Psychological Research (2014) 78:574–583
DOI 10.1007/s00426-013-0509-5

ORIGINAL ARTICLE

The difficulty of letting go: moderators of the deactivation of completed intentions

Moritz Walser · Thomas Goschke · Rico Fischer

Received: 20 February 2013 / Accepted: 24 July 2013 / Published online: 11 August 2013

Abstract Recent studies showed that prospective memory (PM) intentions might not be deactivated directly after completion. The residual activation leads to aftereffects which are reflected as interference in performance when former PM cues of old intentions are interspersed in the new task (i.e., intention deactivation failure, Walser et al., J Exp Psychol Learn Mem Cogn 38(4):1030–1044, 2012). In the present study, we investigated potential mechanisms that might support the deactivation process of completed intentions by manipulating the task demands (e.g., working memory load) between intention completion and measurement of aftereffects. Aftereffects on repeated PM-cue trials were found when working memory load was low (control condition), but were reduced when available resources were sparse (working memory load condition). When participants were asked to reflect upon the to-be-deactivated PM cue, subsequent aftereffects were increased. Further, overall aftereffects were larger for participants low in self-reported action control. Results show that the nature of the filler-task activity determines whether the representation of the completed intention is destabilized (working memory load) or strengthened (intention reflection). The (at least partial) overwriting of completed intention representations by new working memory task representations seems therefore to reflect a supporting factor for the deactivation of completed intentions.

Electronic supplementary material The online version of this article (doi:10.1007/s00426-013-0509-5) contains supplementary material, which is available to authorized users.

M. Walser (✉) · T. Goschke · R. Fischer
Department of Psychology, Technische Universität Dresden, 01062 Dresden, Germany
e-mail: walser@psychologie.tu-dresden.de

Introduction

Our daily lives are characterized by constantly remembering to perform delayed intentions such as buying groceries when passing by the supermarket after work. The ability to form, maintain, recall and execute delayed intentions has been the subject of many prospective memory (PM) research initiatives (for an overview see Kliegel, McDaniel, & Einstein, 2008).

Recent work has begun to investigate the fate of the representation of delayed intentions after they have been successfully completed. Although one would expect that if intentions are completed they should no longer affect performance on following tasks, previous studies demonstrated that completed intentions might nevertheless affect subsequent processing. Such aftereffects of completed intentions have been investigated using two different paradigms.

First, several studies based on the postponed-intention paradigm (Goschke & Kuhl, 1993) have focused on assessing the activation level of memory representations of the to-be-performed action by measuring response times (RTs) to intention-related items (e.g., words semantically related to the intended action). In such studies, it has repeatedly been found that completed intentions are immediately deactivated (Meilán, 2008) or even inhibited after task completion, as indicated by increased RTs to words (Marsh, Hicks, & Bink, 1998; Marsh, Hicks, & Bryan, 1999) or motor plans (Badets, Blandin, Bouquet, & Shea, 2006) related to a completed intention (but see Penningroth, 2011).

Second, other studies investigated aftereffects of completed intentions using typical event-based PM paradigms (e.g., Einstein & McDaniel, 1990). In these paradigms the content of the intended action is usually extremely simple (e.g., to press a specific key). Hence, they rather focus on the investigation whether a PM cue (i.e., the signal to execute the intended action) still triggers the retrieval of the intended action even after the intention has been successfully completed. Aftereffects of completed intentions are assessed by examining ongoing-task performance on trials in which formerly relevant PM cues (i.e., so-called $PM_{REPEATED}$ trials) appear. That is, one is interested whether $PM_{REPEATED}$ trials still trigger the retrieval of the intention even after its completion (i.e., if the PM cue and/or PM cue-intended action link is still active) (Scullin, Bugg, & McDaniel, 2012; Scullin, Bugg, McDaniel, & Einstein, 2011; Scullin & Bugg, 2013; Walser, Fischer, & Goschke, 2012; Walser, Plessow, Goschke, & Fischer, 2013).

Scullin et al. (2011), for example, investigated aftereffects of PM cues of completed intentions in both young and older adults. In their study, an ongoing image rating task was combined with a PM task (i.e., press the *Q*-key in response to a pre-specified PM-cue word). After that participants were instructed that the PM task was finished. In a subsequent lexical-decision task words that previously served as PM cues were interspersed. Increased lexical-decision RTs on $PM_{REPEATED}$ trials were primarily found for older adults and interpreted as impairments of intention deactivation (for a similar finding of age differences on commission errors see Scullin et al., 2012; for no age differences see Bugg, Scullin, & McDaniel, 2013). For young adults, Scullin et al. (2011) and Scullin, Einstein, & McDaniel (2009) did not find evidence for aftereffects of completed intentions when assessing RTs. Further, in all studies in which they found reliable commission errors for young adults, PM cues were salient and ongoing tasks between PM task and measurement of aftereffects matched (Bugg et al., 2013; Scullin et al., 2012; Scullin & Bugg, 2013).

Further evidence for such apparent deactivation failures was provided by Walser et al. (2012) who investigated aftereffects of completed intentions in young adults in conditions in which they had to maintain and perform a new PM task. Participants performed a digit categorization task with an embedded PM task, which required a different key press (i.e., space bar) on PM-cue trials which differed in one particular visual feature (e.g., a digit surrounded by a black square) from standard trials. Whereas the relevant PM-cue feature changed in each block, irrelevant PM cues from the previous block were occasionally repeated in the following block. In four experiments, Walser and colleagues consistently found increased ongoing-task RTs on $PM_{REPEATED}$ trials as compared to control trials (so-called oddball trials).

Different possible mechanisms underlying aftereffects of completed intentions have been discussed in previous studies. First, based on the multiprocess view (McDaniel & Einstein, 2000) aftereffects were interpreted as spontaneous cue-triggered reactivation of the associated intended action on $PM_{REPEATED}$ trials (Scullin & Bugg, 2013). Second, it has been proposed that aftereffects are rather due to residual heightened sub-threshold activation (Goschke & Kuhl, 1993) of the to-be-forgotten intention representation, which might even constitute a prerequisite for cue-triggered reactivation (for a more thorough discussion of possible mechanisms underlying aftereffects see also Walser et al., 2012).

Although numerous studies have been dedicated to the investigation of aftereffects of completed intentions, little progress has been made in the understanding of how intentions are deactivated. Put differently, why are deactivation failures observed in the first place when intentions are completed?

In the present study, we investigated putative processes that may support or hinder the deactivation of completed intentions. Theoretically, at least two opposing mechanisms are conceivable to facilitate successful intention deactivation.[1]

On the one hand, some authors hypothesized that completed intentions might require a specific resource-demanding deactivation process (Beckmann, 1994; Penningroth, 2011). For example, Beckmann (1994) could show that the deactivation of unsuccessfully completed intentions (i.e., of words related to the content of the intention) increased as a function of free cognitive resources available after intention completion. Based on Beckmann's findings and her own work, Penningroth (2011) speculated that sufficient available cognitive resources might not only lead to a deactivation of completed intentions, but even to a transient inhibition (Badets et al., 2006; Marsh et al., 1998, 1999).

Following this reasoning, the finding of aftereffects of completed intentions (Scullin et al., 2012; Scullin & Bugg, 2013; Walser et al., 2012) might be attributed to a lack of available cognitive resources between intention completion and measurement of aftereffects. That is, sparse cognitive resources or a lack of time to implement the resource-demanding deactivation process (e.g., Walser et al., 2012, immediate start of the next block) might impair the deactivation process to work sufficiently. Put differently, one could assume a deactivation mechanism that requires available cognitive resources.

Alternatively, it is conceivable that intention deactivation does not require a specific disengagement process, but that deactivation is a function of new information replacing or interfering with the memory representation of the old intention (for a similar discussion of interference-based

[1] Note that in the context of aftereffects of completed intentions the term "deactivation" should not be considered as a deliberate process, but rather refers to a passive process, as participants generally do not receive instructions to actively forget the completed intention representation.

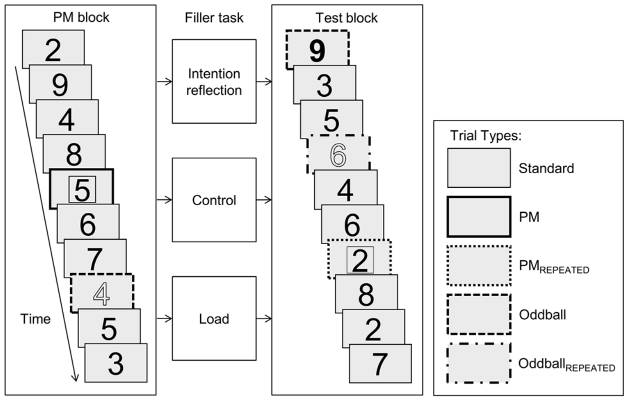

Fig. 1 Example trials of the PM and test block. Participants had to perform number categorization judgments on all trials except for prospective memory (PM) trials, in which they had to press the space bar. On each block sequence participants performed one of three different filler tasks between the PM block and the test block. Note, framing of trial types were not present in the experiment but serve exclusively to illustrate different trial types in this figure

deactivation in short-term memory see, e.g., Berman, Jonides, & Lewis, 2009; Campoy, 2012). Thus, any demanding task will help to overwrite the former intention representation (or the associative link between PM cue and intended action). If this is correct, the stability of the intention representation (and thus, the size of the resulting aftereffects) should depend on the nature of information processing between intention completion and measurement of aftereffects. Performing cognitively demanding tasks between intention completion and measurement of aftereffects should destabilize intention representations (e.g., by overwriting task representations of the completed intentions), thereby diminishing aftereffects of completed intentions. Going even further, aftereffects of completed intentions might even increase when tasks are performed that strengthen and stabilize memory representations of the completed intention (e.g., reflecting upon the completed intention).

To distinguish between these possibilities, we adopted the paradigm of Walser et al. (2012) in which deactivation failures had been reported. By including specific tasks to be performed right after intention completion but before the measurement of aftereffects (i.e., filler tasks, see Fig. 1), we aimed at modulating the efficiency of deactivation of completed intention representation, thus, either increasing or decreasing aftereffects. Three different filler-task conditions were implemented in a within-subjects design: a control condition, a working memory load condition and an intention reflection condition, respectively.

The first filler task (control) served to provide a standard condition for a deactivation process to work. Participants were required to slowly read out letter strings for 90 s, a procedure that is known to occupy the phonological loop and thus, helps to prevent rumination about the recent PM task (e.g., Emerson & Miyake, 2003; Goschke, 2000) without posing cognitive load. Assuming a deactivation process that requires cognitive resources (Beckmann, 1994; Penningroth, 2011), the control filler task, in which cognitive resources are not diminished, the deactivation process should be sufficiently established to allow for a deactivation of completed intentions. The assumption of an interference-based intention deactivation, on the other hand, predicts that aftereffects should only be observed if the relatively low-demanding control condition would not be sufficiently demanding to overwrite the old intention representation.

In the second filler task (load condition), participants performed a high working memory load task between intention completion and measurement of aftereffects to limit available cognitive resources. A deactivation process that requires the same specific cognitive resources that were taken by the load task should work less efficiently predicting increased aftereffects compared to the control condition. According to the assumption of an interference-based intention deactivation, new cognitively demanding contents in working memory might destabilize and override the memory representation of the completed intention (Berman et al., 2009), which should lead to decreased aftereffects compared to the control condition.

The third filler task (intention-reflection condition) served to further test whether the activation level of a completed intention representation can be modulated. Participants had to reflect upon visual features of the PM cue of the completed intention. Even though the true working memory demand of this task is hard to predict we consider working memory demands to be considerably less than in the working memory load condition.[2] Assuming a deactivation process that requires cognitive resources, this would predict reduced aftereffects in the intention reflection condition than in the working memory load condition. Alternatively, if the representation of the finished intention can be stabilized or destabilized depending on the nature of new working memory contents, a task that requires the active use and reflection upon this intention representation would predict a strengthening and stabilization of this representation (Whitmer & Gotlib, 2012), which consequently results in more pronounced aftereffects.

Finally, we investigated inter-individual differences in the ability to deactivate completed intentions. For

[2] It is nevertheless conceivable that the intention reflection task may also include central executive processing to some extent (e.g., retrieving PM from long-term memory, imaging features, etc.). We thank Suzanna Penningroth for mentioning this point. At the same time, however, this seems not to the extent than classical working memory load tasks that are frequently used to measure the limits of individual working memory capacity as in the tasks included in the working memory load filler task.

example, previous research has demonstrated that intentions are stored in an increased activation status especially for individuals low in self-reported action control (i.e., state orientation) as compared to individuals high in action control (i.e., action orientation) (e.g., Goschke & Kuhl, 1993). Accordingly, state orientation is defined as a tendency to experience indecisiveness and hesitation concerning new intentions whereas action orientation is defined as the ability to decisively initiate new intentions (Goschke & Kuhl, 1993; Jostmann & Koole, 2010). Action vs. state orientation has also been discussed as a potential moderator of intention deactivation (Beckmann, 1994; Penningroth, 2011). State-oriented as compared to action-oriented participants showed residual activation of unsuccessfully completed intentions (Beckmann, 1994). In the present study, we therefore hypothesized that state-oriented participants would show larger aftereffects of completed intentions as compared to action-oriented participants.

Method

Participants

Fifty-one students of the Technische Universität Dresden [15 male, age $M = 23.57$, standard deviation (SD) = 3.78] participated for 10 € or course credits in two experimental sessions lasting about 1 h 30 min and 1 h, respectively. Both sessions were separated by 2–5 days. Participants were categorized as state (<6) or action (≥6) oriented based on the standard values of the prospective and decision-related action orientation (AOD) scale (total score 0–12) of the Action Control Scale-90 (Kuhl, 1994). Twenty-four participants scored as state oriented ($M = 2.96$, SD = 1.83) and 27 participants as action oriented ($M = 8.59$, SD = 2.15).

Apparatus and stimuli

Stimuli were displayed on a 19-in. monitor. Digits 2–9 served as stimuli and were presented in Arial font (font size: 80 pixels/visual angle 2.2°) in black against a gray background. On PM trials, $\text{PM}_{\text{REPEATED}}$ trials, oddball trials and $\text{oddball}_{\text{REPEATED}}$ trials stimuli differed from standard trials with respect to one of 36 different features. For instance, digits could appear surrounded by a black square, in bold font, with different font color (for depictions of all features see online Supplemental Materials). Participants responded with the *S* key (left index finger), *L* key (right index finger) and space bar (thumb of the dominant hand) on a standard German (*QWERTZ*) keyboard.

Procedure and design

Experimental procedure was adapted from Walser et al. (2012) (Fig. 1). Participants performed a digit categorization task responding with their left and right index fingers to odd and even digits, respectively. After a first practice block of 36 standard trials, a second practice block contained trials entailing the 36 different stimulus features serving as PM trials, $\text{PM}_{\text{REPEATED}}$ trials, oddball trials and $\text{oddball}_{\text{REPEATED}}$ trials in the experiment. For the digit categorization task, each trial began with a fixation cross (font size: 18 pixels, 500 ms) followed by the imperative stimulus that remained on the screen until a response was given. If no or an erroneous response was given within 3,000 ms, a low-pitch tone (450 Hz) and the feedback *zu langsam* (too slow) or *Fehler* (error) was provided for 200 ms.

The experiment consisted of a PM block, filler tasks, and a test block. In the PM block, specific PM cues and oddball trials were included. Oddball trials were trials that differed from standard trials (e.g., digits with different font color, digits in bold font, see Fig. 1) but were never used as PM cues during the experiment. To PM cues only participants were instructed to press the space bar with the thumb of their dominant hand instead of performing the digit categorization task. The PM block ended with the instruction that the task was finished (i.e., "Thank you! The present task is finished now."). Note that participants were not asked to deliberately forget the PM task, because the instruction to forget a particular item might have even increased its activation state (Wegner, Schneider, Carter, & White, 1987). Subsequently the experimenter read out the standardized instruction of the following filler task. In the control condition, participants had to read aloud individual letters of a letter string from a sheet of paper (instruction: "Please read out the following letter strings slowly."). In the load condition participants were required to repeat letter strings as fast and accurately as possible backwards (e.g., "L, M, O" → "O, M, L"; instruction: "Please repeat the following letter strings as fast as possible backwards."). The experimenter started with a three letter string. When participants succeeded with three subsequent correct strings, letter-string length was increased by one. In case of an error, letter-string length was reduced by one. In the intention-reflection condition participants were instructed to try to imagine the PM cue of the just-finished PM task and to describe the PM cue as precisely as possible (instruction: "Please think again about the just-completed task. Try to imagine the stimulus feature on which you responded to by pressing the space bar and describe it as well as possible."). The experimenter supported this task by specific questions

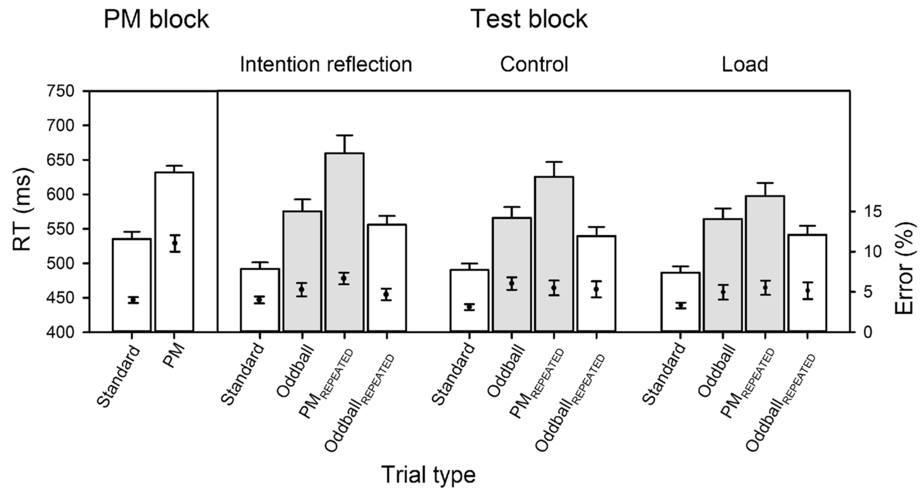

Fig. 2 Mean RTs and error rates for the PM block as a function of trial type (standard, PM), and for the test block as a function of trial type (standard, oddball, $PM_{REPEATED}$, $oddball_{REPEATED}$) and filler task (intention reflection, control, load). *Error bars* represent standard errors

(e.g., concerning cue size, cue color). The filler task (90 s) ended with a high-pitch tone (1 s, 700 Hz). The filler task was followed by a test block in which participants had to perform the digit categorization task on all trials.

In each experimental session, this block sequence was presented for 12 cycles separated by short breaks and each containing a new to be-acted-upon PM cue. Digits were assigned at random to serve as standard, PM, $PM_{REPEATED}$, oddball or $oddball_{REPEATED}$ trial. A PM block consisted of 48 trials (40 standard, 4 oddball and 4 PM trials). The test block contained 96 trials (84 standard, 4 oddball, 4 $PM_{REPEATED}$, and 4 $oddball_{REPEATED}$ trials). Aftereffects of completed intentions were assessed as difference scores between $PM_{REPEATED}$ trials and oddball trials of the test block. We used $oddball_{REPEATED}$ trials to ensure that putative increased RTs on $PM_{REPEATED}$ trials were not due to an increased orientation reaction to familiar stimuli (see also Walser et al., 2012, Experiment 2). In each session, participants performed each filler task four times in randomized order, the only constraints being that the same filler task could only occur twice in a row and that across all participants each filler task occurred 17 times within each of the 12 cycles. For each participant filler-task order differed between sessions. We used two sessions to increase statistical power while avoiding the individual session from being too long. At the beginning of the first session demographic information and the Action Control Scale-90 were administered.

Results

Erroneous trials (3.7 %) and trials with RTs 2.5 SDs above or below a participant's mean RT for a given trial type (PM block: 2.9 %; test block: 2.7 %) were excluded.

PM block

We conducted mixed ANOVAs on RTs and error data of the ongoing task including the factors trial type (standard, oddball) and action-state orientation (action- vs. state oriented). For RTs oddball trials led to an orientation response as indicated by slower RTs on oddball trials ($M = 701$ ms, $SD = 106$ ms) than on standard trials ($M = 542$ ms, $SD = 60$ ms), $F(1, 49) = 381.20$, $p < .001$, $\eta^2 = 0.89$ (Fig. 2; Table 1). RTs did not vary as a function of action vs. state orientation, $F(1, 49) = 1.65$, $p = .205$, $\eta^2 = 0.03$. Both factors did not interact, $F(1, 49) = 1.19$, $p = .280$, $\eta^2 = 0.02$.

A subsequent t test revealed that in PM trials state-oriented participants responded slower ($M = 668$ ms, $SD = 69$ ms) than action-oriented participants ($M = 623$ ms, $SD = 62$ ms), $t(49) = 2.45$, $p = .018$, $d = 0.70$. This finding was substantiated by a slight correlation between RTs on PM trials and the AOD score, $r = -.251$, $p = .038$ (one-tailed).

Participants committed more errors on oddball trials ($M = 7.8$ %, $SD = 5.2$ %; including 1.3 % false PM-cue alarms) than on standard trials [$M = 3.4$ %, $SD = 2.0$ %, $F(1, 49) = 56.21$, $p < .001$, $\eta^2 = 0.53$]. In PM trials, action and state-oriented participants performed equally well, $t(49) = 0.11$, $p = .914$, $d = 0.03$, and committed overall 10.5 % ($SD = 5.8$ %) errors.

Test block

A mixed ANOVA included the factors trial type (standard, oddball, $PM_{REPEATED}$, $oddball_{REPEATED}$), filler task (intention reflection, control, load), and action-state orientation (action vs. state oriented). RTs were affected by trial type, $F(3, 147) = 147.92$, $p < .001$, $\eta^2 = 0.75$. Planned contrasts revealed shorter RTs on standard ($M = 496$ ms, $SD = 52$ ms) than on oddball trials ($M = 570$ ms,

Table 1 Mean RTs and error rates by action vs. state orientation, block, and trial type

	State orientation		Action orientation	
	RT (ms)	Error (%)	RT (ms)	Error (%)
PM block				
Standard	552 (62)	3.2 (1.9)	532 (56)	3.5 (2.1)
Oddball	720 (108)	6.7 (4.2)	682 (102)	8.6 (5.9)
PM	668 (69)	10.6 (6.1)	623 (62)	10.5 (5.6)
Test block				
Intention reflection				
Standard	508 (56)	3.1 (1.8)	490 (52)	3.6 (2.5)
Oddball	581 (92)	3.4 (3.2)	572 (88)	4.4 (4.9)
$PM_{REPEATED}$	689 (159)	5.8 (3.4)	624 (116)	5.7 (4.1)
$Oddball_{REPEATED}$	578 (76)	4.4 (3.9)	545 (65)	4.9 (5.6)
Control				
Standard	506 (57)	2.6 (1.7)	488 (48)	3.1 (2.1)
Oddball	577 (94)	4.8 (4.0)	561 (81)	5.3 (4.4)
$PM_{REPEATED}$	645 (126)	5.6 (4.8)	611 (106)	4.4 (4.4)
$Oddball_{REPEATED}$	561 (77)	4.3 (4.8)	537 (73)	5.7 (5.7)
Load				
Standard	504 (57)	2.9 (1.7)	482 (44)	3.2 (2.3)
Oddball	576 (89)	3.4 (3.8)	555 (73)	4.2 (4.7)
$PM_{REPEATED}$	631 (113)	4.8 (4.5)	580 (96)	5.1 (5.1)
$Oddball_{REPEATED}$	550 (69)	4.0 (4.0)	544 (77)	5.2 (5.7)

State orientation: $n = 24$; action orientation: $n = 27$; standard deviations in parentheses

SD = 82 ms), $F(1, 49) = 178.22$, $p < .001$, $\eta^2 = 0.78$, denoting an effect of attention orienting. Responses to $PM_{REPEATED}$ trials were slower ($M = 630$ ms, SD = 113 ms) compared to oddball trials, $F(1, 49) = 124.14$, $p < .001$, $\eta^2 = 0.72$ (reflecting aftereffects of completed intentions) and to $oddball_{REPEATED}$ trials ($M = 553$ ms, SD = 69 ms),[3] $F(1, 49) = 99.88$, $p < .001$, $\eta^2 = 0.67$. The main effect of filler task was significant, $F(2, 98) = 11.82$, $p < .001$, $\eta^2 = 0.19$. Repeated contrasts showed larger RTs in the intention-reflection condition ($M = 574$ ms, SD = 88 ms) than in the control condition ($M = 561$ ms, SD = 82 ms), $F(1, 49) = 7.89$, $p = .007$, $\eta^2 = 0.14$; and shorter RTs in the load condition ($M = 553$ ms, SD = 78 ms) than in the control condition, $F(1, 49) = 6.40$, $p = .015$, $\eta^2 = 0.12$.

Trial type interacted with filler task, $F(6, 294) = 5.64$, $p = .001$, $\eta^2 = 0.10$. Most important, planned contrasts showed that aftereffects of completed intentions following the load condition [$M = 39$ ms, SD = 51 ms; $PM_{REPEATED}$ trials: $M = 604$ ms, SD = 106 ms; oddball trials: $M = 565$ ms, SD = 81 ms; $t(50) = 5.55$, $p < .001$, $d = 0.41$] were smaller compared to aftereffects measured after the control condition [$M = 58$ ms, SD = 48 ms; $PM_{REPEATED}$ trials: $M = 627$ ms, SD = 116 ms; oddball trials: $M = 569$ ms, SD = 87 ms; $t(50) = 8.65$, $p < .001$, $d = 0.57$], $F(1, 49) = 4.17$, $p = .046$, $\eta^2 = 0.08$. At the same time, aftereffects following the intention-reflection condition [$M = 78$ ms, SD = 77 ms; $PM_{REPEATED}$ trials: $M = 655$ ms, SD = 140 ms; oddball trials: $M = 577$ ms, SD = 89 ms; $t(50) = 8.65$, $p < .001$, $d = 0.67$] were larger compared to those following the control condition, $F(1, 49) = 4.76$, $p = .034$, $\eta^2 = 0.09$ (Fig. 2).

To disregard the possibility that smaller aftereffects of completed intentions following the load condition compared to control condition might have been due to repeated cycles of filler tasks in which participants may have sustained an intention reflection strategy also for subsequent control conditions,[4] we specifically compared aftereffects of completed intentions in the very first cycle between participants starting with the load condition ($n = 17$) and participants starting with the control condition ($n = 17$). Importantly, despite the immense reduction in power, we still found evidence for smaller aftereffects in the load condition ($M = 46$ ms, SD = 98 ms) compared to the control condition ($M = 104$ ms, SD = 104 ms), $t(32) = 1.70$, $p = .050$ (one-tailed), $d = 0.60$.

To further exclude the possibility that aftereffects were affected by the repeated cycles design, e.g., due to increased shielding of irrelevant $PM_{REPEATED}$ and/or oddball information over the course of the experimental session,[5] we analyzed aftereffects (i.e., $PM_{REPEATED}$ trials vs. oddball trials) as a function of repeated cycles exclusively for the first experimental session and independently of the filler-task conditions. Aftereffects did not vary as a function of repeated cycles as indicated by no main effect of repeated cycles, $F(11, 550) = 1.43$, $p = .180$, $\eta^2 = 0.03$; nor a trial type × repeated cycles interaction, $F < 1$.

In line with our previous study (Walser et al., 2012) we investigated the decline of aftereffects within the test block in all filler-task conditions by comparing aftereffects (i.e., $PM_{REPEATED}$ trials vs. oddball trials) between the first three $PM_{REPEATED}$ trial encounters and the last three encounters. Most important, we found the same decrease of aftereffects from early encounters to late encounters in all filler-task conditions (load early: $M = 63$ ms, late: 18 ms; control early: $M = 81$ ms, late: $M = 31$ ms; intention reflection early: $M = 115$ ms, late: $M = 43$ ms; aftereffects were significant in all conditions, $ps < .034$), as indicated by a

[3] The finding of increased RTs on $PM_{REPEATED}$ trials compared to $oddball_{REPEATED}$ trials rules out the alternative explanation that increased RTs on $PM_{REPEATED}$ trials were due to an increased orientation reaction to familiar stimuli. As RTs on $oddball_{REPEATED}$ trials were even faster compared to oddball trials, we used in line with our previous study (Walser et al., 2012) regular oddball trials as more conservative baseline comparison for $PM_{REPEATED}$ trials.

[4] We thank Michael Scullin for highlighting this point.

[5] We are grateful to Julie Bugg for suggesting this analysis.

trial type × block position interaction, $F(1, 50) = 55.89$, $p < .001$, $\eta^2 = 0.52$, and a non-significant trial type × filler task × block position interaction, $F(2, 100) = 1.47$, $p = .236$, $\eta^2 = 0.03$. Consequently, different aftereffects for the three filler-task conditions cannot be explained by different decline functions of aftereffects with temporal distance to intention completion (for a thorough investigation and discussion of the underlying mechanisms of such decline functions, see Walser et al., 2013).

As it is conceivable that filler-task conditions might also affect standard trial RTs in the test block, we compared standard trial RTs across the three filler-task conditions, which yielded significance, $F(2, 100) = 5.09$, $p = .011$, $\eta^2 = 0.09$. Specifically, we found smaller RTs in the load condition ($M = 493$ ms, SD = 51 ms) than in the control condition ($M = 497$ ms, SD = 53 ms), $F(1, 50) = 5.23$, $p = .026$, $\eta^2 = 0.09$ (planned contrasts). This difference could not be attributed to post-$PM_{REPEATED}$ trial slowing, which should be stronger for larger $PM_{REPEATED}$ aftereffects (control condition) compared to conditions of smaller $PM_{REPEATED}$ aftereffects (load condition). That is, reanalyzing standard trial RTs without trials following deviant trials still led to smaller RTs in the load condition ($M = 491$ ms) than in the control condition ($M = 496$ ms), $F(1, 50) = 5.28$, $p = .026$, $\eta^2 = 0.10$ (planned contrasts). Standard trial RTs between the control condition and the intention reflection condition ($M = 498$ ms, SD = 52 ms) did not differ, $F < 1$.

With respect to action-state orientation, the interaction with trial type (including all four trial types) fell short of significance, $F(3, 147) = 3.05$, $p = .067$, $\eta^2 = 0.06$. For the evaluation of aftereffects of completed intentions, however, only the comparison between $PM_{REPEATED}$ trials and oddball trials is informative. Here, state-oriented participants revealed stronger aftereffects ($M = 77$ ms, SD = 44 ms; $PM_{REPEATED}$ trials: $M = 655$ ms, SD = 124 ms; oddball trials: $M = 578$ ms, SD = 88 ms; $t[23] = 8.48$, $p < .001$, $d = 0.71$) than action-oriented participants ($M = 43$ ms, SD = 32 ms; $PM_{REPEATED}$ trials: $M = 606$ ms, SD = 99 ms; oddball trials: $M = 563$ ms, SD = 77 ms; $t[26] = 6.92$, $p < .001$, $d = 0.48$), $F(1, 49) = 10.43$, $p = .002$, $\eta^2 = 0.17$ (planned contrasts). In line with this result, the size of the overall aftereffect of completed intentions correlated negatively with the individual action-state orientation scores, $r = -.37$, $p = .008$, indicating smaller aftereffects the larger the scores for action-orientation (Fig. 3). Finally, the trial type × filler task × action-state orientation interaction was not significant $F(6, 294) = 1.77$, $p = .148$, $\eta^2 = 0.03$.

Error rates were affected by trial type, $F(3, 147) = 11.26$, $p < .001$, $\eta^2 = 0.19$. Planned contrasts showed less errors on standard trials ($M = 3.1$ %, SD = 2.0 %) than on oddball trials ($M = 4.2$ %, SD = 4.2 %), $F(1, 49) = 10.74$, $p = .002$, $\eta^2 = 0.18$. Participants made more errors on $PM_{REPEATED}$ trials ($M = 5.2$ %, SD = 3.0 %) than on oddball trials, $F(1, 49) = 6.69$, $p = .013$, $\eta^2 = 0.12$, but did not differ between $PM_{REPEATED}$ trials and $oddball_{REPEATED}$ trials ($M = 4.7$ %, SD = 3.7 %), $F(1, 49) = 1.18$, $p = .282$, $\eta^2 = 0.02$. The remaining main effects and interactions were not significant, $ps > .310$.[6]

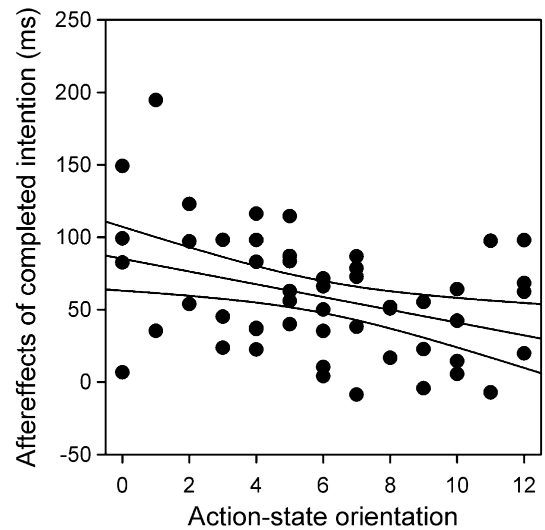

Fig. 3 Correlation between the size of the aftereffect of completed intentions (RT on $PM_{REPEATED}$ trials minus RT on oddball trials) and the individual action-state orientation score on the prospective and decision-related AOD scale, $r = -.37$, $p = .008$. Note, larger scores indicate stronger action orientation

Discussion

In the current study we manipulated the type of processing in the interval between completion of an intention and the measurement of potential aftereffects of completed intentions by implementing three different filler-task conditions: a cognitively low-demanding control condition, a cognitively high-demanding load condition and an intention-reflection condition. Results showed that aftereffects depended on the type of filler task performed right after

[6] As participants hardly made any commission errors (overall during 24[0.02%] trials) we only computed an error analysis including all error types (i.e., commission errors, misses, ongoing-task errors). Note that the relatively low commission error rate compared to other paradigms (e.g., Scullin et al., 2012) might be because in our paradigm the symbolic PM information on $PM_{REPEATED}$ trials was completely irrelevant and thus could be ignored for performing the ongoing task. Further, the ongoing task digits which appeared in the PM block and Test block were at random and not associated with the PM cue. In contrast, other studies used specific words as PM cues which had to be processes completely on $PM_{REPEATED}$ trials, thereby increasing the probability of commission errors.

intention completion. The load condition with increased working memory load (and thus, depleted cognitive resources) was associated with smaller aftereffects compared to the control condition. Apparently better deactivation under increased cognitive load speaks against the assumption that the deactivation of completed intentions represents a process that depends on free cognitive resources. Instead, it is conceivable that occupying working memory with cognitively demanding tasks may destabilize the former intention representation, which eventually might be overwritten by interfering working memory content. This reasoning might initially seem at odds with recent observations of more pronounced aftereffects when a new PM task had to be performed and maintained in working memory when testing for aftereffects of completed intentions (Walser et al. 2012). Current work in our lab suggests that the efficiency of intention deactivation may critically depend on the similarity of old and new intentions. The process of monitoring for new PM cues may have reactivated old intention representations when features of the old intention are encountered. Therefore, it is plausible that in Walser et al. (2012) aftereffects may be augmented when similar intentions have to be performed. In the present study, test blocks did not include new PM tasks (no monitoring). Here, performing a demanding working memory task after intention completion reduced aftereffects.

Furthermore, we also found increased aftereffects in the intention-reflection condition as compared to the control condition, suggesting that aftereffects of completed intentions might also be increased by reflecting upon them. Together, these findings corroborate the interpretation that the activation level of the former intention, and thus, the efficiency of the deactivation process, can be modulated by the type of processing after intention completion.

It should be noted though, that in neither filler-task condition we found evidence for a complete deactivation of completed intentions. The most plausible assumption is that a complete deactivation depends on a number of components. First, we specifically adopted a PM paradigm known for its deactivation failure (Walser et al., 2012) that allows for experimentally induced reductions or increases in aftereffects. It entails features known to support increased aftereffects, such as PM-cue salience and ongoing-task match during PM task and measurement of aftereffects (Scullin et al., 2012). Secondly, intention representations consist of multiple aspects, such as an abstract representation of the content of the intended action as well as of the PM cue and the link between PM cue and intended action. Thus, working memory load may be able to overwrite certain aspects of the intention representation while having less effect on others (e.g., PM cue-action link).

The differences between control and load conditions cannot be explained by an increase of aftereffects in the control condition. More specifically, it has been argued that due to repeated cycles of different filler tasks in a within-subject design the encounter of an intention-reflection condition may result in a transfer of increased rumination also to the control condition. In this perspective, only the load condition would allow for a facilitated deactivation as it prevents rumination. We regard this possibility as rather unlikely, because first, in the control condition we intentionally implemented a cognitively low-demanding task that specifically requires the phonological loop (i.e., repeating letter strings aloud) and has been used to prevent rumination and inner speech (Emerson & Miyake, 2003; Goschke, 2000). Furthermore, using a between-subject test of the very first test block in the experiment, aftereffects were again smaller in the load condition than in the control condition, suggesting that rumination maintenance due to repeated filler-task cycles cannot explain the data pattern. This finding also shows that our paradigm is comparable to other finished PM paradigms using only a single PM block-test block cycle (e.g., Scullin & Bugg, 2013) and not only to the PM repetition error paradigm (e.g., Marsh, Hicks, Hancock, & Munsayac, 2002) in which participants have to continuously update the relevance of the PM cue and response.

Interestingly, we found slightly shorter standard trial RTs in the load condition compared to the control condition. Yet, we do not think that this small difference in standard trial RTs does reflect a speed up that would be able to explain differences in the aftereffects of completed intentions between filler-task conditions. Although very speculative, it is tempting to interpret the slightly shorter RTs in the load condition as a further consequence of the reduced activation level of the finished intention, which not only results in reduced aftereffects but also to less interference with the ongoing task even on standard trials (cf. Scullin & Bugg, 2013). This pattern was, however, not so clear in the intention reflection condition compared to the control condition. This might have been due to the fact that reflecting upon the PM cue might not have fostered the whole intention representation but primarily the representation of the PM cue, thereby leading to increased spontaneous retrieval on $PM_{REPEATED}$ trials while not more strongly interfering on standard trials with the ongoing task. Even though we are aware that these interpretations have to be handled with care we think that they may provide fertile grounds for future research.

Although our study demonstrated a clear modulation in the size of aftereffects of completed intentions by different filler tasks, future studies in this line would benefit from a clearer refinement of filler-task conditions. For instance, they might more thoroughly investigate which specific working memory task conditions affecting different aspects of working memory (e.g., spatial or verbal) might especially support the deactivation process. It is even conceivable that deactivation of some aspects of an intention representation might rather be supported by spatial working memory tasks (e.g., the PM cue representation) whereas deactivation of other aspects might be rather supported by verbal working memory tasks (e.g., the semantic representation of the intended action plan). In addition, future studies might quantify how filler-task performance (e.g., using computerized *n*-back tasks) is related to the size of aftereffects. For instance, it might be conceivable that impaired working memory performance might be related to increased aftereffects.

While studies based on the postponed-intention paradigm (Goschke & Kuhl, 1993) result more frequently in findings of intention inhibition (Badets et al., 2006; Marsh et al., 1998, 1999), studies focusing on PM-cue aftereffects tend to show evidence for intention deactivation or residual intention activation (Scullin et al., 2011, 2012; Scullin & Bugg, 2013; Walser et al., 2012, 2013). Although results from these two paradigms appear contradictory, one has to take into account that they assess different underlying processes of intention memory. Whereas the postponed-intention paradigm assesses the activation level of the semantic content of the intention, the event-based PM paradigm assesses the readiness or strength of the associative link between the PM cue and the to-be-executed action, while strongly simplifying the PM response. In principle, it is conceivable that the activation level of the semantic intention representation may vary independently from the readiness (or strength) of the associative link between PM cue and intended action. On speculative terms one might expect that different mechanisms might underlie the deactivation of both aspects. Future research is required to investigate which similar and dissimilar mechanisms might underlie the deactivation of both aspects, e.g., using the sequential priming paradigm (e.g., Webb & Sheeran, 2007).[7]

In the present study, we also tested for inter-individual differences in terms of action vs. state orientation on PM performance and the ability to deactivate completed intentions. In line with previous research we found slowed PM performance for state- compared to action-oriented participants (Kazén, Kaschel, & Kuhl, 2008). This finding supports the idea of an paradoxical effect that albeit intentions are stored in an increased activation level in state- compared to action-oriented individuals (Goschke & Kuhl, 1993) state orientation might be associated with an impaired initiation of postponed intentions. Note that our data and previous work by Kazén et al. (2008) could be interpreted as evidence that state orientation is associated with impaired intention initiation as reflected by increased RTs but not with an impaired probability to execute the PM task, as reflected by no error rate differences between groups.

In addition to the observed difficulties in initiating intentions, we found that state-oriented participants also produced increased aftereffects of completed intentions. This result is congruent with findings that state orientation might be associated with impaired disengagement from unsuccessfully completed intentions (Beckmann, 1994) or the content of intentions (Penningroth, 2011). Even though it is tempting to relate these findings to demonstrations of increased aftereffects for individuals with lower executive control integrity (e.g., elderly, Scullin et al., 2011, 2012), direct comparisons, however, would at present seem premature. Longer responses to PM cues for state-oriented individuals, e.g., may reflect more elaborate processing (e.g., stabilizing the intention representation; Goschke & Kuhl, 1993). Therefore, one might speculate whether increased aftereffects for state-oriented participants reflect an impaired deactivation process of completed intentions or an increased intention representation (or a combination of both). Although this reasoning is rather speculative, we believe it provides fertile grounds for the further investigation of inter-individual differences in aftereffects of completed intentions.

[7] We thank Suzanna Penningroth for suggesting this paradigm.

Acknowledgments We thank Dana Hantusch, Guanyu Huang, Lea Kern, Julia Kleindienst, and Marcus Möschl for assistance in data collection. We are grateful to Julie Bugg, Suzanna Penningroth, and Michael Scullin for thoughtful comments on earlier versions of this manuscript. This research was partly supported by the German Research Foundation (DFG) (SFB 940/1-2013).

References

Badets, A., Blandin, Y., Bouquet, C. A., & Shea, C. H. (2006). The intention superiority effect in motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(3), 491–505. doi:10.1037/0278-7393.32.3.491.

Beckmann, J. (1994). Volitional correlates of action versus state orientation. In J. Kuhl & J. Beckmann (Eds.), *Volition and personality: action versus state orientation* (pp. 155–166). Seattle: Hogrefe & Huber.

Berman, M. G., Jonides, J., & Lewis, R. L. (2009). In search of decay in verbal short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(2), 317–333. doi:10.1037/a0014873.

Bugg, J. M., Scullin, M. K., & McDaniel, M. A. (2013). Strengthening encoding via implementation intention formation increases prospective memory commission errors. *Psychonomic Bulletin & Review, 20*(3), 522–527. doi:10.3758/s13423-013-0378-3.

Campoy, G. (2012). Evidence for decay in verbal short-term memory: a commentary on Berman, Jonides, and Lewis (2009). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(4), 1129–1136. doi:10.1037/a0026934.

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 717–726. doi:10.1037/0278-7393.16.4.717.

Emerson, M. J., & Miyake, A. (2003). The role of inner speech in task switching: a dual-task investigation. *Journal of Memory and Language, 48*(1), 148–168. doi:10.1016/S0749-596X(02)00511-9.

Goschke, T. (2000). Intentional reconfiguration and involuntary persistence in task set switching. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: attention and performance XVIII* (pp. 331–355). Cambridge: MIT Press.

Goschke, T., & Kuhl, J. (1993). Representation of intentions: persisting activation in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(5), 1211–1226. doi:10.1037/0278-7393.19.5.1211.

Jostmann, N. B., & Koole, S. L. (2010). Dealing with high demands: the role of action versus state orientation. In R. H. Hoyle (Ed.), *Handbook of personality and self-regulation* (pp. 332–352). Oxford: Wiley-Blackwell.

Kazén, M., Kaschel, R., & Kuhl, J. (2008). Individual differences in intention initiation under demanding conditions: interactive effects of state vs. action orientation and enactment difficulty. *Journal of Research in Personality, 42*(3), 693–715. doi:10.1016/j.jrp.2007.09.005.

Kliegel, M., McDaniel, M. A., & Einstein, G. O. (2008). *Prospective memory: cognitive, neuroscience, developmental, and applied perspectives*. New York: Taylor & Francis Group/Lawrence Erlbaum Associates.

Kuhl, J. (1994). Action versus state orientation: psychometric properties of the Action Control Scale (ACS-90). In J. Kuhl & J. Beckmann (Eds.), *Volition and personality: action versus state orientation* (pp. 47–59). Seattle: Hogrefe.

Marsh, R. L., Hicks, J. L., & Bink, M. L. (1998). Activation of completed, uncompleted, and partially completed intentions. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(2), 350–361. doi:10.1037/0278-7393.24.2.350.

Marsh, R. L., Hicks, J. L., & Bryan, E. S. (1999). The activation of unrelated and canceled intentions. *Memory & Cognition, 27*, 320–327. doi:10.3758/BF03211415.

Marsh, R. L., Hicks, J. L., Hancock, T. W., & Munsayac, K. (2002). Investigating the output monitoring component of event-based prospective memory performance. *Memory & Cognition, 30*(2), 302–311. doi:10.3758/BF03195291.

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

Meilán, J. J. (2008). Activation and deactivation processes in the postponed intention paradigm. *Psychologia, 51*(1), 89–97. doi:10.2117/psysoc.2008.89.

Penningroth, S. L. (2011). When does the intention-superiority effect occur? Activation patterns before and after task completion, and moderating variables. *Journal of Cognitive Psychology, 23*(1), 140–156. doi:10.1080/20445911.2011.474195.

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

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

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

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

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

Walser, M., Plessow, F., Goschke, T., & Fischer, R. (2013). The role of temporal delay and repeated prospective memory cue exposure on the deactivation of completed intentions. *Psychological Research*. doi:10.1007/s00426-013-0510-z.

Webb, T. L., & Sheeran, P. (2007). How do implementation intentions promote goal attainment? A test of component processes. *Journal of Experimental Social Psychology, 43*(2), 295–302. doi:10.1016/j.jesp.2006.02.001.

Wegner, D. M., Schneider, D. J., Carter, S. R, 3rd, & White, T. L. (1987). Paradoxical effects of thought suppression. *Journal of Personality and Social Psychology, 53*(1), 5–13. doi:10.1037/0022-3514.53.1.5.

Whitmer, A. J., & Gotlib, I. H. (2012). An attentional scope model of rumination. *Psychological Bulletin*. doi:10.1037/a0030923.