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Aftereffects and Deactivation of Completed Prospective Memory Intentions: A Systematic Review

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Abstract

Prospective memory, the ability to perform an intended action in the future, is an essential aspect of goal-directed behavior. Intentions influence our behavior and shape the way we process and interact with our environment. One important question for research on prospective memory and goal-directed behavior is whether this influence stops after the intention has been completed successfully. Are intention representations deactivated from memory after their completion? And if so, how? Here we systematically review twenty years of research on intention deactivation and so-called aftereffects of completed intentions across different research fields in order to offer an integrative perspective on this topic. We first introduce the currently dominant accounts of aftereffects (inhibition vs. retrieval) and illustrate the paradigms, findings and interpretations that these accounts developed from. We then review the evidence for each account based on the extant research in these paradigms. While early studies proposed a rapid deactivation or even inhibition of completed intentions, more recent studies mostly suggested that intentions continue to be retrieved even after completion and interfere with subsequent performance. Although these accounts of aftereffects seem mutually exclusive, we will show that they might be two sides of the same coin. That is, intention deactivation and the occurrence of aftereffects are modulated by a multitude of factors that either foster a rapid deactivation or lead to continued retrieval of completed intentions. Lastly, we outline future directions and novel experimental procedures for research on mechanisms and modulators of intention deactivation and discuss practical implications of our findings.

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Keywords

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1. Introduction

Voluntary action and our ability to anticipate consequences of our actions enable an enormous flexibility in our behavior: They allow us to adjust behavior according to short-term and long-term goals, postpone immediate actions, and flexibly adapt to changing task demands (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Goschke, 2013; Kuhl, 1996; Miyake et al., 2000). The building blocks of such goal-directed yet flexible behavior are intentions.

Since early days of research on voluntary action and “the will”, philosophers and psychologists assumed that intentions are characterized by *special* properties that guide and shape our attention, thoughts and actions (Bratman, 1987; Goschke & Bolte, 2018; Lewin, 1926; Meiran, Cole, & Braver, 2012). That is, they entail capacities to plan ahead and anticipate future goal states, and they enable us to schedule, establish and maintain (sub) goals over extended periods of time. Consequently, intentions align behavior to promote goal attainment. In some cases, intentions guide action control to attain immediate goals. For example, when we grasp a glass of water to take a drink, the intention prompts us to align our gaze towards the glass and align our hand orientation and grasping movement in a way that—at least in most cases—enables us to take a drink without pouring water on ourselves (see Rosenbaum, Herbort, van der Wei, & Weiss, 2014, for a brief introduction to action control).

In other cases, intentions guide behavior to attain future-directed goals. Often, specific actions cannot be performed immediately, but need to be postponed and remembered until later while we pursue different ongoing activities or tasks. For example, if we plan to call a friend after a meeting or take medication after dinner, we need to postpone and maintain these intentions until a specific moment. Eventually—after the meeting or dinner—we need to remember to initiate our intended action (i.e., make the phone call or take the medication). Although such prospective intentions may not necessarily change our immediate actions, they may nevertheless impact current performance. We might recognize intention-related information more quickly (Badets, Blandin, Bouquet, & Shea, 2006; Goschke & Kuhl, 1993); for instance, a medical ad might grab our attention while we are eating dinner. Alternatively, we may experience costs to ongoing activities while we maintain and actively pursue an intention (Burgess, Quayle, & Frith, 2001; Heathcote, Loft, & Remington, 2015; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; McDaniel & Einstein, 2000; Meier & Rey-Mermet, 2018; R. E. Smith, 2003); for instance, we might miss parts of the meeting while looking at our schedule to find a time slot for calling our friend.

Importantly, over the last two decades a growing body of literature has suggested that intentions do not necessarily lose their “grip” on behavior once they are completed. Instead, intentions still impact behavior despite successful intention realization and goal achievement. For instance, due to the persisting activation of intentions, we might wonder whether we forgot to tell our friend something after having talked to them or we might take our medication twice "by accident", that is, make a commission error (e.g., Scullin, Bugg, & McDaniel, 2012). It is easy to see how such so-called *aftereffects of completed intentions* could have drastic consequences when they cause interruptions that lead to oversights in critical tasks like air-traffic control (e.g., Dismukes, 2012) or when it is vital to adhere to the correct dosage of a medication (e.g., Kimmel et al., 2007). Furthermore, one might even argue that aftereffects of completed intentions could partly account for perseverative behaviors (e.g., following prefrontal-cortex lesions; Milner, 1963; Owen, Roberts, Hodges, & Robbins, 1993).

The aim of the present article is therefore to review the rapidly expanding literature on aftereffects of completed intentions in order to provide a progress report on studies that investigate aftereffects and their underlying mechanisms. To this aim, we will first introduce the concept of intention and illustrate the main types of aftereffects that intentions can incur after completion. Second, we will outline two currently dominant accounts of the mechanisms underlying aftereffects, describe the basic paradigms that were used to assess aftereffects, and illustrate how different findings in these paradigms are interpreted according to these accounts. Third, we will present our review procedures and the studies included in our review. Fourth, we will review the extant accounts of aftereffects, discuss potential mechanisms underlying successful/unsuccessful intention deactivation and provide a unifying perspective on these accounts. Lastly, we will identify open questions within this research area and discuss practical implications of these findings.

2. Aftereffects of completed intentions and their underlying mechanisms

For the purpose of this review, we follow the definition of an intention as a mental state in which a person is committed to executing an action plan to achieve a desired goal (e.g., Gollwitzer, 1999; Goschke, 2013). In this respect, we particularly focus on postponed actions and future-directed action plans that have been studied in the literature extensively under the term prospective memory (PM; e.g., Kvavilashvili, 1987; Rummel & McDaniel, 2019). Within this framework, the term intention refers to a more or less complex (sequence of) action(s) that is delayed until a specific later occasion while we engage in ongoing tasks. Such intentions may, for instance, be time-based, like remembering to take a pizza out of the oven after 15 minutes or event-based, like remembering to transfer a message to a colleague when we meet her at a conference. While intentions are often embedded in overarching goals (e.g., Gollwitzer, 2018), the majority of studies we review in this article focus on intentions that—at least to our knowledge—were *not* embedded in explicit overarching goals within an experiment. That is, in these studies participants often postponed single actions until a specific retrieval cue (PM cue, e.g., an alarm or reminder) signaled an opportunity to perform this action. Although these intentions were most likely embedded in participants' higher-order goals, for instance, to attain monetary compensation or to earn credit for a psychology course, they were not represented as an explicit sub-goal of a higher-order goal within the experiment itself (but see, e.g., Denzler, Förster, & Liberman, 2009, for an exception).

The present review is primarily motivated by the observation that intentions often persist in affecting behavior despite successful goal attainment and intention completion. Accordingly, such aftereffects of completed intentions refer to phenomena that are observed in tasks that participants perform *after* they actively pursued and successfully completed an intention[1]. Specifically, aftereffects of completed intentions have most prominently been reported in terms of performance costs associated with stimuli that describe or refer to parts of a completed intention (e.g., Marsh, Hicks, & Bink, 1998) or are semantically associated with retrieval cues (e.g., Förster, Liberman, & Higgins, 2005), and in terms of performance costs associated with as well as erroneous repetitions of an already completed and thus no-longer-relevant intention (commission errors) when participants encounter no-longer-relevant PM cues after intention completion (e.g., Scullin et al., 2012).

In the following, we will first introduce two dominant accounts of aftereffects of completed intentions—namely, the inhibition of completed intentions and the continued retrieval of completed intentions accounts. We will then present the respective paradigms and logics that they were derived from. Finally, we will review the evidence for each account and consider alternatives and extensions based on the relevant studies we identified.

2.1. Inhibition of completed intentions

The inhibition account of aftereffects originates primarily from findings of slower lexical decisions about stimuli that are related to a completed action or are semantically associated with a retrieval cue after intention completion (e.g., Förster et al., 2005; Marsh et al., 1998; see Figures 2 & 3). Building on the idea of an inverse relation between response times (RTs) and memory activation (Ratcliff & McKoon, 1978), the inhibition account posits that these findings show that the activation level of an intention representation in memory is actively reduced upon intention completion. An extreme interpretation of this account is that the activation level of intention-related memory contents might even drop below a baseline of unrelated memory contents that were recently acquired. Within this interpretation, inhibition represents an active suppression of intention-related memory contents. In a less extreme interpretation, inhibition reduces the activation level of a completed intention towards a neutral baseline but not necessarily below it. In this sense, inhibition is seen less as an active suppression but more as an (active) deactivation process that might gradually decrease the activation level of an intention representation after intention completion. The inhibition account has received much attention in the literature as it contains a plausible functionality: Inhibition of completed intentions may facilitate establishing novel intention representations (Förster, Liberman, & Friedman, 2007; Förster et al., 2005; Marsh et al., 1998; see also Mayr & Keele, 2000).

2.2. Continued retrieval of completed intentions

In contrast to the inhibition account, the retrieval account of aftereffects originates primarily from findings of performance costs and commission errors when no-longer-relevant PM cues are encountered after intention completion (e.g., Scullin et al., 2012; Walser, Fischer, &

[1]Note that the term “aftereffect” is also used in the PM literature when referring to performance slowing that can be observed in trials directly after participants performed an intended action in response to a PM cue—that is, when the intended action is supposed to be performed (Meier & Rey-Mermet, 2012).

Goschke, 2012; see Figure 4). According to the multiprocess view of PM, (postponed) intentions can be retrieved *spontaneously* without allocating attention and cognitive resources towards monitoring the environment for retrieval cues (e.g., Einstein & McDaniel, 2005; McDaniel, Umanath, Einstein, & Waldum, 2015). In other words, intentions can "pop" into mind in the presence of a strong retrieval cue such as when a salient alarm gives us the signal to take the pizza out of the oven. From this perspective, aftereffects originate from the continued retrieval of completed intentions, which interferes with ongoing-task performance or increases susceptibility to commission errors. This occurs via one of three routes: (a) by disrupting the processing fluency of a task and triggering a subsequent search in memory for the relevance of the no-longer-relevant PM cue (discrepancy-plus-search view; Breneiser & McDaniel, 2006; Lee & McDaniel, 2013), (b) by reflexively reactivating the stimulus–response association between a PM cue and an intended action (reflexive-associative processes; McDaniel, Guynn, Einstein, & Breneiser, 2004; McDaniel et al., 2015), or (c) via a combination of intention retrieval and a failure to exert cognitive control over performing the already completed action (dual-mechanisms account; Bugg, Scullin, & Rauvola, 2016; Scullin & Bugg, 2013).

An alternative view is that continued retrieval of completed intentions is not spontaneous, but rather participants continue to actively monitor for the cue associated with the completed intention (preparatory attentional monitoring theory; e.g., R. E. Smith, 2003) or strategically slow down their ongoing-task responses after completing an intention in order to increase the chance of detecting the cue (delay theory of PM; Heathcote et al., 2015; Strickland, Loft, Remington, & Heathcote, 2018). From this alternative perspective, aftereffects result from retrieval of a completed intention, but their occurrence hinges on the presence of top-down controlled monitoring processes or strategic response slowing after intention completion.

Importantly, according to the retrieval account of aftereffects, the direction and magnitude of aftereffects of completed intentions is predicted by variables that affect the retrieval process, such as the salience of a PM cue, the strength of the association between a PM cue and an intended action (i.e., PM-cue–action link) or the ability to exert cognitive control over performing an already completed action.

These two theoretical accounts of aftereffects—inhibition and continued intention retrieval—initially seem difficult to reconcile. In fact, their predictions and explanations for aftereffects are often mutually exclusive, and the accounts posit qualitatively different conclusions from seemingly similar data patterns. However, as the next section will begin to make clear, this is not terribly surprising given that these accounts were developed based on heterogeneous paradigms and conceptions of completed intentions. We will next introduce these paradigms.

3. Paradigms to assess aftereffects of completed intentions

All paradigms used to assess aftereffects of completed intentions follow a common logic. Each paradigm consists of an *active phase* during which an intention is encoded, maintained and actively pursued, the actual retrieval and performance of an intention (i.e., intention completion), and a subsequent *finished phase*, during which aftereffects of completed intentions are assessed[2]. This differs from paradigms that assess uncompleted intentions (e.g., Goschke & Kuhl, 1993; Zeigarnik, 1938) that have been cancelled (e.g., Bugg & Scullin, 2013), suspended (e.g., Boywitt, Rummel, & Meiser, 2015), or were never performed (e.g., Bugg et al., 2016, 0-target condition). Thus, paradigms that focus on aftereffects of completed intentions assess the extent to which representations formed and/or processes engaged prior to intention completion persist or can be observed after an intention has been successfully completed. For instance, there may be heightened memory activation of intention representations (intention-superiority effect; Goschke & Kuhl, 1993; see also, Cohen, Kantner, Dixon, & Lindsay, 2011; Schult & Steffens, 2017) or the process of intention retrieval may persist (e.g., Kliegel, McDaniel, & Einstein, 2008). The paradigms differ, however, in the aspects of an intention they focus on, their methodology, dependent measures and consequently in the interpretation of findings. Here we will focus on three types of influential paradigms (script-based paradigms and two forms of event-based PM paradigms), introduce prototypical examples of each type and illustrate how different patterns of findings relate to different interpretations within these paradigms. Figure 1 provides a schematic overview of these paradigms, aftereffect measures, and predicted findings.

3.1. Script-based paradigms

Early studies on aftereffects of completed intentions were based on the postponed-intention paradigm which is thought to assess memory activation or accessibility of the content (i.e., the specific actions) of intention representations (Goschke & Kuhl, 1993). As illustrated in Figure 2, participants typically memorize two action scripts (e.g., *setting a table; clearing a desk*) that each comprise short action phrases before they are informed which script they should perform later and which they should not perform at all (neutral script). After script performance, the central measure of aftereffects in these paradigms is lexical decision RT for words from the performed script (e.g., *spread*, *table*) compared to words from the neutral script that was memorized but not (intended to be) performed (e.g., *open*, *pencil*). Assuming an inverse relation between RT and memory activation (Ratcliff & McKoon, 1978), faster responses to words from the performed script compared to the neutral script are thought to reflect a heightened memory activation of semantic networks related to the completed intention; similar or slower responses to words from the performed compared to the neutral-script are thought to reflect a deactivation or inhibition.

3.2. Event-based PM paradigms

In contrast to script-based paradigms, one key feature of event-based PM paradigms (Einstein & McDaniel, 1990) is that intended actions are designed to be simple, so that the ability to *remember to do something* can be studied with minimal conflation from the ability to *remember what needs to be done* (e.g., Ellis, Kvavilashvili, & Milne, 1999). Hence, in

[2]Note that many studies do not explicitly distinguish between active and finished phases. We decided to use this terminology in order to provide a guide for comparing similar phases across different paradigms. The finished phase of the experimental procedure has been referred to in many different ways such as "test block" (Walser, Fischer, & Goschke, 2012), "phase 2" (Pink & Dodson, 2013; Scullin, Bugg, & McDaniel, 2012), "completed phase" (Anderson & Einstein, 2017), "finished PM phase" (Bugg, Scullin, & Rauvola, 2016) and "block 2" (Cohen, Gordon, Jaudas, Hefer, & Dreisbach, 2017). Here we decided to use an active/finished terminology to more clearly delineate phases of the experiment in which an intention is "active" and should be pursued compared to phases in which the intention is "finished" and should not be pursued (Bugg & Streeper, 2019).

typical event-based PM paradigms participants are instructed to perform a simple intended action (e.g., pressing a specific key) upon encountering specific, rarely occurring events that serve as retrieval cues (i.e., PM cues such as a specific word, picture, or symbol). Mirroring the real world circumstances of being busily engaged in ongoing activities (e.g., driving a car) when needing to remember to complete an intention (e.g., return a phone call), in laboratory settings the PM task is embedded within an ongoing task (e.g., lexical decision, image rating). Two approaches within aftereffects research using event-based PM tasks can be distinguished.

3.2.1. Event-based PM paradigms with semantic associates of PM cues—

In an early line of research, Förster et al. (2005) combined elements of script-based paradigms and event-based PM paradigms to assess aftereffects in response to stimuli that are semantically related to PM cues from a completed PM task. Hence, this paradigm is also thought to assess memory activation or accessibility of the content of intention representations. As illustrated in Figure 3, participants in their study performed an event-based PM task that required detecting a combination of pictures (, ) during an image-rating task that alternated with a lexical decision task. After detecting this PM-cue combination, the central measure of aftereffects was lexical decision RT for words semantically related to the PM cue *glasses* (e.g., *professor*, *read*, and *sun*) compared to unrelated words (e.g., *dance*, *orange*). Similar to aftereffects in script-based paradigms, faster responses to PM-cue related words compared to control words are thought to represent heightened memory activation of a completed intention. Similar or slower responses are thought to represent intention deactivation or inhibition.

3.2.2. Event-based PM paradigms with no-longer-relevant PM cues—

In a second, more recent, line of research, several authors adopted paradigms in which participants typically perform an event-based task embedded within an ongoing task until they are explicitly instructed that the PM task is completed (Figure 4). In the subsequent finished phase, the exact PM cue that had signaled a retrieval opportunity during the active phase is presented as a no-longer-relevant PM cue for which the ongoing task should be performed. This shifts the focus of the paradigm away from assessing accessibility of intention-related memory contents towards assessing accessibility of PM-cue representations and retrieval of episodic bindings (stimulus–response links) between PM cues and intended actions. The number of active and finished phases in an experiment and the specific measures of aftereffects depend on the implemented paradigm.

In commission error paradigms, aftereffects are measured primarily in terms of erroneous PM responses (commission errors) in trials with no-longer-relevant PM cues occurring up to two (Scullin & Bugg, 2013; Scullin et al., 2012) or three subsequent trials (Anderson & Einstein, 2017) post-presentation of the cue. Here, participants usually perform a single active phase followed by a single finished phase in which only an ongoing task is performed (Figure 4A). Based on the reasoning that participants might change the way they approached this task after making a single commission error (e.g., participants might reconceptualize the finished phase as an active phase), these studies typically examine whether experimental conditions affected the *risk* for making a commission error. That is, the number of participants that made at least one commission error is compared to the number that did not make a commission error (e.g., Scullin et al., 2012). Additionally, the number of commission errors made on average is examined across conditions.

In repeated-cycles paradigms, aftereffects are measured primarily in terms of ongoing-task performance (RTs, error rates and/or commission-error rates) in no-longer-relevant PM trials compared to unrelated control trials[3] (e.g., Walser et al., 2012; see also Scullin, Einstein, & McDaniel, 2009). Here, participants usually alternate between active and finished phases over the course of several experimental cycles (Figure 4B). In order to reduce carry-over effects between cycles, PM cues change from cycle to cycle and finished phases are ongoing-task only (but see, Walser, Goschke, Möschl, & Fischer, 2017 for PM tasks in both active and finished phases). In both the commission-error and repeated cycles paradigms, commission errors and slower or more erroneous ongoing-task performance in no-longer-relevant PM trials are thought to represent interference from the continued retrieval of a completed intention. In contrast, the absence of interference is thought to represent a successful deactivation or inhibition.

3.3. Free recall of naturalistic intentions

Lastly, some studies investigated the accessibility of to-be-performed and already performed every-day life intentions through questionnaires and speeded written recall tasks (e.g., Freeman & Ellis, 2003). While assessing such naturalistic intentions provides high external validity, it is difficult to infer the mechanisms underlying the observations in these studies. For example, an increased recall of to-be-completed over completed tasks may result from a deactivation or (partial) inhibition of completed tasks, but also from a facilitation of to-be-completed tasks, or both. Given this difficulty and the few studies using this approach, we do not consider these paradigms extensively.

In the following section, we present our review procedure and summarize the key findings from each reviewed study. Based on this, we will then critically review the evidence for and against the inhibition and continued retrieval of completed intentions.

4. Review procedure and results

4.1. Study selection and inclusion criteria

For our review we conducted a search of the databases PubMED, PsycARTICLES, PsycINFO and Web of Science for articles published until August 9, 2019 (see Table 1, for the search string). This search resulted in 36 findings in PubMED, 18 in PsycARTICLES, 134 in PsycINFO, and 181 in Web of Science.

We used the following inclusion criteria to select relevant articles: Peer-reviewed articles that used (a) laboratory paradigms, in which participants had to perform a prospective memory task and after intention completion were engaged in a finished phase in which

[3]Note that control trials have also been referred to as "oddball trials" (e.g., Walser et al., 2012). Despite the difference in terminology, the key feature of these trials is that they are matched to PM cues in salience and frequency of appearance but were never used as PM cues within the same experiment. These control trials serve as a baseline to distinguish aftereffects from orienting responses to novel or salient stimuli.

activation of the completed intention representation was assessed; and (b) naturalistic studies in which recognition or recall of performed versus to-be-performed intentions were assessed. Additionally, we examined references from relevant papers to detect potentially relevant articles that were not retrieved by the databases. Further, we set Google scholar alerts until August 14, 2019, to detect new articles citing our pre-selected articles. This search strategy led to the inclusion of 36 studies. The main results and interpretations of these studies are presented in Table 2. Since the main aim of this review is to provide a systematic overview and integrative theoretical perspective on aftereffects and intention deactivation, we did not conduct a meta-analysis. We do, however, supply effect-size estimates and a brief summary of effects for the reviewed studies based on the available data in the published articles (Tables 3 and 4). Based on this, we will integrate the reviewed findings with a focus on clarifying theory. The R script and the data used for the reported effect size calculations can be downloaded from https://osf.io/7kvjy/?view_only=abe71464165b4d4894c2a0cca40cde36.

4.2. Summary of review results

As Table 2 shows, the majority of studies on aftereffects used event-based PM paradigms with no-longer-relevant PM cues, followed by script-based paradigms, event-based PM paradigms with semantic associates of PM cues, and studies on the free recall of naturalistic intentions. Several studies with script-based paradigms suggest an inhibition or deactivation of completed intentions. That is, after script performance, lexical decisions were slower or at least similar for words from a performed script than for words from a neutral script that was not performed (Marsh et al., 1998; Marsh, Hicks, & Bryan, 1999; Meilán, 2008; but see Cohen, Dixon, & Lindsay, 2005; Penningroth, 2011). Similarly, studies that used event-based PM paradigms with semantic associates of PM cues also suggest an inhibition of completed intentions, since after PM-task completion, lexical decisions were slower for PM-cue related words than for control words (e.g., Förster et al., 2005; see also Denzler et al., 2009; Denzler, Häfner, & Förster, 2011). Studies on the free-recall of naturalistic intentions showed that participants recalled activities that were completed less frequently than activities they intended to complete over the course of a certain time period (e.g., one week) (Freeman & Ellis, 2003; Maylor, Chater, & Brown, 2001; Maylor, Darby, & Della Sala, 2000). While it is not possible to pin-point the exact mechanism underlying these findings, they illustrate that the activation levels of intention-related concepts are subject to change depending on the completion status of an intention. By contrast, the majority of studies that used event-based PM paradigms with no-longer-relevant PM cues suggest a continued retrieval of completed intentions. That is, after completing a PM task, ongoing-task performance was slower and sometimes more erroneous in response to no-longer-relevant PM cues than in response to control cues and participants made commission errors in no-longer-relevant PM trials or shortly thereafter (e.g., Schaper & Grundgeiger, 2017; Scullin et al., 2012; Walser et al., 2012).

The majority of reviewed studies used small samples, ranging anywhere from 9–40 participants per condition or study (Table 3). Overall, these studies reported medium to large aftereffects in RTs for ongoing-task performance during finished phases. Consistent with predictions from aftereffect accounts (Table 5), effect sizes were larger in conditions thought to exacerbate aftereffects, but these effects also showed large variability. Additionally, commission errors did not occur in all studies that used event-based PM paradigms with no-longer-relevant PM cues (Table 4). Commission errors were mostly reported to occur in studies in which participants performed a single active phase, followed by a single finished phase when (no-longer-relevant) PM cues were salient and could be identified through the same processing operations that were needed to perform the ongoing task in both phases (e.g., the word *fish* in a lexical decision task). Most of these studies assessed the risk for making a commission error after intention completion and showed that this commission-error risk seemed to be increased in older adults, when cognitive-control abilities were impaired, or when attention was divided during finished phases. Notably, however, the odds ratios for the commission-error risk in these studies often exhibit wide confidence intervals, suggesting a considerable variability of effects that most likely is owed to rather small sample sizes in the experiments. We will next discuss the evidence for and against intention inhibition and continued intention retrieval as the main sources of aftereffects of completed intentions.

5. Discussion

Although a few studies on aftereffects of completed intentions suggest that intention representations seem to be at least partly deactivated after intention completion, the majority of studies consistently demonstrate failures of successful intention deactivation after intention completion. Particularly, the repeated observation of commission errors and interference from no-longer-relevant PM cues renders the assumption of an immediate, *complete* deactivation of intentions as highly unlikely. Consequently, these findings raise the question about the mechanisms behind aftereffects and how intention deactivation occurs. In the following sections, we will review the evidence for the two dominant accounts of aftereffects of completed intentions (inhibition and retrieval accounts), specific predictions from the retrieval account (Table 5), and alternatives and extensions of the retrieval account discussed in the literature (Table 6). Then we will discuss potential reasons for the heterogeneity of findings from different paradigms and propose a way to reconcile the notions of intention inhibition and continued intention retrieval.

5.1. Inhibition account

The notion that aftereffects reflect an inhibition of completed intentions is supported by findings of a below baseline activation of the content of action scripts after script completion (Marsh et al., 1998) or cancellation in script-based paradigms (Marsh et al., 1999), and below baseline activation of semantic associates of PM cues in event-based PM paradigms (Förster et al., 2005; see also Denzler et al., 2009, 2011). This below baseline activation was also observed after performing a series of unrelated actions (e.g., distributing cutlery, sharpening a pencil, pouring water; Marsh et al., 1999) that were not part of an overarching action script describing a coherent activity, and after performing complex motor patterns that were not acquired via verbal instructions (Badets et al., 2006; for an overview of aftereffects of delayed motor intentions, see Badets & Osiurak, 2015). One study by Förster et al. (2005) additionally suggested that inhibition of a completed intention was stronger when participants had a high expectation to encounter a PM cue and successful intention completion was incentivized (Exp. 4–6) and also suggested that inhibition was gradually released over time. Only two studies suggested an immediate return to baseline activation (Meilán, 2008) or a residually heightened memory activation of intentions after completion (Penningroth, 2011; see also Cohen et al., 2005). Lastly, three studies suggested that memory accessibility of everyday-life intentions changes upon intention completion (Freeman & Ellis, 2003; Maylor et al., 2001, 2000).

5.2. Retrieval account

The notion that aftereffects result from continued retrieval of completed intentions is supported by findings of commission errors and slower ongoing task performance in response to no-longer-relevant PM cues in event-based PM paradigms, which has been shown in several laboratory studies (see Table 2; e.g., Scullin & Bugg, 2013; Walser et al., 2012) and a computational model of PM (Gilbert, Hadjipavlou, & Raoelison, 2013). It is further corroborated by findings of repeated thoughts about the finished PM task after encountering no-longer-relevant PM cues (Anderson & Einstein, 2017) and activation during no-longer-relevant PM trials in brain areas that are also activated by PM cues during active phases (Beck, Ruge, Walser, & Goschke, 2014).

The majority of the reviewed studies with no-longer-relevant PM cues provide support for predictions derived from the retrieval account (Table 5). That is, the occurrence or size of aftereffects is modulated by factors that foster or attenuate retrieval of active intentions according to popular views of PM functioning (e.g., McDaniel et al., 2015). Specifically, the strength or integrity of stimulus–response associations between a PM cue and an intended action (Bugg, Scullin, & McDaniel, 2013), the context match between active and finished phases, the salience of PM cues, and the processing overlap between the PM task and ongoing task seem to play an important role in the genesis of aftereffects. That is, salient PM cues with a strong association to the intended action and the matching of ongoing tasks in active and finished phases have been shown to exacerbate aftereffects (e.g., Bugg et al., 2013; Scullin et al., 2012). These factors can also explain why some studies did not observe aftereffects (e.g., Scullin et al., 2009). In such studies, features of the PM task did not encourage or barely encouraged spontaneous intention retrieval (McDaniel et al., 2015). For instance, Cohen et al. (2017) observed no aftereffects when PM cues were non-salient and required additional processing than ongoing-task stimuli (i.e., a double-sided arrow in a display of single-headed arrows). Similarly, Scullin et al. (2011, 2009) observed no aftereffects when PM cues were nonsalient words in an image rating task and aftereffects were measured during a subsequent (mismatching) lexical decision task.

Furthermore, several studies support the notion that aftereffects result from a combination of continued intention retrieval and failed cognitive control (i.e., response suppression) over intention execution (dual-mechanisms account; e.g., Bugg & Scullin, 2013). For instance, aftereffects increased under high cognitive control demands (divided attention) during finished phases (e.g., Schaper & Grundgeiger, 2017) or when participants showed impaired cognitive control abilities (e.g., Scullin et al., 2011). Recently, Schaper and Grundgeiger (2019) argued that similar effects observed following the cancellation of an encoded PM task might not necessarily reflect failed response suppression. That is, providing time for response suppression after encountering a no-longer-relevant PM cue did not reduce commission errors in their study. It is unclear, however, whether these effects would translate to conditions in which an intention was completed successfully.

Extending the dual mechanisms account, aftereffects have been shown to be exacerbated by personal dispositions that attenuate the disengagement from completed tasks or attained goals (e.g., Hedberg & Higgins, 2011) or aging, presumably due to reduced cognitive control over intention execution (e.g., Bugg et al., 2016). Consequently, aftereffects in general seem to be modulated by cognitive control over the response conflict between a to-be-performed ongoing-task response and a no-longer-relevant PM response that arises from intention retrieval in no-longer-relevant PM trials. Although results are ambiguous regarding the effects of preparatory control mobilization on aftereffects, Anderson and Einstein (2017) suggested that using some kind of preparatory strategy to elaborate on the completion of a PM task might reduce aftereffects by supporting formation of a stop tag for intention completion (Bugg & Scullin, 2013; but see Bugg et al., 2016).

Lastly, regarding the role(s) of preparatory monitoring for PM cues (e.g., R. E. Smith, 2003) or strategic response slowing (e.g., Heathcote et al., 2015), several studies observed aftereffects even when participants most likely did not monitor for PM cues and did not strategically delay their ongoing-task responses after intention completion (e.g., Beck et al., 2014; Bugg & Scullin, 2013; Scullin & Bugg, 2013). Hence, it seems unlikely that these factors constitute preconditions for aftereffects. Yet, in select paradigms, monitoring for *novel* PM cues during finished phases seemed to exacerbate aftereffects (Anderson & Einstein, 2017; Walser et al., 2012, 2017)[4]. Importantly, however, these effects likely do not stem from continued monitoring for no-longer-relevant PM cues but may be explained by a persisting higher-order attentional search set or retrieval mode. In brief, the idea is that forming an intention that requires detecting particular stimuli (PM cues) establishes an attentional search set for that specific (class of) stimuli. Additionally, it might also establish a more generalized search set or sensitivity towards anything that deviates from ongoing-task stimuli (see also Walser et al., 2017), and/or a general preparedness to categorize such deviant stimuli as retrieval cues (i.e., retrieval mode; Guynn, 2003; Underwood, Guynn, & Cohen, 2015). While a PM-cue specific search set would likely be deactivated when performing a novel PM task, a generalized deviant search set or retrieval mode would remain active as long as participants perform any kind of PM task. Consequently, when performing a new PM task during finished phases, such a persisting generalized deviant search set or retrieval mode may not only exacerbate orienting reactions to deviant stimuli in general but also increase the likelihood that no-longer-relevant PM cues trigger intention retrieval. By contrast, when no PM task has to be performed during the finished phase, even the very generalized deviant search set and retrieval mode would be deactivated (Guynn, 2003), explaining why aftereffects are significantly reduced under these conditions (Walser et al., 2012, 2017).

[4]Walser et al. (2017) showed that increasing the similarity between the completed and the novel PM task in the finished phase (i.e., same intended action, same PM-cue modality) exacerbated aftereffects. However, even performing a substantially different event-based PM task during this phase (i.e., different intended action, PM-cue modality and PM-response modality) incurred substantially larger aftereffects than performing only the ongoing task.

5.2.1. Alternatives and extensions of the retrieval account—While aftereffects in event-based PM paradigms with no-longer-relevant PM cues can be explained by continued retrieval of completed intentions, some alternatives and extensions of retrieval accounts have been discussed in the literature (Table 6) and will be discussed next, with the weakest alternatives and extensions presented first. Some attribute the occurrence of aftereffects to features of the experimental paradigm, like confusion of participants about the finished task instructions, the proximity of response buttons for PM and ongoing-task responses, or to participants lacking cognitive resources for postactional processing to actively disengage from a completed intention (see Penningroth, 2011). Although Schaper and Grundgeiger (2019) recently suggested that encountering no-longer-relevant PM cues might prompt participants to erroneously form an intention to perform the already completed PM task again, leading to commission errors, it seems unlikely that aftereffects of completed intentions can be explained solely by these factors. They might, however, nevertheless contribute to the occurrence of aftereffects.

Other views attribute aftereffects to memory processes besides continued intention retrieval, like a lack of episodic traces for having performed the intended action (Bugg & Scullin, 2013; Bugg et al., 2016) or to output-monitoring errors—that is, failures to remember one's past responses (i.e., output monitoring; e.g., Cohen & Hicks, 2017; see Marsh, Hicks, Cook, & Mayhorn, 2007 for such errors during active phases). Regarding the role of episodic traces, performing the intended action might foster rapid intention deactivation as it presumably enables the creation of episodic traces, and thereby the binding of a stop-tag to the cognitive representation of a no-longer-relevant PM cue-response association (Bugg & Scullin, 2013; Bugg et al., 2016). Consistent with this idea, commission-error risk and performance costs in response to no-longer relevant PM cues generally seem to be larger when the intention is cancelled after encoding (Schaper & Grundgeiger, 2019), suspended briefly (Boywitt et al., 2015), or never performed because no retrieval cues appeared during the active phase (Bugg & Scullin, 2013; Bugg et al., 2016). By contrast, regarding the role of output monitoring, most likely only a small portion of aftereffects in event-based PM paradigms may be attributed to failures of output monitoring. That is, although commission errors and output-monitoring errors show conceptual similarities—both represent erroneous repetitions of no-longer-relevant actions—the paradigms to assess them differ substantially (Table 6).

Additionally, it is unlikely that aftereffects are limited to direct associations between the *specific* PM cue and the intended action that are acquired during intention completion (e.g., Abrams & Greenwald, 2000) or already at intention encoding (e.g., Meiran, Pereg, Kessler, Cole, & Braver, 2015). Although aftereffects certainly can arise from such direct stimulus–response links, aftereffects have also been shown to generalize beyond specific PM-cue exemplars towards more abstract stimulus representations (i.e., concepts representing a stimulus category; Walser et al., 2012; Walser, Plessow, Goschke, & Fischer, 2014).

A further suggestion posits that aftereffects may be modulated by memory encoding after intention completion. Supporting this notion, several studies showed that completed intentions do not simply decay over time (Scullin & Bugg, 2013; Scullin et al., 2011) but instead, their activation decreases through an active response reconfiguration over repeated encounters of no-longer-relevant PM cues (i.e., associating the no-longer relevant PM cue with a new response; Walser, Plessow, et al., 2014). Such a response-reconfiguration process could also explain why aftereffects declined with repeated encounters of semantic associates of PM cues (Förster et al., 2005) or have been reported to be larger during the first half compared to the second half of a finished phase (Walser et al., 2012). However, given that these studies investigated aftereffects over rather short time frames of about 3–10 min, it is unclear whether a time-dependent decay of intentions would become visible over longer time frames. Relatedly, although it is possible to reduce aftereffects by encoding novel memory representations that are unrelated to a PM task before the finished phase (e.g., performing a backwards-letter span task; Walser, Goschke, & Fischer, 2014) or immediately after encountering a no-longer-relevant PM cue (Schaper & Grundgeiger, 2018), the mechanisms underlying these effects are not clear.

Lastly, some studies assert that heightened memory activation of intention-related compared to unrelated memory contents (e.g., Penningroth, 2011) may be a precondition for intention retrieval after intention completion (Walser et al., 2012; Walser, Goschke, et al., 2014). To our knowledge, however, no study has directly tested the link between intention activation and aftereffects of completed intentions. Findings of larger aftereffects with suspended, cancelled or uncompleted intentions (Bugg & Scullin, 2013; Marsh et al., 1999; Schaper & Grundgeiger, 2017; West, McNerney, & Travers, 2007) that presumably exhibit heightened memory activation (Goschke & Kuhl, 1993; Zeigarnik, 1938) may be viewed as preliminary support for such a link. However, they could also be explained by a lack of episodic traces for having performed an intended action, as participants in these studies often had no opportunity to complete the intention (i.e., stop-tag account; Bugg & Scullin, 2013; Giesen & Rothermund, 2014).

5.3. Inhibition and intention retrieval: dichotomy or continuum?

Taken together, the studies we reviewed show that both inhibition and retrieval accounts of aftereffects seem to be supported reasonably well. Critically, however, both views seem mutually exclusive. That is, when assuming a *complete* inhibition of all components of a completed intention, there would be no response slowing in response to no-longer-relevant PM cues and it would not be possible to make commission errors, since the cognitive intention representation and the intended action would not be retrievable. In contrast to this assumption, our review suggests that, although intentions are often completely deactivated or inhibited, they can also continue to be retrieved after completion. In other words, some deactivation can occur, which allows us to flexibly adapt to novel situations and goals, but also parts of a completed intention seem to remain active. These findings seem to fit well with everyday experiences of being able to focus on ongoing tasks and future tasks most of the time without being (overly) distracted by recollecting tasks that we have already performed.

Consequently, findings of continued intention retrieval only stand in contrast with findings of intention inhibition when assuming a perfect inhibition mechanism, which, based on the reviewed studies, seems highly unlikely. Instead, it is conceivable that our cognitive system generally deactivates or inhibits intention representations after completion. This process, however, might sometimes completely or partially fail or take time, which would result in effects of residual activation or continued intention retrieval (e.g., commission errors) due to *incomplete* intention inhibition. That is, instead of assuming a dichotomy of either inhibition or continued intention retrieval, we argue that intention deactivation most likely moves along a continuum between a full *re*-activation and a full *de*-activation or inhibition. Critically, this continuum is shifted by a multitude of factors that affect retrieval of intentions and perhaps also cognitive control over retrieval (Table 5, Table 7).

6. Future directions

The present review raises several questions and open issues. Tackling these may not only further our theoretical understanding of prospective remembering and intention deactivation, but might also help improve predictions about the conditions under which aftereffects are particularly likely and individuals who are most at risk to experience interference from completed intentions and/or to make commission errors (see Table 7 for our current understanding about these conditions). In a broader sense, this might also inform mechanisms and modulators of goal-directed, yet flexible behavior.

6.1. Heterogeneity of findings in different paradigms

While the concept of intention deactivation as a continuum between full reactivation and full deactivation (inhibition) is a way to reconcile the seemingly contradictory findings of intention inhibition and continued intention retrieval, it is nevertheless unclear why different paradigms produce divergent findings even though they presumably assess a common concept. In our opinion, some explanations for this are conceivable.

First, the direction and mechanism of aftereffects might depend on which component of an intention each paradigm focuses on. More specifically, testing aftereffects of stimuli that are semantically related to a completed intention or PM cues (like in studies that suggest intention inhibition) presumably captures the accessibility or retrieval of the semantic content of an intention. Testing aftereffects of no-longer-relevant PM cues (like in studies suggesting continued intention retrieval), on the other hand, presumably captures accessibility or retrieval of PM-cue representations, intended actions or stimulus–response associations between PM cue and intended action. Recent studies provide evidence for a dissociation of multiple components of intention representations (Burgess, Gonen-Yaacovi, & Volle, 2011; Cohen, West, & Craik, 2001; Momennejad & Haynes, 2012). In theory, these components of intention representations might be affected by intention deactivation to different extents and/or become deactivated on different time scales—thus explaining divergent findings across paradigms. That is, semantic networks that are associated with a PM cue or the content of an intended action, might become inhibited more rapidly after intention completion. In contrast, PM-cue representations, intended actions and their association might be deactivated or inhibited slowly and cause intention interference due to continued intention retrieval. However, while this distinction seems plausible, it is not clear cut, given that PM-cue–action associations seemed to be deactivated rapidly after intention completion in some studies (4-target condition; Bugg & Scullin, 2013; Bugg et al., 2016).

Second, as we mentioned in the introduction, the majority of reviewed studies focus on single intentions that were not part of an explicit overarching goal or at least were only relevant to achieving a single well-defined goal. As suggested by an anonymous reviewer, the direction and extent of aftereffects might depend upon how an intention is embedded within a goal hierarchy (e.g., Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001) or the utility of an intention for reaching a specific goal (e.g., Kruglanski et al., 2002). For instance, if my goal is to *make a salad* and I completed the intention to *slice the tomatoes*, stimuli related to this intention (e.g., *ketchup*, *mozzarella*, *the color red*) might exhibit heightened memory activation only as long as the salad has not been completed. Once the salad and/or the dinner is finished, the completed intention should be deactivated or inhibited. The presence and activation status of an overarching goal has indeed been theorized and shown to affect retrieval of active intentions (e.g., Gollwitzer & Cohen, 2008). Specifically, effects of implementation intentions—that is, encoding an intention as an *if–then plan* (e.g., *If I see the word fish, I will press the Q key*)—have been shown to be modulated by the activation of a higher-order goal (Sheeran, Webb, & Gollwitzer, 2005; Webb & Sheeran, 2008). In the reviewed studies, however, there is preliminary evidence suggesting that in script-based paradigms the direction of aftereffects might not necessarily depend upon whether or not an overarching goal exists. Marsh et al. (1999; see also Cohen, Dixon, & Lindsay, 2005) for instance, also found “intention inhibition” for unrelated action phrases (e.g., *distribute the cutlery, sharpen the pencil*) that were not part of an overarching script. Future studies are needed to determine the effects of goals on aftereffects and the deactivation of completed intentions across paradigms.

Third, findings that suggest an inhibition of completed intentions (Förster et al., 2005; Marsh et al., 1998) may be reinterpreted as evidence for continued intention retrieval after completion. Most studies that favored an inhibition account of aftereffects employed lexical decision tasks (e.g., Marsh et al., 1998). In these tasks, both intention inhibition and continued retrieval of completed intentions could lead to slower responses to intention-related stimuli: Intention inhibition would reduce lexical accessibility of intention-related memory contents and also impair lexical decisions, while spontaneous retrieval of a completed intention would interfere with and also impair lexical decisions. Note, however, that this reinterpretation, if correct, implies that the notion of an inverse relation between RT and activation in memory (Ratcliff & McKoon, 1978) should hold prior to intention completion, but should be reversed after intention completion. That is, slower responses to intention-related stimuli in facilitation paradigms would only reflect decreased memory activation for stimuli or memory contents that are relevant for current task performance. When stimuli become irrelevant or are associated with a *stop-tag* due to intention completion (Bugg & Scullin, 2013), the RT–activation relation might change so that slower responses to intention-related stimuli in facilitation paradigms reflect interference from continued intention retrieval and/or residual activation.[5]

[5]As suggested by an anonymous reviewer, this would only be true if an intention satisfies only one goal or if all goals that involve this intention are completed—like in a simple event-based PM task. If an intention subserves a “larger goal” (e.g., *making dinner*) made up of multiple “smaller intentions” (e.g., *washing a salad*, *cutting tomatoes*) or subserves multiple goals that are not satisfied yet, the RT–activation relation should remain the same until all goals involving this intention are completed.

6.2. Factors modulating aftereffects and additional questions

Additionally, the research we reviewed poses questions regarding the factors that modulate aftereffects of completed intentions, the interrelation of different aftereffect measures, and the relation of aftereffects to phenomena outside of PM research and in everyday life. In the following section we will briefly discuss some of these questions.

First, if increased aftereffects with novel PM tasks during finished phases indeed result from a general sensitivity towards deviance or persistence of a retrieval mode, ongoing-task performance in deviant trials that never served as PM cues should differ between conditions in which participants are instructed to perform a PM task and conditions in which participants do not perform a PM task beforehand (i.e., ongoing-task only conditions). Although Walser et al. (2017) reported preliminary evidence for this pattern, future research is needed to determine the validity of this notion. Relatedly, future research is needed to determine whether exacerbated response slowing in trials following a no-longer-relevant PM cue (Anderson & Einstein, 2017) results from an increased sensitivity towards deviance and/or a persisting retrieval mode, or from difficulty to re-engage the ongoing-task set after the no-longer-relevant intention has been retrieved (i.e., task-switch costs; e.g., Kiesel et al., 2010).

Second, the residual activation view of aftereffects we introduced in Table 6 suggests that residually heightened activation of completed intentions could be a precondition or mediator of aftereffects (see Guynn, 2003, for a similar notion regarding retrieval of active intentions). If so, residual activation might increase the likelihood of spontaneous intention retrieval, which in turn would exacerbate aftereffects. To test this, future studies would need to determine to what extent memory activation of completed intentions is related to the occurrence and size of aftereffects and whether aftereffects can arise in the absence of residually heightened intention activation. Such studies could, for instance, use action scripts that are performed in response to a PM cue to assess intention activation of script words or semantic associates of a PM cue and at the same time test aftereffects in no-longer-relevant PM trials. Additionally, achieving this aim might benefit from using neurophysiological methods to assess in what ways activation of brain areas related to the content of the intended action and/or a retrieval cue changes with intention completion.

Third, regarding the involvement of cognitive control in intention deactivation, it seems necessary to determine (a) the relative involvement of control over intention execution and response selection in intention deactivation, (b) whether it is possible to control spontaneous intention retrieval itself, (c) whether intention deactivation is also modulated by short-term (i.e., trial-by-trial) cognitive-control demands, and (d) to what extent we can proactively mobilize control over these processes. This would help to identify conditions in which aftereffects might become particularly problematic and inform the development of strategies to aid rapid intention deactivation. Relatedly, within research on intention inhibition, it seems necessary to clarify under which conditions intention-related memory activation may go below a baseline activation level, when this inhibition may be released, and under which conditions activation levels simply decrease after compared to before intention completion. That is, when does inhibition work like “intention suppression” versus “active deactivation”?

Fourth, to date it is unclear in what ways different aftereffect measures relate to each other and whether aftereffects in these measures result from similar or different underlying processes (e.g., RTs, commission error risk/rates, thoughts about the completed intention). For instance, Anderson and Einstein (2017) argued that the absence of commission errors does not necessarily reflect a direct deactivation of an intention. Instead, residual activation in combination with good task understanding or intact cognitive control after intention retrieval might also lead to the absence of commission errors (see dual-mechanisms account; Bugg & Scullin, 2013). Hence, future research might benefit from adding measures that may be more sensitive to capture aftereffects in the absence of commission errors.

Lastly, in our introduction, we presented accidental overmedication as an example for a failure of intention deactivation. Although there are some reports of such commission errors in everyday life (e.g., Kimmel et al., 2007), their prevalence and potentially negative consequences in real life are widely unknown—especially for potential high risk groups such as older adults. Based on intuition, commission errors seem to be (way) less common than forgetting to perform an intended action (omission errors). Future studies could answer these questions, for instance, via experience sampling of real-life prospective memory failures and aftereffects (e.g., Anderson & McDaniel, 2019; Krönke et al., 2018), or by adding items to existing self-report measures of PM to capture aftereffects (e.g., G. Smith, Della Sala, Logie, & Maylor, 2000). The reliability of such measures, however, would depend upon another unknown factor—whether and to what extent people are aware of making commission errors.

6.3. Relation of aftereffects to other phenomena and applied perspectives

An issue that goes beyond the scope of this review, but is interesting from a theoretical perspective, is the relation of aftereffects of completed intentions to other research areas such as task switching (e.g., Kiesel et al., 2010) or instruction-based learning (e.g., Meiran et al., 2012). For instance, *N*−2 repetition costs may be viewed as similar to aftereffects of completed intentions. This so-called backward-inhibition effect refers to the finding that switching to a previously relevant task set impairs task performance more than switching to a novel task set (Mayr & Keele, 2000). Indeed, both *N*−2 repetition costs and slowed lexical decisions about intention-related words after intention completion have been explained by a common mechanism—inhibition of previously relevant task sets (e.g., Koch, Gade, Schuch, & Philipp, 2010). However, similar to aftereffects in event-based PM tasks, *N*−2 repetition costs have also been theorized to stem from continued retrieval of a previously relevant task set. That is, the reactivated *N*−2 task set is thought to interfere with the still residually active *N*-1 task set that was just switched from (e.g., MacLeod, 2007).

Relatedly, research on instruction-based learning showed that instructed stimulus–response mappings incur costs in terms of stimulus- or response-congruency effects even when stimuli that are specified in these mappings occur in a task-irrelevant context or dimension (Liefooghe, Degryse, & Theeuwes, 2016; Meiran et al., 2012). Moreover binding instructed stimulus-response mappings to specific task contexts requires actual performance or prior practice (Braem, Liefooghe, De Houwer, Brass, & Abrahamse, 2017). Similar to these effects, no-longer-relevant PM cues have been shown to elicit intention retrieval in contexts in which an intention is no-longer relevant (e.g., Anderson & Einstein, 2017; Walser et al., 2012). Additionally, commission errors have been shown to occur more frequently when an intention has been cancelled or intention completion was not possible due to the absence of PM cues (Bugg & Scullin, 2013; Bugg et al., 2016; Schaper & Grundgeiger, 2017).

Beyond these laboratory phenomena, the research we presented in this review offers some practical applications. For instance, the modulating factors we identified might not necessarily be limited to laboratory paradigms but could translate to everyday life. Specifically, it might be possible, for instance, to reduce the risk of accidental overmedication by avoiding distractions while taking or administering medication (Schaper & Grundgeiger, 2018) or instantiating a context change afterwards by placing the medication in a specific location that one is less likely to encounter "by accident" after having taken the intended dosage (Scullin et al., 2012). Additionally, our review might benefit research in applied areas, like research on (sub) clinical symptoms such as persisting negative thoughts (e.g., Whitmer & Gotlib, 2012), intrusions (e.g., Ehlers & Clark, 2000) or ruminations (e.g., Beckmann, 1994). Although we are aware that these phenomena also affect behavior through multiple mechanisms, on the surface, perseverative thoughts, for instance, could alternatively be viewed as difficulties in "deactivating" no-longer-relevant experiences. On speculative terms, identifying similarities in the underlying mechanisms and modulating factors of these phenomena, might not only help predict the occurrence of such clinical symptoms but might also inform potential routes of action to alleviate them.

In summary, although the effects we discussed in this section originate from different research areas, there nevertheless may be similarities in their underlying mechanisms. Hence, it may be worthwhile for research on PM and intention deactivation to broaden its scope and consider conceptually related phenomena in other research areas and vice versa.

7. Conclusion

In the present article, we reviewed empirical studies on aftereffects of completed intentions. Our motivation was to provide an up-to-date overview of experimental procedures and main results of aftereffect research, a synopsis of current theories about the source of aftereffects as well as to highlight commonalities and differences between different lines of research in this field. Our review shows that intention deactivation does not operate like a light switch. That is, we neither experience massive interference from finished tasks all the time nor do we experience no aftereffects at all. Instead, intention deactivation is better conceptualized as a continuum of decreasing activation levels below those that were present before the intention was completed, and ultimately reaching baseline levels akin to neutral stimuli. This general process might not be linear, it may sometimes be faulty, and its time course may be accelerated or decelerated by a diversity of factors. Consequently, the central question guiding research on intention deactivation should not be *whether* completed intentions are inhibited or continue to be retrieved, but *when* and *under what circumstances*.

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Statement of public significance

This systematic review shows that intended actions can persistently affect performance even after they have been completed and become no-longer relevant. Importantly, the deactivation of completed intentions does not work on an all-or-nothing basis but instead operates on a continuum from full intention retrieval to a complete deactivation or even inhibition, depending on a variety of factors.

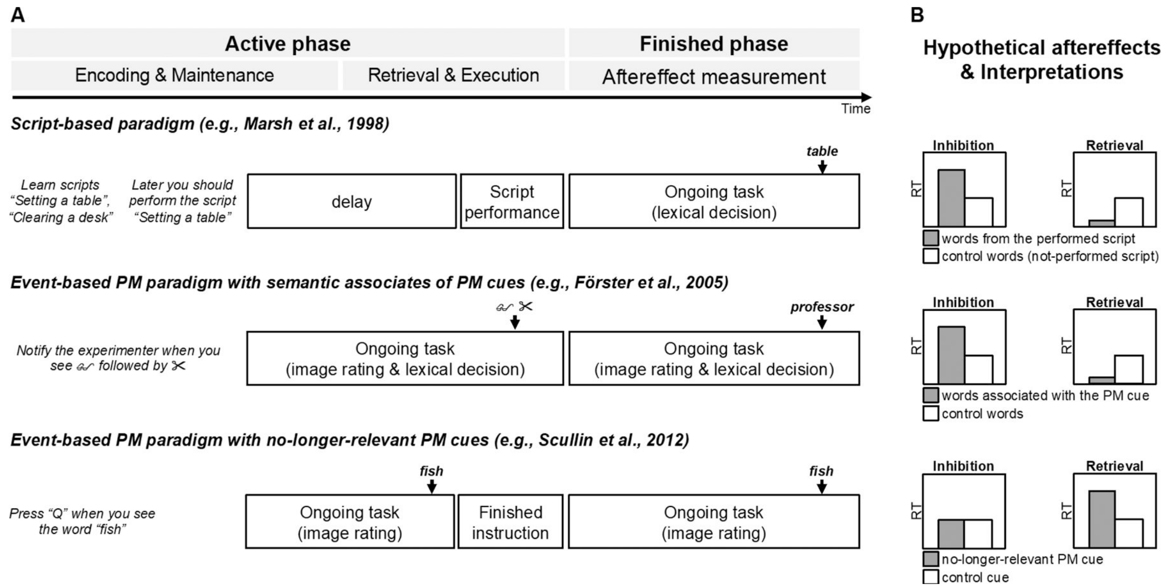

Figure 1.

(A) Schematic illustration of prototypical experimental procedures of paradigms to assess aftereffects of completed intentions. All procedures and paradigms comprise an *active phase* during which an intention is encoded and maintained, retrieved and completed (for exceptions, see Boywitt et al., 2015; Bugg & Scullin, 2013; Bugg et al., 2016) and a subsequent *finished phase* during which aftereffects of the completed intention are assessed. In event-based PM paradigms with semantic associates of PM cues, image-rating and lexical decision tasks alternated over multiple blocks. The PM cue appeared only during an image-rating task, while semantic associates of the PM cue appeared only during lexical decision tasks. (B) Hypothetical aftereffects and their interpretation within each type of paradigm. Aftereffects are illustrated idealized for response times (RT) in facilitation tasks (e.g., lexical decision tasks), in which intention-related words or no-longer-relevant PM cues serve as targets. Here, high activation or continued retrieval of intention-related concepts will speed up lexical access. In interference tasks in which intention-related words serve as distractors (e.g., Stroop tasks) predictions are reversed and high activation or continued retrieval will interfere with and thus slow down lexical access. Intention deactivation (i.e., return to baseline activation) would not predict any performance differences in either paradigm. Note also that in event-based PM paradigms with no-longer-relevant PM cues, both intention deactivation and intention inhibition would predict the same data pattern.

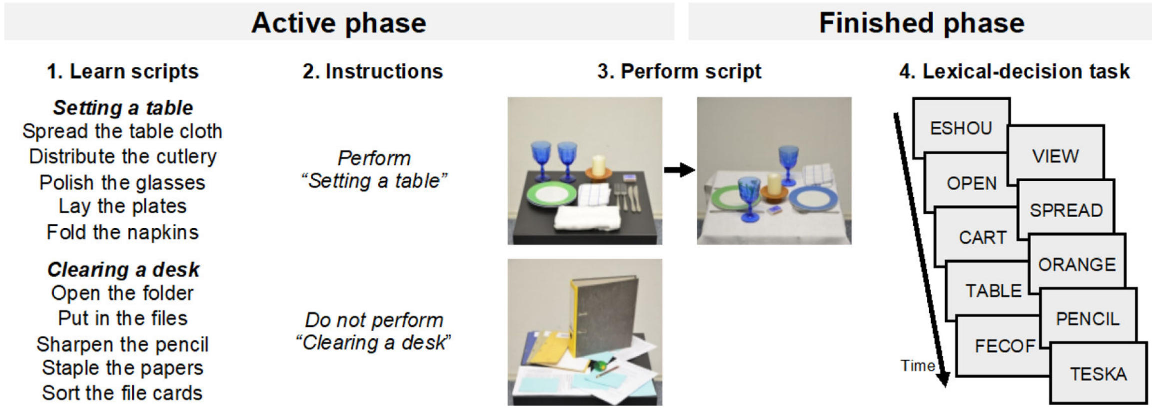

Figure 2.

Procedure of a script-based paradigm adapted from the Marsh et al. (1998) study. A schematic illustration of the completed intention condition is shown. Participants first learned two scripts, each with five action phrases until they were able to reproduce them once completely in a written free recall test. Subsequently, participants were instructed which script they should perform later and which not (neutral script). Materials for script performance were set up at a table behind the computer. After script performance, aftereffects were assessed in a lexical decision task by comparing lexical decision RTs between words from the performed script and words from the neutral script that was not (intended to be) performed. In an uncompleted-intention condition, the lexical decision task preceded script performance in order to assess memory activation of to-be-performed intentions.

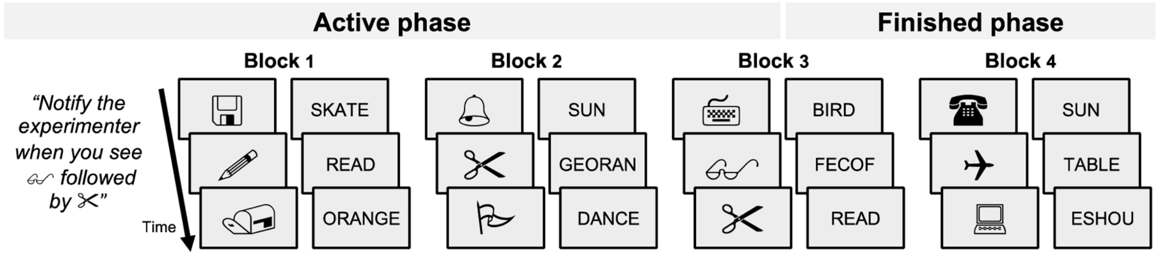

Figure 3.

Procedure of an event-based PM paradigm with semantic associates of PM cues adapted from the Förster et al. (2005) study. Participants performed four blocks that each consisted of an event-based PM task embedded within an image-rating task, followed by a lexical decision task. The PM task instructed participants to stop the experiment and inform the experimenter whenever they saw a picture of glasses () followed by a picture of scissors () during the image-rating tasks. This PM-cue combination was presented only once (during Block 3). The lexical decision tasks in between the image ratings served to assess the memory accessibility of intention-related words. Blocks 1 and 2 served as the active phase, while blocks 3 and 4 served as the finished phase. Aftereffects were assessed by comparing lexical decision RTs between words related to *glasses* and unrelated control words. Additionally, memory accessibility of PM-cue related words was compared between participants who did perform a PM task during the image rating task and participants who did not perform a PM task during the experiment.

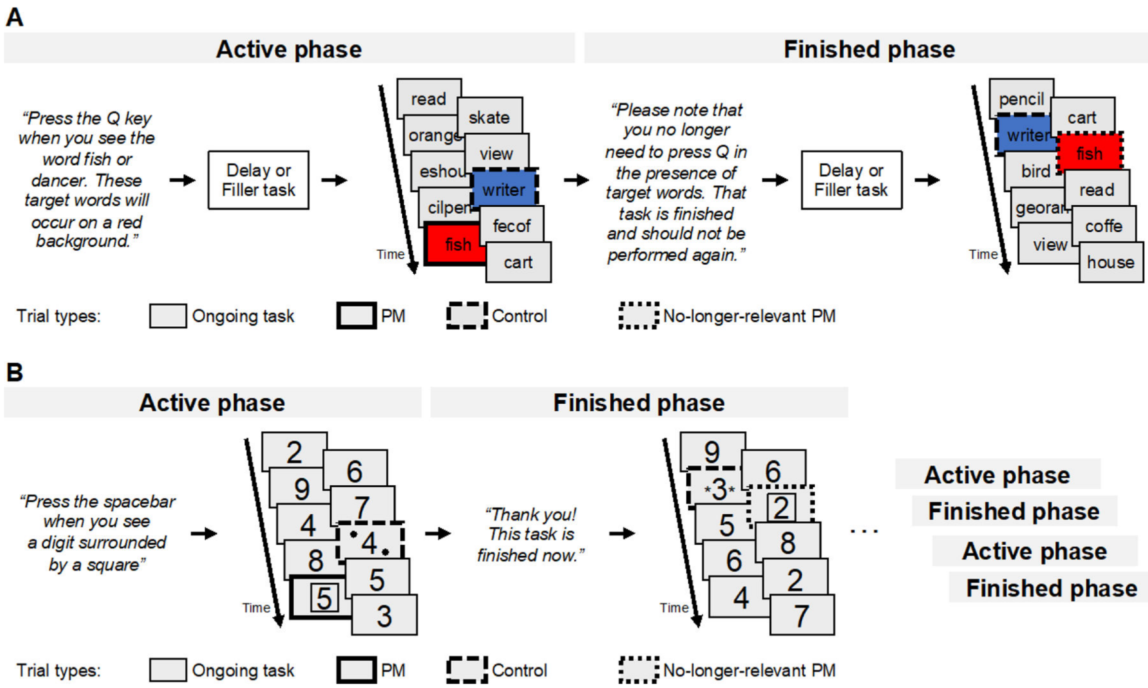

Figure 4.

Schematic illustration of event-based PM paradigms to assess aftereffects of completed intentions. Example trials are given for one active and finished phase. (A) Commission-error paradigm adapted from the Scullin et al. (2012) study. Participants performed a single active phase, followed by a single finished phase. As an ongoing task, participants categorized letter strings as words or non-words. In the active phase, participants were additionally instructed to press the *Q* key whenever they encountered a specific word (PM cue) presented on a salient background. At the end of the active phase, participants were instructed that the PM task had been completed and that they should perform the ongoing task only in the finished phase. Aftereffects were assessed in terms of commission errors in or shortly after no-longer-relevant PM trials. (B) Repeated-cycles paradigm adapted from the Walser et al. (2012) study. Participants performed multiple cycles of active and finished phases. As an ongoing task, participants categorized digits as odd or even. In the active phase, participants were additionally instructed to press the spacebar instead of performing the ongoing task whenever they encountered a specific symbol among a digit (PM cue). At the end of the active phase, participants were instructed that the PM task had been completed and that they should perform the ongoing task only in the finished phase. Aftereffects were assessed by comparing ongoing-task performance (RTs, ongoing-task errors, commission errors) between no-longer-relevant PM trials and control trials that presented a different symbol than PM trials among a digit. Ongoing-task trials did not contain a symbol. After the finished phase, the next active-finished cycle started. Note that framing was not present in the experiments but exclusively serves to illustrate different trial types.

Table 1

String used for literature search in databases.

((“prospective memory” OR “intention*”) AND (“completed intention*” OR “intention completion” OR “finished intention*” OR “fulfilled intention*” OR “intention fulfillment” OR “completed goal*” OR “goal completion” OR “finished goal*” OR “fulfilled goal*” OR “goal fulfillment” OR “completed task*” OR “task completion” OR “finished task*” OR “fulfilled task*” OR “task fulfillment” OR “intention interference” OR “intention deactivation” OR “intention inhibition” OR “goal inhibition” OR “goal deactivation” OR “persisting activation” OR “residual activation” OR “commission error*” OR “aftereffect*” OR “negative prospective memory” OR “deactivation process*”))

Note. We added the qualifier [Title/Abstract] after each quoted search term for our search in PubMED, excluded a full-text search in PsycARTICLES and PsycINFO, and used the “Topics” search in Web of Science.

Table 2

Overview of the reviewed studies on the deactivation of completed intentions.

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
Script-based paradigms and related procedures				
Badets, Blandin, Bouquet, and Shea (2006)	Recognition of learned line patterns (motor sequences) / computer instruction (delayed motor intentions)	• Slower recognition of performed line patterns than of not-performed control patterns	Inhibition	-
Cohen, Dixon, and Lindsay (2005)	Stroop-color naming / computer instruction	• Higher Stroop interference from words that described a performed than a not-performed action	Continued retrieval	• Similar aftereffects in younger and older adults • Aftereffects increased from the first to the second encounter of intention-related items
Marsh, Hicks, and Bink (1998)	Lexical decision task / computer instruction	• Slower lexical decisions for words from a performed than a not-performed action script	Inhibition or deactivation	• faster lexical decisions for words from an interrupted than a not-performed action script (intention-superiority effect) • Completed and interrupted portions of an action script showed similar accessibility (similar lexical-decision RTs)
Marsh, Hicks, and Bryan (1999)	Lexical decision task / computer instruction	• Slower lexical decisions for words from a performed than a not-performed action script	Inhibition or deactivation	• Inhibition finding also for unrelated completed and cancelled intentions
Meilán (2008)	Recognition of learned verbal scripts / signal	• No difference in recognition RTs for words from a performed and a not-performed action script	Deactivation	-
Penningroth (2011)	Lexical decision task / self-initiated time-based cued vs. experimenter cued	• Faster lexical decisions for words from a performed than a not-performed action script	Continued retrieval	• Only state-oriented participants showed a higher sustained intention-superiority effect after intention completion. Action-oriented participants showed comparable accessibility of words from a performed than a not-performed action script. • Sustained intention-superiority effect after intention completion did not differ between self-cued and experimenter-cued action scripts
Event-based PM paradigms with semantic associates of PM cues				
Badets, Albinet, and Blandin (2012)	Verbal-manual task / salient nonfocal PM cues (delayed motor intentions)	• Slower responses for the verbal-manual task in the intention-based than in the stimulus-based group	Inhibition	-
Denzler, Förster, and Lieberman (2009)	Lexical decision task / nonsalient focal PM cue	• Stabbing a voodoo doll (intention condition) decreased memory accessibility of aggression-related	Inhibition	• Completing an aggressive intention reduced memory accessibility of aggression-related words compared to completing a non-aggressive intention,

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
		words more than watching a voodoo doll (no-intention condition)-the decrease of memory accessibility from pre to post measurement was larger after stabbing than after watching		but also led participants to choose pictures with more aggressive content in a picture selection task • Aggressive acts that did not lead to intention completion increased accessibility of aggression-related words
Denzler, Häfner, and Förster (2011)	Lexical decision task / nonsalient focal PM cue	• Watching a violent computer game with the goal to vent anger (intention condition) produced a stronger decrease in memory accessibility of aggression-related words from pre to post measurement than watching a violent computer game without a goal (no-intention condition)	Inhibition	• Similar findings when participants played a violent computer game to vent anger • Participants who reported a high general tendency to vent their anger, showed reduced relative accessibility of aggression after playing a violent computer game
Förster, Liberman, and Higgins (2005)	Lexical decision task or Stroop-color naming / nonsalient focal PM cue	• Completing a PM task (intention condition) produced a stronger decrease in accessibility of PM-cue related compared to unrelated words (i.e., faster lexical decisions or increased Stroop interference) from pre to post measurement than not performing a PM task (no-intention condition)	Inhibition	• Initial inhibition of completed goals that returns to baseline activation levels overtime • No inhibition effect for unfulfilled goals • Post-completion inhibition increased with increasing expectations to fulfill a goal, increasing goal value or both
Hedberg and Higgins (2011)	Lexical decision task / nonsalient focal PM cue	• Promotion-focused used individuals showed a negative correlation between accessibility of PM-cue related words and delay length after intention completion • Prevention-focued used individuals showed a positive correlation between accessibility of PM-cue related words and delay length after intention completion	Promotion-focused individuals: decreased accessibility Prevention-focused individuals: increased accessibility	-
Event-based PM paradigms with no-longer-relevant PM cues				
Anderson and Einstein (2017)	Lexical decision task / nonsalient focal PM cues	• Slower lexical decisions in no-longer-relevant PM than in control trials • More frequent thoughts about the finished PM task after no-longer-relevant PM trials than after control trials • Commission errors in no-longer-relevant PM trials • Slower lexical decisions in the first trial after a no-longer-relevant PM trial	Continued retrieval	• Conditions hypothesized to facilitate intention deactivation (clarity, one-off, new PM task) still produced aftereffects: Mainly in slower lexical decisions during or after no-longer-relevant PM trials and thoughts about the finished PM task after no-longer-relevant PM trials • Thought probe measures indicated that no-longer-relevant PM cues often elicit conscious retrieval of a completed intention

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
		than in the first trial after a control trial		
Beck, Ruge, Walser, and Goschke (2014)	Spatial compatibility task / salient focal PM cues	• Slower ongoing-task responses in no-longer-relevant PM than in ongoing-task trials • Commission errors not analyzed	Continued retrieval	• Similar event-related brain activation in no-longer-relevant PM trials and PM trials • Event-related brain activation in no-longer-relevant PM trials likely reflected processing of PM cues and not merely processing of response conflicts between PM and ongoing-task response • Monitoring related sustained rostro-lateral prefrontal cortex activation stopped after intention completion
Bugg and Scullin (2013)	Lexical decision task / salient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Lower commission-error risk after performing a PM task to 4 PM cues vs. 0 PM cues or cancelling performance of a PM task • Lower commission-error risk with no-longer-relevant PM cues that were presented (and responded to most times) during active phases than with no-longer-relevant PM cues that were not presented during active phases
Bugg, Scullin, and McDaniel (2013)	Lexical decision task / salient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Commission-error risk was modulated by the strength of PM-cue-action associations: Higher commission-error risk after encoding PM tasks as an implementation intention (*if-then plan*) than after standard encoding • Commission error risk did not differ between younger and older adults
Bugg, Scullin, and Rauvola (2016)	Lexical decision task / salient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Lower commission-error risk and fewer commission errors after performing a PM task to 4 PM cues than 0 PM cues • Higher commission-error risk and more commission errors in older than in younger adults after performing a PM task to 4 PM cues, but no age differences with 0 PM cues • Preparing participants for the occurrence of no-longer-relevant PM cues (preparatory instructional strategy) did not affect commission errors • Reduced commission-error risk for older adults after practicing to withhold the no-longer relevant PM response or practicing to give ongoing-task responses in no-longer-relevant PM trials (forgetting practice) compared to standard finished instructions

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
				• Forgetting practice eliminated age differences in commission-error risk and commission-error rates after performing a PM task to 4 PM cues
Cohen, Gordon, Jaudas, Hefer, and Dreisbach (2017)	Flanker task / nonsalient nonfocal PM cues	• No commission errors in no-longer-relevant PM trials • No RT difference between no-longer-relevant PM trials and control trials	Deactivation	• Absence of behavioral monitoring costs after intention completion
El Haj, Coello, Kapogiannis, Gallouj, and Antoine (2018)	Text reading task / nonsalient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Higher commission-error rates in older adults with Alzheimer's disease than in healthy older adults • Positive correlation between commission-error rates and Stroop interference and between commission-error and PM omission rates in older adults with and without Alzheimer's disease
Gilbert, Hadjipavlou, and Raoelison (2013)	Letter size discrimination / nonsalient nonfocal PM cues (computational model and simulation)	• Simulating persistence of a PM-task memory trace after intention completion produced slower ongoing-task responses in no-longer-relevant PM trials than in control trials and commission errors in no-longer-relevant PM trials	Continued retrieval	• Reducing the strength of PM-cue-action associations reduced commission-error rates but continued to produce slower ongoing-task responses in no-longer-relevant PM than in control trials
Möschl, Walser, Plessow, Goschke, and Fischer (2017)	Word categorization / salient focal or nonsalient nonfocal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in control trials • Commission errors in salient focal no-longer-relevant PM trials but not in nonsalient nonfocal no-longer-relevant PM trials	Continued retrieval	• Commission errors with salient focal no-longer-relevant PM cues but not with nonsalient nonfocal no-longer-relevant PM cues • Tendency for increased commission-error risk with salient focal no-longer-relevant PM cues after acute-stress induction
Möschl, Walser, Surrey, and Miller (2019)	1-back or 2-back letter task / nonsalient nonfocal PM cues	• Commission errors occurred only in ongoing-task trials, not in no-longer-relevant PM trials • RT aftereffects not analyzed	Deactivation	• No effect of acute stress on commission-error risk in ongoing-task trials
Pink and Dodson (2013)	Lexical decision task / salient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Increased commission-error rates in no-longer-relevant PM trials under divided attention after completing a habitual PM task
Schaper and Grundgeiger (2017)	Parity judgments / salient focal PM cues	• Commission errors after no-longer-relevant PM trials: Retrieval and execution opportunity of the PM task	Continued retrieval	• More commission errors in cancelled than in finished-intention condition • No commission errors in the finished phase under divided attention

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
		were separated by a delay (i.e., delay-execute paradigm)		• Commission errors occurred even when PM responses were only possible 45 s after occurrence of a no-longer-relevant PM cue • CRT slowing in first trial after vs. first trial prior to or second trial after a no-longer-relevant PM trial was similar in cancelled-intention and active-intention group and larger than in completed intention and no-intention group • CInterruptions during the delay between PM cue and response opportunity reduced commission-error rates
Schaper and Grundgeiger (2019)	Lexical decision task / salient focal PM cues	• Finished intention condition: no commission errors in no-longer-relevant PM trials; Retrieval and execution opportunity of the PM task were separated by a delay (i.e., delay-execute paradigm) • RT aftereffects not analyzed	Deactivation	• Commission errors occurred in cancelled intention conditions with 1 s response lag or pause • In cancelled-intention condition, commission error rates in no-longer-relevant PM trials did not differ between conditions with a 1 s or 2 s response lag between no-longer-relevant PM cue and response opportunity during ongoing task trials and a pause condition in which the delay occurred between ongoing task trials
Scullin and Bugg (2013)	Lexical decision task / salient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Commission-error risk increased with higher levels of fatigue (modulation by cognitive-control availability) • No behavioral monitoring costs during finished phase • No effects of delay after intention completion on commission errors • Most participants thought that the PM task was finished after finished instruction
Scullin, Bugg, and McDaniel (2012)	Lexical decision task / salient or nonsalient focal PM cues	• Commission errors in no-longer-relevant PM trials • RT aftereffects not analyzed	Continued retrieval	• Higher commission-error risk in older than in younger adults • Commission-error risk in older adults correlated with deficits in inhibitory functioning • Higher commission-error risk with salient than with nonsalient no-longer-relevant PM cues and when ongoing tasks matched between active and finished phases
Scullin, Bugg, McDaniel, and Einstein (2011)	Lexical decision task / salient focal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in control trials in older adults but not in younger adults	Younger adults: Deactivation Older adults: Continued retrieval	• Stronger response slowing in no-longer-relevant PM trials in older adults with deficits in inhibitory functioning

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
		• No commission errors in no-longer-relevant PM trials		
Scullin, Einstein, and McDaniel (2009)	Lexical decision task / salient focal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in control trials only with suspended but not with completed intentions • Commission errors not analyzed	Deactivation	• No effects of delay after intention completion on RT aftereffects
Walser, Fischer, and Goschke (2012)	Parity judgments / salient nonfocal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in novel or familiar oddball trials • Commission errors in no-longer-relevant PM trials	Continued retrieval	• Similar response slowing for no-longer-relevant PM cues that were described verbally but not shown during encoding and for exemplars of categorical no-longer-relevant PM cues that were not presented during active phases • Larger RT aftereffects in finished phases with a new PM task than in ongoing-task-only phases • RT aftereffects declined from early to late encounters of no-longer-relevant PM cues
Walser, Fischer, Goschke, Kirschbaum, and Plessow (2013)	Word categorization / nonsalient focal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in ongoing-task trials • Very low number of commission errors (not analyzed)	Continued retrieval	• No effect of acute stress on response slowing in no-longer-relevant PM trials
Walser, Goschke, and Fischer (2014)	Parity judgments / salient nonfocal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in oddball trials • Very low number of commission errors (not analyzed)	Continued retrieval	• RT aftereffects increased after participants described the PM cue compared to after participants read neutral letter strings aloud after intention completion • RT aftereffects decreased after participants performed a demanding backwards-letter span task compared to after they read neutral letter strings aloud after intention completion • Increased aftereffects for participants low in self-reported action control
Walser, Goschke, Möschl, and Fischer (2017)	Parity judgments or word categorizations / salient/ nonsalient and focal/nonfocal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in oddball trials • Higher commission error rates in no-longer-relevant PM trials than in control trials	Continued retrieval or Deactivation	• When ongoing tasks differed between active and finished phases, commission errors and ongoing-task response slowing in no-longer-relevant PM versus oddball trials only occurred when a PM task was performed during finished phases • RT aftereffects decreased more when novel PM tasks in finished phases required shifting spatial attention to different locations than the finished PM task (different PM-cue categories) than when both

Study	Ongoing task / Retrieval cue	Main aftereffect results	Interpretation	Additional findings
				PM tasks required attending similar locations (same PM-cue category) • When PM tasks in finished phases required a novel PM response, participants gave false-alarm responses with the novel PM response in no-longer-relevant PM trials. They did not make commission errors with the old PM response • Forming a novel dissimilar intention did not lead to overwriting of the completed intention representation
Walser, Plessow, Goschke, and Fischer (2014)	Parity judgments / salient nonfocal PM cues	• Slower ongoing-task responses in no-longer-relevant PM trials than in oddball trials • Very low number of commission errors (not analyzed)	Continued retrieval	• RT aftereffects declined over repeated encounters of no-longer-relevant PM trials • Performance differences between no-longer-relevant PM trials and oddball trials were not related to the delay after intention completion
Free recall of naturalistic intentions				
Freeman and Ellis (2003)	• / free recall in speeded written fluency task	• Younger adults recalled more to-be-completed activities that they intended to perform in the following week than activities they completed one week ago • Older adults recalled a similar amount of to-be-completed and completed activities	Relative inaccessibility / inhibition	• No difference between younger and older adults in the relative inaccessibility (inhibition) of completed intentions
Maylor, Chater, and Brown (2001)	• / free recall in speeded written fluency task	• Less recall of activities that were completed the day/Week/year before testing than of to-be-completed activities that were intended to be performed the day/Week/year after testing	No interpretation given	-
Maylor, Darby, and Della Sala (2000)	• / free recall in speeded written or verbal fluency task	• More recall of completed than to-be-completed activities (intention-inferiority effect) in older adults, no differences in middle aged adults in speeded written fluency task • Only younger adults recalled less completed than to-be-completed activities (intention-superiority effect), but not older adults or dementia patients	Older adults: Reduced facilitation of to-be-completed tasks and/or reduced inhibition of completed tasks	-

Note. The terms focal and nonfocal PM cues refer to the processing overlap between a PM task and an ongoing task. A PM cue is considered focal when it can be identified through the same processing operations that are needed to perform the ongoing task. For instance, if a PM task requires identifying the word *fish* within an ongoing word-categorization task. A PM cue is considered nonfocal when processing operations that are needed to identify the PM cue differ from those required to perform the ongoing task. For instance, if a PM task requires identifying words that contain the letter-string *tra* within an ongoing word-categorization task. Note also that many studies presented in this table postulated both continued intention retrieval and/or residual intention activation as the processes or mechanisms underlying aftereffects of completed intentions or did not exactly separate between those two accounts. Hence, within this table we used the term continued retrieval to refer to both mechanisms.

Table 3

Response time aftereffects in the reviewed studies.

Study Experiment	Condition	*Participants N (n)*	Intention-related *M* (*SD*)	Control *M* (*SD*)	*Aftereffect* M_{diff} (SE_{diff})	d_{AV} (*SE*)	g_{AV} [95% CI]
Script-based paradigms and related procedures							
Badets, Blandin, Bouquet, and Shea (2006) - intention groups							
Exp. 1	Recognition test 2	9	–	–	–	–	–
Exp. 2	Recognition test 2	9	–	–	–	–	–
Cohen, Dixon, and Lindsay (2005)							
Exp. 1 (“Forget the task” condition)	Overall (younger & older adults, Stroop paradigm)	51	764 (121)	732 (104)	32 (12)	0.28 (0.20)[a]	0.28 [−0.11; 0.67][a]
	Older adults (Stroop paradigm)	(24)	836 (78)	793 (71)	44 (12)	0.58 (0.30)[a]	0.56 [−0.02; 1.14][a]
	Younger adults (Stroop paradigm)	(27)	702 (118)	671 (95)	31 (16)	0.29 (0.28)[a]	0.28 [−0.26; 0.82][a]
Marsh, Hicks, and Bryan (1999)							
Exp. 2	After performance	24	$t(23) = 2.90$	–	0.59[b]	–	
Exp. 3	After performance	32	$t(31) = 3.00$	–	0.53[b]	–	
Exp. 4	After performance	24	$t(23) = 2.10$	–	0.43[b]	–	
	After interruption	(24)	$t(23) = 2.00$	–	0.41[b]	–	
Marsh, Hicks, and Bryan (1999)							
Exp. 1	After performance (unrelated activities)	40	$t(39) = 2.20$	–	0.35[b]	–	
Exp. 2	After performance	40	$t(39) = 2.19$	–	0.35[b]	–	
	After cancellation	(40)	$t(39) = 2.37$	–	0.37[b]	–	
Meilán (2008)							
	Post-intentional measure	30	863	894	−31	–	–
Penningroth (2011)							
Overall	After performance	191	532 (79)	541 (84)	−8 (5)	−0.10 (0.10)	−0.10 [−0.30; 0.10]
Action orientation	After performance	(106)	537 (79)	545 (83)	−7 (6)	−0.09 (0.14)	−0.09 [−0.36; 0.18]
State orientation	After performance	(85)	526 (78)	536 (85)	−10 (7)	−0.12 (0.15)	−0.12 [−0.42; 0.18]
Event-based PM paradigms with semantic associates of PM cues							

Study Experiment & Condition		Participants *N* (*n*)	Intention-related *M* (*SD*)	Control *M* (*SD*)	Aftereffect M_{diff} (SE_{diff})	d_{AV} (*SE*)	g_{AV} [95% CI]
Badets, Albinet, and Blandin (2012) - intention-based group							
	Verbal-manual task	12	–	–	–	–	–
Denzler, Förster, and Lieberman (2009) - goal groups							
Exp. 1	Exp. group 2, block 3 (revenge, watching stabbing)	15 [91/6][c]	732 (180)	709 (93)	23 (34)	0.16 (0.37)	0.15 [−0.57; 0.87]
	Exp. group 2, block 3 (revenge, stabbing)	15 [91/6][c]	790 (73)	699 (84)	91 (16)	1.16 (0.39)	1.09 [0.31;1.86]
Exp. 2	Goal-fulfillment, block 2 (revenge story)	17 [51/3][c]	836 (86)	720 (150)	116 (26)	0.95 (0.36)	0.90 [0.19; 1.06]
Exp. 3	Goal-fulfillment, block 2 (revenge story)	20 [83/4][c]	738 (232)	666 (167)	72 (36)	0.36 (0.32)	0.34 [−0.28; 0.96]
	Punching bag target, block 2 (story)	20 [83/4][c]	621 (90)	687 (129)	−66 (20)	−0.59 (0.30)	−0.57 [−1.20; 0.07]
	Wrong target, block 2 (story)	20 [83/4][c]	577 (71)	622 (97)	−45 (15)	−0.53 (0.31)	−0.51 [−1.14; 0.13]
Denzler, Häfner, and Förster (2011) - goal groups							
Exp. 1	Block 2	23 [47/2][c]	–	–	−1 (28)	–	–
Exp. 2	Block 2	14 [28/2][c]	–	–	−30 (20)	–	–
Förster, Liberman, and Higgins (2005) -goal groups							
Exp. 1	Block 3	17 [35/2][c]	981 (130)	707 (136)	274 (25)	2.06 (0.38)	1.96 [1.13; 2.78]
Exp. 2	Block 3 (Stroop paradigm)	15 [31/2][c]	488 (107)	479 (92)	9 (20)	0.09 (0.37)[a]	0.09 [−0.63; 0.8][a]
Exp. 3	Block 3	34 [104/3][c]	734 (112)	668 (92)	66 (14)	0.64 (0.25)	0.63 [0.14; 1.11]
Exp. 4	Block 3, high fulfillment expectancy	15 [47/3][c]	751 (98)	662 (75)	89 (18)	1.02 (0.39)	0.96 [0.20; 1.72]
	Block 3, low fulfillment expectancy	15 [47/3][c]	687 (109)	647 (88)	40 (20)	0.40 (0.37)	0.38 [−0.34; 1.10]
Exp. 5	Block 3, high goal value	13 [41/3][c]	721 (96)	628 (66)	93 (19)	1.13 (0.42)	1.06 [0.22; 1.87]
	Block 3, low goal value	13 [41/3][c]	758 (179)	701 (107)	57 (36)	0.39 (0.40)	0.36 [−0.42; 1.13]
Exp. 6	Block 3, high goal value, high fulfillment expectancy	15 [75/5][c]	769 (112)	645 (67)	124 (21)	1.34 (0.39)	1.27 [0.47; 2.05]
	Block 3, high goal value, low fulfillment expectancy	15 [75/5][c]	690 (123)	638 (103)	52 (23)	0.46 (0.38)	0.43 [−0.29; 1.15]
	Block 3, low goal value, high fulfillment expectancy	15 [75/5][c]	659 (93)	632 (84)	27 (18)	0.30 (0.37)	0.29 [−0.43; 1.01]

Study Experiment & Condition		*Participants N (n)*	Intention-related *M (SD)*	Control *M (SD)*	*Aftereffect* M_{diff} (SE_{diff})	d_{AV} *(SE)*	g_{AV} [95% CI]
	Block 3, low goal value, low fulfillment expectancy	15 [75/5][c]	681 (113)	664 (143)	17 (27)	0.13 (0.37)	0.12 [−0.59; 0.84]
Hedberg and Higgins (2011)							
Study 1	Promotion focus × Manipulated Delay	132	$\beta = -10.30$, $t(126) = 3.05$[d]	–	–	–	
	Prevention focus × Manipulated Delay	(132)	$\beta = 10.18$, $t(126) = 3.08$[d]	–	–	–	
Event-based PM paradigms with no-longer-relevant PM cues							
Anderson and Einstein (2017)							
Exp. 1	Completed intention	30	610 (175)	543 (159)	67 (24)	0.40 (0.26)	0.39 [−0.12; 0.90]
Exp. 2	Control (completed intention)	21	572 (142)	526 (128)	46 (23)	0.34 (0.32)	0.33 [−0.28; 0.93]
	Clarity instruction	21	536 (92)	507 (73)	29 (14)	0.35 (0.32)	0.34 [−0.28; 0.94]
	One-off instruction	22	496 (75)	497 (56)	−1 (11)	−0.02 (0.30)	−0.01 [−0.61; 0.58]
	PM task in finished phase	21	585 (128)	531 (82)	54 (20)	0.50 (0.32)	0.48 [−0.14; 1.09]
Beck, Ruge, Walser, and Goschke (2014)							
	Post-PM block ($PM_{REPEATED}$ vs. ongoing-task trials)	47	–	–	40 (5)	–	–
Bugg and Scullin (2013)							
Exp. 1		53	–	–	–	–	–
Exp. 2		68	–	–	–	–	–
Exp. 3		40	–	–	–	–	–
Bugg, Scullin, and McDaniel (2013)							
	Overall	110	–	–	–	–	–
Bugg, Scullin, and Rauvola (2016)							
Exp. 1		35	–	–	–	–	–
Exp. 2		92	–	–	–	–	–
Exp. 3		56	–	–	–	–	–
Cohen, Gordon, Jaudas, Hefer, and Dreisbach (2017)							
Exp. 2	Forget condition	20	–	–	–	–	–
El Haj, Coello, Kapogiannis, Gallouj, and Antoine (2018)		51	–	–	–	–	–
Möschl, Walser, Plessow, Goschke, and Fischer (2017)							
Stress group	Focal condition	40	790 (150)	717 (130)	73 (17)	0.52 (0.23)	0.51 [0.06; 0.95]

Study Experiment & Condition		*Participants N (n)*	Intention-related *M* (*SD*)	Control *M* (*SD*)	*Aftereffect* M_{diff} (SE_{diff})	d_{AV} *(SE)*	g_{AV} [95% CI]
	Nonfocal condition, low PM load	(40)	726 (182)	673 (182)	53 (22)	0.29 (0.23)	0.29 [−0.16; 0.73]
	Nonfocal condition, high PM load	(40)	723 (161)	674 (100)	49 (18)	0.37 (0.23)	0.36 [−0.08; 0.80]
No-Stress group	Focal condition	40	852 (166)	747 (120)	105 (19)	0.72 (0.23)	0.71 [0.26; 1.16]
	Nonfocal condition, low PM load	(40)	793 (244)	723 (141)	70 (28)	0.35 (0.23)	0.34 [−0.10; 0.78]
	Nonfocal condition, high PM load	(40)	793 (196)	709 (118)	84 (22)	0.52 (0.23)	0.51 [0.06; 0.95]
Möschl, Walser, Surrey, and Miller (2019)							
	Nonfocal PM task	79	–	–	–	–	–
Pink and Dodson (2013)							
Exp. 1 A		89	–	–	–	–	–
Exp. 1 B		89	–	–	–	–	–
Schaper and Grundgeiger (2017)							
Exp. 1	Finished intention & cancelled intention conditions	39	–	–	–	–	–
Exp. 2	Finished intention & cancelled intention conditions	120	–	–	–	–	–
Schaper and Grundgeiger (2019)							
Exp. 1		39	–	–	–	–	–
Exp. 2		64	–	–	–	–	–
Exp. 3		350	–	–	–	–	–
Scullin and Bugg (2013)							
	Overall	72	–	–	–	–	–
Scullin, Bugg, and McDaniel (2012)							
	Overall	145	–	–	–	–	–
Scullin, Bugg, McDaniel, and Einstein (2011)							
	Older adults, first presentation of target	38	816 (203)	734 (138)	82 (24)	0.47 (0.24)	0.46 [0.01; 0.92]
	Younger adults, first presentation of target	40	526 (124)	511 (99)	15 (14)	0.13 (0.23)	0.13 [−0.31; 0.57]
Scullin, Einstein, and McDaniel (2009)							
Exp. 1	Suspended condition	24	533	512	21	–	–
Exp. 2	Suspended condition	48	558	539	19	–	–

Study Experiment & Condition		Participants *N* (*n*)	Intention-related *M* (*SD*)	Control *M* (*SD*)	*Aftereffect* M_{diff} (SE_{diff})	d_{AV} (*SE*)	g_{AV} [95% CI]
	Finished condition	48	532	539	−7	–	–
Walser, Fischer, and Goschke (2012)							
Exp. 1	PM task in finished phase (overall)	12	842 (131)	716 (118)	126 (28)	1.01 (0.43)	0.94 [0.08; 1.78]
Exp. 2	PM task in finished phase, $Oddball_{REPEATED}$ (overall)	12	887 (144)	747 (150)	140 (33)	0.95 (0.43)	0.89 [0.04; 1.72]
	$PM_{REPEATED}$ vs. $Oddball_{REPEATED}$ (overall)	(12)	887 (144)	698 (135)	189 (31)	1.35 (0.44)	1.26 [0.37; 2.13]
Exp. 3	No PM task in finished phase (overall)	12	653 (151)	606 (151)	47 (34)	0.31 (0.42)	0.29 [−0.52; 1.09]
Exp. 4	PM task in finished phase, categorical PM cues (overall)	12	793 (130)	722 (139)	71 (30)	0.53 (0.42)	0.49 [−0.33; 1.30]
Walser, Fischer, Goschke, Kirschbaum, and Plessow (2013) – $PM_{REPEATED}$ vs. Standard							
	Stress group	41	651 (103)	580 (87)	71 (12)	0.74 (0.23)	0.73 [0.28; 1.18]
	No-Stress group	41	643 (104)	572 (74)	71 (12)	0.79 (0.23)	0.77 [0.32; 1.22]
Walser, Goschke, and Fischer (2014) – $PM_{REPEATED}$ vs. Oddball							
Action orientation	Intention reflection	27	624 (116)	572 (88)	52 (16)	0.83 (0.30)	0.80 [0.21; 1.39]
	Control	(27)	611 (106)	561 (81)	50 (15)	0.61 (0.30)	0.59 [0.01; 1.17]
	Load condition	(27)	580 (96)	555 (73)	25 (13)	0.54 (0.30)	0.52 [−0.06; 1.10]
State orientation	Intention reflection	24	689 (159)	581 (92)	108 (24)	0.51 (0.28)	0.49 [−0.05; 1.03]
	Control	(24)	645 (126)	577 (94)	68 (18)	0.53 (0.28)	0.51 [−0.03; 1.05]
	Load condition	(24)	631 (113)	576 (89)	55 (17)	0.29 (0.28)	0.28 [−0.25; 0.82]
Walser, Goschke, Möschl, and Fischer (2017)							
Exp. 1	PM-cue category repetition, response repetition	26	966 (162)	813 (136)	153 (23)	1.02 (0.29)	0.99 [0.41; 1.56]
	PM-cue category repetition, response switch	(26)	814 (170)	711 (124)	103 (24)	0.69 (0.29)	0.67 [0.11; 1.23]
	PM-cue category switch, response repetition	(26)	949 (163)	803 (152)	146 (24)	0.93 (0.29)	0.90 [0.32; 1.47]
	PM-cue category switch, response switch	(26)	796 (188)	712 (108)	84 (27)	0.55 (0.29)	0.53 [−0.02; 1.08]
Exp. 2	PM-cue category repetition, response repetition	24	1015 (179)	857 (160)	158 (27)	0.93 (0.31)	0.90 [0.30; 1.49]
	PM-cue category repetition, response switch	(24)	996 (169)	837 (151)	159 (26)	0.99 (0.31)	0.96 [0.36; 1.55]

Study Experiment & Condition		*Participants N* (*n*)	Intention-related *M* (*SD*)	Control *M* (*SD*)	*Aftereffect* M_{diff} (SE_{diff})	d_{AV} (*SE*)	g_{AV} [95% CI]
Exp. 3	PM task repetition	16	909 (183)	754 (165)	155 (34)	0.89 (0.37)	0.84 [0.11; 1.56]
	PM task switch	(16)	759 (135)	668 (117)	91 (25)	0.72 (0.37)	0.68 [−0.04; 1.39]
	Ongoing task only	(16)	635 (108)	630 (108)	5 (21)	0.05 (0.35)	0.04 [−0.65; 0.74]
Exp. 4	PM-cue category repetition (shape)	32	959 (205)	945 (207)	14 (28)	0.07 (0.25)	0.07 [−0.42; 0.56]
	PM-cue category switch (shape)	(32)	970 (193)	877 (166)	93 (25)	0.52 (0.26)	0.50 [0.004; 1.00]
	PM-cue category repetition (color)	(32)	986 (214)	906 (165)	80 (27)	0.42 (0.26)	0.41 [−0.09; 0.90]
	PM-cue category switch (color)	(32)	983 (200)	896 (175)	87 (26)	0.46 (0.26)	0.45 [−0.05; 0.95]
Walser, Plessow, Goschke, and Fischer (2014)							
Exp. 1	Test block 1 (cue set A)	28	617 (92)	589 (88)	28 (13)	0.31 (0.27)	0.30 [−0.23; 0.83]
	Test block 2 (cue set A)	(28)	549 (60)	547 (72)	2 (10)	0.03 (0.27)	0.03 [−0.49; 0.55]
	Test block 2 (cue set B)	(28)	567 (85)	564 (81)	3 (12)	0.04 (0.27)	0.04 [−0.49; 0.56]
Exp. 2	Test block 2 (cue set B)	16	646 (120)	602 (90)	44 (21)	0.41 (0.36)	0.39 [−0.31; 1.09]
Exp. 3	Short block, low frequency (4 trials)	24	610 (139)	575 (110)	35 (20)	0.28 (0.29)	0.27 [−0.30; 0.84]
	Short block, high frequency (12 trials)	(24)	575 (113)	566 (109)	9 (18)	0.08 (0.29)	0.08 [−0.49; 0.64]
	Long block, low frequency (4 trials)	(24)	662 (153)	614 (113)	48 (22)	0.36 (0.30)	0.35 [−0.23; 0.91]
	Long block, high frequency (12 trials)	(24)	576 (112)	559 (93)	17 (17)	0.17 (0.29)	0.16 [−0.41; 0.73]

Note. Where possible, we report descriptive data for intention-related stimuli (e.g., script words, semantic associates of PM cues, no-longer-relevant PM cues) and control stimuli that were reported in the original studies. If this data was not available, we report the difference measures or the test statistic for the comparison of these measures from the original studies. Effect sizes were calculated for within-subject effects according to Lakens (2013). Confidence intervals for Hedge's g_{AV} were approximated based on non-centralized *t*-distributions using R 3.6.0 statistical software (R Core Team, 2019) and the MBESS package (version 4.4.3; Kelley, 2007, 2018) with non-centrality parameters estimated from g_{AV}. Since no study reported correlations between response times for intention-related and control trials, we calculated SE_{diff} assuming a high correlation between repeated measures ($r = .70$; see online supplement for sensitivity analyses). Positive values of M_{diff}, d_{AV} and g_{AV} indicate that responses were slower to intention-related than to control stimuli. In script-based paradigms and event-based PM paradigms with semantic associates of PM cues, slower responses to intention-related stimuli are thought to represent intention inhibition. In event-based PM paradigms with no-longer-relevant PM cues, slower responses to no-longer-relevant PM cues are thought to represent interference due to continued intention retrieval. Numbers of participants in parentheses (*n*) indicate that the conditions tested in an experiment were manipulated within subjects. Empty cells, denoted by "−", indicate that this data was not available and calculating effect sizes was not possible.

[a] Interference paradigm: Negative values of M_{diff}, d_{AV} and g_{AV} indicate that responses were slower to intention-related than to control stimuli.

[b] The effect size represents d_z calculated from *t*-values and degrees of freedom for the comparison of intention-related and control stimuli reported in the original study.

[c]The exact number of participants in each group of the experiment was not reported. Therefore, we estimated *n* assuming an even distribution of participants across groups. In some cases, we discarded one or more participants from the overall *N* to achieve an even distribution. The overall number of participants in the experiment and the number of groups are reported in brackets [*N*/groups]. In Exp. 3 of the Förster et al. (2005) study, it is unclear whether data is reported from 108 or 104 participants.

[d]Linear regression of difference scores (PM-cue related vs. control words) across all blocks (i.e., active & finished intention phases).

Table 4.

Commission errors in the reviewed studies.

Study Experiment & Condition		N	$n \geq 1$ CE	Comparison	*OR* [95% CI]	Test statistic	*ES*
Event-based PM paradigms with no-longer-relevant PM cues							
Anderson and Einstein (2017)							
Exp. 1	Completed intention	32	8	Completed intention vs. Suspended intention	0.38 [0.13; 1.09]	$X^2(1) = 3.33$	0.23
	Suspended intention	32	15				
Exp. 2	Completed intention	21	7	Completed intention vs. All others (Exp. 2)	3.56 [1.10; 11.49]	$X^2(3) = 5.04$	0.24
	Clarity instruction	22	3	Completed intention vs. Clarity instruction	3.17 [0.69; 14.46]	$X^2(1) = 2.34$	0.23
	One-off instruction	22	3	Completed intention vs. One-off instruction	3.17 [0.69; 14.46]	$X^2(1) = 2.34$	0.23
	PM task in finished phase	21	2	Completed intention vs. PM task in finished phase	4.75 [0.85; 26.43]	$X^2(1) = 3.54$	0.29
Beck, Ruge, Walser, and Goschke (2014)							
		47	-	-	-	-	-
Bugg and Scullin (2013)							
Exp. 1	0 targets	27	15	0 target vs. 4 target	-	$X^2(1) = 20.15$	0.62
	4 targets	26	0				
Exp. 2	0 targets	24	11	0 target vs. 4 target	-	$X^2(1) = 14.27$	0.55
	4 targets	24	0				
	Cancelled intention	20	9	Cancelled intention vs. 4 target	-	$X^2(1) = 11.73$	0.52
Exp. 3	4 targets, non-presented PM cue	20	7	Non-presented PM cue vs. Presented PM cue	4.85 [0.86; 27.22]	$X^2(1) = 3.58$	0.30
	4 targets, presented PM cue	20	2				
Bugg, Scullin, and McDaniel (2013)							
Overall	Implementation intention encoding	55	-	Implementation intention encoding vs. Standard encoding	-	$X^2(1) = 7.7$	0.26
	Standard encoding	55	-				
Younger adults	Implementation intention encoding	31	-	Implementation intention encoding vs. Standard encoding	-	$X^2(1) = 3.84$	0.25
	Standard encoding	32	-				
Older adults	Implementation intention encoding	24	-	Implementation intention encoding vs. Standard encoding	-	$X^2(1) = 3.85$	0.29
	Standard encoding	23	-				
Bugg, Scullin, and Rauvola (2016)							

Study Experiment	Condition	N	$n \geq 1$ CE	Comparison	OR [95% CI]	Test statistic	ES
Exp. 1	Older adults, 0 targets	18	12	0 target vs. 4 target	6.50 [1.47; 28.80]	$X^2(1) = 6.56$	0.43
	Older adults, 4 targets	17	4				
Exp. 2	Older adults, 0 targets, preparatory instructions	25	14	0 target vs. 4 target (older adults, preparatory instructions)	9.33 [2.21; 39.46]	$X^2(1) = 8.68$	0.42
	Older adults, 4 targets, preparatory instructions	25	3				
	Younger adults, 0 targets, preparatory instructions	17	11	0 target vs. 4 target (younger adults, preparatory instructions)	9.63 [2.23; 41.46]	$X^2(1) = 12.65$	0.55
	Younger adults, 4 targets, preparatory instructions	25	4				
Exp. 3	Older adults, 4 targets, forgetting practice	30	1	Older adults, forgetting practice vs. Younger adults, forgetting practice	0.86 [0.05; 14.51]	$X^2(1) = 0.01$	0.01
	Younger adults, 4 targets, forgetting practice	26	1				
Cohen, Gordon, Jaudas, Hefer, and Dreisbach (2017)							
Exp. 1		60	0	-	-	-	-
Exp. 2		40	0	-	-	-	-
El Haj, Coello, Kapogiannis, Gallouj, and Antoine (2018)							
	Commission-error rates	51	-	Commission-error rates: Older adults with Alzheimer's dementia ($n = 24$) vs. Healthy older adults ($n = 27$)	-	$Z = -2.85$	0.87^{b}
			-				
Möschl, Walser, Plessow, Goschke, and Fischer (2017)							
Focal condition	Stress group	40	11	Stress group vs. No-Stress group	4.68 [1.19; 18.34]	$X^2(1) = 5.54$	0.26
	No-Stress group	40	3				
Nonfocal	Stress group	(40)	1	-	-	-	-
condition	No-Stress group	(40)	0				
Möschl, Walser, Surrey, and Miller (2019)							
	Stress group	39	5	Stress group vs. No-Stress group	0.83 [0.23; 2.99]	$X^2(1) = 0.08$	0.03
	No-Stress group	40	6				
Pink and Dodson (2013)							
Exp. 1 A	Commission-error rates	89	-	Commission-error rates: Habit, divided attention vs. All others (Habit, full attention; No-habit, full attention; No-habit, divided attention; contrast [3, −1, −1, −1])	-	$F(1, 81) = 6.53$, $MSE = .08$	$.07^{b}$
Exp. 1 B	Commission-error rates	89	-	Commission-error rates: Habit, divided attention vs. All others (Habit, full attention; No-habit,	-	$F(1, 83) = 4.72$, $MSE = .10$	$.05^{b}$

Study Experiment & Condition		*N*	*n* ≥ 1 CE	Comparison	*OR* [95% CI]	Test statistic	*ES*
				full attention; No-habit, divided attention; contrast [3, −1, −1, −1])			
Schaper and Grundgeiger (2017)							
Exp. 1	Cancelled intention	20	5	Cancelled intention vs. Finished intention	-	-	-
	Finished intention	19	0				
Exp. 2	Cancelled intention	40	13	Cancelled intention vs. Finished intention	3.37 [1.07; 10.61]	$X^2(1) = 4.59$	0.24
	Finished intention	40	5				
	Cancelled intention, divided attention	20	0	Finished intention, divided attention vs. Finished intention	0.37 [0.04; 3.39]	$X^2(1) = 0.83$	0.12
	Finished intention, divided attention	20	1				
Schaper and Grundgeiger (2019)							
Exp. 1	Cancelled intention, 1 s response lag	20	7	Cancelled intention: 1 s response lag vs. 1 s pause	0.92 [0.25; 3.42]	$X^2(1) = 0.01$	0.02
	Cancelled intention, 1 s pause	19	7			$t(37) = 0.51$	0.16[b]
Exp. 2	Cancelled intention, 2 s response lag	20	5	Cancelled intention: 2 s response lag vs. 2 s pause	0.40 [0.11; 1.49]	$X^2(1) = 1.91$	0.21
	Cancelled intention, 2 s pause	22	10			$t(40) = 1.00$	0.30[b]
	Finished intention, 2 s response lag	22	0	Finished intention, 2 s response lag vs. Cancelled intention, 2 s response lag	-	$X^2(1) = 6.24$	0.39
				Finished intention, 2 s response lag vs. Cancelled intention, 2 s pause	-	$X^2(1)= 12.94$	0.54
Exp. 3	Cancelled intention, 2 s pause	170	82	Cancelled intention: 2 s response lag vs. 2 s pause	0.82 [0.53; 1.27]	$X^2(1) = 0.71$	0.05
	Cancelled intention, 2 s response lag	157	68			$t(328) = 0.66$	0.07[b]
	Finished intention, 2 s response lag	23	0	-	-	-	-
Scullin and Bugg (2013)							
	Finished block, short delay	34	10	Finished block, short delay vs. Finished block, long delay	1.46 [0.50; 4.28]	$X^2(1) = 0.47$	0.08
	Finished block, long delay	36	8				
Scullin, Bugg, and McDaniel (2012)							
Nonsalient-cue, task match	Older adults	24	0.08% (0.23)[a]	Commission-error rates: Older adults vs. Younger adults	-	$t(46) = 1.14$	0.32[b]
	Younger adults	24	0.02% (0.10)[a]				
Salient cue, task mismatch	Older adults	24	0.02% (0.10)[a]	Commission-error rates: Older adults vs. Younger adults		$t(47) = 1.52$	0.43[b]

Study Experiment & Condition		N	$n \geq 1$ CE	Comparison	*OR* [95% CI]	Test statistic	*ES*
	Younger adults	25	0% (0)[a]				
Salient cue, task match	Older adults	24	0.44% (0.48)[a]	Commission-error rates: Older adults vs. Younger adults	-	$t(46) = 2.32$	0.66[b]
	Younger adults	24	0.18% (0.36)[a]				
Overall		145	26	Older adults vs. Younger adults	-	$X^2(1) = 6.95$	0.22
Scullin, Bugg, McDaniel, and Einstein (2011)							
	Older adults	38	0	-	-	-	-
	Younger adults	40	0				
Scullin, Einstein, and McDaniel (2009)							
Exp. 1	Suspended condition	24	-	-	-	-	-
Exp. 2	Overall	96	-	-	-	-	-
Walser, Fischer, and Goschke (2012)							
Exp. 1		12	-	-	-	-	-
Exp. 2		12	-	-	-	-	-
Exp. 3		12	-	-	-	-	-
Exp. 4		12	-	-	-	-	-
Walser, Fischer, Goschke, Kirschbaum, and Plessow (2013)							
	Overall	82	0.01%[a]	-	-	-	-
Walser, Goschke, and Fischer (2014)							
	Overall	51	0.02%[a]	-	-	-	-
Walser, Goschke, Möschl, and Fischer (2017)							
Exp. 1 (PM task in finished phase)	PM-cue category repetition	26	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials			
	PM response repetition			M_{diff} = 6.3%	-	$t(25) = 6.33$	1.60[b]
	PM response switch			M_{diff} = 5.4% (new PM response)		$t(25) = 3.89$	0.99[b]
	PM-cue category switch	(26)	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials			
	PM response repetition			M_{diff} =1.9%	-	$t(25) = 3.09$	0.85[b]
	PM response switch			M_{diff} = 0.6% (new PM response)		$t(25) = 1.07$	0.21[b]
Exp. 2 (PM task in finished phase)	PM-cue category repetition	24	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials			

Study Experiment & Condition		*N*	*n* ≥ 1 CE	Comparison	*OR* [95% CI]	Test statistic	*ES*
	PM response repetition			M_{diff} =4.3%	-	$t(23) = 2.68$	0.76[b]
	PM response switch			M_{diff} = 4.3% (new PM response)		$t(23) = 4.26$	1.28[b]
				M_{diff} = 0.2% (old PM response)		$t(23) = 1.00$	0.29[b]
Exp. 3 (PM task in finished phase)	PM-cue category repetition	16	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials	-		
	PM response repetition			M_{diff} = 8.4%		$t(15) = 5.70$	1.97[b]
	PM-cue category switch	(16)	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials	-		
	PM response switch			M_{diff} = 0.2%		$t(15) = 1.00$	0.33[b]
no PM task in finished phase	Ongoing task only	(16)	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials	-	$t(15) = 1.29$	0.35[b]
Exp. 4	PM-cue category repetition/ switch &	32	-	Commission-error rates: $PM_{REPEATED}$ vs. Oddball trials			
(PM task in finished phase)	PM response repetition				-		
	Shape PM cue in active phase			M_{diff} = 2.7%		$t(31) = 4.96$	0.91[b]
	Color PM cue in active phase			M_{diff} = 5.9%		$t(31) = 3.67$	0.50[b]
Walser, Plessow, Goschke, and Fischer (2014)							
Exp. 1	Overall	28	0.02%[a]	-	-	-	-
Exp. 2	Overall	16	-	-	-	-	-
Exp. 3	Overall	24	0.02%[a]	-	-	-	-

Note. Where possible, we report the number of subjects who made at least one commission error (CE**)** and/or the percentage of commission errors from the original studies and calculated odds ratios (*OR*), X^2 and effect sizes (*ES*). If this data was not available, we supply X^2 and effect sizes as reported in the original studies. Confidence intervals for odds ratios were estimated according to Woolf (1955). For X^2 tests of the commission error risk, effect sizes represent *Phi*. For comparisons of commission-error rates between conditions, we supply the test statistics and effect sizes reported in the original studies. The corresponding effect sizes represent ηp^2 (*F*-tests) or Hedge's g_S (*t*-Tests) for between-subject effects calculated according to Lakens (2013). El Haj et al. (2018) reported a Mann-Whitney U test and *Cohen's d* for the analysis of commission-error rates. Numbers of participants in parentheses (*n*) indicate that the conditions tested in an experiment were manipulated within subjects. Empty cells, denoted by "−", indicate that this data was not available and calculating effect sizes was not possible.

[a]Percentage of commission errors made by participants (commission-error rate).

[b]Comparison of commission-error rates between conditions or between trial types.

Table 5

Views and predictions about the source of aftereffects.

Source of Aftereffects & modulating factors	Key Findings	Support
Intention inhibition	• Slower lexical decisions for words related to performed or cancelled actions (Marsh 1998, 1999) or for words semantically associated with PM cues (Förster et al., 2005; see also Denzler et al., 2009, 2011)	
Goal value/expectancy	• Increased interference from PM-cue related words under high goal value, goal expectancy and in interaction with both (Förster et al., 2007)	✓
Intention deactivation	• No performance differences between words from a performed script and neutral words (Meilán, 2008)	
	• Faster lexical decisions for words from a performed script compared to neutral words (Penningroth, 2007)	✓/✗
Continued intention retrieval		
Likelihood or ease of intention retrieval		
Strength or integrity of associations between PM cue and intended action	• Larger aftereffects through implementation-intention encoding of a PM task (i.e., as an *"if-then"* plan; Bugg et al., 2013), which presumably strengthens the PM-cue-intended action association	
	• Stronger aftereffects after repeatedly performing an intended action (i.e., habit formation; Pink & Dodson, 2013; but see Bugg & Scullin, 2013; Bugg et al., 2016 for different findings in a Zeigarnik-like context)	
	• Reduced aftereffects when practicing withholding the PM response or performing the ongoing task in no-longer-relevant PM trials (i.e., weakening the PM-cue-intended action association through forgetting practice; Bugg et al., 2016)	✓
	• Reduced aftereffects after repeated encounters of no-longer-relevant PM cues in the finished phase, which presumably leads to a gradual association of the no-longer-relevant PM cue with ongoing-task responses (i.e., response-reconfiguration; Walser, Plessow, et al., 2014; cf. Cohen et al., 2005)	
	• Reduced commission errors in a simulation study after reducing the strength of PM-cue-action associations (Gilbert et al., 2013)	
Context match between active and finished phases	• Larger aftereffects when ongoing tasks matched between active and finished phases (e.g., both lexical decision tasks) than when ongoing tasks mismatched (e.g., image-rating task and lexical decision task) (Scullin et al., 2012)	
	• Aftereffects mostly reported in studies with ongoing-task match between active and finished phases (Anderson & Einstein, 2017; Beck et al., 2014; Bugg & Scullin, 2013; Bugg et al., 2016; Möschl et al., 2017; Pink & Dodson, 2013; Scullin & Bugg, 2013; Scullin et al., 2011, 2009; Walser et al., 2012; Walser, Fischer, Goschke, Kirschbaum, & Plessow, 2013; Walser, Goschke, et al., 2014; Walser, Plessow, et al., 2014)	✓
	• No aftereffects in studies with ongoing-task mismatch between active and finished phases (Cohen et al., 2017; Walser et al., 2017)	
Salience of no-longer-relevant PM cues and processing overlap between PM task and ongoing task	• Higher commission-error risk and commission-error rates when PM cues were perceptually salient and identifying PM cues required the same processing as performing the ongoing task (e.g., the word *fish* on a red background screen within a word-categorization task) than with nonsalient PM cues (black background screen) in ongoing task match conditions (Scullin et al., 2012)	
	• Few commission errors when PM tasks required additional processing of ongoing-task stimuli to identify PM cues: For instance, when PM tasks required participants to identify words that contain the letter string *tra* in a lexical decision task (Beck et al., 2014; Cohen et al., 2017; Moschl, Walser, Plessow, Goschke, & Fischer, 2017; Walser et al., 2012; Walser, Goschke, & Fischer, 2014; Walser, Plessow, Goschke, & Fischer, 2014; cf. Pink & Dodson, 2013)	✓
Availability of cognitive control over intention execution (Bugg et al., 2016; Scullin & Bugg, 2013)		

Source of Aftereffects & modulating factors	Key Findings	Support
Cognitive-control abilities or demands after intention completion	• More commission errors under high cognitive-control demands, like divided attention in finished phases (Pink & Dodson, 2013; cf. Schaper & Grundgeiger, 2017), with fatigued subjects (Scullin & Bugg, 2013) or when tasks specifically facilitate attention allocation to no-longer-relevant cues (Walser et al., 2017) • Higher commission-error risk for older adults with intact spontaneous retrieval (Mullet et al., 2013) but impaired inhibitory functioning (e.g., Lustig, Hasher, & Zacks, 2007; cf. Verhaeghen, 2011; Bugg, 2014 for evidence of spared control with age) when PM tasks needed to be suspended briefly (Boywitt, Rummel, & Meiser, 2015) or were finished (Bugg et al., 2016; Scullin & Bugg, 2013; Scullin et al., 2012; cf. Bugg et al., 2013; Cohen et al., 2005) • Higher commission error risk for older adults with Alzheimer's disease, who show impaired cognitive-control abilities (El Haj, Coello, Kapogiannis, Gallouj, & Antoine, 2018) • Transient activation of rostro-lateral prefrontal cortex that is argued to reflect a mobilization of reactive cognitive control in order to solve response conflicts (Braver, 2012) during encounters of no-longer-relevant PM cues (Beck et al. 2014) • Commission errors occur for cancelled intentions, despite forced response lags between no-longer-relevant PM cue and response opportunity, which is thought to provide time to mobilize cognitive control over intention execution (Schaper & Grundgeiger, 2019)	✓/✗
Personal dispositions or motivational orientations for control mobilization to disengage from finished intentions	• Higher memory accessibility of intention-related semantic networks after intention completion in prevention-focused individuals who often try to maintain a successfully attained goal state (e.g., Higgins, 1997) than in promotion-focused participants who often try to attain a new goal after finishing one (Hedberg & Higgins, 2011) • Stronger response slowing in no-longer-relevant PM trials in individuals with low self-reported action control (Kuhl, 1992), than in individuals with high self-reported action control (Walser, Goschke, et al., 2014; see Penningroth, 2011 for a similar finding in a script-based paradigm)	✓
Preparing for the occurrence of no-longer-relevant PM cues	• Compared to standard finished instructions, preparatory instructions after intention completion did not reduce the commission error risk in older adults, while nominally more younger adults made a commission error with this strategy (Bugg et al. 2016) • Practicing not giving the PM response to no-longer-relevant PM cues (i.e., forgetting practice), reduced commission errors in older adults, but had no effect in younger adults (because commission-error rates were already on floor; Bugg et al. 2016) • Fewer commission errors after verbalizing and writing down the finished PM task instructions or when informing participants at the beginning of the PM task that the task would be completed as soon as a single PM cue appeared (Anderson & Einstein, 2017)	✓/✗
Preparatory monitoring for PM cues or strategic response slowing as prerequisites for continued intention retrieval		
Performance costs in ongoing tasks during finished phases	• Commission errors occurred even though ongoing-task RTs in the finished phase did not differ between an intention and a no-intention condition, suggesting that participants did not continue monitoring for PM cues (Scullin & Bugg, 2013) or strategically slow down responding • Aftereffects occurred despite a decrease of ongoing task RTs in the finished compared to the active phase, suggesting that participants disengaged from monitoring after intention completion.(e.g., Möschl et al., 2017; Schaper & Grundgeiger, 2017; Walser et al., 2012, 2013) • No-longer-relevant PM cues elicited event-related activation in ventral parietal cortex, precuneus and posterior cingulate cortex (stimulus-driven attention and episodic memory retrieval; e.g., Cabeza, Ciaramelli, & Moscovitch, 2012; Summerfield & Egner, 2009) without behavioral monitoring costs or activation in rostro-lateral prefrontal cortex (Beck et al., 2014) that can be related to monitoring for PM cues (e.g., Cona, Scarpazza, Sartori, Moscovitch, & Bisiacchi, 2015; McDaniel et al., 2015) • Performing another (novel) PM task during finished phases (i.e., monitoring for another PM cue) increased aftereffects (Walser et al., 2012, 2017), even after changing the ongoing task, PM-cue type, PM-cue focality and PM response between novel and finished PM tasks (Walser et al., 2017). In this study, participants mostly made commission errors by giving the new PM response required for the novel PM task instead of the previous PM response. • Performing another PM task during finished phases increased response slowing after no-longer-relevant PM trials (Anderson & Einstein, 2017)	✗

Note. Support for the views presented in this table by the reviewed studies is indicated by: ✓ (full support), ✓/✗ (partial support), and ✗ (no support). Empty cells, denoted by “–”, indicate that a source of aftereffects or a modulating factor has not been tested yet.

Table 6

Alternative explanations and extensions of retrieval accounts of aftereffects.

Hypothesis	Key Findings	Support
Aftereffects occur due to confusion about finished task instructions, which leads to continued PM task performance.	• No participant reported having thought about the completed PM task at beginning of the finished phase (Anderson & Einstein, 2017) • Commission-error findings were robust against excluding participants, who indicated the slightest doubt about the finished instructions or gave false alarm PM responses in the active phase (Scullin et al., 2012) • No effect of knowledge of no-longer-relevant PM cues in the finished phase (Bugg et al., 2016)	✗
Commission errors occur due to the closeness of response buttons for ongoing-task response and PM response.	• Commission errors occurred when giving PM responses required an overt hand movement (Scullin et al., 2012)	✗
Aftereffects stem from a lack of episodic traces for intention completion (stop-tag account).	• More commission errors when PM tasks were cancelled or unexpectedly no PM cue appeared (Bugg & Scullin, 2013; Bugg et al., 2016; cf. Anderson & Einstein, 2017)	✓
Commission errors are errors of output monitoring (Cohen & Hicks, 2017)—a person's ability to remember his/her past responses in order to not repeat them (e.g., Koriat, Ben-Zur, & Sheffer, 1988).	• Conceptual similarity (in both paradigms PM responses become irrelevant at a certain point), but in paradigms that assess aftereffects participants are explicitly instructed that the PM task has been completed and that both PM cues *and* PM responses are no longer task relevant. By contrast, in output-monitoring paradigms it is up to the participants to recognize that they have responded to a PM cue and they have to mark the PM response as irrelevant themselves.	–
Aftereffects stem from a lack of time or cognitive resources for complete intention deactivation	• Aftereffects decreased with repeated exposure (and responding) to no-longer-relevant PM cues, but not over time (Walser, Plessow, et al., 2014) • No effects of introducing a delay between active and finished phases on aftereffects (Scullin & Bugg, 2013; Scullin et al., 2011) • Aftereffects decreased after demanding working memory task following intention completion (Walser, Goschke, et al., 2014)	✓/✗
Aftereffects in response to no-longer-relevant PM cues represent stimulus-triggered retrieval of specific stimulus-response links acquired during PM-task performance or at encoding.	• Aftereffects are not limited to specific PM cues (e.g., Walser et al., 2012; Anderson & Einstein, 2017) • Aftereffects occur for instructed PM cues that were never encountered during the active phase (Walser, Plessow et al. 2014)	✓/✗
Aftereffects stem from a lack of novel memoranda to overwrite completed intention representations (e.g., Walser, Goschke, et al., 2014).	• Aftereffects increased (no overwriting) when performing a novel PM task after intention completion (Walser et al., 2017) • Aftereffects decreased after performing demanding unrelated tasks (i.e., verbal backwards-letter span) after intention completion (Walser, Goschke, et al., 2014) • Fewer commission errors after filling the response delay between PM cue and the opportunity to perform the intended action during a delay-execute PM task with an unrelated task (Schaper & Grundgeiger, 2017) • When explicitly asking participants if they tried to deactivate the completed intention by thinking of a new task, almost every participant indicated that they did *not* use that strategy at all (Bugg et al., 2016)	✓/✗

Hypothesis	Key Findings	Support
Aftereffects stem from a residually heightened activation of completed intention representations in memory after intention completion.	• Preliminary support for a relation between memory activation of intention representations and intention retrieval: More frequent recall of uncompleted over completed tasks Zeigarnik (1938) Subjects with larger intention-superiority effects, more frequently performed the intended action (Schult & Steffens, 2017) • However, these findings could also be explained by a lack of episodic traces for intention completion with suspended, cancelled or uncompleted intentions (i.e., stop-tag account; e.g., Bugg & Scullin, 2013; Giesen & Rothermund, 2014)	–

Note. Support for the views presented in this table by the reviewed studies is indicated by: ✓ (full support), ✓/✗ (partial support), and ✗ (no support). Empty cells, denoted by "−", indicate that an alternative explanation or extension has not been tested yet.

Table 7

Conditions under which intention deactivation becomes difficult.

1. Strong link between retrieval cue and intended action (e.g., through implementation-intention encoding)
2. Impaired encoding of having performed an intended action (i.e., lack of episodic traces for intention completion)
3. Impaired cognitive control over intention execution
4. Salient retrieval cues
5. Remaining in the context in which the intention was completed
6. Pursuing another intention of a similar type (i.e., an event-based intention) after completion

Note. Although each of these factors likely exacerbates the occurrence of aftereffects and commission errors, whether or not aftereffects occur at all might nevertheless depend on a combination of multiple factors.