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BRIEF REPORT

Adult Age Differences, Response Management, and Cue Focality in Event-Based Prospective Memory: A Meta-Analysis on the Role of Task Order Specificity

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The present meta-analysis investigated whether event-based prospective memory (PM) age effects differ by task order specificity. In specified PM tasks, the order of the ongoing and the PM task response is predetermined, which imposes demands on cognitive control to navigate the possible response options. In contrast, unspecified PM tasks do not require responding in a particular order. Based on 57 studies and more than 5,500 younger and older adults, results showed larger PM age effects in specified compared with unspecified PM tasks. Additionally, the effect of task focality on age differences was replicated. Results suggest that both pre- and postretrieval processes independently affect PM age effects.

Keywords: prospective memory, age effects, task switching, dual task, meta-analysis

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For the past three decades, cognitive aging researchers have investigated whether performance on prospective memory (PM) declines in old age. In their meta-analytic review, Henry, MacLeod, Phillips, and Crawford (2004) concluded that older adults generally perform worse than younger adults in laboratory-based PM tasks, with particularly pronounced age deficits in event-based tasks imposing high levels of controlled, strategic cognitive demand. However, age differences in event-based PM in laboratory settings differ largely across studies. Whereas some studies have found substantial age-related declines in PM performance (e.g., Bisiacchi, Tarantino, & Ciccola, 2008; Mäntylä, 1994; Maylor, 1996), others have revealed that older adults perform as well as their younger counterparts in some event-based PM tasks (e.g., Einstein & McDaniel, 1990; Jäger & Kliegel, 2008; Reese & Cherry, 2002; Vogels, Dekker, Brouwer, & de Jong, 2002; West & Bowry, 2005).

Consequently, attempts have been made to solve this puzzle of inconsistent age-related declines in PM (McDaniel, Einstein, & Rendell, 2008). In their Multiprocess Framework of event-based PM, McDaniel and Einstein (2000) argue that one important factor influencing PM age effects is cue focality (see also Einstein & McDaniel, 2005; McDaniel et al., 2008). Focal PM tasks are those in which the ongoing task involves processing the defining features of the PM cues (e.g., keeping words in working memory while remembering to press a button whenever a specific word appears; Einstein & McDaniel, 1990). In this case, it is assumed that the PM cues are sufficiently processed during the ongoing task to enable relatively spontaneous retrieval of the intended action. In contrast, nonfocal PM tasks are those in which the defining features of the PM cues are not part of the information being extracted in the service of the ongoing task (e.g., keeping words in working memory while remembering to press a button whenever the background of the screen shows a particular pattern; Park, Hertzog,

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Kidder, Morrell, & Mayhorn, 1997). In nonfocal tasks, prospective remembering is thought to require considerable strategic attentional resources to carry out additional monitoring for PM cue detection. In line with these predictions, a meta-analytic study on the role of focal versus nonfocal cues in event-based PM (Kliegel, Phillips, & Jäger, 2008c) reported more pronounced age effects in nonfocal compared with focal PM tasks. However, even in focal PM tasks age effects remained reliably larger than zero, suggesting that there are other important moderating factors beyond cue focality contributing to the variability in PM age effects.

A recent conceptual discussion has extended the focus from (preretrieval) factors determining the detection of the PM cue to later phases in the PM process *after* the cue has been successfully detected when participants must navigate between completing the PM and ongoing task (e.g., Bisiacchi, Schiff, Ciccola, & Kliegel, 2009; Kliegel, Altgassen, Hering, & Rose, 2011). Notably, across all areas of PM research, one important aspect of the experimental procedure varies across paradigms: whether the order of responses in terms of the ongoing and the PM task is predetermined or not. In other words, a *specified task order* is instructed in some PM paradigms: here, participants have to either immediately interrupt the ongoing task as soon as they encounter a PM cue and directly perform the PM action (e.g., by refraining from rating the target word and immediately hitting the PM key; Kliegel, Ramuschkat, & Martin, 2003) or make sure to respond first to the ongoing task and then immediately afterward respond to the PM task (e.g., by first naming the picture event cue and then hitting the associated target PM key; Bisiacchi et al., 2008). An everyday life example of a specified task order is where one must immediately interrupt an ongoing conversation to give a message to a colleague who is leaving the office. In contrast, other PM paradigms are instructed with *no particular task order*: here, participants are simply asked to remember and execute the associated PM action while also responding to the item in terms of the ongoing task and the order in which the participant carries these out is unrestricted. For example, Einstein and McDaniel (1990) instructed participants to memorize words and to press a designated key whenever a target word appeared (i.e., participants were free to execute the PM response immediately or after completing the ongoing task trial). In the real world, an example of a situation with no particular task order is when the colleague one has to pass on a message to is currently engaged in a conversation and one has time to finish the ongoing activity before passing on the note and the order in which one completes the two tasks is flexible.

Considering this fundamental difference in how PM is assessed, the current meta-analysis tests whether PM age effects differ between specified and unspecified PM tasks. From reviewing the literature on the moderating role of task order specificity, a specified order may produce larger age effects because it imposes additional demands on cognitive control to navigate the possible response options (after retrieval of the PM cue). For example, inhibitory processes are needed to suppress the initial response tendency if it conflicts with the instructed order; this is likely to affect older adults in particular, as inhibitory control demands are known to affect PM performance in older adults (see Kliegel, Mackinlay, & Jäger, 2008b). Likewise, Schnitzspahn, Stahl, Zeintl, Kaller, and Kliegel (2012) showed that adult age differences in PM were explained by task switching and inhibitory abilities. In contrast, an unspecified response situation may allow for greater freedom in the order in which one responds as it does not inherently require responding in a particular order. This lower demand on cognitive navigation of responses may make this type of PM task easier, especially for older adults. On the other hand, there is the alternative possibility that this freedom may impose response ambiguity what could produce a response conflict between the two equal response options and hence may tax controlled attention.

The present study therefore investigated the role of task order specificity as a moderator of PM age effects. Based on the available body of literature on adult age differences in event-based PM, we used meta-analytic techniques to test whether PM age effects significantly differed between specified and unspecified PM tasks as well as whether these differences varied by cue focality.

Method

Selection of Studies

A computer-based search involving PsycInfo, PubMed, Web of Science, and Psyndex was conducted using the terms 'prospective memory,' 'delayed intention,' 'aging,' 'older adults', and 'development.' We also inspected the references of five reviews on age differences in PM (Henry et al., 2004; Kliegel & Jäger, 2006a; Kliegel, Mackinlay, & Jäger, 2008a; McDaniel & Einstein, 2007; Phillips, Henry, & Martin, 2008) to find any additional studies.

Eligibility Criteria

To be included in the meta-analysis studies had to fulfill the following criteria: (1) The study investigated groups of younger and older adults and all participants were healthy and community-dwelling. Only groups for which the mean age exceeded 60 years were considered 'older.' For younger adults the mean age was permitted to vary between 18 and 59 years, but following Kliegel et al. (2008c) we also required the mean age of the older groups to be a minimum of 15 years higher than the mean age of the younger groups. (2) The study applied one or more laboratory-based event-based PM tasks and reported performance in terms of number or proportion of correct PM responses. (3) Only PM tasks were included that were embedded in an ongoing task for which performance was also assessed to ensure that resources had to be shared between the ongoing and the PM task. For example, PM tasks were not included for which the cue occurred only during an instruction for another task. (4) The PM task consisted of multiple trials (i.e., more than one). Hence, studies applying single-trial PM tasks were not included because of associated low reliability (see Kliegel et al., 2008c, for a similar approach). (5) Delay-execute conditions (i.e., where the PM response had to be shown not until a certain amount of time has elapsed) were not included as they are different from typical PM tasks. (6) To avoid including highly related results reported in journal articles and book chapters, we only included studies that were published in peer-reviewed journals. An exception was allowed for the studies of Maylor, Darbie, Logie, Della Sala, and Smith (2002b) and McDaniel et al. (2008) because the authors declared that they were not intending to submit the results to a journal for publication. (7) The paper was written in English or German.

Classification of Prospective Memory Tasks

Before statistical computing, PM tasks were classified as specified or unspecified according to the criteria above: In specified PM tasks, participants were instructed a particular order regarding the responses in terms of the ongoing and the PM task, that is, in the particular moment when the PM cue appeared, to immediately interrupt or stop working on the ongoing task and directly perform the PM action or responding first in terms of the ongoing and afterward in terms of the PM task. In unspecified PM tasks, instructions did not require responding in a particular order when a PM event occurred. From 57 studies that met the inclusion criteria, a total of 121 effect sizes Hedges' *g* were calculated, 47 for specified and 74 for unspecified PM tasks. The initial specified/unspecified classifications were made by one of the authors of the present study. Thereafter, independent classifications for all effects were obtained from three other authors and compared with the initial classifications. This resulted in agreement on 98 classifications (81.0%) between the four raters demonstrating an acceptable level of reliability (Light's *Kappa* (Light, 1971) = .82, p = .005). Next, we asked the authors of included studies to verify our classifications resulting in agreement on 113 classifications (93.4%) between the raters and the study-authors demonstrating a good reliability (Light's *Kappa* = .86, $p < .001$). All following analyses are based on the classifications of study-authors.[1] Note that focal/nonfocal classifications were used as reported in the meta-analysis of Kliegel and colleagues (2008c) for 95 of the 121 effect sizes Hedges' *g* (78.5%). The remaining 26 effects were classified by the authors of the present study according to the descriptions of Kliegel et al. (2008c) resulting in a perfect agreement between the four raters (for the final classification see Supplemental Table 1).

Calculation of Effect Sizes

PM age effect sizes were calculated in terms of Hedges' *g* and then transformed to unbiased estimates Hedges' *d*, because the former measure overestimates effects, particularly in small samples (DeCoster, 2004; Rustenbach, 2003). We also used effect sizes as calculated and reported by Kliegel et al. (2008c) whenever possible.[2] We avoided including dependent effect sizes in the meta-analysis to meet the assumption of statistical independence between effects. Hence, if a study included more than one PM performance measure for the same sample (e.g., if cognitive load was manipulated within-subjects) without reporting mean PM performance across the multiple measures, we calculated the arithmetic mean of multiple dependent effect sizes Hedges' *g* before deriving a single effect size Hedges' *d*. Alternatively, we used statistics that collapsed across the multiple PM performance measures, such as an *F* statistic for the main effect of age collapsed across a within-subjects manipulation. Additionally, if a single group of younger adults was compared with more than one group of older adults, these multiple old-age groups were combined before calculating a single effect size Hedges' *d* (the identical procedure was followed if there was more than one group of younger adults which was compared with a single group of older adults).[3]

Statistical Analyses

Following Kliegel et al. (2008c), we used the fixed effects categorical meta-analytic model (Hedges & Olkin, 1985) for all analyses. To estimate population effect sizes for age differences in PM performance, study-level effect sizes Hedges' *d* were pooled to derive the weighted average effect sizes $d\bullet$ across all studies, and also separately for the subgroups of focal specified, nonfocal specified, focal unspecified, and nonfocal unspecified PM tasks (Hedges & Olkin, 1985; Rustenbach, 2003). Further analyses included evaluating the assumption of homogeneity of effect sizes within and between the subgroups. Q_{Wi} statistics evaluate homogeneity of effect sizes within each subgroup; the sum of individual Q_{Wi} (i.e., Q_W) provides an estimate of total homogeneity. If these statistics are nonsignificant, homogeneity of effect sizes within subgroups can be assumed. Additionally, for each homogeneity statistic, we calculated the I^2 index as a measure of the degree of inconsistency in the study results (Higgins, Thompson, Deeks, & Altman, 2003). It represents the percentage of variance across studies not attributed to chance alone. I^2 does not inherently depend on the number of studies included in the meta-analysis and is therefore a more reliable approach to quantify heterogeneity (Higgins et al., 2003). Additionally, we provide the descriptions 'low,' 'moderate,' and "high" to I^2 values of 25%, 50%, and 75%, as suggested by Higgins et al. (2003). Heterogeneity between the subgroups was evaluated by computing Q_B; statistically significant values of Q_B indicate that the partitioning into the respective subgroups explains variance among effect sizes (Hedges & Olkin, 1985; Rustenbach, 2003). Additionally, to statistically evaluate whether PM age effects vary as function of task order specificity and cue focality, we performed a weighted multiple regression using the reciprocal of the variance of individual Hedges' *d* as the

[1] Note that we assured that the study-authors understood the classification rules before using their judgments for the analyses. For five studies, the authors did not respond but in all of these cases, the description of task order specificity was clearly reported in the articles and the respective classifications of the four raters had resulted in a perfect agreement.

[2] In three studies, there were very small differences between PM performance of younger and older adults, but no standard deviations were reported and *F* values were described as < 1. Therefore, effect sizes could not be calculated and were thus estimated as zero for these studies (i.e., Einstein & McDaniel, 1990; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995, Experiments 2 and 3; McDaniel, Einstein, Stout, & Morgan, 2003, Experiment 2b). We examined whether the zero replacement technique influenced the results. Specifically, we repeated the analysis after estimating effect sizes on the basis of the assumption that *F* values were 1 in the aforementioned studies. As *F*s were reported to be < 1 in these studies, setting *F* values to 1 yields an upper boundary for the study-level effects that were actually obtained (see Kliegel et al., 2008c, for a similar approach). This analysis revealed the same pattern of results.

[3] One study (i.e., Salthouse, Berish, & Siedlecki, 2004) reported multiple PM measures for the same sample whereby the PM measures were a mixture of tasks that were classified as specified and unspecified, respectively. For this study, separate effect sizes Hedges' *d* were calculated for specified and unspecified PM tasks. The same was analogously applied for five studies (i.e., d'Ydewalle et al., 1999; Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2009; Niedzwinska & Barzykowski, 2012; Vogels et al., 2002; West & Craik, 2001) that reported multiple PM measures for the same sample which were classified as focal and nonfocal (see Kliegel et al., 2008c, for a similar approach). However, excluding these six studies did not alter the pattern of results.

case weight and adjusted the standard deviations of the model parameters (DeCoster, 2004).

Results

In total, data from 5,590 different (i.e., nonoverlapping) participants were incorporated (2,963 younger and 2,627 older adults). Weighted average mean ages were 26.4 years (range = 18.4–59.4) and 71.4 years (range = 62.9–79.0) for the younger and older groups, respectively. Supplemental Table 1 presents all 115 study-level effects Hedges' d for age differences in PM performance: 15 for focal specified (13.0%), 22 for nonfocal specified (19.1%), 44 for focal unspecified (38.3%), and 34 for nonfocal unspecified PM tasks (29.6%).[4] This corresponds to the breakdown into the main subgroups of 37 specified (32.2%) and 78 unspecified (67.8%), and accordingly 59 focal (51.3%) and 56 nonfocal study-level effects (48.7%). Positive values of d indicate higher performance of younger adults, whereas negative values of d indicate higher performance of older adults. Additionally, in Supplemental Figure 1, effect sizes Hedges' d are plotted against sample sizes.

Weighted Average Effect Sizes

The weighted average PM age effect across all studies was $d\bullet = .62$ ($SD = .03$). The weighted average PM age effect sizes were $d\bullet = .60$ ($SD = .06$) for focal specified, $d\bullet = .89$ ($SD = .06$) for nonfocal specified, $d\bullet = .43$ ($SD = .05$) for focal unspecified, and $d\bullet = .66$ ($SD = .05$) for nonfocal unspecified PM tasks (see Supplemental Figure 2). All these effect sizes were reliably greater than zero, $zs > 8.77$, $ps < .001$. There was a main effect of task order specificity, with more pronounced PM age effects in specified ($d\bullet = .73$, $SD = .04$) compared with unspecified PM tasks ($d\bullet = .55$, $SD = .03$; $z = 2.35$, $p = .019$). Also, there was a main effect of cue focality, with more pronounced PM age effects in nonfocal ($d\bullet = .74$, $SD = .04$) compared with focal PM tasks ($d\bullet = .50$, $SD = .04$; $z = 3.48$, $p < .001$). There was no interaction of task order specificity and cue focality ($z = 0.43$, $p = .668$). Further analyses on the subgroups showed that the effect of task order specificity was present both within focal and nonfocal PM tasks ($zs > 2.35$, $ps < .019$). Also, the effect of cue focality was present both within specified and unspecified PM tasks ($zs > 3.30$, $ps < .001$).

Tests of Homogeneity of Effect Sizes

Heterogeneity of effect sizes within subgroups was low for focal specified, $Q_W(14) = 13.89$, $p = .458$, $I^2 = 0.0\%$, high for nonfocal specified, $Q_W(21) = 98.58$, $p < .001$, $I^2 = 78.7\%$, moderate for focal unspecified, $Q_W(43) = 99.20$, $p < .001$, $I^2 = 56.7\%$, and moderate for nonfocal unspecified PM task, $Q_W(33) = 77.30$, $p < .001$, $I^2 = 57.3\%$. Total heterogeneity within subgroups was moderate, $Q_W(111) = 288.97$, $p < .001$, $I^2 = 61.6\%$. In comparison with that, there was high heterogeneity between the four subgroups, $Q_B(3) = 34.51$, $p < .001$, $I^2 = 91.3\%$. The pattern of moderate heterogeneity within subgroups and high heterogeneity between subgroups was identical for both main effects (each with two subgroups, i.e., specified vs. unspecified and focal vs. nonfocal PM tasks).

Discussion

To answer the question of whether age effects in PM are moderated by postretrieval response management processes, a meta-analysis comparing specified and unspecified PM tasks was conducted. In all analyses, estimated population PM age effects were reliably greater than zero (note that there was no evidence that the present results were due to publication bias[5]). When comparing task types, we 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. Tests of homogeneity indicated that these moderator variables explain a significant proportion of variance across observed effects. There was no interaction between task order specificity and cue focality.

Conceptually, the present findings of larger age effects in specified and in nonfocal PM tasks are in line with predictions that higher demand on cognitive control, especially task switching and inhibition, is associated with larger PM age effects (e.g., Schnitzspahn et al., 2012). With respect to the task order specificity effect, considering the cognitive processes that occur immediately after successful PM cue detection in specified PM tasks (namely that participants must navigate between the PM and ongoing task response options and decide on the correct order), cognitive control is necessary to manage this situation. In contrast, compared with specified PM tasks, there is a higher degree of freedom of response management in unspecified PM tasks and this seems to pose fewer problems to older adults. Clearly, future work will have to pin down the exact nature of the processes involved. It could be argued that these unspecified tasks are simply easier and therefore might affect PM performance in general and that the present results might be due to ceiling-effects in younger adults. However, there was no evidence of such a potential confound.[6]

Second, concerning the focality effect, the present results are in line with the proposal of the 'multiprocess framework' of event-based prospective memory that PM age effects should be larger in nonfocal than focal PM tasks because of a higher degree of controlled, strategic cognitive processes necessary in nonfocal tasks to detect PM cues (see also McDaniel et al., 2008; Rendell, McDaniel, Forbes, & Einstein, 2007). Recent neural evidence supports the idea that focal cues involve less strategic monitoring than nonfocal cues (Cona, Bisiacchi, & Moscovitch, 2013).

[4] The two subgroups of task order specificity did not differ with respect to frequencies of focal/nonfocal PM tasks, $\chi^2(df = 1) = 1.93$, $p = .164$.

[5] To evaluate potential publication bias, we computed the "fail-safe N" (using the Stouffer method, cf. DeCoster, 2004). This refers to the number of additional studies with null findings that would have to be included in the analyses so that the mean effect sizes would not be significantly different from zero. This analysis suggested that a sufficient number of studies had been included in the present meta-analysis to reliably estimate population effect sizes (fail-safe Ns were 585 for focal specified, 1,635 for nonfocal specified, 1,275 for focal unspecified, 2,066 for nonfocal unspecified, and 21,602 for the total sample of study-level effects).

[6] We evaluated whether present results are attributable to ceiling-effects in younger adults. We concluded that this was not the case as average mean performance of younger adults across studies was only 76.9% for focal specified, 74.8% for nonfocal specified, 73.9% for focal unspecified, and 70.7% for nonfocal unspecified PM tasks.

In terms of the importance in considering both moderators, the difference between PM age effects of nonfocal specified and focal unspecified PM tasks (i.e., .89 vs. .43, respectively) was more than twice as much compared with when only cue focality was taken into account (i.e., .72 for nonfocal vs. .54 for focal PM tasks, as reported by Kliegel et al., 2008c). Thus, the results of the current study critically extend previous findings and support conceptual perspectives that focus on multiple phases of the PM process after cue detection. For example, Kliegel et al. (2011) differentiate between an intention initiation phase (where the execution of the intention is triggered by a cue) and an intention execution phase (where the intention is executed in accordance with the previously formed plan in terms of a particular task order). Hence, cue monitoring (as function of cue focality) and response management (as function of task order specificity) may be separable processes underlining the need to explicitly consider a postretrieval response management phase in PM models. This notion nicely dovetails with findings from the delayed-execute paradigm introduced by Einstein, McDaniel, Manzi, Cochran, and Baker (2000) where participants had to delay their PM response after detection of the initial cue for some time, and this delay resulted in larger age differences (presumably because of working memory demands during the second delay; see also Kliegel & Jäger, 2006b). We suggest that present data should be integrated with those results into the broader conceptual notion that postretrieval processes are a critical aspect of PM, particularly in explaining variability in age differences in PM Thus, conceptually, results of the current work provide evidence that cue focality as preretrieval *and* response management as postretrieval processes *independently* affect PM age effects.

Beyond its conceptual implications, present findings have methodological and applied implications for designing paradigms to test PM across the life span and in patient populations with reduced cognitive control (e.g., Parkinson's or dementia). Our results indicate that group effects are most likely in tasks with a specified task order, especially if nonfocal cues are used. Further, when PM performance is compared with performance in other cognitive domains (e.g., cognitive control), choosing between specified and unspecified PM tasks (as a moderator of PM) will affect the findings. Moreover, as specific developmental phases or neuropsychological conditions may pose particular challenges for underlying pre- or post-PM retrieval processes it will be important for future research to disentangle the differential role of both possible sources of variability in PM for specific age or patient groups.

Limitations of the present study include the possibility that even when the task was instructed properly, participants may have forgotten that they had to respond in a particular order or explicitly decided to respond in a different order. However, this likely comprised a minority of cases given the large sample size and we are therefore convinced that such effects are negligible in comparison with the effect of task order specificity. A further limitation concerns the diversity of effects across studies. Although the heterogeneity within subgroups was moderate, it limits the interpretation of reported population effects as the data may be poorly described by a single-point estimate. Other factors beyond task order specificity and cue focality may additionally account for the variability across studies such as cue distinctiveness, the association between PM cues and intended actions, the complexity of the ongoing task, or the importance associated with performing the PM task. In addition, the large number of studies with positive age effects (i.e., age detriments) raises the question of whether the present distribution of effects may be affected by a publication bias to publishing studies with larger age effects more often (see Supplemental Figure 1). However, although this could be possible, the present result of an overall PM age detriment is in line with prior meta-analyses (Henry et al., 2004; Kliegel et al., 2008c), and there was no evidence that the results were attributable to publication bias (see also Footnote 5).

Conclusion

Although the role of the monitoring requirements of focal and nonfocal cues for moderating PM age differences in preretrieval phases was confirmed, current conceptual views were critically extended by revealing that PM age effects seem to be additionally moderated by response management processes between the PM and the ongoing task action occurring in later PM process phases and that both mechanisms seem to be independent from each other in their influence on age effects.

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