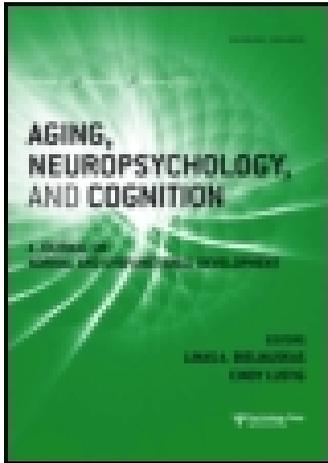


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The best of both worlds: emotional cues improve prospective memory execution and reduce repetition errors

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The best of both worlds: emotional cues improve prospective memory execution and reduce repetition errors

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Prospective memory (PM) errors are commonly investigated as failures to execute an intended task (e.g., taking medication), and some studies suggest that emotional PM cues significantly reduce such failures. In Experiment 1, we extended these findings and additionally explored whether improved PM performance with emotional cues comes at the expense of performance on the ongoing task. Our results indicated that both younger and older adults are more likely to respond to emotional than to neutral PM cues, but the emotional cues did not differentially disrupt the performance on the ongoing task for either age group. Because older adults are also prone to mistakenly repeating a completed PM task, in Experiment 2 we further examined whether emotional PM cues increased repetition errors for older adults. Despite equivalent opportunity for repetition errors across cue type, older adults committed significantly fewer repetition errors with emotional than with neutral cues. Thus, these experiments demonstrated that older adults can effectively use emotional cues to help them initiate actions and to minimize repetition errors.

Keywords: prospective memory; aging; emotion; monitoring; repetition errors

Prospective memory (PM) plays a central role in planning and executing everyday tasks and can be a primary factor in maintaining health (e.g., taking medication), social relationships (e.g., keeping a lunch date), personal independence (e.g., paying bills), and safety (turning off the oven). In the laboratory, PM investigations require participants to engage in an ongoing task (e.g., making judgments about words) while simultaneously remembering to execute another task at some point in the future (e.g., press a key when a specific word appears). Laboratory studies demonstrate that PM can decline with age, especially in situations that demand strategic, controlled processing or that require monitoring (e.g., Henry, MacLeod, Phillips, & Crawford, 2004; Mullet et al., 2013). For example, older adults tend to do poorly when they must monitor a clock in order to complete a PM task (e.g., Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2009), must respond to many different PM cues (Cohen, West, & Craik, 2001; Einstein, Holland, McDaniel, & Guynn, 1992), or are engaged in a task that diverts attention away from the PM intention (Kliegel, Jager, & Phillips, 2008). Older adults tend to perform relatively well when prompted by a single cue and when engaged in a task that orients their attention to the PM cue (Mullet et al., 2013).

Older adults also tend to be successful when the PM cues are distinctive or salient (e.g., Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; Cherry et al., 2001; Cohen,

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Dixon, Lindsay, & Masson, 2003; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000). For example, older adults show heightened PM for physically salient cues that appear in a distinctive font or location (Cohen et al., 2003; Einstein et al., 2000). More recently, researchers have investigated whether emotion increases the saliency of PM cues and consequently boosts PM success. A number of related findings suggest that emotion may indeed enhance cue saliency. For example, evidence in the attentional literature demonstrates that affective targets are detected more quickly than neutral targets (e.g., Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001) and that emotion can facilitate visual processing (e.g., Phelps, Ling, & Carrasco, 2006). In addition, memory is better for affective relative to neutral items in retrospective memory tasks (e.g., Buchanan & Adolphs, 2004; Cahill & McGaugh, 1995; Denburg, Buchanan, Tranel, & Adolphs, 2003; Gruhn, Smith, & Baltes, 2005; Murphy & Isaacowitz, 2008; Ochsner, 2000). One would expect then that emotion might elevate the distinctiveness of a PM cue, thereby improving cue detection and PM success.

A handful of studies have examined the influence of emotion on PM with younger and older adults, with mixed results (e.g., Altgassen, Henry, Bürgler, & Kliegel, 2011; Altgassen et al., 2010; Rendell et al., 2011; Schnitzspahn, Horn, Bayen, & Kliegel, 2012). For example, Altgassen et al. (2010) demonstrated better PM for both positive and negative PM cues relative to neutral PM cues, though this finding was reliable for older but not younger adults. Similarly, Schnitzspahn et al. (2012) reported that older but not younger adults showed heightened PM with positive and negative cues relative to neutral cues. However, Rendell et al. (2011) found reliably better PM for positive targets relative to neutral targets for older and younger adults, but negative cues did not elicit reliably better performance than neutral cues for either age group. Altgassen et al. (2011) reported the same pattern across PM cue types with young adults. These studies suggest that emotional PM cues may be more salient or distinctive than neutral cues, at least in some circumstances, and that the effect may be more consistent for older than younger adults.

While the extant studies are suggestive, additional data are needed for a more complete understanding of interplay between PM, emotion, and age. One limitation of the previous work concerns the stimuli used as PM cues. For example, some studies used very few stimuli (two or three items per cue type) to assess the influence of emotion on performance (e.g., Altgassen et al., 2010, 2011), and the specific characteristics of the cues that were selected may have accentuated or attenuated the emotional effects. Furthermore, in all previous studies, the emotional PM cues were no more arousing than the neutral PM cues, and in some cases the arousal level may have varied across positive and negative cues (Altgassen et al., 2010, 2011; Rendell et al., 2011; Schnitzspahn et al., 2012). As arousal plays a central role in the impact of emotion on memory (e.g., Ochsner, 2000; Reisberg, Heuer, McLean, & O'Shaughnessy, 1988; Thomas & LaBar, 2005), a full understanding of the influence of emotion on PM across age groups requires a more systematic control of arousal. In the present research, we compared the performance of younger and older adults using highly arousing emotional cues, equated the arousal level of positive and negative cues, and sampled from among eight instances of each emotional category.

A second limitation of previous studies is that, with one exception (Schnitzspahn et al., 2012), the studies did not include a measure of monitoring, which is essential for understanding the cognitive processes that underlie any cognitive benefits of emotional cues. According to the multiprocess theory (McDaniel & Einstein, 2000,

2007), PM retrieval can be accomplished through a variety of processes, ranging from strategic, controlled monitoring processes to more automatic spontaneous retrieval processes. Spontaneous retrieval processes are cue-driven processes that are initiated by processing of the PM target and occur in the absence of monitoring. According to McDaniel and Einstein, a number of processes may contribute to spontaneous retrieval, including a reflexive associative process (where processing of the target reflexively leads to retrieval of the intended action), a discrepancy plus search (where the processing fluency of the PM cue is discrepant relative to other items in that context, and this leads to a search of memory for the source of the discrepancy), and an alert that occurs with distinctive or salient items (where an item captures attention and stimulates further processing of the significance that item). By contrast, according to the preparatory attentional and memory model (Smith, 2003, 2010), PM always requires strategic, controlled processes, and increases in PM performance should derive from increases in these processes.

Emotional PM cues may boost PM either by encouraging monitoring or by enhancing spontaneous retrieval processes. For example, to the extent that emotional cues are distinctive and highly arousing, they could foster greater interest and focus on the PM task and stimulate increased levels of monitoring. Related research has shown that instructions that emphasize the significance of the PM task lead to higher levels of task interference or slowing on the ongoing task (relative to instructions that deemphasize the PM task), and investigators have interpreted this task interference to reflect preparatory attentional processes or monitoring (Einstein et al., 2005; Harrison & Einstein, 2010; Loft, Kearney, & Remington, 2008; Smith & Bayen, 2004). From this perspective, any improved PM performance with emotional cues should be associated with increased levels of monitoring.

On the other hand, emotional cues might enhance spontaneous retrieval processes. Related studies have shown that unique or distinctive PM cues lead to very high PM performance (Brandimonte & Passolunghi, 1994; Cherry et al., 2001; Cohen et al., 2003; Einstein & McDaniel, 1990; Einstein et al., 2000; McDaniel & Einstein, 1993) and that this high PM can occur with no evidence of monitoring (Harrison & Einstein, 2010). If emotion operates to boost the saliency of PM targets, then one would expect that emotion, like other cue manipulations (e.g., perceptual distinctiveness), would reduce the need for intentional monitoring and stimulate retrieval via spontaneous retrieval processes. If this were the case, then benefits of emotional PM cues should be accompanied by no increases, but perhaps decreases, in task interference or monitoring. In fact, Schnitzspahn et al. (2012) reported no differences in ongoing task performance across positive, negative, and neutral PM conditions for younger or older adults. However, as noted earlier, their PM stimuli did not vary with respect to arousal, and it is possible that highly arousing emotional PM cues may disrupt the ongoing task to a greater extent than moderately arousing stimuli. In addition, Schnitzspahn et al. (2012) did not provide a control condition for comparison of ongoing task performance, and thus it is impossible to assess the extent of monitoring in the PM task above baseline. The present investigation thus assessed younger and older adults' performance on an ongoing task across blocks that included no PM target, neutral targets, highly arousing positive targets, or highly arousing negative targets.

Our first experiment was designed to assess the PM performance for neutral and highly arousing positive and negative emotional targets. In addition, we evaluated whether monitoring varied with the type of PM target. For this study, younger and older adults engaged in an ongoing lexical decision task (LDT) and were instructed to press a key

whenever a PM target appeared in the LDT. PM cues varied across four blocks of LDT trials: no PM cue (control), neutral cue, negative cue, and positive cue. The control block was used to assess whether the PM cues differentially affected LDT performance. By comparing the PM and LDT performance across blocks for each age group, we sought to determine whether highly arousing positive and negative cues have similar effects on the PM performance of younger and older adults and to understand the cognitive processes that underlie this effect.

Experiment 1

Experiment 1 used a modified version of the lexical decision paradigm pioneered by Marsh, Hicks, and Watson (2002). Participants engaged in an ongoing LDT and were instructed to press a key whenever a PM target appeared in the LDT. Participants completed four blocks of lexical decision trials, including a control block (no PM task) and three different PM blocks (neutral targets, highly arousing positive targets, and highly arousing negative targets). Monitoring or task interference was assessed by comparing LDT performance (accuracy and response time) across blocks.

Method

Participants

Forty undergraduates (ages 18–25 years; $M = 19.1$) from the College of Charleston and 36 healthy, community-dwelling older adults (ages 55–88 years; $M = 69.6$) participated in this experiment. Younger adults volunteered as one way to fulfill a course requirement, and older adults were compensated 10 dollars for the study.¹ Younger adults had an average of 13.4 ($SD = .86$) years of education and a mean score of 19.6 ($SD = 4.4$) on the extended range vocabulary test (ERVT; Educational Testing Service, 1976). Older adults had an average education level of 16.2 years ($SD = 1.9$) and a mean score of 25.1 ($SD = 5.2$) on the ERVT. All older adults had a Mini-Cog score of 3 and self-reported good physical and mental health. The data from four older adults were excluded from analyses because of very poor performance on the LDT (accuracy under 75%).

Materials

Stimuli for the LDT included 240 words and 240 non-words. The words were drawn from the affective norms for English words database (ANEW; Bradley & Lang, 1999), which provides the ratings for the arousal level of words on a scale of 1–9 (with 1 being least arousing and 9 being most arousing), the valence of words on a scale of 1–9 (with 1 being most negative and 9 being most positive), and word frequency in standard American English writing (using values from Kucera and Francis (1967)). One-third of the 240 words used in this study had a neutral valence (range 4–6, $M = 4.97$, $SD = .51$), one-third had a negative valence rating (all scores <4 , $M = 2.95$, $SD = .68$), and one-third had a positive valence rating (all scores >6 , $M = 7.03$, $SD = .60$). Although the words differed in valence, stimuli for the LDT were selected to be moderate to low in arousal (all scores <5.5), and arousal level did not differ across word valence, $F < 1$. Similarly, word frequency did not vary across word valence, $F < 1$.

The non-words were drawn from English Lexicon Project (Balota et al., 2007) non-word generator, were between 4 and 10 letters long, and were pronounceable to English speakers (e.g., “bransit”).

There were four blocks of LD trials, with 240 trials in each. Each block contained 60 words (20 positive, 20 negative, and 20 neutral) and 60 non-words, and each item was presented twice.

Three out of the four LDT blocks included two PM target words, which were also drawn from the ANEW database (Bradley & Lang, 1999). The fourth block served as a control block, providing a baseline for the LDT. The valence of the PM targets varied across blocks, with one block containing only neutral PM targets (e.g., museum and bowl), one block containing only positive, highly arousing PM targets (e.g., cash and passion), and one block containing only negative, highly arousing PM targets (e.g., panic and killer). The two PM target words used in each block were drawn from pools of eight neutral words (M arousal = 3.6, valence = 5.1), eight highly arousing, positive words (M arousal = 7.5, valence = 8.2), or eight highly arousing, negative words (M arousal = 7.5, valence = 2.2). Word frequency ($M = 19.8$) and length ($M = 6.2$) were equated across PM target type. Valence ratings varied significantly across PM target types, $F(2, 23) = 303.1$, $P < .001$. Negative and positive PM targets did not vary in arousal ($F < 1$), but both were significantly more arousing than neutral targets (both P s $< .001$).

Within the PM blocks, each of the two PM target words was repeated, so that participants saw four PM targets per block. For every PM block, the first target appeared after the 50th trial, and at least 50 trials intervened between each of the four PM targets. The PM target words within each block replaced lexical decision words of the same valence, so that all blocks consisted of 240 trials with equal proportions of positive, negative, and neutral words. The PM targets were counterbalanced across participants so that each of the eight PM targets within each valence was used an equal number of times across the study. We used multiple PM target items to ensure that our results did not reflect idiosyncratic responding to one or two specific targets.

We used partial counterbalancing to vary the order of block type (control, positive PM, negative PM, and neutral PM) across participants so that each block type was presented equally often as the first, second, third, or fourth block of trials across participants, thus controlling for both practice and fatigue effects in LDT responding.

In addition to the stimuli for the LDT and PM tasks, we also used paper-and-pencil questionnaires as filler tasks at the beginning of each block. These tasks included the ERVT, a health and education questionnaire, and a creativity task that required participants to create designs for different objects (e.g., flags, flowerpots, etc.). The filler tasks were included to introduce a delay between the presentation of the PM instructions and the onset of the LDT trials. These tasks were presented in the same order to all participants.

Procedure

All participants were tested individually and completed the ongoing LDT and PM tasks on a computer. EPrime (V2; Psychology Software Tools, Pittsburgh, PA) was used to implement the experimental paradigm. Participants first completed a consent form and then read the instructions for the LDT. Participants were instructed to make word/non-word judgments about strings of letters that appeared individually on the computer screen. They were told to press the key with the green sticker (the “J” key) if the string was a word and to press the key with the red sticker (the “F” key) if the string was not a word,

and that items would remain on-screen until a response was made. Speed of responding in the LDT was emphasized as the primary interest in this study. Participants completed 10 practice trials and were then given instructions for the first block of critical trials.

If the participants' first block was a control block, they were reminded of the LDT instructions and the emphasis on speeded responding once more and were then given a 4-min filler task. If the participants' first block was a PM block, they were instructed that in addition to the LDT, they had a secondary PM task. For this task, participants were told to press the key with the yellow sticker (in this case the "T" key) instead of the "word" key whenever they saw one of two target words (e.g., "cash" or "passion"). Participants then repeated these instructions (along with the target words) to the experimenter. Participants were then reminded that their primary task was speeded responding for the lexical decision judgments. They were given a 4-min filler task, and after the filler task they completed the block of trials. No further mention was made of the PM task. At the completion of each block, participants repeated this sequence for the next block of trials, with PM instructions (two new targets per block) followed by a 4-min filler task, and then the LDT.

Results

Prospective memory performance

PM responses were counted as correct if they were initiated within two trials of when the PM cue appeared. The mean percentage of correct PM responses across age groups and conditions is shown in Table 1. A 2 (age) \times 3 (cue type) mixed analysis of variance (ANOVA) indicated a main effect of cue type, $F(2, 140) = 9.8, P < .001, \eta^2 = .12$. There was no main effect of age, $F < 1$, nor was there an age \times cue type interaction, $F < 1$. Based on a meta-analysis by Kleigel, Jager, and Phillips (2008), the average effect size for age differences in PM with focal cues is in the medium range (.54). Our power to detect a medium-size main effect using G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) was .89, and our power to detect a medium-size age \times block interaction was .95.

Further analyses showed that PM performance was reliably higher with positive cues than with neutral cues, $F(1, 70) = 16.5, P < .001, \eta^2 = .19$, and similarly that PM performance was reliably better with negative cues than with neutral cues, $F(1, 70) = 10.4, P < .005, \eta^2 = .13$. PM performance did not differ across the positive and negative blocks, $F(1, 70) = 1.04, P = .31, \eta^2 = .01$. We note that we had good power (.94) to detect a medium-size effect here.

As the findings in the literature regarding the influence of emotional cues on PM have been mixed with respect to valence and age group, we conducted additional analyses to confirm that the boost in PM was reliable for each age group and valence type. For younger adults, a one-way repeated measures ANOVA indicated a main effect of cue type,

Table 1. Mean percentage of correct PM responses (and *SD*) by age and cue type in Experiment 1.

Age group	PM cue type		
	Neutral	Positive	Negative
Younger adults ($n = 40$)	28.8 (27.4)	50.0 (33.0)	44.4 (28.6)
Older adults ($n = 32$)	24.2 (32.0)	44.5 (33.4)	42.8 (37.0)

$F(2, 78) = 5.98, P < .004, \eta^2 = .13$. Further analyses showed that PM performance was reliably higher with positive cues than with neutral cues, $F(1, 39) = 8.7, P < .005, \eta^2 = .18$, and similarly that PM performance was significantly better with negative cues than with neutral cues, $F(1, 39) = 6.8, P < .01, \eta^2 = .15$. PM performance did not differ across the positive and negative blocks, $F < 1$.

Older adults showed an identical pattern: A one-way repeated measures ANOVA indicated a main effect of PM cue type, $F(2, 62) = 4.0, P < .05, \eta^2 = .12$. Further analyses showed that PM performance was reliably higher with positive cues than with neutral cues, $F(1, 31) = 8.3, P < .01, \eta^2 = .19$, and similarly that PM performance was reliably better with negative cues than with neutral cues, $F(1, 31) = 5.2, P < .05, \eta^2 = .12$. PM performance did not differ across the positive and negative blocks, $F < 1$.

Monitoring

Monitoring costs, also referred to as preparatory attentional processes, are typically reflected in the speed of performing the ongoing task (Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith & Bayen, 2004). Response times were evaluated only for LDT trials with correct responses on word trials, and response times were trimmed to exclude responses that were 2.5 *SDs* beyond the mean for each participant. Furthermore, trials that included a PM target, or on which a participant made a PM response, were not included in response time analyses. Mean response times by age group and block type are displayed in Table 2.

A 2 (age) \times 4 (block type) mixed ANOVA indicated a main effect of age, $F(1, 70) = 41.0, P < .001, \eta^2 = .37$, with younger adults responding significantly faster on the LDT than older adults. There was also a main effect of block type on response time, $F(3, 210) = 15.33, P < .001, \eta^2 = .18$. Further analyses showed that response times were significantly faster in the control block than in each of the PM blocks (neutral, $F(1, 70) = 50.4, P < .001, \eta^2 = .42$; positive, $F(1, 70) = 34.7, P < .001, \eta^2 = .33$; negative, $F(1, 70) = 16.5, P < .001, \eta^2 = .19$). Thus, there was evidence of monitoring for each PM cue type. There was no difference in response times for the negative block versus the neutral block, $F(1, 70) = 1.22, P > .3$, while response times for the positive PM block were marginally *faster* than the response times in the neutral PM block, $F(1, 70) = 3.9, P = .052, \eta^2 = .05$. Response times did not differ across the positive PM and negative PM blocks, $F < 1$. Together, these data indicate that while the PM task disrupted the performance for all PM cue types, there was no additional disruption for emotional relative to neutral PM cues. Finally, there was no age \times block type interaction, $F < 1$. Note that the typical effect sizes for monitoring with a single focal target event are in the medium to large range (Smith, Hunt, McVay, & McConnell, 2007). Our power to detect a medium effect size was above .99 for all null effects (i.e., the negative cue versus the

Table 2. Mean LDT response times (and standard deviations) by age and block type in Experiment 1.

Age group	Block type			
	Control	Neutral	Positive	Negative
Younger adults ($n = 40$)	790 (136)	901 (163)	868 (133)	869 (152)
Older adults ($n = 32$)	1087 (256)	1212 (309)	1180 (286)	1201 (302)

neutral cue block comparison, the positive cue versus the neutral cue block comparison, and the age \times block interaction).

Discussion

Participants in Experiment 1 engaged in an ongoing LDT as their primary task and completed an additional PM task on three out of the four LDT blocks. The nature of the PM cues varied across these three blocks, with either neutral cues, highly arousing positive cues, or highly arousing negative cues included in a given block. The data indicated two key findings. First, both younger and older adults were significantly more likely to execute a PM task when prompted by an emotionally arousing cue than when prompted by a neutral cue, and the boost in PM performance with emotional cues was similar across age groups. Second, this enhanced PM did not result from greater effort in or attention to the PM task for either age group. Although performing a PM task induced costs on the LDT, there were no additional costs when PM cues were emotional rather than neutral, despite the fact that emotional cues elicited better PM performance.

The finding of enhanced PM with emotional cues is consistent with recent studies in showing that PM performance can be enhanced when targets are emotional rather than neutral in nature (Altgassen et al., 2010; Rendell et al., 2011; Schnitzspahn et al., 2012). We note, however, that our findings differ from some studies in two ways. First, we found no reliable age difference in overall PM performance, and while numerous other researchers have also reported similar PM performance across age groups (e.g., Cherry & LeCompte, 1999; Einstein & McDaniel, 1990; Kvavilashvili et al., 2009; Reese & Cherry, 2002), others have reported significant declines in PM with age (e.g., Maylor, 1993, 1996; Smith & Bayen, 2006; West, Herndon, & Covell, 2003). The lack of a reliable age difference in the present study is consistent, though, with the recent suggestion by other researchers that age differences in PM are minimized in paradigms that discourage controlled, strategic processing by using a large number of trials in each block and using a small number of focal PM cues on each block (e.g., Einstein, McDaniel, & Scullin, 2012; Henry et al., 2004; Mullet et al., 2013).

Our study also differed from previous studies in that both younger and older adults showed reliable PM enhancement with emotional cues, and the enhancement was equivalent for positive and negative cues. In some studies, younger adults have not always demonstrated the emotional enhancement in PM (Altgassen et al., 2010; Schnitzspahn et al., 2012), and in other studies the effect was reliable for both age groups but was evident only for positive items (e.g., Altgassen et al., 2011; Rendell et al., 2011). As noted earlier, the variation in performance across studies may be driven by differences in methodology. Other investigations have used small stimulus sets (e.g., Altgassen et al., 2010, 2011) and have used non-arousing emotional items or failed to equate arousal across negative and positive conditions (Altgassen et al., 2010; Rendell et al., 2011; Schnitzspahn et al., 2012). Here, we used 16 emotional stimuli, all of which were highly arousing by ANEW norms (Bradley & Lang, 1999). As arousal is known to influence stimulus salience (e.g., Ohman, Flykt, et al., 2001) and memorability (e.g., Denburg et al., 2003; Gruhn et al., 2005), and studies demonstrating the influence of emotion on attention have tended to use very arousing stimuli (e.g., Ohman, Lundqvist, et al., 2001; Phelps et al., 2006), we believe that the arousing nature of our emotional stimuli may be responsible for the consistent effects across age groups and emotional valence observed here. It is possible that positive or negative valence alone is insufficient to consistently

boost PM performance, and that the emotional enhancement observed here is related to the arousing nature of the PM cues.

It is also possible that the robust advantage for positive and negative cues in our study may have been due in part to the contrast between those cues (all of which were highly arousing) and the non-target items (all of which had low-to-moderate arousal ratings). While the non-target items did include items of positive, negative, and neutral valence, the lack of highly arousing stimuli among non-target items may have enhanced the salience of the arousing PM cues. We note, however, that the use of moderately arousing stimuli in the ongoing task most closely parallels everyday situations: People are likely to encounter items and events in ongoing tasks throughout the day that are positively or negatively valenced but are only moderately arousing (e.g., a humorous e-mail, an irritating telemarketer), but they are unlikely to have a day filled with highly arousing items or events (e.g., a promotion letter, a flat tire). Thus, in everyday life, highly arousing PM targets may be very effective in cuing PMs in part because they tend to occur in moderately arousing contexts.

Our findings are consistent with a large literature, suggesting that emotional information enjoys a relatively privileged status in a number of different cognitive processes (e.g., Buchanan & Adolphs, 2004; Cahill & McGaugh, 1995; Dimberg & Ohman, 1996; Hamann, 2001; Ohman, Flykt, et al., 2001; Phelps et al., 2006) and extend this privileged status to PM as well. The data indicate that emotion may be another factor that boosts cue saliency, thus reducing the need for deliberate maintenance of the PM intention while performing the ongoing task (e.g., Brandimonte & Passolunghi, 1994; Einstein et al., 2000; West, Wymbs, Jakubek, & Herndon, 2003).

Experiment 2

The data from E1 confirm that highly arousing, emotional cues can boost PM responses, and in E2 we explored whether these cues might also lead to over-responding in a PM task, resulting in repetition errors. Repetition errors occur when an individual mistakenly repeats a completed PM task, like feeding the dog twice or taking a second dose of medication (Einstein, McDaniel, Smith, & Shaw, 1998). Whereas the majority of PM investigations have examined omission errors (or failures to execute a PM task), more recent studies have begun to assess repetition errors and the conditions under which they are most likely to occur. While these errors are less common for younger adults, older adults are prone to repetition errors, especially with habitual PM tasks that must be completed on a recurring basis (Einstein et al., 1998; McDaniel, Bugg, Ramuschkat, Kleigel, & Einstein, 2009; Scullin, Bugg, & McDaniel, 2012; Scullin, Bugg, McDaniel, & Einstein, 2011). Older adults consistently show higher repetition error rates than younger adults, and these repetition errors may result from age-related deficits in inhibitory functioning (Scullin et al., 2011, 2012). In fact, some data suggest that older adults may be more likely to mistakenly repeat rather than to forget a PM task (e.g., over-medicate rather than under-medicate; McDaniel et al., 2009). Younger adults, by contrast, generally show very low repetition error rates (less than 10%; Einstein et al., 1998; Scullin et al., 2012), and evidence suggests that they successfully inhibit PM intentions when they become obsolete (Scullin et al., 2011). Because repetition error rates are typically very low for younger adults, Experiment 2 investigated these types of PM errors only with older adults.

To maximize the potential for repetition errors, we examined older adults' PM performance in a habitual PM paradigm. Habitual PM tasks (e.g., taking medication,

feeding the dog) are particularly likely to elicit repetition errors in older adults as they involve executing a PM task, then withholding the PM response for a specific timeframe, and then remembering to execute again. Success over time in a habitual paradigm may involve temporary suppression of the intended action (e.g., Scullin et al., 2011, 2012), as well as distinguishing the current intention from a number of previous similar intentions (e.g., did I take my medication today, or was that yesterday; Einstein et al., 1998). The ability to make such temporal distinctions decreases with age (e.g., Johnson, Hashtroudi, & Lindsay, 1993; Kausler, Lichty, & Davis, 1985; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), and this source memory deficit may contribute to increased repetition errors for older adults on habitual tasks (Einstein et al., 1998; McDaniel et al., 2009).

Little is known about the impact of cue distinctiveness or emotion on repetition errors, though at least one investigation with physically distinctive cues suggests that salient cues may increase repetition error rates (Scullin et al., 2012). Given the ease with which older adults detect and respond to emotional cues, and the fact that responses to these cues may be more automatic than strategic (e.g., May, Owens, & Einstein, 2012; McDaniel & Einstein, 2007), it is quite possible that older adults may be more prone to repeat a PM response if an emotional cue occurs after the PM task has been completed.

It is also possible, however, that emotionally salient cues differ from perceptually distinctive cues and may reduce older adults' repetition errors. In other investigations, emotion has been shown to heighten memory for central details of an event (Christianson, 1992; Heuer & Reisberg, 1990; Kensinger, 2007). For example, participants are more likely to remember whether they had previously seen a specific negative stimulus (e.g., snake) than a specific neutral stimulus (e.g., lamp; Kensinger, Garoff-Eaton, & Schacter, 2006). If emotional PM cues result in a more vivid and detailed memory for the initial specific PM response, they may reduce repetition errors. In Experiment 2, we compared older adults' repetition error rates for neutral and emotional PM cues in a habitual PM task.

As participants must first successfully execute the PM task in order to have the opportunity to commit a repetition error, our goal was to use task conditions that encouraged high PM hit rates across neutral and emotional blocks, thus creating ample and equivalent opportunities for repetition errors with both neutral and emotional cues. We therefore adopted a paradigm that required participants to execute a simple PM task in a repeated fashion, and had participants respond to one neutral (or emotional) PM cue (e.g., "kettle") for seven blocks of LD trials and then one emotional (or neutral) PM cue (e.g., "terrorist") for a second set of seven blocks. To emphasize the significance of the PM task, we likened the task to taking medication once (and only once) each day and alerted participants to the start of each new block (or "day") as they progressed through the trials. Participants were told to respond to the cue once and only once per block (preferably at the first occurrence of the PM cue), even though the PM cue appeared three times within each block. Our goal was to examine repetition error rates with neutral versus emotional cues.

Method

Participants

Twenty-seven healthy, community-dwelling older adults (ages 61–84 years; $M = 67.3$) participated in this study. The participants provided their own transportation and were given free parking and compensated 10 dollars for the 90-min study. Older adults had an

average education level of 16.8 years ($SD = 2.1$) and a mean score of 31.3 ($SD = 6.2$) on the ERVT. All older adults had a Mini-Cog score of 3 and self-reported good physical and mental health. Three participants failed to follow instructions (and never responded to the PM task), and thus their data were excluded from the analyses.

Materials

Stimuli for the LDT were very similar to those in Experiment 1 and included 280 words and 280 non-words. As in Experiment 1, the words were selected from the ANEW database (Bradley & Lang, 1999). One-third of the 280 words selected were neutral (range 4–6, $M = 4.97$, $SD = 0.51$), one-third were positive (all scores >6 , $M = 7.03$, $SD = 0.60$), and one-third were negative (all scores <4 , $M = 2.95$, $SD = 0.68$). All of the words were moderate to low in arousal (all scores <5.5).

The non-words were drawn from English Lexicon Project non-word generator (Balota et al., 2007), were between 4 and 10 letters long, and were pronounceable to English speakers.

Twelve PM target words were chosen from the ANEW database: six highly arousing, negatively valenced words (M arousal = 7.5, valence = 2.2) and six non-arousing, neutrally valenced words (M arousal = 3.6, valence = 5.1).² We again used multiple PM target items across participants to ensure that our results did not reflect idiosyncratic responding to one or two specific targets.

The experiment consisted of 14 blocks of 120 lexical decision trials, with each block containing 20 words (six positive, six negative, seven neutral, one PM target) and 20 non-words. Words and non-words each appeared three times per block. The order of item presentation was programmed so that the full set of words and non-words appeared once in a random order before any repeated. The PM target appeared three times per block, occurring once each between trials 33 and 37, 78 and 82, and 113 and 117.

For each participant, one target word (either neutral or negative) served as the PM cue for the first set of seven LDT blocks, and a second target word (either negative or neutral) served as the PM target for the second set of LDT blocks. Half of the participants began with negative cues, and the other half began with neutral cues.

Procedure

All participants first completed a consent form and then read instructions for the LDT-PM task via computer. EPrime (V2; Psychology Software Tools) was used to implement the experiment. As in Experiment 1, participants were instructed to make word/non-word judgments about strings of letters that appeared individually on the computer screen. Participants were told that items would remain on-screen until a response was made. Participants then completed 10 practice trials of the LDT.

Next, participants were told that they were going to complete seven blocks of the lexical decision trials and were informed that words would repeat within each block. They were then instructed that on each block they had an additional task to complete during the LDT trials, namely they were told to press the key marked with the yellow sticker (here, the “T” key) instead of the word key whenever one specific target word (e.g., “panic”) appeared. They were informed that like the other words within a block, the target word would repeat, but they were instructed to press the yellow key once and only once per block.

To encourage comprehension of the PM instructions and success with the PM task, participants were told to conceptualize the task as similar to taking medication. Specifically, they were told to press the key once per “day” (just like taking medication once each day), but to avoid pressing the yellow key more than once within any given block (just as you would not want to take medication more than the prescribed dosage). Participants were also instructed to make every effort to respond to the very first occurrence of a target word within each block, just as it is important to take medication on time every day. If they missed the first time, they were to press the key on the second or even third occurrence if necessary, but were again reminded to press the key only once per block. Participants then repeated these instructions (along with the target word) back to the experimenter.

To ensure that participants understood when one block ended and a new one began, each block trial began with a statement noting the day of the week (e.g., “You are about to begin trials for the MONDAY block”). When participants fully understood the PM instructions, the experimental trials began. As a final measure to boost PM performance, there was no delay between the PM instruction and the onset of task.

As participants progressed through the experiment, the day of the week changed to alert participants to the start of each new block. After the first seven blocks, participants took a short break and completed paperwork and then returned for the final seven blocks. At that point, participants were instructed that they were going to complete another seven blocks of the LDT. They were then given a new PM target (e.g., “museum”) and were again instructed to press the yellow key *once and only once* per block when the target appeared. The blocks for the second week proceeded in the same way as those of the first week. At the completion of the final seven blocks, participants were given the ERVT with no time restrictions and then were debriefed.

Results

Prospective memory success

Participants were instructed to press a key once (and only once) when they saw the target word within each block of trials. Ideally, participants were told to press the key on the very first appearance of the target in each block; however, the target appeared three times in each block, and thus participants had three opportunities per block to execute the PM task. We used several measures to capture PM accuracy, including percentage of first-target detections, percentage of blocks in which a PM target was detected at least once, and a weighted PM success score. For each measure, PM responses were counted as correct if they were initiated within two trials of when the PM cue appeared.

The mean success rates for these measures are displayed by condition in [Table 3](#). A one-way repeated measures ANOVA indicated no effect of cue type on success in

Table 3. PM performance scores (and *SDs*) by cue type in Experiment 2.

Cue type	PM measure			
	First-target detection rate	Percentage of blocks with a PM response	Weighted PM success score	PM repetition error rate
Neutral	90.0% (14.1)	94.0% (9.3)	19.75 (1.96)	12.7% (6.6)
Negative	90.4% (12.4)	94.4% (8.0)	19.83 (1.69)	2.7% (5.6)

responding to the first PM target, $F < 1$, with participants demonstrating very high first-target detection rates in both the neutral cue and the negative cue conditions. Similarly, there was no effect of cue type on overall PM success (responding to at least one target in each block), $F < 1$, with participants demonstrating very high PM success rates in both the neutral cue and the negative cue conditions.

We developed a third measure to capture participants' success in detecting the PM target early in each block. This measure, which we refer to as the weighted PM success score, was calculated by assigning participants a score of 3 if they pressed the key the first time the target appeared, a score of 2 if they pressed the key the second time the target appeared, and a score of 1 if they pressed the key the third time the target appeared. As there were seven blocks per condition, the maximum score a participant could earn in each condition was 21. A one-way repeated measures ANOVA indicated no effect of cue type on the weighted PM success score, $F < 1$, with participants demonstrating very high weighted PM success in both the neutral cue condition and the negative cue conditions.

Together, the measures of first-target detection rate, percentage of blocks with a PM response, and the weighted PM success score all indicate that our efforts to maximize PM responding were successful. There were no differences in performance across conditions, and all three measures reflect consistently high PM success across blocks and conditions. Critically for the purpose of this experiment, these data indicate that there were significant and equivalent opportunities for repetition errors in both the neutral and negative conditions.

Prospective memory repetition errors

As repetition errors were conditional on PM success, we calculated the repetition error rate by dividing the number of repetition errors by the number of opportunities for repetition errors. Thus, if a participant pressed the key on the first appearance of a target, and then pressed the key again on one of the two subsequent appearances of the target, the repetition score would be .50.

A repeated measures ANOVA indicated a reliable effect of cue type on repetition error rate, $F(1, 23) = 10.3$, $P < .01$, $\eta^2 = .31$, with participants committing significantly more repetition errors when PM targets were neutral relative to when they were emotional.

Discussion

In Experiment 2, we examined older adults' repetition errors for neutral and highly arousing, negative PM cues in a habitual PM task. Critically, we were successful in our efforts to create ample and equivalent opportunity for repetition errors across PM cue types, as performance was near ceiling for PM hit rates in neutral and arousing, emotional conditions. Despite equivalent opportunity for repetition errors across PM cue types, older adults committed significantly more repetition errors when PM cues were neutral than when they were emotional.

General discussion

PM can fail in two ways: Individuals can forget to execute a task or can mistakenly repeat a completed task. These failures can be embarrassing (e.g., forgetting a lunch date), costly (paying a bill twice), or dangerous (e.g., over-medicating). In two studies, we

demonstrated that omission errors and repetition errors are both reduced when PM cues are highly arousing and emotional.

In Experiment 1, younger and older adults made fewer omission errors when cues were arousing and emotional versus neutral in nature. Furthermore, although adding a PM task generally produced costs to the ongoing task, there was no additional cost to that task when PM cues were emotional versus neutral. Thus, the data from E1 align with other investigations (e.g., Altgassen et al., 2010; Rendell et al., 2011; Schnitzspahn et al., 2012) in demonstrating that emotional cues can improve PM execution, and they extend these findings in a number of ways. First, the current data demonstrate that when multiple highly arousing PM cues are utilized across participants, both younger and older adults show enhanced responding to these cues relative to neutral cues, and the benefit is similar across cue valence. Second, the present data suggest that the improvement in PM with arousing cues does not derive from increased effort, attention, or monitoring when responding to those cues; rather, emotion improves PM without negatively affecting the performance on an ongoing task. These findings align with a growing literature, suggesting that arousing, emotional information is detected more easily than neutral information and is processed preferentially (e.g., Ohman, Flykt, et al., 2001; Phelps et al., 2006), and furthermore that emotion enjoys a relatively privileged status in many cognitive processes, including attention and retrospective memory (Buchanan & Adolphs, 2004; Cahill & McGaugh, 1995; Ochsner, 2000). The present data also extend other evidence suggesting that emotional processing is spared with age (e.g., Carstensen & Turk-Charles, 1994; Isaacowitz & Blanchard-Fields, 2012), and that older adults' memory is enhanced by emotional content (e.g., Fung & Carstensen, 2003; May, Rahhal, Berry, & Leighton, 2005; Murphy & Isaacowitz, 2008).

We note, however, that our findings from E1 are not consistent with some PM studies that have reported heightened PM with positive but not negative cues (Altgassen et al., 2011; Rendell et al., 2011), or with other reports of a positivity bias with age (e.g., Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2003; Mather & Knight, 2005). It is important to note, though, that not all PM studies have demonstrated this bias for positive cues (e.g., Altgassen et al., 2010; Schnitzspahn et al., 2012), and similarly many studies of retrospective memory have failed to demonstrate a positivity bias for older adults (e.g., Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Emery & Hess, 2008; Gruhn et al., 2005; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002). As discussed earlier, our use of a relatively large stimulus set in which positive and negative cues were highly arousing (and equated with respect to arousal levels) may have led to more consistent results across valence and age groups.

Our findings from E1 also differ from experiments that demonstrate that under focal cue conditions, participants may not demonstrate significant monitoring costs, especially for salient cues (e.g., McDaniel & Einstein, 2000; Mullet et al., 2013; Scullin, McDaniel, & Einstein, 2010). By contrast, younger and older adults in E1 showed reliable monitoring for all PM cue types. While some studies show that both younger and older adults are less likely to show monitoring costs for focal PM tasks (e.g., Mullet et al., 2013), there are other published studies in which participants demonstrate significant monitoring costs in a focal task (e.g., Cohen & Gollwitzer, 2008), even with salient cues (e.g., Smith et al., 2007). Indeed, the work of Cohen and Gollwitzer may provide some insight into the source of the monitoring costs we observed in Experiment 1. Cohen and Gollwitzer found that participants were more likely to show monitoring costs as the number of different PM cues increased, and monitoring was significant with three or more cues. Our study included a total of six different cues for each participant (two per condition) and

additionally required that participants update the cues with each new block. This PM load, especially the need to update memory to include only the currently relevant targets, may have induced monitoring.

In Experiment 2, we evaluated whether the tendency to over-respond in a PM task differed for neutral versus negative cues. Here, older adults completed a PM task designed to strain recollection of whether or not an action had previously been performed (as is thought to be the case when taking medication; McDaniel & Einstein, 2007). We designed the paradigm to minimize omission errors and maximize the opportunity for repetition errors. Older adults were in fact highly successful in making a PM response at least once each block, regardless of the nature of the PM cue. While the lack of a difference in omission errors across conditions may have resulted from ceiling effects in performance, the fact that we equated omission errors across neutral and arousing cues could suggest that there is a limit to the benefit of emotional cues: Highly arousing cues may not increase the likelihood of successfully executing a PM task under habitual task conditions, where the PM task is highly practiced and the same cue is used repetitively. However, although arousing cues may not reduce the omission errors in habitual PM tasks, they do provide some benefit in that they serve to reduce repetition errors. When the PM cues were neutral, participants were significantly more likely to mistakenly repeat the PM response than they were when cues were emotional.

In related research (e.g., McDaniel et al., 2009), older adults made fewer repetition errors when required to perform a complex motor task as part of the PM response. It is possible that a common mechanism underlies both of these effects, as both manipulations may have reduced repetition errors by improving memory for the specific PM event. Adding a complex motor response provides additional sensory information (Gathercole & Conway, 1988), which may in turn produce a more distinctive memory record for the PM event (Johnson & Raye, 1981). Similarly, emotional cues (at least negative ones) have been shown to enhance memory for specific details of an item or event (Kensinger, 2007; Kensinger et al., 2006). For example, in a study by Kensinger et al. (2006), participants were significantly more likely to remember whether they had seen a specific snake than a specific bird. If memory for a specific PM event is enhanced by the addition of either a complex motor response or an emotional cue, participants should have greater access to temporal and contextual details of the PM event (e.g., when, where, and how the PM cue was most recently perceived and/or the task was executed) that prevent them from mistakenly repeating it. At this point, it seems that negative cues add temporal and contextual specificity to the performance of an intended action, and further research is needed to determine whether positive emotional cues produce similar benefits. Together, the data from these studies suggest that emotional cues have a win-win impact on PM performance for older adults, increasing the likelihood of successfully completing a PM task and decreasing the likelihood of mistakenly repeating that task.

Notes

1. The younger adult data reported here were also reported in May et al. (2012), and are included here to enable a comparison of the impact of emotional cues across age groups.
2. The extended duration of the habitual paradigm prevented us from including three different PM cue types (negative, positive, neutral) in this study. In order to create a habitual PM task as well as provide ample opportunity for repetition errors, our paradigm included seven blocks of lexical decision trials (with 120 trials per block) for each cue type, thus requiring nearly 900 lexical decisions per cue type. In order to limit the total duration of the study, we included blocks with neutral cues and blocks with negative cues. We chose to use negative rather than

positive cues for the emotional condition as related research suggests that negative but not positive cues elicit better PM in older adults because they are more salient and memorable (Schnitzspahn et al., 2012), and salient, memorable cues may automatically trigger a PM response and increase repetition errors.

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