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Beyond monitoring: After-effects of responding to prospective memory targets

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ABSTRACT

Responding to bivalent stimuli (i.e., stimuli with features relevant for different tasks) slows subsequent performance. In prospective memory research, prospective memory targets can be considered as bivalent stimuli because they typically involve features relevant for both the prospective memory task and the ongoing task. The purpose of this study was to investigate how responding to a prospective memory target slows subsequent performance. In two experiments, we embedded the prospective memory task 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. The specific trajectory of the slowing depended on the amount of task-set overlap. These results demonstrate that responding to prospective memory targets results in after-effects, a so far neglected cost on ongoing task performance.

1. Introduction

A current issue in cognitive psychology is the adjustment of cognitive control following a conflict. Cognitive control is the ability to maintain current goal representations in face of conflict. It enables us to flexibly select goal-relevant features while suppressing distracting ones. A conflict can be triggered by responding to stimuli with relevant features for two different tasks (i.e., bivalent stimuli). Typically, responding to conflict stimuli not only slows performance on these stimuli, but also on subsequent (non-conflict) stimuli (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Meier, Woodward, Rey-Mermet, & Graf, 2009; Rey-Mermet & Meier, 2012a, 2012b; Woodward, Meier, Tipper, & Graf, 2003; Woodward, Metzak, Meier, & Holroyd, 2008). In prospective memory research, prospective memory targets can be considered as bivalent because they typically involve features relevant for both the prospective memory task and the ongoing task. The goal of the present study was to investigate how responding to a prospective memory target would affect subsequent ongoing task performance.

Prospective memory refers to the ability to remember to perform a particular task at some designated point in the future. In laboratory tasks, participants have to execute a particular action when a target event occurs in the course of an ongoing activity. For example, while participants perform a lexical decision task about letter strings (the ongoing task), they must press a particular key when they encounter a designated target word (i.e., the prospective memory task). Typically, prospective memory targets have relevant features for both the ongoing task and the prospective memory task, which turns them into bivalent stimuli.

A controversial issue in prospective memory research is the nature of memory retrieval (Einstein & McDaniel, 2010; Smith, 2010). One theory puts forward that prospective memory retrieval is the consequence of *strategic monitoring* for

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the prospective memory task and comes always along with a cost, expressed as a slowing in ongoing task performance (Smith, 2003; Smith & Bayen, 2004). Another theory posits that prospective memory retrieval can occur either spontaneously or as the consequence of monitoring. Whether one relies on spontaneous retrieval or monitoring depends on the features of the prospective memory task, the ongoing task, and the rememberer (McDaniel & Einstein, 2000).

Critically, spontaneous retrieval of the prospective memory task should not affect ongoing task performance. This seems to hold for some situations, 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, Hicks, & Cook, 2005; Meiser & Schult, 2008; cf., Meier & Graf, 2000), and when cues are focal (e.g., Scullin, McDaniel, & Einstein, 2010; Scullin, McDaniel, Shelton, & Lee, 2010).

In contrast, strategic monitoring results in a cost that can be measured as a performance slowing in the ongoing task (Brandimonte, Ferrante, Feresin, & Delbello, 2001; Marsh et al., 2003; Smith, 2003, 2010; Smith, Hunt, McVay, & McConnell, 2007). This occurs for example, when the prospective memory task is important (Kliegel, Martin, McDaniel, & Einstein, 2004; Smith & Bayen, 2004), 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), and when there are multiple targets (Cohen et al., 2008; Einstein et al., 2005). Moreover, the magnitude of this monitoring cost depends on the kind of ongoing task trials. For example, Marsh, Cook, and Hicks (2006) presented words and pictures for an ongoing naming task and they used words or pictures as prospective memory targets. They found slower ongoing task performance on words when the prospective memory target was also defined as a word, and conversely, slower performance on pictures when the prospective memory target was defined as a picture. Thus, the monitoring cost was larger for ongoing task trials that had overlapping features with the prospective memory targets than for those that had no overlapping features.

Most of the previous studies aimed at investigating the presence or absence of a monitoring cost. However, Loft, Kearney, and Remington (2008, Experiments 1 and 3) provided evidence that besides the expectancy-based monitoring cost, a second source of slowing exists, which is 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. Critically, the performance slowing was larger for the group in which participants responded to prospective memory targets. This suggests that responding to prospective memory targets resulted in an additional after-effect, expressed as a slowing in ongoing task performance similar to the usual, expectancy-based, monitoring cost. This finding is particularly interesting because it suggests that monitoring cost may be generally overestimated.

The purpose of the present study was to investigate the specific trajectory of the after-effects of target presentation on ongoing task performance. We present two experiments, in which we kept the expectancy-based monitoring costs constant. Specifically, we used a within-subjects design consisting of three blocks during which the prospective memory task was activated all the time, but prospective memory targets appeared only in the middle block. This allowed investigating the after-effects that are specific to the presentation of prospective memory targets by comparing performance in Block 2 to the average performance in Blocks 1 and 3.

This procedure is based on the assumption that expectancy-based costs follow a linear trajectory across blocks. This assumption is based on our previous task switching findings in which we administered only two blocks (one purely univalent, one with occasional bivalent stimuli) and counterbalanced block type across block order (Meier et al., 2009, Experiment 3). The results showed exactly the same pattern as when the design with three blocks was used (with purely univalent Blocks 1 and 3 and occasionally occurring bivalent stimuli in Block 2). Moreover, in the domain of prospective memory, Loft et al. (2008, Experiment 3) have explicitly investigated how attention allocation policies changes across three blocks. In one condition, prospective memory instructions were given and prospective memory targets occurred (but only in block 2). In another condition, prospective memory instructions were given, but no prospective memory targets occurred. They reasoned that Block 1 provides a robust baseline measure of attention allocation policy and that Block 3 provides a subsequent measure of policy after a period of time with or without target presentation. The most important result for the purpose of the present study is that although the RT reduction from Block1 to Block 3 was more pronounced when no prospective memory targets were presented, the difference between the means of Blocks 1 and 3 and Block 2 was very similar for both conditions, indicating a linear trajectory of change in expectancy-based monitoring, independent of whether or not cues were actually encountered.

We used three different ongoing tasks in order to manipulate the amount of task-set overlap between the prospective memory targets and the ongoing tasks. In Experiment 1, the ongoing task was to perform parity decisions (odd vs. even), colour decisions (red vs. blue), and case decisions (uppercase vs. lowercase). Stimuli were black numerals for the parity decision, coloured symbols for the colour decision, and black letters for the case decision, all displayed in triplicates (e.g., 777, &&&, and nnn, respectively; see Fig. 1). However, for some case decisions, stimuli were turned into prospective memory targets by presenting consonant–vowel–consonant triplicates (e.g., nen) and by requiring participants to press a designated key whenever they encountered them. In Experiment 2, we investigated the after-effects of target presentation when the task-set overlap between the prospective memory task and the ongoing task was increased. Accordingly, we created prospective

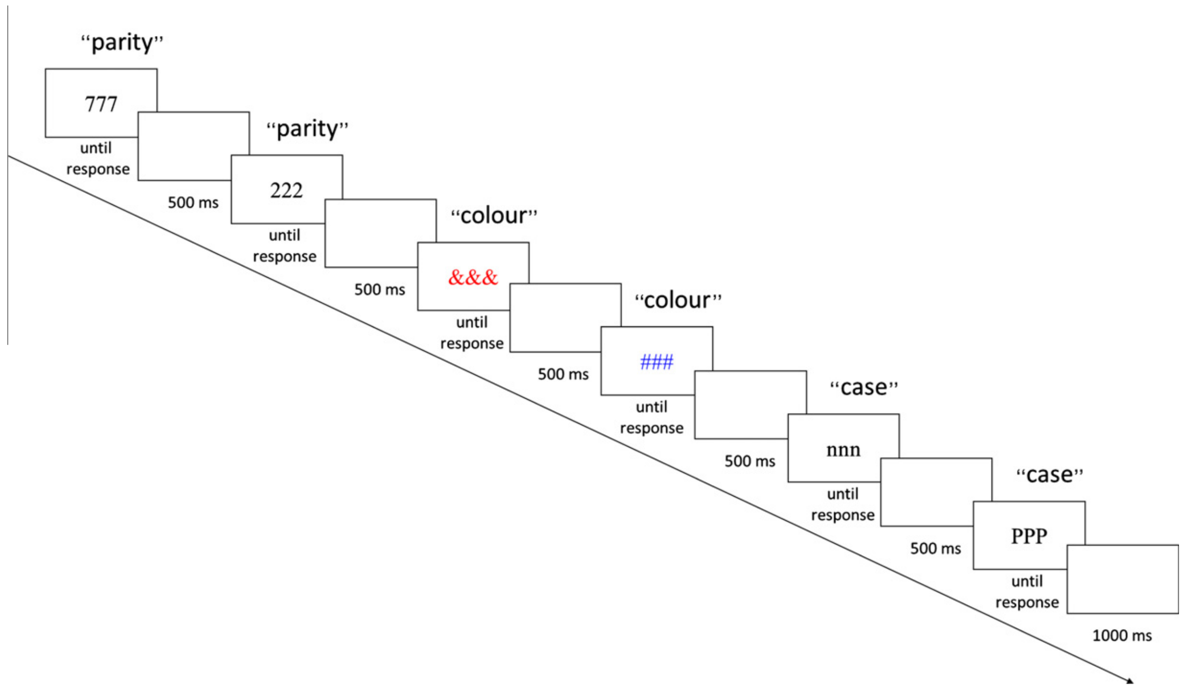

Fig. 1. Example of an ongoing task sequence consisting of two parity decisions, two colour decisions (the symbols were presented either in blue or red), and two case decisions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

memory targets with relevant features for two tasks of the ongoing task. That is, the prospective memory targets were red or blue letters, thus sharing features with both the colour- and case-decision trials of the ongoing task.

Using this particular experimental set-up was, in part, motivated by the fact that in the domain of task switching, we have explored the impact of the occasional presentation of bivalent stimuli with a very similar method. In this line of research we have found that occasionally responding to bivalent stimuli resulted in a general slowing for all subsequent univalent trials, even those sharing no relevant features with the bivalent stimuli (Meier et al., 2009; see also Rey-Mermet & Meier, 2012a; Woodward et al., 2003, 2008). From this view, one would predict that responding to a prospective memory target would result in a general and long-lasting slowing. In the domain of cognitive control, another line of research has suggested that the after-effects of conflict stimuli are specific to the particular source of a conflict (Akçay & Hazeltine, 2008; Egner, Delano, & Hirsch, 2007; Funes, Lupiáñez, & Humphreys, 2010; Notebaert & Verguts, 2008). From this view, one would predict that responding to a prospective memory target would result in a slowing for those ongoing task trials that have overlapping features with the prospective memory targets. Thus, one purpose of this study was to distinguish between these possibilities.

2. Experiment 1

2.1. Method

2.1.1. Participants

The participants were 40 volunteers (20 men, mean age = 22.9, *SD* = 4.2) from the University of Bern.

2.1.2. Materials

We used the same materials as Meier et al. (2009, Experiment 1). 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 centre of the computer screen in 60-point Times New Roman font.

2.1.3. 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. 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, they were required to press the space key (the prospective memory task) rather than to perform the case decision. Participants were asked to repeat these instructions in order to make sure that they understood.

After these instructions, a block of 30 trial sequences was presented for practice. Each trial sequence required making two parity decisions, two colour decisions, and two case decisions, always in the same order, as illustrated in Fig. 1. Each stimulus was determined randomly with the restriction that no stimulus repetition was allowed. 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 trial sequence, 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 trial sequences, with the first two trial sequences serving as "warm-up" sequences and excluded from the analyses. The second and third blocks had 30 trial sequences each.

For the first and third blocks (i.e., the non-target blocks), only univalent stimuli were presented as ongoing task trials. For the second block (i.e., the target block), stimuli were univalent except on 10% 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. For counterbalancing, they appeared on the first case decision of the trial sequence for half of the participants and on the second case decision for the other half. Trial sequences with prospective memory targets were evenly interspersed among the 30 trial sequences of the block, occurring in every fifth trial sequence, specifically in the 3rd, 8th, 13th, 18th, 23th, and 28th sequences. The entire experiment lasted about 20 min.

2.1.4. Data analysis

For each participant, the accuracy and the median decision times (DTs) for correct responses were computed for each trial type (switch and repetition), for each task of the ongoing task, and for each trial sequence following a prospective memory target in the target block and for each corresponding trial sequence in the non-target Blocks 1 and 3. For analysis, this trial sequence was designated with the label T, with successive trial sequences labelled $T + 1$, $T + 2$, $T + 3$, and $T + 4$. Mean accuracies and median DTs were then averaged across switch and repetition trials for each task of the ongoing task, each trial sequence, each block, and each participant.[1] To account for general training effects, we further averaged the data from the non-target blocks 1 and 3 for each task of the ongoing task, each trial sequence, and each participant.

An alpha level of .05 was used for all statistical tests. Greenhouse–Geisser corrections are reported where appropriate and effect sizes are expressed as partial η^2 values.

2.2. Results

2.2.1. Performance on prospective memory targets

Mean accuracy on prospective memory targets was .92 ($SE = .02$). Mean DTs of correctly responding to prospective memory targets was 980 ms ($SE = 26$).

2.2.2. Ongoing task performance

As the main objective was to examine the after-effects of target presentation on ongoing task performance, we examined on how many trial sequences following a prospective memory target a performance slowing occurred. The most relevant results, depicted in Fig. 2, are the DTs from the ongoing task trials in the target block compared to those in the non-target block for the trial sequences $T + 1$ to $T + 4$. A three-way repeated-measures analysis of variance (ANOVA) on the DTs of the ongoing task trials, with the factors block (non-target, target), task (parity, colour, case), and trial sequence ($T + 1$, $T + 2$, $T + 3$, $T + 4$) showed a significant main effect of task, $F(1.71, 66.75) = 6.53$, $p < .01$, $\eta^2 = .14$, and of trial sequence, $F(2.16, 84.22) = 6.40$, $p < .01$, $\eta^2 = .14$. Critically, the interaction between block and trial sequence was significant, $F(2.55, 99.28) = 3.64$, $p < .05$, $\eta^2 = .08$. No other effect reached significance, $Fs < 2.84$, $ps > .05$, $\eta^2 < .07$. Thus, performance was slowed in the target block compared to the non-target block, revealing after-effects of target presentation. However, these after-effects dissipated rapidly.

Despite the lack of a three-way interaction, but due to the theoretical and practical interest, we conducted follow-up ANOVAs with the factors block (non-target, target) and task (parity, colour, case) for each of the four trial sequences separately. For $T + 1$, there was a main effect of block $F(1, 39) = 8.75$, $p < .01$, $\eta^2 = .18$. For the subsequent sequences (i.e., $T + 2$, $T + 3$, and $T + 4$), only the main effect of task was significant ($T + 2$: $F(1.47, 57.28) = 5.33$, $p < .05$, $\eta^2 = .12$; $T + 3$: $F(2, 78) = 5.71$, $p < .01$, $\eta^2 = .13$; and $T + 4$: $F(2, 78) = 5.26$, $p < .01$, $\eta^2 = .12$). No other effect reached significance, $Fs < 2.32$, $ps > .05$, $\eta^2 < .06$. Thus, performance was slowed for the first trial sequence following prospective memory targets.

[1] In the present study, participants were instructed to perform each task of the ongoing task twice in succession (see Fig. 1). This results in switch and repetition trials which allows to examine whether responding to prospective memory targets affects switch and repetition trials differentially, and thus contributes to switch costs (i.e., the slower performance on switch compared to repetition trials). We carried out all the analyses including switch vs. repetition as an additional independent variable. However, as switch and repetition trials had never a differential impact on the after-effects of target presentation, we collapsed the data over this factor.

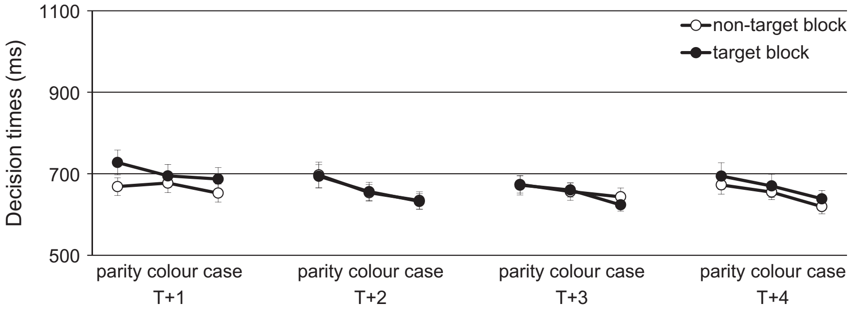

Fig. 2. Experiment 1. Mean decision times for trial sequences following a prospective memory target in the target block (filled circles) compared to the corresponding trial sequences from the non-target block (empty circles). Trial sequence *T* refers to the trial sequence containing a prospective memory target; subsequent trial sequences (presented here) are labelled *T* + 1, *T* + 2, *T* + 3, and *T* + 4, respectively. Error bars represent standard errors.

Finally, we analyzed the accuracy rates of the ongoing task trials. Consistent with the instruction to respond as quickly and accurately as possible, accuracy was close to ceiling (96%). We also conducted a three-way repeated-measures ANOVA on the accuracy rates of the ongoing task trials, with the factors block (non-target, target), task (parity, colour, case) and trial sequence ($T + 1$, $T + 2$, $T + 3$, $T + 4$). The ANOVA revealed no significant effects, all Fs < 2.88, ps > .05, $\eta^2 < .07$. Thus, no speed-accuracy trade-off compromised the critical DT effects.

2.3. Discussion

The primary goal of Experiment 1 was to examine the trajectory of the after-effects caused by prospective memory targets. The results showed a performance slowing on the first sequence of ongoing task trials following prospective memory targets. This suggests that responding to a prospective memory target resulted in a short-lived adjustment of cognitive control. However, it also indicates that even in situations with minimal task-set overlap, responding to prospective memory targets results in an ongoing task cost that is different from the more common expectancy-based monitoring cost. This adds to the existing evidence that in prospective memory research expectancy-based monitoring costs may typically be overestimated.

The interpretation of the after-effects as a separate source of slowing is based on the assumption that changes in expectancy-based monitoring across blocks follow a linear trajectory. As already noted in the introduction this assumption is justified by previous research. However, it is noteworthy that the results of Experiment 1 provide further support for this assumption because of the equivalence of the decision times in the averaged non-target block and target Block 2 except for those trials that immediately follow the presentation of prospective memory targets (Fig. 2).

The general adjustment of cognitive control triggered by responding to a prospective memory target is different from the conflict-specific adjustment found in some studies of cognitive control (cf., Akçay & Hazeltine, 2008; Egner et al., 2007; Funes et al., 2010; Notebaert & Verguts, 2008). Moreover, the fact that the after-effect was short-lived also indicates that the conflict induced by prospective memory targets results in different cognitive processes than the conflict typically induced with bivalent stimuli (cf., Meier et al., 2009). One explanation is that with prospective memory targets conflict is induced by instructions (i.e., top down), while in studies of task switching the conflict is typically induced by the stimuli (i.e., bottom up). Moreover, the studies from research on cognitive control typically involve situations in which a larger overlap of stimulus and/or response features is present and this may also have contributed to the relatively small effects in Experiment 1.

Thus, we designed a second experiment to investigate the after-effects of responding to a prospective memory target when the conflict induced by prospective memory targets was increased, that is, with greater task-set overlap between the prospective memory task and the ongoing task. To this end, we created prospective memory targets with relevant features for two tasks of the ongoing task. Using the same ongoing task as in Experiment 1 (i.e., the regular alternations between a parity, a colour, and a case decision), we presented red or blue letters as prospective memory targets and we asked participants to press the space key when encountering these letters. As a consequence, the prospective memory targets had relevant features for the prospective memory task and also for the colour and case decisions of the ongoing task. We expected that an increase in task-set overlap would result in larger and potentially longer-lasting after-effects.

3. Experiment 2

3.1. Method

3.1.1. Participants

The participants were 37 different volunteers (19 men, mean age = 23.2, SD = 3.2) from the University of Bern.

3.1.2. Materials and procedure

The materials and procedure was similar to Experiment 1 except that prospective memory targets were defined as coloured (red or blue) letters. 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.

3.1.3. Data analysis

The data analysis was identical to Experiment 1.

3.2. Results

3.2.1. Performance on prospective memory targets

Mean accuracy on prospective memory targets was .75 (SE = .03). Mean DTs of correctly responding to prospective memory targets was 1295 ms (SE = 71). Overall, three participants pressed the space bar once in the colour decision task (intrusion error). Two of these errors occurred in Block 2 and one in Block 3.

3.2.2. Ongoing task performance

Fig. 3 depicts the means of the median DTs for the trial sequences $T + 1$ to $T + 4$. To examine the after-effects of prospective memory targets, we carried out a three-way repeated-measures ANOVA on the DTs of the ongoing task trials, with the factors block (non-target, target), task (parity, colour, case), and trial sequence ($T + 1$, $T + 2$, $T + 3$, $T + 4$). This ANOVA revealed a significant main effect of block, $F(1,36) = 23.74$, $p < .001$, $\eta^2 = .40$, caused by slower responses in the target block than in the non-target block. Thus, responding to prospective memory targets produced after-effects on ongoing task performance. The ANOVA also showed a significant main effect of task, $F(2,72) = 12.63$, $p < .001$, $\eta^2 = .26$, and of trial sequence, $F(2.20,79.20) = 20.20$, $p < .001$, $\eta^2 = .36$, as well as a significant interaction between these factors, $F(4.71,169.61) = 4.15$, $p < .01$, $\eta^2 = .10$. Critically, the interactions between block and task, between block and trial sequence, and between block, task and trial sequence were also significant, $F(2,72) = 8.06$, $p < .01$, $\eta^2 = .18$, $F(2.13,76.77) = 14.41$, $p < .001$, $\eta^2 = .29$, and $F(4.02,144.82) = 2.76$, $p < .05$, $\eta^2 = .07$, respectively. These interactions underscore that the performance slowing due to target presentation decreased differentially across tasks and trial sequences.

We conducted follow-up ANOVAs with the factors block (non-target, target) and task (parity, colour, case) for each of the four trial sequences to investigate this decrease more thoroughly. The ANOVA on $T + 1$ revealed a significant main effect of block, $F(1,36) = 29.51$, $p < .001$, $\eta^2 = .45$, and of task, $F(2,72) = 17.49$, $p < .001$, $\eta^2 = .33$, as well as a significant interaction, $F(2,72) = 4.92$, $p < .05$, $\eta^2 = .12$. Thus, the performance slowing due to responding to a prospective memory target affected the three ongoing tasks differentially. However, it was significantly different from zero for all three tasks (parity: 210 ms with $t(36) = 4.80$, $p < .001$; colour: 191 ms with $t(36) = 4.23$, $p < .001$; and case: 78 ms with $t(36) = 2.96$, $p < .01$). Therefore, for $T + 1$, responding to prospective memory targets produced after-effects on all three ongoing tasks.

The ANOVA on $T + 2$ revealed a significant main effect of block, $F(1,36) = 10.67$, $p < .01$, $\eta^2 = .23$, and of task, $F(1.50,53.92) = 9.20$, $p < .01$, $\eta^2 = .20$, as well as a significant interaction, $F(1.35,48.68) = 7.23$, $p < .01$, $\eta^2 = .17$. As before, the performance slowing in $T + 2$ was differentially affected by the three tasks of the ongoing task. However, it was only significantly different from zero for the colour decisions (132 ms), $t(36) = 3.51$, $p < .01$, but not for the parity and case decisions (25 ms and 23 ms, respectively), $ts < 1.38$, $ps > .05$.

The ANOVA on $T + 3$ revealed a significant main effect of block, $F(1,36) = 7.86$, $p < .01$, $\eta^2 = .18$, and of task, $F(2,72) = 5.73$, $p < .01$, $\eta^2 = .14$. Despite the lack of a significant interaction, $F(1.60,57.53) = 2.08$, $p = .14$, $\eta^2 = .05$, Fig. 3 suggests a larger performance slowing for the colour decisions. In fact, this slowing was significantly different from zero for the colour decisions (68 ms), $t(36) = 2.71$, $p < .05$, and for the case decisions (28 ms), $t(36) = 1.91$, $p < .05$ (one-tailed), but not for the parity

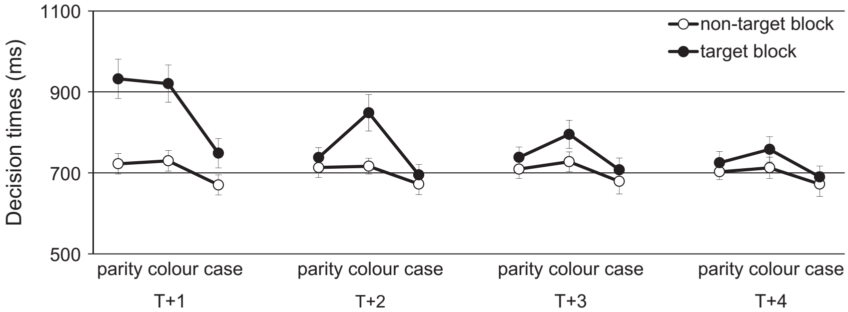

Fig. 3. Experiment 2. Mean decision times for trial sequences following a prospective memory target in the target block (filled circles) compared to the corresponding trial sequences from the non-target block (empty circles). Trial sequence T refers to the trial sequence containing a prospective memory target; subsequent trial sequences (represented here) are labelled $T + 1$, $T + 2$, $T + 3$, and $T + 4$, respectively. Error bars represent standard errors.

decisions (29 ms), $t(36) = 1.65$, $p = .11$. Thus, for $T + 3$, responding to prospective memory targets produced after-effects for the ongoing task trials sharing features with the targets (i.e., the colour- and case-decision trials).

The ANOVA on $T + 4$ revealed a significant main effect of task, $F(2,72) = 3.21$, $p < .05$, $\eta^2 = .08$. No other effect reached significance, $Fs < 4.03$, $ps > .05$, $\eta^2 < .10$. However, slowing was significantly different from zero for the colour decisions (46 ms), $t(36) = 1.69$, $p < .05$ (one-tailed; for parity and case decisions: 22 ms and 18 ms, respectively, $ts < 1.20$, $ps > .05$). Thus, for $T + 4$, responding to prospective memory targets produced after-effects for the colour-decision trials.

Finally, we also conducted a three-way repeated-measures ANOVA on the accuracy rates of the ongoing task trials, with the factors block (non-target, target), task (parity, colour, case) and trial sequence ($T + 1$, $T + 2$, $T + 3$, $T + 4$). The ANOVA revealed a significant main effect of task, $F(2,72) = 9.11$, $p < .001$, $\eta^2 = .20$, indicating more accurate responses on case decisions ($M = .98$, $SE = .004$) than on parity and colour decisions ($M = .96$, $SE = .006$, and $M = .96$, $SE = .005$, respectively). No other effect reached significance, $Fs < 2.51$, $ps > .05$, $\eta^2 < .06$. Thus, no speed-accuracy trade-off compromised the critical DT effects.

3.3. Discussion

The goal of Experiment 2 was to examine the after-effects of responding to a prospective memory target when the task-set overlap between the prospective memory task and the ongoing task was increased. As in Experiment 1, the results revealed that performance was slowed on all ongoing task trials immediately after the prospective memory target (i.e., on trial sequence $T + 1$) replicating the presence of short-lived after-effects. 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 and case decisions). Thus, we replicated and extended the finding that after-effects of responding to prospective memory targets are an additional source of ongoing task slowing which is different from the expectancy-based slowing due to monitoring for prospective memory targets.

It may be surprising, at first glance that immediately after the presentation of the prospective memory targets (i.e., on the trial sequences $T + 1$) parity decisions were slowed to a similar degree as colour decisions (see Fig. 3), despite the fact that this task had no overlap with the prospective memory targets. However, this effect can be explained by the fact that switching away from and back to the ongoing task requires a reconfiguration of the cognitive system that is costly. As these particular task switching operations occur only infrequently it is likely that they require more effort than simply repeatedly switching between the ongoing tasks. We would like to point out that the effect is also present in Experiment 1, although less pronounced.

The short-lived and general slowing that even affected the task with non-overlapping stimulus features conforms partly to the results from studies of the bivalency effect, in which typically a general, but long-lasting slowing is found (Meier et al., 2009). They also conform partly to those studies that have reported specific after-effects by revealing a longer lasting cost only for those ongoing task trials that had overlapping stimulus features with the prospective memory targets (cf., Akçay & Hazeltine, 2008; Egner et al., 2007; Funes et al., 2010; Notebaert & Verguts, 2008). However, none of these accounts can explain the whole pattern of our results. It is likely that different components from each of these explanations contribute to the specific pattern of our results. We outline these components in detail in the general discussion.

4. General discussion

The purpose of the present study was to investigate the trajectory of the after-effect triggered by responding to a prospective memory target. Across three experimental blocks, participants performed repeatedly three simple ongoing tasks in a regular order. In the critical block, prospective memory targets were presented occasionally on one of the tasks. In Experiment 1, the prospective memory targets had overlapping features with one task only, creating minimal task-set overlap between the prospective memory task and the ongoing task. In Experiments 2, the prospective memory targets had overlapping features with two ongoing tasks, thus increasing the task-set overlap. 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 between the prospective memory task and the ongoing task in Experiment 2 revealed a longer lasting effect that sporadically slowed performance on those ongoing task trials that had overlapping features with the prospective memory targets.

We propose that these effects are the consequence of encountering a cognitive conflict, triggered by responding to the bivalent prospective memory targets. Responding to prospective memory targets not only involves the detection of the target event and the retrieval of the intention. It also requires switching away from and back to the ongoing task. These task switching processes require a reconfiguration of the cognitive system that is costly. Importantly, these particular task switching processes occur only infrequently and thus it is likely that they require more effort than simply repeatedly switching between the ongoing tasks. By this explanation the slowing that occurs immediately after responding to prospective memory targets and even in the absence of overlapping stimulus features can be explained. In addition, the relative infrequency of the occurrence of prospective memory targets may cause attentional capture and as a consequence requires a reorientation to the ongoing task. This reasoning is in line with an orienting account that has originally been put forward to explain post-error slowing, but it can also explain why slowing occurs after infrequent events (e.g., Notebaert et al., 2009). Importantly, the orienting effect is typically short-lived, but would be sufficient to explain the slowing on the first trial sequences after the prospective memory targets.

Moreover, prospective memory targets require a different response than the ongoing task trials (i.e., to press the space bar). Thus, responding to the prospective memory task strengthens the association between the ongoing tasks with overlapping stimulus features and the (unusual) prospective memory response. On subsequent ongoing task trials, the reactivation of the prospective memory response may interfere with the activation of the ongoing task response, which results in a performance slowing for the tasks with overlapping stimulus features (cf., Metzker & Dreisbach, 2009). This interference effect dissipates across subsequent ongoing task responses. Thus, this explanation can account for the longer-living after-effects, in particular on the colour and case decisions of Experiment 2.

However, prospective memory targets may also act as reminders for future prospective memory tasks. That is, responding to a particular prospective memory target may not only involve the retrieval of the intention but may also encourage subsequent monitoring for further prospective memory targets. It has been demonstrated that prospective memory lures can indeed have such consequences (Scullin, McDaniel, & Einstein, 2010). However, the implementation of a monitoring strategy would result in a different pattern of results. Rather than to wane across subsequent trials as in the present study, one would rather expect that expectancy-based monitoring would steadily increase across trials. However, our results show that the most pronounced slowing occurs immediately after the occurrence of a prospective memory target and that it declines rapidly afterwards.

The finding that responding to a prospective memory target results in robust after-effects suggests that monitoring costs may be overestimated in prospective memory research. Depending on the degree of task-set overlap between the ongoing task and the prospective memory targets, the cost of adjusting cognitive control after responding to a prospective memory target can continue for several trials after the prospective memory response. In the present study, it lasted at least for 6 s (required for making one trial sequence, i.e., six decisions, each requiring approximately 700 ms, plus 2 blanks of 500 ms, plus one blank of 1000 ms) and up to 24 s (four trial sequences with six decisions each). As a consequence, if the goal of an experiment is to measure "pure" expectancy-based monitoring costs it would be necessary to include additional control conditions.

One strategy may be to include an additional control group as in the work by Loft et al. (2008). However, the present study suggests that it is also possible to identify the contribution of the after-effects of prospective memory targets by using a within-subjects design. In either case however, an additional control condition is necessary in which no prospective memory instructions are given. Thus, further research is necessary to determine the specific contribution of the after-effects triggered by responding to a prospective memory target to overall monitoring costs. We also would like to highlight that – besides of an economical reason –, the advantage of the present within-subjects approach compared to the between-subjects approach that requires testing an additional control group (i.e., which receives prospective memory instructions, but is not presented with prospective memory targets), is the possibility to test the specific trajectory of the after-effects.

The results of the present study also provide insights for research on cognitive control. They suggest that bivalency that is induced top-down reflects different processes than bivalency that is induced bottom-up. This is consistent with results from neuroimaging studies. Responding to prospective memory targets is typically associated with activation differences in prefrontal cortex, particularly the fronto-polar cortex, (Burgess, Quayle, & Frith, 2001; Reynolds, West, & Braver, 2009). In contrast, responding to bivalent stimuli is rather associated with activations in the anterior cingulate cortex (Botvinick, Cohen, & Carter, 2004; Botvinick et al., 2001; Grundy et al., 2011; Woodward et al., 2008). Thus, there is converging evidence form behavioural studies and from neuroimaging that the specific source of conflict (i.e., top-down vs. bottom up) leads to a different pattern of results.

5. Conclusion

To summarize, the results of the present study provide evidence that responding to prospective memory targets results in after-effects that are expressed as a slowing in ongoing task performance. This slowing has a different source than the slowing due to expectancy-based monitoring that is typically used in prospective memory research to infer the resource demands of a prospective memory task. Thus, it is necessary to disentangle the sources of slowing to obtain an unbiased measure of the monitoring costs.

This study also contributes to the debate on whether prospective memory retrieval can occur spontaneously, that is, whether preparatory attentional processes are always necessary (cf. Einstein & McDaniel, 2010; Knight et al., 2011; Scullin, McDaniel, & Einstein, 2010; Smith, 2010). Recent evidence indicates that spontaneous retrieval of prospective memory targets can indeed occur even in the absence of strategic monitoring. For example, Knight et al. (2011) demonstrated that out-of context processing of cues which are to be used as prospective memory targets in a later phase of an experiment is slowed in the absence of strategic monitoring. Similarly, Cohen, Kantner, Dixon, and Lindsay (2011) demonstrated that processing to-be-remembered information in an unrelated Stroop task also slowed performance and thus provided evidence for the automaticity of spontaneous retrieval (i.e., the intention–interference effect). Here, we demonstrate that responding to prospective memory targets results in after effects that slow down subsequent ongoing task performance. Thus, monitoring costs provide an impure measure of preparatory attention processes and the contribution of preparatory attentional processes as measured by ongoing task performance may have been overestimated. Spontaneous retrieval may even be involved in the presence of slowed ongoing task performance.

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