Prospective memory in older adults: Where we are now, and what is next

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Acknowledgements : MK acknowledges financial support from the Swiss National Science Foundation (SNSF)

Key words from List: Cognition, Memory, Daily Life

Other suggestions: Prospective memory, Everyday Memory, Multiprocess Theory, Emotion, Intraindividual Variability, EEG

Abstract

The interplay of cognitive abilities that constitute the process of "remembering to remember" is referred to as prospective memory. Prospective memory is an essential ability to meet everyday life challenges across the lifespan, constitutes a key element of autonomy and independence and is especially important in old age with increasing social and health-related prospective memory demands. The present paper first presents major findings from the current state of the art in research on age effects in prospective memory. In a second part, it presents four focus areas for future research outlining possible conceptual, methodological and neuroscientific advancements.

"Without an intact prospective memory it is scarcely possible to function independently in an everyday life context. An older person living independently must be able to remember to keep appointments, pay bills, take medicine and carry out domestic chores." (Cohen, 1996, p. 54).

1. What is prospective memory?

A cognitive process that has been given increased attention by researchers in psychology, gerontology and geriatrics is remembering to perform previously planned activities, referred to as prospective memory (PM; see Ellis & Kvavilashvili, 2000; Kliegel, McDaniel & Einstein, 2008). PM tasks such as remembering to take medication after breakfast concern the self-initiated retrieval of intentions at a specific moment and are contrasted with retrospective memory tasks, which involve the externally prompted retrieval of information content such as the retrieval of previously studied foreign language words in a vocabulary test. PM tasks can be classified as *event-based* tasks, in which the execution of the intended action is triggered by a particular event (e.g., "forward a birthday invitation card when you see a specific friend for the next time"), or *time-based* tasks, which require remembering to perform the intended action at a specific point in time or after a specified period of time has elapsed (e.g., "call the friend at 3pm to invite her to your birthday"). Thus, successful completion of a PM task requires the correct retrieval of the content of the delayed intention; i.e., cue-event/target-time and intended action(s) (*retrospective component*, mainly related to mnemonic processes) as well as the timely detection of the prospective cue-event/target-time and its execution (*prospective component*, mainly related to executive control). Importantly, the appropriate instance for carrying out the intended action is always embedded within ongoing activities (referred to as the *ongoing task,* OT) that fill the delay between intention formation and the critical moment of realization and that have to be interrupted in order to complete the prospective intention.

2. Why is it important to study PM in gerontology?

Several reasons have been motivating research on PM from its beginning: First, PM is an *ubiquitous cognitive task* and, second, we frequently fail to execute our previously planned intentions (McDaniel & Einstein, 2007). This has led to the conclusion that PM is a cognitive process that is of great relevance in everyday life. In fact, early questionnaire studies have suggested that more than half of everyday memory problems may, at least in part, be PM problems (e.g., Crovitz & Daniel, 1984). In line with these initial observations, Woods, Weinborn, Velnoweth, Rooney, and Bucks (2012) recently reported systematic evidence demonstrating that individual differences in laboratory tests of PM performance were related to individual differences in markers of *everyday functioning* and *independence*. PM also appears to be of high *clinical relevance*. Several groups have revealed partly severe deficits in a number of clinical populations, especially those associated with aging such as Parkinson's disease, Mild Cognitive Impairment or Alzheimer (e.g., Kliegel, Jäger, Altgassen & Shum, 2008; Kliegel, Altgassen, Hering & Rose, 2011). Besides the prevalence of PM errors in those populations, failures of prospective remembering are reported to have more frustrating consequences than failures of retrospective memory (Smith, Della Sala, Logie, & Maylor, 2000); thus, they constitute a key aspect of subjective cognitive complaints in clinical neuropsychology and geriatrics.

3. Does PM decline with advancing age?

In his seminal chapter, Craik (1986) suggested that typical PM tasks are characterized by high demands on self-initiated processes and low environmental support. Since the ability to recruit self-initiated processes declines with advancing age, it has been argued that PM performance should be particularly sensitive to the effects of aging (Maylor, 1995; McDaniel & Einstein, 2000). Consistent with this possibility, in the first meta-analytic review on age effects in PM, Henry, MacLeod, Phillips, and Crawford (2004) conclude that, on average, older adults perform worse than young adults in laboratory-based PM tasks. However, closer inspection of the literature reveals that age-related differences across individual studies vary substantially. While some studies found pronounced age-related declines in PM performance (e.g., Maylor, 1996; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997), other reports revealed that older adults perform as well as their young counterparts in some event-based PM tasks (e.g., Einstein & McDaniel, 1990). Consequently, solving the “puzzle of inconsistent age-related declines in prospective memory” (McDaniel, Einstein, & Rendell, 2008, p. 141) constitutes a pressing issue in research on PM and aging. In this context, three main patterns of results suggesting important moderators of age effects in PM have been revealed by the three main meta-analyses published in this area.

(A) *The Age-PM Paradox*: Considering the broader literature that has studied PM in the lab and also using more naturalistic tasks in older adults’ everyday life (e.g., asking them to send a text message twice a day), results have revealed a unique pattern introduced as the age PM paradox (Rendell & Craik, 2000; see also Schnitzspahn et al., 2011). This phenomenon is reflected in an *age advantage* across tasks carried out in the everyday environments of the participants (e.g., remembering to call the experimenter once a day) and a pattern in reverse direction (*age deficit*) in tasks carried out in the laboratory (e.g., remembering to press a prospective response button upon encountering a specific word in a test session). In their meta-analysis, Henry et al. conclude that this may indicate that PM performance in real life tasks (i.e., PM ‘tasks’ that naturally occur in everyday life such as the examples given above) may actually be spared, even if aging was associated with a decline in the basic cognitive processes involved in PM (such as inhibition or switching; see Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). So far, this hypothesis awaits systematic testing.

(B) *Focal versus nonfocal tasks*: According to the multiprocess theory of PM (McDaniel & Einstein, 2000), two processes may lead to successfully perform a PM task: spontaneous retrieval and strategic processing. Importantly, these two processes differ with regard to which attentional resources are engaged when working on a PM task: While relying on spontaneous retrieval is assumed to be less costly, strategic monitoring requires attentional control. This distinction (in combination with the general assumption of reduced controlled attention in older adults) has been used to explain the differential pattern of age effects in PM: If PM tasks rely on spontaneous retrieval, no age effects are expected; if, by contrast, controlled attention is required to monitor for the cue, age effects are predicted. Conceptually, the multiprocess theory has suggested several factors that determine which of these two processing routes are used. The most prominent of these factors is cue focality. This refers to the overlap between the processing required for the OT and the PM cue (Einstein & McDaniel, 2005): The greater the overlap (i.e., the more focal the cue, e.g., when being engaged in an ongoing lexical decision task and having to detect a specific word such as 'tornado' as PM cue), the more the information that is required for the PM task is already treated in the course of the OT, enabling spontaneous retrieval of the PM. By contrast, in the case of nonfocal cues, there is no or only a small overlap (e.g., having to detect a specific syllable such as 'tor' in a lexical decision task). Here, controlled attention is required for the extra cue monitoring which is assumed to be especially difficult for older adults. In line with the general prediction of the multiprocess theory, Kliegel et al.'s (2008) metaanalysis confirmed larger age differences for nonfocal versus focal cues; yet, they also revealed reliable age deficits for focal tasks, suggesting that other variables besides cue focality need to be identified as additional moderators.

(C) *Cue monitoring versus response coordination*: One of those moderators was recently revealed by a metaanalysis by Ihle et al. (2013) who extended the focus from the cognitive processes involved in *pre-cue-detection* such as cue monitoring to the analysis of *post-cue-retrieval processes*. Specifically, to answer the question of whether age effects in PM are further moderated by post-retrieval response management processes, they compared PM and aging studies as to whether they used PM paradigms that required a fixed order of responses after detecting a PM cue (e.g., immediately interrupting the OT and switching to the PM task) or whether participants had to freely coordinate the two parallel task goals in their responses. Again, in all analyses, estimated population PM age effects were reliably greater than zero suggesting clear age deficits in the PM tasks analyzed. When comparing task types, however, they found a main effect of task order specificity with larger PM age effects in specified than in unspecified PM tasks and, confirming prior results, a main effect of cue focality with larger PM age effects in nonfocal compared with focal PM tasks. Conceptually important, there was no interaction between task order specificity and cue focality suggesting that both (pre-detection) cue monitoring and (post-retrieval) response coordination exert independent effects on age-related PM performance.

4. Major issues for the next decade

While research on the descriptive pattern of whether and how PM changes across adulthood has made some important progress, a number of open issues have been raised in the recent past that all target the important question of *why* PM changes across adulthood and in old age. In the following second part of this review, we will therefore highlight some of the – we believe – most promising avenues towards a deeper understanding of the *mechanisms* of age differences in PM.

4.1. Conceptual advancements

The initial version of the *multiprocess theory* (McDaniel & Einstein, 2000) has suggested three other variables besides cue focality as possible moderators of PM performance in general (i.e., OT absorption, cue distinctiveness and cue-action association). So far, those factors have received much less attention, especially with respect to PM age effects. Moreover, so far, the specific interplay of those factors and the potentially differential processing routes and their role in explaining age effects in PM remain mostly unclear. To systematically examine whether the predicted factors influence PM performance and especially age effects independently or whether they are interacting will be instrumental for both theory development and understanding aging mechanisms. For example, focality is likely to be a factor that might interact with the other factors. In both, focal and nonfocal tasks the PM target cues can be distinct or non-distinct which holds true for the other factors of the multiprocess theory, as well. As a first step in that direction, in a recent study, testing this interplay we manipulated both factors focality and cue distinctiveness in young and older adults within one study. Besides confirming a general impact of both factors on PM performance, results showed that both factors were also interacting: The benefit from distinct cues was greater in the focal than in nonfocal tasks suggesting that distinctiveness mainly affects spontaneous retrieval. Moreover, age interacted with distinctiveness to the extent that only younger adults profited from distinct cues. Importantly, both age and focality impacted OT costs but not so cue distinctiveness and, while younger adults' costs in the focal condition were not different from zero, the older adults showed significant costs even in the focal condition. Together, this suggests that the same task was approached differently by young and older adults: While younger adults (successfully) relied on spontaneous retrieval where appropriate (focal tasks), older adults were strategically monitoring, even in focal and distinct tasks, therefore preventing possible facilitation effects of distinct cues. Future studies will have to systematically advance this comprehensive conceptual approach elaborating on the full interplay of the factors suggested by the multiprocess theory.

In this context, it is interesting to note that a recent variant of the multiprocess theory put forward by Scullin, McDaniel, and Shelton (2013) seems to dovetail with the differential task approach observed in above mentioned data. In detail, Scullin et al. have suggested that in principle both spontaneous retrieval and controlled processing may be utilized dynamically in one PM task. This may be the case if the context reinforces the expectation that a PM cue may appear (e.g., after successful PM retrieval individuals engage more in monitoring). If that is not the case (e.g., prior to the first cue or in a context where a PM cue is unlikely to appear), individuals may rely on spontaneous retrieval. These *dynamic changes in resource allocation* have recently been shown in younger adults and it will be important to examine whether older adults are capable of such adaptive and short-term adjustments of attention allocation or whether there are age-dependent stable differences in how individuals approach a PM task. Our previously discussed results would rather suggest older adults to more likely show continuous engagement in controlled processes even when a task would not require those.

Another area of conceptual advancement in PM and aging research is the recent inclusion of non-cognitive dimensions in explanatory models such as emotion or motivation. In terms of *emotional mechanisms*, two ways in which emotions could influence PM are currently being discussed: Either by the valence of the PM task itself or by the mood state of the participant. The first line of research can be addressed by using emotional PM cues or intentions compared to neutral ones while keeping the participants' mood on a neutral level. The second line of research can be addressed by using neutral PM task material after inducing specific mood states and compare subsequent performance to a neutral mood condition. Concerning the first line of research, initial studies examining the interaction between task valence and PM in young and older adults suggest better performance for positive and negative PM cues compared to neutral cues (e.g., May, Manning, Einstein, Becker, & Owens, 2015; Schnitzspahn, Horn, Bayen, & Kliegel, 2012), especially in older adults; diminishing or even eliminating age differences in the emotional conditions.

Much less is known concerning the second line of research. A first study (Schnitzspahn et al., 2014) observed that young, but not older adults showed impaired PM under sad and happy mood compared to a neutral mood condition. Recently, our group conducted a study testing the effects of acute stress on PM in young and older adults. Results fully replicate the findings from the former study on general mood effects, as young but not older adults were impaired in their PM performance under acute stress. Thus, these first findings suggest that older adults are better able to cope with a PM task under different emotional states than young adults. Of course, future research is needed to replicate and extend these initial findings. In terms of mechanisms, the effects of emotional task material have been attributed to enhanced saliency which may lower the required level of cognitive control to detect cues or remember intentions, but direct evidence is missing. Concerning the interaction effect of mood and age on PM, one possible explanation may be better emotion regulation in older adults, but again this hypothesis needs to be tested empirically.

Besides emotional effects, the role of *contextual and motivational variables* has been addressed, mostly in the context of the age PM paradox. Here, different factors have been discussed to possibly contribute to age benefits in naturalistic settings such as higher efficiency in the use of reminders, higher structure of daily routine, higher perceived social importance and higher motivation in older adults when performing PM tasks in their everyday life (e.g., Aberle et al., 2010). Following-up on this reasoning, it may also be that age deficits in the laboratory are at least partially moderated by motivational consequences of the laboratory situation itself. In accordance with the *stereotype threat theory* and the vast literature on stereotypes on advanced age it may well be that the situation of being tested on one’s PM memory performance in the lab, may activate negative stereotypes on age which then are expected to deplete task-related motivation and in consequence PM performance, especially in older adults. To test this assumption, in a recent study we asked older and younger participants to read a text that they would be questioned about later in the experiment (OT) and at the same time to remember to underline certain target letters or words when they occurred in the text (PM task). Half of the participants were instructed that the test would “evaluate whether their memory was normal” (memory condition), whereas the other half of the participants were instructed more neutrally that the test would “evaluate their reading ability” (reading condition). Older adults performed worse than younger adults only when the instructions highlighted the mnemonic component of the task. Thus, researchers should carefully choose task instructions and minimize possible stereotype-related instructions. To better understand the processes that underlie the pattern of PM performance observed in older adults when possibly being affected by stereotypes, future studies will have to uncover the specific roles of changes in motivation and/or anxiety levels in a laboratory setting. Furthermore, studies would have to show whether the same applies to more naturalistic conditions, or whether naturalistic conditions allow older adults to compensate despite possible stereotype threat effects (and how they do so).

4.2 Methodological advancements

One further avenue in future PM and aging research will be to use methodological and analytical advancements to elaborate on the underlying cognitive processes. So far, it is debated how well mean-level measures averaging across entire conditions or blocks in terms of PM/OT performance and calculating global OT costs can adequately depict the multifaceted attentional processes underlying successful prospective remembering (such as the dynamic changes in resource allocation suggested by Scullin et al., 2013). In this context, PM research has only very recently started to consider the variability of an individual's OT response times. In general, such *intraindividual variability (IIV)* represents relatively reversible fluctuations in functioning over short time periods such as in trial-to-trial IIV in response time tasks. IIV is increased in older adults across a number of task domains. Conceptually important for PM and aging research, a key mechanism underlying increased IIV in older adults is that IIV reflects lapses of attention resulting from transient periods of inefficient or non-optimal executive control processes (Bunce, MacDonald, & Hultsch, 2004). This may be particularly critical in certain PM conditions with a relatively large demand on executively controlled processes such as in nonfocal PM tasks. Thus, considering IIV in OT response times seems a fruitful methodological advance. First PM studies using this approach have already revealed promising results. For example, some studies have investigated parameters from Ratcliff's diffusion model, which aims at comprehensively explaining cognitive processes by taking into account both response time and accuracy of responses. Using this approach, Horn, Bayen, and Smith (2011) investigated the cost of PM on OT performance in younger adults. They found that (compared to an ongoing-task-only condition) PM load decreased the drift rate parameter (indicating deficient information uptake) and led to a more conservative response criterion in OT trials (see also Boywitt & Rummel, 2012).

To study the particular demands on executively controlled processes in focal versus nonfocal PM tasks in more detail, IIV in these two conditions has been compared. For example, by investigating parameters from the ex-Gaussian distribution in younger adults, Loft, Bowden, Ball, and Brewer (2014) revealed a shift in the entire response time distribution (μ) in a nonfocal compared to a focal PM condition (indicating a more continuous PM monitoring profile in nonfocal PM) and an increase in skew (τ) in the nonfocal compared to the focal condition (indicating lapses of attention in nonfocal PM). Horn and Bayen (2015) showed with the diffusion model approach that increases in peripheral nondecision time emerged in a nonfocal (but not in a focal) PM task, possibly reflecting a PM-target-checking strategy before and after the ongoing decisions. In addition, comparing IIV in younger and older adults, Horn, Bayen, and Smith (2013) found that such increases in peripheral nondecision time in a nonfocal PM task were larger for older than for younger adults, possibly indicating older adults' lower capacity to recruit additional executive resources for PM-target checking). Taken together, these first studies suggest that investigating IIV in OT response times has additional value (over and beyond traditional mean-level measures) as a sensitive indicator of attentional processes underlying prospective remembering to foster theorizing in PM and aging research.

4.3 Neuroscientific advancements

As a final route of future advancements we want to highlight the use of neuroscientific approaches to examine the mechanisms of age effects in PM performance. In general, there are two major approaches that have been used to investigate the neural correlates of PM: (1) neuroimaging studies applying functional magnet-resonance imaging (fMRI) or positron-emission-tomography (PET) and (2) neurophysiological recording techniques assessing event-related brain potentials (ERPs) to understand the neural underpinnings of aging in PM with high temporal resolution. In terms of major findings, neuroimaging studies have identified one particular brain region involved in maintaining intentions: the anterior prefrontal cortex (aPFC, Brodman Area 10; e.g., Beck, Ruge, Walser, & Goschke, 2014; Benoit, Gilbert, Frith, & Burgess, 2012; Burgess, Dumontheil, & Gilbert, 2007; Burgess, Quayle, & Frith, 2001; Burgess, Scott, & Frith, 2003; Gonneaud et al., 2014; Okuda et al., 1998). Furthermore, a functional dissociation of different parts of the aPFC has been noted when being engaged in a PM task (compared to pure OT blocks).Here, the lateral aPFC has been found to increase in activation whereas the medial aPFC shows decreased activation (Burgess et al., 2003). This activation pattern was set into context with the *Gateway Hypothesis* (Burgess et al., 2007), which proposes that the aPFC balances between inner representations – mediated by the lateral aPFC, for example PM intentions – or events in the environment (mediated by the medial aPFC, for example external OT stimuli). Other brain regions such as the anterior and posterior cingulate cortex, temporal cortex and insula are implied in PM processing as well but they remain less intensely studied (for reviews see Burgess, Gonen-Yaacovi, & Volle, 2011; Cona, Scarpazza, Sartori, Moscovitch, & Bisiacchi, 2015). Although, by now, there is a growing understanding of the structural and functional neurobiology of PM, surprisingly, so far no study has looked at adult age differences or developmental changes. This highlights an important gap in the current literature and identifies a clear avenue for future research. As cognitive aging is associated with a depletion of the dopaminergic system and a reduction in brain volume in different regions related to the networks associated to PM, among them the prefrontal areas (for a review see Park & Reuter-Lorenz, 2009), investigating the neural changes of PM in older adults will foster our understanding of PM development but will also be of interest for general models of neural aging and for the Gateway role of the aPFC.

With respect to the second major approach to the neural correlates of PM (recording the electroencephalogram to investigate ERP's)several specific ERPs for prospective remembering have been identified (for a review see West, 2011). The N300 is a negativity over occipital-parietal regions and begins 200 ms after stimulus onset with peaks between 300 ms and 500 ms after stimulus onset. The frontal positivity is a positive deflection of the midline frontal region and starts corresponding to the N300. The N300 is considered as neural correlate for cue detection whereas the frontal positivity relates more to processes of switching between the OT and PM task (e.g., Bisiacchi, Schiff, Ciccola, & Kliegel, 2009; West, Bowry, & Krompinger, 2006; Zöllig et al., 2007). The parietal positivity is a sustained positivity complex over parietal regions between 400 ms and 1200 ms after stimulus onset and consists of three subcomponents itself. The P3b relates to the detection of low probability cues, the recognition old-new effect is associated to the retrieval of the intention and the prospective positivity is linked to task configuration processes.

Although these ERP components are well established not so much is known about the developmental trajectories and there exist only a few studies on age effects (e.g., West, Herndon, & Covell, 2003; Zöllig, Martin, & Kliegel, 2010; Zöllig et al., 2007). Regarding the N300, studies consistently showed decreased amplitudes in older adults compared to younger adults. It suggests that older adults have impairments in attention allocation processes related to cue detection. The amplitude of the parietal positivity is attenuated as well in older adults compared to younger adults but again the evidence is mixed. West, Herndon, et al. (2003) did not find significant differences between younger and older adults in amplitudes of the parietal positivity and argued that retrieval of intentions is rather intact after successful cue detection in older adults. Furthermore, studies showed also differences in neural recruitment during prospective remembering for younger and older adults. For example, Zöllig et al. (2010) showed for the encoding phase of their PM task, that older adults recruited more frontal resources to later realize intentions more successfully.

Bringing the empirical findings in line with the process model suggested by Kliegel et al. (2011) it has been shown that older adults show already different activation patterns as younger adults at encoding that corresponds to the intention formation phase. For intention retrieval, studies showed amplitude decreases in older adults that correspond to their lower PM performance indicating difficulties detecting the cue in the environment. Although it is consistently argued that older adults have problems to recruit mainly frontally mediated attentional processes, the exact underlying mechanisms that serve age differences are not fully understood. Future studies should investigate different task conditions to identify the different neural processing routes in younger and older adults in prospective remembering. For example, varying the distinctiveness of the PM cue to investigate effects on the N300 could be a promising route given that cue detection seems to be one of the key mechanisms.

5. Concluding remarks

Due to the complex nature of the various mnemonic, attentional and executive processes involved in PM future work on PM and aging will have enormous conceptual significance for not only advancing PM research but gerontology in general. It will help specifying the interplay of more or less controlled attentional processes with memory encoding and retrieval functions in explaining age differences and thereby help integrating different domains in cognitive but also in emotional and motivational aging. In terms of levels, it will do so both on a behavioral and a neuroscience level and using traditional mean level but also variability approaches. Importantly, advancing PM research in gerontology will also have high applied significance for our aging society. Given that PM is associated with more than half of everyday memory problems and especially those that are instrumental for leading independent autonomous lives in old age, future research on the mechanisms underlying age differences in this crucial cognitive function will be of highest significance designing evidence-based intervention programs for the aging population.

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