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Aging and the Strategic Use of Context to Control Prospective Memory Monitoring

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Monitoring the environment for the occurrence of prospective memory (PM) targets is a resource-demanding process that produces cost to ongoing activities. The current study investigated younger and older adults' ability to monitor strategically, which involves the heightening and relaxation of monitoring when it is contextually appropriate thereby affording conservation of limited-capacity attentional resources. Participants performed a lexical-decision task in which words or nonwords were presented in upper or lower locations of the screen. The specific condition was correctly informed that PM targets ("tor" syllable) would occur only in word trials (simple cue; Experiment 1), in word trials in the upper location (complex cue; Experiments 2 and 3A), or in red trials in the upper location (complex cue; Experiment 3B), whereas the nonspecific condition was told that targets could appear in any context. The results showed that older adults generally exhibited similar monitoring patterns as younger adults. When context varied randomly on each trial, younger and older adults in the specific condition utilized simple (Experiment 1) but not complex (Experiment 2) contextual cues to reduce monitoring in unexpected contexts relative to the nonspecific condition. Notably, younger but not older adults were able to use the location dimension of the complex cue to reduce monitoring in unexpected (lower) contexts. When context varied more predictably (i.e., changed every eight trials), both younger and older adults were able to monitor strategically in response to the complex contextual cue (Experiments 3A and 3B). Together these findings suggest that context-sensitive PM monitoring processes generally remain intact with increased age.

Keywords: aging, prospective memory, attention, strategic monitoring, context

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Event-based prospective memory (PM) refers to the ability to remember to execute future intentions (e.g., doctor's appointment) in response to external cues (e.g., office). It is generally assumed that monitoring the environment for the occurrence of cues (i.e., targets) is a resource-demanding process that produces cost to ongoing activities (Guynn, 2003; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Scullin, McDaniel, & Shelton, 2013; Smith, 2003). For example, monitoring for the location of the doctor's office may cause one to drive more slowly. Given the attentional demands of monitoring, a cognitive system that supports flexible allocation of attentional resources to support prospective remembering in a context-specific manner (i.e., *strategic monitoring*) is clearly advantageous, as deployment of costly resources can be reduced when in contexts in which targets are not expected to appear. Previous studies have demonstrated that younger adults are able to strategically monitor as evidenced by the increase in monitoring in contexts in which targets are expected (e.g., near medical complex) and the relaxation of monitoring in contexts in which targets are not expected (e.g., near home; see Smith, 2017 for a review). However, with one notable exception (see Kominsky & Reese-Melancon, 2017), there has been no research examining older adults' ability to strategically monitor.

The question concerning possible age-related differences in strategic monitoring is of practical and theoretical importance. If strategic monitoring abilities decline with age, it is possible that difficulties in daily living associated with the forgetting of PM intentions (Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012) might be compounded by the disruption to daily activities caused by ineffective engagement of PM monitoring processes. Theoretically, declines in strategic monitoring with age may provide insight into the processes underlying strategic monitoring and causes of age-related changes in PM. Monitoring strategically requires at least the following processes: encoding of the PM intention, binding of the intention to the relevant context(s), maintenance of the context-PM intention associations, identification of context(s) while engaging in an ongoing task, the engagement of attentional resources to check for the PM target in relevant contexts, and the disengagement of monitoring in irrelevant contexts.

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In the current study, we draw upon past research with younger adults to investigate age-related differences in strategic monitoring under conditions that differentially tax a subset of the above processes. The general hypothesis guiding this investigation is that age-related differences may depend on the attentional demands associated with strategic monitoring. In the next section, we provide a brief overview of the relevant literature on PM monitoring and age differences in PM. Then we survey the literature on strategic monitoring with an eye toward developing the rationale for the above hypothesis.

Aging and Prospective Memory Monitoring

Monitoring is a frontally mediated process that involves maintaining a PM intention in focal awareness and actively searching for the occurrence of targets (Brewer, Knight, Marsh, & Unsworth, 2010; Burgess, Quayle, & Frith, 2001; McDaniel, LaMontagne, Beck, Scullin, & Braver, 2013). Considerable research has demonstrated that monitoring produces *cost* to ongoing task performance (i.e., slower responding) compared with when the same task is performed without an intention (Guynn, 2003; Marsh et al., 2003; Smith, 2003). It is generally assumed that cost occurs because the ongoing and PM tasks draw on the same limited-capacity resources, so as more resources are devoted to noticing PM targets, fewer are available for ongoing task processing (Einstein & McDaniel, 2010; Smith, Hunt, McVay, & McConnell, 2007; but see Heathcote, Loft, & Remington, 2015; Strickland, Heathcote, Remington, & Loft, 2017). Guynn's (2003) two-process theory of strategic monitoring further suggests that this cost arises because of maintenance of a *prospective retrieval mode* that reflects a global state of readiness to perform the PM task as well as a *target checking* process that determines whether or not the current stimulus contains intention-relevant features. The prospective retrieval mode is thought to operate globally across all trials of the ongoing task, whereas target checking operates at a more local level and is selectively engaged on a trial-by-trial basis.

Given the attentional demands imposed by PM monitoring, and general declines in executive functioning with increased age (Braver & West, 2008; Hasher & Zacks, 1988; West, 1996), it may not be surprising that older adults typically show worse target detection than younger adults (for meta-analyses see Kliegel, Jäger, & Phillips, 2008; Uttl, 2008, 2011). This age difference is generally thought to occur because age-related declines in executive attention lead to ineffective allocation of attentional resources to support prospective remembering (McDaniel & Einstein, 2011; Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010). However, an equally important topic that has received relatively little empirical consideration is whether age-related declines in executive attention limit the ability to monitor strategically.

The current study examined the largely unexplored question of whether older adults' difficulties in allocating limited-capacity attentional resources to the PM task manifest in their having difficulty *disengaging* monitoring in contexts in which PM targets are *not* expected to appear. Addressing this question required use of a paradigm that measures strategic monitoring,[1] the heightening (engagement) of monitoring when contextually appropriate and the relaxation (disengagement) of monitoring when it is not. The critical feature of such a paradigm is the inclusion of unexpected contexts where PM targets are not anticipated to occur, in addition to expected contexts that are a staple of PM paradigms.

Strategic monitoring is typically examined in one of two ways. In the phase (global) level procedure, participants perform an ongoing task (e.g., lexical-decision task [LDT]) composed of two distinct phases. In the *specific* condition, participants are told that PM targets will only occur in one (i.e., Phase 1 LDT; *expected context*) but not the other (i.e., Phase 2 LDT; *unexpected context*), whereas those in the *nonspecific* condition are told that targets can occur in either phase (Ball, Brewer, Loft, & Bowden, 2015; Cohen, Jaudas, Hirschhorn, Sobin, & Gollwitzer, 2012; Knight et al., 2011; Marsh, Hicks, & Cook, 2006). In the trial (local) level procedure, participants perform an ongoing task (e.g., LDT) that varies on some dimension (e.g., word type). Participants in the *specific* condition are told that PM targets will occur in one trial type (i.e., words; *expected context*) but not the other (i.e., nonwords; *unexpected context*), whereas those in the *nonspecific* condition are told that targets can occur in either trial type (Bugg & Ball, 2017; Cohen et al., 2012; Kuhlmann & Rummel, 2014; Lourenço & Maylor, 2014; Lourenço, White, & Maylor, 2013). The typical finding across both procedures, at least for younger adults, is that monitoring cost is identical across conditions in expected contexts (e.g., Phase 1 LDT; word trials). More important, however, only participants in the specific condition are able to reduce monitoring in unexpected contexts (e.g., Phase 2 LDT; nonword trials. (Although the nonspecific condition expect targets to occur in either context, for consistency we use the terms expected context and unexpected context to refer to Phase 1/words and Phase 2/nonwords, respectively, for the nonspecific condition.)

Although such findings suggest that individuals *can* strategically monitor, they do not necessarily speak to the processes underlying this ability. We suggest that strategic monitoring requires multiple processes, including the *encoding* and *maintenance* of PM-context associations, *identification of context* (as expected or unexpected) while performing the ongoing task, and the *engagement* and *disengagement* of PM-specific target checks following context identification. There are, therefore, several possible reasons to expect age differences in strategic monitoring. First, prior research suggests that aging is associated with greater difficulty in binding and retrieving multiple pieces of information in memory (Naveh-Benjamin, 2000). Older adults may, therefore, have greater difficulty in binding contextual features (e.g., phase, or word type) with the PM target (e.g., "TOR" syllable) and action (e.g., "7" key) and maintaining this intention-context association during the task (hereafter we refer to this as the *binding account*). Alternatively, aging is also associated with general declines in executive attention (Braver & West, 2008; Hasher & Zacks, 1988; West, 1996). Prior research suggests that both context identification (Ball & Bugg, 2018) and the engagement or disengagement of monitoring (Lourenço & Maylor, 2014) are dependent on these limited-capacity processing resources. Older adults may, therefore, have greater difficulty in identifying the appropriate context and/or adjusting monitoring accordingly, particularly when context changes rapidly and unpredictably (hereafter we refer to this as the *attention account*).

[1] Most theories of PM consider monitoring (i.e., devoting attention to the PM intention) to be strategic in nature. In the current study, we specifically refer to "strategic monitoring" as the flexible allocation of attention to increase and decrease monitoring in response to contextual cues.

In the single aging study on strategic monitoring to date, Kominsky and Reese-Melancon (2017) used a similar phase level procedure as described above. Of interest to the authors, it was found that both younger and older adults similarly limited monitoring to the context in which they expected targets to appear. That is, both age groups engaged monitoring in the expected context (e.g., Phase 1 LDT) and disengaged monitoring in the unexpected context (e.g., Phase 2 LDT). These findings suggest older adults had little difficulty in binding context information with the PM intention and that younger and older adults were similarly able to utilize context to engage (e.g., expected context) or disengage (e.g., unexpected context) a prospective retrieval mode (i.e., strategically monitor at a global level).

However, these findings leave open the question of whether older adults can strategically implement local level target checking (i.e., on a trial-by-trial basis). While both phase level and trial level procedures require context (e.g., phase, word type) to be bound with the PM intention and maintained throughout the ongoing task to guide attention toward detecting relevant features that signal for monitoring, it is likely the case that context identification and the engagement or disengagement of monitoring are more attentionally demanding in the trial level procedure. When defined by a particular phase, context only needs to be identified at the outset of each ongoing task phase and then attention (e.g., target checks) can remain constant throughout the remainder of the phase (e.g., do not target check on any trial if in unexpected context). In contrast, when defined by a particular trial type context needs to be (rapidly) identified on each and every trial and attention must continuously be adjusted (e.g., target check on words but not nonwords). Accordingly, local-level strategic monitoring may be more sensitive to age-related declines in executive attention (i.e., the attention account). The purpose of Experiment 1 was to, therefore, examine age differences in local-level strategic target checking processes.

Experiment 1

Experiment 1 served as an initial investigation of local level (i.e., trial-by-trial) strategic monitoring ability in older adults. To do this, we used the trial level procedure described (Lourenço et al., 2013). Participants performed an ongoing LDT in which words and nonword were presented randomly. Participants in the specific condition were told that PM targets ("TOR" syllable) would occur in word (expected context) but nonword trials (unexpected context), whereas those in the nonspecific condition were told that targets could occur in either trial type. Stimuli were also presented (randomly) in upper and lower locations of the computer screen to match the procedure of subsequent experiments in which the contextual cue contained both word and location information. However, location information was meaningless to participants for all intents and purposes, as it was not relevant to the ongoing (lexical decision) task or the specified PM context (word trials).

The critical comparison for examining strategic monitoring with this procedure involves contrasting costs on the *same stimulus type* (e.g., word trials) across conditions that *only differ in expectations* (i.e., specific vs. nonspecific; Bugg & Ball, 2017; Lourenço et al., 2013). This allows for a direct comparison of how context expectations influence strategic target checking while controlling for any stimulus effects (e.g., faster lexical decisions for words).[2] Strategic monitoring is evidenced by comparable monitoring cost across conditions in the expected (word) context, but reduced monitoring in the unexpected (nonword) context for those in the specific compared with the nonspecific condition (Bugg & Ball, 2017; Lourenço et al., 2013). According to the attention account, it was hypothesized that strategic monitoring would be evidenced by younger adults but not older adults. If, in contrast to this hypothesis, it is found that older adults implement local-level strategic monitoring as effectively as younger adults, as in Kominsky and Reese-Melancon (2017), this may suggest that age-related differences in this paradigm may not be strongly influenced by the attentional demands associated with context identification and context-dependent allocation of monitoring resources.

Method

The research reported here was approved by the Institutional Review Board at Washington University in St. Louis and was conducted using appropriate ethical guidelines.

Participants. Sixty-three younger adults (age 18–23) from Washington University who received course credit and 63 community dwelling older adults (age 60–80) who received monetary compensation for participation were randomly assigned to either the specific or nonspecific condition. We selected the sample sizes for all experiments based on prior research (Bugg & Ball, 2017; Lourenço & Maylor, 2014; Lourenço et al., 2013) as well as unpublished data from our laboratory showing robust effects with younger adults using similar procedures. Two younger and three older adults failed to detect any PM targets during the experiment and were unable to recall the PM instructions in a postexperimental questionnaire. Because this is indicative of a retrospective memory failure rather than a PM failure, these participants were not included in any analyses (Zimmermann & Meier, 2006). Additionally, one younger and one older adult had average cost estimates that were greater than 3 *SD*s from their respective group means and were, therefore, excluded from all analyses (Ball & Aschenbrenner, 2017). The final sample, therefore, consisted of 30 younger adults in each condition, and 29 and 30 older adults in the specific and nonspecific condition, respectively. Demographic information can be found in Table 1.

Materials. The ongoing LDT consisted of 268 words and 268 nonwords from the ELP database (Balota et al., 2007) that were four to nine letters in length and consisted of two to four syllables (mean Kuèera–Francis frequency of 82). All items were lower case and appeared in upper and lower portions of the screen in a 30-point font. The upper and lower locations were presented 40 and 60%, respectively, from the top of the screen. The same PM targets were used as Lourenço et al. (2013): dormitory, factory, history, torches, torment, tornado, tortoise, and victory.

Procedure. Participants were tested individually in ~30 min sessions. The general procedure (modeled after Lourenço et

[2] The primary issue with comparing strategic monitoring across stimulus type (i.e., words vs. nonwords) within a condition (e.g., specific condition) is that words are typically responded to more quickly than nonwords. Thus, any *cost* difference across the two stimulus types is not necessarily directly comparable because possessing a PM intention may differentially slow one trial type (e.g., words) compared with another (e.g., nonwords). Thus, the most appropriate comparison is for the same trial (e.g., word trials) across conditions that only differ in expectations.

Table 1
Demographic Information and Vocabulary Scores for Younger and Older Adults Across Conditions in Experiments 1, 2,and 3

		Younger		Older		
Experiment	Variables	Specific	Nonspecific	Specific	Nonspecific	Significance
1	*N*	30	30	29	30	
	Age	19.0 (1.07)	19.1 (1.28)	69.0 (5.68)	68.9 (4.49)	*
	Education	14.0 (1.03)	13.7 (.95)	16.7 (1.56)	17.2 (2.58)	*
	Vocab	32.4 (2.98)	31.7 (2.59)	36.8 (2.20)	35.9 (2.02)	*
2	*N*	37	37	29	30	
	Age	20.3 (2.00)	19.9 (1.87)	69.5 (6.41)	71.6 (6.86)	*
	Education	13.8 (1.84)	13.7 (1.57)	16.0 (2.81)	16.1 (2.28)	*
	Vocab	33.0 (2.94)	32.9 (3.15)	34.5 (3.17)	34.5 (4.17)	*
3A	*N*	30	30	26	27	
	Age	19.7 (1.18)	19.1 (1.28)	73.8 (7.46)	75.8 (7.30)	*
	Education	13.4 (1.40)	13.0 (1.13)	15.8 (1.83)	15.9 (2.85)	*
	Vocab	33.6 (3.05)	32.5 (2.92)	35.1 (3.08)	34.6 (2.54)	*
3B	*N*	30		30		
	Age	19.6 (.97)		67.8 (4.78)		*
	Education	14.2 (1.05)		16.4 (2.14)		*
	Vocab	32.1 (3.05)		35.4 (2.2)		*

Note. Each variable was submitted to a 2 (Age) × 2 (Condition) analysis of variance (ANOVA) separately for Experiments 1, 2, and 3A. Because there was no effect of condition or interaction of condition and age for any analysis, the significance column refers only to the main effect of age (e.g., older adults had higher vocabulary scores). Because specific and nonspecific blocks were within-subjects for Experiment 3B, each variable was submitted to a between-subjects (age) ANOVA. *SD* in parentheses.

al., 2013) for Experiments 1 and 2 can be found in Figure 1. For the ongoing LDT, participants were instructed to make lexical decisions to items that appeared in the upper or lower locations on the screen as quickly and accurately as possible, after which a blank screen would appear to indicate that they should press the spacebar to continue to the next trial. Participants performed a brief (16 trials) practice LDT phase, followed by the baseline block (no intention) then PM block. Before beginning the PM block, participants were additionally instructed that whenever they saw the syllable "TOR" they should press the 7 key after making their lexical decision. Participants in the *specific* condition were told, "The 'tor' syllable will only occur in words; the 'tor' syllable will never occur in nonwords." Participants in the *nonspecific* condition were told, "The 'tor' syllable will occur in words or nonwords." Participants were then asked to repeat the PM instructions (without looking at the computer screen). If any details were left out, the experimenter reiterated the instructions until participants could fully repeat them. Participants were then given a verbal "quiz" asking what (a) syllable, (b) action, and (c) context they were to respond to. The correct answer was provided if any question was responded to incorrectly. Following PM instructions, a 5 min delay was created by having participants fill out a demographics questionnaire and the Shipley Vocabulary Test (Shipley, 1940). At the end of the experiment all participants filled out a postexperimental questionnaire to check their memory for the PM task. Participants that were unable to correctly remember all three PM-relevant task instructions (i.e., the syllable, action, and context) were excluded from analyses.

The baseline and PM blocks each consisted of 252 LDT items (126 words and 126 nonwords), with half of each presented in the upper and lower locations. Presentation of stimuli and

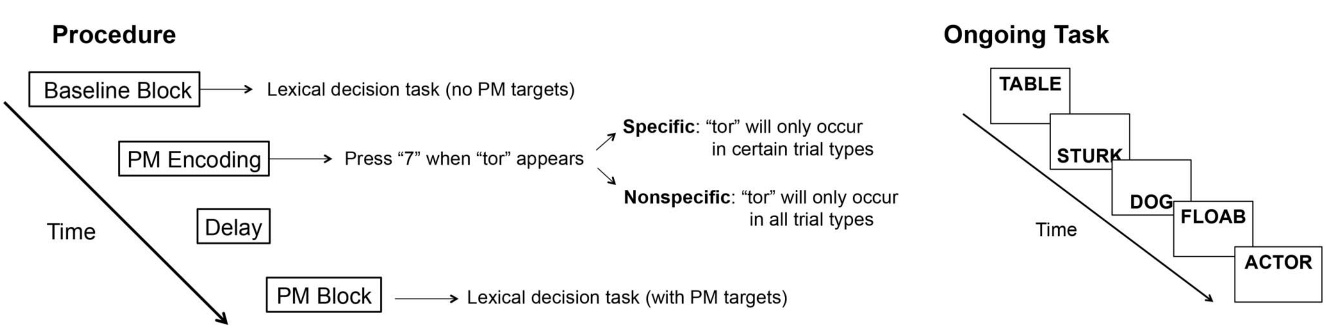

Figure 1. General procedure used in Experiments 1 and 2.

location was randomized for each participant. Half of the PM targets were randomly presented in the upper and lower location each. The PM targets were presented every 31 trials on Trials 31, 62, 93, 124, 155, 186, 217, and 248. The order of appearance for the eight PM targets was randomized between participants.

Results

LDT performance. The following data analytic procedure was used for all experiments. For accuracy and response time (RT) analyses, the first six trials of the baseline and PM blocks, the PM target trial, and the three trials following the PM target were excluded (Bugg & Ball, 2017). RT analyses were conducted on correct trials only and were trimmed at 2.5 *SD*s from each participant's mean separately for each block (Lourenço et al., 2013). To account for age-related slowing, we also transformed RTs to within-participant z-scores based on the individual's overall mean and *SD* (Faust, Balota, Spieler, & Ferraro, 1999). However, because ongoing task accuracy was high (see Tables 2 and 3), relatively unaffected by PM demands, and did not contradict the RT data, and because the z-transformed RT data exhibited the same pattern of results as the standard RT analyses,[3] we only report full analyses for the standard RT measures for all experiments (Bugg & Ball, 2017). The primary dependent variable for all RT analyses was the cost measure (PM RT—baseline RT) across the different contexts because preliminary analyses indicated that there was significant slowing in the PM block because of possessing an intention (relative to the baseline block) for all Experiments 1, 2, and 3A. There was no baseline block in Experiment 3B and, thus, the dependent variable was mean RT. The α level was set at .05 for all analyses.

Response times. Descriptive statistics for RT measures can be found in Table 2. Mean RT cost (PM RT—baseline RT) was submitted to a 2 (word type: word vs. nonword) $\times$ 2 (condition: specific vs. nonspecific) $\times$ 2 (age: younger vs. older) mixed-factorial analysis of variance (ANOVA), with age and condition as the between-subjects factors. For brevity, we will only discuss the relevant findings. However, the results from the full model can be found in Table 3.

There was evidence of strategic monitoring as indicated by the significant word type x condition interaction, $F(1, 115) = 10.35$. However, this did not differ as a function of age, as indicated by the null three-way interaction,[4] $F(1, 115) = 3.14$. As can be seen in Figure 2, the Word Type $\times$ Condition interaction reflects that while there were no cost differences between conditions in the expected (word) context, $F < 1$, cost was reduced in the unexpected (nonword) context for the specific relative to the nonspecific condition, $F(1, 117) = 8.70$, $p = .004$, $\eta_p^2 = .069$.

Target detection. To examine PM performance, the proportion of successfully detected PM targets within the word context was submitted to a 2 (condition: specific vs. nonspecific) $\times$ 2 (age: younger vs. older) between-subjects ANOVA (see Figure 3). As is commonly the case in nonfocal PM tasks, target detection was worse for older adults, $F(1, 115) = 3.97$, $p = .049$, $\eta_p^2 = .033$. However, there was no effect of condition, and no Age $\times$ Condition interaction, Fs < 1.

Discussion

The results of Experiment 1 demonstrated for the first time age-equivalence in local level strategic monitoring when context varied randomly. That is, both younger and older adults showed comparable monitoring across conditions in the expected (word) context, and both age groups in the specific condition were similarly able to reduce monitoring in unexpected (nonword) contexts relative to the nonspecific condition. This extends the prior findings of Kominsky and Reese-Melancon (2017) by demonstrating a similar pattern of results when context changed much more quickly and unpredictably. Notably, despite similar monitoring for both age groups, consistent with prior research older adults still detected fewer PM targets (Kliegel et al., 2008; Uttl, 2008, 2011). These findings suggest that older adults are able to flexibly heighten and relax target checking in response to contextual cues, but ongoing task demands may nevertheless usurp limited-capacity resources in expected contexts that may otherwise be devoted to target detection. Also, consistent with prior research (Lourenço & Maylor, 2014; Lourenço et al., 2013), PM performance did not differ between specific and nonspecific conditions, which makes sense given that both conditions expected PM targets to occur in word trials.

Experiment 2

The finding of age-equivalence in local level strategic monitoring in Experiment 1 was somewhat surprising given the attentional demands needed to quickly identify the appropriate context to engage monitoring when context varied unpredictably (Lourenço & Maylor, 2014). However, before concluding that age-related differences in this paradigm are not strongly affected by the attentional demands associated with context identification and context-dependent allocation of monitoring resources, we aimed to provide a stronger test of the hypothesis by further heightening the attentional demands associated with these processes. In Experiment 2, we examined whether strategic monitoring would also be evidenced for younger and older adults in response to *complex* (contextual) *cues* that varied randomly. A complex cue refers to the co-occurrence of two or more contextual features (Bugg & Ball, 2017), such as using location (e.g., left side of the street) and identity (e.g., medical buildings) information to strategically monitor for the doctor's office. Prior research in the visual search domain suggests that identification and detection of feature conjunctions is more attentionally demanding than a single feature and may, there-

[3] Full analyses for the z-transformed RTs for all experiments can be found in the supplemental material.

[4] As can be seen in Figure 2, the marginal three-way interaction primarily reflects that the difference between word and nonword costs in the specific condition was greater for older adults than younger adults. However, both younger and older adults in the specific condition show reduced monitoring on nonword trials relative to the nonspecific condition. Thus, the marginal interaction does not contradict the primary finding of similar strategic monitoring patterns across age groups.

Table 2
Mean Ongoing Task Accuracy and Response Times for Younger and Older Adults Across Conditions in the Expected and Unexpected Contexts of Experiment 1

Block	Age	Condition	Accuracy		Response times	
			Expected (word)	Unexpected (nonword)	Expected (word)	Unexpected (nonword)
Baseline	YA	Specific	.90 (.012)	.94 (.008)	763 (14)	813 (20)
		Nonspecific	.89 (.01)	.93 (.01)	760 (17)	816 (19)
	OA	Specific	.98 (.004)	.96 (.011)	1052 (29)	1164 (39)
		Nonspecific	.96 (.005)	.95 (.01)	1043 (27)	1133 (32)
PM	YA	Specific	.92 (.012)	.95 (.008)	878 (19)	868 (18)
		Nonspecific	.92 (.007)	.93 (.009)	897 (24)	918 (24)
	OA	Specific	.97 (.004)	.95 (.014)	1234 (39)	1220 (44)
		Nonspecific	.97 (.006)	.96 (.012)	1213 (33)	1256 (38)

fore, impose greater attentional demands on strategic monitoring than the simple cues that have been used in prior strategic monitoring research (see, e.g., Treisman & Gelade, 1980, that detection of feature conjunctions [i.e., complex contextual cue] is more attentionally demanding than detection of feature singletons [i.e., simple context cue]).

The procedure for Experiment 2 was identical to Experiment 1 except that participants in the specific condition were instructed that PM targets would occur in *words* in the *upper location* (the *expected context*) but not in other trial types (i.e., upper nonword, lower word, and lower nonword trials, which are referred to as the *unexpected contexts*), whereas those in the nonspecific condition were instructed that targets could occur in either word type and in either location of the screen. Based on the results of Experiment 1, one hypothesis was that both younger and older adults would similarly be able to reduce monitoring in unexpected contexts with a complex cue given that the memory demands (remember a specific context) and ongoing task demands (making a lexical decision) are fairly similar. However, the primary difference is that in the current study participants in the specific condition must bind multiple context features (i.e., word and location) with the PM intention, which may be more difficult than binding a single context feature (i.e., word) as in Experiment 1. Additionally, participants must attempt to identify contexts as expected or unexpected based on a conjunction of features (i.e., words in the upper location), which should be more attentionally demanding than searching for only a single feature (words). Given both memory (i.e., binding account; Naveh-Benjamin, 2000) and attentional (i.e., attentional account; Braver & West, 2008; Hasher & Zacks, 1988; West, 1996) declines with increased age, an alternative prediction was that younger, but not older, adults would show evidence for strategic monitoring using a complex contextual cue.

Method

Participants. Seventy-six younger adults (age 18–25) from Washington University who received course credit and 69 community dwelling older adults (age 60–93) who received monetary compensation for participation were randomly assigned to either the specific or nonspecific condition. However, 10 older adults that failed to detect any PM targets and were unable to recall the PM instructions in a postexperimental questionnaire were not included in analyses. Additionally, two younger adults had average cost estimates that were greater than 3 *SD*s from their respective group means and were, therefore, excluded from analyses. The final sample, therefore, consisted of 37 younger adults in each condition, and 29 and 30 older adults in the specific and nonspecific conditions, respectively (see Table 1). Participants were tested individually in ~30 min sessions.

Materials and procedure. The materials and procedure were identical to Experiment 1, except that participants in the *specific* condition were told, “The ‘tor’ syllable will only occur in words in the upper location; the ‘tor’ syllable will never occur in nonwords or in the lower location.” Participants in the *nonspecific* condition were told, “The ‘tor’ syllable will occur in words or nonwords in either location.” Additionally, the eight PM targets always appeared in words in the upper location. Participants that were unable to correctly remember all three PM-relevant task instructions (i.e., the syllable, action, and both context features) were excluded from analyses.

Results

Response times. Mean RT cost was submitted to a 2 (word type: word vs. nonword) × 2 (location: upper vs. lower) × 2 (condition: specific vs. nonspecific) × 2 (age: younger vs. older) mixed-factorial ANOVA. Descriptive statistics for the RT measures can be found in Table 4, and results from the full ANOVA model can be found in Table 3. More important, the four-way interaction was significant, $F(1, 129) = 4.14$. This interaction primarily reflects that a slightly different pattern of monitoring was evident for younger than older adults. To explore this four-way interaction, we, therefore, conducted separate 2 (word type: word vs. nonword) × 2 (location: upper vs. lower) × 2 (condition: specific vs. nonspecific) ANOVAs for younger and older adults.

[5] Note that using Holm-Bonferroni correction for multiple comparisons, this effect is no longer significant. However, we have replicated this exact pattern of results in a group of younger adults in unpublished data from our laboratory.

Table 3
Results From the Omnibus ANOVA of Mean Reaction Times for Each Experiment

Experiment	Factor	*df*	*F*	MSE	η_p^2	Significance	
1	Condition	1, 115	3.38	17526	.029	.069	*ns*
	Age	1, 115	2.86	17526	.024	.094	*ns*
	Condition × Age	1, 115	.10	17526	.001	.754	*ns*
	Word Type	1, 115	69.68	3788	.377	<.001	***
	Word Type × Condition	1, 115	10.35	3788	.083	.002	**
	Word Type × Age	1, 115	5.68	3788	.047	.019	*
	Word Type × Condition × Age	1, 115	3.14	3788	.027	.079	*ns*
2	Condition	1, 129	1.04	44522	.008	.311	*ns*
	Age	1, 129	3.58	44522	.027	.061	*ns*
	Condition × Age	1, 129	.01	44522	.000	.914	*ns*
	Word Type	1, 129	46.72	8629	.266	<.001	***
	Word Type × Condition	1, 129	3.73	8629	.028	.056	*ns*
	Word Type × Age	1, 129	3.94	8629	.030	.049	*
	Word Type × Condition × Age	1, 129	1.21	8629	.009	.274	*ns*
	Location	1, 129	18.78	5531	.127	<.001	***
	Location × Condition	1, 129	3.30	5531	.025	.071	*ns*
	Location × Age	1, 129	.42	5531	.003	.519	*ns*
	Location × Condition × Age	1, 129	.97	5531	.007	.326	*ns*
	Word Type × Location	1, 129	.39	5329	.003	.535	*ns*
	Word Type × Location × Condition	1, 129	.31	5329	.002	.580	*ns*
	Word Type × Location × Age	1, 129	.04	5329	.000	.840	*ns*
	Word Type × Location × Condition × Age	1, 129	4.14	5329	.031	.044	*
3A	Condition	1, 109	27.38	66418	.201	<.001	***
	Age	1, 109	1.98	66418	.018	.162	*ns*
	Condition × Age	1, 109	.63	66418	.006	.430	*ns*
	Word Type	1, 109	254.65	9580	.700	<.001	***
	Word Type × Condition	1, 109	7.69	9580	.066	.007	**
	Word Type × Age	1, 109	.86	9580	.008	.357	*ns*
	Word Type × Condition × Age	1, 109	3.86	9580	.034	.052	*ns*
	Location	1, 109	69.04	6329	.388	<.001	***
	Location × Condition	1, 109	47.68	6329	.304	<.001	***
	Location × Age	1, 109	.65	6329	.006	.422	*ns*
	Location × Condition × Age	1, 109	3.18	6329	.028	.077	*ns*
	Word Type × Location	1, 109	11.78	5632	.098	<.001	***
	Word Type × Location × Condition	1, 109	26.91	5632	.198	<.001	***
	Word Type × Location × Age	1, 109	34.61	5632	.241	<.001	***
	Word Type × Location × Condition × Age	1, 109	4.28	5632	.038	.041	*
3B	Block	1, 58	15.86	16476	.215	<.001	***
	Age	1, 58	31.33	283511	.351	<.001	***
	Block × Age	1, 58	.53	16476	.009	.468	*ns*
	Color	1, 58	73.65	3222	.559	<.001	***
	Color × Block	1, 58	37.88	3101	.395	<.001	***
	Color × Age	1, 58	.83	3222	.014	.367	*ns*
	Color × Block × Age	1, 58	2.16	3101	.036	.147	*ns*
	Location	1, 58	9.32	3194	.139	.003	**
	Location × Block	1, 58	21.49	3166	.270	<.001	***
	Location × Age	1, 58	.41	3194	.007	.523	*ns*
	Location × Block × Age	1, 58	.02	3166	.000	.898	*ns*
	Color × Location	1, 58	.42	1499	.007	.521	ns
	Color × Location × Block	1, 58	16.73	2287	.224	<.001	***
	Color × Location × Age	1, 58	.00	1499	.000	.945	*ns*
	Color × Location × Block × Age	1, 58	.12	2287	.002	.733	*ns*

Note. *ns* = not significant.
* $p < .05$. ** $p < .01$. *** $p < .001$.

For younger adults, cost was reduced for nonwords, $F(1, 72) = 20.60$, $p < .001$, $\eta_p^2 = .222$, and in the lower location, $F(1, 72) = 14.49$, $p < .001$, $\eta^2 = .168$, but there was no effect of condition, $F < 1$. The only significant interaction was with location and condition, $F(1, 72) = 8.38$, $p = .005$, $\eta_p^2 = .104$ (all other Fs < 1.51, ps $> .223$). As can be seen in Figure 4, this interaction reflects similar cost between conditions in the upper location, $F < 1$, but reduced cost for the specific condition in the lower location relative to the nonspecific condition, $F(1, 72) = 4.48$, $p = .038$, $\eta^2 = .059$.[5] For older adults, cost was reduced for nonwords, $F(1, 57) = 24.11$, $p < .001$, $\eta_p^2 = .297$, and in the lower location, $F(1, 57) = 6.99$, $p = .011$, $\eta_p^2 = .168$. However, there was no effect of condition, $F < 1$, and no significant interactions (all Fs < 2.85, ps $> .098$).

Target detection. The proportion of successfully detected PM targets was submitted to a 2 (condition: specific vs. nonspecific) × 2 (age: younger vs. older) between-subjects ANOVA (see Figure 3). Similar to Experiment 1, target detection was worse for older adults, $F(1, 129) = 3.94$, $p = .049$, $\eta_p^2 = .03$, and there was no effect of condition and no interaction between the two, Fs < 1.

Discussion

The primary finding of Experiment 2 was that local level strategic monitoring patterns differed considerably from those of Experiment 1 and prior studies using simple contextual cues (e.g., Lourenço & Maylor, 2014; Lourenço et al., 2013). Although (as anticipated) both age groups monitored similarly across conditions in the expected context (upper words), there was no evidence of relaxation of monitoring in the specific condition for either age group in response to the conjunction of features *or* word type. However, younger, but not older, adults in the specific condition used location information to reduce monitoring in lower contexts relative to the nonspecific condition.[6]

On the one hand the diverging patterns across Experiments 1 and 2 appear most readily attributable to the degree to which identifying particular contexts places demands on attention—

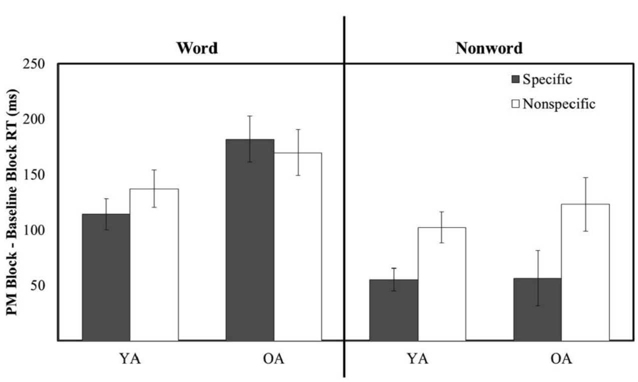

Figure 2. Cost estimates plotted separately by word type (word, nonword) for younger (YA) and older (OA) adults in each condition of Experiment 1. Participants in the specific condition expected targets to occur in word trials but not in nonword trials, whereas those in the nonspecific condition expected targets to occur in both trial types. Error bars reflect *SE*s.

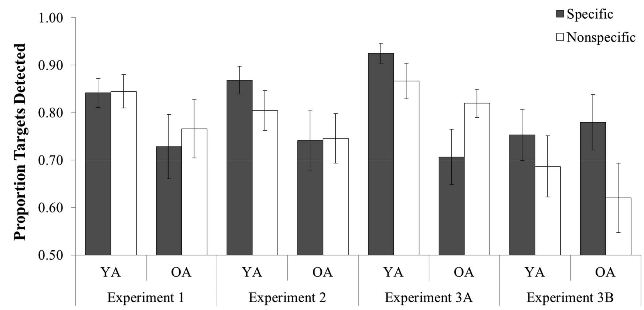

Figure 3. Proportion of prospective memory targets detected for younger (YA) and older (OA) adults across conditions for each experiment. Error bars reflect *SEs*.

identifying a conjunction of features (i.e., complex cue) is presumably more demanding than identifying a single feature (i.e., simple cue; cf., Treisman & Gelade, 1980) before regulating monitoring. Similarly, this account appears to aptly describe the pattern of findings within Experiment 2. It is well known that the location of a stimulus is relatively automatically processed (Chen, 2009; Logan, 1998; Mayr, 1996), whereas attention is needed poststimulus onset to identify lexical properties (word or nonword; Besner, Risko, & Sklair, 2005; McCann, Folk, & Johnston, 1992) and to detect feature conjunctions (e.g., word or upper; Prinzmetal, Presti, & Posner, 1986; Treisman & Gelade, 1980). Thus, it is reasonable to assume that location information may have required fewer attentional resources to detect and use to guide monitoring. However, on this account, one may have expected older adults to demonstrate a similar pattern of results, particularly given prior research in other domains suggesting location-based attention control is generally spared with age (e.g., Bugg, 2014a; Connelly & Hasher, 1993). One possibility is that older adults may have had greater difficulty maintaining the intention-context association (i.e., PM targets associated with words in upper location) while performing the ongoing task. If so, bottom-up attentional capture from location information may not have been automatically processed to facilitate strategic monitoring (Folk, Remington, & Wright, 1994).

Alternatively, older adults may have successfully maintained the intention-context association but nevertheless had difficulty resolving interference (Jonides et al., 2000; Pettigrew & Martin,

[6] One alternative interpretation is that participants reduced monitoring as a function of the objective PM occurrence (i.e., lower costs in nonwords and in lower locations) but not as a function of induced expectations. This would suggest that both younger and older adults were sensitive to the learned correlations (of target occurrence) over the sequence of trials but not to the instructions, per se. To test this idea, we examined costs in the first and second halves of the PM block. This analysis revealed that participants did get faster over time and this differed by location (i.e., faster in lower locations). Participants were also marginally faster on nonword trials in the second half. Therefore, it does appear that there may be some degree of learning over time, at least for location information. More important, however, these effects did not differ as a function of condition. The same analyses in Experiments 1 and 3A, however, revealed no learning over time as a function of objective PM occurrence and this did not differ by condition. Experiment 3B showed some learning over time, but this did not differ as a function of block.

Table 4
Mean Ongoing Task Accuracy and Response Times for Younger and Older Adults Across Conditions in the Expected and Unexpected Contexts in Experiments 2, 3A, and 3B

				Accuracy				Response times			
				Expected	Unexpected			Expected	Unexpected		
Experiment	Block	Age	Condition[a]/block[b]	Upper word[a]/red[b]	Upper nonword[a]/blue[b]	Lower word[a]/red[b]	Lower nonword[a]/blue[b]	Upper word[a]/red[b]	Upper nonword[a]/blue[b]	Lower word[a]/red[b]	Lower nonword[a]/blue[b]
2	Baseline	YA	Specific	.91 (.012)	.94 (.006)	.88 (.01)	.95 (.007)	726 (11)	796 (20)	772 (14)	789 (18)
			Nonspecific	.92 (.009)	.92 (.013)	.88 (.011)	.95 (.009)	760 (20)	846 (25)	793 (17)	851 (25)
		OA	Specific	.97 (.005)	.95 (.008)	.97 (.004)	.95 (.008)	1028 (37)	1147 (40)	1074 (39)	1193 (38)
			Nonspecific	.97 (.007)	.95 (.008)	.96 (.007)	.94 (.009)	1097 (47)	1246 (52)	1160 (44)	1299 (46)
	PM	YA	Specific	.95 (.006)	.92 (.008)	.88 (.012)	.97 (.005)	849 (21)	866 (22)	846 (19)	824 (20)
			Nonspecific	.93 (.009)	.92 (.015)	.90 (.009)	.94 (.009)	866 (25)	931 (31)	905 (26)	918 (28)
		OA	Specific	.97 (.004)	.94 (.009)	.97 (.006)	.95 (.009)	1193 (53)	1237 (47)	1223 (52)	1224 (41)
			Nonspecific	.96 (.006)	.95 (.011)	.96 (.008)	.95 (.008)	1269 (44)	1359 (44)	1293 (42)	1397 (44)
3A	Baseline	YA	Specific	.97 (.005)	.94 (.01)	.96 (.008)	.97 (.009)	437 (22)	516 (28)	428 (24)	513 (29)
			Nonspecific	.96 (.007)	.96 (.009)	.97 (.007)	.97 (.006)	454 (30)	516 (37)	423 (28)	512 (36)
		OA	Specific	.97 (.012)	.97 (.013)	.97 (.006)	.97 (.01)	794 (51)	824 (55)	792 (50)	870 (57)
			Nonspecific	.98 (.006)	.96 (.01)	.97 (.005)	.97 (.009)	844 (38)	894 (46)	813 (38)	923 (46)
	PM	YA	Specific	.94 (.009)	.98 (.003)	.96 (.006)	.97 (.005)	625 (28)	436 (27)	414 (30)	368 (25)
			Nonspecific	.92 (.013)	.96 (.011)	.95 (.014)	.96 (.007)	628 (29)	613 (33)	628 (30)	571 (30)
		OA	Specific	.93 (.013)	.96 (.011)	.94 (.01)	.97 (.007)	934 (40)	860 (53)	881 (51)	769 (49)
			Nonspecific	.95 (.007)	.96 (.008)	.94 (.007)	.98 (.007)	1023 (37)	1030 (39)	1062 (37)	953 (36)
3B	PM	YA	Specific	.93 (.011)	.94 (.01)	.94 (.008)	.94 (.009)	745 (19)	663 (17)	716 (25)	671 (17)
			Nonspecific	.94 (.008)	.94 (.007)	.95 (.006)	.93 (.007)	720 (24)	718 (23)	770 (28)	739 (26)
		OA	Specific	.95 (.009)	.96 (.006)	.97 (.005)	.97 (.005)	1020 (49)	910 (38)	992 (48)	926 (42)
			Nonspecific	.97 (.005)	.96 (.006)	.96 (.005)	.96 (.005)	992 (49)	999 (48)	1053 (48)	1025 (46)

Note. The expected and unexpected columns refer to the contexts in which participants in the specific conditions expected or did not expect, respectively, prospective memory (PM) targets to appear. Participants in the nonspecific condition were told targets could appear in any context.
[a] Refers to Experiments 2 and 3A. [b] Refers to Experiment 3B.

2014) from context features that partially overlapped with the complex contextual cue. That is, older adults may have had greater difficulty inhibiting (Hasher & Zacks, 1988) the automatic tendency to target check when *either* of the relevant context features was present (i.e., upper locations or word trials). Consistent with this idea, as can be seen in Figure 4 older adults in the specific condition showed some evidence of reduced cost relative to the nonspecific condition in the lower nonword context that shared no overlapping features with the specific cue (although this difference only approached significance, $F(1, 57) = 3.41$, $p = .07$).

Lastly, older adults may have had greater difficulty in forming and retrieving the association between the target (e.g., "TOR" syllable), action (e.g., "7" key), and *multiple* context features (i.e., word and location) compared with the simple contextual cue of Experiment 1 that led to ineffective engagement of local-level strategic target checking. Although only participants who remembered the PM instructions at the end of the experiment were included in analyses, the quality of encoding may have nevertheless influenced the integrity of strategic monitoring.

Regarding PM performance, as with Experiment 1 older adults detected fewer PM targets than younger adults, consistent with the idea that ongoing task demands usurp limited-capacity resources in expected contexts that may otherwise be devoted to target detection. Additionally, PM performance did not differ between specific and nonspecific conditions.

Experiment 3A

The previous experiments demonstrated that older adults used simple but not complex contextual cues to guide strategic monitoring when context changed unpredictably (i.e., varied trial-by-trial). The primary age difference was that younger but not older adults still showed some evidence for strategic monitoring based on location information with use of the complex contextual cue (though neither group used the conjunction to guide monitoring). One interpretation is that the heightened attentional demands associated with identification of the complex cue on a trial-by-trial basis especially disadvantaged older adults possibly because of theoretically anticipated reductions in executive attention with age (i.e., the attention account). However, an alternative interpretation is that the age difference is primarily accounted for by age-related deficits in the ability to bind multiple context features (i.e., word type and location) with the intention and maintain these intention-context associations during the task (i.e., the binding account).

Experiment 3A aimed to adjudicate between these accounts by examining whether older adults strategically monitor when environmental support is available to facilitate identification of the complex cue (Lourenço & Maylor, 2014). In the blocked procedure, context is blocked in sets of eight trials (e.g., eight lower nonword trials followed by eight upper word trials, etc.)

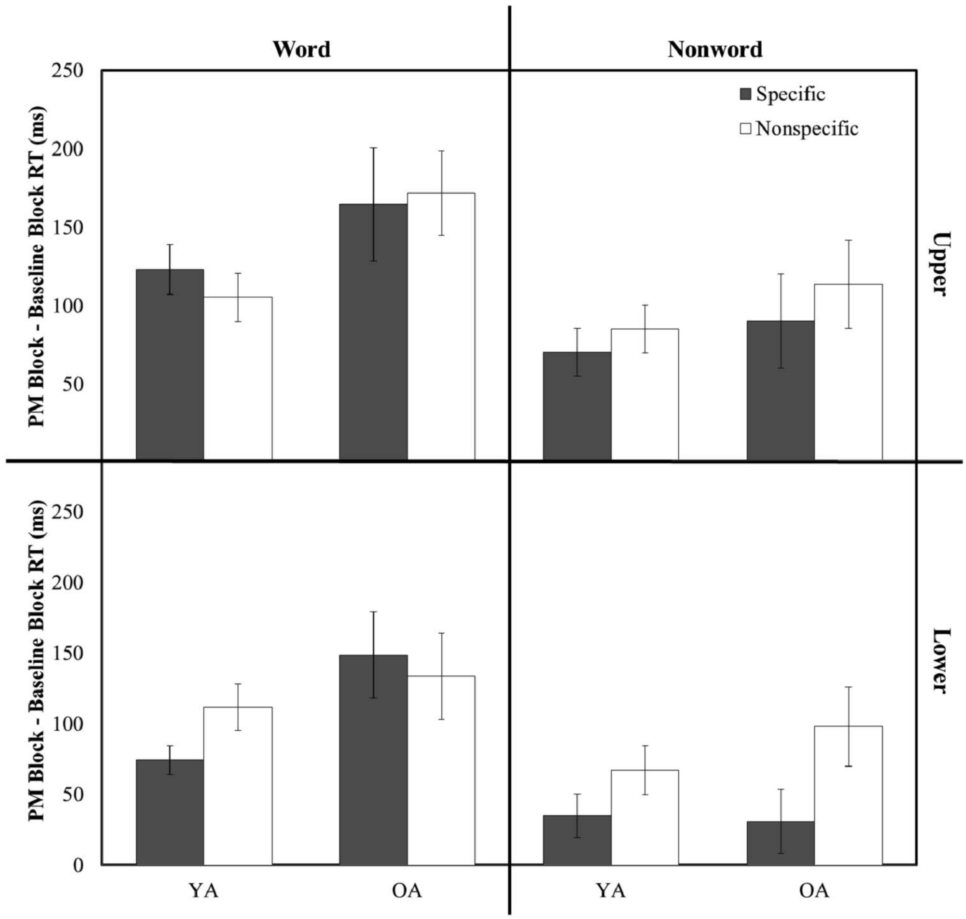

Figure 4. Cost estimates plotted separately by word type (word, nonword) and location (upper, lower) for younger (YA) and older (OA) adults in each condition of Experiment 2. Participants in the specific condition expected targets to occur in word trials in the upper location but not in the other trial types (i.e., upper nonword, lower word, and lower nonword), whereas those in the nonspecific condition expected targets to occur in all trial types. Error bars reflect *SE*s.

such that participants need not rapidly identify context and adjust monitoring in an unpredictable fashion. Two prior findings from younger adult samples demonstrate the environmental support provided by the blocked procedure. First, in a study that used a simple contextual cue, the evidence for strategic monitoring (i.e., degree to which monitoring was reduced in the unexpected context for the specific condition) was stronger with the blocked procedure than it was with the random procedure (where context varied trial-to-trial as in Experiments 1 and 2; Lourenço & Maylor, 2014). Second, the blocked procedure was successful in producing evidence for strategic monitoring based on the conjunction of features corresponding to the complex contextual cue (Bugg & Ball, 2017), a pattern not found with the random procedure in Experiment 2.

The predictions were as follows. If the binding account is valid, there should be little evidence of strategic monitoring for older adults even with the greater environmental support provided by the blocked procedure because participants must still bind multiple context features (word type and location) with the intention and maintain this intention-context association during the experiment just as in Experiment 2. In contrast, if the attention account is valid, the age-related difference observed in Experiment 2 should be alleviated with use of the blocked procedure. This prediction is based on the premise that the blocked procedure reduces demands on attentional control (Lourenço & Maylor, 2014) and the assumption that the environmental support it provides may buffer against age-related declines in executive attention.

Method

Participants. Sixty younger adults (age 18–23) from Washington University received course credit and 62 community dwelling older adults (age 61–91) received monetary compensation for participation and were randomly assigned to either the specific or nonspecific condition. However, eight older adults that failed to detect any PM targets and were unable to recall the PM instructions in a postexperimental questionnaire were not included in analyses. Additionally, one older adult that had an average cost estimate greater than 3 *SD*s from their respective group mean was excluded from analyses. The final sample consisted of 30 younger

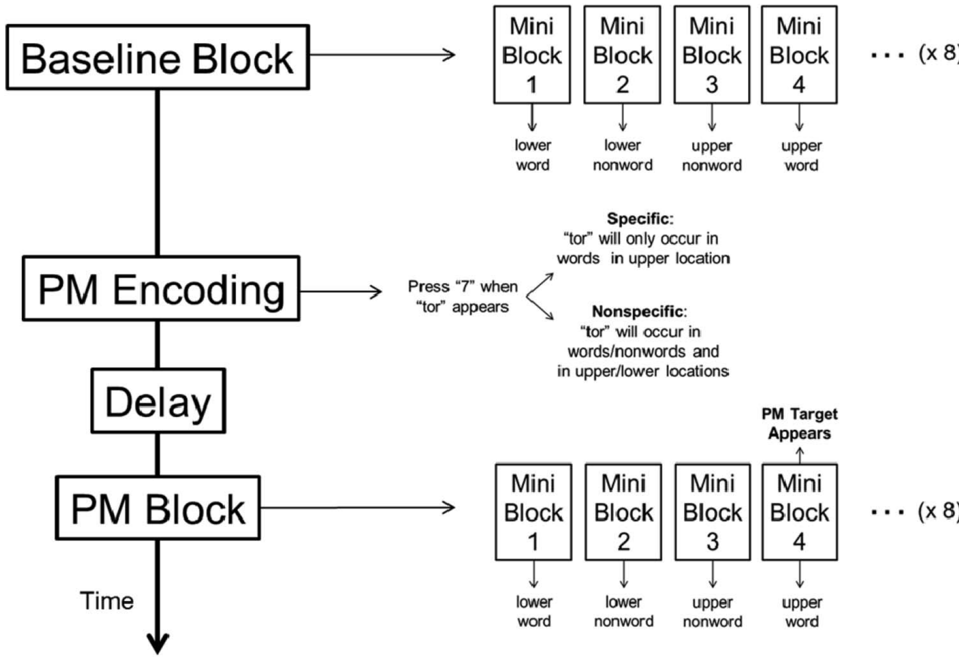

Figure 5. Procedure used in Experiment 3A. Each miniblock comprised eight trials. Mini blocks were contiguous, meaning there was no break between mini blocks.

adults in each condition, and 26 and 27 older adults in the specific and nonspecific conditions, respectively (see Table 1).

Materials and procedure.

Materials. The materials were identical to those of Experiments 1 and 2, with the addition of four words and four nonwords for the blocking procedure.

Procedure. Participants were tested individually in ~30 min sessions. The procedure was modeled after the blocked PM procedure used by Lourenço and Maylor (2014) and adapted by Bugg and Ball (2017) for use with a complex contextual cue. The instructions for the ongoing LDT, baseline block, and PM block were identical to those of Experiment 2. The only difference was that before beginning the practice phase, participants were explicitly instructed that word type (word or nonword) and location (upper or lower) would be presented in blocks of eight trials and that the eight block pattern would continue throughout the experiment.

The baseline and PM blocks each consisted of 256 LDT items (128 words and 128 nonwords), with half of each presented in the upper location and half in the lower location, blocked in sets of eight trials. In both the baseline and PM blocks there was a total of eight miniblocks of each trial type (e.g., eight blocks of words in the upper location, eight blocks of words in the lower location, etc.) with eight items within each block. Block order for each trial type was pseudorandomized such that no two blocks of the same trial type were presented consecutively (e.g., an upper nonword block could not follow an upper nonword block). Additionally, in the PM block, the upper word block (in which PM targets were to appear) always occurred as the fourth block in each eighth of the set of 256 trials (see Figure 5 below). Block order was determined pre-experimentally and was identical for each participant.

The PM target syllable "tor" always appeared in words in the upper location and was presented once in each of the eight upper-word blocks. The PM targets were presented on Trials 28, 62, 93, 125, 155, 190, 219, and 252, and appeared between the 3rd and 6th position of the eight trial blocks. The order of appearance for the eight PM targets was randomized between participants.

Results

Response times. Mean RT cost was submitted to a 2 (word type: word vs. nonword) × 2 (location: upper vs. lower) × 2 (condition: specific vs. nonspecific) × 2 (age: younger vs. older) mixed-factorial ANOVA. RTs for each block can be found in Table 4, and results from the full ANOVA model can be found in Table 3. As can be seen in Figure 6, there were negative cost values (i.e., RTs were *faster* in the PM than baseline block) across several contexts. It is important to note that this does not mean participants were not monitoring. Across several studies using the same procedure Bugg and Ball (2017) found the same pattern of results for the PM conditions, but the speed up from the baseline to PM block for these groups was significantly less robust than a control condition with no PM intention, suggesting that monitoring processes were still being engaged. More important, the four-way interaction was significant, $F(1, 109) = 4.28$. To explore the four-way interaction, we compared costs between specific and nonspecific conditions across each context, separately for younger and older adults.

For younger adults, replicating Bugg and Ball (2017) there was no cost difference between the conditions in the upper-word (expected) context, $F < 1$. In contrast, participants in the specific condition showed reduced cost relative to the nonspecific condi-

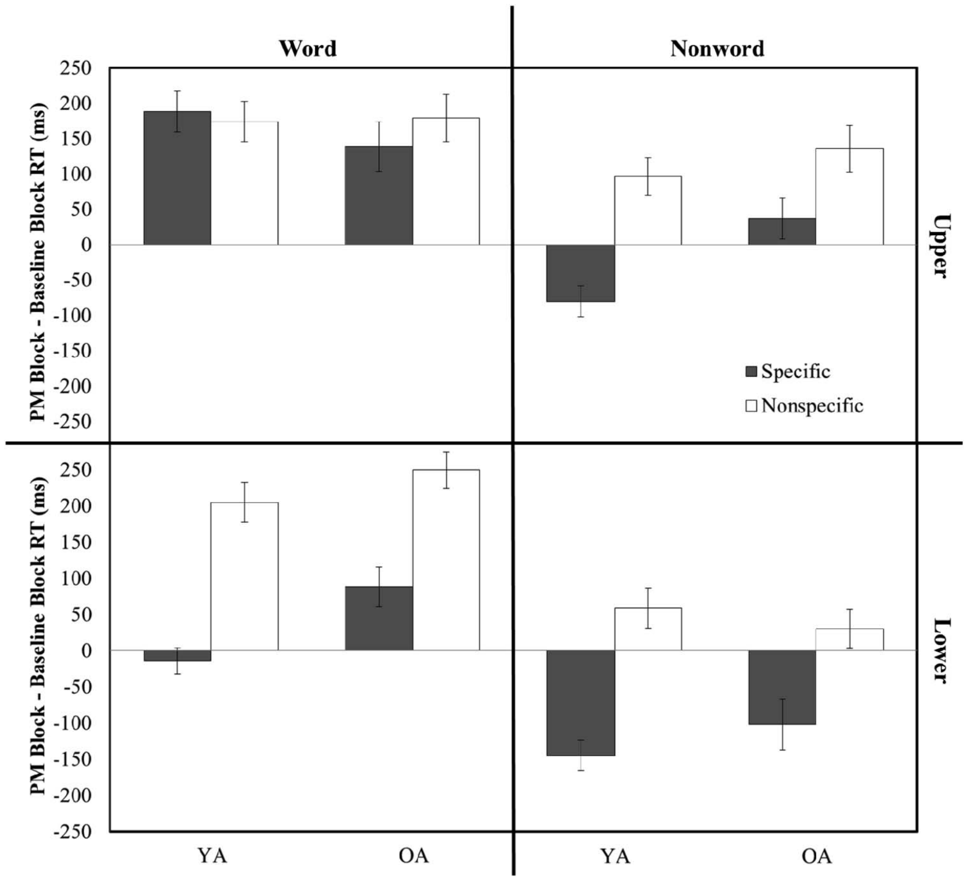

Figure 6. Cost estimates plotted separately by word type (word, nonword) and location (upper, lower) for younger (YA) and older (OA) adults in each condition of Experiment 3A. Participants in the specific condition expected targets to occur in word trials in the upper location but not in the other trial types (i.e., upper nonword, lower word, and lower nonword), whereas those in the nonspecific condition expected targets to occur in all trial types. Error bars reflect *SE*s.

tion across all unexpected contexts [*upper nonword*: $F(1, 58) = 26.16$, $p < .001$, $\eta_p^2 = .311$; *lower word*: $F(1, 58) = 44.24$, $p < .001$, $\eta_p^2 = .433$; *lower nonword*: $F(1, 58) = 35.0$, $p < .001$, $\eta_p^2 = .376$]. More important, older adults showed an identical pattern of results,[7] with no difference between conditions in the expected context, $F < 1$, and reduced costs for the specific condition in the unexpected contexts [*upper nonword*: $F(1, 51) = 5.12$, $p = .028$, $\eta_p^2 = .091$; *lower word*: $F(1, 51) = 19.04$, $p < .001$, $\eta_p^2 = .272$; *lower nonword*: $F(1, 51) = 8.86$, $p = .004$, $\eta_p^2 = .148$].

Target detection. To examine PM performance, the proportion of successfully detected PM targets was submitted to a 2 (condition: specific vs. nonspecific) × 2 (age: younger vs. older) between-subjects ANOVA (see Figure 3). As with previous experiments, there was no effect of condition, $F < 1$, and a significant effect of age, $F(1, 109) = 11.94$, $p = .001$, $\eta_p^2 = .099$. Somewhat surprisingly, however, there was a Condition × Age interaction, $F(1, 109) = 4.96$, $p = .028$, $\eta_p^2 = .043$. This interaction reflects that while there was no age difference in performance in the nonspecific condition, $F < 1$, younger adults detected more PM targets than older adults in the specific condition, $F(1, 54) = 13.73$, $p < .001$, $\eta_p^2 = .203$. Notably, however, there were no differences across conditions for younger adults, $F(1, 58) = 1.84$, $p = .180$, $\eta_p^2 = .031$, or older adults, $F(1, 51) = 2.94$, $p = .092$, $\eta_p^2 = .055$.

Experiment 3B

Experiment 3A showed that both younger and older adults were able to monitor strategically in response to a complex contextual cue. However, before discussing the implications of these findings, we first address a potential limitation of the procedure used. In Experiment 3A, context was blocked by word type (i.e., each block of eight trials contained the same word type), meaning that once the context was identified participants could theoretically make a lexical decision without fully processing the stimuli (Bugg & Ball, 2017). This raises the possibility that strategic monitoring was observed for older adults

[7] As can be seen in Figure 6, the four-way interaction primarily reflects that there was a greater reduction in cost for younger than older adults in the specific condition in the upper-nonword and lower-word contexts, but no age difference in the upper-word or lower-nonword contexts. For the nonspecific condition, there were no age differences across any context. However, this does not contradict the primary finding that both younger and older adults in the specific condition were able to reduce monitoring relative to the nonspecific condition in unexpected contexts.

because the attentional demands of the ongoing task were reduced and not because of blocking. To alleviate these concerns, Experiment 3B was designed to conceptually replicate the findings of Experiment 3A using a blocked procedure where contextual information was independent of ongoing task processing. In Experiment 3B, ongoing task stimuli (word or nonwords) varied randomly on each trial (as in Experiments 1 and 2) and context was blocked by color (red or blue) and location (upper or lower). If the strategic monitoring pattern observed in Experiment 3A was simply an artifact of blocking by word type (i.e., reduced ongoing task demands) then we expected to see little evidence of strategic monitoring in response to the complex contextual cue (color and location) as in Experiment 2. In contrast, if the blocked procedure facilitates strategic monitoring regardless of the contextual features present, we expected to see an identical pattern of results as Experiment 3A.

Method

Participants. Thirty younger adults (age 18–23) from Washington University received course credit and 35 community dwelling older adults (age 61–91) received monetary compensation for participation. However, five older adults that failed to detect any PM targets and were unable to recall the PM instructions in a postexperimental questionnaire were not included in analyses. The final sample, therefore, consisted of 30 younger and 30 older adults (see Table 1).

Materials and procedure.

Materials. The materials were identical to Experiment 3A, with the addition of 144 words, 144 nonwords, and 2 PM targets.

Procedure. The procedure was identical to Experiment 3A with the following exceptions: words and nonwords were presented randomly; items were blocked by color (red, blue) and location (upper, lower) in sets of 10 trials (instead of 8); there were 10 presentations (instead of 8) of each context (i.e., upper-red, upper-blue, lower-red, and lower blue); participants performed both the specific and nonspecific blocks (but no control block); only half of the "expected" contexts contained a PM target. In the specific block participants were told that the syllable "tor" would only appear in the upper location of the screen and in red ink (and, thus, targets would never appear in the lower location or in blue ink), whereas in the nonspecific block they were told that the syllable "tor" could appear in either upper or lower locations and in either red or blue ink.

The LDT stimuli consisted of 400 words and 400 nonwords, with half of each trial type presented randomly in each block (i.e., specific, nonspecific). The PM targets were 10 words containing the 'tor' syllable, half of which were randomly presented in each block. Notably, only every other upper-red context contained a PM target, which always appeared on the fourth trial of the miniblock (Trials 34, 114, 194, 274, and 364 within each block). This allowed us to examine ongoing task responding during expected blocks that were not contaminated by slowing because of responding to the PM target. Block order (specific, nonspecific) was counterbalanced across participants.

Results

Response times. Mean RTs (collapsed across word type) for the expected contexts with no PM targets and unexpected contexts were submitted to a 2 (color: red vs. blue) $\times$ 2 (location: upper vs. lower) $\times$ 2 (block: specific vs. nonspecific) $\times$ 2 (age: younger vs. older) mixed-factorial ANOVA, with age as the only between-subjects factor. Mean RTs can be found in Table 4, and results from the full ANOVA model can be found in Table 3.

Consistent with Experiment 3A, there was evidence of strategic monitoring in response to the complex cue as indicated by the significant Color $\times$ Location $\times$ Block interaction, $F(1, 58) = 16.73$, and this did not differ as a function of age as indicated by the null four-way interaction, $F < 1$. As can be seen in Figure 7, the three-way interaction reflects that while there were no RT differences between blocks in the expected (upper red) context, $F = 3.30$, $p = .074$, $\eta_p^2 = .053$, cost was reduced in all unexpected contexts in the specific block (*upper blue*: $F(1, 58) = 26.91$, $p < .001$, $\eta_p^2 = .313$; *lower red*: $F(1, 58) = 16.0$, $p < .001$, $\eta_p^2 = .213$; *lower blue*: $F(1, 58) = 31.48$, $p < .001$, $\eta_p^2 = .348$).

Target detection. The proportion of successfully detected PM targets was submitted to a 2 (block: specific vs. nonspecific) $\times$ 2 (age: younger vs. older) mixed-factorial ANOVA (see Figure 3). There was no effect of block or age, and no interaction between the two, Fs $<$ 2.37, ps $>$ .126, η_p^2s $<$ .040.

Discussion of Experiments 3A and 3B

The primary finding of Experiment 3A was that there was a similar pattern of local level strategic monitoring for both age groups in response to the complex contextual cue (word type and location) when using the blocked procedure. Both younger and older adults in the specific condition showed equivalent cost to the nonspecific condition in the expected context, and reduced cost across all unexpected contexts. This pattern was conceptually replicated in Experiment 3B where ongoing task stimuli varied randomly on each trial, suggesting that the findings of Experiment 3A were not simply an artifact of blocking stimuli by word type. These patterns are in stark contrast to those of Experiment 2 where younger adults were only able to use location information to reduce monitoring, and older adults were unable to strategically monitor at all. Given that Experiments 2 and 3A both used the same intention-context association, we can rule out the binding account, which posits that older adults have difficulty forming and retrieving the association between the PM intention and complex cue. Experiment 3B additionally suggests that older as well as younger adults can successfully bind other contextual features (i.e., color) with the PM intention. Collectively, these patterns are consistent with the attention account positing that older adults (and to a lesser degree, younger adults) appear to have difficulty in coordinating context identification and context-dependent allocation of monitoring resources in response to a complex cue during a demanding ongoing task in which the occurrence of context is unpredictable.

The precise attentional mechanism by which the environmental support afforded by the blocked procedure facilitated strategic monitoring is unknown. The blocked procedure may have reduced attentional demands associated with context identification by providing a larger time window for participants to identify the appropriate context and increase or decrease monitoring accordingly (see Lourenço & Maylor, 2014). That is, if context identification was not completed on the first trial of the block, there were additional opportunities on subsequent trials to identify the context and adjust monitoring accordingly. Alternatively, the blocked procedure may have facilitated inhibition of target checks in unexpected contexts that shared overlapping features (i.e., lower word/red, upper nonword/blue) with the context

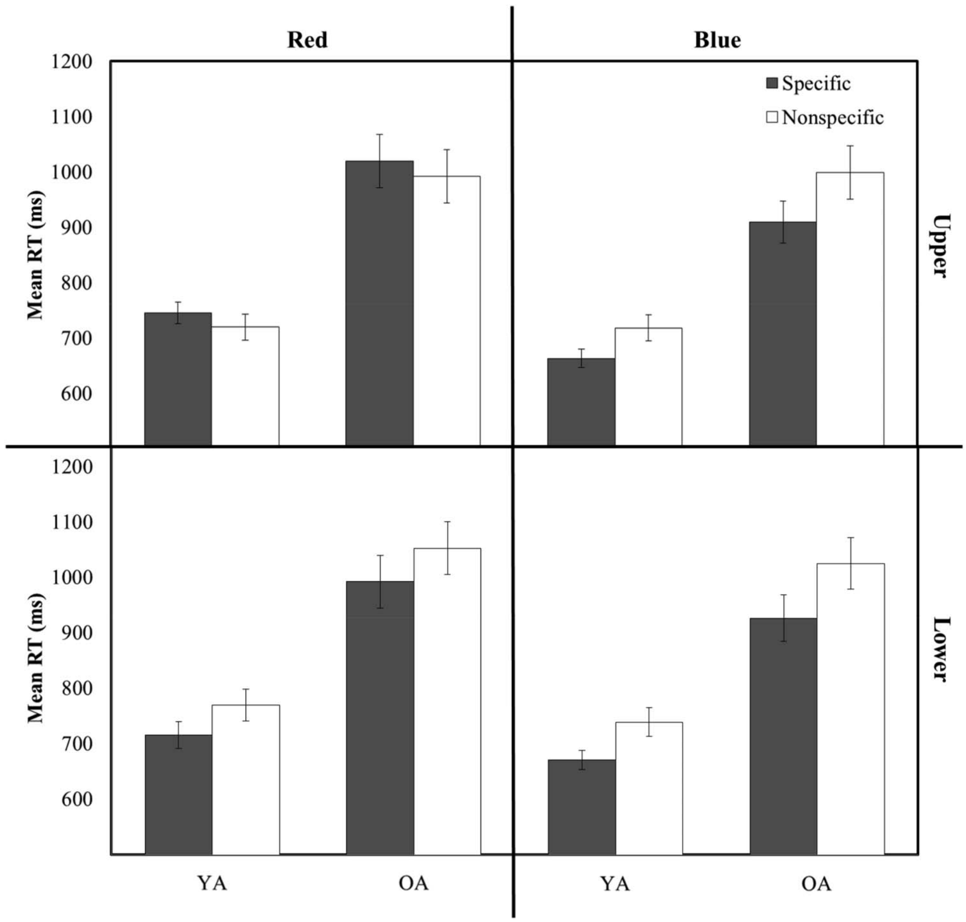

Figure 7. Mean reaction times (RTs) plotted separately by color (red, blue) and location (upper, lower) for younger (YA) and older (OA) adults in each block of Experiment 3B. In specific blocks, participants expected targets to occur in red trials in the upper location but not in the other trial types (i.e., upper blue, lower red, and lower blue), whereas in nonspecific blocks, participants expected targets to occur in all trial types. Error bars reflect *SE*s.

cue because it was possible to predict the context on subsequent trials after initial context identification (at or near the start of a block; cf. Boywitt, Rummel, & Meiser, 2015 for evidence that older adults have difficulty utilizing context for inhibitory purposes, albeit to reduce false responding on PM lure trials in their study). Additional research is needed to pinpoint the precise mechanism.

Contrary to the prior experiments, target detection was generally comparable between younger and older adults. This suggests that the blocked procedure may provide environmental support (relative to the random procedure) that aids older adults in preparing to respond to PM targets in expected contexts. The one exception was in Experiment 3A in which younger adults in the specific condition detected more targets than older adults. However, we do not wish to make strong claims about these findings because this pattern was just the opposite in Experiment 3B (i.e., younger adults in the nonspecific condition tended to detect more targets than older adults, although this difference was not significant). Thus, future research is needed to better understand how context influences target detection and whether or not environmental support can eliminate often-observed age differences in PM performance.

General Discussion

The current study examined age differences in the ability to increase and decrease monitoring in response to contextual cues. The results suggest that older adults generally exhibited similar monitoring patterns as younger adults across all experiments. Using the random procedure with a simple cue (i.e., words) in Experiment 1, and the blocked procedure with a complex cue (i.e., words/red trials in the upper location) in Experiments 3A/3B, both younger and older adults in the specific condition were similarly able to reduce monitoring in unexpected contexts. Furthermore, neither age group exhibited strategic monitoring in response to a complex cue using the random procedure of Experiment 2. There was, however, a slight divergence in monitoring patterns in Experiment 2, whereby younger, but not older, adults were able to use location information to reduce monitoring in unexpected (lower) contexts. Together these findings suggest that strategic monitoring ability is generally intact with increased age and is neither limited to simple contextual cues nor distinguishable ongoing task phases that clearly differentiate the appropriate contexts in which monitoring should be engaged (Kominsky & Reese-

Melancon, 2017). Furthermore, the current findings indicate that this ability extends across a variety of contextual features (i.e., word type, color, and location). However, the contrasting findings of Experiments 2 and those of Experiments 3A and 3B also highlight a potential boundary condition in which attentional demands associated with context identification might limit strategic monitoring processes in older (and to a lesser degree, younger) adults.

Aging and Strategic Monitoring

Although not explicitly discussed in theoretical accounts of strategic monitoring (e.g., Guynn, 2003), we assumed that identifying contextual information and adjusting monitoring accordingly are attentionally demanding processes based on prior research by Lourenço and Maylor (2014) showing weaker evidence of strategic monitoring using the random (trial-level) procedure than the blocked (every eight trials) procedure. Consistent with this idea, the results from the current study suggest that identifying the appropriate context and adjusting the amount of attention that is allocated to monitoring indeed requires some degree of limited-capacity resources; otherwise, it is unclear why the random procedure with a complex cue, but not the random procedure with a simple cue or blocked procedure with a complex cue, largely eliminated evidence for strategic monitoring. Interestingly, there was relatively little difference in monitoring patterns across age groups despite theoretically anticipated declines in executive attention (Braver & West, 2008; Hasher & Zacks, 1988; West, 1996) that should influence the ability to monitor strategically for older adults. Only when context was defined by multiple features and its occurrence was unpredictable was there any age difference in monitoring patterns (Experiment 2), and even then younger adults only showed weak evidence of strategic monitoring. Notably, the results of Experiment 3A and 3B ruled out the alternative account that age differences in associative binding processes may account for any potential age differences in strategic monitoring. Together these findings suggest that context-sensitive memory and attentional processes generally remain intact with increased age despite executive declines that may influence other aspects of PM (e.g., target detection).[8]

Along these lines, there is a growing body of research suggesting that not all aspects of attention control exhibit similar age-related decline. The dual mechanisms of control framework posits that attention control operates via two distinct processing modes: *proactive control* involves top-down, sustained use of goal representations to bias attention before stimulus onset, whereas *reactive control* involves stimulus-driven, transient reactivation of goals to bias attention on an as needed basis (Braver, 2012; Braver, Gray, & Burgess, 2007). More important, research suggests aging is associated with declines in proactive, but not reactive, control (Bugg, 2014a, 2014b; Paxton, Barch, Racine, & Braver, 2008). This distinction is important in the context of the current study because local level strategic monitoring is arguably reactive in nature, perhaps especially to the extent that a sufficiently strong context-intention association is formed at encoding. That is, at least in Experiments 1 and 2 where context varied unpredictably, activation of task goals (e.g., disengaging target checks on nonwords) could only occur poststimulus onset following context identification. In the blocked procedure of Experiments 3A and 3B strategic target checking could theoretically be accomplished by either control mechanism (e.g., following the initial context identification of the context participants could proactively activate the task goal for the remaining trials in the same context, or they could reactively activate the task goal on a trial-by-trial basis). This could in part explain why monitoring patterns were generally comparable across age groups despite the fact that strategic monitoring requires some degree of limited-capacity processing. Unfortunately, no prior studies in the attention control domain have examined reactive control processes in response to feature conjunctions and, therefore, unclear whether such a mechanistic account fully explains the difference in monitoring patterns in response to simple versus complex cues. However, the finding that older adults in the specific condition of Experiment 2 showed evidence of target checking when either of the expected context features was present (word trials, upper location, or the conjunction of the two) is at least consistent with the idea that target checks may be reactive in nature (see Boywitt et al., 2015 for evidence that age-related declines in inhibition result in greater false responding to PM lures). Possibly the environmental support provided by the blocked procedure served to enhance top-down control of monitoring and reduce reactive target checks in Experiments 3A and 3B.

Finally, it is important to note that in the current study (as well as in prior studies) strategic monitoring patterns were evidenced by a relaxation of monitoring in unexpected contexts but equivalent monitoring in expected contexts for the specific relative to the nonspecific condition. In other words, the specific condition did not heighten monitoring above and beyond that of the nonspecific condition in expected contexts. Thus, another possible reason for the comparable strategic monitoring patterns across age groups is that the *disengagement* of target checks may not place high demands on limited-capacity resources. However, it may be the case that if attention were needed to *engage* monitoring on a trial-by-trial basis in expected contexts then age-related executive attention deficits may limit strategic monitoring.

Target Detection

Although not of primary interest to the current study, the results are consistent with prior research showing that trial level[9] context expectations had little influence on PM target detection (Bugg & Ball, 2017; Lourenço & Maylor, 2014; Lourenço et al., 2013; but see Kuhlmann & Rummel, 2014). Furthermore, poorer target detection for older

[8] It should be noted that the number of older adults excluded from analyses because of failures to recall the PM instructions was generally higher than what is typically observed, at least in Experiments 2 and 3A (but see Ball & Aschenbrenner, 2017). It is, therefore, possible that complex contextual cues may not be as helpful for older adults because they may be less likely to actually remember what the appropriate context to monitor is. It is also possible that age invariance in strategic monitoring simply reflects that our older adult population was comparable with younger adults in executive functioning. Unfortunately, we do not have psychometric data from these participants that can be examined for potential age differences in cognitive abilities. Notably, the older adult sample in the current study was selected from a pool of older adults that has been used extensively by researchers within our department. These studies have shown age differences across a variety of cognitive abilities, including attention or executive function (e.g., Bugg, 2014b), episodic memory (e.g., Wahlheim, Ball, & Richmond, 2017), prospective memory (e.g., Ball & Aschenbrenner, 2017), and processing speed (e.g., McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). We have no reason to believe that the current sample differs from the broader population characterized in these prior studies.

[9] This is in contrast to phase level context expectations that often do show an influence on target detection (Ball et al., 2015; Cook, Marsh, & Hicks, 2005; Kominksy & Reese-Melancon, 2017; Meier, Zimmermann, & Perrig, 2006; Nowinski & Dismukes, 2005).

adults in Experiments 1 and 2 is consistent with prior research suggesting that older adults have difficulty in appropriately allocating limited-capacity resources toward target detection (McDaniel & Einstein, 2011). An interesting find was that target detection was generally comparable across age groups using the blocked procedure in Experiments 3A and 3B (with the exception of the specific condition in Experiment 3A). We, therefore, tentatively suggest that context-based environmental support provided by the blocked procedure may facilitate intention fulfillment for older adults. However, future research is needed to validate these claims and to better understand how contextual cues influence target detection across the life span.

Conclusion

The results from the current study suggest older adults' difficulties in allocating limited-capacity attentional resources to the PM task relative to younger adults (McDaniel & Einstein, 2011; Rendell, McDaniel, Forbes, & Einstein, 2007; Rose et al., 2010) do not necessarily manifest in their having difficulty reducing monitoring in contexts in which PM targets are not expected to appear. Such findings are of theoretical importance, suggesting that context-dependent PM monitoring processes generally remain intact with increased age. Practically speaking, such findings would suggest that difficulties in daily living associated with forgetting of PM intentions (Woods et al., 2012) may not be compounded by disruptions to daily activities because of unnecessary engagement of costly monitoring resources in contexts in which targets are not expected to appear. However, as intentions established in everyday life likely consist of a multitude of features, future research examining how different types of contextual information (e.g., perceptual, temporal, and spatial) are utilized to guide monitoring will be valuable in providing insight into the processes underlying strategic monitoring and causes of age-related changes in PM.

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