Fitting an ex-Gaussian function to examine costs in event-based prospective memory: Evidence for a continuous monitoring profile ☆,☆☆

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ABSTRACT

Event-based prospective memory (PM) tasks require individuals to remember to perform a deferred action when a target event occurs. PM task requirements can slow ongoing task responses on non-target trials ('costs') under conditions where the defining features of targets are non-focal to the ongoing task, which is indicative that individuals have allocated some form of cognitive control process to the PM task. Recent fits of the ex-Gaussian mathematical function to non-target trial response distributions by prior studies have indicated that these control processes are transiently allocated. In the current paper, fits of the ex-Gaussian function to data reported by Loft and Humphreys (2012) demonstrate a shift in the entire response time distribution (μ) and an increase in skew (τ) for a non-focal PM condition required to remember to make a PM response if presented with category exemplars, compared to a control condition. This change in μ is indicative of a more continuous PM monitoring profile than that reported by prior studies. In addition, within–subject variability in μ was reliably correlated with PM accuracy, suggesting that these control processes allocated on a regular basis were functional to PM accuracy. In contrast, when the ongoing task directed attention to the defining features of targets (focal PM) there was a trend level increase in μ, but the within–subject variability in μ was not correlated with PM accuracy, consistent with the theoretical premise that focal PM tasks are not as dependent on cognitive control as non-focal PM tasks.

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1. Introduction

Remembering to perform deferred actions at appropriate points in the future is referred to as prospective memory (PM). Event-based PM tasks require individuals to remember to perform an action when a particular event occurs. In a typical laboratory event-based PM task, participants are required to perform a specific action (e.g., press the "9" key) if a target event (e.g., a word with the syllable 'tor' in it) is presented in an ongoing task (e.g., lexical decision task) (Einstein & McDaniel, 1990). Theories of PM have focused on how participants become aware of the special relevance of targets while engaged in ongoing tasks. Consistent with the multi-process view of PM, there is evidence that processing targets can lead to spontaneous PM retrieval under certain conditions, such as where the ongoing task directs attention to the defining features of PM targets processed at encoding (focal PM task) (Einstein & McDaniel, 2005). However, there is also evidence that target

detection can require some form of cognitive control, particularly under conditions where PM target features are not part of the information being extracted for the ongoing task (non-focal PM task). That is, numerous studies have shown that non-focal PM task requirements slow ongoing task performance by 30–100 ms on non-target trials, relative to individuals performing the ongoing task without PM task requirements. This robust effect is referred to as the 'cost' to the ongoing task (for a review see Smith, Hunt, McVay, & McConnell, 2007). Costs to ongoing tasks have been extensively used as evidence for the theoretical claims made by preparatory attentional and memory processes (PAM) theory and the multi-process view regarding under what circumstances PM retrieval requires cognitive control (for reviews see Einstein & McDaniel, 2010; Smith, 2010).

There are several theories regarding the cognitive control processes that give rise to costs (for reviews see Hicks, Marsh, & Cook, 2005; Loft, Humphreys, & Whitney, 2008). Smith's (2003) PAM theory claims that capacity-consuming 'preparatory attentional processes' are required to stimulate the recognition of targets. Guynn (2003) proposed that individuals maintain a PM 'retrieval mode', described as a general mental set for treating ongoing task stimuli as PM retrieval cues. Hicks, Marsh, and Cook (2005) claim that metacognitive beliefs, formed at the time of intention encoding, determine the allocation of attention to PM tasks, referred to as 'attentional allocation policies'. Although not

explicitly addressed by these theories, given the dual-task nature of event-based PM it would be reasonable to assume that these types of control processes are allocated to the PM task on a reasonably regular basis throughout the ongoing task. Researchers have also claimed that individuals 'monitor' (Einstein & McDaniel, 2005) or 'check' (Guynn, 2003) for PM targets, but have not discussed how regularly these control processes might operate throughout the ongoing task. As a starting point for further constraining current theorizing, it would be useful then to determine the extent to which costs reflect control processes that operate regularly on ongoing task trials, as opposed to more transiently. While an increased mean response time (MRT) suggests that some form of control process has been directed toward the PM task at the expense of the ongoing task, it cannot be used to address how frequently these control processes are allocated.

Brewer (2011) and Ball, Brewer, Loft, and Bowden (in press) recently fit ex-Gaussian functions to non-target trial response time distributions in order to examine how frequently PM control processes are allocated to the types of non-focal PM tasks that are commonly used in the PM literature (i.e., syllable or categorical PM targets embedded in ongoing lexical decision tasks). There are many useful mathematical functions that could be used, including the ex-Gaussian, Wald, Gamma, and Weibull functions (Hohle, 1965; Luce, 1986; Van Zandt, 2000). In our prior research, and in the current study, we used the ex-Gaussian function because it provides good fits to response time distributions across a wide range of tasks, including Stroop (Heathcote, Popiel, & Mewhort, 1991) and recognition memory (Balota & Spieler, 1999). The ex-Gaussian function is a convolution of a normal (Gaussian) distribution and an exponential distribution (Eq. (1)). At each time point x, the probability density of the ex-Gaussian function is bound by three parameters: mu (μ) is the mean of the Gaussian distribution, sigma (σ) is the standard deviation of the Gaussian distribution, and tau (τ) is both the mean and standard deviation of the exponential component, which is analogous to skew.

$$f(x|\mu,\ \sigma,\ \tau) = \frac{1}{\tau\sqrt{2\pi}} \exp\left(\frac{\sigma^2}{2\tau^2} - \frac{x-\mu}{\tau}\right) \cdot \int_{-\infty}^{\left[\left(\frac{x-\mu}{\sigma}\right) - \left(\frac{\sigma}{\tau}\right)\right]} \exp\left(-\frac{y^2}{2}\right) dy$$

The sum of the two main parameters yields the mean of the total distribution, whereas its variance can be calculated by adding the squares of the standard deviations of two parameters ($\sigma^2 + \tau^2$). The sum of the estimates for μ and τ is approximately equal to MRT, because the sum of the true values of μ and τ is equal to the true mean of the ex-Gaussian. Importantly, when response times are positively skewed and fit to an ex-Gaussian distribution, MRT does not estimate μ in a normal distribution, because MRT is now assumed to be a convolution of μ and τ. Thus, estimates of μ and τ can be generated and analysed separately to determine whether a variable that influenced MRT did so via μ, τ, or both. Fig. 1 illustrates that an increase in μ shifts the leading edge of the mean of the ex-Gaussian distribution to the right. A shift in μ for a PM condition compared to a control condition would reflect control processes applied to non-target trials regularly throughout the ongoing task. For example, interference effects due to response competition during various attention tasks have been associated primarily with an overall shift in the RT distribution (e.g., Spieler, Balota, & Faust, 2000). An increase in τ leads to a positive skew in the distribution (i.e., an increase in mean of the exponential component). A change in the relative frequency of slow responses (τ) to non-target trials for a PM condition compared to control condition would reflect more transient periods in which participants have engaged PM control processes (see Balota & Yap, 2011 for more details on the interpretation of RT distribution analyses).

Surprisingly, the Brewer (2011) and Ball et al. (in press) fits of the ex-Gaussian functions to non-target trial response time distributions provided little support for the idea that costs in non-focal PM reflect control processes that are applied regularly during the ongoing task,
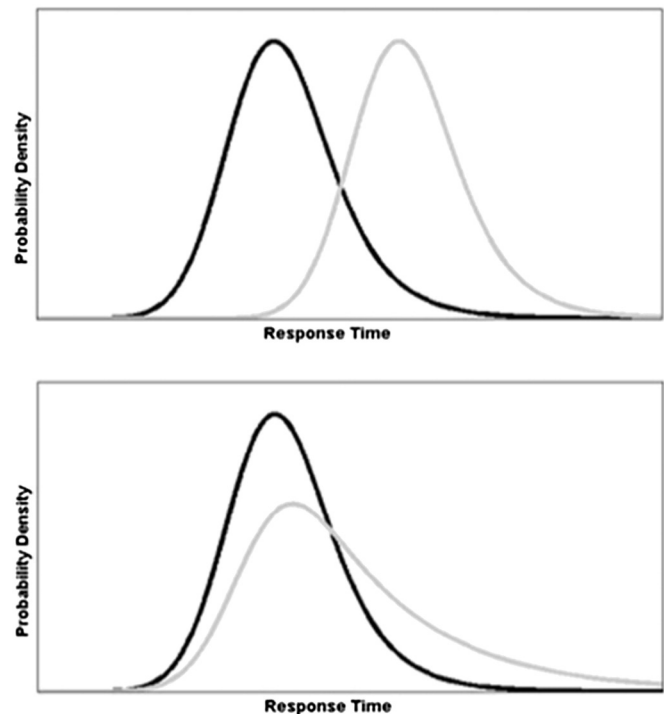

Fig. 1. Changes to the shape of a hypothetical distribution when each of the ex-Gaussian parameter mu (μ) (top panel) and tau (τ) (bottom panel) is manipulated.

as would be indicated by a change in μ. Participants in the Brewer (2011) study performed a lexical decision task and were required to make a PM response if presented with words that contained the syllable 'tor' (e.g., doctor). This PM task is commonly used and was non-focal because lexical decision making does not require the selective processing of individual syllables (Meeks, Hicks, & Marsh, 2007). Participants in the Brewer study were slower to make non-target lexical decisions under PM conditions compared to control conditions without a PM task. An ex-Gaussian analysis revealed that costs were due to an increase in τ, which was indicative of the PM demand changing the relative frequency of slow responses, and thus reflected control processes allocated to the PM task on a transient basis (Balota & Yap, 2011).

The Ball et al. (in press) study used a second type of commonly used non-focal PM task, requiring participants to make a PM response when presented with a category exemplar (animal) during an ongoing lexical decision task. In line with Brewer (2011) this category PM task only caused an increase in τ compared to a control condition that only made lexical decisions, which was again indicative of transient PM control. However, the lack of an effect of category PM on μ may have been due to the fact that, in order to manipulate the context in which participants expected targets to occur, Ball et al. did not present targets at all for the first half of the ongoing task period. Loft, Kearney, and Remington (2008) showed that the use of PM control processes decrease when targets are not presented for significant periods of time.

In the current paper we fit the ex-Gaussian mathematical function to the category non-focal condition originally reported by Loft and Humphreys (2012), in which targets were presented on a regular basis (approximately every 25 trials) and thus was more consistent with the prior PM literature. Loft and Humphreys reported a cost for participants required to make a non-focal PM response when presented with a category exemplar during an ongoing lexical decision task, compared to a control condition that only made lexical decisions. Although a non-focal PM task, the detection of category exemplars is arguably better supported by the process of lexical decision making than detecting PM syllables, because both the lexical decision task and non-focal PM task require the processing of whole letter strings (see Loft &

Remington, 2013). Coupled with the fact that Brewer (2011) did not find a change in μ with a syllable PM task, we did not necessarily expect to find a change in μ with the categorical PM task. Nonetheless, as outlined earlier, the cognitive mechanisms specified in current theories of PM, and the dual-task nature of event-based PM, both imply that PM control processes may well be allocated on a reasonably regular basis. In addition to exploring whether there was an increase in μ, based on the prior literature we did expect to find a change in τ with non-focal categorical PM demands. We also examined the consequences of any change in μ and τ for PM by linking changes in these RT distribution parameters to within-subject variations in PM accuracy.

We further extend prior research by fitting the ex-Gaussian function to non-target trial response time distributions that were observed under focal PM conditions. Loft and Humphreys (2012) reported an increased MRT of 23 ms for participants in a focal condition that were required to make a PM response when presented with a specific word in the ongoing lexical decision task, compared to the control condition ($p = .14$). This finding that focal PM tasks cause small, yet non-significant, costs is often reported in the PM literature (but see Smith et al., 2007 who reported significant costs with focal tasks). A reasonable conclusion is that the MRT's indicate that focal PM demands have no significant effect on the ongoing task. However, this is not necessarily the case because a significant increase in one of component of the response time distribution can be offset by a slight decrease in another component, thereby diluting the impact of PM demands on MRT (see Heathcote, 1991). Moreover, fits of the ex-Gaussian function to the focal condition will provide an indication of the extent to which the small increase in MRT under focal conditions is more associated with control process that operate regularly on non-target trials (μ), or with transient control process (τ). However, consistent with the premise of the multi-process view that focal PM retrieval is not dependent on the allocation of preceding PM control processes (Einstein & McDaniel, 2005), we do not expect any change in ex-Gaussian parameters under focal conditions to be correlated with PM accuracy at the within-subject level.

2. Method

2.1. Participants

The data from 192 participants from the Loft and Humphreys (2012) study was used. Participation was part of a course requirement (119 females, mean age was 20.23). Ninety-six of these participants had been randomly assigned by Loft and Humphreys to the control condition, 48 to a non-focal PM condition, and 48 to a focal PM condition. Note that Loft and Humphreys also included additional between-subject focal (N = 48) and non-focal (N = 48) conditions where the importance of the PM task was emphasized. We do not present this additional data because the purpose of the current study was to fit the ex-Gaussian function to standard PM conditions.

2.2. Materials

A pool of 384 medium frequency words (occurring 20–50 times per million) were randomly selected from the Sydney Morning Herald word database (Dennis, 1995). Of these, 184 were used as words, and 200 were converted to non-words by randomly replacing each vowel in each word (e.g., chemist to chamust). Two lists were created, and each list contained 92 words and 100 non-words. Each list had a designated category of PM targets embedded within it (sports or fruits). Eight medium-typicality exemplars from each category were used as targets (Van Overschelde, Rawson, & Dunlosky, 2004). In list A, the category was sport (golf, softball, soccer, cricket, hockey, lacrosse, tennis, rugby). In list B, the category was fruit (grape, pear, peach, melon, cherry, banana, plum, mango). Note that Loft and Humphreys (2012) used words and non-words from one list as stimuli for lexical decision, and

a random subset of non target words from the other list as new items in a recognition memory task. The assignment of lists to the lexical decision and recognition task was counterbalanced by Loft and Humphreys, but we only report data from the lexical decision phase.

For the lexical decision task, the presentation of words and non-words within each list was random, except that targets were presented at random between trials 5 and 25, 26 and 50, 51 and 75, 76 and 100, 101 and 125, 126 and 150, 151 and 175, and 176 and 200. The focal condition was presented with one category exemplar eight times, one at each allocated target trial position. In the non-focal condition, one category exemplar was presented in each allocated target trial position. Overall, in the non-focal conditions, eight different category exemplars were presented. In the control condition, targets were also presented, but the targets held no special significance.

2.3. Procedure

For lexical decision, participants were instructed to decide whether letter strings were English words or non-words and to respond by pressing "f" for a word or "j" for a non-word.

The first display was a fixation point "+" displayed in white on a black background for 500 ms. The fixation point was then replaced by a blank screen for 250 ms, followed by the presentation of the letter string, which remained on the screen until the participant made a response. Participants were told to respond as quickly and accurately as possible. Participants in the non-focal condition were instructed to press the "9" key when presented with an exemplar of their PM target category during the ongoing task. Participants in the focal condition were instructed to press the "9" key when presented with their specific target word. This instruction does not specify whether the ongoing task response should also be made on target trials. However, prior research has shown that this instruction results in the vast majority of PM responses being made *instead* of the ongoing task response (e.g., Einstein et al., 2005; Loft & Remington, 2013; Smith, 2003; Smith et al., 2007). Participants completed a three minute puzzle after the PM instruction before beginning the task.

3. Results

PM accuracy, lexical decision response time, and ex-Gaussian parameter values are presented in Table 1. For the analyses of costs (standard analyses and ex-Gaussian analysis) we conducted contrasts that compared the focal condition to the control condition, and the non-focal condition to the control condition. We also included a comparison of the non-focal condition to the focal condition to directly test (see Nieuwenhuis, Forstmann, & Wagenmakers, 2011) the effect of target focality on MRT and on the response time distributions.

3.1. PM accuracy

PM responses were scored as correct if participants pressed the "9" key on the target trial or on the following two trials, although the majority of PM responses (98.5%) were made on the target trial (and typically replaced the ongoing task response). The focal condition made the PM response to more PM targets than the non-focal condition, $t(94) = 5.01$, $p < .001$, $d = 1.05$.

Table 1
Prospective memory accuracy (PM accuracy), lexical decision non- target mean response time (LD MRT), and ex-Gaussian components (μ, τ, and σ) as a function of condition. Standard deviations are in parentheses.

	PM accuracy	LD MRT	Mu (μ)	Tau (τ)	Sigma (σ)
Control		598 ms (91 ms)	471 (59)	128 (54)	49 (17)
Focal PM	.85 (.20)	621 ms (85 ms)	489 (47)	133 (65)	46 (19)
Non-focal PM	.60 (.27)	692 ms (130 ms)	527 (74)	166 (91)	53 (21)

3.2. Standard analysis of costs

Lexical decision accuracy was near ceiling ($M = .96$), and there were no differences between conditions (smallest $p = .12$). For response times, we excluded the first two trials, target trials, PM false alarms, and the two trials following target trials and false alarms. Additionally, we only used word trials (e.g., Brewer, 2011; Loft & Remington, 2013; Smith et al., 2007). Due to the fact that targets could only be presented on word trials, we were not surprised to find that there were no costs to non-word trials (see Cohen, Jaudas, Hirschhorn, Sobin, & Gollwitzer, 2012). We excluded incorrect lexical decisions, response times less than 300 ms, and response times greater than 3SDs from the participants' grand mean. MRTs to non-target word trials were 94 ms longer for participants in the non-focal PM condition compared to participants in the control condition, $t(142) = 5.06$, $p < .001$, $d = .84$, and were 71 ms longer for participants in the non-focal PM condition compared to participants in the focal PM condition, $t(94) = 3.17$, $p < .01$, $d = .65$. The 23 ms increase in MRT for participants in the focal condition compared to participants in the control condition did not reach statistical significance, $t(142) = 1.47$, $p = .14$, $d = .26$. MRT to non-target word trials was positively correlated with PM accuracy for the non-focal condition, $r = .37$, $p < .01$, but not the focal condition, $r = .003$, $p = .98$.

3.3. Ex-Gaussian analysis of costs

In line with Brewer (2011) and Ball et al. (in press), we used the same data exclusion criteria in the ex-Gaussian analysis as we had previously applied to the standard analysis. The ex-Gaussian function was fitted to each individual participant's data to obtain estimates of the μ, σ, and τ distribution parameters using the QMPE software (Heathcote, Brown, & Cousineau, 2004). We used the maximum possible number of quantiles (N-1) in order to minimize parameter estimate bias and maximize efficiency. For example, if after data exclusions, a participant had 78 accepted trials, then the model would use 77 quantiles for that participant. The proportional convergence tolerance for the objective function value was fixed at 1×10^{-9} and the tolerance for the L∞-norm of the parameter vector was 1×10^{-5}. Model fits were obtained in under 300 iterations, and the fits for all participants were successful.

There was a significant increase in the μ component of the non-target trial response time distribution for participants in the non-focal condition compared to participants in the control condition, $t(142) = 4.94$, $p < .001$, $d = .84$, and for participants in the non-focal condition compared to participants in the focal condition, $t(94) = 3.00$, $p < .01$, $d = .61$. There was also a significant increase in the τ component of the non-target trial response time distribution for participants in the non-focal condition compared to participants in the control condition, $t(142) = 2.92$, $p < .01$, $d = .48$, and for participants in the non-focal condition compared to participants in the focal condition, $t(94) = 2.04$, $p < .05$, $d = .42$. There was no significant difference in the σ component of the non-target trial response time distribution between the non-focal and control conditions, $t(142) = 1.23$, $p = .22$, $d = .21$, or between the non-focal and focal conditions, $t(94) = 1.71$, $p = .09$, $d = .35$. There was a significant positive correlation between the μ component and PM accuracy, $r = .46$, $p = .001$, indicating that participants with a larger μ detected more non-focal PM targets. There was no significant correlation between the τ component and PM accuracy, $r = .15$, $p = .31$, or between the σ component and PM accuracy, $r = .01$, $p = .97$, for the non-focal condition.

There was a trend level increase in the μ component of the non-target trial response time distribution for participants in the focal condition compared to participants in the control condition, $t(142) = 1.84$, $p = .07$, $d = .34$. There was no change in the τ component, $t(142) = 0.45$, $p = .65$, $d = .08$, or in the σ component, $t(142) = 1.17$, $p = .25$, $d = .20$, for participants in the focal condition compared to participants in

the control condition. Neither the μ component ($r = .19$, $p = .19$), τ component ($r = .23$, $p = .12$), or σ component ($r = .17$, $p = .25$) of the non-target trial response time distributions were significantly correlated with PM accuracy for participants in the focal condition.

Finally, the correlation between the μ component and PM accuracy for the non-focal condition ($r = .46$) was marginally stronger than the correlation between the μ component and PM accuracy for the focal condition ($r = .19$), $z = 1.45$, $p = .07$.

4. Discussion

Using MRT to examine costs has dominated the PM literature (Einstein & McDaniel, 2010; Smith, 2010). Several theoretical proposals have been made regarding the control processes that underlie costs. Researchers contend that individuals allocate 'preparatory attention processes' (Smith, 2003), instantiate PM 'retrieval modes', 'check' for targets (Guynn, 2003), or 'monitor' for targets (Einstein & McDaniel, 2005). It was perhaps a little surprising then that both Brewer (2011) and Ball et al. (in press) found that costs resulting from two commonly used non-focal (syllable or categorical) PM tasks were solely due to an increase in the τ component of the non-target trial response time distribution, because this suggested that the control processes underlying costs reflected transient control processes that only affected a small subset of non-target ongoing task trials. Our current ex-Gaussian function fits demonstrate that a non-focal (categorical) PM task requirement increased both the μ and τ components of the non-target trial response time distribution, which is indicative of a more continuous PM monitoring profile than that reported by prior studies. Furthermore, variability in μ, but not variability in τ, was reliably correlated with PM accuracy for participants in the non-focal condition.

There is arguably a lack of specificity in current verbal theorizing regarding the mechanisms underlying costs in PM. Analysing response time distributions has the advantage that it allows researchers to determine the extent to which costs reflect control process that operate regularly, as opposed to more transiently. However, we need to be clear that our goal was to characterize the non-target trial response time distribution, and we need to take great care in assuring that we do not attempt to map specific cognitive operations onto ex-Gaussian parameters, because the ex-Gaussian function makes no assumptions about underlying cognitive processes. What we can conclude from our current ex-Gaussian fits is that when individuals have categorical non-focal PM task requirements, and when targets are regularly presented during the ongoing task, some form of control process is likely to be allocated to the PM task at the expense of the ongoing task that causes an increase in the entire non-target response time distribution (shift in μ).

This finding makes sense given that the dual-task nature of the event-based PM paradigm is analogous to traditional divided attention paradigms (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). A key feature of any divided attention task is that performance in the divided attention condition (PM task + ongoing task) is compared with performance in a full attention condition (ongoing task only). However, traditional divided attention and PM tasks can be differentiated (Smith, 2003). Participants performing PM tasks must interrupt their ongoing activity in response to an intermittently occurring event, whereas participants performing divided attention tasks must potentially respond fairly continuously to a frequently occurring secondary task stimulus. That is, for PM tasks, targets are embedded in ongoing tasks with ongoing task responses required on many trials and PM responses required on few trials. Nonetheless, consistent with the operationalization of divided attention, current theories of PM seem to be describing cognitive mechanisms that should occur quite regularly (preparatory attention, checking, monitoring), and we found evidence for a continuous PM monitoring profile in the current study when individuals had categorical PM requirements.

In addition to this, we can conclude that extra PM control processes are likely to be devoted to a smaller subset of non-target trials (resulting

in a shift in τ). We tentatively further suggest that participants regularly mapped the semantic features of lexical decision letter strings to their PM category, and that a small subset of letter strings needed extra PM processing before being dismissed as non-targets. This interpretation can be more fully tested in future research by manipulating the semantic or phonetic relatedness of non-target items to PM categories, and examining whether this affects which response times fall in the tail of the response time distribution. This can directly test whether the effect is thus driven by the stimulus materials and not by more general meta-cognitive changes in monitoring strategies (Scullin, McDaniel, & Shelton, 2013).

It is also possible that some of the elevation in MRT and associated increases in the μ and τ component for the non-focal condition reflect periods of ongoing task goal neglect (Duncan, Emslie, Williams, Johnson, & Freer, 1996), or momentary lapses of attention from the entire task set (Teasdale et al., 1995). However, it is unclear why participants would be more likely to neglect the ongoing task goal, or withdraw attention from the entire ongoing task and PM set, when under non-focal conditions compared to when under control or focal conditions. Furthermore, we found that variability in the μ component was positively correlated with non-focal PM performance, indicating that the underlying cognitive control processes were indeed functional to PM retrieval. Future research should examine the underlying cognitive control mechanisms that mediate individual differences in response time distribution estimates effects on PM target detection.

It is common for researchers to dichotomize event-PM tasks into those that require cognitive control processes (non-focal PM tasks) and those that can rely more on spontaneous retrieval (focal PM tasks). This has undoubtedly been a very useful approach for advancing our understanding of PM. However, the difference in ex-Gaussian components contributing to the increase in MRT for syllable non-focal PM tasks (Brewer, 2011) and current categorical non-focal PM tasks, suggests that cognitive control under non-focal conditions is unlikely to be unitary. Instead, multiple distinct cognitive control patterns, reflecting different PM control processes, are likely employed depending on the exact nature of the non-focal PM task. It is interesting to note that according to the multi-process view, the category PM task is more focal to lexical decision making than the syllable PM task is to lexical decision making. The slower MRT's for syllable PM tasks seem to be caused a small number of slow RT's that fall in the tail of the distribution (Brewer, 2011), and this may reflect that participants do not routinely remember to check the syllable status of stimuli because this PM task is very non-focal, but at the same time each PM check may slow down lexical decision making to a large degree. In contrast, individuals may check the PM category status of stimuli more regularly because this is better supported by lexical decision making (thereby changing μ), but each PM check may slow the lexical decision task to a smaller extent. The current paper highlights the importance of examining non-target trial response time distributions in addition to MRT when examining costs in event-based PM.

It would be informative for future research to fit the ex-Gaussian function to other non-focal PM tasks that are perhaps less frequently used in the PM literature. This includes PM conditions where targets are perceptually non-focal; that is, in a different field of view from ongoing task stimuli (Hicks, Cook, & Marsh, 2005). McBride and Abney (2012), and Abney, McBride, and Petrella (2013) found evidence that non-focal PM requirements to detect words containing repeated vowels, or to detect palindrome words (e.g., civic), caused an increase in both the μ and τ components of the non-target trial response time distributions of ongoing tasks such as living/non-living judgement.

The finding that the 23 ms increase in MRT for the focal condition compared to the control condition was associated with a trend level increase in the μ component of the non-target trial response time distribution, but not the τ component, is of theoretical interest. The assumption of the multi-process view is that while the initial noticing of a target can be automatic, resources are then required to verify targets (Einstein & McDaniel, 2010). Encountering the target-like item may cause that

item to be processed with more or less fluency than is expected in that context. This discrepancy in processing (relative to other items in the ongoing task) may then stimulate a strategic search for the source of that discrepancy (McDaniel, Guynn, Einstein, & Breneiser, 2004). If this discrepancy plus search process occurs often enough it could potentially have produced the trend level increase in μ. Nonetheless, the bottom line that the increase in μ was not reliably correlated with PM performance, and was marginally weaker than the correlation between the μ component and PM accuracy for the non-focal condition, which is consistent with the claim of the multi-process view that focal PM retrieval is not as dependent on the allocation of PM control processes as non-focal PM retrieval.

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