is also relevant, because in this condition, the same stimuli were presented as in the ProM condition, but they carried no prospective memory bivalency. The lack of an after-effect in the control condition indicates that the after-effects in the ProM condition are specifically related to performing the prospective memory task and are not simply an artifact of unspecific features of the prospective memory targets.

Importantly, when the prospective memory task was deactivated, responding to formerly relevant prospective memory targets did not produce after-effects. We did not find commission errors and there was no significant slowing on the prospective memory lures. Moreover, responding to the deactivated targets did not trigger any after-effects on the subsequent trials. It is likely that due to their nonoverlapping nature, the prospective memory lures were not noticed at all as former prospective memory targets. In fact, even in the zero-target condition, in which participants did not have the opportunity to perform the prospective memory task and thus it might be argued that the intention should be represented in a more activated state, no indication of an after-effect occurred (cf. Bugg & Scullin, 2013; Goschke & Kuhl, 1996; Lewin, 1926). A likely explanation for the failure of after-effects of responding to deactivated intentions is rooted in their nonoverlapping nature. Given that typically monitoring is necessary for prospective memory target detection in situations of low process overlap, a finding that we replicated in the present study, it is likely that the "finished" instruction also deactivated monitoring. In consequence, the deactivated prospective memory targets were not noticed at all. From a perspective of research on task switching and cognitive control, this indicates that processing deactivated nonoverlapping prospective memory targets does not keep triggering bivalency after their deactivation.

Together the results of Experiment 1, in which processing overlap was low, demonstrate that after-effects of responding to activated and deactivated prospective memory targets follow different trajectories. While there was a substantial slowing for the first trial after responding to an activated prospective memory task, there was no indication of any after-effect of responding to a deactivated prospective memory target.

In Experiment 2, we followed up on this result. More specifically, we tested the hypothesis that an increase in process overlaps would provoke an after-effect of correctly responding to deactivated prospective memory targets. Toward this goal, we made a small change to the prospective memory task, by instructing the participants to respond to the category of animals. We reasoned that making lexical decisions for the ongoing task and recognizing animals for the prospective memory task would increase the amount of processing overlap (cf. Meier & Graf, 2000; Walter & Meier, 2016). In line, we expected that the prospective memory targets would be noticed after the deactivation of the prospective memory task.

Experiment 2

Method

Participants

Eighty-one different students from the University of Bern were recruited from the subject pool of the institute of psychology (*M* age 22.6 years; 60.5% female, 14.8% male, 24.7% not specified). Participants were pseudorandomly assigned to either the ProM condition ($n = 40$), the zero-target condition ($n = 21$), or the control condition ($n = 20$).

Materials, Procedure, Data Preparation and Statistical Analysis

The same materials were used as in Experiment 1 except that the prospective memory targets were defined as instance of the category animals. Specifically, we used the German words KATZE, NASHORN, TIGER, SCHLANGE, PFERD, ADLER (English: cat, rhino, tiger, snake, horse, eagle). As in Experiment 1, for the zero-target condition, these stimuli were replaced in the active phase with the following six prospective memory placeholders: GEIGE, HORN, GITARRE, POSAUNE, KLAVIER, TROMPETE (English: violin, horn, guitar, trombone, piano, trumpet). For the control condition, the same stimuli were used as for the ProM condition. Procedure, data preparation, and statistical analyses were identical to Experiment 1.

Results

Prospective Memory Performance and After-Effects of Responding to Activated Prospective Memory Targets

Proportion of correct prospective memory responses (out of 6) was .57 ($SD = .27$). Two participants responded correctly to all six targets, eleven responded to five targets, eight responded to four targets, nine responded to three targets, four responded to two targets, four responded to one target, and two did not respond to any prospective memory target. Thus, for the analysis of after-effects of responding 38 out of 40 participants in the ProM condition could be included. Trajectory of after-effects was compared to the zero-target condition and the control condition with 20 participants each.

As in Experiment 1, after-effects of responding to activated prospective memory targets were calculated as the difference between mean performance on the five ongoing task trials before each target and the five ongoing task trials following each target. For the zero-target and the control condition after-effects of responding to prospective memory placeholders were calculated accordingly. The results are depicted in Figure 1B. A visual inspection indicates an after-effect for the ProM condition, in particular for the first trial after responding to the prospective memory target ($M = 263$ ms). An ANOVA with the between-subjects factor condition (ProM, zero-target, control) and the within-subjects factor position (ProM + 1, ProM + 2, ProM + 3, ProM + 4, and ProM + 5) revealed a significant effect of condition and a significant Condition × Position interaction, $F(2, 76) = 4.20$, $p = .02$, $\eta_p^2 = .10$, and $F(7.13, 271.04) = 3.68$, $p = .001$, $\eta_p^2 = .09$, respectively. The effect of position was not significant, and $F(3.57, 271.04) = 2.14$, $p = .08$, $\eta_p^2 = .027$. Separate one-way ANOVAs to follow up on the significant Condition × Position interaction revealed a significant after-effect on trial ProM + 1, $F(2, 76) = 12.03$, $p < .001$, $\eta_p^2 = .24$. Pairwise comparisons showed higher after-effects for the ProM condition compared to the zero-target condition, $t(57) = 3.43$, $p^* = .001$, and the control condition, $t(56) = 3.705$, $p^* < .001$, whereas the latter did not differ, $t(39) = .77$, $p^* = 1.00$. The ANOVAs on the following four trials revealed no significant effects (all *F*s < 1.00, all *p*s > .10).

After-Effects of Responding to Deactivated Prospective Memory Targets

Proportion of correct responses to deactivated prospective memory targets (out of 6) was .98 ($SD = .06$) for the ProM condition, .94 ($SD = .10$) for the zero-target condition, and .92 ($SD = .10$) for the control condition. Participants did not make any commission errors. To test for a potential slowing effect (intention interference) in correctly responding to the deactivated prospective memory targets (i.e., ProM lures), we carried out an analysis of covariance (ANCOVA) with the mean ongoing task reaction times of deactivated Block 5 as a covariate. The covariate was significantly related to response times for deactivated prospective memory targets (and their placeholders in the control condition, respectively), $F(1, 76) = 84.50$, $p < .001$, $\eta_p^2 = .53$. However, there was no difference between the three experimental conditions (ProM, zero-target, control condition), $F(2, 77) = 1.54$, $p = .220$, $\eta_p^2 = .04$. The specific values for the estimated deactivated prospective memory target response times after controlling for mean block performance were 708 ms, 711 ms, and 657 ms, for the ProM condition, zero-target condition, and control condition, respectively, indicating at least a numerical interference effect.

As in Experiment 1, after-effects of correctly responding to deactivated prospective memory targets (i.e., lures) were calculated as the difference between mean performance on the five ongoing task trials before each lure and the five ongoing task trials following each lure. For the zero-target and the control condition after-effects of responding to prospective memory placeholders were calculated accordingly. The results are depicted in Figure 2B. A visual inspection indicates an after-effect for the zero-target condition, in particular for the first trial after responding to the deactivated prospective memory target ($M = 120$ ms). The ANOVA with the between-subjects factor condition and the within-subjects factor position revealed a significant effect of condition and a significant Condition × Position interaction, $F(2, 78) = 8.40$, $p < .001$, $\eta_p^2 = .18$, and $F(8, 312) = 2.56$, $p = .01$, $\eta_p^2 = .06$, respectively. The effect of position was not significant, $F(4, 312) = .61$, $p = .66$, $\eta_p^2 = .01$. Next, we compared the after-effects for each position separately across conditions. The one-way ANOVA on the first trial following a ProM lure with the between-subjects factor condition revealed a significant after-effect on Lure + 1, $F(2, 78) = 12.00$, $p < .001$, $\eta_p^2 = .24$. Post hoc tests indicated that the after-effect differed between the zero-target condition and both the ProM condition, $t(59) = -3.96$, $p^* = .001$, and the control condition, $t(39) = 3.76$, $p^* < .001$, whereas they did not differ statistically in the latter two conditions, $t(58) = 2.06$, $p^* = .234$. The following series of ANOVAs, on the second (Lure + 2), third (Lure + 3), and fifth (Lure + 5) positions showed no significant effects (all Fs < 1.72, all ps $> .10$). However, there was a significant effect on Lure + 4, $F(2, 78) = 4.28$, $p = .017$, $\eta_p^2 = .10$, suggesting an after-effect on both the ProM condition, $t(58) = 2.99$, $p^* = .03$, and the zero-target condition, $t(39) = 2.24$, $p^* = .04$, compared to the control condition. The difference between the ProM condition and the zero-target condition was not significant, $t(59) = -.28$, $p^* = 1.00$. As in Experiment 1 and against our expectations, there were no immediate after-effects of correctly responding to deactivated prospective memory targets in the ProM condition. In order to quantify the evidence for the null hypothesis, we also compared after-effects on each position with a Bayesian t-test against zero. The BFs were .344, .123, .126, .499, and .556 for Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5, respectively. Taking into account the inconsistent direction of the effects, particularly for Lure + 4 and Lure + 5 (cf. Figure 2B), which gave "inconclusive" BFs, we consider these results again as evidence for the null hypothesis.

Monitoring Costs and Ongoing Task Performance

Ongoing task performance across blocks and conditions and monitoring costs are presented in Table 3. Due to the overlap between processes required for the ongoing task and noticing the prospective memory targets, we expected no substantial monitoring costs in the ProM condition and in the zero-target condition. A one-way ANOVA revealed a marginal significant difference between groups, $F(2, 78) = 2.49$, $p = .09$, $\eta_p^2 = .06$. Posthoc tests revealed similar monitoring costs in the ProM condition and the zero-target condition. Monitoring costs in the ProM condition tended to be higher compared to the control condition, $t(58) = 2.39$, $p^* = .09$, while there was no difference between the zero-target condition and the control condition, $t(39) = 1.69$, $p^* = .293$, and between the ProM condition and the zero-target condition, $t(59) = .24$, $p^* = 1.00$.

As in Experiment 1, we also tested for monitoring in the deactivated block. Again, we conducted a one-way ANCOVA on ongoing task response times in the deactivated Block 5 with the between-subjects factor condition and the covariate Block 1 (baseline) to take into account a priori response time differences between groups. The covariate was significantly related to performance in the deactivated block, $F(1, 77) = 17.52$, $p < .001$, $\eta_p^2 = .19$. In contrast, after controlling for baseline performance, there was no difference between the three experimental conditions (ProM, zero-target, control), $F(2, 77) = 2.09$, $p = .131$, $\eta_p^2 = .05$. The specific values for the estimated Block 5 response times after controlling for baseline block performance were 732 ms, 744 ms, and 781 ms, for the ProM condition, zero-target condition, and the control condition, respectively.

Discussion

The goal of Experiment 2 was to investigate after-effects of responding to activated as well as to deactivated prospective memory targets for categorical targets with a parallel processing overlap, that is with higher focality compared to Experiment 1. When the prospective memory task was activated, the results showed that after correctly responding to prospective memory targets slowing occurred but only on the first trial after responding to the prospective memory target. This result replicates and extends Experiment 1 by showing that switching back from the prospective memory task to the ongoing task involves a cost, which however, seemed to be somewhat reduced both in size and longevity due to the higher processing overlap.

As in Experiment 1, we did not find commission errors and there was no significant slowing on the prospective memory lures. However, in Experiment 2 correctly responding to deactivated prospective memory targets (i.e., lures) produced an after-effect. Specifically, for the zero-target condition, a large after-effect occurred on the trial following the deactivated prospective memory target, indicating that the target was noticed. It is likely that noticing the deactivated prospective memory target triggered the retrieval of the prospective memory task and this interfered with ongoing task processing. Interestingly, a lingering after-effect also occurred some trials later and this effect seemed to materialize both in the zero-target and in the ProM condition. Thus, it is possible that pondering about the prospective memory task had some delayed effect as well. However, as this effect was not predicted and it may represent a spurious result as indicated by the Bayesian analysis, further interpretation is not warranted. More important, the immediate after-effect occurred only in the zero-target condition and not in the ProM condition. This suggests that unfulfilled intentions in fact are represented in a special status, probably with higher activation (Goschke & Kuhl, 1996; Lewin, 1926), compared to finished intentions that had been fulfilled.

Together the results of Experiments 1 and 2 suggest that after-effects of responding to activated and deactivated prospective memory targets show a different trajectory, depending on the process overlap between ongoing task and prospective memory task. In

Table 3

Means (and Standard Errors) of Ongoing Task Performance in Each Block and Condition in Experiment 2

Condition	Block 1	Block 2	Block 3	Block 4	Block 5	Monitoring costs
			Response times			
ProM condition	761 (22)	827 (24)	836 (27)	763 (23)	734 (21)	+67 (18)
Zero-target condition	807 (31)	865 (33)	845 (37)	801 (32)	778 (28)	+59 (29)
Control condition	700 (31)	701 (34)	693 (38)	700 (32)	741 (29)	+1 (16)
			Accuracy rates			
ProM condition	0.93 (0.01)	0.92 (0.01)	0.91 (0.01)	0.92 (0.01)	0.90 (0.01)	
Zero-target condition	0.96 (0.01)	0.94 (0.01)	0.94 (0.01)	0.94 (0.01)	0.94 (0.01)	
Control condition	0.92 (0.01)	0.90 (0.01)	0.91 (0.01)	0.91 (0.01)	0.89 (0.01)	

Note. Monitoring costs represent the mean difference between RTs in Block 1 and 2. Positive scores represent performance slowing from Block 1 to Block 2 whereas negative scores represent faster RTs in Block 2 compared to Block1.

Experiment 2, there was still a substantial slowing for the first trial after responding to an activated prospective memory task. Moreover, there was also an after-effect of responding to a deactivated prospective memory target in the zero-target condition, in which there was no opportunity for performing the prospective memory task in the active phase. The lack of an after-effect for the ProM condition indicates that the process overlap in this condition may not have been sufficient to trigger the retrieval of the deactivated prospective memory task. Experiment 3 was set up to test this possibility.

In Experiment 3, we followed up on the hypothesis that a further increase in process overlaps would also induce an after-effect of correctly responding to deactivated prospective memory targets in the ProM condition. Toward this goal, we reduced prospective load by instructing the participants to respond to the word CAT (Meier & Zimmermann, 2015). Making lexical decisions for the ongoing task and recognizing the word CAT for the prospective memory task provides an additional overlap opportunity, that is, a sequential processing overlap (Meier & Graf, 2000). We reasoned that it is even more likely that these prospective memory targets would be noticed after the deactivation of the prospective memory task. In contrast, we suspected that the after-effect of responding to the activated prospective memory task would be further reduced by the high amount of processing overlaps.

Experiment 3

Method

Participants

Experiment 3 included another 66 students from the University of Bern who did not participate in either of the two previous experiments. Again, they were recruited from the subject pool of the institute (*M* age 22.4 years; 56.1% female, 16.7% male, 27.3% not specified). Participants were pseudorandomly assigned to the ProM condition ($n = 26$), the zero-target condition ($n = 20$), or the control condition ($n = 20$). Compared to Experiments 1 and 2, we tested fewer participants in the ProM condition because due to the high process overlap we expected higher prospective memory performance and thus a larger number of observations for the analysis of after-effects of responding prospective memory targets.

Materials, Procedure, Data Preparation and Statistical Analysis

The same materials were used as in Experiments 1 and 2, except that the prospective memory targets were defined as the German word *KATZE* (English: CAT). Procedure, data preparation and statistical analysis were identical to Experiment 1.

Results

Prospective Memory Performance and After-Effects of Responding to Activated Prospective Memory Targets

Proportion of correct prospective memory responses (out of 6) was .88 ($SD = .17$). Sixteen participants responded correctly to all six targets, five responded to five targets, two responded to four targets, and three responded to three targets. Thus, for the analysis of after-effects of responding, all 26 participants in the ProM condition could be included. Trajectory of after-effects was compared to the zero-target condition and the control condition with 20 participants each.

After-effects of responding to activated prospective memory targets were calculated as in Experiments 1 and 2. The results are depicted in Figure 1C. A visual inspection indicates an after-effect for the ProM condition, in particular for the first trial after responding to the prospective memory target ($M = 167$ ms). The ANOVA with the between-subjects factor condition (ProM, zero-target, control) and the within-subjects factor position (ProM + 1, ProM + 2, ProM + 3, ProM + 4, and ProM + 5) revealed a significant effect of condition, $F(2, 62) = 4.37$, $p = .02$, $\eta_p^2 = .12$. The effect of position and the Condition × Position interaction were not significant, $F(3.17, 196.21) = 1.91$, $p = .13$, $\eta_p^2 = .03$, and $F(6.33, 196.21) = 1.37$, $p = .23$, $\eta_p^2 = .04$, respectively. The effect of condition was due to a stronger after-effect in the ProM condition compared to the zero-target, $t(44) = 2.29$, $p^* = .046$, and the control condition, $t(43) = 2.60$, $p^* = .045$, while the latter two conditions did not differ, $t(37) = .05$, $p^* = 1.00$. Moreover, a separate one-way ANOVA on the first trial after responding to the prospective memory target (ProM + 1) gave a significant effect, $F(2, 62) = 8.72$, $p < .001$, $\eta_p^2 = .22$, and posthoc tests revealed higher after-effects in the ProM condition compared to the zero-target, $t(44) = 2.90$, $p^* = .005$, and the control condition, $t(43) = 5.13$, $p^* = .001$, whereas the latter did not differ, $t(37) = .46$, $p^* = 1.00$. The ANOVAs on the following four trials revealed no significant effects (all *F*s < 1.94, all *p*s $> .10$).

After-Effects of Responding to Deactivated Prospective Memory Targets

Proportion of correct responses to deactivated prospective memory targets (out of 6) was .98 ($SD = .06$) for the ProM condition, .97 ($SD = .07$) for the zero-target condition, and .94 ($SD = .22$) for the control condition. Participants did not make any commission errors. To test for a potential slowing effect (intention interference) in correctly responding to the deactivated prospective memory targets (i.e., ProM lures), we carried out an analysis of covariance (ANCOVA) with the mean ongoing task reaction times of deactivated Block 5 as a covariate. The covariate was significantly related to response times for deactivated prospective memory targets (and their placeholders in the control condition, respectively), $F(1, 61) = 109.18$, $p < .001$, $\eta_p^2 = .64$. There was also a significant difference between the three experimental conditions (ProM condition, Zero-target condition, Control condition), $F(2, 61) = 3.59$, $p = .034$, $\eta_p^2 = .11$. The specific values for the estimated deactivated prospective memory target RTs after controlling for mean block performance were 685 ms, 717 ms, and 620 ms, for the ProM condition, zero-target condition, and control condition, respectively. Pairwise comparisons of these estimates revealed a significant difference between the zero-target condition and the control condition, $t(38) = 2.64$, $p^* = .033$, while the difference between ProM condition and the zero-target condition, and between the ProM condition and the control condition was not significant, $t(44) = .94$, $p^* = 1.00$, and $t(44) = 1.90$, $p^* = .193$, respectively.

After-effects of correctly responding to deactivated prospective memory targets (i.e., lures) were calculated as in Experiments 1 and 2. The results are depicted in Figure 2C. A visual inspection indicates an after-effect for the zero-target condition, in particular for the first trial after responding to the deactivated prospective memory target (M = 119 ms). An ANOVA with the between-subjects factor condition and the within-subjects factor position (Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5) revealed no significant effects, $F(2, 62) = 2.84$, $p = .07$, $\eta_p^2 = .08$ for condition, $F(2.69, 167) = 2.26$, $p = .09$, $\eta_p^2 = .04$, for position and $F(5.39, 167) = 1.11$, $p = .36$, $\eta_p^2 = .03$ for the interaction, respectively. Next, we compared the after-effects for each position separately. A one-way ANOVA revealed a significant effect of condition on Lure + 1, $F(2, 62) = 5.04$, $p = .009$, $\eta_p^2 = .14$, showing that participants in the zero-target condition had significantly higher after-effects compared to the ProM condition, $t(44) = –2.20$, $p^* = .047$, and the control condition, $t(37) = 2.80$, $p^* = .012$, while the latter two conditions did not differ, $t(43) = .93$, $p^* = 1.00$. For all the following positions the effect of condition was not significant (all Fs < 1.04, all ps $> .10$). Similar to Experiments 1 and 2, and still against our expectations, there were no significant after-effects of correctly responding to deactivated prospective memory targets in the ProM condition. In order to quantify the evidence for the null hypothesis, we compared after-effects on each position with a Bayesian t-test against zero. The BFs were .167, .205, 1.021, .153, and .183 for Lure + 1, Lure + 2, Lure + 3, Lure + 4, and Lure + 5, respectively. In general the results provide again evidence for the null hypothesis except for Lure + 3, for which the evidence is inconclusive.

Monitoring Costs and Ongoing Task Performance

Ongoing task performance across blocks and conditions, and monitoring costs are presented in Table 4. Due to the overlap between processes required for the ongoing task and noticing the prospective memory targets and the sequential overlap for prospective memory targets, we expected no substantial monitoring costs in the ProM condition and in the zero-target condition. While a one-way ANOVA revealed a significant effect of Condition, $F(2, 63) = 3.54$, $p = .035$, $\eta_p^2 = .10$, posthoc tests revealed no differences between the three conditions (all p^*s $>.077$). A follow-up analysis, in which we compared monitoring costs against zero indicated no difference for the ProM condition, $t(25) = 1.02$, $p = .32$, while there was a performance benefit (i.e., faster performance in Block 2 compared to Block 1) in both the zero-target and the control condition, $t(19) = –2.33$, $p = .03$, and $t(19) = –2.83$, $p = .01$, respectively.

As in Experiments 1 and 2, we also tested for monitoring in the deactivated block. Again, we conducted a one-way ANCOVA on ongoing task response times in the deactivated Block 5 with the between-subjects factor condition and the covariate Block 1 (baseline) to take into account a priori response time differences between groups. The covariate was significantly related to performance in the deactivated block, $F(1, 62) = 39.00$, $p < .001$, $\eta_p^2 = .39$. In contrast, after controlling for baseline performance, there was no difference between the three experimental conditions (ProM, zero-target, control), $F(2, 62) = .95$, $p = .392$, $\eta_p^2 = .03$. The specific values for the estimated Block 5 response times after controlling for baseline block performance were 762 ms, 795 ms, and 782 ms, for the ProM condition, zero-target condition, and the control condition, respectively.

Discussion

The goal of Experiment 3 was to test the effect of a further increase in process overlaps for the after-effects of responding to activated and deactivated prospective memory targets. In general, the results showed a similar pattern as Experiment 2. When the prospective memory task was activated, an after-effect occurred on the first trial after correctly responding to prospective memory targets. When the prospective memory task was deactivated, in the zero-target condition responding to lures showed significant intention interference and also produced an after-effect as in Experiment 2. However, in the ProM condition, even adding a sequential overlap by using specific prospective memory targets did not induce a reliable after-effect.

Together, the results replicate the findings from Experiments 1 and 2, namely that process overlaps modulate after-effects of responding to activated and deactivated prospective memory targets differently. In order to compare these effects directly, in the next section, we present the most important analyses across experiments (see Figure 3 for a graphical summary).

Combined Analyses of Experiments 1, 2, and 3

Prospective Memory Performance and After-Effects of Responding to Activated Prospective Memory Targets as a Function of Processing Overlap

First, we compared prospective memory performance (proportion of correct responses to prospective memory targets) across Experiment 1 (low overlap), Experiment 2 (parallel overlap), and Experiment 3 (parallel and sequential overlap) considering only participants of the ProM conditions. The ANOVA revealed a

Table 4

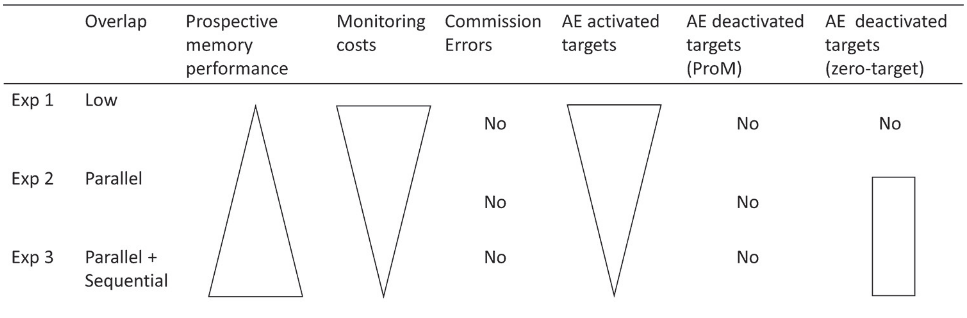
Means (and Standard Errors) of Ongoing Task Performance in Each Block and Condition in Experiment 3

Condition	Block 1	Block 2	Block 3	Block 4	Block 5	Monitoring costs
			Response times			
ProM condition	850 (51)	875 (48)	842 (44)	792 (39)	778 (39)	+25 (24)
Zero-target condition	850 (59)	811 (55)	831 (50)	788 (44)	811 (44)	–39 (17)
Control condition	777 (59)	740 (55)	719 (50)	717 (44)	747 (44)	–37 (13)
			Accuracy rates			
ProM condition	0.94 (0.01)	0.93 (0.01)	0.92 (0.01)	0.92 (0.01)	0.91 (0.01)	
Zero-target condition	0.94 (0.01)	0.93 (0.01)	0.93 (0.01)	0.93 (0.01)	0.91 (0.01)	
Control condition	0.95 (0.01)	0.93 (0.01)	0.93 (0.01)	0.92 (0.01)	0.91 (0.01)	

Note. Monitoring costs represent the mean difference between RTs in Block 1 and 2. Positive scores represent performance slowing from Block 1 to Block 2 whereas negative scores represent faster RTs in Block 2 compared to Block1.

Figure 3

Graphical Summary of the Results as a Function of Process Overlaps (AE = After-Effect; ProM = ProM Condition; Zero-Target = Zero-Target Condition)



Note. The broader the shape, the stronger is the effect.

significant effect of experiment, $F(2, 103) = 36.00$, $p < .001$, $\eta_p^2 = .41$. Prospective memory performance differed between all three experiments, with the highest performance for combined parallel and sequential overlap (Experiment 3) and the lowest for low overlap (Experiment 1), thus validating the assumption that increasing processing overlap leads to higher prospective memory performance.

After-effects of responding to prospective memory targets in the active phase were also analyzed as a function of experiment considering only participants from the ProM condition. Given that an after-effect appeared mainly on the first trial after responding in the single experiments, we restricted the analysis to the ProM + 1 trial (i.e., the first trial after a prospective memory target). The ANOVA revealed a significant effect of experiment, $F(2, 90) = 4.27$, $p = .017$, $\eta_p^2 = .09$, and posthoc tests showed that the after-effect of responding to a prospective memory target was significantly higher when the overlap was low (Experiment 1) compared to when both a parallel and sequential overlap was present (Experiment 3), $t(53) = 2.51$, $p^* = .018$. Although numerically the after-effect for the parallel overlap experiment (Experiment 2) was smaller than for the low overlap experiment (Experiment 1) and higher than for the parallel and sequential overlap experiment (Experiment 3), posthoc tests revealed no significant differences, $t(65) = 1.84$, $p^* = .11$, and $t(62) = 1.42$, $p^* = 1.00$, respectively.

Responding to Deactivated Prospective Memory Targets as a Function of Processing Overlap

To test for a potential slowing effect (intention interference) in correctly responding to the deactivated prospective memory targets (i.e., ProM lures), we carried out an analysis of covariance (ANCOVA) with the mean ongoing task reaction times of deactivated Block 5 as a covariate and the experiment and condition (ProM, zero-target, control) as between-subjects factors. The covariate was significantly related to response times for deactivated prospective memory targets (and their placeholders in the control condition, respectively), $F(1, 215) = 402.82$, $p < .001$, $\eta_p^2 = .65$. After controlling for mean block performance, there was a difference between experiments, $F(2, 215) = 3.77$, $p = .025$, $\eta_p^2 = .03$, and between the three experimental conditions, $F(2, 215) = 5.02$, $p = .007$, $\eta_p^2 = .05$, while the interaction between experiment and condition was not significant, $F(4, 215) = .40$, $p = .806$, $\eta_p^2 = .01$. Participants responded faster to the specific targets in Experiment 3, than to categorical targets in Experiments 1 and 2, estimated deactivated prospective memory target RTs after controlling for mean block performance were 706 ms, 703 ms, and 658 ms, respectively. Posthoc tests revealed a significant difference between Experiment 1 and Experiment 3, $t(143) = 2.50$, $p^* = .042$, a marginally significant effect between Experiment 2 and Experiment 3, $t(143) = 2.34$, $p^* = .064$, while Experiments 1 and 2 did not differ, $t(158) = .16$, $p^* = 1.000$. Across experiments, the specific values for the estimated deactivated prospective memory target RTs after controlling for mean block performance were 705 ms, 709 ms, and 653 ms, for the ProM condition, zero-target condition, and control condition, respectively. Pairwise comparisons of these estimates revealed that both the ProM condition and the zero-target condition differed from the control condition, $t(162) = 2.88$, $p^* = .015$, and $t(118) = 2.80$, $p^* = .018$, respectively, while the ProM condition and the zero-target condition did not differ, $t(164) = .22$, $p^* = 1.00$. These results indicate that overall an intention interference effect occurred for both, the ProM condition and the zero-target condition.

After-Effects of Responding to Deactivated Prospective Memory Targets as a Function of Processing Overlap

After-effects of correctly responding to deactivated prospective memory targets (i.e., lures) were also analyzed as a function of experiment and condition. We included only those participants with prospective memory instructions, that is, the ProM condition and the zero-target condition. As for the analysis of after-effects of responding to activated targets, we also focused on the first trial presented after the deactivated prospective memory target (i.e., Lure + 1). The ANOVA revealed a significant effect of experiment, of condition, and a significant Experiment × Condition interaction, $F(2, 161) = 3.38$, $p = .036$, $\eta_p^2 = .04$, $F(1, 161) = 14.36$, $p < .001$, $\eta_p^2 = .08$, and $F(2, 161) = 3.86$, $p = .023$, $\eta_p^2 = .05$, respectively. For the zero-target condition, posthoc tests indicated a higher after-effect for both parallel overlap (Experiment 2) and parallel and sequential overlap (Experiment 3) compared to low overlap (Experiment 1), $t(39) = -2.31$, $p^* = .015$, and $t(38) = -2.18$, $p^* = .017$, respectively. After-effects for the parallel overlap and for the parallel and sequential overlap did not differ, $t(39) = .01$, $p^* = 1.00$. Due to the theoretical impact, we used Bayesian *t*-test to quantify this effect. The resulting Bayes factor of BF = .230 indicates evidence for the null hypothesis. For the ProM condition, there were no differences between the three experiments (all p*s = 1.00), which is not surprising as no after-effect occurred in each single experiment to start with (see Figure 2).

Monitoring Costs and Ongoing Task Performance as a Function of Processing Overlap

We also compared monitoring costs across the three experiments for the ProM condition and the zero-target condition. As expected, the ANOVA revealed a significant effect of experiment, $F(2, 161) = 35.09$, $p < .001$, $\eta_p^2 = .30$, but no effect of condition and no interaction, $F(1, 161) = .94$, $p = .33$, $\eta_p^2 = .01$, and $F(2, 161) = .63$, $p = .535$, $\eta_p^2 = .01$, respectively. Posthoc tests showed that monitoring costs were higher with low overlap compared to both parallel and parallel and sequential overlap, $t(78) = 4.62$, $p^* < .001$, and $t(64) = 4.72$, $p^* < .001$, respectively. Monitoring costs tended to be higher for parallel compared to both parallel and sequential overlap, $t(64) = 1.38$, $p^* = .071$.

For the sake of completeness, we also tested for monitoring in the deactivated block across experiments, and across all three conditions with a two-way ANCOVA on ongoing task response times in the deactivated Block 5 with the between-subjects factors condition and experiment, and the covariate Block 1 (baseline) to take into account a priori response time differences between groups. The covariate was significantly related to performance in the deactivated block, $F(1, 217) = 500.49$, $p < .001$, $\eta_p^2 = .70$. However, there was no difference between the three experimental conditions (ProM, zero-target, control), $F(2, 217) = 1.35$, $p = .263$, $\eta_p^2 = .01$, and between experiments $F(2, 217) = 1.07$, $p = .344$, $\eta_p^2 = .01$, and there was no interaction between condition and experiment (i.e., overlap), $F(4, 217) = .77$, $p = .545$ $\eta_p^2 = .01$. The specific values for the estimated Block 5 response times after controlling for baseline block performance were 749 ms, 761 ms, and 773 ms, for the ProM condition, zero-target condition, and the control condition, respectively.

General Discussion

The goal of this study was to provide a fine-grained analysis of costs that can occur in prospective memory tasks. Specifically, we tested across three experiments whether processing overlaps affect after-effects of responding to activated prospective memory targets and deactivated prospective memory targets differently. We hypothesized that responding to activated prospective memory targets would result in larger after-effects when overlaps are low, that is when task switching between the ongoing task and the prospective memory task involves high cognitive resource demands. In contrast, for deactivated prospective memory targets, we predicted the opposite pattern, that is, larger after-effects for high processing overlaps. The results regarding after-effects of activated prospective memory targets confirmed the expectations. Across the three experiments with increasing processing overlaps, we found consistent after-effects. Importantly, the size (and potentially also the duration) of the after-effects decreased with increasing processing overlaps. The results regarding the after-effects of deactivated prospective memory targets partially confirmed our expectations. In line with our expectations, after-effects of deactivated prospective memory targets occurred in the zero-target condition in which the participants were instructed for the prospective memory task but did not have the opportunity to perform it. Specifically, after-effects were present in the high overlap conditions but not in the low overlap condition. In contrast to our expectations, no consistent after-effects of deactivated prospective memory targets occurred in the ProM condition, in which participants had the opportunity to perform the prospective memory task. The differential results for the zero-target condition and the ProM condition indicate that uncompleted intentions remain in an unsaturated state that is more likely to trigger interfering cognitive processes that slow down ongoing task performance after encountering deactivated prospective memory targets. Together, the results are consistent with our expectations that after-effects of responding to activated prospective memory targets and deactivated prospective memory targets are affected differently by varying process overlaps.

Our results further corroborate that besides the intensely investigated monitoring costs, other costs can occur in prospective memory tasks. Regarding the after-effects of responding to activated prospective memory targets, the prominent theories of monitoring costs, that is the preparatory attentional and memory (PAM) theory (Smith, 2003) and the delay view (i.e., prospective memory decision control (PMDC) model; Strickland et al., 2018, 2021) do not explain these effects. Rather than addressing and systematically investigating them, they intentionally excluded the trials after responding to prospective memory targets "to avoid finding an artifactual cost associated with response processes in the prospective memory condition" (Smith & Bayen, 2004; p. 762) and "to avoid any confounding of the non-PM trial analysis caused by post-PM slowing" (Strickland et al., 2021; p. 7), respectively. We would like to emphasize that the consistent presence of after-effects of responding to prospective memory targets as an additional ongoing task cost is in line with previous studies that have used more complex ongoing tasks (i.e., a task switching environment), which probably better reflect the real-world requirements of prospective remembering (cf. Meier, 2019). In those studies, the duration of the after-effects was more long-lasting than in the present study and thus after-effects of responding may affect monitoring costs even when a few trials are excluded (Meier & Rey-Mermet, 2012, 2018). We believe that it is important for prospective memory researchers to acknowledge the importance of task switching when responding to the prospective memory task and switching back to the ongoing task. The results of the present study are in line with studies on the effect of occasionally occurring bivalent stimuli in the domain of task switching. These studies have demonstrated that responding to bivalent stimuli leads to a cost on subsequent nonconflict trials (Grundy & Shedden, 2014; Meier et al., 2009; Metzak et al., 2013; Woodward et al., 2003). In prospective memory, the short-lived slowing varies systematically with the resource demands required for switching from the ongoing task to the prospective memory task and back (i.e., the degree of overlap). This suggests that it is related to task switching rather than prospective memory retrieval per se. Moreover, other sources of ongoing task costs such as increased target checking, strategic delaying, or strategy updating would all predict a longer lasting and more enduring slowing (cf. Scullin et al., 2013), indicating that these sources represent different phenomena. For the future, we suggest that rather than exclude after-effects of responding to (activated) prospective memory targets from analysis, a more interesting approach is to test the conditions under which these after-effects vary. The present study is a step in this direction by demonstrating that the size of the after-effects vary systematically according to process overlaps. Future modeling work may also test whether the PAM theory and the PMDC model can be modified to account for these findings.

Regarding the investigation of after-effects of responding to deactivated prospective memory targets, our results complement previous studies on deactivated intentions with the finished paradigm (cf. Bugg & Streeper, 2019; Möschl et al., 2020). These studies have mainly tested situations with very salient target events and high processing overlaps. Under these conditions, commission errors occurred. In contrast, in our experiments with less salient targets but a systematic variation of process overlaps, no commission errors occurred at all, similar to the studies with the repeated cycles paradigm by Walser and colleagues (2012, 2014, 2017). Numerically, the results of our study also suggest an increasing intention interference effect across processing overlaps, with most pronounced interference effect when both parallel and sequential overlap was present (see Möschl et al., 2017, for a similar result with the repeated cycles paradigm). However, statistically, only the interference effect in the zero-target condition became significant. Nevertheless, in the overall analysis, which includes all experiments, a significant interference effect was revealed for both the ProM target and the zero-target condition, suggesting that after-effects in terms of intention interference occurred more generally. More interesting, in the present study we found consistent after-effects of correctly responding to deactivated prospective memory targets on the following trial, but only for the zero-target condition. Against the hypothesis that the bivalent nature of prospective memory targets would survive deactivation, no carry-over effects occurred for the ProM-condition in the deactivation phase. Responding to deactivated targets and potentially noticing the prospective memory nature of the targets and retrieving the intention only translated into a response time slowing when the prospective memory task had not been fulfilled. We suspect that most likely, these after-effects are due to noticing the prospective memory targets as special stimuli, pondering about the appropriateness of the context together with the requirement to withhold a programmed response, which the participants did not have had the possibility to perform (cf. Bugg & Scullin, 2013; Bugg et al., 2016). This contrasts with after-effects of responding to activated intentions which are related to switching tasks (and responses).

On a more general level, our study shows that rather than using a binary distinction between focal and nonfocal tasks, the process overlap framework allows for more fine-grained grading and fuels more sophisticated differentiations (see Figure 3). Consistent with predictions, we found that across experiments prospective memory performance increased with higher overlap and that monitoring costs decreased. Similarly, after-effects of responding to activated prospective memory targets decreased across experiments. The pattern of results for after-effects of responding to deactivated targets is more thought provoking. As the size of the after-effect was similar in the parallel overlap experiment (Experiment 2) and in the parallel and sequential overlap experiment (Experiment 3), it seems that this effect varies according to the presence of a parallel overlap but is not further increased through the additional sequential overlap. Overall, after-effects of responding to deactivated targets do not seem to vary systematically with the overall amount of process overlaps and seem to be restricted to the zero-target condition. Future research is necessary to provide more solid evidence for the generality of this interpretation. For example, future research might include a sequential overlap-only condition to test whether sequential and parallel overlaps are functionally isomorphic. Moreover, in the present study, we used a semantic ongoing task and overlaps were varied mainly by changing the prospective memory targets. According to the process overlap framework similar predictions are possible for a perceptual ongoing task (Meier & Graf, 2000).

To conclude, our study shows that beyond monitoring costs other kinds of costs occur in prospective memory situations. We specifically addressed after-effects of responding to activated and deactivated prospective memory targets and we found a differential pattern of effects depending on process overlaps. Therefore, the present study advances our understanding of the multiple effects that a prospective memory task can have on ongoing activities and it highlights the usefulness of the process overlap framework to guide systematic investigations.

References

Anderson, F. T., & Einstein, G. O. (2017). The fate of completed intentions. *Memory*, *25*(4), 467–480. https://doi.org/10.1080/09658211.2016.1187756

Anderson, F. T., Strube, M. J., & McDaniel, M. A. (2019). Toward a better understanding of costs in prospective memory: A meta-analytic review. *Psychological Bulletin*, *145*(11), 1053–1081. https://doi.org/10.1037/bul0000208

Baayen, R. H., Piepenbrock, R., & Van Rijn, H. (1993). *The CELEX lexical database (CD-ROM) Linguistic data consortium*. University of Pennsylvania.

Bugg, J. M., & Scullin, M. K. (2013). Controlling intentions: The surprising ease of stopping after going relative to stopping after never having gone. *Psychological Science*, *24*(12), 2463–2471. https://doi.org/10.1177/0956797613494850

Bugg, J. M., & Streeper, E. (2019). Fate of suspended and completed prospective memory intentions. In J. Rummel & M. A. McDaniel (Eds.), *Current issues in memory: Prospective memory* (pp. 44–59). Routledge. https://doi.org/10.4324/9781351000154-4

Bugg, J. M., Scullin, M. K., & Rauvola, R. S. (2016). Forgetting no-longer-relevant prospective memory intentions is (sometimes) harder with age but easier with forgetting practice. *Psychology and Aging*, *31*(4), 358–369. https://doi.org/10.1037/pag0000087

Cohen, A. L., Gordon, A., Jaudas, A., Hefer, C., & Dreisbach, G. (2017). Let it go: The flexible engagement and disengagement of monitoring processes in a non-focal prospective memory task. *Psychological Research*, *81*(2), 366–377. https://doi.org/10.1007/s00426-016-0744-7

Cottini, M., & Meier, B. (2020). Prospective memory monitoring and after-effects of deactivated intentions across the lifespan. *Cognitive Development*, *53*, 100844. https://doi.org/10.1016/j.cogdev.2019.100844

Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in Psychology*, *5*, 781. https://doi.org/10.3389/fpsyg.2014.00781

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory. Multiple retrieval processes. *Current Directions in Psychological Science*, *14*(6), 286–290. https://doi.org/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*(4), 1082–1088. https://doi.org/10.1037/a0019184

Goschke, T., & Kuhl, J. (1996). Remembering what to do: Explicit and implicit memory for intentions. In M. Brandimonte, G. O. Einstein & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 53–91). Erlbaum.

Grundy, J. G., & Shedden, J. M. (2014). A role for recency of response conflict in producing the bivalency effect. *Psychological Research*, *78*(5), 679–691. https://doi.org/10.1007/s00426-013-0520-x

Heathcote, A., Loft, S., & Remington, R. W. (2015). Slow down and remember to remember! A delay theory of prospective memory costs. *Psychological Review*, *122*(2), 376–410. https://doi.org/10.1037/a0038952

Lewin, K. (1926). Vorsatz, wille und bedürfnis [Intention, will, and need]. *Psychologische Forschung*, *7*(1), 330–385. https://doi.org/10.1007/BF02424365

Loft, S., & Remington, R. W. (2013). Wait a second: Brief delays in responding reduce focality effects in event-based prospective memory. *The Quarterly Journal of Experimental Psychology*, *66*(7), 1432–1447. https://doi.org/10.1080/17470218.2012.750677

Marsh, R. L., Hicks, J. L., & Hancock, T. W. (2000). On the interaction of ongoing cognitive activity and the nature of an event-based intention. *Applied Cognitive Psychology*, *14*(7), S29–S41. https://doi.org/10.1002/acp.769

Maylor, E. A. (1996). Age-related impairment in an event-based prospective-memory task. *Psychology and Aging*, *11*(1), 74–78. https://doi.org/10.1037/0882-7974.11.1.74

McBride, D. M., & Abney, D. H. (2012). A comparison of transfer-appropriate processing and multi-process frameworks for prospective memory performance. *Experimental Psychology*, *59*(4), 190–198. https://doi.org/10.1027/1618-3169/a000143

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*(7), S127–S144. https://doi.org/10.1002/acp.775

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(3), 605–614. https://doi.org/10.1037/0278-7393.30.3.605

Meier, B. (2019). Toward an ecological approach to prospective memory? The impact of Neisser's seminal talk on prospective memory research. *Frontiers in Psychology*, *10*, 1005. https://doi.org/10.3389/fpsyg.2019.01005

Meier, B., & Graf, P. (2000). Transfer appropriate processing for prospective memory tests. *Applied Cognitive Psychology*, *14*(7), S11–S27. https://doi.org/10.1002/acp.768

Meier, B., & Rey-Mermet, A. (2012). Beyond monitoring: After-effects of responding to prospective memory targets. *Consciousness and Cognition*, *21*(4), 1644–1653. https://doi.org/10.1016/j.concog.2012.09.003

Meier, B., & Rey-Mermet, A. (2018). After-effects without monitoring costs: The impact of prospective memory instructions on task switching performance. *Acta Psychologica*, *184*, 85–99. https://doi.org/10.1016/j.actpsy.2017.04.010

Meier, B., Woodward, T. S., Rey-Mermet, A., & Graf, P. (2009). The bivalency effect in task switching: general and enduring. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, *63*(3), 201–210. https://doi.org/10.1037/a0014311

Meier, B., & Zimmermann, T. D. (2015). Loads and loads and loads: The influence of prospective load, retrospective load, and ongoing task load in prospective memory. *Frontiers in Human Neuroscience*, *9*, 322. https://doi.org/10.3389/fnhum.2015.00322

Meier, B., Zimmermann, T. D., & Perrig, W. J. (2006). Retrieval experience in prospective memory: Strategic monitoring and spontaneous retrieval. *Memory*, *14*(7), 872–889. https://doi.org/10.1080/09658210600783774

Meiser, T., & Schult, J. C. (2008). On the automatic nature of the task-appropriate processing effect in event-based prospective memory. *European Journal of Cognitive Psychology*, *20*(2), 290–311. https://doi.org/10.1080/09541440701319068

Metzak, P. D., Meier, B., Graf, P., & Woodward, T. S. (2013). More than a surprise: The bivalency effect in task switching. *Journal of Cognitive Psychology*, *25*(7), 833–842. https://doi.org/10.1080/20445911.2013.832196

Möschl, M., Fischer, R., Bugg, J. M., Scullin, M. K., Goschke, T., & Walser, M. (2020). After-effects and deactivation of completed prospective memory intentions: A systematic review. *Psychological Bulletin*, *146*(3), 245–278. https://doi.org/10.1037/bul0000221

Möschl, M., Walser, M., Plessow, F., Goschke, T., & Fischer, R. (2017). Acute stress shifts the balance between controlled and automatic processes in prospective memory. *Neurobiology of Learning and Memory*, *144*, 53–67. https://doi.org/10.1016/j.nlm.2017.06.002

Rummel, J., Einstein, G. O., & Rampey, H. (2012). Implementation-intention encoding in a prospective memory task enhances spontaneous retrieval of intentions. *Memory*, *20*(8), 803–817. https://doi.org/10.1080/09658211.2012.707214

Scullin, M. K., & Bugg, J. M. (2013). Failing to forget: Prospective memory commission errors can result from spontaneous retrieval and impaired executive control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(3), 965–971. https://doi.org/10.1037/a0029198

Scullin, M. K., Bugg, J. M., & McDaniel, M. A. (2012). Whoops, I did it again: Commission errors in prospective memory. *Psychology and Aging*, *27*(1), 46–53. https://doi.org/10.1037/a0026112

Scullin, M. K., Bugg, J. M., McDaniel, M. A., & Einstein, G. O. (2011). Prospective memory and aging: Preserved spontaneous retrieval, but impaired deactivation, in older adults. *Memory & Cognition*, *39*(7), 1232–1240. https://doi.org/10.3758/s13421-011-0106-z

Scullin, M. K., Einstein, G. O., & McDaniel, M. A. (2009). Evidence for spontaneous retrieval of suspended but not finished prospective memories. *Memory & Cognition*, *37*(4), 425–433. https://doi.org/10.3758/MC.37.4.425

Scullin, M. K., McDaniel, M. A., & Shelton, J. T. (2013). The dynamic multiprocess framework: Evidence from prospective memory with contextual variability. *Cognitive Psychology*, *67*(1-2), 55–71. https://doi.org/10.1016/j.cogpsych.2013.07.001

Shelton, J. T., & Scullin, M. K. (2017). The dynamic interplay between bottom-up and top-down processes supporting prospective remembering. *Current Directions in Psychological Science*, *26*(4), 352–358. https://doi.org/10.1177/0963721417700504

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*(3), 347–361. https://doi.org/10.1037/0278-7393.29.3.347

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(4), 756–777. https://doi.org/10.1037/0278-7393.30.4.756

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*(4), 734–746. https://doi.org/10.1037/0278-7393.33.4.734

Streeper, E., & Bugg, J. M. (2021). Deactivation of prospective memory intentions: Examining the role of the stimulus-response link. *Memory & Cognition*, *49*(2), 364–379. https://doi.org/10.3758/s13421-020-01091-9

Strickland, L., Heathcote, A., Humphreys, M. S., & Loft, S. (2021). Target learning in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Advance online publication. https://doi.org/10.1037/xlm0000900

Strickland, L., Loft, S., Remington, R. W., & Heathcote, A. (2018). Racing to remember: A theory of decision control in event-based prospective memory. *Psychological Review*, *125*(6), 851–887. https://doi.org/10.1037/rev0000113

Wagenmakers, E.-J., Verhagen, A. J., Ly, A., Matzke, D., Steingroever, H., Rouder, J. N., & Morey, R. D. (2015). The need for Bayesian hypothesis testing in psychological science. In S. O. Lilienfeld & I. Waldman (Eds.), *Psychological science under scrutiny: Recent challenges and proposed solutions* (pp. 123–138). Wiley and Sons. https://doi.org/10.1002/9781119095910

Walser, M., Fischer, R., & Goschke, T. (2012). The failure of deactivating intentions: After-effects of completed intentions in the repeated prospective memory cue paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(4), 1030–1044. https://doi.org/10.1037/a0027000

Walser, M., Goschke, T., & Fischer, R. (2014). The difficulty of letting go: Moderators of the deactivation of completed intentions. *Psychological Research*, *78*(4), 574–583. https://doi.org/10.1007/s00426-013-0509-5

Walser, M., Goschke, T., Möschl, M., & Fischer, R. (2017). Intention deactivation: Effects of prospective memory task similarity on after-effects of completed intentions. *Psychological Research*, *81*(5), 961–981. https://doi.org/10.1007/s00426-016-0795-9

Walter, S., & Meier, B. (2016). The impact of absolute importance and processing overlaps on prospective memory performance. *Applied Cognitive Psychology*, *30*(2), 170–177. https://doi.org/10.1002/acp.3174

Woodward, T. S., Meier, B., Tipper, C., & Graf, P. (2003). Bivalency is costly: Bivalent stimuli elicit cautious responding. *Experimental Psychology*, *50*(4), 233–238. https://doi.org/10.1026/1618-3169.50.4.233

Appendix

Ongoing Task Response Times for the Calculation of After-Effects

Table A1

Means (and Standard Deviations) of Ongoing Task Performance Summarized for the Five Trials Before the Occurrence of the Prospective Memory Target and, Separately, the Five Trials After the Occurrence of the Prospective Memory Target Across Experiments and Conditions

		Mean ProM-1to ProM-5		ProM + 1		ProM + 2		ProM + 3		ProM + 4		ProM + 5	
Experiment	Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Exp 1													
	ProM	1,032	327	1,510	707	1,121	418	1,169	757	1,094	476	1,040	398
	Zero-target	947	221	857	226	871	267	872	249	896	203	881	239
	Control	719	128	717	181	730	173	700	155	718	147	754	199
Exp 2													
	ProM	788	152	1,051	346	823	194	839	264	866	288	811	236
	Zero-target	853	223	864	294	839	293	884	384	853	257	887	217
	Control	700	146	684	171	707	208	737	279	689	149	704	248
Exp 3													
	ProM	825	283	992	318	894	276	821	244	869	404	834	281
	Zero-target	844	267	850	246	855	344	834	237	792	221	841	321
	Control	726	133	705	131	749	218	698	127	732	138	692	126

(*Appendices continue*)

Table A2

Means (and Standard Deviations) of Ongoing Task Performance Summarized for the Five Trials Before the Occurrence of the Prospective Memory Lure and, Separately, the Five Trials After the Occurrence of the Prospective Memory Lure Across Experiments and Conditions

		Mean lure-1to Lure-5		Lure + 1		Lure + 2		Lure + 3		Lure + 4		Lure + 5	
Experiment	Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Exp 1													
	ProM	751	228	748	231	771	242	759	233	731	240	778	254
	Zero-target	774	154	773	139	754	162	732	125	725	141	720	183
	Control	733	155	679	118	707	169	744	168	747	193	686	144
Exp 2													
	ProM	728	114	707	149	728	195	724	149	757	165	699	128
	Zero-target	761	154	881	296	763	230	780	206	800	256	766	159
	Control	769	190	680	126	707	160	722	168	705	140	740	196
Exp 3													
	ProM	753	198	765	218	778	217	821	325	761	371	739	270
	Zero-target	780	210	900	340	845	339	822	325	820	238	759	224
	Control	738	96	718	109	734	102	745	152	710	138	714	113

Received September 20, 2021
Revision received March 9, 2022
Accepted April 10, 2022 ■