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Article

Exploring the Relationship between Emotional Valence and Prospective Memory Metamemory in Younger and Older Adults

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Abstract: Prospective memory (PM) plays a crucial role in daily autonomy. Metamemory and emotional valence have both been shown to influence PM performance in younger and older adults. However, when considered together, the relationship between emotional valence, metamemory, and PM has not been examined yet, especially whether metamemory PM representations develop with task experience (i.e., before versus after performing a task). We collected data from 25 younger and 19 older adults using an event-based PM task with emotional cues (positive, negative, or neutral). Results revealed that younger adults' predictions underestimated performance for neutral and negative cues. After performing the task, they showed more accurate representations for neutral cues, indicating that they monitored their representations. Older adults' predictions overestimated performance for negative PM cues, and they did not modify representations after performing the task. Thus, we do not find evidence that older adults are able to coherently monitor their PM representations. These findings highlight the importance of understanding PM representations, especially in older adults, as they may lead to less strategy use and more impaired PM performance in negative everyday situations.

Keywords: prospective memory; emotions; metamemory; aging; memory

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1. Introduction

Prospective memory (PM) is the ability to remember to execute intended actions in the future [1,2]. Research differentiates between two types of PM tasks: (1) event-based PM tasks, which consist of remembering to execute the intended actions when a specific event or cue occurs, such as remembering to take your medication after dinner, and (2) time-based PM tasks, which consist of remembering to execute the intended actions at a specific time or after a certain amount of time has elapsed, such as remembering to take the cake out of the oven after 30 min. PM has been identified as an important cognitive process that is highly predictive for independence and daily-life autonomy, making it particularly relevant for older adults [3,4]. Although PM is highly frequent in everyday life [5], available research suggests that, at least in controlled laboratory PM tasks, older adults perform worse than younger adults [6]. This decline in PM performance in older adults may partially be explained by reduced general cognitive abilities, such as working-memory (WM). As WM is involved in maintaining PM intentions while performing other tasks, PM performance is influenced by WM load, with older adults being more affected due to their age-related decline in WM [7]. However, decline in WM or other associated cognitive abilities such as episodic memory or executive functions does not fully explain PM performance in older age, suggesting that other factors may be at play as well [7–9].

Recently, a new and promising line of research has emerged focusing on the additional role of metamemory in PM performance in older adults [1,10–14]. Metamemory is defined as one's knowledge about the functioning, development, use, and capacities of the memory system in general, as well as of their own memory in particular [15–17]. It is composed of two processes: (1) metacognitive monitoring, which reflects the information about our memory performance provided by the environment that individuals use to shape their memory representations, such as predicting one's memory performance and/or being confident or not about our memories and our memory abilities; and (2) metacognitive control, which is a regulation process that individuals use to shape their memory representations, such as activating and using specific strategies for a given task at encoding, maintenance, and/or retrieval. Both components are interdependent, as the accuracy of individuals' representations is important for individuals to implement effective strategies for memory tasks [15,17]. Indeed, if there is a discrepancy between metamemory representations and actual memory performance, such as high representations while having actually poor memory performance, individuals will not look for and implement strategies as they are not aware of their poor performance in memory. As PM failures represent half of the reported memory failures by younger and older adults in their daily lives, it seems essential to understand whether they have accurate metamemory representations of their PM performance on which they can rely to implement effective strategies and succeed at PM tasks [5,18].

What is known about this in the context of PM? Certain of the previous studies on metamemory and PM asked participants to make predictions (i.e., how well participants think they will perform at a task) to assess the accuracy of their representations compared to their actual performance. They demonstrated that younger adults are underconfident in laboratory PM tasks, meaning that they actually perform better than they predicted, while older adults are overconfident, meaning that they perform worse than they predicted [10,11,14]. Even though the previous studies have not examined what may have influenced participants' representations, these results established the importance of differential discrepancies between metamemory representations for PM tasks and the actual PM performance in both younger and older adults. Interestingly, a more recent study by Ng et al. (2018) [13] indicated that at an individual level, after having performed the PM task, the predictions of some participants age 50 and older became more accurate (i.e., they became closer to their actual PM performance). This is of particular interest as it suggests that updating abilities may be preserved, subsequently enabling older adults to adjust their representations. Thus, older adults could benefit from interventions targeting metamemory representations and the implementation of strategies.

However, at least two main conceptual questions remain open. First, what is influencing individual PM representations? Emotions may be a particularly interesting factor to consider. Indeed, Phelps (2006) [19] explains that emotions may have an influence on three components of episodic memory: encoding, consolidation, and subjective remembering. The author indicated that during the appraisal of stimuli, the amygdala evaluates their relevance and modulates the thresholds of attentional and perceptual processes in favor of emotional stimuli compared to neutral stimuli. Consistent with this idea, previous reviews indicated that emotional stimuli facilitate memory performance, as they may be considered more relevant than neutral stimuli, subsequently enhancing encoding and retrieval [20,21]. Regarding age differences, certain studies demonstrated that younger adults, driven by "learning" goals, would be more sensitive to negative stimuli, which would lead them to perform better for these stimuli compared to other valences (see, for example, [22]). While some studies suggest that older adults exhibit a positivity bias, remembering positive stimuli more due to 'hedonic' goals (see, for example, [22]), this idea is contested by others in the literature who argue for a negativity-avoidance bias [23]. As it shares common factors with retrospective memory, these questions also emerged in the context of PM, with a meta-analysis by Hostler et al. (2018) [24] suggesting the existence of positivity bias in PM. These findings led researchers focusing on metamemory to wonder whether these effects would also apply to metamemory representations. However, they demonstrated inconsistent results. Studies on retrospective memory demonstrated that emotional valence has an important influence on predictions, meaning that both younger and older adults judged that they were more likely to remember emotional than neutral stimuli [25–30]. However, participants' predictions for emotional stimuli did not necessarily match their actual performance, as in some studies participants reported higher predictions for specific emotional stimuli (e.g., positive stimuli), while their performance was actually either influenced by another valence or by neutral stimuli [25] or not influenced at all by stimuli valence [26,27,29,30]. This suggests an interesting dissociation, indicating that participants might have biased representations of their memory abilities when emotional stimuli are encountered and that this may be valence-specific (and possibly also age-dependent). Importantly, however, as the relationship between metamemory, emotions, and PM has not been studied yet, it currently remains unclear whether these findings apply to PM. The present study sets out to explore this open question as its first aim.

A second open question is whether PM representations are sensitive to prior task experience, as suggested by Ng et al.'s study (2018) [13]. This is of particular importance because if younger and older adults are able to update their metamemory representations according to the task, they may subsequently implement and use effective strategies to succeed at the task in the future. Only one previous study demonstrated that younger adults were underconfident and that their metamemory representations for PM did not change with task experience [14]. However, this has not been investigated in older adults yet. Thus, in addition to predictions, it seems relevant to consider postdictions (i.e., how well participants think they have performed after experiencing the task). The inclusion of both predictions and postdictions may allow us to establish whether participants, and especially older adults, are able to change their metamemory representations for PM. The present study sets out to explore this issue as its second aim.

Taken together, based on the previous but scarce literature, this exploratory study aimed to explore the role of metamemory in age-related PM performance. More specifically, it targeted two currently open questions and investigated the relationship between metamemory and PM in younger and older adults with emotional stimuli. We aimed to explore the effects of cue valence on the relationship between predictions, postdictions, and actual PM performance, depending on PM cues' valence and age. Based on previous findings, we expected that younger adults would outperform older adults on the event-based PM task. We also expected that younger adults would be underconfident regarding their metamemory PM representations, while older adults would be overconfident. Regarding the effect of cues' emotional valence on metamemory representations and PM performance, we explored this relationship without specific hypotheses as the literature demonstrated inconsistencies.

2. Materials and Methods

The initial sample consisted of 38 younger adults (undergraduate students; 18–30 years old) and 33 community-dwelling older adults (65 years old and older) from the Geneva area (Switzerland). We had to exclude data because of (1) computer technological problems (n = 9), (2) exclusion criteria such as cognitive screening being below threshold (n = 11), indication of neurological or psychiatric diseases (n = 4), (3) voluntary dropout (n = 2), or (4) misunderstanding of the task (n = 1). Thus, the final sample consisted of 25 younger adults and 19 older adults, with 77.3% being female (thus, gender will be controlled for in the analyses). The mean age of younger adults was 22.12 years (*SD* = 2.47), while the mean age of older adults was 73.37 years (*SD* = 4.40; see Table 1 for descriptive data).

Table 1. Descriptive Statistics for both Age Groups.

Variables	Younger Adults (n = 25)	Older Adults (n = 19)	*T*-Test
Age M *(SD)*	22.12 (2.47)	73.37 (4.40)	-
Gender (female)	76%	78.9%	-
MoCA M *(SD)*	28.12 (1.45)	26.84 (1.12)	3.18 **

Note: This table displays the means and standard deviations of age and Montreal Cognitive Assessment scores (MoCA; [31]) for younger and older adults. The percentage of females in each group is also displayed. *T*-test results for the number of years in school are also provided. ** $p < 0.01$.

2.1. Measures

2.1.1. Socio-Demographic Questionnaire

Participants answered a socio-demographic questionnaire to collect descriptive data and define whether they could be included in this study, such as their current medical treatment and neurological and psychopathological history. Gender was assessed using an open-ended format, which allowed participants to self-identify without referring to predefined categories. All participants indicated “male” or "female."

2.1.2. Cognitive Prescreening: MoCA

The MoCA is a brief screening tool to assess cognitive functioning. The screening duration is around 10 min. It is sensitive to very early cognitive impairment as it targets different cognitive domains such as visuospatial and executive skills (e.g., drawing a clock with a specific time), language (e.g., naming depicted animals), short-term and long-term memory systems (e.g., repeating a list of five words after the experimenter and recalling the same words five minutes after the first trial), attention (e.g., clapping when a specific letter is named by the experimenter), abstraction (e.g., explicating the similarities between two objects like a banana and an orange, which are both fruits), and orientation (e.g., being able to give the date and location to the experimenter) [31]. Total scores ranging from 26 to 30 indicate normal cognitive functioning; scores ranging from 18 to 25 indicate mild cognitive impairment (MCI); scores from 10 to 17 indicate moderate cognitive impairment; and scores under 10 indicate severe cognitive impairment. Participants were administered a French-standardized version of the MoCA. Only participants with scores equal to or superior to 26 were included in this study.

2.1.3. Ongoing Task: 2-Back Task

We used a similar paradigm to the ones used by Cona et al., (2015) and Hering et al., (2018) [3,32], in which a PM event-based task is embedded in a 2-back WM task. Participants were instructed to press the keys “m” (No) or “n” (Yes), which were counterbalanced, on a French-Swiss keyboard to indicate whether the picture displayed on the computer’s screen has been displayed twice before. Even though the pictures were displayed for 1000 milliseconds (ms), participants’ answers were registered for 2500 ms. Every picture was followed by a black screen for 1500 ms. Then, a fixation cross appeared for 2500 ms. For the following analyses, all reaction times below 100 ms were excluded [33]. The task was composed of a baseline block followed by six experimental blocks. During the baseline block, participants practiced the 2-back task. After that, instructions for the PM task were given for the next 6 blocks. Each block was composed of 60 emotional pictures (IAPS; [34]), including five emotional PM cues. The pictures were of positive, neutral, and negative valence, and each block contained an equal number of pictures of all three valence categories (see Table 2 for valence and arousal ratings). ANOVAs with the arousal values as a dependent variable and valence as a fixed factor were performed, respectively, for the PM cues and 2-back stimuli. For the PM cues, the ANOVA revealed a significant main effect of valence: $F(2, 27) = 58.96$, $p < 0.001$, $\eta^2_p = 0.81$. Further comparisons indicated that arousal differed between neutral and negative stimuli ($p < 0.001$) and between neutral and positive stimuli ($p < 0.001$), but arousal was similar between negative and positive stimuli ($p > 0.05$). For 2-back stimuli, the main effect of valence was significant: $F(2, 323) = 345.22$, $p < 0.001$, $\eta^2_p = 0.68$. Further comparisons indicated that neutral stimuli were significantly different from positive and negative stimuli ($p < 0.001$), and positive stimuli were significantly different from negative ones ($p < 0.01$). For the experimental blocks, in total, there were 23.3% of 2-back hits in the ongoing task.

Table 2. Arousal and Valence Ratings for PM Cues and 2-Back Task Stimuli.

Stimulus Type	Condition	Arousal	Valence
PM Cues	Positive	5.42	7.31
	Neutral	3.16	5.01
	Negative	4.91	2.71
2-Back Task	Positive	4.93	7.39
	Neutral	3.18	5.03
	Negative	5.18	3.08

Note: Arousal and valence scores are based on the Self-Assessment-Manikin Likert scale, as provided by the IAPS norms.

2.1.4. Event-Based Prospective Memory Task

The event-based PM task was embedded in the ongoing task. Participants were instructed to remember to press the red-dot key of the keyboard (i.e., the “c” key) whenever PM target pictures appeared on the screen instead of performing the ongoing task. Five target emotional pictures were presented to the participants before each block (30 PM cues in total). Each of the five PM target pictures was presented for 4000 ms before the block was memorized by the participants. For two of the six blocks, the PM target pictures were of positive valence; for two others of the six blocks, they were of neutral valence; and for the last two of the six blocks, they were of negative valence. The presentation order of the blocks was counterbalanced. To assess the retrospective memory of the PM targets, at the end of the six experimental blocks, participants performed a recognition block. During this recognition block, the 30 PM cues were presented on the screen along with 60 different emotional pictures that had been previously used for the 2-back task. Each picture was displayed on the screen until participants answered.

2.1.5. Metamemory Assessment: Predictions and Postdictions

For each block, after the presentation of the five PM targets, participants were asked to make predictions on their performance. They had to type the percentage of probability that they thought they would remember to perform the PM task (“According to you, what is the probability in percentage from 0 to 100% that you will press the red-dot key when these five pictures are displayed? 0%, meaning that you would not answer correctly at all, and 100%, meaning that you will answer correctly to every picture.”). In order to avoid stressing the importance of the PM task over the ongoing task, the same question was asked for the 2-back task: (“According to you, what will be your percentage of success from 0 to 100% at the task of pressing for the same or different images?" 0%, meaning that you would not answer correctly at all, and 100%, meaning that you will answer correctly to every picture). After executing each block, participants were asked to make predictions about their performance. They had to type the percentage of success they think they had performed on the PM task: (“According to you, what was your success rate in percentage from 0 to 100% at the task of pressing the red-dot key for the five pictures? 0%, meaning that you answered correctly to any picture, and 100%, meaning that you answered correctly to every picture.”). The same question was asked for the 2-back task: (“According to you, what was your success rate in percentage from 0 to 100% at the task of categorizing the same or different pictures? 0%, meaning that you answered correctly to any picture, and 100%, meaning that you answered correctly to every picture”).

2.2. Procedure

After obtaining their informed consent, the experimenter administered the MoCA to the participants. Following this, instructions for the ongoing task were displayed on the computer screen, and the experimenter asked participants whether they had questions and asked them to explain the task with their own words. Participants performed a practice block for the ongoing task, which included emotional pictures of the three different valences (positive, neutral, and negative). After completion of this practice block, participants received the instructions for the PM task. The experimenter asked participants whether they had any questions; if not, they were presented with the first five PM emotional target cues (positive, neutral, or negative) of the first PM block. To avoid confusion, the target PM pictures were never used for the ongoing task. Before performing each block, participants had to predict their PM performance in percentage both for the PM and the ongoing tasks. Similarly, at the end of each block, participants provided their predictions for both the PM and the ongoing tasks. Participants underwent two blocks of combined ongoing and PM tasks for each valence (positive, neutral, and negative), meaning that there were six experimental blocks in total. Finally, the recognition block was instructed and completed by participants.

2.3. Analytical Approach

Statistical analyses were performed using the software JASP (version 0.16.4.0) [35]. To test our hypotheses, we conducted ANOVAs with gender as a covariate to test potential differences between age groups and across valences on PM, 2-back accuracy, and reaction times. Similarly, ANOVAs with gender as a covariate were conducted to test potential differences in predictions and postdictions between age groups and across valences of PM cues. In order to disentangle interaction effects between our variables of interest, Bonferroni post-hoc comparisons were applied when required. *P*-values under the threshold of 0.05 were considered significant.

3. Results

For the following analyses, all reaction times below 100 ms were excluded, representing 24.51% of the initial data [33].

3.1. Descrptive Statistics

Independent sample *t*-tests demonstrated that on the MoCA, younger adults performed better than older adults (see Table 1).

3.2. Prospective Memory

3.2.1. Accuracy

We conducted a repeated measures ANOVA with age (younger adults vs. older adults) as a between factor, cues' valence as a within factor (positive vs. neutral vs. negative), gender and MoCA as covariates, and PM mean performance for each PM cue's valence as dependent variables. A main effect of age was present, indicating that younger adults ($M = 0.77$, $SD = 0.18$) performed better on PM than older adults ($M = 0.52$, $SD = 0.31$; see Table 3), $F(1, 40) = 4.77$, $p = 0.03$, $\eta^2_p = 0.11$. The effects of PM cues' valence and gender were not significant. Analyses revealed that the main effect of the covariate MoCA was significant, indicating that participants with higher global functioning performed better on the PM task than other participants independently of their age and valence of PM cues, $F(1, 40) = 4.77$, $p = 0.01$, $\eta^2_p = 0.14$. Results demonstrated a significant interaction effect between age and valence: $F(2, 80) = 3.3$, $p = 0.04$, $\eta^2_p = 0.08$. Bonferroni post-hoc comparisons indicated that younger adults ($M = 0.80$, $SD = 0.16$; see Table 3) were more accurate than older adults on negative cues ($M = 0.46$, $SD = 0.32$; $p_{bonf} = 0.03$), but not on positive and neutral cues (all other comparisons $p_{bonf} > 0.05$. Post-hoc power analyses were performed for all our analyses using G*Power 3.1 [36]. They revealed high power ranging from 0.98 to 1 for all the analyses presented in this paper, except for the interaction between valence and age in the 2-back task. We still included this result in this paper, however, it must be interpreted carefully.

Table 3. Means and Standard Deviations for Each Task by Age and Stimuli Valence.

	Younger Adults (n = 25)			Older Adults (n = 19)		
	Positive	**Neutral**	**Negative**	**Positive**	**Neutral**	**Negative**
Ongoing Task						
Correct Hits						
M (*SD*)						
Correct YES	0.79 (0.13)	0.78 (0.16)	0.82 (0.15)	0.58 (0.28)	0.52 (0.29)	0.51 (0.25)
Correct NO	0.84 (0.19)	0.86 (0.12)	0.83 (0.12)	0.54 (0.32)	0.57 (0.31)	0.49 (0.31)
RT						
M (*SD*)						
Correct YES	649.94 (88.84)	675.16 (98.51)	662.13 (96.50)	775.98 (72.72)	766.04 (61.80)	790.57 (76.31)
Correct NO	689.46 (72.31)	672.76 (68.76)	700.32 (66.91)	784.26 (71.95)	765.14 (84.10)	785.97 (75.57)
PM						
Accuracy M (*SD*)	0.75 (0.26)	0.75 (0.21)	0.80 (0.16)	0.52 (0.37)	0.60 (0.35)	0.46 (0.32)
RT M (*SD*)	779.90 (76.91)	774.93 (68.02)	793.64 (59.27)	862.41 (55.19)	835.38 (51.09)	856.26 (48.15)
Recognition of PM cues						
Accuracy M (*SD*)	0.86 (0.22)	0.85 (0.12)	0.83 (0.19)	0.78 (0.25)	0.76 (0.28)	0.77 (0.24)

3.2.2. Reaction Times

We conducted a repeated measures ANOVA with age (younger vs. older adult) as a between factor, cues' valence as a within factor (positive vs. neutral vs. negative), gender and MoCA as covariates, and PM mean reaction times for each PM cue's valence as dependent variables. A main effect of age was present, indicating that younger adults (M = 780.41, SD = 66.02) answered faster than older adults (M = 853.68, SD = 49.65; see Table 3) to the PM cues, $F(1, 33) = 7.79$, $p < 0.01$, $\eta^2_p = 0.19$. No other effects emerged (all effects $p > 0.05$).

3.3. *Ongoing Task: Correct Hits*

3.3.1. Accuracy

We performed a repeated measures ANOVA with age (younger and older adults) as a between factor, stimulus valence (positive vs. neutral vs. negative) and correct hits (correct "Yes" vs. correct "No") as a within factor, gender and MoCA as covariates, and means of 2-back performance for each valence and correct hits categories as dependent variables. Results indicate no significant effect of valence, gender, or correct hits (respectively, $F(2, 80) = 0.03$, $p = 0.97$, $\eta^2_p < 0.01$; $F(1, 40) = 0.28$, $p = 0.60$, $\eta^2_p < 0.01$; $F(1, 80) = 0.14$, $p = 0.71$, $\eta^2_p < 0.01$). There was a significant main effect of age, indicating that younger adults (M = 0.80, SD = 0.15) performed better than older adults (M = 0.53, SD = 0.26; see Table 3) on the 2-back task, $F(1, 40) = 14.22$, $p < 0.001$, $\eta^2_p = 0.26$. Results also revealed a significant interaction effect between age and valence: $F(2, 80) = 3.3$, $p = 0.04$, $\eta^2_p = 0.08$. Post-hoc *t*-tests using Bonferroni corrections revealed that older adults' performance for negative stimuli (M = 0.50, SD = 0.28) was worse than for positive stimuli (M = 0.56, SD = 0.30; $p_{bonf} < 0.001$) and neutral stimuli (M = 0.54, SD = 0.30; $p_{bonf} = 0.02$). This difference in performance depending on valence was not found in younger adults (for all younger adults' comparisons, $p_{bonf} = 1$).

3.3.2. Reaction Times

We performed a repeated measures ANOVA with age (younger and older adults) as a between factor, stimulus valence (positive vs. neutral vs. negative) and correct hits (correct same vs. correct different answers) as a within factor, gender and MoCA as covariates, and means of reaction times for each valence and correct hits categories as dependent variables. Results indicated a main effect of age, meaning that younger adults (M = 674.96, SD = 81.97) were faster to answer to the 2-back stimuli than older adults (M = 777.99, SD = 73.74; see Table 3), $F(1, 38) = 12.8$, $p < 0.001$, $\eta^2_p = 0.25$. Moreover, analyses revealed that the main effect of the covariate MoCA was significant, indicating that participants with higher global functioning performed faster on the 2-back task than other participants independently of their age and the valence of the stimuli, $F(1, 38) = 7.58$, $p = 0.001$, $\eta^2_p = 0.17$). Other effects were not significant (all effects $p > 0.14$).

3.4. Predictions

We performed a repeated measures ANOVA with age (younger vs. older adult) as a between factor, PM cues' valence as a within factor (positive vs. neutral vs. negative), gender and MoCA as covariates, and means of predictions for PM performance as a dependent variable. There was no main effect of age, of valence, nor interaction effect between age and valence. ($F(1, 41) = 1.17$, $p = 0.29$, $\eta^2_p = 0.03$; $F(2, 80) = 0.35$, $p = 0.71$, $\eta^2_p < 0.01$; $F(2, 80) = 1.52$, $p = 0.23$, $\eta^2_p = 0.04$, respectively).

3.5. Postdictions

Following the same approach, we conducted a repeated measures ANOVA with age (younger vs. older adults) as a between factor, PM cues' valence as a within factor (positive vs. neutral vs. negative), gender as a covariate, and means of postdiction for PM performance as dependent variables. It revealed no main effect of age, valence, or interaction between age and valence ($F(1, 40) < 0.01$, $p = 0.98$, $\eta^2_p < 0.01$; $F(2, 80) = 0.57$, $p = 0.57$, $\eta^2_p = 0.01$; $F(2, 80) = 0.59$, $p = 0.56$, $\eta^2_p = 0.02$, respectively).

3.6. Prediction Accuracy: Difference between Predictions and Actual PM Performance

The difference scores were calculated by subtracting participants' mean prediction for each valence from their actual PM performance for each valence, respectively. This resulted in either positive scores, which indicated that participants overestimated their PM performance, or negative scores, which indicated that they underestimated their PM performance.

A repeated measures ANOVA was conducted with age (younger vs. older adults) as a between factor, PM cues' valence as a within factor (positive vs. neutral vs. negative), gender and MoCA as covariates, and the difference scores between predictions and actual PM performance as dependent variables. As the assumption of sphericity was violated, we applied Huyn-Feldt corrections and provided corrected values. This repeated measures ANOVA revealed a main effect of age, meaning that older adults (M = 16.28, SD = 37.56) had a higher difference score between predictions and actual performance than younger adults ($M = -11.73$, SD = 22.31), F (1, 40) = 12.34, $p = < 0.001$, $\eta^2_p = 0.24$. In details, older adults seemed to overestimate their later PM performance, while younger adults seemed to underestimate their performance (see Figure 1). The main effects of valence and the interaction between age and valence were not significant ($F(1.81, 72.23) = 0.46$, $p = 0.61$, $\eta^2_p = 0.04$; $F(1.81, 72.23) = 1.17$, $p = 0.31$, $\eta^2_p = 0.03$, respectively). To confirm that we actually observed reliable over- and underestimation in the predictions, we performed further t-tests to test whether the difference scores were different from 0. In younger adults, results indicated that the negative and neutral difference scores between predictions and actual PM performance were significantly different from 0, meaning that younger adults' predictions were significantly lower than their actual PM performance for these stimuli ($t(24) = -2.75$; $p = 0.01$, d = -0.55; $t(24) = -3.61$; $p < 0.01$, d = -0.72, respectively). This was not the case for positive PM targets (t(24) = -1.47; $p = 0.16$, d = -0.29). In older adults, t-tests revealed that the negative difference score between predictions and actual PM performance was significantly different from 0, meaning that older adults' predictions were significantly higher than their actual performance for negative stimuli (t(18) = 2.85;

p = 0.01, d = 0.66). This was not the case for neutral or positive PM targets (respectively, t(18) = 0.78; p = 0.45, d = 0.18; t(18) = 2.10; p = 0.05, d = 0.48).

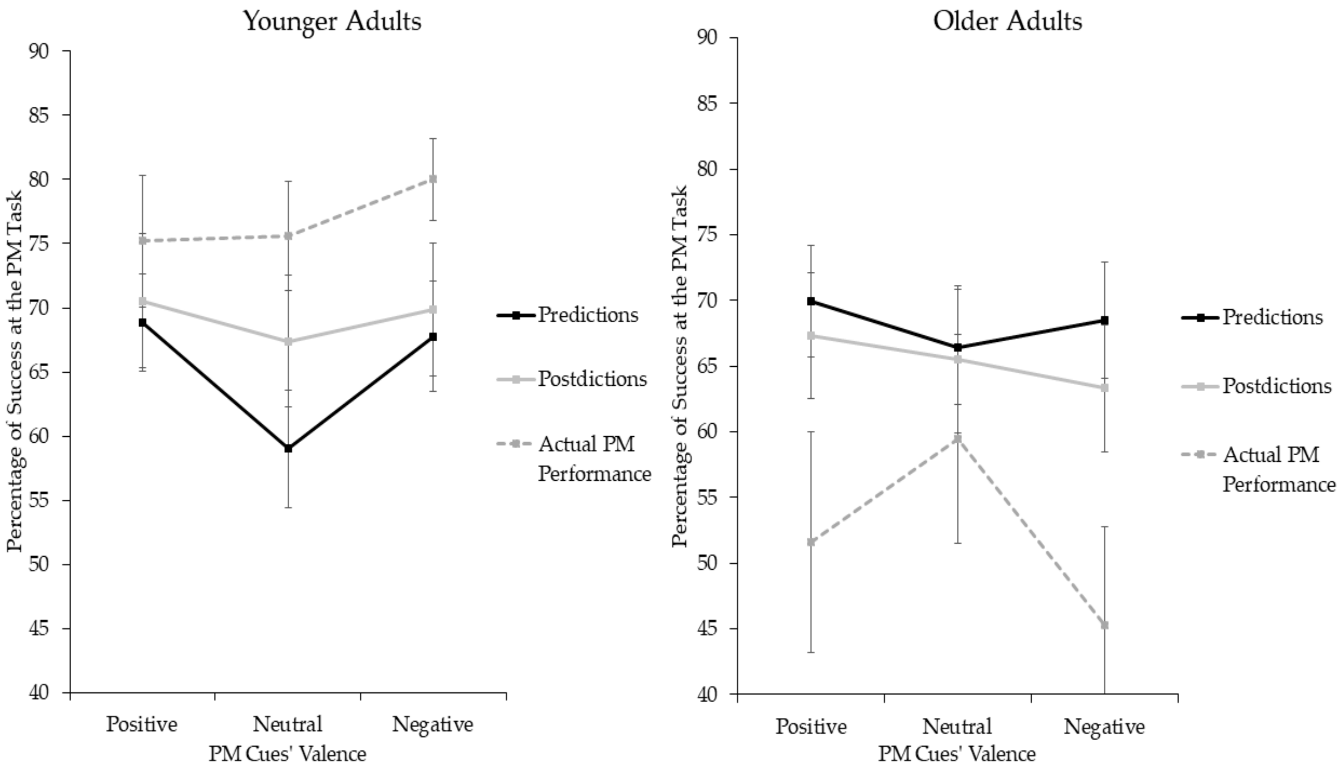

Figure 1. Representation of PM Predictions, Postdictions, and Actual Performance of Younger and Older Adults by Valence of PM Cues. Note: error bars represent standard errors.

3.7. Postdiction Accuracy: Difference between Postdictions and Actual PM Performance

Similarly to prediction difference scores, the postdiction difference scores were calculated by subtracting participants' mean postdiction for each valence from their actual PM performance for each valence, respectively. This resulted in either positive scores, which indicated that participants overestimated their PM performance, or negative scores, which indicated that they underestimated their PM performance after performing the PM task.

We performed a repeated measures ANOVA with age (younger vs. older adults) as a between factor, PM cues' valence as a within factor (positive vs. neutral vs. negative), gender and MoCA as covariates, and the difference scores between postdictions and actual PM performance for PM performance as a dependent variable. Results revealed a main effect of age, meaning that older adults (M = 13.29, SD = 36.38) showed a higher difference in scores between postdictions and actual PM performance than younger adults (M = −23, SD = 20.38), $F(1, 40) = 8.28$, $p < 0.01$, $\eta^2_p = 0.17$. In more detail, mirroring the results on predictions, older adults seemed to overestimate their PM performance, while younger adults seemed to underestimate their PM performance (see Figure 1). The main effects of valence and the interaction between age and valence were not significant ($F(2, 80) = 0.13$, $p = 0.88$, $\eta^2_p < 0.01$; $F(2, 80) = 1.18$, $p = 0.31$, $\eta^2_p = 0.03$, respectively). Again, further t-tests were conducted to understand whether these difference scores were significantly different from 0. For both younger and older adults, only the negative difference score between postdictions and actual PM performance was significantly different from 0, respectively: t(24) = −2.38; p = 0.03, d = −0.48; t(18) = 2.85; p = 0.01, d = 0.66. This indicates that younger adults' postdictions were lower than their actual PM performance for negative PM cues, while older adults' postdictions were higher than their actual PM performance for these same negative PM cues. This was not the case for neutral or positive PM targets, respectively, for younger adults, t(24) = −1.78; p = 0.09, d = −0.36; t(24) = −1.39; p = 0.18, d = −0.29; for older adults, t(18) = 0.67; p = 0.51, d = 0.15; t(18) = 1.83; p = 0.08, d = 0.42).

3.8. Recognition Task

A repeated measures ANOVA with gender and MoCA as covariates was performed on the recognition task. It revealed no significant effect of age ($F(1, 40) = 3.05$, $p = 0.09$, $\eta^2_p = 0.07$), of valence ($F(2, 80) = 0.93$, $p = 0.40$, $\eta^2_p = 0.02$), nor interaction between age and valence ($F(2, 80) = 0.23$, $p = 0.80$, $\eta^2_p < 0.01$), indicating that younger and older adults remembered the PM cues similarly and independently of their valence.

4. Discussion

The aims of this study were to explore for the first time the relationship between metamemory, emotions, and PM. In detail, our objectives were to investigate whether emotional valence influences PM representations and whether PM metamemory representations are sensitive to task experience, especially in older adults. We hypothesized that younger adults would outperform older adults on the event-based PM task. Additionally, we expected that younger adults would be underconfident regarding their metamemory PM representations, while older adults would be overconfident. As for the effect of cues' emotional valence on metamemory representations and PM performance, we explored this relationship without specific hypotheses due to the inconsistencies described in previous literature. Results indicated that younger adults' PM performance was higher than older adults' performance. Moreover, younger adults were more accurate than older adults with negative PM cues. Despite the absence of differences between younger and older adults' predictions and postdictions on PM performance, results demonstrated that younger adults' predictions underestimated performance for neutral and negative PM cues. After performing the task, they showed more accurate representations of neutral cues. Older adults' predictions overestimated performance for negative PM cues, and they did not modify representations after performing the task.

4.1. Emotional Valence and Influence on PM Performance

Similarly to previous studies investigating PM and age, we observed higher accuracy and faster reaction times for younger adults on the PM task compared to older adults. These age effects are common for PM laboratory tasks and can be explained by age-related declines that occur in normal cognitive aging [37–39]. Similarly, observed effects on reaction times are in line with the general cognitive slowing reported in older adults across multiple cognitive tasks [40].

In terms of the effect of cue valence on PM performance, we observed interaction effects between age and emotional valence on the PM task: while younger adults have a similar performance for all cues' valences, older adults perform worse for negative compared to positive and neutral cues. Moreover, younger adults outperform older adults for negative PM cues. Prior research indicated that negative pictures, independently of their arousal ratings, capture attention, which can potentially impair cognitive performance [41]. Other studies demonstrated that highly arousing pictures can also disrupt attentional processing and lead to greater errors, slower reaction times, and difficulties disengaging attention from these stimuli [42,43]. These previous findings could possibly be related to why older adults performed worse on negative stimuli both for the PM and 2-back tasks compared to other variables and compared to younger adults. Indeed, as there were mean differences in arousal across our stimuli, participants' performance may have been disrupted by stimuli of negative valence, especially those higher in arousal, subsequently leading to impaired performance. Why would this effect arise only in older adults? As greater age is related to cognitive slowing, they may be more sensitive to the effects of valence and arousal compared to younger adults, who may compensate with better cognitive resources [40]. Indeed, certain authors demonstrated that IAPS negative pictures are rated as more negative and more arousing by older adults than younger adults [44].

Moreover, when considering metamemory representations, neither older nor younger adults were able to update their representations for negative cues. Thus, this effect of valence and arousal may not only impair cognitive performance but also metacognitive processes in both younger and older adults. These laboratory findings imply the need to further investigate PM performance to understand how this could be transferred to daily life, especially in the context of daily activities that may elicit negative emotions high in arousal. Indeed, such activities may then subsequently disrupt older adults' abilities to perform their PM intentions and, to a further extent, lead to a loss of autonomy.

While we did not replicate the positivity bias, which hypothesized that older adults would perform better for positive stimuli compared to neutral and negative ones because of emotional regulation processes [45], our findings are in line with a so far heterogeneous pattern of results regarding valence effects on age-related PM performance, with some studies reporting higher accuracy for positive PM cues [46–48] and others not finding this effect [32,49,50]. Recent studies are in favor of the existence of a negativity-avoidance bias [23,51]. Several experimental studies demonstrated that positive stimuli elicit approach, as they are motivationally associated with reward in obtention, while negative stimuli usually elicit avoidance, as they are motivationally associated with negative consequences [51–54]. A longitudinal study by Windsor et al., (2012) [55] demonstrated that approach tendencies are significantly higher in younger adults than in older adults and that these tendencies decrease with age, while avoidance tendencies remain stable across the lifespan. In other words, it seems that the ratio between approach and avoidance tendencies evolves with age, possibly leading to an increase in avoidance behaviors in older adults. Thus, in respect of previous research and our study's results, the hypothesis of negativity-avoidance seems credible to explain older adults' performance for negative PM cues. More importantly, the key focus of the present study was not the effect of valence on performance but rather the way metamemory predictions might change with different valence dimensions, how accurate those predictions are, and how this may interact with task experience. We discuss those main research questions in the following section.

4.2. Sensitivity of Metamemory PM Representations to Task Experience

We observed no difference in predictions and postdictions for emotional PM cues in younger adults nor in older adults, indicating that participants considered that they would (predictions) and that they have (postdictions) remembered the PM cues similarly, independently of their valence. Moreover, there was no difference in predictions or postdictions between younger and older adults. However, when comparing these representations with the actual PM performance, we observed interesting new results. Results revealed that, before performing the task, younger adults had accurate predictions of their PM abilities for positive cues, while they underestimated their performance for neutral and negative PM cues. However, after having performed the task, younger adults had accurate postdictions for both positive and neutral cues but still underestimated their PM performance for negative cues. Both before and after experiencing the task, older adults were accurate for positive and neutral PM cues, but they overestimated how well they had performed for negative PM cues.

The scarce available literature on pre- and postdictions (all of which were conducted on neutral tasks) indicated that younger adults underestimated their PM performance, while older adults overestimated their PM performance [10,11]. The current findings extend this pattern by including emotional PM cues and demonstrating differences in age-related PM metamemory representations depending on the cues' valence. We observed that younger adults were able to modify their representations of their PM abilities for neutral cues after having performed the task. However, for older adults, the picture was less clear, as we were not able to demonstrate a change in their representations before and after experiencing the task.

As for possible mechanisms, we have to remain speculative at this point, but as previously mentioned, studies have shown that, in general, positive stimuli tend to elicit approach tendencies while negative stimuli elicit avoidance tendencies [52–54]. Moreover, younger adults seem to have a higher tendency to approach than to avoid. However, these tendencies evolve across the lifespan, leading to an increase in the avoidance of negative stimuli in older adults [23,55]. Thus, younger adults may be accurate about their metamemory representations for PM positive cues because they elicit approach tendencies, which are high in younger adults. Having higher approach tendencies compared to avoidance tendencies could lead younger adults to focus on positive PM cues and help them remember to perform the PM task for these stimuli. For neutral PM cues, they may be underconfident before experiencing the task, as these stimuli do not elicit action tendencies. However, after performing the task, they may conclude that their performance is higher than expected, and subsequently, they may adjust their representations. When it comes to negative PM cues, as they are aversive, they elicit avoidance tendencies, which may lead younger adults to have less confidence in their ability to remember to execute the intention.

As individuals age, they experience multiple life and emotional situations, which may lead older adults to have accurate metamemory representations of their PM performance for positive and neutral cues. However, as their avoidance tendencies increase with greater age, they may focus less on negative PM cues than they expect, leading to overconfidence both before and after experiencing the task. It is possible that older adults are not aware of their increased avoidance of negative cues, leading them to not adjust their PM metamemory representations for these stimuli. Another explanation might be that, because of age-related cognitive decline, older adults are not able to modify their metamemory representations based only on interoceptive cues. Indeed, previous studies indicated that interoception (i.e., the physical sensations that are perceived by individuals and may influence well-being and self-reports) decreases and is less associated with emotions in older adults compared to younger adults [56,57]. However, as underlined above, those explanations have to remain post-hoc interpretations and may only serve as stimulating thoughts for future research that will have to follow up on our initial results.

4.3. Recognition Task

The recognition task aimed at checking whether participants forgot which cues were the PM targets. We observed no difference between younger and older adults, and participants correctly recognized the PM cues among the 2-back stimuli. This indicates that the retrospective memory component of PM (i.e., the content of the intention to be performed, such as which pictures are considered target PM cues) was preserved, thus the poorer performance of older adults on PM performance is more likely related to an impaired prospective component of PM (i.e., remembering to execute the intended action, such as pressing the specific key when the target PM cue is displayed). This is consistent with previous findings, which specify that even when adjusting the difficulty of the ongoing task, age differences are still present on the prospective component of PM tasks (cited in [52]). Thus, older adults may have issues initiating the execution of their intentions, potentially because of a decrease in executive functions with age [58–60]. It is also possible that, during the task, pictures were displayed too fast for older adults to have time to process them and initiate the correct action, while during the recognition block they had unlimited time to recognize PM targets.

4.4. Limitations and Perspectives

Even though our exploratory study provides new and interesting findings on the relationship between emotions, metamemory, and PM, it has certain limitations. Noteworthy is the fact that we have a relatively small sample of participants, although it is similar to other studies targeting affective PM in older adults (see, e.g., [3,50]). Nevertheless, future studies should replicate these results using a larger sample of participants to further explore the relationship between emotions, PM, and metamemory.

Noteworthy is the fact that the valence and arousal ratings provided in our method section come from the IAPS norms [34]. However, as explained in a paper by Grühn &

Scheibe (2008) [44], these norms may not be representative of the older adult population, as they were obtained by soliciting younger adult psychology students. Indeed, the authors indicated that, in their study, older adults rated negative stimuli as more negative and arousing than the official norms, while positive stimuli were rated as more positive but less arousing than these norms. Thus, older adults may have been more sensitive to these dimensions compared to younger adults, and this may partially explain why they performed worse than younger adults on the 2-back and PM tasks for negative stimuli. Future studies should consider using different datasets of emotional pictures for younger versus older adults that would match their valence and arousal sensitivity.

Regarding metamemory and emotions, it would be interesting to investigate participants' approaches and avoidance tendencies, for example, by including the BIS-BAS scale [61]. It would enable us to assess whether the findings of Windsor et al., (2012) [55] and Wolfe et al., (2022) [23] relate to cognitive performance, especially PM performance. Moreover, other methods such as EEG measures may also be relevant to further investigating these questions, as they could indicate whether participants recruit more cognitive resources for specific valence cues, and the Frontal Index Asymmetry Index seems to be a reliable measure to assess approach and avoidance tendencies [3,62]. On another level, it could be more precise to have item-by-item predictions and postdictions instead of having global ones by valence for the PM cues. This would enable us to have a closer look at metamemory representations and how participants modify them depending on the content of the pictures. Indeed, a meta-analysis demonstrated that attentional biases were greater for stimuli representing food, erotic interactions, and babies compared to smiling faces and mixed stimuli [63]. The authors explained that these stimuli are considered relevant for individuals as they relate to common concerns such as nourishment, reproduction, and caretaking. Thus, it may be interesting to investigate whether this allocation of attention results in higher PM accuracy and higher monitoring of PM representations for these types of PM cues in both younger and older adults.

Additionally, to further explore whether older adults can monitor their metamemory representations for PM performance, future studies should consider using external performance indicators, such as feedback. Indeed, it would enable older adults to not only rely on their potentially outdated representations and/or impaired interoception but also to consider more external and objective cues.

5. Conclusions

Taken together, this study is the first to explore emotions, metamemory, and PM in both younger and older adults using predictions and postdictions. It confirms previous studies' findings on younger and older adults' confidence regarding their PM performance: younger adults tend to be underconfident in their pre- and postdictions, while older adults tend to be overconfident in their PM performance. Our results add to the literature on emotions, metamemory, and PM by demonstrating that PM representations may differ depending on PM cues' valence and that those effects seem to be partially different in younger and older adults. Moreover, we demonstrated that younger adults are able to modify their metamemory representations for neutral PM cues but not for negative ones. When it comes to older adults, they do not seem to modify their representations for negative PM cues and seem to benefit less from task experience. Hence, further studies examining the factors underlying the age- and valence-related development of PM representations will be an important avenue for future research, as understanding whether older adults have the ability to modify their metamemory representations is crucial to comprehending how interventions and strategies for learning may benefit them. Indeed, as older adults are overconfident in their PM performance when encountering negative cues, they may not feel the need to adopt strategies when confronted with PM tasks that elicit negative feelings in their daily lives (such as paying the bills or scheduling their dentist appointment), subsequently impacting their autonomy. Therefore, future studies should further investigate, in a larger sample of participants, the ability of older adults to monitor their metamemory representations for PM performance using emotional cues.

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