Effects of Task and Individual Characteristics on the Aftereffects of Event-based Prospective Memory and Their Mechanisms: Postprint

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Abstract

Aftereffects of prospective memory refer to the phenomenon wherein individuals erroneously repeat executing completed prospective memory intentions, or wherein completed intentions interfere with ongoing tasks. Based on the multi-process theory of prospective memory, literature review reveals that task characteristics (prospective memory task characteristics, ongoing task characteristics, task context) and individual characteristics modulate event-based prospective memory aftereffects. Currently, theoretical explanations regarding the processing mechanisms of event-based prospective memory aftereffects mainly include automatic processing, controlled processing, retrieval-inhibition processing, stop-tag processing, dual-process, and dynamic multiprocess, among others. Among them, automatic processing can be divided into reflexive-associative processing and discrepancy-search processing, while controlled processing can be further divided into monitoring processing and inhibitory processing. The formation of event-based prospective memory aftereffects is more closely related to automatic processing and monitoring processing, whereas the attenuation of aftereffects relies more on inhibitory processing. Future research needs to thoroughly investigate the processing mechanisms of event-based prospective memory aftereffects, increase examination of prospective memory aftereffects across different types and in naturalistic contexts, and focus on exploring

Full Text

Preamble

Effects of Task Characteristics and Individual Traits on the Aftereffects of Event-Based Prospective Memory and Its Mechanism

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Abstract: The aftereffects of prospective memory (PM) refer to the phenomenon where individuals erroneously repeat an already completed PM intention (commission errors) or where completed intentions interfere with ongoing task performance. Based on the multiprocess theory of PM, a literature review reveals that task characteristics (PM task features, ongoing task features, task context) and individual traits modulate the aftereffects of event-based PM. Current theoretical explanations for the processing mechanisms of event-based PM aftereffects include automatic processing, controlled processing, extraction-inhibition processing, stop-tag processing, dual processing, and dynamic multiprocess frameworks. Among these, automatic processing can be subdivided into reflexive-associative and discrepancy-plus-search processing, while controlled processing can be divided into monitoring and inhibition processing. The formation of event-based PM aftereffects is more closely related to automatic and monitoring processing, whereas the deactivation of such aftereffects depends more heavily on inhibitory processing. Future research should further investigate the processing mechanisms of event-based PM aftereffects, expand examinations of different types of PM aftereffects and those in naturalistic contexts, and focus on exploring strategies to reduce PM aftereffects.

Keywords: aftereffects of prospective memory, task characteristics, individual traits, automatic processing, controlled processing
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In daily life, we frequently need to remember to complete future events or activities. This future-oriented memory is called prospective memory (PM), defined as remembering to execute a planned event or activity at an appropriate future time or in an appropriate situation (Einstein & McDaniel, 1990). PM is typically divided into event-based PM and time-based PM. Event-based PM has clear external cues, whereas time-based PM lacks obvious external cues and relies more on internal self-monitoring. Research indicates that intention representations may at least partially deactivate after PM task completion (Matos & Albuquerque, 2021b; Schaper & Grundgeiger, 2019; Walser, Plessow et al., 2014). However, the vast majority of studies consistently demonstrate that PM intentions do not completely deactivate after completion, leading to PM aftereffects (Bugg & Streeper, 2019; Cottini & Meier, 2020; Matos & Albuquerque, 2021a; Matos et al., 2020; Meier & Cottini, 2023; Möschl et al., 2020; Streeper & Bugg, 2021). For example, patients who remember to take daily medication may, after completing their prescribed dose, repeat the dose due to forgetting. When medications have significant side effects, overdosing can seriously affect health (Kimmel et al., 2007).

This phenomenon is termed PM aftereffects, referring to instances where individuals erroneously repeat an already completed PM intention (commission error, CE) or where completed intentions interfere with ongoing task performance (Bugg et al., 2016; Cottini & Meier, 2020; Matos & Albuquerque, 2021a; Meier & Cottini, 2023; Meier & Rey-Mermet, 2012, 2018; Möschl et al., 2020; Walser et al., 2017; Walser, Plessow et al., 2014; Xin et al., 2022; Guo et al., 2019; Xin et al., 2019; Xin et al., 2020; Zhou et al., 2020).

Dual-process or multiprocess theories posit that PM processing involves both automatic and controlled processing (McDaniel & Einstein, 2000; Scullin et al., 2013). Automatic processing does not consume cognitive resources and involves spontaneous retrieval when encountering target cues. Controlled processing, in contrast, consumes cognitive resources, requiring individuals to continuously monitor target cues and potential situations. This theory suggests that a range of factors determines whether PM processing consumes more cognitive resources, including task characteristics (PM task and ongoing task features) and individual traits (Einstein & McDaniel, 2005; Einstein et al., 2005; McDaniel & Einstein, 2000; Scullin et al., 2013). Although this theory was proposed for the PM activation phase, the activation and completion phases are closely related, and factors affecting PM performance during activation may also influence completed PM intentions (Matos & Albuquerque, 2021a; Möschl et al., 2020). Currently, some researchers have separately examined the effects of PM tasks, ongoing tasks, and individual traits on event-based PM aftereffects (Bugg & Scullin, 2013; Cottini & Meier, 2020; Matos & Albuquerque, 2021b; Matos et al., 2020; Meier & Cottini, 2023; Pink & Dodson, 2013; Schaper & Grundgeiger, 2017; Scullin et al., 2012; Scullin et al., 2011; Scullin et al., 2009; Walser, Goschke & Fischer, 2014; Walser et al., 2017), but no study has systematically reviewed the effects of task and individual characteristics on event-based PM aftereffects. Moreover, previous reviews of the cognitive and neural mechanisms of event-based PM aftereffects have been insufficient, mostly focusing on either formation or deactivation (Matos & Albuquerque, 2021a; Möschl et al., 2020; Huang et al., 2018), without detailed examination of both formation and deactivation mechanisms. Therefore, this paper will sequentially introduce the differential effects of task and individual characteristics on event-based PM aftereffects, further review the cognitive and neural mechanisms underlying formation and deactivation, and finally summarize limitations of existing research and future directions.

2. Effects of Task Characteristics and Individual Traits on Event-Based PM Aftereffects

2.1. Effects of Task Characteristics on Event-Based PM Aftereffects

2.1.1. PM Task Characteristics Task characteristics refer to general properties of tasks, such as task type. Research on event-based PM aftereffects includes both PM tasks and ongoing tasks, and their effects can be comprehensively analyzed from the features of both tasks. PM task characteristics mainly include PM cue features (salience, focality, semantic and perceptual cue types, number of cues, etc.) and PM task nature (habitual PM tasks, similarity between activation and completion phases, etc.). Research shows that PM cue features not only relate to PM performance during activation but also affect the magnitude of PM aftereffects.

Salient cues typically manipulate the specificity of PM cues to make them clearly distinct from other stimuli. Most studies change the color of PM cues: non-salient cues are usually black or white, matching the color of ongoing task stimuli, whereas salient cues are typically red, clearly different from ongoing task stimuli. Research finds that salient cues, due to their "prominent" external visual features, promote spontaneous retrieval of PM intentions (Harrison et al., 2014; Kretschmer-Trendowicz & Altgassen, 2016; Smith et al., 2007). Scullin et al. (2012) systematically compared the effects of salient and non-salient cues on PM aftereffects, finding that salient cues produced more commission errors than non-salient cues. This may be because salient cues remain at a higher activation level during the completion phase, making spontaneous retrieval more likely and thus increasing PM aftereffects.

Previous research rarely distinguished between cue salience and focality, with most studies directly using salient and focal PM cues (Bugg & Scullin, 2013; Bugg et al., 2013; Bugg et al., 2016; Pink & Dodson, 2013; Scullin & Bugg, 2013; Scullin et al., 2011; Scullin et al., 2009). In addition to salient cues, focal cues also increase PM aftereffects (Hefer et al., 2017; Meier & Cottini, 2023; Meier & Rey-Mermet, 2018). Focality refers to whether the ongoing task can promote processing of key features of PM cues; if it can, this constitutes focal processing, otherwise it is non-focal processing. Under focal processing conditions, processing of the ongoing task facilitates processing of key features of target cues, which involves automatic processing. Meier and Cottini (2023) used commission errors and reaction times to original PM cues and ongoing tasks as indicators, finding that focal cues enhanced processing overlap between PM and ongoing tasks, leading to spontaneous retrieval of completed intentions and thus increasing PM aftereffects.

Recent research shows that semantic and perceptual cue types modulate PM aftereffects. Unlike salient cues, perceptual cues do not always have "prominent" external features and may be quite similar to perceptual features of ongoing task stimuli. Cottini and Meier (2020) randomly assigned participants to semantic or perceptual cue conditions. In the perceptual cue condition, participants performed a specific key press when encountering red or yellow objects, whereas in the semantic cue condition, they responded when encountering objects belonging to animals or ships. Using commission errors and reaction times to original PM cues and ongoing tasks as indicators, they found that semantic cues produced larger PM aftereffects than perceptual cues. They argued that semantic cues consume more cognitive resources than perceptual cues and rely more on monitoring processing. In the PM activation phase, monitoring processing strengthens the association between PM cues and intentions, and active monitoring increases PM aftereffects.

Bugg and Scullin (2013) manipulated the number of cues, finding that incomplete PM intention conditions (0 PM cues) produced more PM aftereffects than completed intention conditions (4 PM cues). This can be explained by the Zeigarnik effect, which states that unexecuted intentions are more memorable than executed ones (Marsh et al., 1998; Zeigarnik, 1938). Therefore, compared to 4 cues, the 0-cue condition may maintain PM intentions at a higher activation level, making commission errors more likely and producing larger PM aftereffects.

Multiple executions of PM intentions may yield two outcomes: (1) increased cue-intention activity association, promoting spontaneous retrieval of completed PM intentions and causing PM aftereffects (McDaniel et al., 2009; Pink & Dodson, 2013); (2) increased contextual traces of completed PM intentions or formation of richer intention completion representations, making it easier to form memories of not executing (No-Go). When cognitive resources are sufficient, inhibitory control can deactivate completed PM intentions, thereby reducing PM aftereffects, which involves inhibitory processing (Bugg et al., 2016; Walser, Plessow et al., 2014). Since prior execution of PM tasks facilitates deactivation of completed intentions, what effect does the number of cue presentations have on PM aftereffects? Walser and Plessow et al. (2014) manipulated the number of PM cue presentations during the completion phase (4 or 12 times) and found that 12 presentations of PM cues did not increase PM aftereffects. Multiple executions of PM responses promoted deactivation of completed intentions, consistent with the second outcome described above, and is better explained by inhibitory processing.

Researchers mostly explain the effects of cue features on PM aftereffects based on the strength of cue-intention activity associations, which relates to PM intention encoding methods. Manipulation of encoding methods primarily occurs during the encoding phase of PM intention formation, where instructions are used to increase or decrease the strength of PM cue-intention associations. Compared to standard encoding, implementation intention encoding produces larger PM aftereffects (Bugg et al., 2013). Implementation intention encoding establishes the strength of association between cues and intentions, specifically using the "if-then" format: "If I encounter X, then I will perform Y." This strategy contains two components: the "if" component involves detecting the anticipated situation, while the "then" component automatically activates and executes the behavior associated with the target intention (Bugg et al., 2013; Zimmermann & Meier, 2010). This encoding strategy prompts individuals to mentally represent the situation and tightly link it to behavioral responses, promoting spontaneous retrieval of completed intentions and thus increasing PM aftereffects.

In addition to cue features, PM task nature also affects the magnitude of PM aftereffects. Most studies require participants to execute PM tasks multiple times during the activation phase and then respond to ongoing tasks when encountering original PM cues during the completion phase. Habitual PM tasks refer to establishing specific responses to PM targets during the activation phase, creating habitual stimulus-response associations that promote spontaneous retrieval of completed intentions and cause PM aftereffects. Multiple executions of PM intentions do not necessarily produce habitual PM responses. Compared to executing PM intentions only several or a dozen times, executing them dozens of times is more likely to produce habitual PM responses. Therefore, habitual PM tasks with multiple executions may lead to automatic processing of completed PM intentions and may also produce richer intention completion representations for inhibitory processing of completed intentions. Since PM aftereffects are modulated by multiple factors (e.g., task load, individual executive control levels), these factors all influence research results. If larger PM aftereffects are observed in habitual PM tasks compared to non-habitual PM tasks, automatic or dual-process explanations are more appropriate. If smaller PM aftereffects are observed in habitual PM tasks, inhibitory processing explanations are more appropriate. McDaniel et al. (2009) found that habitual PM tasks increase cue-intention activity associations, leading to higher commission errors. Similarly, Pink and Dodson (2013) manipulated PM task habituality and found that habitual conditions increased commission errors compared to non-habitual conditions. Habitual responses to PM cues formed during the activation phase place completed intentions at a high activation level, making spontaneous retrieval more likely and requiring higher-level inhibitory control for deactivation. Individuals typically experience inhibitory failure, resulting in PM aftereffects.

Walser et al. (2017) investigated how similarity between activation and completion phases affects PM aftereffects. This study divided PM cues and response types during activation and completion phases into four conditions: both cues and response types similar, both different, cues similar but response types different, and cues different but response types similar. Using commission errors and reaction times to original PM cues and ongoing tasks as indicators, they found that only similarity in PM cues between activation and completion phases promoted spontaneous retrieval of completed PM intentions, leading to larger PM aftereffects. PM aftereffects represent sustained activation of stimulus components of intention representations, and cue similarity triggers automatic retrieval of action components for original PM cues. This does not store PM intention representations as specific associations between cues and behavioral responses, because similarity in response types between activation and completion phases did not affect PM aftereffect magnitude, suggesting that representations of completed PM intentions may not be stored as specific cue-keypress associations (Walser et al., 2017).

2.1.2. Ongoing Task Characteristics In addition to PM task characteristics, ongoing task characteristics also affect PM aftereffects. Ongoing task features include ongoing task load and matching between activation and completion phases. If ongoing task cognitive load increases, cognitive resources available for inhibiting completed PM intentions decrease. When cognitive resources are insufficient, inhibitory failure occurs, leading to PM aftereffects. Some researchers increased ongoing task cognitive load during the completion phase, such as adding tone monitoring tasks (Boywitt et al., 2015) or digit monitoring tasks (Pink & Dodson, 2013), and found that increased ongoing task cognitive load increased PM aftereffects. Recently, Matos et al. (2020) added a counting recall task to an ongoing lexical decision task, requiring participants to count the number of yellow screens (medium load) or all colored screens (high load) in addition to performing the ongoing task. Using commission errors and reaction times to original PM cues and ongoing tasks as indicators, they found that medium load conditions produced larger PM aftereffects compared to no load, with no difference between medium and high load conditions. High load conditions did not produce larger PM aftereffects, possibly because cognitive load interfered with PM cue processing, preventing completed PM intentions from entering conscious awareness. Given that no significant PM aftereffects were observed under high ongoing task cognitive load, the relationship between ongoing task cognitive load and PM aftereffects may be non-linear, meaning that increased ongoing task cognitive load does not necessarily increase PM aftereffects.

Previous research rarely distinguished between ongoing tasks in PM activation and completion phases, mostly setting them as identical (Matos & Albuquerque, 2021a; Möschl et al., 2020; Scullin et al., 2011; Scullin et al., 2009). Scullin et al. (2012) found that matching between activation and completion phase ongoing tasks affected PM aftereffects. In the matching condition, both phases used lexical decision tasks, whereas in the non-matching condition, the activation phase used picture rating tasks and the completion phase used lexical decision tasks. Results showed that matching ongoing tasks between activation and completion phases produced higher commission errors. Matching increased cognitive processing overlap, promoting spontaneous retrieval of completed PM intentions. When encountering original PM cues during the completion phase, inhibitory failure was more likely, resulting in PM aftereffects.

2.1.3. Task Context In addition to PM and ongoing task characteristics, PM aftereffects also relate to task context, which refers to task-related settings and execution backgrounds. Task paradigms and background settings between activation and completion phases are associated with formation and deactivation of PM aftereffects. Laboratory research assessing event-based PM aftereffects mainly employs two paradigms: event-based PM paradigms with semantic associates of PM cues and event-based PM paradigms with no longer relevant PM cues. The latter can be subdivided into three types: repetition error paradigm, repeated cycles paradigm, and commission errors paradigm (Matos & Albuquerque, 2021a; Möschl et al., 2020). (1) The semantic association paradigm requires participants to retrieve picture combinations during picture rating tasks alternating with lexical decision tasks. When retrieving PM picture cue combinations, reaction times for lexical decisions of words semantically related to PM cues are compared to unrelated words. Similar or slower reactions are considered evidence of deactivation or inhibition of completed intentions (Förster et al., 2005). (2) The repetition error paradigm does not involve a PM completion phase, typically requiring participants to perform a specific PM response when PM cues first appear and a different key press when cues reappear. Therefore, if participants correctly respond to the first PM cue presentation but still perform the original PM response when the cue reappears, this results in commission errors (Matos & Albuquerque, 2021a). (3) The repeated cycles paradigm involves participants completing multiple cycles of activation and completion phases (Walser et al., 2012; Walser, Goschke & Fischer, 2014; Walser et al., 2017; Walser, Plessow et al., 2014). After the activation phase, participants are informed that the PM task is completed and they should only perform the ongoing task. After the completion phase, a new activation-completion cycle begins with different PM cues. PM aftereffects are assessed by comparing differences (reaction times, ongoing task errors, commission errors, etc.) between no-longer-relevant PM cues and baseline trials. (4) The commission errors paradigm requires participants to execute single activation and completion phases (Bugg & Scullin, 2013; Bugg et al., 2013; Bugg & Streeper, 2019; Scullin & Bugg, 2013; Scullin et al., 2012; Scullin et al., 2011), without requiring participants to respond only to the first PM cue presentation. During activation, participants perform ongoing tasks and specific responses to PM targets. During completion, they do not need to respond to original PM targets, only performing ongoing tasks. PM aftereffects are reflected by participants' responses to original PM targets during completion or interference with ongoing tasks (Möschl et al., 2020). Schaper and Grundgeiger (2017) developed a delay-execute paradigm based on the commission errors paradigm to examine PM aftereffects. This paradigm requires a clear time delay between intention retrieval and execution of the associated action. It differs from the commission errors paradigm in two key ways: first, only the delay-execute paradigm has an obvious temporal pause between intention retrieval and execution; second, PM cues in the delay-execute paradigm typically have high salience to ensure intention retrieval, whereas commission errors paradigms do not always use highly salient PM cues. Paradigms differ substantially. For example, the semantic association paradigm involves semantic networks associated with cues or anticipated actions, which may be inhibited more quickly after intention completion. Paradigms with no-longer-relevant PM cues involve cue representations, anticipated actions, or stimulus-response associations that are more difficult to deactivate after intention completion (Möschl et al., 2020). Additionally, semantic association and repetition error paradigms do not involve PM completion phases, whereas repeated cycles, commission errors, and delay-execute paradigms all involve both activation and completion phases. The repeated cycles paradigm requires constantly switching responses to formed PM intentions when measuring PM aftereffects, whereas the commission errors paradigm has relatively lower demands on this ability, and the indicators used to measure PM aftereffects also differ between them. In summary, differences in task paradigms may also affect PM aftereffect magnitude.

In addition to task paradigms, time delay and task load between activation and completion phases also relate to PM aftereffects. Over time and with interference from other memory content, intention representations may gradually deactivate after intention completion (Walser, Plessow et al., 2014). Scullin et al. (2009, 2011) manipulated the interval between encountering original PM cues during the completion phase to create long (requiring a picture rating task with 80 trials) and short (requiring a picture rating task with 24 trials) time delays. Using reaction times to original PM cues and ongoing tasks as indicators, they found no significant difference in reaction times between original PM cues and baseline trials under both delay conditions, suggesting that time delay does not affect PM aftereffects. In contrast, Walser et al. (2012) found that PM aftereffects gradually decreased with increased delay time. Similarly, Walser and Plessow et al. (2014) set two blocks containing original PM cues during the completion phase and found that participants responded more slowly only to original PM cues in the first block, with no difference between original PM cues and baseline trials in the second block, indicating that PM aftereffects are less likely under long delay conditions. Currently, conclusions about the relationship between time delay and PM aftereffects remain inconsistent. Possible reasons for these discrepancies include the paradigms used, types of PM and ongoing tasks, and delay interval settings. Walser et al. used the repeated cycles paradigm with perceptual cues (symbol judgment) and a digit parity judgment ongoing task, with time delays set through block sequences. Scullin et al. primarily used the commission errors paradigm with semantic cues (specific word judgment) and a lexical classification ongoing task, with time delays set by varying trial numbers.

Increasing task load between activation and completion phases also affects PM aftereffect magnitude. Walser and Goschke et al. (2014) manipulated task load between PM activation and completion phases and found that, compared to control conditions, performing a more cognitively demanding task after the activation phase reduced PM aftereffects. Recently, Matos and Albuquerque (2021b) also investigated the effect of task load between PM activation and completion phases on PM aftereffects. Participants completed a verbal comprehension task under no working memory load and 3-back and 1-back tasks under high and low working memory load, respectively. Using reaction times to original PM cues and ongoing tasks as indicators, they found that both high and low task loads produced fewer PM aftereffects compared to no working memory load. Deactivation of completed PM intentions depends on cognitive resources available before the completion phase begins. Immediately performing a medium or high working memory load task after the PM activation phase promotes deactivation of completed PM intentions.

2.2. Effects of Individual Traits on Event-Based PM Aftereffects

2.2.1. Age In addition to task characteristics, individual traits also affect PM aftereffects. Individual traits refer to characteristics and differences individuals possess in physiological, psychological, and behavioral aspects. Numerous studies have examined age-related differences in PM aftereffects, finding that PM aftereffects are closely associated with cognitive aging (Boywitt et al., 2015; Bugg et al., 2013; Bugg et al., 2016; Cottini & Meier, 2020; May et al., 2015; Scullin et al., 2012; Scullin et al., 2011). Cottini and Meier (2020) first compared PM aftereffects across three age groups, finding that children monitored

PM cues less than young and older adults during activation, but both children and older adults showed larger PM aftereffects than young adults during completion. Children' s cognitive functions are still developing, making it difficult to fully inhibit completed PM intentions (Cottini & Meier, 2020). Additionally, cognitive aging reduces inhibitory control ability, which is closely related to preventing dominant responses and reducing interference from irrelevant stimuli. Compared to young adults, children and older adults, due to insufficient inhibitory control, have difficulty inhibiting spontaneous retrieval of completed PM intentions during completion, easily forming PM aftereffects (Scullin et al., 2011; Xin et al., 2019).

2.2.2. Executive Control and Output Monitoring Executive control is a higher-order cognitive ability referring to individuals' capacity to store, plan, and manipulate relevant information in a top-down, goal-directed manner during information processing (Braver & Barch, 2002). Executive control ability is negatively correlated with PM aftereffect magnitude (Scullin et al., 2012; Scullin et al., 2011). Scullin et al. (2012, 2011) used Stroop tasks, Trail Making Tests, and Wisconsin Card Sorting Tasks to measure individual executive control ability and investigate its relationship with PM aftereffects, finding that higher executive control ability corresponded to less pronounced PM aftereffects. Output monitoring of completed PM intentions is an important factor in reducing PM aftereffects. During completion, individuals must notice and recall that they have already executed the original PM intention. Output monitoring refers to memory for whether an intended action has been completed (Ball et al., 2018; Skladzien, 2010). Output monitoring failure may lead to repetition of planned actions or omission of planned actions. Ball et al. (2018) found that attentional control relates to output monitoring during PM activation, while output monitoring of completed PM intentions relates to episodic memory. When participants correctly judge that original PM cues have previously appeared and press the "repeat" button, this constitutes successful output monitoring. Output monitoring failure occurs when participants judge original PM cues as appearing for the first time and incorrectly press the "first appearance" button (i.e., commission error) or fail to detect original PM cues (i.e., miss). Results showed that regardless of attentional processing involved, once PM intentions are completed, output monitoring performance relates to episodic information about original PM cues. Stronger output monitoring ability promotes deactivation of completed PM intentions.

2.2.3. Personality Traits Action versus state orientation is considered a potential moderator of PM aftereffects (Penningroth, 2011). State orientation refers to the tendency to be indecisive and hesitant about new intentions, whereas action orientation refers to the tendency to take immediate action and decisively initiate new intentions (Goschke & Kuhl, 1993). Kuhl and Beckmann (1994) proposed that individuals may have tendencies toward action or state orientation, considered a personality trait that develops and stabilizes over time.

Research shows that state-oriented individuals maintain intentions at higher activation levels more than action-oriented individuals. Moreover, state-oriented participants show more persistent retrieval of unsuccessfully completed intentions (Beckmann, 1994; Goschke & Kuhl, 1993). According to the residual activation view, PM tasks typically remain at higher activation levels than other memory contents. When completed PM intentions continue to maintain high activation levels, PM aftereffects occur (Walser et al., 2012). Walser and Goschke et al. (2014) used reaction times to original PM cues and ongoing tasks as indicators, finding that state-oriented individuals produced larger PM aftereffects than action-oriented individuals. State-oriented individuals' slower responses to PM cues may reflect elaborative processing, which strengthens PM intention representations, making completed PM intentions more difficult to deactivate and thus producing larger PM aftereffects.

Considering PM task characteristics comprehensively, salient and focal cues and increased cue-intention association strength promote spontaneous retrieval of completed PM intentions, while semantic cues may promote sustained monitoring of completed PM intentions. Both facilitate PM aftereffect formation. Compared to unexecuted PM intentions, executed PM intentions promote deactivation of PM aftereffects. Reducing cue salience, focality, and cue-intention association strength facilitates deactivation of completed PM intentions. Compared to semantic cues, perceptual cues also promote deactivation of completed PM intentions. Habitual PM tasks and similarity in PM cue types between activation and completion phases typically promote automatic processing of completed PM intentions, making it difficult for individuals to inhibit spontaneously retrieved PM intentions and thus facilitating PM aftereffect formation. However, reducing PM task habituality and similarity in PM cue types between activation and completion phases may promote deactivation of PM aftereffects.

Regarding ongoing task characteristics, high ongoing task cognitive load typically consumes more cognitive resources, leaving insufficient resources for inhibiting completed PM intentions during completion, thus facilitating PM aftereffect formation. Matching between activation and completion phase ongoing tasks promotes spontaneous retrieval of completed PM intentions, requiring higher-level inhibitory control for deactivation. Individuals typically experience inhibitory failure, resulting in PM aftereffects. Therefore, reducing ongoing task cognitive load allows limited cognitive resources to be used for inhibiting completed PM intentions. Moreover, reducing matching between activation and completion phase ongoing tasks may reduce spontaneous retrieval of completed PM intentions and promote deactivation of PM aftereffects.

Task context settings may also affect PM aftereffects, including task paradigms and settings between activation and completion phases. Currently, only speculation exists that paradigm differences may affect PM aftereffect magnitude, but which paradigms more effectively promote formation or deactivation requires further investigation. Deactivation of completed PM intentions relates to settings between activation and completion phases. Typically, increasing time delay between phases reduces activation levels of completed intentions and promotes deactivation of intention representations. Increasing task load between phases may interfere with retrieval of completed PM intentions. Both facilitate deactivation of PM aftereffects. Conversely, reducing time delay and task load between phases may facilitate PM aftereffect formation.

Regarding individual traits, cognitive aging associated with increasing age makes it difficult to deactivate completed PM intentions, facilitating PM aftereffect formation. Executive control and output monitoring abilities are closely related to PM aftereffect deactivation; higher abilities promote deactivation, while lower abilities facilitate formation. Action-oriented individuals have advantages in initiating new intentions and inhibiting completed PM intentions, more likely promoting deactivation. State-oriented individuals have difficulty deactivating completed PM intentions, facilitating PM aftereffect formation.

3. Cognitive and Neural Mechanisms of Formation and Deactivation of Event-Based PM Aftereffects

Research on PM aftereffects has primarily focused on influencing factors, with limited exploration of processing mechanisms. Most studies address mechanism questions through prospective interference effects, which refer to interference with ongoing tasks (slower ongoing task reaction times) when executing PM intentions (Marsh et al., 2006; McDaniel & Einstein, 2000). In PM aftereffect research, reaction times during the completion phase (including original PM cues and ongoing tasks) can be compared to baseline conditions (ongoing tasks only). If no difference exists, completed PM intentions do not consume cognitive resources, supporting automatic processing. If reaction times in experimental conditions are slower than baseline, completed PM intentions consume cognitive resources during completion, supporting controlled processing. PM aftereffect formation and deactivation may involve different processing mechanisms: formation relates more closely to automatic and monitoring processing, while deactivation depends more heavily on inhibitory processing.

3.1. Cognitive and Neural Mechanisms of Event-Based PM Aftereffect Formation

3.1.1. Cognitive Processing Mechanisms of Event-Based PM Aftereffect Formation: Automatic and Monitoring Processing Automatic processing theory posits that PM aftereffect formation does not consume cognitive resources and does not require allocating cognitive resources to monitor environments for original PM cues. During activation, encoded and executed PM intentions establish strong stimulus-response associations that remain at high activation levels. During completion, encountering original PM cues triggers spontaneous retrieval of completed PM intentions, causing PM aftereffects (Anderson & Einstein, 2017; Bugg et al., 2013; Cohen et al., 2020; Meier & Rey-Mermet, 2018; Scullin & Bugg, 2013; Scullin et al., 2011; Scullin et al., 2009). Automatic processing of PM aftereffects can be subdivided into reflexive-associative and discrepancy-plus-search processing (Kurtz et al., 2022; McDaniel et al., 2015; Scullin et al., 2013). Reflexive-associative processing holds that after forming and storing PM intentions in long-term memory, encountering original PM cues reflexively reactivates stimulus-response associations between original PM cues and anticipated actions (McDaniel et al., 2004; McDaniel et al., 2015), forming PM aftereffects. Discrepancy-plus-search processing argues that performing specific responses to PM cues during ongoing tasks creates differential experiences that trigger automatic memory searches for the source of experienced differences (Breneiser & Mcdaniel, 2006). This interferes with task processing fluency, triggering subsequent automatic searches in memory and retrieving completed PM intentions (Kurtz et al., 2022), thus forming PM aftereffects. Since both spontaneous retrieval processes may manifest as slowed ongoing task reaction times or commission errors during completion (Bugg & Streeper, 2019; Möschl et al., 2020), PM aftereffects reflected by these processes cannot be directly distinguished through discrete indicators like reaction times or commission errors. Mouse-tracking technology can record continuous response data, tracking mouse movement direction and speed and providing information about cognitive processing that may occur during response selection. Kurtz et al. (2022) combined this technology to examine whether PM aftereffects (based on commission errors, reaction times to original PM cues and ongoing tasks) depend on reflexive-associative or discrepancy-plus-search processing in spontaneous retrieval. When comparing trials encountering original PM cues during completion to ongoing task trials, decreased mouse movement speed would support discrepancy-plus-search processing, while increased movement curvature and angle would support reflexive-associative processing. They found that encountering original PM cues during completion increased mouse movement curvature and angle, validating reflexive-associative processing.

Controlled processing theory holds that PM aftereffect formation consumes cognitive resources. Based on where cognitive resources are allocated, this is divided into strategic monitoring and inhibition processing. Strategic monitoring holds that completed PM intentions remain at high activation levels, and participants continue to invest cognitive resources in sustained searching and active monitoring during completion, similar to preparatory attentional and memory processing. When encountering original PM cues during completion, individuals no longer need to perform specific key presses, only ongoing task responses. Because individuals continuously monitor original PM cues, they may strategically slow ongoing task responses after completing PM intentions to increase opportunities for detecting original PM cues. This increased detection opportunity may reduce commission errors but increases interference with ongoing tasks during completion. PM aftereffect formation relates to top-down monitoring processing or strategic slowing after intention completion. Therefore, more invested cognitive resources lead to stronger monitoring and easier PM aftereffect formation (Meier & Rey-Mermet, 2012; Möschl et al., 2019; Strickland et al., 2018; Walser et al., 2012; Walser et al., 2017).

According to the core assumptions of PM multiprocess theory, top-down and bottom-up processes involve all PM stages (encoding, storage, retrieval, execution, and deactivation) (Ellis, 1996; Kliegel et al., 2002; Matos & Albuquerque, 2021a). This theory suggests that PM aftereffects involve two distinct processing mechanisms: spontaneous retrieval and inhibition (Scullin & Bugg, 2013). Researchers have also proposed the dynamic multiprocess view based on multiprocess theory, which holds that cognitive resource occupation during PM task completion is not a simple all-or-none relationship but involves selective, dynamic allocation of cognitive resources based on contextual features (Scullin et al., 2013; Shelton & Scullin, 2017). According to the dynamic multiprocess view, both bottom-up automatic processing and top-down strategic processing are involved when intentions are completed or no longer needed, with individuals dynamically adjusting cognitive resource investment based on task context (Bugg & Streeper, 2019; Matos & Albuquerque, 2021a). For example, when ongoing task cognitive load is low, sufficient cognitive resources exist to inhibit retrieval of completed PM intentions, whereas when ongoing task load is high, insufficient resources for inhibiting completed PM intentions lead to more automatic processing. Therefore, individuals dynamically adjust cognitive strategies across different ongoing task load blocks. Encountering original PM cues during completion (especially salient, focal cues) triggers spontaneous retrieval of previously related intention content, which is automatic processing. Inhibitory processing suppresses retrieval or execution of completed intentions. Additionally, reflexive-associative and discrepancy-plus-search processes involved in spontaneous retrieval affect the involvement of controlled processing (Kurtz et al., 2022). Reflexive-associative processing only allows cognitive control to affect response levels to completed PM intentions, inhibiting execution of completed PM intentions triggered by conditioned reflexes (late inhibition). Discrepancy-plus-search processing allows cognitive control to function at the memory level, inhibiting or interrupting associative memory searches for experienced differences when encountering original PM cues (early inhibition). Therefore, according to dual-process and dynamic multiprocess views, individuals may dynamically adjust cognitive strategies during PM aftereffect formation. Completed PM intentions trigger automatic processing, and individuals may inhibit original PM responses. When cognitive control is impaired, inhibitory failure occurs, forming PM aftereffects.

In summary, during completion, individuals repeating completed PM intentions or completed intentions interfering with ongoing tasks both form PM aftereffects. Among these, encountering completed PM intentions and spontaneously retrieving them more easily produces commission errors (Anderson & Einstein, 2017; Scullin & Bugg, 2013; Scullin et al., 2011; Scullin et al., 2009). Sustained monitoring of completed PM intentions during completion leads to prolonged reaction times to original PM cues and ongoing tasks, interfering with ongoing tasks (Meier & Rey-Mermet, 2012; Möschl et al., 2019; Walser et al., 2012; Walser et al., 2017). Dual-process and dynamic multiprocess theories support both spontaneous retrieval and inhibitory processing of completed PM intentions. When cognitive resources are insufficient, PM aftereffects form. However, when cognitive resources are sufficient, PM aftereffect deactivation is also promoted. Therefore, automatic and monitoring processing may more effectively explain PM aftereffect formation.

3.1.2. Neural Mechanisms of Event-Based PM Aftereffect Formation

Since PM aftereffect formation closely relates to automatic and monitoring processing, reviewing relevant neural pathways can elucidate the neural mechanisms of PM aftereffect formation. Beck et al. (2014) used functional magnetic resonance imaging (fMRI) to dissociate brain region activation related to automatic and monitoring processing in PM aftereffects. Encountering original PM cues during PM completion activated brain regions including the insula, posterior cingulate cortex, ventral frontoparietal network, and medial temporal lobe, which are associated with spontaneous retrieval of PM intentions (Beck et al., 2014; Cona et al., 2015), see Figure 1 [Figure 1: see original paper]. Brain regions activated by reflexive-associative and discrepancy-plus-search spontaneous retrieval are generally similar but have some differences. During completion, the insula selectively processes and amplifies relevant features of PM cues, then transmits this information to the posterior cingulate cortex (Cona & Rothen, 2019). In discrepancy-plus-search spontaneous retrieval, information transmitted to the posterior cingulate cortex is further conveyed to the ventral frontal cortex, which supports shifting attentional resources from external cues to internal memory to search for corresponding stored traces. After PM completion, repeated original PM cues still trigger retrieval of corresponding intention representations from long-term memory, involving retrospective or episodic memory retrieval processes that activate medial temporal lobe regions. The medial temporal lobe establishes automatic associations between cues and intention activities and maintains them in an activated state. When encountering original PM cues, relevant intention content is spontaneously retrieved, forming PM aftereffects (Beck et al., 2014; Scullin et al., 2020; Huang et al., 2018). Similarly, reflexive-associative spontaneous retrieval also involves the insula, posterior cingulate cortex, and medial temporal lobe. Unlike discrepancy-plus-search processing, information transmitted to the posterior cingulate cortex is first sent to the rostrolateral prefrontal cortex, which maintains completed PM intentions in an activated state in long-term memory, and through the ventral parietal cortex, reflexively retrieves completed PM intentions, forming PM aftereffects (Beck et al., 2014; Cabeza & Moscovitch, 2013).

In monitoring processing, relevant information about repeated original PM cues is first amplified through the insula and then transmitted to the anterior cingulate cortex. During completion, original PM cues and ongoing task stimuli may produce competing conflict signals, activating the anterior cingulate cortex. The insula and anterior cingulate cortex together constitute the “salience network,” which detects internal and external information related to PM intentions. The anterior cingulate cortex typically co-activates with the dorsolateral prefrontal cortex and posterior parietal cortex to form a “cognitive control network structure" that monitors completed PM intentions (Beck et al., 2014; Cona et al., 2015; Friedman & Robbins, 2022; Huang et al., 2018). The anterior cingulate cortex transmits conflict signals between original PM cues and ongoing tasks to the dorsal frontoparietal network. The dorsal frontoparietal network, composed of the dorsolateral prefrontal cortex, precuneus, and posterior parietal cortex, relates to strategic monitoring processing, see Figure 2 [Figure 2: see original paper]. Based on this signal, the dorsal frontoparietal network allocates top-down attention according to ongoing task and original PM cue response requirements, regulates processing of relevant stimulus features in sensory cortex, maintains activation of completed PM intentions, and monitors appearance of original PM cues. Greater cognitive resource investment more easily forms PM aftereffects (Cona & Rothen, 2019; Cona et al., 2015).

3.2. Cognitive and Neural Mechanisms of Event-Based PM Aftereffect Deactivation

3.2.1. Cognitive Processing Mechanisms of Event-Based PM Aftereffect Deactivation: Inhibitory Processing Unlike PM aftereffect formation, aftereffect deactivation is more closely related to inhibitory processing. Inhibitory processing theory holds that activation levels of PM intention representations are actively reduced after intention completion. Activation levels of memory content related to PM intentions may drop below baseline levels, involving active inhibition of memory content related to completed PM intentions. Another view suggests that inhibitory processing reduces activation levels of completed PM intentions to near but not below baseline levels, not involving active inhibition but rather deactivation of activated completed PM intentions. Moreover, inhibiting completed PM intentions helps establish new intention representations (El Haj et al., 2018; Matos & Albuquerque, 2021a; Möschl et al., 2020). Strong PM intentions formed during activation require inhibitory processing during completion when original PM tasks are no longer required, ensuring execution of ongoing tasks. However, inhibitory processing may involve two different modes: first identifying original PM cues then inhibiting completed PM intentions, or direct inhibition (without identifying original PM cues). The former refers to identifying original PM cues during completion and then investing cognitive resources to inhibit completed PM intentions. The latter refers to treating the entire completion phase block as ongoing task trials to directly inhibit identification of original PM cues and execution of completed PM intentions.

The stop-tag theory posits that deep episodic traces and rich intention completion representations are formed for PM intentions during activation. Instructions during completion bind stop-tags to cognitive representations of no-longer-relevant PM cue-response associations, making it easier to form memories of not executing (Bugg & Scullin, 2013; Bugg et al., 2016). According to memory reconsolidation theory, when memories are reactivated, they temporarily become unstable. In this unstable state, memories may be terminated (Nader & Hardt, 2009). Encountering original PM cues during completion reactivates goal-action associations, making them temporarily unstable and ready for memory termination. Therefore, encountering original PM cues during completion no longer triggers memory for original PM intentions, promoting deactivation of PM aftereffects.

According to the dynamic multiprocess view, individuals also spontaneously retrieve completed PM intentions during aftereffect deactivation, but individuals with higher cognitive control can more successfully inhibit completed PM intentions (Bugg & Scullin, 2013; Bugg et al., 2016; Bugg & Streeper, 2019; Kurtz et al., 2022; Matos et al., 2020; Schaper & Grundgeiger, 2019; Scullin & Bugg, 2013). When individuals realize PM intentions are completed, they may inhibit both intention activation and original PM responses (Bugg et al., 2016), and may also bind stop-tags to PM cue-response associations so that individuals encode new intentions of not performing previous actions when encountering original PM cues again (Bugg & Scullin, 2013). Both PM aftereffect formation and deactivation involve dual-process mechanisms: the former results from insufficient inhibitory processing, forming PM aftereffects, while the latter involves higher-level inhibitory processing that deactivates completed PM intentions. Combining automatic, monitoring, and dual-process theories, an extraction-inhibition processing pattern may also exist, which essentially still requires first identifying original PM cues and then inhibiting completed PM intentions (Matos & Albuquerque, 2021a; Möschl et al., 2020). This view partially explains PM aftereffect deactivation. Extraction-inhibition processing can be divided into automatic extraction-inhibition and monitoring extraction-inhibition. Automatic extraction-inhibition is consistent with the dual-process theory described above, while monitoring extraction-inhibition involves sustained monitoring of completed PM intentions, extracting and then inhibiting them. Because individuals continuously invest cognitive resources in monitoring completed PM intentions, encountering original PM cues during completion first leads to identification and then extraction of completed PM intentions, a process that consumes cognitive resources. After completed PM intentions are extracted, inhibitory processing is needed for deactivation. Therefore, high-level inhibitory processing more easily promotes deactivation of completed PM intentions, while low-level inhibitory processing makes deactivation difficult. Currently, only a few studies mention possible extraction-inhibition processing patterns, but have not systematically investigated differences between automatic and monitoring extraction-inhibition. Future research could use unified experimental paradigms to distinguish between them.

In PM aftereffect research, participants are typically told during completion that they do not need to execute original PM responses when encountering original PM cues, treating them as ongoing task responses. This process involves inhibiting extraction and execution of completed PM intentions (Möschl et al., 2020; Pink & Dodson, 2013; Scullin & Bugg, 2013; Guo et al., 2019; Xin et al., 2020). Stop-tag, dual-process, and dynamic multiprocess theories all involve inhibitory processing. To deactivate completed PM intentions, cognitive resources must be invested to inhibit them or form a preparation state of not executing when encountering completed PM intentions during completion. Therefore, inhibitory processing may more effectively explain PM aftereffect deactivation.

3.2.2. Neural Mechanisms of Event-Based PM Aftereffect Deactivation PM aftereffect deactivation is closely related to inhibitory processing. In addition to the insula, anterior cingulate cortex, dorsolateral prefrontal cortex, precuneus, and posterior parietal cortex, inhibitory processing also relates to the rostral prefrontal cortex, lateral orbitofrontal cortex, and supplementary motor area (Cona & Rothen, 2019; Cona et al., 2015; Scullin et al., 2020). When encountering original PM cues during completion, relevant information is amplified through the insula and transmitted to the cingulate cortex. At this point, PM responses to completed PM intentions are no longer needed, so encountering original PM cues generates response conflict signals, and individuals must inhibit responses to completed PM intentions, activating the anterior cingulate cortex and rostral prefrontal cortex. The lateral orbitofrontal cortex relates to establishing new stimulus-response associations and inhibiting old dominant responses after learning, and involves evaluating the appropriateness of previous stimulus-response associations appearing in the current context, linking to decision-making and difficulty of cognitive control responses (Izquierdo et al., 2017). When encountering original PM cues during completion, individuals must judge whether to continue PM responses, involving cognitive control processes consistent with controlled processing views. Currently, although no research has systematically reviewed the neural mechanisms of dual processing in PM aftereffects, speculation is possible based on neural pathways involved in automatic and inhibitory processing (see Figure 3 [Figure 3: see original paper]). When encountering original PM cues during completion, relevant information is amplified through the insula and transmitted to the cingulate cortex, which may activate neural pathways related to both automatic and inhibitory processing. Deactivation of completed PM intentions depends on inhibitory processing. When cognitive resources are sufficient, PM aftereffect deactivation is promoted, but when cognitive resources and inhibitory control abilities are insufficient, inhibitory failure occurs, leading to PM aftereffects. Additionally, the neural mechanisms of the extraction-inhibition model can be speculated from brain regions activated by automatic, monitoring, and inhibitory processing. Future research needs to increase investigation of neural mechanisms of PM aftereffects and systematically review brain regions involved in PM aftereffect deactivation.

4. Summary and Outlook

Completed PM intentions may not fully deactivate, leading to commission errors or interference with ongoing task performance, producing PM aftereffects. Based on PM multiprocess theory, factors influencing PM aftereffects can be broadly categorized as: PM task characteristics, ongoing task characteristics, task context, and individual traits. Current cognitive mechanism explanations for PM aftereffect formation and deactivation mainly involve automatic processing, controlled processing, extraction-inhibition processing, stop-tag processing, dual processing, and dynamic multiprocess frameworks. Among these, automatic processing is subdivided into reflexive-associative and discrepancy-plus-search processing, while controlled processing can be divided into monitoring and inhibitory processing. Extraction-inhibition processing includes spontaneous extraction-inhibition and monitoring extraction-inhibition. Neuroimaging evidence suggests that PM aftereffects may involve neural pathways for automatic, controlled, and dual processing. However, research on PM aftereffects has several limitations requiring further investigation.

4.1. In-Depth Investigation of Processing Mechanisms of Event-Based PM Aftereffects

Several important questions remain regarding processing mechanisms of event-based PM aftereffects. First, in automatic processing, the extent to which reflexive-associative and discrepancy-plus-search spontaneous retrieval participate in processing completed PM intentions and under what conditions remain unclear. Most studies only infer whether automatic processing occurred based on results, without directly investigating relationships between reflexive-associative/discrepancy-plus-search spontaneous retrieval and PM aftereffects. Similarly, it is unclear when cognitive control participates in deactivation of completed PM intentions. Moreover, does cognitive control inhibit retrieval of completed PM intention content, or only inhibit execution of completed intentions, or both? Second, previous mechanism investigations only analyzed response data from participants showing PM aftereffects (commission errors or interference with ongoing tasks), assuming that participants without PM aftereffects successfully inhibited completed PM intentions and did not spontaneously retrieve them. However, if participants without commission errors show slower responses to original PM cues than baseline, this suggests that even though they inhibited repetition of completed PM intentions, they still spontaneously retrieved completed PM intentions (Matos & Albuquerque, 2021a). Finally, only two studies have directly investigated neural mechanisms of PM aftereffects, both with small samples of middle-aged and older adults (Beck et al., 2014; Scullin et al., 2020), limiting generalizability. Therefore, future research should further investigate processing mechanisms of event-based PM aftereffects, combining neuroimaging techniques to comprehensively explain differences between reflexive-associative and discrepancy-plus-search processing in spontaneous retrieval, and explore which stage after intention completion involves cognitive control. Additionally, future research could use larger samples for functional neuroimaging studies of PM aftereffects in healthy young, middle-aged, and older adults and clinical populations, comprehensively analyzing response data from participants with and without PM aftereffects to further clarify mechanisms.

4.2. Increasing Investigation of PM Aftereffects in Different Types and Naturalistic Contexts

Currently, research on PM aftereffects primarily uses experimental paradigms based on event-based PM, which may not fully capture PM aftereffects. Different PM types have different cognitive resource demands. In event-based PM tasks, target events may automatically activate extraction of intention content. Time-based PM requires self-related initiation to recover intention content, demanding more executive control resources, requiring individuals to actively monitor target contexts and attend to temporal information changes to ensure successful PM task execution (Einstein & McDaniel, 1990). Experimental paradigms designed for event-based PM include clear external cues, measuring PM aftereffects by observing responses to original PM cues during completion. Time-based PM lacks obvious external cues, making it difficult to use the same indicators as event-based PM to measure aftereffects. Alternative indicators may be needed, such as frequency of time monitoring and repeated PM key presses during PM completion. Currently, no research has examined time-based PM aftereffects. Future research could design paradigms to measure time-based PM aftereffects based on existing paradigms combined with time-based PM features.

Existing research on PM aftereffects has mostly been conducted in laboratory contexts. Compared to real-life contexts, laboratory contexts typically have shorter intention maintenance phases, with participants usually encountering the first PM cue after only a few ongoing task trials. Shorter intention maintenance times during completion may prevent participants from having adequate time to deactivate completed PM intentions, potentially overestimating PM aftereffects. Moreover, PM in real-world contexts typically requires more complex action plans. Additionally, laboratory investigations of PM aftereffects mostly rely on objective indicators such as commission errors or reaction times. Schaper and Grundgeiger (2019) suggest that participants may not realize that executing completed PM intentions is erroneous during completion. When encountering original PM cues during completion, do individuals generate thoughts related to activating or inhibiting PM intention content? Future research could increase investigation of PM aftereffects in naturalistic contexts, using more complex action plan paradigms to adapt to real-world situations. Furthermore, researchers could collect subjective evaluation information from participants during PM completion, asking them to report thoughts about completed PM intentions, combining subjective evaluation information with objective indicators to increase understanding of PM aftereffects.

4.3. Focusing on Exploring Strategies to Reduce PM Aftereffects

Research shows that both young and older adults may experience PM aftereffects, but this phenomenon is particularly prominent in older adults (Bugg et al., 2016; Scullin et al., 2012; Scullin et al., 2009). Currently, research on PM aftereffects has mainly focused on healthy young and older adults, with few studies examining clinical populations. El Haj et al. (2018) found that Alzheimer' s disease patients showed more commission errors than healthy older adults. They not only have difficulty extracting PM-related information but also struggle to inhibit completed PM intentions. Therefore, future research should expand investigation of PM aftereffects in clinical populations and focus on exploring strategies to reduce PM aftereffects, which would not only effectively improve individuals' daily life quality but also have important clinical significance.

Bugg et al. (2016) found that forgetting practice strategies can effectively reduce PM aftereffects. Forgetting practice specifically involves participants performing a practice task before stimulus presentation, where they only execute the current task when encountering previous targets without performing PM responses. This strategy essentially reduces PM aftereffects by inhibiting repetition of completed intentions, aiming to help individuals forget previous relevant intentions and form "No-Go" memories through practice training (Bugg et al., 2016). Research shows that external reminders can improve PM. For example, in daily life, tools like sticky notes, memos, or alarms can serve as reminders to help execute tasks (Faytell et al., 2018; Jones et al., 2021). Anderson and Einstein (2017) suggest that creating daily medication checklists as information cues can effectively reduce PM aftereffects in clinical patients. External cue cues are highly manipulable in daily life and are therefore commonly used strategies. Currently, only a few studies have examined strategies to reduce PM aftereffects, but PM aftereffects have significant negative impacts on daily life. Future research should increase investigation of strategies to reduce PM aftereffects to improve people' s daily life quality.

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Note: Figure translations are in progress. See original paper for figures.