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BRIEF REPORT

Mood Impairs Time-Based Prospective Memory in Young but Not Older Adults: The Mediating Role of Attentional Control

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The present study examined age-by-mood interactions in prospective memory and the potential role of attentional control. Positive, negative, or neutral mood was induced in young and older adults. Subsequent time-based prospective memory performance was tested, incorporating a measure of online attentional control shifts between the ongoing and the prospective memory task via time monitoring behavior. Mood impaired prospective memory in the young, but not older, adults. Moderated mediation analyses showed that mood effects in the young were mediated by changes in time monitoring. Results are discussed in relation to findings from the broader cognitive emotional aging literature.

Keywords: aging, emotion, mood, prospective memory, time monitoring

A pervasive, real-world dual task requiring both memory and cognitive control is prospective memory (PM; Zeintl, Kliegel, & Hofer, 2007). Specifically, PM describes the ability to remember and realize a planned action at a particular moment in the future while being engaged in an ongoing activity (Ellis & Kvavilashvili, 2000) such as remembering to take medication on time. Besides its high everyday importance (Terry, 1988), it has been suggested to be especially important in older adults (McDaniel, Einstein, & Rendell, 2008), as it is related to independence in old age (Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012). Accordingly, researchers in the area of cognitive aging have become increasingly interested in PM. Most studies conducted in the laboratory show a general age decline in PM (McDaniel & Einstein, 2007). In terms of mechanisms, a meta-analysis by Henry, MacLeod, Phillips, and Crawford (2004) reported larger age effects for PM tasks requiring high levels of controlled attention, whereas age differences tend to be reduced when intention retrieval is supported by spontaneous processes, for example, when the ongoing activity involves processing the defining features of the prospective memory target cue (Kliegel, Jäger, & Phillips, 2008).

Recently, the influence of emotional variables on PM and possible age effects have been considered, with the earliest studies manipulating the valence of the PM cues (e.g., Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; Schnitzspahn, Horn, Bayen, & Kliegel, 2012). These studies found that older adults' PM task performance was enhanced when cues were positive (e.g., love as cue word) or negative (e.g., loss as cue word), in comparison with a neutral condition (e.g., affect as cue word), and thereby reducing age effects (Schnitzspahn et al., 2012) or even eliminating them

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completely (Altgassen et al., 2010). Furthermore, age effects were also reduced when the to-be-remembered intention was positive, but not when it was negative or neutral (Rendell et al., 2011). What remain unclear are the precise cognitive mechanisms underlying these effects. Generally, the effects have been attributed to enhanced salience of emotional task material which therefore may require less cognitive control to detect the cues, but direct evidence is lacking.

A second line of research initiated to study age by emotion interactions in cognitive functioning has focused on mood effects. To our knowledge there is no existing literature on mood by age interactions in PM, and even considering the broader field of cognitive aging, our understanding of how mood and cognitive functioning interact is still in its infancy, with the few studies conducted producing heterogeneous results. It has been found that negative mood disrupts older, but not younger, adults' performance when making causal attributions (Mienaltowski & Blanchard-Fields, 2005) and planning (Phillips, Smith, & Gilhooly, 2002) but fails to influence either age groups recall (Emery, Hess, & Elliot, 2012) or working memory (Scheibe & Blanchard-Fields, 2009). Concerning positive mood, Phillips et al. (2002) found an impairing effect on planning in young and especially pronounced in older adults, whereas a study focusing on older adults only (Carpenter, Peters, Västfjäll, & Isen, 2013) reports that mild positive mood enhanced working memory and decision making. Furthermore, positive mood exacerbates false memories in older but not younger adults, whereas correct recall is not influenced (Emery et al., 2012). As can be seen, more research is clearly needed to better understand age differences in mood effects on cognitive performance.

It was therefore the aim to address this issue in a study targeting time-based PM (i.e., remembering to do something at a specified time while working on an ongoing activity). The present study is the first to examine whether mood affects PM differentially in young versus older adults. More importantly, from a conceptual perspective, we aimed to examine the cognitive mechanisms underlying any potential effects. Focusing on *time-based* PM allows us to close the descriptive gap concerning possible mood by age interactions in PM and to provide some broader insights into the cognitive mechanisms associated with these interactions in tasks requiring cognitive control in general. In a time-based PM task participants have to deploy cognitive control to periodically switch between the ongoing activity and the PM task to monitor the approaching target time. These switches have to be self-initiated because there are no reminders and the clock participants use to monitor the time is only temporarily visible when requested (d'Ydewalle, Bouckaert, & Brunfaut, 2001). Thus, besides output performance in both single tasks (i.e., the ongoing and the PM task itself), the *proactive* allocation of cognitive control toward the PM task can be assessed online by examining participants self-initiated switches between the ongoing and the PM task analyzing time monitoring data. Capitalizing on these task features, in the present study the prediction was tested that possible mood effects on PM are actually mediated by mood-related changes in the proactive allocation of cognitive control processes.

Conceptually, this prediction rests on two studies conducted in young adults only. Kliegel and colleagues (2005) showed that performance in a time-based PM task was *impaired* after a sad mood induction compared with a neutral control condition. More precisely, lowered performance under sad mood was attributable to a decreased timeliness of PM responses rather than complete forgetting which was related to inefficient time monitoring. Interestingly for present purposes, recently, Rummel, Hepp, Klein, and Silberleitner (2012) tested negative and positive mood effects, compared with a neutral condition, on *event-based* PM in young adults. Event-based tasks demand the performance of an intended action after the recognition of an external cue in the environment (Einstein & McDaniel, 1996). Surprisingly, their results showed *increased* PM performance in the sad mood condition as compared with the happy one while performance in the neutral condition was descriptively in between the two. Rummel et al. suggested their results may differ from Kliegel et al.'s (2005) as different monitoring processes support time-based and event-based PM task performance and these processes may be differentially influenced by mood. Thus, although monitoring behavior or the controlled cognitive processes underlying PM performance were not assessed in this study, they were used post hoc to explain the heterogeneous results.

In sum, the present study set out to systematically examine mood by age interactions in a time-based PM task and to directly test the prediction that mood effects on PM are mediated through changes in proactive cognitive control indexed by time monitoring behavior. Analytically, a path analysis-based moderated mediation model using bootstrapping (Preacher, Rucker, & Hayes, 2007) was applied for this purpose.

Method

Participants and Design

The sample included 121 adults, 64 young (M_{age} = 19.11 years, age range: 18–25 years) and 57 older ones (M_{age} = 69.79 years, age range: 59–84 years). All participants reported good physical and mental health. Young and older adults did not differ in self-rated depression and anxiety as measured with the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983), $t(119) = 1.32$, $p = .19$. The participants were randomly assigned to one of three mood conditions. Thus, the study followed a 2 (age: young vs. old) $\times$ 3 (mood: negative, neutral, positive) between-subjects-design.

Materials

Mood induction. To induce mood, we used six film clips (two negative, two neutral, and two positive ones).[1] Examples for the material include a documentary on the desert (neutral mood), a dancing scene (positive mood), and a hanging scene (negative mood). In accordance with former studies (Phillips et al., 2002), all film clips lasted between 6 and 7 minutes. Every participant was exposed to both clips of one mood.

Mood assessment. Two subscales, arousal and affective state of the Self-Assessment Manikin scale (SAM; Bradley &

[1] Because mood induction procedures have not been extensively used with older adults, it was important to ensure that materials used were appropriate for both age groups. Thus, the specific film clips were selected after a pilot work with 68 separate participants, 56 young (aged 18–26 years) and 12 older adults (aged 62–74 years).

Lang, 1994), were used to check the effectiveness of the mood induction.

PM task. Following Kliegel et al. (2005), we embedded a time-based PM task in an *n*-back working memory ongoing task. In the ongoing task, participants viewed pseudorandom sequences of animal words on a computer screen, each displayed for 2 s with a pause of 1 s between stimuli. Instructions were given to press a "yes" key if the stimulus was the same as that which occurred two positions before, otherwise a "no" key had to be pressed. The *n*-back task consisted of two blocks, each comprising 80 words in total lasting 4 min. The order of the words was randomized with the restriction that a "no" response was correct on 66 trials and a "yes" response was correct on 14 trials in each block. To score *n*-back performance, correct rejections and hits were added for each participant (see, e.g., Verhaeghen & Basak, 2005).

For the PM task, participants had to remember to press a target key at 1-min intervals from the start of the *n*-back task as accurately as possible. To monitor the time, participants could press the "space" key to see a time counter clock (00:00) which appeared for 3 s. Every hit on the target key that occurred within a target window of 5 s around the exact target time (i.e., each minute) was scored as a correct PM response (see, e.g., Kliegel, Martin, McDaniel, & Einstein, 2001). To examine clock monitoring behavior, we focused on the number of clock checks in the 10-s time interval immediately before each 1-min target, as this has been shown to be the critical time period for accurate PM responses (see, e.g., Kliegel et al., 2001).

Procedure

After signing consent forms and filling in the sociodemographic questionnaire and the HADS, the initial mood was measured with the first SAM. Instructions for the *n*-back task were given, followed by a practice trial of 12 items. Afterward, participants completed an ongoing-task only block comprising 50 trials. The instructions for the PM task and the clock monitoring followed. Participants' mood was measured for the second time with a SAM. Then the first mood induction film was shown, with about one third of the participants in the neutral mood condition, one third in the negative, and the rest in the positive mood condition. Immediately after the film, participants completed a third SAM. Next, the experimenter started the first PM task block. As Kliegel et al. (2005) showed that mood effects on PM are rather short lasting, a second film clip matching the mood from the first one was shown to renew the induced mood. It was followed by another SAM and the second PM task block. At the end of the experiment, participants completed a fifth SAM.

Results

Mood Induction

In accordance with Rummel et al. (2012) mood nonresponders were identified on the basis of the individual affective-state scores. Therefore, the mean affective-state ratings of the neutral mood condition after watching the two film clips were combined (i.e., $M = 3.84$; $SD = 1.19$) and used as the cut-off point. Young ($M = 3.81$; $SD = 1.29$) and older adults ($M = 3.88$; $SD = 1.09$) did not differ in this score, $p = .87$. Those participants in the sad (happy) mood condition who scored higher (lower) than the cut-off point were classified as mood nonresponders. In doing so, we identified 4 mood nonresponders, which were excluded from all further analyses.

The affective-state scores (see Table 1) were submitted to a 3 × 2 × 3 ANOVA with mood condition and age as between-participants factors and mood measurement time-point as within-participants factor. The mean of the two mood measurements before the mood induction was used as the baseline, which was contrasted with the mean of the two mood measurements after film segments one and two. In addition, the very last mood measurement after the PM task was included. There were main effects of mood condition, $F(2, 111) = 32.96$, $p < .001$, $\eta^2 = .37$, and mood measurement time-point, $F(2, 111) = 12.40$, $p < .001$, $\eta^2 = .10$, whereas the age effect did not reach significance, $p = .57$. Furthermore, the interaction between age and mood reached significance, $F(2, 111) = 6.51$, $p < .01$, $\eta^2 = .11$. In addition, the interactions between time point and age, $F(2, 111) = 3.97$, $p < .05$, $\eta^2 = .04$, between time point and mood, $F(4, 222) = 38.27$, $p < .001$, $\eta^2 = .41$ and between time point, age, and mood, $F(4, 222) = 8.86$, $p < .001$, $\eta^2 = .14$, all reached significance.

Exploring the age × mood interaction, follow-up analyses were conducted separately for the two age groups. There was no significant mood effect in the baseline mood measurement for the young and the older adults, $ps > .05$. After the mood induction, there was a clear mood effect in the anticipated direction in the young, $F(2, 61) = 58.84$, $p < .001$, $\eta^2 = .66$, and older adults, $F(2, 50) = 44.68$, $p < .001$, $\eta^2 = .64$. Participants in the positive mood group showed lower ratings than participants in the neutral

Table 1
Self-Assessment Scores of Affective State in Both Age Groups Separated by Mood Condition and Mood Measurement Time Point

	Mood condition					
	Young adults			Older adults		
Time point	Negative ($n = 22$)	Neutral ($n = 21$)	Positive ($n = 21$)	Negative ($n = 19$)	Neutral ($n = 16$)	Positive ($n = 18$)
Before induction	3.61 (1.25)	3.48 (.97)	3.17 (.97)	3.11 (1.20)	3.34 (1.17)	3.97 (.88)
After induction	5.57 (.93)	3.81 (1.29)	2.19 (.78)	6.53 (1.47)	3.88 (1.09)	2.61 (1.24)
After PM task	5.32 (1.17)	3.90 (1.18)	2.43 (.93)	3.63 (1.77)	3.31 (1.14)	3.94 (1.73)

Note. Affective state was assessed using a 9-point Likert scale with low values representing a positive mood and high values standing for a negative mood. Mean scores with standard deviations in parentheses are displayed.

group (young: $t(40) = 4.92$, $p < .001$, $d = 1.52$; old: $t(32) = 3.14$, $p < .01$, $d = 1.09$), whereas participants in the negative mood group showed significantly higher ratings than participants in the neutral control condition (young: $t(41) = -5.15$, $p < .001$, $d = -1.57$; old: $t(33) = 5.97$, $p < .001$, $d = 1.78$). An age differential finding emerged for the final mood assessment: While the mood effect remained in the final mood measurement in the young adults, $F(2, 61) = 37.11$, $p < .001$, $\eta^2 = .55$, the older adults in the three different mood conditions did not differ from each other anymore concerning their self-reported mood at the end of the testing,[2] $F(2, 50) = .67$, $p = .52$, $\eta^2 = .03$.

PM Performance

Investigating PM hits (see Figure 1), main effects of age, $F(1, 111) = 31.05$, $p < .001$, $\eta^2 = .22$, and mood, $F(2, 111) = 5.41$, $p < .01$; $\eta^2 = .09$, were qualified by a significant interaction, $F(2, 111) = 3.18$, $p < .05$, $\eta^2 = .05$. Young adults outperformed the older adults, $t(115) = -5.22$, $p < .001$, $d = 0.98$, across all mood conditions. Collapsed across both age groups, PM was better in the neutral compared with the negative, $t(76) = 2.11$, $p < .05$, $d = 0.53$ and the positive mood condition, $t(74) = 3.02$, $p < .01$, $d = 0.76$. PM performance between the positive and the negative mood group did not differ from each other, $p = .23$. Exploring the age × mood interaction, further analyses were conducted separately for the two age groups. They revealed a significant simple main effect of mood for young adults, $F(2, 61) = 8.98$, $p < .001$, $\eta^2 = .23$, but not for older adults, $p = .37$. Specifically, PM in the young adults was significantly reduced in the negative, $t(41) = 3.64$, $p < .01$, $d = 1.11$ and positive, $t(40) = 3.91$, $p < .001$, $d = 1.21$ mood condition compared with the neutral one. There were no significant PM performance differences between mood groups in the older adults.[3]

Ongoing Task Performance

Investigating *n*-back performance, there was only a significant main effect for age, $F(1, 111) = 22.62$, $p < .001$, $\eta^2 = .17$. Young adults ($M = 69.98$, $SD = 2.52$) outperformed the older adults ($M = 66.36$, $SD = 5.51$), $F(1, 115) = 22.02$, $p < .001$, $\eta^2 = .16$ across all mood conditions. Neither the mood effect nor the interaction between mood and age reached significance, $ps > .05$.

Time Monitoring

Concerning time monitoring, there was a significant main effect for age, $F(1, 111) = 9.93$, $p < .01$, $\eta^2 = .08$, whereas the main mood effect, $F(2, 111) = 2.96$, $p = .06$, $\eta^2 = .05$, as well as the interaction between mood and age approached significance, $F(2, 111) = 2.59$, $p = .08$, $\eta^2 = .05$. Across all mood conditions, young adults ($M = 6.50$; $SD = 3.41$) checked the clock more often than older adults, $M = 4.43$; $SD = 4.00$; $t(115) = -3.01$, $p < .01$, $d = .56$. Further analyses revealed a significant simple main effect of mood for young adults, $F(2, 61) = 7.24$, $p < .01$, $\eta^2 = .19$, but not for older adults, $p = .63$. Resembling the results on PM performance in the young adults, time monitoring was significantly reduced in the negative ($M = 5.36$; $SD = 2.92$; $t(41) = 3.30$, $p < .01$, $d = 1.01$) and positive ($M = 5.57$; $SD = 2.87$; $t(40) = 3.07$, $p < .01$, $d = .95$) mood condition compared with the neutral one ($M = 8.62$; $SD = 3.53$).

Mediation Analyses

To test the hypothesis that the obtained mood effects on PM performance were actually mediated through time monitoring, two mediation analyses were carried out. One compared participants in the negative mood condition with the neutral control condition, the second one the positive and the neutral group. As the mood effects only held true for the young participants, the factor age group was included as a possible moderator. The framework proposed by Preacher et al. (2007) was used. It allows combining mediation and moderation analysis through the construction and estimation of the so-called conditional process model framed as a path model. These models give estimates of direct and indirect effects for different values of the moderator (here: young vs. older adults). Bias-corrected confidence intervals are generated for the indirect effect using bootstrapping (here $n = 5000$ bootstrap samples).

Negative Mood Effects

Results showed the expected mediation of negative mood effects on PM performance by time monitoring as a function of age (see Figure 2a for all effects). A significant conditional indirect effect of $b = -0.51$ ($SE = .19$) with a 95% bias corrected confidence interval of -0.92 to -0.19 was found for the young adults, whereas the bias corrected confidence interval was -0.42 to 0.51 with an indirect effect of $b = 0.07$ ($SE = .24$) for the older adults. Thus, time monitoring mediated the effect of negative mood on PM for the young adults only.

Positive Mood Effects

Again, results showed the expected mediation of positive mood effects on PM performance by time monitoring as a function of age (see Figure 2b for all effects). A significant conditional indirect effect of $b = -1.10$ ($SE = .38$) with a 95% bias corrected confidence interval of -1.92 to -0.41 was found for the young adults, while the bias corrected confidence interval was -1.18 to 0.43 with an indirect effect of $b = -0.30$ ($SE = .41$) for the older adults. Thus, time monitoring mediated the effect of positive mood on PM for the young adults only.

Discussion

The present study tested for the first time how different mood states affect time-based PM performance in young and older

[2] A 3 × 2 × 3 ANOVA with mood and age as between-participants factors and mood measurement time point as within-participants factor was also performed for the arousal scores. Main effects of mood, age, and mood measurement time point were found, whereas the interactions did not reach significance. However, including the arousal states as covariates in the main analyses on PM performance did not change the pattern of our findings. Furthermore, neither the baseline arousal state nor the arousal state after the mood induction was significantly related to the participant's PM performance.

[3] Importantly, the pattern of results held true when considering the first two PM target cues and the last two PM target cues in each block separately. Thus, even directly after the successful mood induction PM performance in the older adults was not influenced by mood. Furthermore, the pattern of PM results also held true when examining performance after each of the two movies per mood condition separately. Thus, the found effects are not restricted to specific films. We thank an anonymous reviewer for suggesting these analyses.

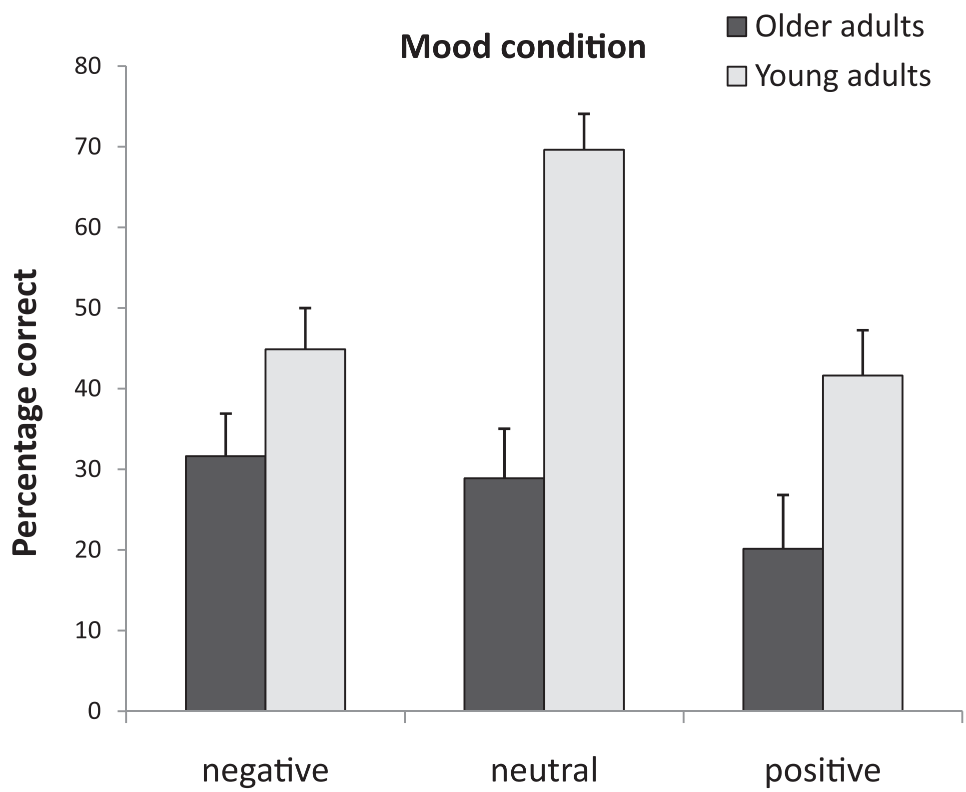

Figure 1. Prospective memory (PM) performance (proportion of correct PM responses) in both age groups as a function of mood condition. Error bars represent the standard error (*SE*).

adults. Interestingly, differential age effects were found: Whereas young adults' PM performance was impaired after a positive as well as a negative mood induction, performance in the older group was not changed by mood states. Further analyses revealed that mood effects on time-based PM performance in young adults were mediated by time monitoring. This held true for both positive and negative mood states.

The finding that young adults' time-based PM performance was impaired by a negative mood is consistent with earlier research (Kliegel et al., 2005). Conceptually, the present study followed up on the suggestion made by Kliegel et al. (2005) and Rummel et al. (2012) that mood effects on PM may be mediated by monitoring behavior and tested it directly. Time monitoring provides an online measure of the proactive allocation of cognitive control toward the PM task, which is especially needed in time-based PM given the lack of external target cues. Results from mediation analyses showed that positive, as well as negative, mood reduced time monitoring which then led to the impairment in PM performance. This finding helps to clarify the conflicting results from the two former studies on mood effects in PM in the young (Kliegel et al., 2005; Rummel et al., 2012). As these studies used different PM tasks which differently require controlled attention (event-based, where the prospective response is triggered by an external cue that needs to be identified as such vs. time-based, where proactive and strategic deployment of controlled attention across the entire task is a constitutive requirement for not missing the target times), performance may be influenced by mood in different ways (i.e., via cue identification vs. proactive and strategic time monitoring). Accordingly, it is possible that mood influences event-based PM in older adults. Future studies using both task types and online measures of cue identification and time monitoring behavior in different age groups are needed to further clarify how PM task types and their underlying monitoring processes mediate mood effects on performance.

Besides its conceptual importance for the field of PM, the present results are also of theoretical interest for the broader field of cognitive aging researchers examining mood effects. As described in the introduction, results in this research area are scarce and heterogeneous. The present results show that underlying proactive cognitive control processes mediate mood effects on performance in a complex cognitive task for which age effects have been revealed to be associated with age-related changes in memory and especially in executive function processes (Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). This finding suggests the conceptual conclusion that differing results in former studies could be caused by differing amounts of required proactive cognitive control to successfully perform a certain task. Indeed, whereas tasks relying mostly on episodic and working memory do not seem to be impaired by mood states (Carpenter et al., 2013; Emery et al., 2012; Scheibe & Blanchard-Fields, 2009), planning (a task heavily relying on proactive control processes) is reduced under positive and negative mood (Phillips et al., 2002).

Especially interesting from a developmental perspective is the finding that neither positive nor negative mood states affected PM

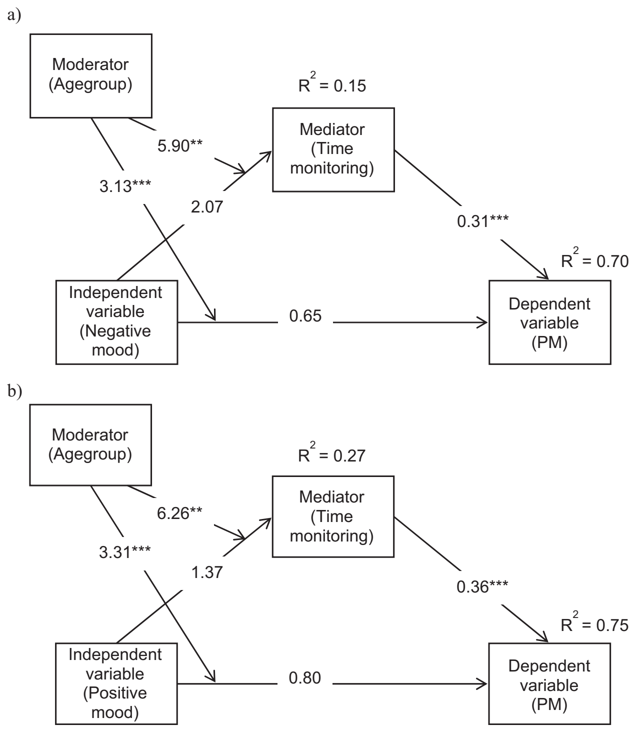

Figure 2. (a) Process model used to test whether negative mood effects on Prospective memory (PM) are mediated by time monitoring. (b) Process model used to test whether positive mood effects on PM are mediated by time monitoring. The path coefficients reported are unstandardized regression coefficients. ** $p < .01$, *** $p < .001$.

performance in older adults. Even if the present study cannot test this assumption, one possible explanation might be that the finding results from a better emotion regulation in the elderly. Whereas young adults stayed in the induced mood until the end of the testing, older adults reverted to their initial, neutral mood. This suggests that older adults may automatically regulate their emotions to maintain a relatively neutral emotional state and are more effective in doing so than their younger counterparts. This would be in line with emotion regulation research in aging which usually shows an age benefit (e.g., Carstensen, Pasupathi, Mayr, & Nesselroade, 2000) and suggests that emotion regulation may be less costly in a cognitive sense for older adults (Scheibe & Blanchard-Fields, 2009). Of course, further studies are required to test this hypothesis directly. Nevertheless, whereas previous studies already show that emotional valence of PM cues improved PM performance exclusively in the elderly (Altgassen et al., 2010; Schnitzspahn et al., 2012), the present data adds that only older adults were able to deal with a specific mood state and a PM task at the same time without showing any mood-related decline in their cognitive performance. Thus, at first view it seems as if older adults have a general advantage over young adults when it comes to emotion-cognition interplays.

According to capacity theories (see, e.g., Seibert & Ellis, 1991) predicting that positive and negative mood will have deleterious effects on cognitive tasks, especially if they are highly resource-demanding, one would have expected stronger mood effects in our older participants as they have less cognitive resources available. However, our finding suggests that pure cognitive processes play a minor role given that we found strong age effects in our cognitive measures (i.e., PM and ongoing task). An alternative explanation for the lack of mood effect in older adults could be that they are more strongly motivated than the young adults to perform well in the cognitive task and accordingly focus more on the task and block out all emotional thoughts or feelings as soon as they start working on it. Moreover, another possible explanation could be that the task was probably more challenging for the older than for the young adults and maybe prevented them from maintaining a mood state because task difficulty was not adapted for the older adults in the present study. On the contrary, it may be that the young adults did not feel challenged enough by the task and let themselves into their mood and distracting thoughts as they felt that they could still deal with the task at the same time. Further studies assessing the effort spend on a task while working on it are needed to clarify whether such motivational factors change monitoring behavior under certain mood states and if this is true for negative as well as positive mood.

One possible limitation of the present study comprises the relatively low PM performance in the older adults. However, the proportion of correct responses was more than 20% across all conditions. Thus, there was still enough room left for performance declines in all experimental conditions and no floor effect occurred. In addition, standard errors in both age groups were comparable, indicating sufficient variance in all conditions.

In sum, the present study extends research on the effects of mood states on PM by adding a developmental perspective and showing differential age effects for the very first time. These findings are of conceptual importance as they add to the emerging attempts to identify underlying mechanisms of mood effects on PM raised by earlier studies and dovetail with the proposal that mood effects on PM may be mediated through monitoring behavior.

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