After-effects without monitoring costs:

The impact of prospective memory instructions on task switching performance

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PUBLISHED IN: ACTA PSYCHOLOGICA

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. doi:10.1016/j.actpsy.2017.04.010

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This work was supported by the Center for Cognition, Learning, and Memory, University of Bern and by a grant from the Janggen-Pöhn Foundation to A. Rey-Mermet.

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Abstract

In a prospective memory task, verbal instructions are used to define an appropriate target event as retrieval cue. This target event is typically part of an ongoing activity and is thus bivalent as it involves features relevant for both the prospective memory task and the ongoing task. Task switching research has demonstrated that responding to bivalent stimuli is costly and can slow down even subsequent performance. Thus, responding to prospective memory targets may also result in after-effects, expressed as slowed subsequent ongoing task performance. So far, ongoing task slowing has been mainly considered as a measure of strategic monitoring for the prospective memory cues. The purpose of this study was to investigate whether after-effects of responding to prospective memory targets contribute to this slowing. In four experiments, a prospective memory task was embedded in a task-switching paradigm and we manipulated the degree of task-set overlap between the prospective memory task and the ongoing task. The results showed consistent after-effects of responding to prospective memory targets in each experiment. Increasing task-set overlap increased the amount and longevity of the after-effects. Surprisingly prospective memory retrieval was not accompanied by strategic monitoring. Thus, this study demonstrates that ongoing task slowing can occur in the absence of monitoring costs.

Keywords: intention memory, cognitive control, task-set overlap

Instructions can turn univalent stimuli into bivalent ones:

The case of prospective memory

For prospective memory, that is, the ability to form an intention, retain it in memory, and retrieve it at the appropriate occasion, instructions are highly relevant. Being able to make plans and to keep promises, be it by external instructions or self-instructions, is important for self-efficacy and for leading a successful life. In laboratory studies, a prospective memory task is created via verbal instructions. For example, participants are instructed to press a particular key on the keyboard when a target stimulus appears during an ongoing computerized decision task. Importantly, by instructions, these target stimuli become bivalent stimuli (i.e., stimuli with relevant features for two different tasks), because not only can they be used to perform the prospective memory task, they can also be used to perform the ongoing task. From task switching research, it is evident that processing bivalent stimuli is costly and can result in slowed performance even for subsequent univalent stimuli (Meier, Woodward, Rey-Mermet, & Graf, 2009; Rogers & Monsell, 1995; Woodward, Meier, Tipper & Graf, 2003). The purpose of this study was to investigate the after-effects of responding to prospective memory targets.

Responding to a prospective memory task requires the detection of the target events which can happen either spontaneously or due to strategic monitoring for the target events (Einstein & McDaniel, 2000). Spontaneous retrieval occurs particularly when prospective memory targets are well specified (e.g., Cohen, Jaudas, & Gollwitzer, 2008; Einstein et al., 2005; Hicks, Marsh, & Cook, 2005; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Meier, von Wartburg, Matter, Rothen, & Reber, 2011), when the processing operations required to identify a prospective memory target are similar to those required to perform the ongoing task (Marsh, Cook, & Hicks, 2006; Marsh, Hicks, & Cook, 2005; Meiser & Schult, 2008; cf., Meier & Graf, 2000), that is, when the prospective memory target cues are focal (e.g., Scullin, McDaniel, & Einstein, 2010; Scullin, McDaniel, Shelton, & Lee, 2010). In situations in which retrieval is spontaneous, ongoing task performance is thus not affected by prospective memory task instructions.

In contrast, when the detection of prospective memory targets occurs as a consequence of strategic monitoring, for example, when the prospective memory task is important (Kliegel, Martin, McDaniel, & Einstein, 2004; Smith & Bayen, 2004, see Walter & Meier, for a recent review), when the occurrence of the prospective memory task is expected to occur within a specific pre-defined time window (Marsh, Hicks, & Cook, 2006; Meier, Zimmermann, & Perrig, 2006), or when there are multiple target events (Cohen et al., 2008; Einstein et al., 2005), retrieval comes along with a cost, expressed as a slowing in ongoing task performance. In fact, according to the preparatory attentional and memory (PAM) theory, prospective memory retrieval is always the consequence of strategic monitoring for the prospective memory task (Smith 2003; Smith & Bayen, 2004).

Operationally, monitoring costs are usually measured as the difference between ongoing task reaction times in a condition with vs. without the prospective memory task. This calculation of monitoring costs does not take into account the possibility that responding to prospective memory target stimuli can also contribute to ongoing task slowing due to the bivalent nature of the prospective memory targets. Specifically, if responding to prospective memory targets leads to a lingering slowing similar to responding to bivalent stimuli in task switching, “monitoring cost” cannot be considered as a pure measure of strategic monitoring. This possibility, which is the focus of the present article, is supported by recent studies that have demonstrated that responding to prospective memory targets slows performance on subsequent ongoing task performance and must thus be considered as an additional source of costs (Loft, Kearney, & Remington, 2008; Meier & Rey-Mermet, 2012).

Loft et al. (2008, Experiments 1 and 3) provided first evidence that besides the expectancy-based monitoring cost, another source of slowing exists which is probably related to the after-effects of responding to prospective memory targets. They tested three groups of participants. In the first group, participants were instructed to perform the prospective memory task and later prospective memory targets were presented. In the second group, participants were instructed to perform the prospective memory task but no prospective memory targets were presented. In the third group, participants were not instructed for the prospective memory task (control group). The results showed a performance slowing in the ongoing task for both groups with prospective memory task instructions compared to the control group. Critically, the performance slowing was larger for the group in which participants responded to prospective memory targets. Therefore, responding to prospective memory targets resulted in an additional cost, likely due to after-effects of responding to prospective memory targets. This suggests that monitoring cost may be generally overestimated.

In a more recent study, we have investigated the specific trajectory of the after-effects of responding to prospective memory targets on ongoing task performance (Meier & Rey-Mermet, 2012). In two experiments, we used a within-subjects design consisting of three blocks in which we kept the expectancy-based monitoring costs constant. The prospective memory task was activated all the time, but prospective memory targets appeared only in the second block. This allowed investigating the after-effects that were specific to the presentation of prospective memory targets by comparing performance in block 2 to blocks 1 and 3 in which no prospective memory targets were presented. In both experiments, the results revealed a performance slowing on ongoing task trials that appeared immediately after responding to a prospective memory target. Increasing the task-set overlap revealed a longer-living effect that sporadically slowed performance on those ongoing task trials that had overlapping features with the prospective memory targets. This demonstrates that responding to prospective memory targets can slow subsequent ongoing task performance and must therefore be considered as a potential source of slowing. Importantly, this slowing may affect the cost thought to represent strategic monitoring for the prospective memory targets. However, as we did not assess monitoring separately in the previous study, it was not possible to determine the size of this influence.

The purpose of the present study was to investigate to what extent the after-effects of prospective memory targets contribute to monitoring costs. To this end, we combined the design used by Loft et al. (2008) which involved a between subject variation of instruction condition and the design used in our previous study (Meier & Rey-Mermet, 2012) which involved within-subjects control blocks. Moreover, we tested the specific trajectory of responding to prospective memory targets for subsequent ongoing task performance. Thus, each experiment involved three conditions. In the first condition ("prospective memory"), participants were instructed for the prospective memory task and they then encountered prospective memory targets. This condition was, in part, a replication of our previous study (particularly Experiments 1 and 4). In the second condition ("expectancy activated"), participants were instructed for the prospective memory task, but they never encountered any targets. Thus, the expectancy for the prospective memory task was activated and we hypothesized that this would lead to strategic monitoring. The third condition was a control condition because no prospective memory task instructions were given.

Participants performed a parity decision on black numerals, a colour decision on red or blue symbols, and a case decision on black letters. Some stimuli for case decisions were turned into prospective memory targets by instructing the participants to press a designated key when they were presented. As our previous study showed that the task-overlap between ongoing task and prospective memory targets affected the size of the after-effects, we varied task-set overlap across experiments. We hypothesized that with higher task-set overlap, stronger after-effects would occur. In Experiments 1 and 2, the prospective memory targets had relevant overlap with one ongoing task (i.e., the case decision). Specifically, they consisted of consonant-vowel-consonant triplicates (e.g., nen) in Experiment 1 and of letters displayed in a different font (e.g., nnn) in Experiment 2. In Experiment 3 and Experiment 4, the prospective memory targets also had relevant features for the case decision task and in addition, they varied on the colour dimension. In Experiment 3, the specific letter colours (yellow and green) were not part of the stimulus set of the colour decision. In Experiment 4, the specific colours (red and blue) were part of the stimulus set of the colour decision. Thus, they had relevant feature overlaps with both the ongoing colour and case decision tasks. Table 1 provides an overview of the experiments, the prospective memory targets, and the expected effects.

Table 1. Overview of the experiments, the prospective memory targets and their expected relationship to task-set overlap, cue focality, resulting after-effects and monitoring costs.

Experiment	Target	Task-set Overlap	After-effects	Monitoring Costs
1	nen	Lower	Lower	Higher
2	nnn	⇩	⇩	⇧
3	nnn			
4	nnn	Higher	Higher	Lower

Note. In Experiment 3, the prospective memory targets were presented in green or yellow colour (i.e., colours not used for the colour decision task) and in Experiment 4, they were presented in red or blue colour (i.e., colours used for the colour decision task).

Experiment 1

Method

Participants. The participants were 60 students (30 men, mean age = 24.2, *SD* = 5.2) from the University of Bern. Twenty participants were pseudo-randomly assigned to each of the three conditions (i.e., prospective memory, expectancy activated, and control). The study was approved by the local ethical committee of the University of Bern.

Materials. For the parity decision, the stimuli were the numerals 1 through 8, each displayed in black and in triplicate (e.g., 777). For the colour decision, the stimuli were the symbols §, %, #, $, displayed in triplicate (e.g., &&&), and either in blue or red. For the case decision, the stimuli were triplicates of the consonants n, p, v, s (e.g., nnn), displayed in black, in either upper- or lowercase. We created a set of eight prospective memory targets by constructing consonant-vowel-consonant triplicates: nen, pip, vov, and sas. These targets were always displayed in black, either in upper- or in lowercase. All stimuli were displayed at the center of the computer screen in 60-point Times New Roman font.

Procedure. Participants were tested individually. They were informed that the experiment involved three different tasks: parity decisions about numerals, colour decisions about symbols, and case decisions about letters. They were instructed to press one of two computer keys (*b* and *n*) with their left and right index fingers respectively, for each of the three tasks. The mapping information, printed on paper, was displayed below the computer screen throughout the experiment. For both conditions with prospective memory instructions (i.e., prospective memory and expectancy activated conditions), participants were further informed that in some of the case-decision trials, triplicates would consist of a consonant, a vowel, and a consonant. In this situation, rather than to perform the case decision, they were instructed to press the space key (i.e., the prospective memory task). Next, participants had to repeat these instructions in order to make sure that they understood.

Next, a block of 30 task triplets was presented for practice. Each task triplet required making a parity decision, a colour decision, and a case decision, always in the same order, as illustrated in Figure 1. The stimulus for each trial was displayed until the participant responded. Then, the screen blanked for 500 ms before the next stimulus appeared. After each task triplet, an additional blank interval of 500 ms was included. After the practice block and a brief break, each participant completed three experimental blocks without any break between blocks. The first block included 32 task triplets, with the first two task triplets serving as “warm-up” triplets and excluded from the analyses. The second and third blocks had 30 task triplets each.

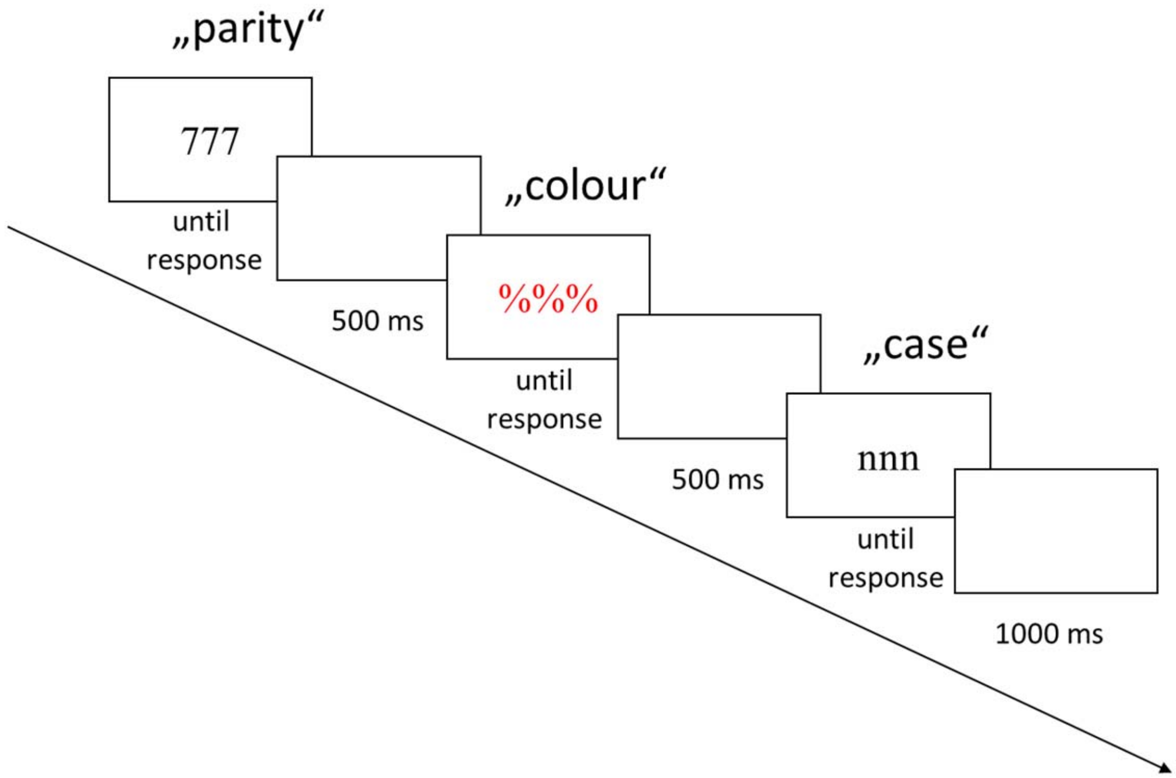

Figure 1. Example of one ongoing task triplet. Participants carried out a parity decision (odd vs. even) on numerals, a colour decision (red vs. blue) on symbols, and a case decision (upper- vs. lowercase) on letters.

For the prospective memory condition, univalent stimuli (i.e., stimuli with relevant features for one task) were presented as ongoing task trials for the first and third blocks. For the second block, stimuli were univalent except on 20% of the case decisions in which prospective memory targets (i.e., consonant-vowel-consonant triplicates) appeared. Prospective memory targets were determined randomly and without replacement. Task triplets with prospective memory targets were evenly interspersed among the 30 task triplets of the block, occurring in every fifth task triplet, specifically in the 3rd, 8th, 13th, 18th, 23th, and 28th triplets. For the two other conditions (i.e., the expectancy activated and control conditions), only univalent stimuli were presented as ongoing task trials in all three blocks. The entire experiment lasted about 20 minutes.

Data analysis. For each participant, the median reaction times (RTs) for correct responses were computed for each block, for each task of the ongoing task, and for each task triplet following a prospective memory target in block 2 and for each corresponding task triplet in blocks without targets. For analysis, this task triplet was designated with the label T, with successive task triplets labelled T+1, T+2, T+3, and T+4. An alpha level of 0.05 was used for all statistical tests. Greenhouse-Geisser corrections are reported where appropriate and effect sizes are expressed as partial η^2 values.

Statistical analysis. The main objective was to examine whether the after-effects of target presentation on ongoing task performance contribute to monitoring costs. To this end, we tested on how many task triplets following a prospective memory target a performance slowing occurred in the prospective memory condition. The most relevant results are thus the RTs from the ongoing task trials in block 2 compared to those from the blocks 1 and 3 for the task triplets T+1 to T+4 in the prospective memory condition. In order to control for expectancy and practice we also compared this condition to the two other experimental conditions (expectancy activated and control).

We conducted a four-way analysis of variance (ANOVA) with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) as within-subject factors and condition (prospective memory, expectancy activated, control) as a between-subjects factor. To keep the results as short as possible, we will only report the interactions involving block and condition because these interactions are most informative regarding our main objective, that is, whether performance across blocks differs between the three conditions. Then, we disentangle these interactions by conducting follow-up three-way repeated-measures ANOVAs for each condition separately, with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4). If the three-way ANOVAs reveals a significant interaction involving block, additional follow-up two-way repeated-measures ANOVAs are reported for each task triplet separately, with block (block 1, block 2, block 3) and task (parity, colour, case). If a two-way ANOVA reveals significant interaction between block and task, additional follow-up one-way repeated-measures ANOVA are reported with the factor block (block 1, block 2, block 3) for each task separately, followed by t-tests (one-tailed to take practice effects into account).

Moreover, to assess performance differences between the three groups with respect to proper monitoring, that is, slowing unconfounded by after-effects, we report a two-way ANOVA, with task (parity, colour, case) as a within-subject factor and condition (prospective memory, expectancy activated, control) as a between-subjects factor for the RTs of block 1 (i.e., before targets were presented).

Results

Accuracy. Mean accuracy on prospective memory targets was .94 (SE = 0.03). Mean accuracy on ongoing task performance was .96 (SE = 0.01) in each of the three conditions (i.e., prospective memory, expectancy activated, and control). The means in each condition were not significantly different from each other, $F < 1$, $p > .05$.

Reaction times. Mean RTs of correctly responding to prospective memory targets was 934 ms (*SE* = 39). A summary of the ongoing task RTs across all blocks and conditions is provided in Figure 1 of the Appendix. The four-way ANOVA with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) as within-subject factors and condition (prospective memory, expectancy activated, control) as a between-subjects factor showed the expected interaction between block and condition, F (3.62, 103.12) = 4.72, $p <$ .01, $\eta^2 = .14$. Thus, performance across blocks differed between the three conditions and to disentangle this interaction, we conducted follow-up three-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) for each condition separately.

Prospective memory condition. For the prospective memory condition, the three-way ANOVA revealed a significant interaction between block and task triplet, F (6, 114) = 4.54, $p <$ .001, $\eta^2 = .19$. Thus, although ongoing task performance was slowed in block 2 compared to blocks 1 and 3, this performance slowing decreased across task triplets (see Appendix, Figure 1a). To disentangle this interaction, we carried out follow-up two-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3) and task (parity, colour, case) for each task triplet separately. This showed relevant results only for the task triplet T+1 and T+4.

For T+1, a follow-up two-way ANOVA revealed a significant main effect of block, F (1.24, 23.59) = 21.79, $p < .001$, $\eta^2 = .53$. Performance was slowed on the first task triplets following the targets in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 3.07, $p < .01$; and block 2 vs. 3: t (19) = 6.48, $p < .001$). This indicates the presence of an after-effect for the first task triplets following the targets.

For T+4, a follow-up two-way ANOVA also showed a significant main effect of block, F (2, 38) = 6.05, p < .01, η^2 = .24. Performance was slower in blocks 1 and 2 (block 1 vs. 2: t (19) = 0.39, p = .70) than in block 3 (block 1 vs. 3: t (19) = 2.48, p < .05; and block 2 vs. 3: t (19) = 4.56, p < .001), suggesting a simple practice effect.

In order to illustrate the after-effects of responding to prospective memory targets, we have summarized these results in Figure 2. Specifically, we have highlighted the differences between ongoing task performance in Block 2 (i.e., after responding to prospective memory targets) and the corresponding ongoing task performance averaged across Blocks 1 and 3.

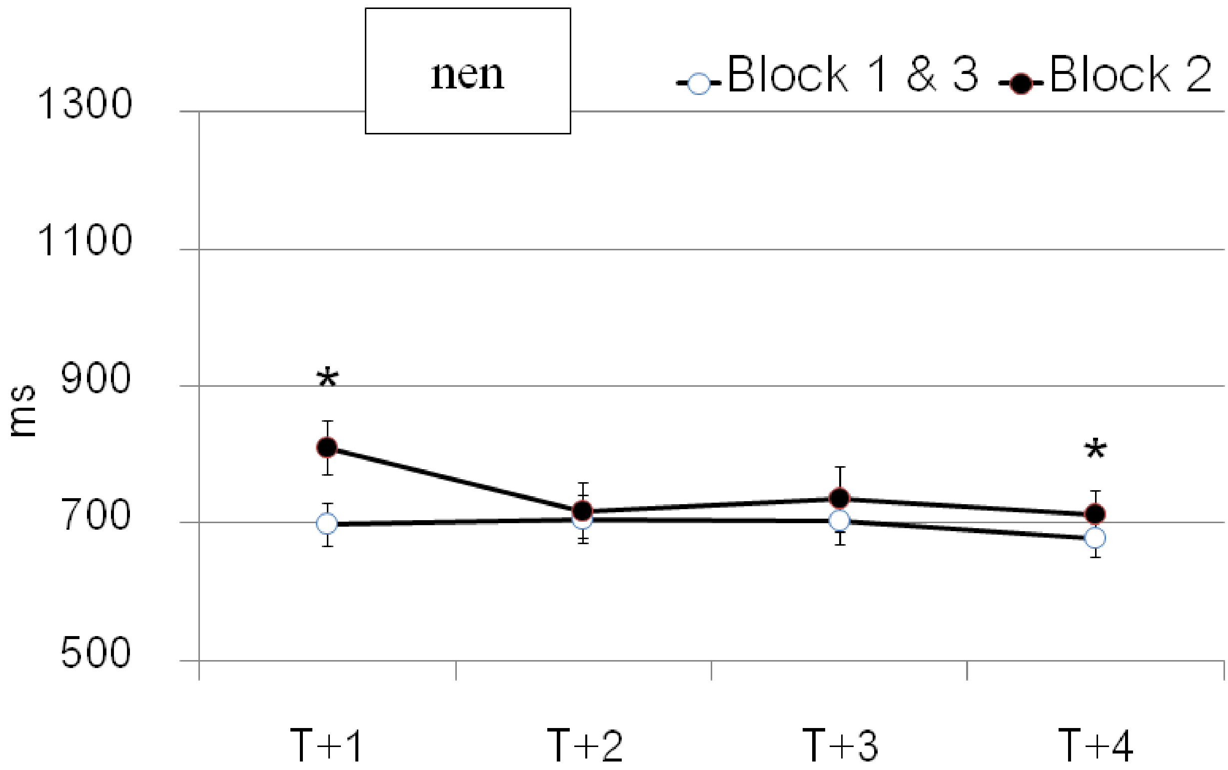

Figure 2. After-effects of responding to prospective memory targets in Experiment 1. Asterisks refer to significant after-effects (p <. 05). Error bars represent standard errors.

Expectancy activated condition. For the expectancy activated condition, the three-way repeated-measures ANOVA with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) showed a significant main effect of block, F (2, 38) = 5.72, p < .01, η_p^2 = .23. Performance was slower in block 1 than in block 2 (block 1 vs. 2: t (19) = 4.07, p < .01), whose performance was, however, not different from block 3 (block 2 vs. 3: t (19) = 0.89, p = .34). Therefore, for the expectancy activated condition, RTs performance decreased across blocks, which indicates a practice effect (see Appendix, Figure 1b).

Control condition. For the control condition, the three-way ANOVA showed a significant main effect of block, F (2, 38) = 6.25, p < .01, η^2 = .25. In this condition, performance was slower in block 1 than in block 2 (block 1 vs. 2: t (19) = 2.06, p < .05), which, in turn, was slower than in block 3 (block 2 vs. 3: t (19) = 1.76, p < .05, one-tailed). Therefore, for the control condition, RT performance decreased across the blocks, which indicates a practice effect (see Appendix Figure 1c).

Monitoring Costs. In order to test for potential monitoring effects, we carried out a two-way ANOVA with task (parity, colour, case) and condition (prospective memory, expectancy activated, control) on the RTs of block 1 only (i.e., before any prospective memory targets occurred). This analysis revealed a significant main effect of condition, F (2, 57) = 3.19, p = .049, η^2 = .10. However, post-hoc Tukey tests did not reveal a significant difference between the three conditions (p > .05). This suggests that prospective memory instructions did not induce monitoring costs.

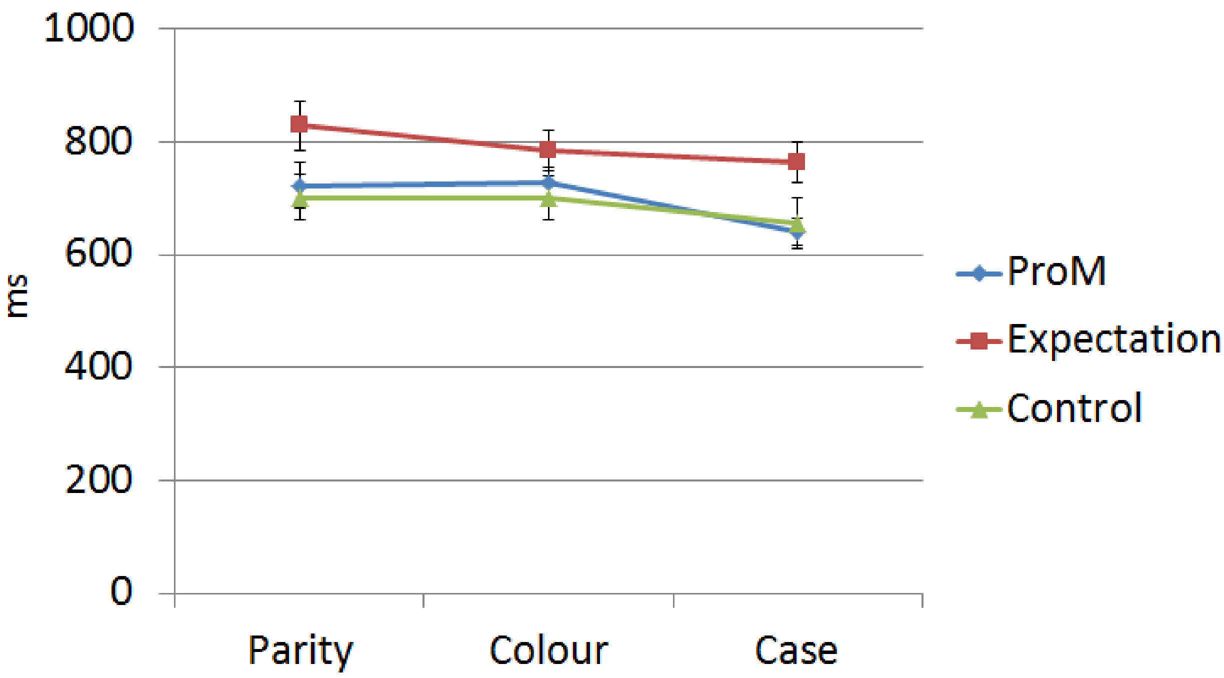

Figure 3. Block 1 ongoing task reaction times indicate no significant monitoring costs in Experiment 1 (ProM = prospective memory condition, Expectation = expectation activated condition, Control = control condition). Error bars represent standard errors.

Discussion

The purpose of Experiment 1 was to determine whether the after-effects of prospective memory targets contribute to monitoring costs when the targets had relevant features for one task of the ongoing task. In the prospective memory condition, the results showed a performance slowing for the first task triplet following the targets, replicating our previous findings (Meier & Rey-Mermet, 2012). This indicates an after-effect of prospective memory targets. In contrast, no such performance slowing was found in the conditions without targets (i.e., the expectancy activated and control conditions). Moreover, when analysing the first block only (i.e., before any target was presented), despite finding a significant effect of condition, post-hoc tests did not reveal any significant group difference. This is due to the fact that the main effect just reached significance in the ANOVA but did not survive the more conservative Tukey post-hoc test. With a more lenient test such as Least Significant Difference (LSD), post hoc tests would have indicated that the expectancy activated group differs from both the prospective memory and the control group. This might be taken as evidence for monitoring costs. However, as the prospective memory group did not differ from the control group, the overall pattern rather indicates that the slower RTs of the expectancy activated group was a chance result of sampling than evidence for monitoring. As can be seen in Figure 1 of the Appendix, this group remained slow across blocks which corroborates this interpretation. Overall, the results suggest the presence of an after-effect of responding to prospective memory targets in the absence of monitoring costs.

To generalize the findings of Experiment 1, we conducted a second experiment in which we kept the task-set overlap between prospective memory task and the ongoing task constant, that is, the prospective memory targets had overlapping features with one of the ongoing tasks (i.e., the case decision), but it varied on another dimension (i.e., the font).

Experiment 2

Method

Participants. The participants were 60 different students (27 men, mean age = 24.1, *SD* = 4.2) from the University of Bern. As in Experiment 1, twenty participants were pseudo-randomly assigned to each condition (i.e., prospective memory, expectancy activated, and control).

Materials and Procedure. The materials and procedure were similar to Experiment 1 except that prospective memory targets were defined as letters written in a different font (i.e., in

Comic Sans MS). For both conditions with prospective memory instructions (i.e., prospective memory and expectancy activated conditions), participants were informed that, in some of the case-decision trials, the letters would be presented in a different font. In this situation, they were required to press the space key (the prospective memory task) rather than to perform the case decision.

Data and statistical analyses. The data and statistical analyses were identical to Experiment 1.

Results

Accuracy. Mean accuracy on prospective memory targets was .81 (*SE* = 0.03). Mean accuracy on ongoing task performance was .95 (*SE* = 0.01), .95 (*SE* = 0.01), and .97 (*SE* = 0.01) for the prospective memory, expectancy activated, and control conditions, respectively. The means in each condition were not significantly different from each other, $F < 2.06$, $p > .05$.

Reaction times. Mean RTs of correctly responding to prospective memory targets was 976 ms (*SE* = 61). Mean RTs for ongoing task are depicted in Figure 2 of the Appendix. The ANOVA with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) as within-subject factors and condition (prospective memory, expectancy activated, control) as between-subjects factor showed a significant two-way interaction between block and condition, F (3.22, 91.87) = 5.05, $p < .01$, $\eta^2 = .15$, and a significant three-way interaction between block, task triplet, and condition, F (9.56, 272.53) = 1.85, $p < .05$, $\eta^2 = .06$. Thus, performance across blocks and task triplets differed between the three conditions. As in Experiment 1, we investigated these differences by carrying out follow-up three-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) for each condition separately.

Prospective memory condition. For the prospective memory condition, the three-way ANOVA revealed a significant interaction between block and task, F (4, 76) = 3, $p < .05$, $\eta^2 = .14$, as well as between block and task triplet, F (3.47, 65.91) = 3.17, $p < .05$, $\eta^2 = .14$. Thus, although ongoing task performance was slowed in block 2 compared to blocks 1 and 3, this performance slowing decreased across tasks and task triplets (Appendix, Figure 2a). To further investigate this performance slowing, we carried out follow-up two-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3) and task (parity, colour, case) for each task triplet separately.

For T+1, the two-way ANOVA revealed a significant interaction between block and task, F (4, 76) = 2.76, $p < .05$, $\eta^2 = .13$. To disentangle this interaction, we conducted a follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3) for each task separately. For all three tasks, the ANOVA showed a significant effect (parity: F (1.26, 24.01) = 9.58, $p < .01$, $\eta^2 = .33$; colour: F (2, 38) = 4.40, $p < .05$, $\eta^2 = .19$; and case: F (2, 38) = 3.91, $p < .05$, $\eta^2 = .17$). Performance on parity decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 2.71, $p < .05$; and block 2 vs. 3: t (19) = 3.65, $p < .01$). Compared to block 1, performance on colour decisions was slowed numerically in block 2 and significantly in block 3 (block 1 vs. 2: t (19) = 1.04, $p = .31$; block 2 vs. 3: t (19) = 4.23, $p < .001$). Performance on case decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 2.05, $p < .05$; and block 2 vs. 3: t (19) = 2.39, $p < .05$). This indicates the presence of an after-effect for the first task triplet after responding to prospective memory targets.

For T+2, the two-way ANOVA revealed a significant interaction between block and task, *F* (4, 76) = 2.47, $p < .05$, $\eta^2 = .11$. The follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3) revealed a significant effect for parity decisions, *F* (2, 38) = 5.62, $p < .01$, $\eta^2 = .23$. Performance on parity decisions was slower in blocks 1 and 2 (block 1 vs. 2: *t* (19) = 0.53, $p = .60$) than in block 3 (block 1 vs. 3: *t* (19) = 3.19, $p < .01$; and block 2 vs. 3: *t* (19) = 3.06, $p < .01$). This indicates a practice effect for parity decisions in the task triplets T+2.

For T+3, the two-way ANOVA showed a significant main effect of block, *F* (2, 38) = 5.59, $p < .01$, $\eta^2 = .23$. Performance was slower in blocks 1 and 2 (block 1 vs. 2: *t* (19) = 0.49, $p = .63$) than in block 3 (block 1 vs. 3: *t* (19) = 2.53, $p < .05$; block 2 vs. 3: *t* (19) = 2.73, $p < .05$). This indicates the presence of a practice effect for the task triplets T+3.

For T+4, the two-way ANOVA showed a significant main effect of block, *F* (2, 38) = 4.90, $p < .05$, $\eta^2 = .20$. Despite the lack of a significant interaction between block and task, *F* (4, 76) = 1.32, $p = .27$, $\eta^2 = .06$, the pattern of results suggests a performance slowing in block 2 for the case decisions (Appendix, Figure 2a). To further investigate this pattern, we conducted a follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3) for each task separately. The ANOVAs revealed a significant effect for the parity and case decisions, *F* (2, 38) = 3.39, $p < .05$, $\eta^2 = .15$, and *F* (2, 38) = 3.19, $p < .05$, $\eta^2 = .14$, respectively. Performance on parity decisions was slower in blocks 1 and 2 (block 1 vs. 2: *t* (19) = 0.55, $p = .58$) than in block 3 (block 1 vs. 3: *t* (19) = 1.96, $p < .05$, one-tailed; and block 2 vs. 3: *t* (19) = 2.44, $p < .05$). In contrast, performance on case decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: *t* (19) = 2.04, $p < .05$; and block 2 vs. 3: *t* (19) = 2.05, $p < .05$).

This indicates a practice effect for parity decisions but an after-effect of the targets for case decisions in the task triplets T+4.

In order to illustrate the after-effects of responding to prospective memory targets, we have summarized the results in Figure 3. Specifically, we have highlighted the differences between ongoing task performance in Block 2 (i.e., after responding to prospective memory targets) and the corresponding ongoing task performance averaged across Blocks 1 and 3.

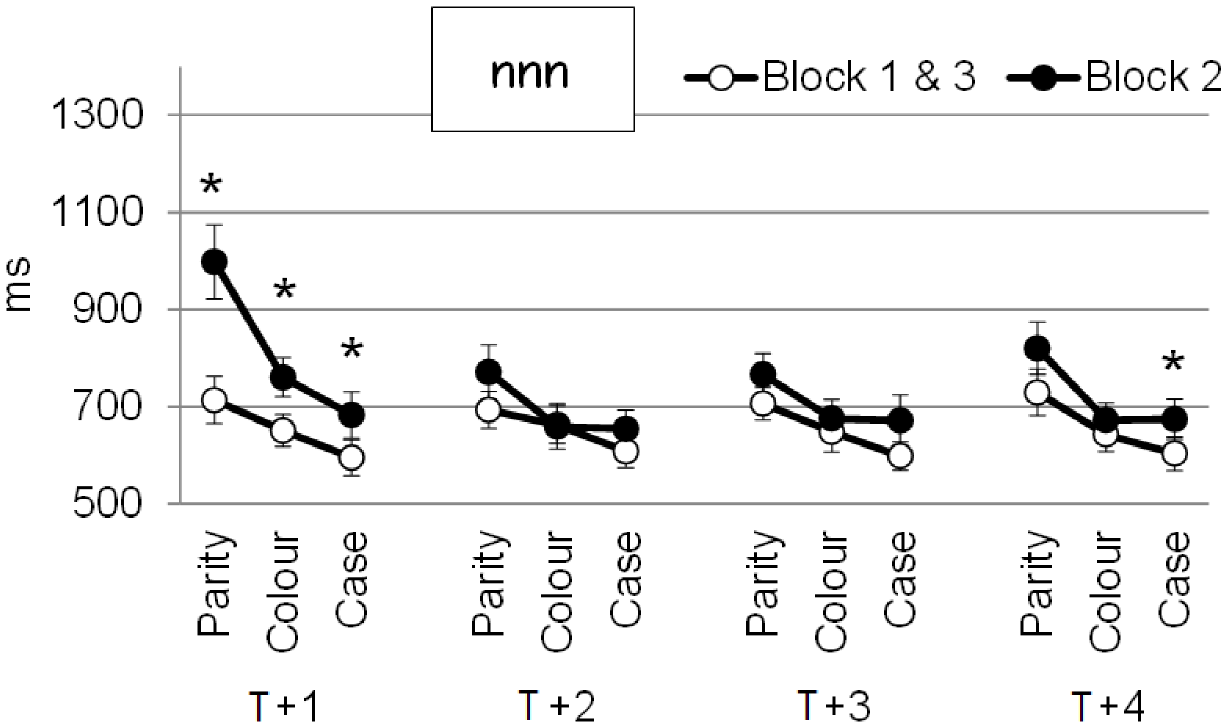

Figure 4. After-effects of responding to prospective memory targets in Experiment 2. Asterisks refer to significant after-effects (p <. 05). Error bars represent standard errors.

Expectancy activated condition. For the expectancy activated condition, the three-way repeated-measures ANOVA with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) showed a significant main effect of block, F (1.47, 28.03) = 8.07, $p < .01$, $\eta^2 = .30$. In this condition, performance was slower in block 1 than in block 2 (block 1 vs. 2: t (19) = 2.83, $p < .05$), whose performance was, however, not different from block 3 (block 2 vs. 3: t (19) = 1.44, $p = .17$). Therefore, for the expectancy activated condition, RTs performance decreased across blocks, which indicates a practice effect (Appendix, Figure 2b).

Control condition. For the control condition, the three-way ANOVA showed a significant main effect of block, F (2, 38) = 7.71, $p < .01$, $\eta^2 = .29$. In this condition, performance was slower in block 1 than in block 2 (block 1 vs. 2: t (19) = 2.89, $p < .01$), whose performance was, however, not different from block 3 (block 2 vs. 3: t (19) = 0.96, $p = .35$). Therefore, for the control condition, RTs performance decreased across blocks, which indicates a practice effect (Appendix, Figure 2c).

Monitoring costs. As in Experiment 1, we determined the presence of monitoring costs unconfounded by the after-effects of targets by analysing the RTs of block 1 only (Figure 5). The two-way ANOVA with task (parity, colour, case) and condition (prospective memory, expectancy activated, control) revealed no main effect or interaction involving condition, Fs < 1.03, ps > .05, $\eta^2 < .03$. Thus, there was no performance difference in block 1 between the conditions. This shows that introducing a prospective memory task did not affect ongoing task performance before the targets occurred.

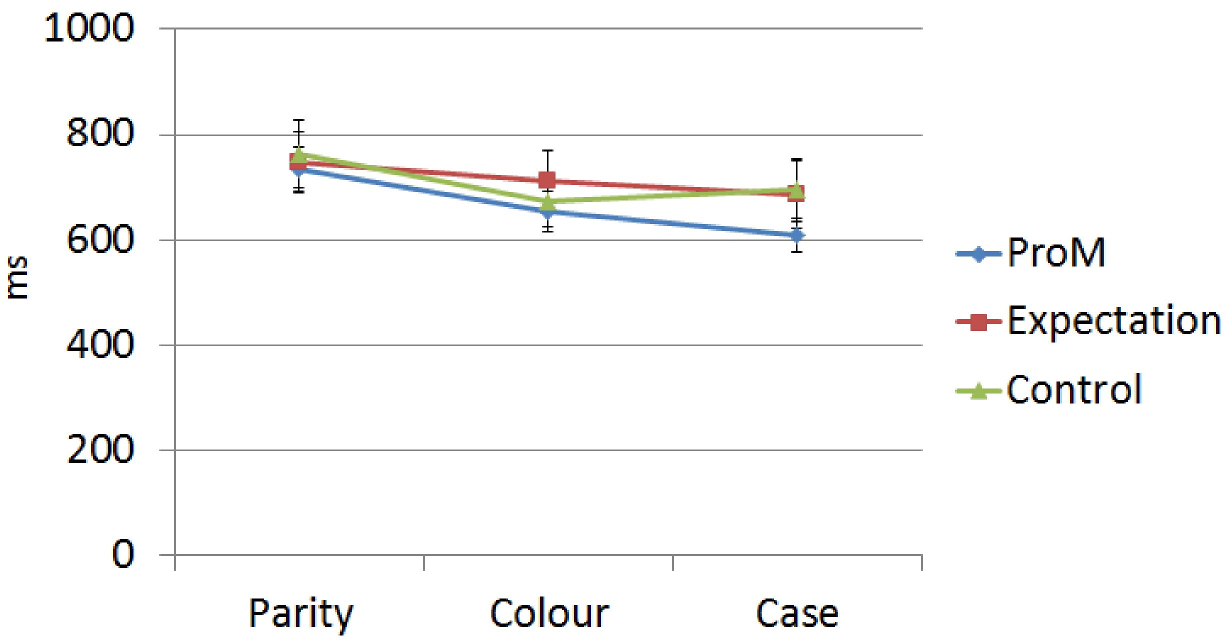

Figure 5. Block 1 ongoing task reaction times indicate no significant monitoring costs in Experiment 2. (ProM = prospective memory condition, Expectation = expectation activated condition, Control = control condition). Error bars represent standard errors.

Discussion

The purpose of Experiment 2 was to generalize the findings of Experiment 1 when the prospective memory targets had relevant features for one ongoing task (i.e., the case decision), but varied on another dimension (i.e., the font). In the prospective memory condition, the results showed a performance slowing for the first task triplet following the targets, replicating our previous findings. In addition, on the last task triplets, performance was also slowed on the task that shared relevant features with the prospective memory targets (i.e., the case decisions). These results replicate and extend the findings our previous findings by demonstrating longer-living after-effects even when the targets had relevant features for one of the ongoing task (Experiment

1; Meier & Rey-Mermet, 2012). In the conditions in which no prospective memory targets were presented (i.e., the expectancy activated and control conditions), no such performance slowing was found. Notably, prospective memory performance was somewhat lower in Experiment 2 than in Experiment 1 and it is possible that this performance difference affected the longevity of the after-effects[1]. Both an increase and a decrease of the after-effects are possible. On the one hand, if participants realize that they have missed a prospective memory target and they ponder about this failure an increase and prolongation of slowing seems likely. On the other hand, if participants may miss a prospective memory target without realizing it. In this situation, post-error slowing would not seem to matter. Rather, after-effects may be reduced, as prospective stimulus bivalency is not even processed.

Moreover, when analysing the first block only (i.e., before any target was presented), we found comparable performance across the three conditions indicating a lack of monitoring cost. Together, these results again demonstrate after-effects of prospective memory targets in the absence of monitoring costs.

In Experiment 3, we increased the task-set overlap between the ongoing task and the prospective memory targets by presenting prospective memory targets which were defined by colour. Thus, the targets not only had relevant features for one ongoing task (i.e., the case decision), they also varied on a relevant dimension for another ongoing task (i.e., the colour decision). By increasing the task-set overlap, we expected to increase the after-effects of responding to prospective memory targets. Specifically, we expected that the performance slowing following the targets would be larger and longer-living in the prospective memory condition, and possibly a performance slowing in both the prospective memory condition and the expectancy activated condition compared to the control condition.

Experiment 3

Method

Participants. The participants were 60 different students (23 men, mean age = 23.5, *SD* = 4.4) from the University of Bern. As in the previous experiments, twenty participants were pseudo-randomly assigned to each condition (i.e., prospective memory, expectancy activated, and control).

Materials and Procedure. The materials and procedure were similar to the previous experiments except that prospective memory targets were defined as yellow or green letters. For both conditions with prospective memory instructions (i.e., prospective memory and expectancy activated conditions), participants were informed that, in some of the case-decision trials, the letters would be presented in yellow or green colour. In this situation, they were required to press the space key (the prospective memory task) rather than to perform the case decision.

Data and statistical analyses. The data and statistical analyses were identical to the previous experiments.

Results

Accuracy. Mean accuracy on prospective memory targets was .97 (*SE* = 0.02). Mean accuracy on ongoing task performance was .96 (*SE* = 0.01), .96 (*SE* = 0.01), and .97 (*SE* = 0.01) for the prospective memory, expectancy activated, and control conditions, respectively. The means in each condition were not significantly different from each other, $F < 1$, $p > .05$.

Reaction times. Mean RTs of correctly responding to prospective memory targets was 896 ms (*SE* = 44). Mean RTs for the ongoing task are depicted in Figure 3 of the Appendix. The four-way analysis of variance (ANOVA) with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) as within-subject factors, and condition (prospective memory, expectancy activated, control) as a between-subjects factor, showed a significant interaction between block and condition, F (4, 114) = 2.80, $p < .05$, $\eta^2 = .09$, and a marginal interaction between block, task triplet, and condition, F (8.84, 252.04) = 1.83, $p < .06$, $\eta^2 = .06$. Thus, performance across blocks and task triplets differed between the three conditions. As in the previous experiments, we investigated these differences by carrying out follow-up three-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) for each condition separately.

Prospective memory condition. For the prospective memory condition, the three-way ANOVA revealed a significant interaction between block and task, F (4, 76) = 2.49, $p < .05$, $\eta^2 = .12$, as well as between block and task triplet, F (3.07, 58.25) = 2.32, $p < .08$, $\eta^2 = .11$. Thus, although ongoing task performance was slowed in block 2 compared to blocks 1 and 3, this performance slowing decreased across tasks and task triplets (Appendix, Figure 3a). To further investigate this performance slowing, we carried out follow-up two-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3) and task (parity, colour, case) for each task triplet separately.

For T+1, the two-way ANOVA revealed a significant main effect of block, F (2, 38) = 5.05, $p < .05$, $\eta^2 = .21$. Despite the lack of a significant interaction between block and task, F (4, 76) = 1.71, $p = .15$, $\eta^2 = .08$, the pattern of results suggests a performance slowing in block 2 for the parity and colour decisions only (Appendix, Figure 3a). To pursue this, we conducted a follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3) for each task separately. The ANOVAs revealed a significant effect for the parity and colour decisions, F (2, 38) = 4.40, $p < .05$, $\eta^2 = .19$, and F (1.27, 24.06) = 6.35, $p < .05$, $\eta^2 = .25$, respectively. In block 2, performance on parity decisions was slowed numerically compared to block 1 and significantly compared to block 3 (block 1 vs. 2: t (19) = 1.20, $p = .24$; block 2 vs. 3: t (19) = 2.97, $p < .01$). Similarly, performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 2.16, $p < .05$; and block 2 vs. 3: t (19) = 2.97, $p < .01$). This indicates the presence of an after-effect for the first two tasks task following the targets.

For T+2, the two-way ANOVA revealed a significant main effect of block, F (2, 38) = 8.25, $p < .01$, $\eta^2 = .30$. Despite the lack of a significant interaction between block and task, F (4, 76) = 1.18, $p = .33$, $\eta^2 = .06$, Figure 3a of the Appendix suggests a performance slowing in block 2 for the colour and case decisions only. Follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3) showed a significant effect for parity and case decisions, F (1.53, 29.12) = 6.68, $p < .01$, $\eta^2 = .26$, and F (2, 38) = 4.22, $p < .05$, $\eta^2 = .18$, respectively, and a marginal effect for colour decisions, F (2, 38) = 3.03, $p < .06$, $\eta^2 = .14$. Performance on parity decisions was slower in blocks 1 and 2 (block 1 vs. 2: t (19) = 0.33, $p = .74$) than in block 3 (block 1 vs. 3: t (19) = 2.83, $p < .05$; and block 2 vs. 3: t (19) = 4.36, $p < .001$). In contrast, performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 1.61, $p < .06$, one-tailed; and block 2 vs. 3: t (19) = 2.65, $p < .05$). Similarly, in block 2 performance on case decisions was slowed numerically compared to block

1 and significantly compared to block 3 (block 1 vs. 2: t (19) = 1.31, p = .20; block 2 vs. 3: t (19) = 2.95, p < .01). This indicates a practice effect for parity decisions, but an after-effect for colour and case decisions in the task triplets T+2.

For T+3, the two-way ANOVA revealed a significant main effect of block, F (2, 38) = 5.05, p < .05, η^2 = .21. Despite the lack of a significant interaction between block and task, F (2.41, 45.78) = 1.78, p = .17, η^2 = .09, the results again suggests a performance slowing in block 2 for the colour decisions only (Appendix, Figure 3a). Follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3) showed a significant effect for parity decisions, F (2, 38) = 3.49, p < .05, η^2 = .15, and a marginal effect for colour decisions, F (2, 38) = 3.01, p < .06, η^2 = .14. Performance on parity decisions was slower in blocks 1 and 2 (block 1 vs. 2: t (19) = 0.15, p = .88) than in block 3 (block 1 vs. 3: t (19) = 2.38, p < .05; and block 2 vs. 3: t (19) = 2.74, p < .05). In contrast, performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 1.66, p < .06, one-tailed; and block 2 vs. 3: t (19) = 2.25, p < .05). This indicates a practice effect for parity decisions, but an after-effect of targets for colour decisions in the task triplets T+3.

For T+4, no main effects or interaction reached significance, Fs < 1.90, ps > .05, η^2 < .09. This indicates that neither a practice effect nor an after-effect affected performance for the task triplets T+4.

In order to illustrate the after-effects of responding to prospective memory targets, we have summarized these results in Figure 6. Specifically, we have highlighted the differences between ongoing task performance in Block 2 (i.e., after responding to prospective memory targets) and the corresponding ongoing task performance averaged across Blocks 1 and 3.

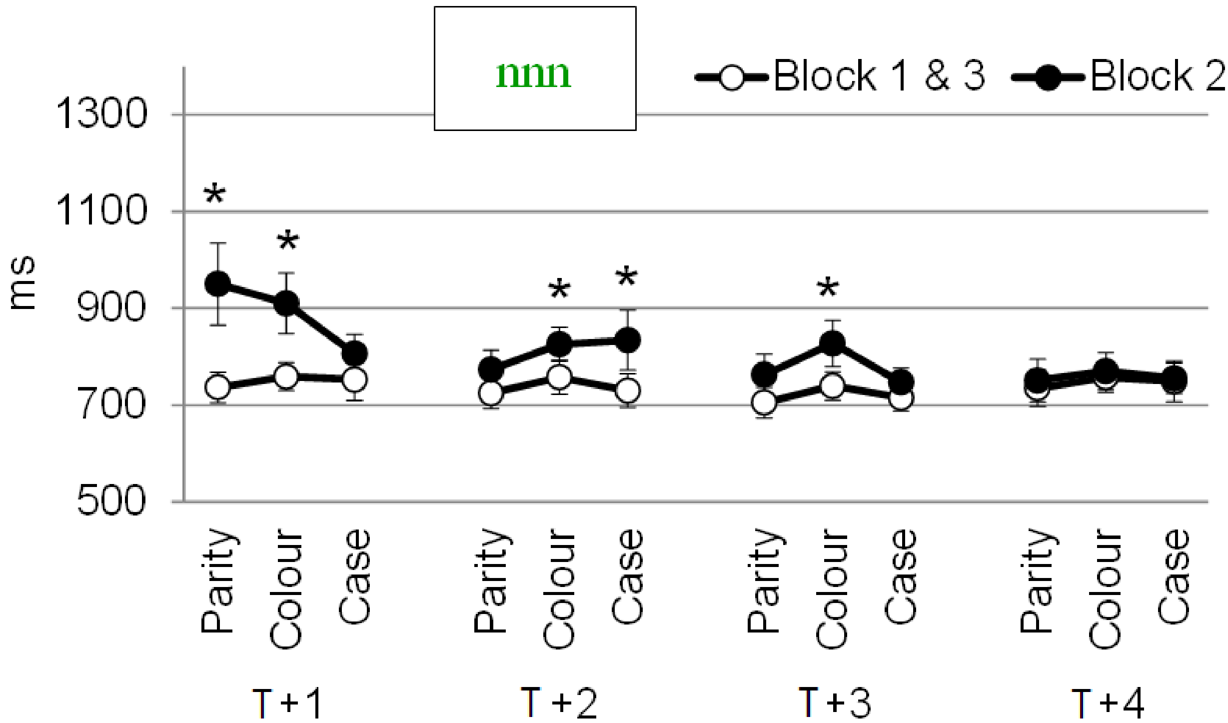

Figure 6. After-effects of responding to prospective memory targets in Experiment 3. Asterisks refer to significant after-effects (p <. 05). Error bars represent standard errors.

Expectancy activated condition. For the expectancy activated condition, the three-way repeated-measures ANOVA with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) showed a marginally significant main effect of block, F (2, 38) = 2.96, p < .06, η^2 = .13. In this condition, performance was slower in block 1 than in blocks 2 and 3 (block 1 vs. 2: t (19) = 2.69, p < .05; and block 1 vs. 3: t (19) = 1.76, p < .05, one-tailed). Therefore, for the expectancy activated condition, RT performance decreased across blocks, which indicates a practice effect (Appendix, Figure 3b).

Control condition. For the control condition, the three-way ANOVA showed no significant main effect or interactions involving block, *F*s < 2.57, *p*s > .05, $\eta^2 < .12$. Therefore, for the control condition, there was no performance difference across blocks (Appendix, Figure 3c).

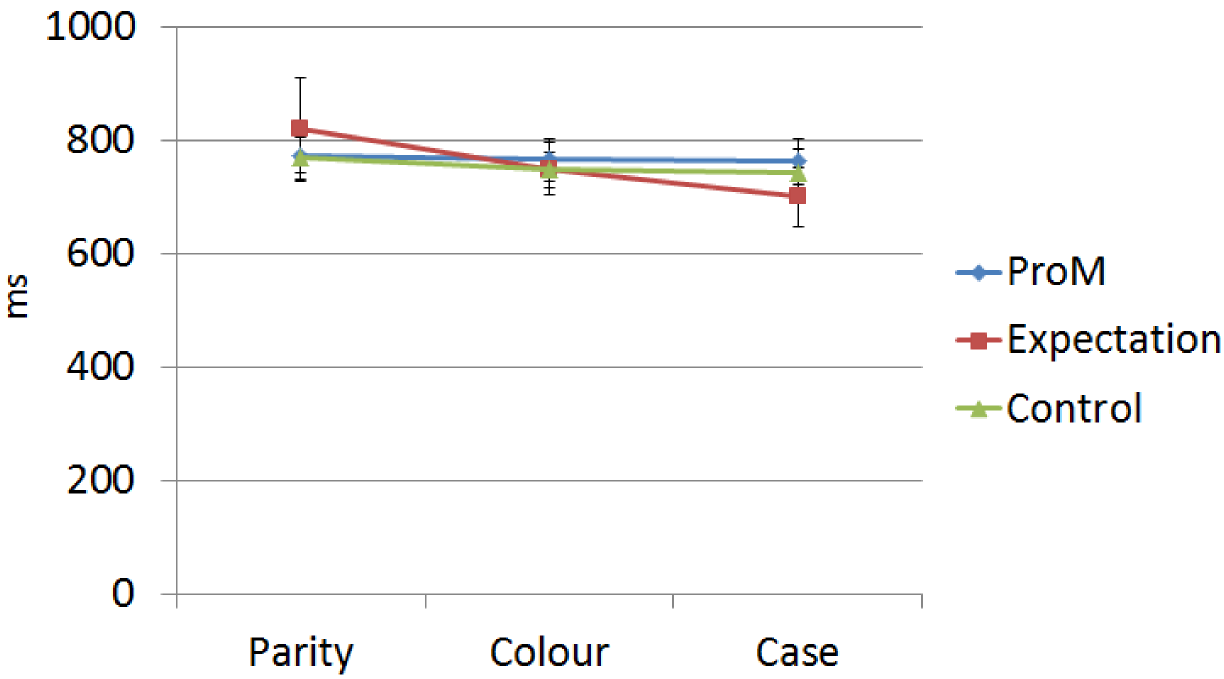

Figure 7. Block 1 ongoing task reaction times indicate no significant monitoring costs in Experiment 3 (ProM = prospective memory condition, Expectation = expectation activated condition, Control = control condition). Error bars represent standard errors.

Monitoring costs. As in the previous experiments, we determined the presence of monitoring costs unconfounded by the after-effects of targets by analysing the RTs of block 1 only (Figure 7). The two-way ANOVA with task (parity, colour, case) and condition (prospective memory, expectancy activated, control) revealed no significant main effects or interactions, *F*s < 2.96, *p*s > .05, $\eta^2 < .05$. Thus, there was no performance difference in block 1 between the conditions. Thus, instructing participants for the prospective memory task did not result in monitoring costs.

Discussion

The purpose of Experiment 3 was to determine whether the after-effects of prospective memory targets contribute to monitoring costs when the task-set overlap between the prospective memory task and the ongoing task was increased. To this end, we presented as targets yellow or green letters. These had relevant features for one task of the ongoing task (i.e., the case decision) but varied on a relevant dimension of another task of the ongoing task (i.e., the colour decision). For the prospective memory condition, the results showed a performance slowing for the first two tasks following the targets. On subsequent task triplets, performance was sporadically slowed on the ongoing tasks that shared relevant features with the prospective memory targets (i.e., the colour and case decisions). Thus, we found long-living after-effects for the ongoing tasks sharing features with the targets. In contrast, in the conditions without targets (i.e., the expectancy activated and control conditions), no such performance slowing was found. Moreover, when analysing the first block only (i.e., before any target was presented), we found similar performance across the three conditions. Together, this demonstrates after-effects of prospective memory targets in the absence of monitoring costs.

To corroborate these results, we investigated the after-effects of responding to a prospective memory target and the monitoring costs when the task-set overlap between the prospective memory task and the ongoing task was further increased in Experiment 4. To this end, we presented red or blue letters as prospective memory targets which had relevant features for two tasks of the ongoing task (i.e., the colour and case decisions). We expected that performance would be slowed on all ongoing task trials immediately after the prospective memory target and also on some subsequent trials, in particular for the tasks which shared features with the prospective memory targets (i.e., the colour and case decisions).

Experiment 4

Method

Participants. The participants were 60 different students (28 men, mean age = 24.1, *SD* = 3.4) from the University of Bern. As in the previous experiments, twenty participants were pseudo-randomly assigned to each condition (i.e., prospective memory, expectancy activated, and control).

Materials and Procedure. The materials and procedure were similar to the previous experiments except that prospective memory targets were defined as red or blue letters. For both conditions with prospective memory instructions (i.e., prospective memory and expectancy activated conditions), participants were informed that, in some of the case-decision trials, the letters would be presented in red or blue colour. In this situation, they were required to press the space key (the prospective memory task) rather than to perform the case decision.

Data and statistical analyses. The data and statistical analyses were identical to the previous experiments.

Results

Accuracy. Mean accuracy on prospective memory targets was .91 (*SE* = 0.03). Mean accuracy on ongoing task performance was .98 (*SE* = 0.003), .96 (*SE* = 0.01), and .96 (*SE* =

0.01) for the prospective memory, expectancy activated, and control conditions, respectively. The means in each condition were not significantly different from each other, $F < 2.05$, $p > .05$.

Reaction times. Mean RTs of correctly responding to prospective memory targets was 1117 ms (*SE* = 51). Mean RTs for ongoing task are depicted in Figure 4 of the Appendix. The ANOVA with block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) as within-subject factors, and condition (prospective memory, expectancy activated, control) as a between-subjects factor, showed a significant interaction between block and condition, F (3.62, 103.17) = 9.61, $p < .001$, $\eta^2 = .25$, and between block, task triplet, and condition, F (9.17, 261.34) = 3.26, $p < .01$, $\eta^2 = .10$. Moreover, the four-way interaction between block, task, task triplet, and condition approached significance, F (15.58, 444.11) = 1.61, $p < .06$, $\eta^2 = .05$. Thus, performance across blocks, tasks, and task triplets differed between the three conditions. To further investigate these differences, we carried out follow-up three-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) for each condition separately.

Prospective memory condition. For the prospective memory condition, the three-way ANOVA revealed a significant interaction between block and task as well as between block and task triplet, F (4, 76) = 4.56, $p < .01$, $\eta^2 = .19$, and F (6, 114) = 6.32, $p < .001$, $\eta^2 = .25$, respectively. In addition, the interaction between block, task, and task triplet approached significance, F (5.15, 97.87) = 2.19, $p < .06$, $\eta^2 = .10$. Thus, although ongoing task performance was slowed in block 2 compared to blocks 1 and 3, this performance slowing decreased across tasks and task triplets (Appendix, Figure 4a). To further investigate this performance slowing, we carried out follow-up two-way repeated-measures ANOVAs with the factors block (block 1, block 2, block 3) and task (parity, colour, case) for each task triplet separately.

For T+1, the two-way ANOVA revealed a significant interaction between block and task, F (2.45, 46.63) = 4.21, $p < .05$, $\eta^2 = .18$. To disentangle this interaction, we conducted a follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3) for each task separately. The ANOVAs showed a significant effect for parity and colour decisions, F (2, 38) = 10.90, $p < .001$, $\eta^2 = .36$, and F (2, 38) = 20.83, $p < .001$, $\eta^2 = .52$, respectively. Performance on parity decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 2.70, $p < .05$; and block 2 vs. 3: t (19) = 4.57, $p < .001$). Similarly, performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 5.17, $p < .001$; and block 2 vs. 3: t (19) = 6.57, $p < .001$). This indicates the presence of an after-effect for the first two tasks following the targets.

For T+2, the two-way ANOVA showed a significant main effect of block, F (2, 38) = 4.17, $p < .05$, $\eta^2 = .18$. Despite the lack of a significant interaction between block and task, F (4, 76) = 1.83, $p = .13$, $\eta^2 = .09$, the results suggest a performance slowing in block 2 for the colour decisions only (Appendix, Figure 4a). This observation was confirmed by follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3), which revealed a significant effect for colour decisions, F (2, 38) = 4.01, $p < .05$, $\eta^2 = .17$. Performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 2.35, $p < .05$; and block 2 vs. 3: t (19) = 2.21, $p < .05$). This indicates an after-effect of prospective memory targets for the colour decisions of the task triplets T+2.

For T+3, the two-way ANOVA showed a significant interaction between block and task, F (4, 76) = 5.21, $p < .01$, $\eta^2 = .21$. The follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3) revealed a significant effect for parity decisions, F (1.44, 27.34) = 6.96, $p < .01$, $\eta^2 = .27$. Performance on parity decisions was slower in blocks 1 and 2 (block 1 vs. 2: t (19) = 0.69, $p = .50$) than in block 3 (block 1 vs. 3: t (19) = 5.80, $p < .001$; and block 2 vs. 3: t (19) = 2.41, $p < .05$). This indicates a practice effect for the parity decisions of the task triplets T+3.

For T+4, the two-way ANOVA showed a significant main effect of block, F (2, 38) = 5.13, $p < .05$, $\eta^2 = .21$. Despite the lack of a significant interaction between block and task, F (4, 76) = 1.42, $p = .23$, $\eta^2 = .07$, the results suggest a performance slowing in block 2 for the colour decisions (Appendix, Figure 4a). This observation was confirmed by follow-up one-way repeated-measures ANOVAs with the factor block (block 1, block 2, block 3), which revealed a significant effect for colour decisions, F (2, 38) = 6.09, $p < .01$, $\eta^2 = .24$. Performance on colour decisions was slowed in block 2 compared to blocks 1 and 3 (block 1 vs. 2: t (19) = 3.05, $p < .01$; and block 2 vs. 3: t (19) = 2.69, $p < .05$). This indicates an after-effect of prospective memory targets for the colour decisions of the task triplets T+4.

In order to illustrate the after-effects of responding to prospective memory targets, we have summarized these results in Figure 8. Specifically, we have highlighted the differences between ongoing task performance in Block 2 (i.e., after responding to prospective memory targets) and the corresponding ongoing task performance averaged across Blocks 1 and 3.

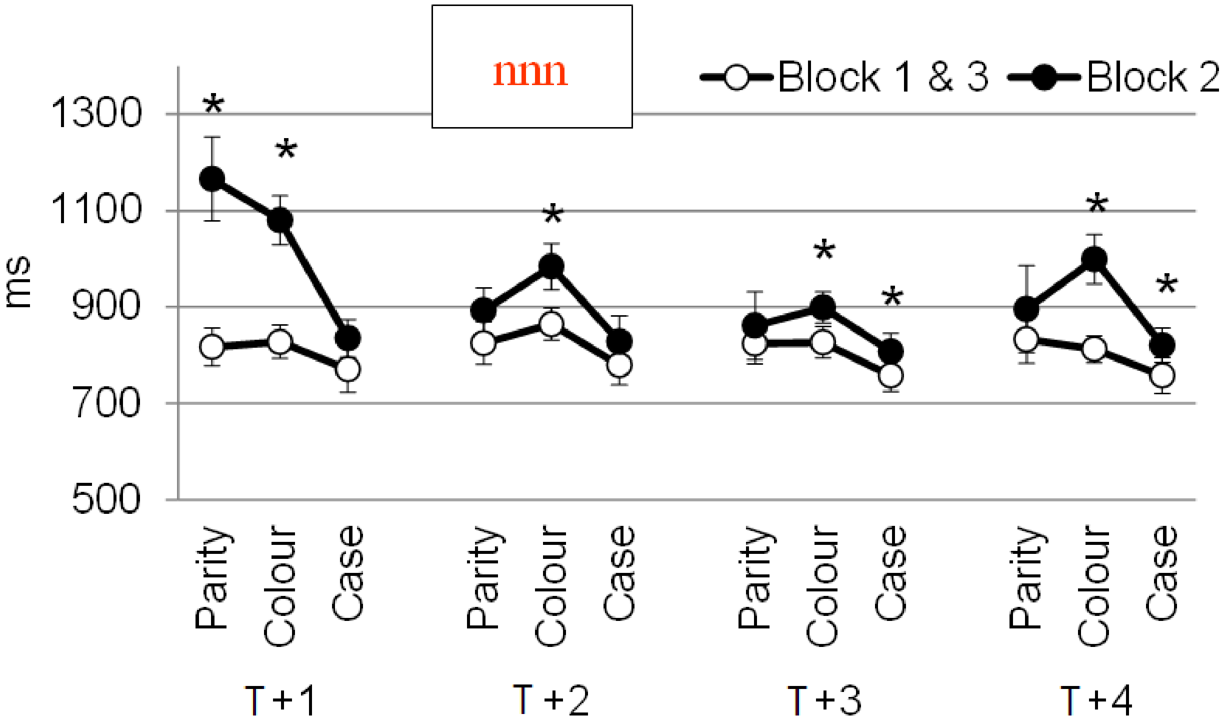

Figure 8. After-effects of responding to prospective memory targets in Experiment 4. Asterisks refer to significant after-effects ($p <. 05$). Error bars represent standard errors.

Expectancy activated condition. For the expectancy activated condition, the three-way repeated-measures ANOVA with the factors block (block 1, block 2, block 3), task (parity, colour, case), and task triplet (T+1, T+2, T+3, T+4) showed a significant main effect of block, F (2, 38) = 7.28, $p < .01$, $\eta^2 = .28$. In this condition, performance was slower in blocks 1 and 2 (block 1 vs. 2: t (19) = 1.48, $p = .15$) than in block 3 (block 1 vs. 3: t (19) = 4.07, $p < .01$; and block 2 vs. 3: t (19) = 2.28, $p < .05$). Therefore, for the expectancy activated condition, RTs performance decreased across blocks, which indicates a practice effect (Appendix, Figure 4b).

Control condition. For the control condition, the three-way ANOVA showed a significant main effect of block, F (2, 38) = 22.66, $p < .001$, $\eta^2 = .54$. In this condition, performance was slower in block 1 than in block 2 (block 1 vs. 2: t (19) = 4.01, p < .01), whose performance was, in turn, slower than in block 3 (block 2 vs. 3: t (19) = 2.36, p < .05). Therefore, for the control condition, RTs performance decreased across the three blocks, which indicates a practice effect (Appendix, Figure 4c).

Monitoring costs. As in the previous experiments, we determined the presence of monitoring costs unconfounded by the after-effects of targets by analysing the RTs of block 1 only (see Figure 9). The two-way ANOVA with task (parity, colour, case) and condition (prospective memory, expectancy activated, control) revealed no main effect or interaction involving condition, Fs < 2.50, ps > .05, η^2 < .08. Thus, there was no performance difference in block 1 between the conditions. This shows that instructing the participants for the prospective memory task did not affect ongoing task performance.

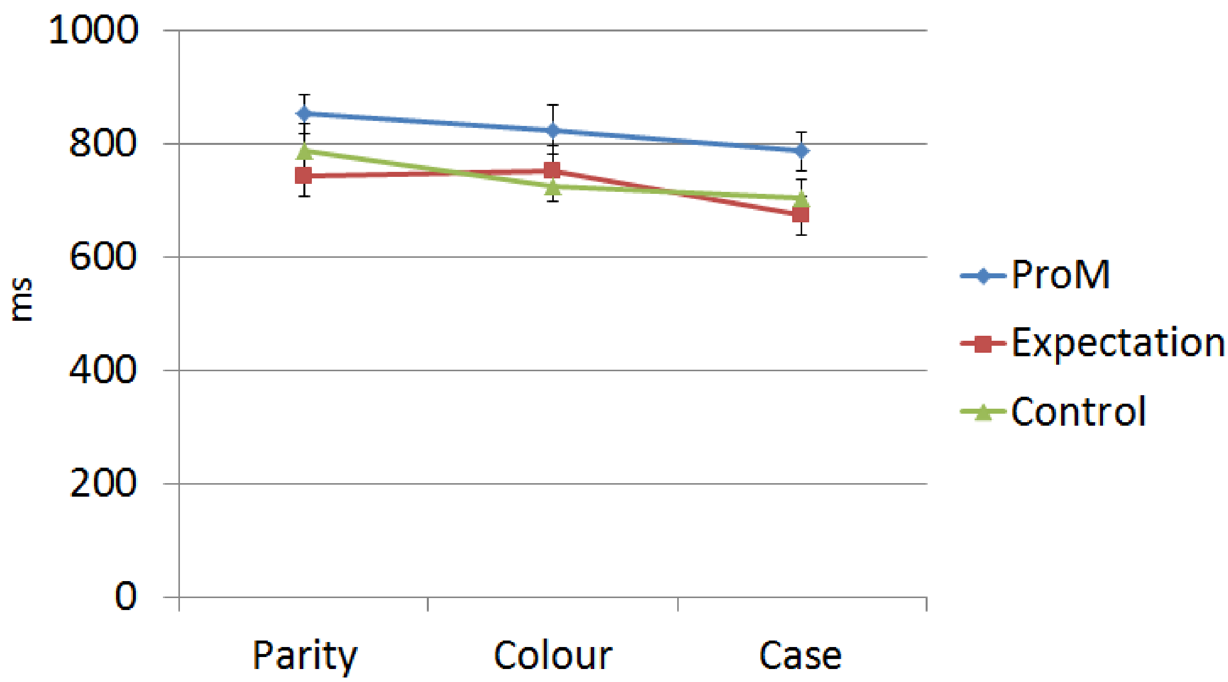

Figure 9. Block 1 ongoing task reaction times indicate no significant monitoring costs in Experiment 4. (ProM = prospective memory condition, Expectation = expectation activated condition, Control = control condition). Error bars represent standard errors.

Discussion

The purpose of Experiment 4 was to determine whether the after-effects of prospective memory targets contribute to monitoring costs when prospective memory targets had relevant features for two tasks of the ongoing task. The results showed a performance slowing for the first two tasks after the targets. In addition, performance was still sporadically slowed on subsequent trials, particularly for those tasks, which shared features with the prospective memory targets (i.e., the colour decisions). These results replicate our previous findings (Meier & Rey-Mermet, 2012, Experiment 2). In contrast, in the conditions without targets (i.e., the expectancy activated and control conditions), no such performance slowing was found. Moreover, when analysing the first block only (i.e., before any target was presented), we found similar performance across the three conditions. Again, these results suggest lack of monitoring costs and they demonstrate after-effects of responding to prospective memory targets in the absence of monitoring costs.

Follow-up analyses of monitoring costs

A consistent but somewhat unexpected finding of the present study is that we did not find any consistent monitoring costs across four separate experiments. As it is possible that a single experiment was simply not enough powerful to give significant effects, we conducted a follow-up analysis across all experiments. This analysis involved the three conditions (prospective memory, expectancy activated, control), task (parity, colour, case) and experiment (1 to 4).

Critically, this three-way ANOVA revealed no significant group effect F (2, 228) = .36, p = .66, η^2 = .003, and no interaction, all Fs <1. Thus, even with a large sample of 240 participants (i.e., 80 per group), there was no hint for any monitoring cost.

General Discussion

In this article, we addressed the fact that in prospective memory research, task instructions turn univalent stimuli into bivalent ones. Specifically, by defining certain target events via verbal instructions as the appropriate cues to perform a previously planned action, processing these target events can even slow down subsequent decision tasks. Importantly, in prospective memory research slowing in contexts in which the prospective memory targets can occur has been interpreted as the result of strategic monitoring for the target events. The present study, however, demonstrates that ongoing task slowing can also be due to another source, namely the after-effects of responding to prospective memory targets.

In four experiments, participants performed three simple ongoing tasks in a regular order during three experimental blocks. In the critical block, prospective memory targets were presented occasionally on one of the tasks. In Experiments 1 and 2, the prospective memory targets had overlapping features with one task of the ongoing task, creating minimal task-set overlap between the prospective memory task and the ongoing task. In Experiments 3, the prospective memory targets had overlapping features with one of the ongoing task and varied on a relevant dimension of another task of the ongoing task. This increased the task-set overlap between the prospective memory task and the ongoing task. In Experiment 4, the prospective memory targets had overlapping features with two ongoing tasks, thus further increasing the task-set overlap. In all experiments, the results revealed a performance slowing on ongoing task trials that appeared immediately after responding to a prospective memory target. Increasing the task-set overlap between the prospective memory task and the ongoing task enhanced the after-effect. Specifically, with higher task-set overlap, a longer-living effect emerged that sporadically slowed performance on those ongoing task trials that had overlapping features with the prospective memory targets.

Against our expectations, we did not find monitoring costs in any experiment. This finding is at odds with the PAM theory, which states that prospective memory retrieval is always the consequence of strategic monitoring (Smith, 2003). However, it is possible that the prospective memory targets were perceptually highly salient in all conditions and as a consequence, participants relied on spontaneous retrieval. Another possibility is that the task switching requirements took up those cognitive resources that are typically engaged in monitoring and as a result, no ongoing task cost occurred. More likely, a combination of high perceptual salience and a lack of resources to engage in strategic monitoring may have been the reason for both the rather high prospective memory performance and the lack of monitoring costs. Critically, in each of the four experiments after-effects of responding to prospective memory targets were found in the absence of monitoring costs. These results demonstrate that ongoing task costs can result from other sources than strategic monitoring. In any case, it would be interesting to follow-up on this issue with less salient prospective memory targets that require strategic monitoring for successful detection and test the interplay between monitoring and after-effects of responding to prospective memory targets.

It is noteworthy that recently another kind of after-effects has attracted interest in prospective memory research (Scullin & Bugg, 2013; Walser, Fischer & Goschke, 2012; Walser, Plessow, Goschke, & Fischer, 2014). In these studies, 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 further instructed that the prospective memory task is over. Nevertheless, they have to perform some further ongoing task trials with some of them containing “deactivated” prospective memory targets. Typically, ongoing task performance an these trials is still slowed (Scullin & Bugg, 2013; Walser et al., 2012; 2014). This suggests that deactivated prospective memory targets still carry bivalency, a result that is in line with other recent results that suggest that instructions can establish stimulus-response representations that have a reflexive impact and are insensitive to the context in which they occur (Braem, Liefooghe, De Houwer, Brass & Abrahamse, in press).

The present results are also informative for research in cognitive control. In fact, a series of studies has demonstrated that, using a similar design as in the present study, occasionally presenting bivalent stimuli amongst univalent stimuli can lead to a long-lasting performance slowing (Meier et al., 2009; Rey-Mermet & Meier, 2013). In contrast to the effects reported here and in our previous study, this “bivalency effect” seems to be more general, affecting all tasks of the task-set (Grundy & Shedden, 2014; Metzak, Meier, Graf & Woodward, 2013; Rey-Mermet & Meier, 2012; 2014). In comparison, responding to prospective memory target events typically produced longer lasting effects only for those stimuli with overlapping features. This suggests that not exactly the same cognitive processes are responsible for these two kinds of after-effects.

The present study demonstrates that prospective memory research is a field in which verbal instructions are particularly important because they can change the significance of stimuli in a way that has multiple consequences for performance. Within prospective memory research, the importance of how to provide instructions has been repeatedly addressed (Walter & Meier, 2012; 2014). Moreover, mental techniques such as implementation intentions and experimental manipulations such as imagining future events or making performance predictions also affect prospective memory performance, eventually without increasing monitoring costs (Addis, Wong & Schacter, 2008; Gollwitzer, 1999; Meier et al., 2011). How these manipulations can modulate after-effects is, however, is still an avenue for future research.

Footnote

[1] We would like to thank an anonymous reviewer for raising this possibility

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Appendix

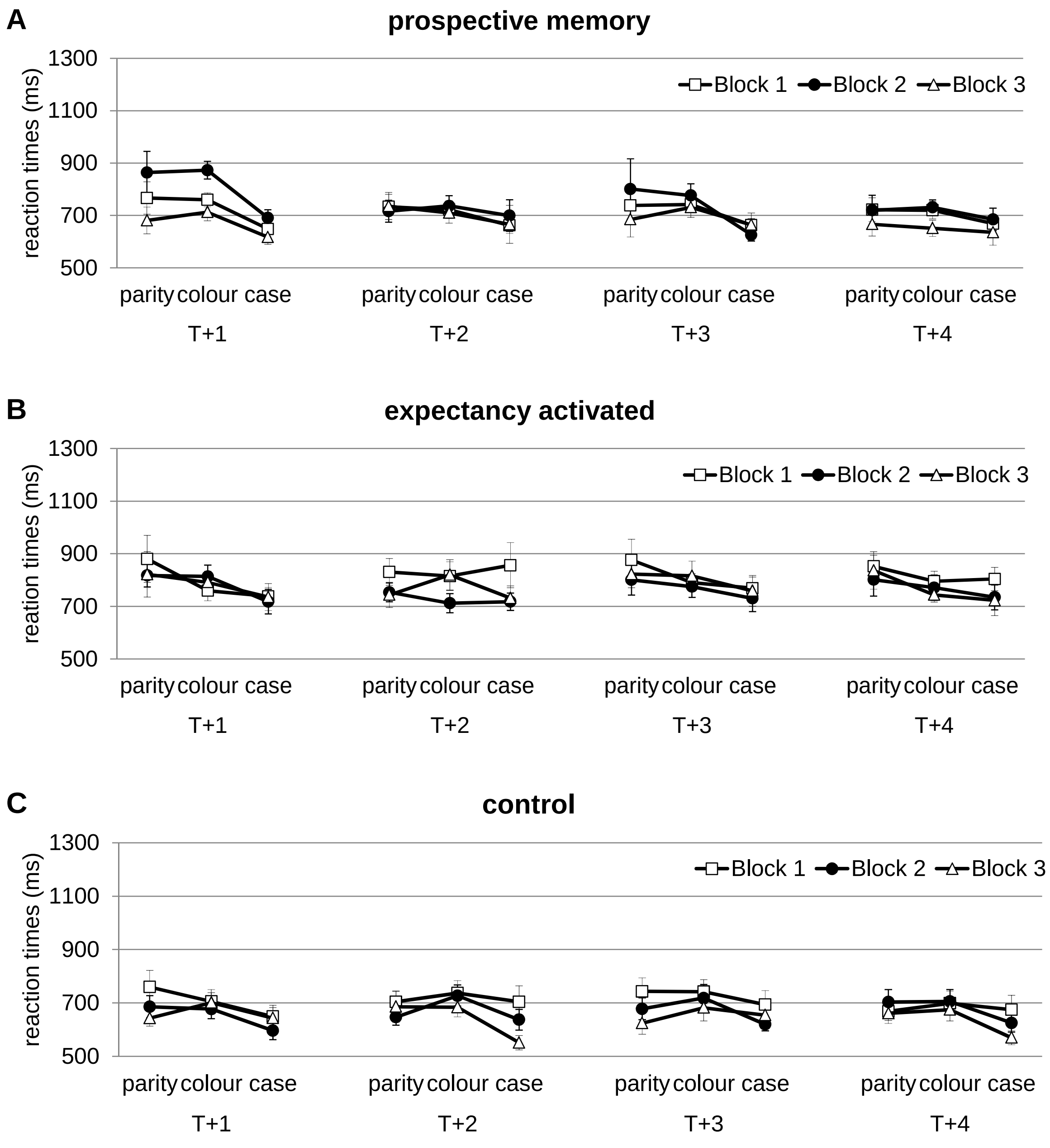

Figure 1. Experiment 1. Mean reaction times for task triplets following a prospective memory target in block 2 (filled circles) compared to the corresponding task triplets from blocks 1 and 3

(empty squares and triangles, respectively). Error bars represent standard errors. A) Prospective memory condition. B) Expectancy activated condition. C) Control condition.

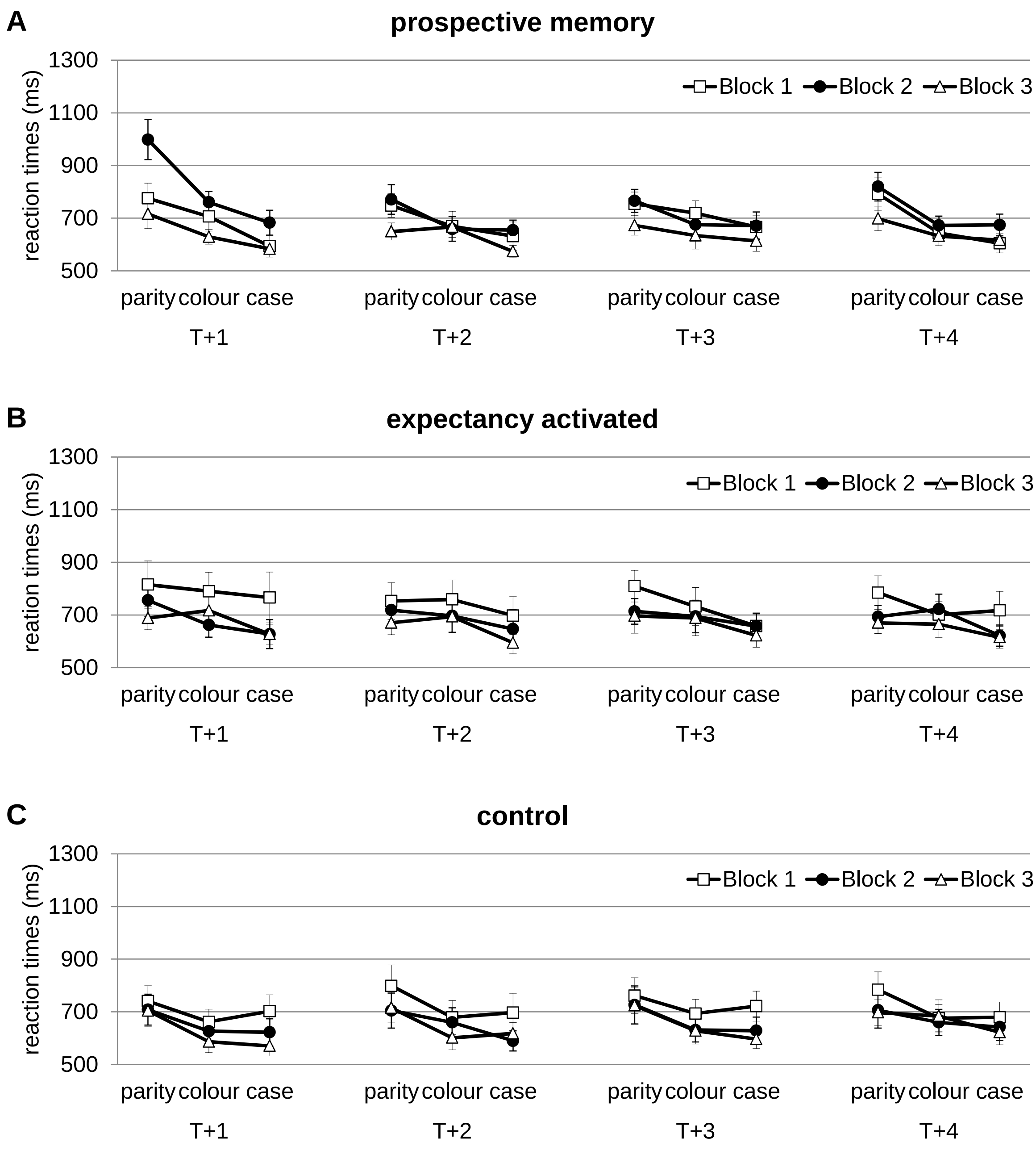

Figure 2. Experiment 2. Mean reaction times for task triplets following a prospective memory target in block 2 (filled circles) compared to the corresponding task triplets from blocks 1 and 3 (empty squares and triangles, respectively). Error bars represent standard errors. A) Prospective memory condition. B) Expectancy activated condition. C) Control condition.

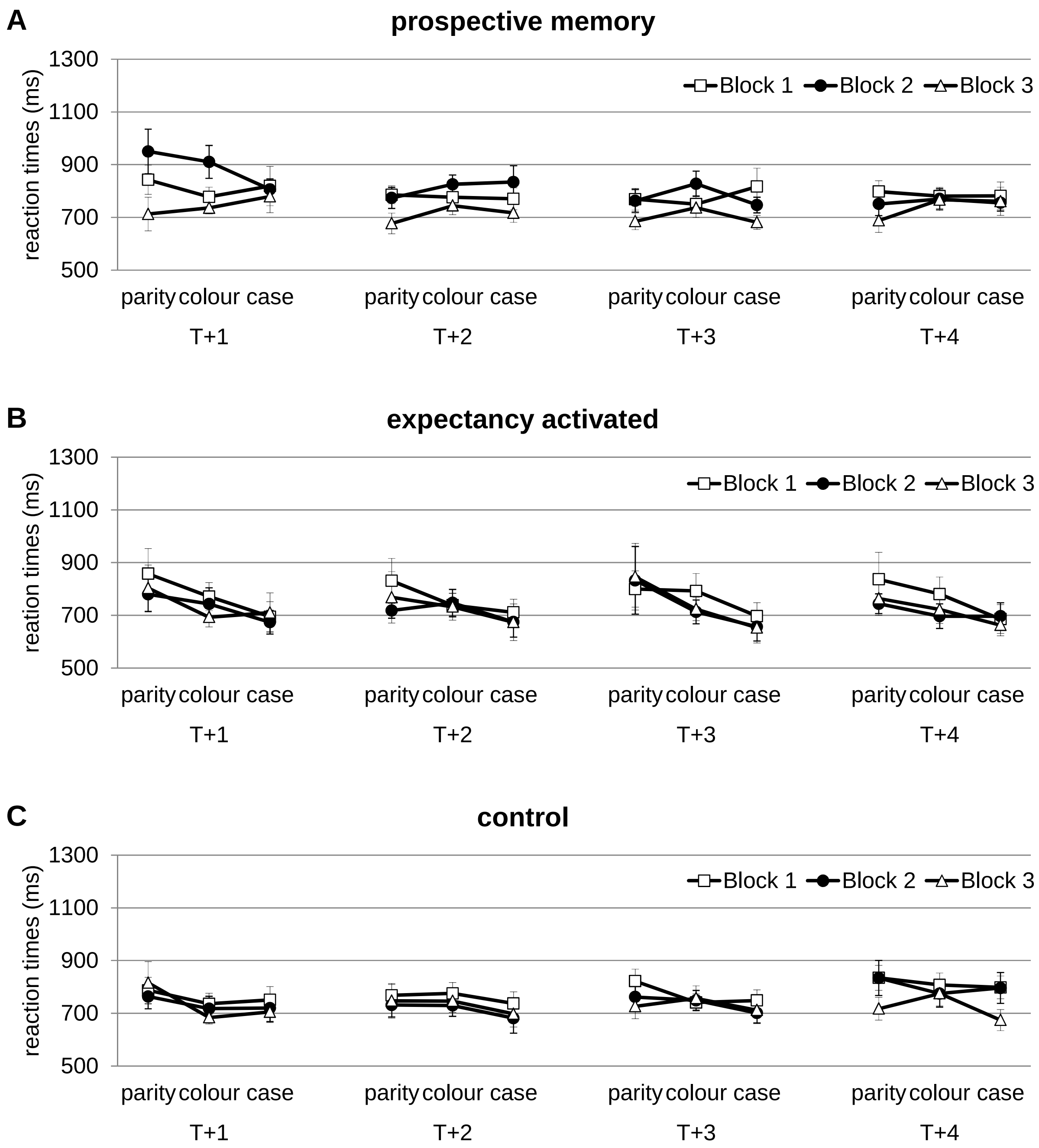

Figure 3. Experiment 3. Mean reaction times for task triplets following a prospective memory target in block 2 (filled circles) compared to the corresponding task triplets from blocks 1 and 3

(empty squares and triangles, respectively). Error bars represent standard errors. A) Prospective memory condition. B) Expectancy activated condition. C) Control condition.

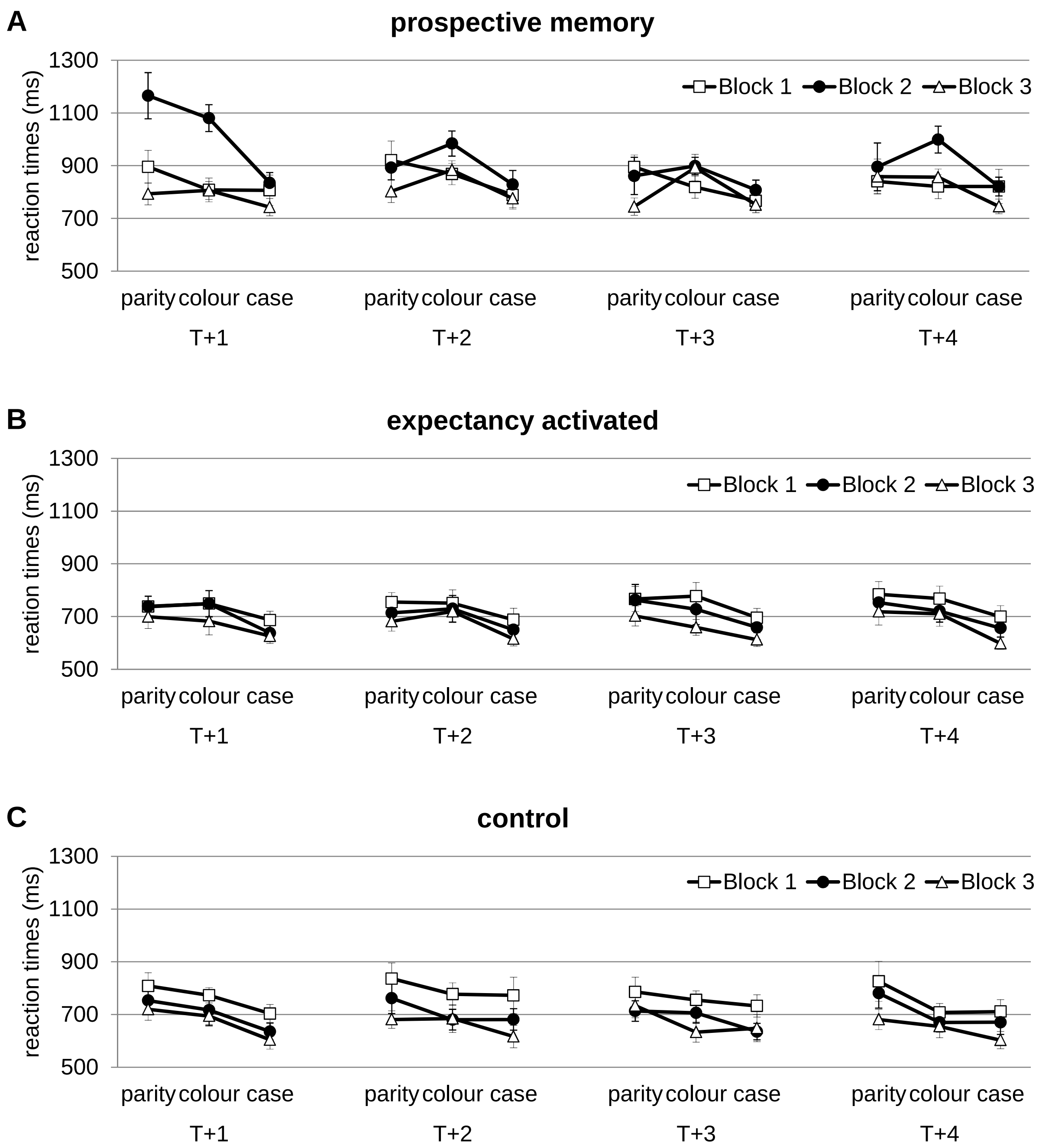

Figure 4. Experiment 4. Mean reaction times for task triplets following a prospective memory target in block 2 (filled circles) compared to the corresponding task triplets from blocks 1 and 3

(empty squares and triangles, respectively). Error bars represent standard errors. A) Prospective memory condition. B) Expectancy activated condition. C) Control condition.