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Whoops, I Did It Again: Commission Errors in Prospective Memory

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Prospective memory research almost exclusively examines remembering to execute an intention, but the ability to forget completed intentions may be similarly important. We had younger and older adults perform a prospective memory task (press *Q* when you see *corn* or *dancer*) and then told them that the intention was completed. Participants later performed a lexical-decision task (Phase 2) in which the prospective memory cues reappeared. Initial prospective memory performance was similar between age groups, but older adults were more likely than younger adults to press *Q* during Phase 2 (i.e., commission errors). This study provides the first experimental demonstration of event-based prospective memory commission errors after all prospective memory tasks are finished and identifies multiple factors that increase risk for commission errors.

Keywords: prospective memory, commission errors, aging, forgetting, inhibition

Prospective memory refers to the ability to remember to execute a delayed intention in the appropriate context. The importance of prospective memory is underscored by the ubiquity of daily prospective memory challenges: attaching documents prior to sending e-mails, packing toiletries before departing for the airport, and taking medication before bed. Failures to remember to perform such tasks (i.e., omission errors) may be inconvenient or have more serious consequences (e.g., negative health outcomes).

Perhaps equally important, but understudied, is the ability to deactivate, or otherwise forget, completed prospective memory intentions. Failure to forget a completed intention can result in the erroneous repetition of the intention (i.e., a commission error). Like omission errors, commission errors may be inconvenient (e.g., sending the same e-mail twice) or lead to more serious consequences (e.g., a medical emergency due to overmedicating). The ability to remember to execute an intention and then forget it might be especially important for sustaining independent living in older adults because many of their prospective memory tasks are critical to maintaining health.

Prior research suggests that younger adults inhibit or otherwise deactivate completed intentions (Marsh, Hicks, & Bink, 1998; Scullin, Einstein, & McDaniel, 2009). We recently tested whether this ability was attenuated in older adults (Scullin, Bugg, McDaniel, & Einstein, 2011). Younger and older adults completed the prospective memory task of pressing the *Q* key for the words *fish* and *writer* during an image-rating phase and then were instructed that the prospective memory task was finished and would not need to be performed again. Still, during a later lexical-decision task, the words *fish* and *writer* appeared (see Figure 1 for a schematic of the paradigm). Though no participants produced errors of commission (i.e., erroneously pressing the *Q* key during the lexical decision phase), there was an age-related increase in intention-related interference (i.e., slowed response latencies to prospective memory words; see also Cohen, Dixon, & Lindsay, 2005), suggesting that older adults were still retrieving their completed intention. Moreover, greater levels of intention interference in the older adults were associated with lower levels of inhibition–executive control, as assessed by performance on Stroop and Trail Making tasks. These results are consistent with theoretical frameworks that suggest (a) age-related preservation of cue-driven spontaneous retrieval (Jennings & Jacoby, 1997; McDaniel & Einstein, 2011; Schmitter-Edgecombe, 1999) but (b) age-related impairment in deleting (inhibiting) no-longer-relevant information (e.g., Lustig, Hasher, & Zacks, 2007). Such patterns may increase the occurrence of spontaneous (but erroneous) retrievals of no-longer-relevant intentions in older adults.

The current experiment was designed to extend the Scullin et al. (2011) "finished" procedure described above. We were particularly interested in whether the spurious retrievals that follow intention completion—that is, retrievals that are outside of *active* prospective memory blocks (cf. Einstein, McDaniel, Smith, & Shaw, 1998; Marsh, Hicks, Hancock, & Munsayac, 2002)—may lead younger or older adults to make a commission error. The critical difference between this procedure and previous output-monitoring prospective-memory procedures (Einstein et al., 1998; Marsh et al., 2002) is that whereas previous procedures examined participants' ability to update and maintain active prospective memory intentions, we were interested in examining whether a commission error could occur after all prospective memory intentions were fulfilled. Prospective memory commission errors have never been examined in this manner.

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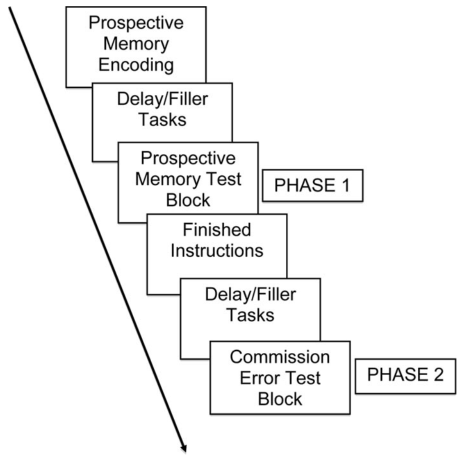

Figure 1. Depiction of the procedure used. Participants encode the prospective memory task and after a delay they perform it in Phase 1. They then receive instructions that the task is finished, and following a delay, see their no-longer-relevant prospective memory cues in Phase 2.

We hypothesized that if the conditions present when encountering a "finished" prospective memory cue were sufficiently similar to those conditions that were present during initial intention execution, then we might observe commission errors (cf. Tulving, 1983). That is, we anticipated that with increased overlap between the prospective memory and commission error phases of the experiment, we would observe relatively automatic responding to the presence of the prospective memory cue (e.g., see Landeira-Fernandez, 1996, for a parallel in the animal behavior literature). We further hypothesized that older adults, who show deficits in exerting (executive) control to oppose responding via habit (Hay & Jacoby, 1999), might be at an elevated risk for making commission errors relative to younger adults. Moreover, we predicted that the tendency in older adults to make a commission error would relate to declines in inhibition–executive function as assessed by the Stroop task and Trail Making test (Scullin et al., 2011). Finally, because commission errors may in part reflect a tendency to perseverate in addition to the inability to inhibit a response, we thought it possible that perseveration errors on the Wisconsin Card Sorting Task (WCST) may be related to commission errors in this study.

In our research, we examined commission errors in three experimental conditions that differed in cue salience and whether the ongoing task used during the initial prospective memory performance phase (Phase 1) overlapped with that which was used during the commission error phase (Phase 2). In both phases, in the salient conditions, the prospective memory cues in the salient conditions always appeared in white font against a salient (e.g., red) background screen, whereas in the nonsalient conditions, the cues appeared in white font against a typical black background screen. In the (ongoing) task-match conditions, the ongoing activity in both Phase 1 and Phase 2 was lexical decision, whereas in the task-mismatch condition, Phase 1 was an image-rating task (Phase 2 remained lexical decision). Because Scullin et al. (2011) used a *nonsalient-cue/task-mismatch* condition and observed no commission errors, in our study we used *nonsalient-cue/task-match*, *salient-cue/task-match,* and *salient-cue/task-mismatch* conditions. We reasoned that the condition that combined a salient cue with ongoing task match (i.e., between Phase 1 and Phase 2) would be the most likely to produce commission errors. The critical predictions for present purposes were that if spontaneous retrieval is relatively preserved in older adults then they should perform the initial prospective memory task as well as younger adults (e.g., McDaniel & Einstein, 2011; Scullin et al., 2011). However, if they are less likely to effectively exert executive control to override the previously associated prospective memory response in Phase 2 (cf. Hay & Jacoby, 1999), then the older adults should demonstrate an increased tendency to make a commission error.

Method

Design and Participants

The experiment was a 2 × 3 between-subjects design that included age group (younger or older) and condition (nonsalient-cue/task-match, salient-cue/task-match, or salient-cue/task-mismatch). Younger adults (n = 73) and older adults (n = 72) were randomly assigned to the three conditions, with 24 participants in each group (except n = 25 younger adults in the salient-cue/task-mismatch condition). Younger adults (M_{age} = 19.19, SD_{age} = 1.11; Range = 18–22) were recruited from the Washington University undergraduate participant pool. Older adult participants (M_{age} = 75.15, SD_{age} = 6.62, Range = 62–87) were community dwelling and reported normal or corrected vision and hearing. Vocabulary test scores were similar across age groups (both Ms = 0.72, $t < 1$), and the older adults (M = 15.31, SD = 3.21) had significantly more years of education than the younger adults (M = 13.01, SD = 1.09), $t(143) = 5.78$.

Procedure and Materials

The procedure (illustrated in Figure 1) and materials followed those used by Scullin et al. (2011) with the exception of the between-subjects manipulations of cue salience and ongoing-task match (Scullin et al. used only a nonsalient-cue/task-mismatch condition). Below, we first describe the task-match condition procedure and then note how the procedure differed in the task-mismatch condition.

Participants in the task-match conditions first received the lexical-decision task instructions. They were instructed that they would be shown a string of letters and to respond as quickly and accurately as possible whether the letters formed a word or not by pressing the keys labeled *Y* and *N* (*5* and *6* on the number pad, respectively). They were next given a lexical decision practice block in which control words (either *fish* and *writer* or *corn* and *dancer*) appeared once each. The control words were matched on number of letters, number of syllables, and frequency (Kucera & Francis, 1967) to the prospective memory target words (and counterbalanced across participants), and they were included to control for target word preexposure (Guynn & McDaniel, 2007).[1]

[1] Control words were also used with the initial intention of comparing response times on those items relative to target items. However, because the presence of commission errors greatly complicates, if not completely confounds, the analysis and interpretation of response times, we do not report those data.

Participants then encoded the prospective memory task. They were given a pair of target words and were instructed to press the *Q* key if they saw either word during the lexical-decision task. In the salient-cue condition, the encoding instructions appeared in a salient background screen (either red or blue, depending on the counterbalance), and participants were informed that the target words would always occur against that red (or blue) screen. In the nonsalient-cue condition, the encoding instructions and target and control words appeared in a typical black background. To ensure understanding of the prospective memory task, participants were required to verbally explain the instructions to the experimenter before continuing. In addition, participants were instructed to only use their right hand during the experiment and to keep their left hand in their lap so that all prospective memory responses (and commission errors) required an overt movement from the number pad to the *Q* key. Compliance was confirmed (or corrected) by the experimenter during a subsequent practice phase that included each target cue once.

Participants next filled out a demographics form and vocabulary test to serve as a delay between encoding and test phases (Einstein & McDaniel, 1990). Then they performed Phase 1, which was an 80-trial experimental block of the lexical-decision task. In Phase 1, each target word and control word appeared twice (total of four prospective memory target events). All target, control, and filler words appeared in white font. Target and control words appeared against red, blue, or black backgrounds, depending on salience condition and counterbalance.

Identical to our prior procedures (Scullin et al., 2011; Scullin et al., 2009) in which no commission errors were observed, after completing the prospective memory task, participants were told that they would continue to perform ongoing decision-making tasks but that they no longer needed to remember to press the *Q* key in the presence of target words. They were further instructed that their only goal was to perform the ongoing decision-making task as quickly and accurately as possible.

Instituting delays (filler tasks) between encoding and test phases is typically used in prospective memory experiments to remove the intention from primary memory (Einstein & McDaniel, 1990), and we complied with this norm by inserting a delay between the finished instructions and Phase 2 (i.e., the commission error phase). During the delay, participants completed a 24-trial block of the lexical-decision task, in which no target or control words appeared, as well as another vocabulary test. Participants then completed Phase 2, which was a 260-trial lexical decision block in which all stimuli were presented in white font. Each target and control word appeared five times with word repetitions separated by at least 11 trials. Target and control words appeared in the same salient or nonsalient background color as during Phase 1. Some filler words and filler nonwords were repeated 2, 3, or 4 times during Phase 2 to control for effects related to repeating the target and control words (Scullin et al., 2009).

The task-mismatch condition was identical to the task-match condition (described above) except that an image-rating task (rather than a lexical-decision task) served as the ongoing task during Phase 1 and the filler task before Phase 2. For this task, participants were instructed that they would see a noun on the screen and that they would have to respond (from 1–3) how easily the word elicited an image in their mind (e.g., *dog* is easy to mentally image).

Following Phase 2, all participants were given a postexperimental questionnaire (Scullin et al., 2011) to confirm their understanding of the ongoing tasks. They were also asked to recall the target words and target key, and if they could not, they were given a target recognition test (target words among six lure words). The postexperimental questionnaire further queried whether participants believed that the prospective memory task was finished when they received those instructions.

The older adults (except for one participant), but not the younger adults, then completed paper versions of the Stroop task and Trail Making test as well as the computerized version of the WCST. The Stroop task (Golden, 1978; Stroop, 1935) involved three 45-s tests. First, participants read color names (*red*, *green*, and *blue*) printed in black ink. Second, participants named ink colors of *XXXX* strings (appearing in *red*, *green*, and *blue*). The third test, which was used to assess inhibitory functioning, required participants to name the ink color of incongruent color names (e.g., the word *blue* written in green ink). Inhibition was indexed as the number of items participants responded to correctly within 45 s during the third phase in which reading of the incongruent word had to be suppressed.

Participants also completed the Trail Making A and B tests (Reitan, 1992). In the first test (A), participants traced lines to connect circles labeled 1–26, in numerical order. In the second test (B), the circles included both numbers and letters, and the participant had to switch between tracing from numbers to letters and back. For example, participants traced from no. 1 to letter A to no. 2 to letter B and so forth. Trail Making B indexes the ability to inhibit currently irrelevant goals, in addition to goal maintenance and task switching (Langenecker, Zubieta, Young, Akil, & Nielson, 2007).

Sixty-five older adults (sample size reduced due to time constraints) then completed the computerized version of the WCST. In this task, participants were shown a series of 128 cards and were asked to use the computer mouse to sort each card to one of four stimulus cards that varied in number, color, and shape (e.g., two green stars). The cards were to be sorted according to number, color, or shape dimensions, but participants were not explicitly told which dimension to use. Following each sorting trial the participant received feedback ("correct" or "incorrect"). The dimension for sorting (e.g., color) stayed the same until a participant sorted 10 cards correctly (consecutively), and then the sorting procedure changed (e.g., to sorting by shapes). The primary measure of interest was perseveration errors, the number of times that a participant erroneously continued to sort a card according to a recently changed dimension. Perseveration errors are theorized to represent failures in executive control processes such as information updating or set shifting and have been dissociated from inhibition processes (Hull, Martin, Beier, Lane, & Hamilton, 2008; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

Results

Alpha was set to .05 unless otherwise noted.

Phase 1: Prospective Memory Hits

Prospective memory hits occurred when a participant pressed the *Q* key on the target trial or one of the two following trials

(Scullin et al., 2011), and prospective memory performance was defined as the number of hits divided by the number of target events (4). The means are presented in Table 1. We conducted a 2 × 3 between-subjects analysis of variance (ANOVA) that included the variables of age group (younger, older), and condition (nonsalient-cue/task-match, salient-cue/task-match, salient-cue/task-mismatch). There were no significant effects, largest $F(2, 139) = 1.94$, $MSE = .04$, for the condition main effect; and, importantly, to note, initial prospective memory performance was similar for the younger ($M = 0.90$) and older ($M = 0.94$) adults, $F(1, 139) = 1.16$, $MSE = 0.04$.[2]

Phase 2: Commission Errors

As illustrated in Table 1, we examined the mean proportion of commission errors [that is, *Q* presses to target words and control words divided by total number of these trials (20) during Phase 2] and conducted a 2 × 3 between-subjects ANOVA that included the variables of age group (younger, older), and condition (nonsalient-cue/task-match, salient-cue/task-match, salient-cue/task-mismatch). Commission errors differed as a function of condition, $F(2, 139) = 14.73$, $MSE = 0.03$, with the salient-cue/task-match condition ($M = 0.18$) producing substantially more commission errors than the nonsalient-cue/task-match and the salient-cue/task-mismatch conditions (*M*s = 0.03 and 0.02, respectively). In general, older adults ($M = 0.11$) made significantly more commission errors than younger adults ($M = 0.03$), $F(1, 139) = 8.30$, $MSE = 0.03$. This effect was qualified, however, by a significant interaction with condition, $F(2, 139) = 3.13$, $MSE = 0.03$, such that older adults exhibited more commission errors than younger adults in the salient-cue/task-match condition, $t(46) = 2.32$, but not (significantly so) in the salient-cue/task-mismatch, $t(47) = 1.52$, or nonsalient-cue/task-match, $t(46) = 1.14$, conditions.[3]

We were further interested in the proportion of participants who made at least one commission error. Those results are displayed in Figure 2. Older adults (26%) were more likely than younger adults (10%) to make at least one commission error, $\chi^2(1, N = 145) = 6.95$.

We also investigated whether any possible participant confusion concerning the task could explain the present results. The age and condition main effects for mean proportion of commission errors (and proportion of participants who made at least one commission error) still obtained when excluding participants who made a false alarm during Phase 1 ($n_{\text{younger}} = 7$, $n_{\text{older}} = 8$),[4] when removing any participants who reported potential confusion on the postexperimental questionnaire (e.g., regarding the finished instructions; $n_{\text{younger}} = 1$, $n_{\text{older}} = 5$),[5] and when removing any participant who could not recall or recognize both the target words and target key after the experiment ($n_{\text{younger}} = 1$, $n_{\text{older}} = 4$).

Inhibition–Executive Functioning

We used the same composite measure of inhibition–executive functioning described in Scullin et al. (2011). This composite measure (termed Z-inhibition) combines the average *Z* scores for the incongruent phase of Stroop and the Trail Making B Test (multiplied by −1 so that lower values equaled worse performance, similar to Stroop). These measures were significantly correlated, $r(70) = .42$. Comparatively, we also created a general speed composite score (termed Z-speed) by averaging the *Z* scores for the neutral color-naming phase of Stroop and Trail Making A (transformed by multiplying values by −1). The general speed measures correlated strongly, $r(70) = .51$. The WCST was not included in the Z-inhibition composite so as to maintain consistency with our previous research (Scullin et al., 2011). Moreover, perseveration errors do not always load onto inhibition constructs (e.g., Hull et al., 2008; Miyake et al., 2000), and in the present study, perseveration errors did not correlate with Stroop, $r(64) = -.01$, or Trail Making B performance, $r(64) = -.11$.

To examine whether inhibitory–executive functioning distinguished those older adults who made a commission error from those older adults who did not make a commission error, we conducted analyses of covariance (ANCOVAs) using the between-subjects factor of whether the older adult made at least one

[2] False alarms (*Q* presses to control words) were rare ($M = 0.06$) and these means are presented in Table 1. A 2 × 3 between-subjects analysis of variance that included the variables of age group (younger, older) and condition (nonsalient-cue/task-match, salient-cue/task-mismatch, salient-cue/task-match) revealed no significant effects for false-alarm rate, largest $F(2, 139) = 2.85$, $MSE = 0.04$, $p = .06$, for the condition main effect. The prospective memory-hits results were not altered if we eliminated participants who made false alarms ($M_{\text{Younger}} = 0.90$, $M_{\text{Older}} = 0.95$), $F(1, 124) = 2.05$, $MSE = 0.04$.

[3] Very few commission errors were made on control trials (see Table 1), and only the older adults made these. A between-subjects analysis of variance in the older adult group demonstrated that mean commission errors made on control trials did not significantly differ across the experimental (cue salience, ongoing task match) conditions, $F(2, 69) = 2.40$, $MSE = 2.68$.

[4] Mean proportion of false alarms correlated with mean proportion of control-trial commission errors, $r(144) = .51$, but not target-trial commission errors, $r(144) = .14$. These results demonstrate that participants who refrained from making a false-alarm error also refrained from making a control-trial commission error. Thus, false alarms did not reflect a global misunderstanding of instructions; making a false alarm did not raise the risk of a target-trial commission error. Consistent with this interpretation, when excluding participants who made false alarms during Phase 1, we still observe significantly more target-trial commission errors in older adults ($M = 0.18$) than in younger adults ($M = 0.08$), $F(1, 124) = 4.84$, $MSE = 0.08$. Likewise, a greater proportion of older adults (15 of 64) relative to younger adults (6 of 66) made at least one commission error, $\chi^2(1) = 4.94$.

[5] Participants who reported confusion on the postexperimental questionnaire, such as disbelief of the finished instructions after the experiment, might have done so possibly out of (true) disbelief, embarrassment over responding when they should not have, or forgetting that they actually did encode that the task was finished. Perhaps a better measure of how well individuals encoded the finished instructions is reflected by their reading time on the screen that indicated the prospective memory task was finished. For the dependent variable of reading time, we conducted a 2 × 2 between subjects ANOVA that included age group (younger or older) and whether the individual had made at least one commission error (yes or no). The only significant effect was the main effect of age group, $F(1, 141) = 23.48$, $MSE = 19361098.80$ (all other *F*s < 1). There was no difference in reading time between those who made commission errors ($M_{younger} = 8{,}737$ ms; $M_{older} = 13{,}202$ ms) and those who did not make commission errors ($M_{younger} = 8{,}503$ ms; $M_{older} = 14{,}252$ ms). Thus, time spent encoding the finished instructions did not predict whether a commission error was made.

Table 1
Mean Proportion of Prospective Memory Hits and False Alarms (Phase 1), and Mean Proportion of Commission Errors to Target Words and Control Words (Phase 2) Across Age Groups and Conditions

	Phase 1		Phase 2	
Variable	Hits	False alarms	Targets	Controls
Younger adults				
Nonsalient-Cue/Task-Match ($n = 24$)	.84 (.27)	.01 (.05)	.02 (.10)	0.0 (0.0)
Salient-Cue/Task-Mismatch ($n = 25$)	.90 (.23)	.02 (.07)	0.0 (0.0)	0.0 (0.0)
Salient-Cue/Task-Match ($n = 24$)	.97 (.08)	.10 (.28)	.18 (.36)	0.0 (0.0)
Older adults				
Nonsalient-cue/Task-Match ($n = 24$)	.91 (.23)	.01 (.05)	.08 (.23)	0.0 (0.0)
Salient-Cue/Task-Mismatch ($n = 24$)	.99 (.05)	.08 (.25)	.06 (.20)	.004 (.02)
Salient-Cue/Task-Match ($n = 24$)	.93 (.25)	.10 (.27)	.44 (.48)	.09 (.28)

Note. Standard deviations are in parentheses.

commission error (vs. those who made no commission errors). In the first test, the dependent measure was Z-inhibition scores and the covariate was Z-speed scores. There was a significant main effect, $F(1, 68) = 4.21$, $MSE = 0.40$, such that inhibitory–executive functioning was worse in older adults who made commission errors ($M_{Z\text{-}inhibition} = -0.41$) than in those who did not ($M_{Z\text{-}inhibition} = 0.15$). We also conducted an ANCOVA to examine whether risk for making a commission error related to number of WCST perseveration errors, after covarying the total WCST trials administered (cf. Heaton, Chelune, Talley, Kay, & Curtiss's, 1993, method for scoring perseveration errors after taking into account total trials). WCST performance did not differentiate older adults who made commission errors ($M = 24.88$) from those who did not make commission errors ($M = 24.10$), $F < 1$.

A related, but distinct question is whether inhibitory–executive functioning predicts the mean proportion of commission errors (which ranged from 0.05 to 1.0).[6] We first conducted a partial correlation between mean proportion of commission errors and Z-inhibition scores (controlling for Z-speed scores) within the group of older adults who made at least one commission error. The correlation was not significant, $r(16) = .20$. In contrast, the partial correlation between total commission errors and WCST perseveration errors (controlling for total trials administered) was significant, $r(14) = .51$. Taken together, this pattern of results indicates that the inhibition composite (used here, and previously by Scullin et al., 2011) partially explains risk for making a commission error, whereas WCST perseveration errors predict the degree to which a particular individual will perseverate on repeating the prospective memory response (i.e., make few or many commission errors).

Discussion

This study reported several novel findings. Consistent with our predictions, the manipulation of cue salience and ongoing-task match indicated that commission errors were most likely with a salient cue and when the ongoing task was the same in Phases 1 and 2. Second, the experiment revealed age-related increases in commission errors, that is, prospective memory impairments that were indexed by an increase in prospective memory responding when it was no longer appropriate to execute the intended action (both in terms of the percentage of participants who made a commission error and the mean proportion of commission errors). In contrast to the view that older adults' prospective memory suffers primarily because of failures to self-initiate retrievals (Craik, 1986), which would result in more errors of omission relative to young adults, our results suggest a different pattern: Older adults retrieved the prospective memory intention at least as often as the younger adults (i.e., no age-differences in errors of omission) but were more likely to fail to suppress the prospective memory response when it was no longer relevant to execute (i.e., age differences in errors of commission).

The finding of commission errors in the current experimental conditions but not in our previous study (Scullin et al., 2011) in which a nonsalient-cue/task-mismatch condition was used points to the importance of environmental features in stimulating spontaneous retrieval and increasing risk of commission errors. The present data suggest that the combination of a salient cue and ongoing-task match increases commission errors and may exacerbate age differences relative to either cue salience or ongoing-task match factors alone. Outside of the lab, the implication is that cues that are likely to capture attention (e.g., a new medicine bottle) and that are present in contexts where the prospective memory intention has previously been performed (e.g., kitchen table) may be especially likely to stimulate retrieval of the prospective memory intention (i.e., taking one's medication), regardless of whether the retrieval is relevant (e.g., prescribed to be taken with breakfast) or no longer relevant (e.g., while eating dinner).

In addition to these environmental features, individual differences in inhibition–executive functioning also influence commission errors. Older adults who made commission errors had reduced Z-inhibition scores relative to those older adults who did not make a commission error, and there was also a positive association between WCST perseveration errors and the degree to which a particular individual continued to (erroneously) repeat the prospective memory response. These divergent patterns (i.e., Z inhibition compared to WCST perseveration errors) may suggest a dissociation between the executive control processes that determine

[6] Of the 26 participants who made a commission error, 4 participants made a single commission error, and 8 participants made a commission error on each prospective memory trial.

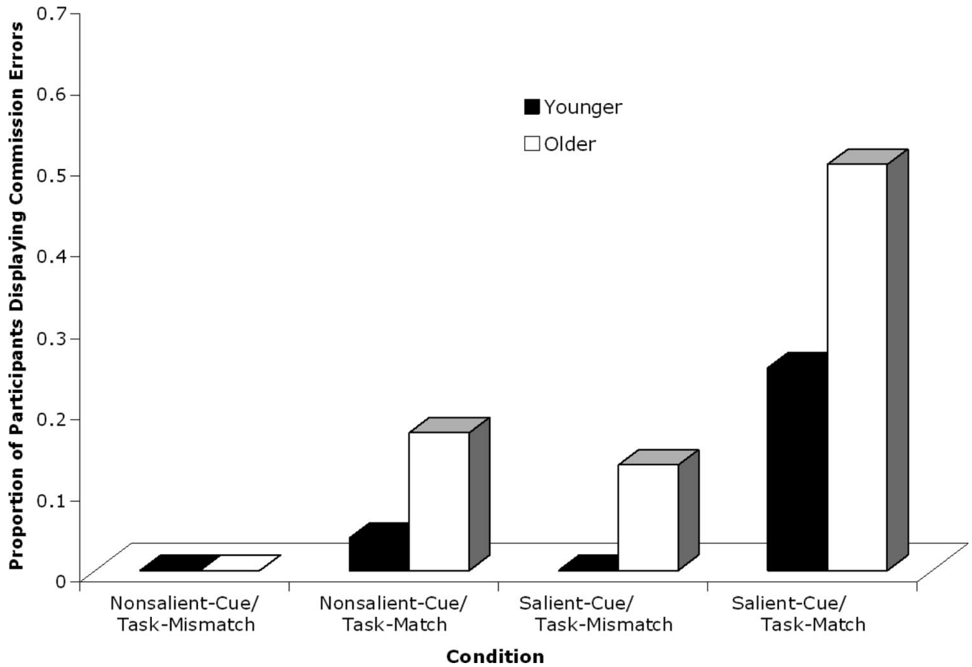

Figure 2. Proportion of younger and older adults who made a commission error across cue salience and ongoing-task match conditions. The results from the nonsalient-cue/task-mismatch condition were adapted from Scullin et al. (2011).

whether one can initially inhibit making a commission error and whether one can quickly "correct" the commission error.

Older adults who offered comments on their postexperimental questionnaires also help inform how commission errors occur. One older adult wrote, "I don't know why [I pressed *Q* again]—it was a conditioned response. Didn't you hear me say 'whoops' during the task?" Another older adult told the experimenter: "I believed [the prospective memory task was over], but the habit had been formed." One older adult who did not make a commission error also commented, "When corn or dancer appeared after I was told I no longer had to press Q, I had to stop myself from doing so." These self-reports suggested that the older adults continued to retrieve their finished intentions during the commission error phase; however, some older adults failed to suppress performing the associated action.

The finding that older adults failed to suppress a no-longer-relevant prospective memory intention is consistent with previous work on aging and prospective memory repetition errors (Einstein et al., 1998; Marsh, Hicks, Cook, & Mayhorn, 2007; McDaniel, Bugg, Ramuschkat, Kliegel, & Einstein, 2009). Einstein et al. gave participants the prospective memory task of remembering to press the *F1* key once and only once during 3-min-ongoing task blocks (waiting at least 30 s into the block to press *F1*). The critical finding was that the older adults were more likely than the younger adults to repeat the prospective memory action (i.e., press *F1*) multiple times, particularly when a resource-demanding ongoing activity was used. The theoretical explanation for such findings was that older adults had more difficulty monitoring their output (i.e., maintaining that they had pressed *F1*) than the younger adults, a skill that likely requires cognitive resources (Koriat, Ben-Zur & Sheffer, 1988).

Whereas Einstein et al. (1998) used a time-based task, Marsh and colleagues (Marsh et al., 2007; Marsh et al., 2002) investigated repetition errors in an event-based paradigm. Participants were told to press "/" every time they saw an animal word, except for if they saw the same animal word a second time and could remember previously pressing "/" to that word, in which case they should instead press the " = " key. Older adults, relative to younger adults, were more likely to press the original "/" key again on repeat trials, thus repeating the initial prospective memory response rather than executing the new (" = ") prospective memory response.

The current study expands the work conducted by Einstein et al. (1998) and Marsh et al. (2002, 2007) in which participants performed tasks that required constant output monitoring and memory updating (of the status of to-be-performed prospective memory intentions) in contexts in which intentions were either (a) temporarily, rather than permanently, irrelevant (Einstein et al.); or (b) no-longer-relevant for particular cues (but still relevant for some cues; Marsh et al.). In our experiment, participants did not need to actively monitor their output or update memories of cues they had seen (and/or responded to) previously because Phases 1 and 2 were separated by clear instructions that the prospective memory task was finished. Thus, this study is novel in revealing commission errors in a context in which there exists no to-be-performed prospective memory intention. The present study also expands previous time-based (Einstein et al.) and categorical-cue (Marsh et al.) studies—both of which are intrinsically more challenging for older adults than younger adults—by demonstrating commission errors in a specific-cue prospective memory task, which was designed to minimize prospective memory difficulties for older adults.

The finding of an age-related increase in commission errors is also consistent with findings outside of the prospective memory literature. Our results converge with research demonstrating an age-related decrease in the exertion of control in opposing responding via habit (Hay & Jacoby, 1999), an age-related impairment in the suppression of previously relevant information (Hartman & Hasher, 1991; also see Zacks, Radvansky, & Hasher, 1996), and an age-related susceptibility to momentary lapses of intention, especially as increasing levels of executive control are required (West, Murphy, Armilio, Craik, & Stuss, 2002).

This study establishes a paradigm for the study of prospective memory commission errors that does not require participants to continuously (or actively) engage in output monitoring or memory updating. We can identify three factors that contribute to risk for commission errors: older age, low inhibitory–executive control, and the combination of cue salience and ongoing-task overlap. There are likely additional individual difference and prospective memory cue–context factors that contribute to risk for making a commission error. For example, prospective memory performance was high in our study (specific cues used and participants practiced the prospective memory task; McDaniel & Scullin, 2010), and presumably, commission errors would be less likely in a situation in which initial prospective memory performance was lower.

We have offered a preliminary theoretical explanation for commission errors in prospective memory: Commission errors occur when a completed intention is spontaneously retrieved and individuals fail to suppress executing the intention. On a neurophysiological level (McDaniel & Einstein, 2011), commission errors should be likely in individuals with preserved medial temporal lobe systems that support spontaneous retrieval (Gordon, Shelton, Bugg, McDaniel, & Head, in press; Moscovitch, 1994), but impaired prefrontal lobe systems which are critical to executive control (e.g., Braver & Barch, 2002; West, 1996). Alternatively, the failure to suppress an intention may also be due to failing to spontaneously retrieve that the intention is finished, or retrieving such finished instructions at a slower rate than retrieving the original intention. If so, then medial temporal lobe impairment might predict commission errors. Further empirical research will help to more completely inform these theoretical accounts, and the utilization of the present paradigm should be fruitful in this pursuit.

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