January 2009

Age Differences in Prospective Memory: An Examination of the Role of Fluctuations in Executive Control

Shannon Robertson
Washington University in St. Louis

WASHINGTON UNIVERSITY

Department of Psychology

Dissertation Committee:

Sandra Hale, Chair

Mark McDaniel

Joel Myerson

Mitchell Sommers

Richard Abrams

Lisa Tabor Connor

Nancy Tye Murray

AGE DIFFERENCES IN PROSPECTIVE MEMORY: AN EXAMINATION OF THE ROLE OF FLUCTUATIONS IN EXECUTIVE CONTROL

by

Shannon Eugene Robertson

A dissertation presented to the

Graduate School of Arts and Sciences of Washington University

in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

August, 2009

Saint Louis, Missouri

ACKNOWLEDGEMENTS

This dissertation is a symbol of my effort for the last ten years to better understand what it means to age. This endeavor was only possible because of the unconditional support and tremendous patience of several individuals.

First, I must thank my parents. The support they provided was incalculably helpful, but most importantly, I must thank them for always encouraging curiosity and instilling in me a passion to learn.

Next, I thank the many faculty members at Washington University who have done so much to help me become as good of a scholar as possible. (I dare say that could not have been an easy undertaking.) Among these individuals, I especially thank Mark McDaniel and Mitch Sommers for their advice and helpful comments on this project. Of course, I cannot give enough thanks to my mentors, Sandy Hale and Joel Myerson. They have been excellent teachers. Without their auspices, guidance, and tolerance, many of my achievements over the past several years would not have been possible.

I also thank all of the undergraduate research assistants who helped me collect the data presented in this work. I wish them all the best in their future endeavors.

Last, but certainly not least, I thank my significant other of the last 13 years, Allison Boswell. Her companionship has been a comfort and a sanctuary during the most difficult times.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIXES

ABSTRACT OF THE DISSERTATION

Age Differences in Prospective Memory: An Examination of the Role of Fluctuations in Executive Control

by

Shannon Eugene Robertson

Doctor of Philosophy in Psychology

Washington University in Saint Louis, 2009

Associate Professor Sandra Hale, Chairperson

Prospective memory (ProM)-remembering to carry out intended actions at appropriate times-is a cognitive function that relies on controlled or automatic processing to various degrees. Age differences in ProM are most likely to be observed on tasks that rely heavily on controlled processes. This is consistent with certain frontal lobe theories of cognitive aging that also make predictions regarding age differences in performance variability on speeded components of ProM tasks that vary in the extent to which controlled processes are required. This study consisted of two experiments designed to test those predictions. In the first experiment, the degree to which controlled processes were necessary was manipulated by varying whether or not the ProM task focused processing on the cue. In the second experiment, this was achieved by varying the salience of the cue. The predictions tested in this study were that (1) age differences in

intraindividual variability of performance on certain aspects of ProM tasks exist and those differences are greater on tasks that encourage the engagement of controlled processing than on those that don't; and (2) individual differences in intraindividual variability predict ProM performance and accounts for age differences in ProM performance.

This was the first study to show that a ProM burden increases the skew of associated RT distributions. This was also the first study to clearly demonstrate that intraindividual variability, as indicated by the skew of RT distributions, is greater for older adults than for young adults. The test of the prediction that this age difference would increase as a function of the degree to which the ProM task required controlled processing was inconclusive. However, concordant with the predictions of frontal lobe theories, this study did find that the age difference in skew was larger when attention was divided than when it was not. This study was also successful in demonstrating the potential that measures of intraindividual variability have as predictors of ProM performance, although it was not possible to conclude that individual differences in intraindividual variability account for age differences in ProM performance.

OVERVIEW

Prospective memory (ProM) – the process of forming an intention to carry out some action in the future and then executing that intention at the appropriate time – is an essential cognitive function that relies to varying degrees, depending on the characteristics of the task, on either controlled or automatic processing. Previous research has indicated that younger adults are likely to outperform older adults when the ProM task relies more heavily on controlled processing than on automatic processing (e.g., Cherry & LeCompte, 1999; Marsh & Hicks, 1998); a finding that is consistent with cognitive aging theories that attribute age differences in ProM performance to age differences in cognitive control, which presumably result from age-related changes in frontal lobe function (e.g. Braver & Barch, 2002; West, 1996, 2001).

One such theory has been proposed by West (2001). This frontal lobe theory of cognitive aging posits that age-related changes in frontal lobe function result in decreased stability of executive control, which in turn leads to age-related increases in the moment-to-moment fluctuations or intraindividual variability in cognitive performance. West's theory is unique in that it leads to specific predictions regarding intraindividual variability in performance on different aspects of typical ProM tasks; predictions that have not been adequately tested. Furthermore, West's theory makes definite predictions about the nature of the intraindividual variability. In particular, the expected group and task influences on intraindividual variability should primarily be reflected in the skew of response time (RT) distributions derived from performance on speeded components of ProM tasks. The primary purposes of the current study were to further examine the ability of West's theory to predict certain characteristics of ProM performance in terms of intraindividual variability, and to assess the ability of this theory to account for age differences in ProM performance. The current research then, is important for theory development in the areas of cognitive aging and ProM. If the predictions of West's theory can be shown to be valid in the current study, it would mean that the application of cognitive control and other theories of cognitive aging to ProM performance are deficient without taking the intraindividual variability of performance into account.

The current study incorporated methodological features and a variety of analytic techniques (e.g., analyses of characteristics of RT distributions) that made it possible to accurately measure intraindividual variability of performance on aspects of ProM tasks that emphasize speed of responding. Consequently, the research described herein was able to effectively identify age differences in intraindividual variability in cognitive performance where they existed. This study sought to answer four questions, described below, that systematically address the predictions made by West's (2001) theory, which links age-related changes in cognitive control (executive control to be more specific) to age differences in both ProM performance and intraindividual variability of performance on components of ProM tasks.

First, does the burden of a ProM intention increase intraindividual variability in performance on the on-going component of a ProM task? West (2001; see also West, Murphy, Armilio, Craik, & Stuss 2002) has proposed that executive control processes – those processes that are required for the selection, planning, and termination of goal-relevant task operations – support ProM performance, and that these processes fluctuate over time. ProM tasks require individuals to maintain an intention during an interval that is filled by some on-going task component that, in laboratory settings, sometimes places an emphasis on speeded cognition (e.g., a lexical decision task [LDT]). Importantly, the presence of ProM intentions (Einstein et al., 2005) are typically manifested as increases in the average RTs for the on-going component, and fluctuations in ProM performance (West, Krompinger, & Bowry, 2005) are evident in the increases or decreases in the average RTs leading to either ProM misses or hits. The frequency and/or magnitude of fluctuations in the processes that support ProM should also influence the intraindividual variability in performance on the on-going component. Furthermore, according to West et al. (2002), intraindividual variability in performance on the on-going component should be greater for ProM tasks that require more executive control than ProM tasks that require less executive control. To test these assumptions, a LDT task was administered to participants both with and without the burden of a ProM intention and under conditions that varied in the extent to which executive control processes should have been engaged.

Second, does the burden of a ProM intention increase intraindividual variability in performance on the on-going component of a ProM task more for older adults than for younger adults? A prediction inherent in West's (2001) theory of cognitive aging is that age differences in the intraindividual variability in performance on the on-going component should be greater for ProM tasks that require more executive control than those that require less executive control. To test this prediction, several ProM tasks that varied in the extent to which executive control processes were recruited were administered to both younger and older adults.

Third, does intraindividual variability in performance on the on-going component of a ProM task predict ProM performance or account for age differences in ProM performance? Intraindividual variability in performance on an on-going task component should be negatively correlated with ProM performance if the processes that support ProM fluctuate over time. Moreover, if fluctuation of these processes increases with age, as has been proposed by West (2001), then individual differences in intraindividual variability in performance on the on-going component should account for any age differences in ProM performance that may exist. This should especially be the case for ProM tasks that rely most heavily on executive control. To test this, the contribution of individual differences in intraindividual variability in performance on an on-going LDT to ProM performance and to age differences in ProM performance was evaluated via a series of hierarchical regression analyses.

Finally, does intraindividual variability in performance on a task that requires executive control predict ProM performance or account for age differences in ProM performance? Previous studies have reported that individual differences in speed (Salthouse, Berish, & Siedlecki, 2004), working memory and recognition memory (Cherry & LeCompte, 1999) and notably, executive function (Martin, Kliegel, & McDaniel, 2003) partly predict ProM performance; however, no study to date has sought to determine whether individual differences in intraindividual variability in cognitive performance predict ProM performance. If the efficiency of executive control processes fluctuates, and ProM is reliant to varying degrees on executive control, then intraindividual variability of performance on a task that relies heavily on executive control should be a stronger predictor of performance on ProM tasks that place greater demands on executive control than ProM tasks that place fewer demands on executive control. To test this, in addition to the ProM tasks mentioned above, a two-back task, which presumably requires executive control, was also administered. The contribution of individual differences in intraindividual variability on the 2-back task to ProM performance and to age differences in ProM performance was evaluated via a series of hierarchical regression analyses.

LITERATURE REVIEW

Prospective memory (ProM) is the capacity for forming an intention to carry out some future act, maintaining that intention, and then retrieving the intention within the appropriate temporal and/or environmental context. ProM plays a prominent role in the day-to-day affairs of most people, and can literally mean the difference between life and death for many. A pilot forgetting to check critical aircraft settings before takeoff, a doctor neglecting to check for missing instruments after surgery, or an older heart patient forgetting to take heart medication are just a few ways in which a failure of ProM can be disastrous. It has even been demonstrated that ProM performance can discriminate healthy older adults from those with mild Alzheimer's dementia (Duchek, Balota, & Cortese, 2006). Thus, given the importance of ProM, it is not surprising that a growing number of researchers are focusing their efforts on understanding the factors that influence ProM performance.

One obvious factor to consider is age; however, as will be discussed below, age differences in ProM performance are not task invariant. Age differences are most reliably found when the ProM task requires controlled rather than automatic processing (e.g., Cherry & LeCompte, 1999; Marsh & Hicks, 1998). This is in agreement with theories of cognitive aging that hypothesize an age-related decline in cognitive control (e.g. Braver & Barch, 2002; West, 1996, 2001); a reasonable tenet given that neuropsychological findings suggest that cognitive control processes are supported by frontal cortex and that this area of the brain is especially susceptible to the damaging effects of age (e.g., Moscovitch & Winocur, 1992; Raz, 2000). Moreover, by most accounts, frontally mediated executive functions play a critical role in ProM (e.g., Martin, Kliegel, & McDaniel, 2003; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999).

Thus, theories of cognitive aging that claim age-related changes in cognitive performance are the result of changes in frontally mediated processes such as cognitive control are especially applicable to the study of age differences in ProM performance. West (2001) has proposed what can be described as a cognitive control theory of cognitive aging in which he argues that selective age-related changes in frontal lobe function result in a decrease in the efficiency of executive control. West's theory leads to predictions regarding performance variability on ProM tasks; however, these predictions have not been tested. The purpose of the present study was to test critical predictions of West's theory of cognitive aging as they pertain to ProM performance.

In developing the rational for the research described herein, a brief primer on ProM and a review of the relevant literature will first be provided. Next, the literature regarding ProM and age will be discussed. After that, the application of West's (2001) theory of cognitive aging to age differences in ProM performance will be presented. Then, because the primary focus of the proposed research is on the predictions made by West's theory regarding the performance variability of individuals, the literature pertaining to age differences in intraindividual variability from other cognitive domains will be discussed. Finally, an overview and rationale for the experiments conducted in this study will be presented.

Primer

At this point it will be helpful to introduce various issues that are pertinent to the study of ProM. In doing so, the following will be discussed: (1) methodological features common to most ProM tasks, (2) a taxonomy of ProM tasks, (3) issues concerning the construct validity of ProM, (4) the neuropsychological foundations of ProM, (5) the role of executive function in ProM, and finally (6) current relevant theoretical thinking on ProM.

Methodological Features of Prospective Memory Tasks

Prospective memory is most useful in real-world situations when a particular task can't be performed immediately. When a task must be delayed, an intention is formed to execute the task at a later time. Many times the intention is associated with some cue (e.g., a physical event, or a specific time) that will serve as a reminder to execute the task. Usually, other unrelated activities must be completed before the intention can be carried out. In order to mimic the characteristics of real-world ProM situations, certain methodological features are present in most experimental ProM tasks. For one, participants are instructed to form some intention, such as to press a button when the word *apple* appears. The word *apple* is often referred to as the ProM cue or target (ProM cue will be used in this report). Second, there is some delay between the formation of the intention and the opportunity to execute the intention. Third, participants are occupied with some on-going task or tasks during that delay which prevent conscious rehearsal of the intention. The on-going task might be a LDT, for example, in a laboratory based situation, or carrying out daily chores and activities in a naturalistic setting. Finally, the appropriate event or time to execute the intention occurs during the on-going task, thereby requiring that performance on the on-going task be at least temporarily suspended while the intention is recalled and carried out. Thus, ProM tasks have both a retrospective component (i.e., memory for what is to be done) and a prospective component (i.e., recognizing that some action must be carried out when a cue is encountered; Einstein, Holland, McDaniel & Guynn, 1992).

Types of Prospective Memory

There are two major types of ProM that can be distinguished on the basis of whether the cue is time-based or event-based. Event-based ProM relies on the occurrence of some event in the environment to facilitate recall of the intention. For example, waking up in the morning and planning to read a particular research article upon arriving home from the office involves the event of arriving home as the ProM cue. In contrast, there is no physical event in the environment to facilitate recall in time-based ProM. Rather, an intention must be executed at a given time. Waking up in the morning and planning to attend a colloquium at four o'clock (assuming that the time isn't associated with some event like an alarm) in the afternoon is an example of time-based ProM.

Besides event-based and time-based ProM, another kind of ProM situation should be mentioned. Habitual ProM tasks (see e.g., Einstein, McDaniel, Smith, & Shaw, 1998) are those that require the repetitive execution of the intention. For example, some older adults must take several medications more than once a day. Obviously, an intention must be formed to take the medication at the appropriate times and to not take the medication beyond the prescribed frequency. Thus, habitual ProM is different from time-based ProM because it requires one to remember whether (and how many times in some cases) the intention has already been realized. This example illustrates why the study of habitual ProM has a great deal of practical importance and it will be discussed further in the section on ProM and aging below.

All types of ProM can be further parsed according to the location of administration (Kvavilashvili, 1992). Specifically, sometimes ProM tasks are administered outside of the laboratory in the context of day-to-day activities, whereas other times they are administered within a laboratory. ProM tasks that are administered out of the laboratory (typically referred to as naturalistic ProM tasks) are usually higher in ecological validity than those conducted within the laboratory, but they lack high levels of experimental control. (It should be noted that even though ProM tasks administered out of the laboratory are often referred to as naturalistic, Kvavilashvili [1992] has suggested that this term be reserved to describe the ecological validity of ProM tasks. One of the tasks used by Rendell and Thomson [1999], for example, required participants to press a button on a hand held computer according to an arbitrarily defined schedule. There was no cover story for why buttons needed to be pressed, and so the task must have seemed quite artificial to participants. Nevertheless, because it seems to be the convention within the literature, the term 'naturalistic' will be used in this report when referring to ProM tasks administered outside of the laboratory, regardless of ecological validity.)

Construct Validity of Prospective Memory

It may seem that retrospective memory (RetM) and ProM are identical constructs and that only the contents of memory differ (i.e., ProM involves the maintenance of an intention). Despite surface similarities, however, research suggests that ProM is indeed a construct separable from RetM. It is probably true that the processes involved in forming an association between an intention and some ProM cue are very similar to those involved in forming an association between two items in a paired-associate cued recall task, and that remembering to do something at a specific time in the future is not too different from recalling an item from a list in a free recall task. A critical difference, however, is that in RetM situations there is always an external request (e.g., an experimenter prompt or test question) for information that is in memory, whereas in ProM situations, the request for information is generated internally (Einstein & McDaniel, 2005). A further and notable difference is that ProM involves much more planning than RetM (Mäntylä, 1996). This is especially true in real-world ProM situations in which individuals must formulate a plan as to what intentions to form and how intentions need to be carried out. For example, imagine the planning that would be required to perform several errands that required stops at different locations in the city on the way home from work.

There are perhaps other differences between ProM and RetM that have not yet been identified, but even if these are the only differences (viz., external requests, planning) existing evidence suggests that these are sufficient to differentiate the two types of memory. For instance, Kvavilashvili (1987) reported no correlation between the retrospective component (i.e., remembering the content of an intention) and the prospective memory component (i.e., remembering to execute the intention) of a ProM task and interpreted this as an indication that ProM and RetM are two separate forms of memory. A more recent factor analytic study by Maylor, Smith, Della Sala, and Logie (2002) conducted on data obtained from healthy older adults and older individuals with Dementia of the Alzheimer's Type (DAT) revealed separate ProM and RetM factors for both healthy older adults and DAT patients. Subsequent oblique rotation of the factors revealed that the factors were related. Consistent with the Maylor et al. study, Cherry and LeCompte (1999) investigated the influence of various individual differences measures on ProM performance and found that working memory (WM) and recognition memory accounted for significantly more of the variance in RetM (free recall) than in ProM. This would not have been the case if RetM and ProM were exactly the same construct.

A recent study conducted by Salthouse, Berish, and Siedlecki (2004) demonstrated the construct validity of ProM and supported the idea that it is separable from RetM. They had participants perform four ProM tasks as well as several tasks representing other cognitive constructs, such as RetM, fluid intelligence, processing speed, executive function, and vocabulary. The ProM construct exhibited good convergent validity in that the four ProM tasks were all highly correlated with a ProM factor even after variance shared with other constructs was taken into account. Furthermore, discriminant validity was demonstrated by the fact that there was a separate ProM factor and it was appreciably less than perfectly correlated with the other cognitive factors.

Neuropsychology of Prospective Memory

Little research has been conducted regarding the neuropsychological foundations of ProM; however, existing literature suggests there is substantial frontal cortex involvement. Shum, Valentine, and Cutmore (1999) compared the performances of several individuals with traumatic brain injury (TBI) with healthy control participants on three tasks of ProM, including an event-based and a time-based task. Shum et al. suggested that, because cortical damage resulting from TBI is typically located in frontal and temporal areas, and because time-based ProM is thought to rely more on frontal processes than event-based ProM, the individuals with TBI would show a larger deficit on the time-based task. Indeed, the individuals with TBI showed deficits on both the time-based and event-based tasks relative to control participants, but the deficit was largest on the time-based task. Burgess, Quayle, and Frith (2001) reported increased regional cerebral blood flow (rCBF), as measured by positron emission tomography (PET), in Brodmann's area 10 and right lateral prefrontal cortex of participants performing event-based ProM tasks regardless of whether the ProM cue actually appeared. Additional activation was seen in the thalamus when the ProM cue appeared and was acted upon suggesting that frontal regions are involved in the maintenance of the intention and thalamic regions are additionally recruited when a ProM cue is identified and the intention is carried out. Similarly, Simons, Scholvinck, Gilbert, Frith, and Burgess (2006) also reported that activity in the anterior prefrontal cortex and Brodmann's area 10 was associated with performing a ProM task.

Some clinical neuropsychological evidence points to the involvement of frontal cortex and supports at least a partial dissociation between ProM and RetM. In a case study of an individual with bilateral frontal cortex infarcts, Cockburn (1995) reported that the individual demonstrated impaired performance on ProM tasks but intact RetM. Similarly, Palmer and McDonald (2000) evaluated the ProM and RetM of individuals who had temporal lobectomies and individuals who had aneurysms resulting in frontal damage. Relative to control participants, the individuals with temporal damage demonstrated impaired RetM and ProM, whereas individuals with frontal damage only showed impaired ProM.

Prospective Memory and Executive Function

The fact that the neuropsychological evidence from cases with brain damage points to a substantial role of frontal cortex in ProM suggests the possibility that frontally mediated executive functions (e.g., working memory, task-switching, inhibitory control, attention, and planning) may be involved in ProM in healthy individuals. Several findings suggest that this is indeed the case. For instance, Einstein, Smith, McDaniel, and Shaw (1997) found that increasing the demands of the on-going portion of a ProM task by adding a digit-monitoring task decreased ProM performance. The authors suggested that the requirement to simultaneously perform the two on-going tasks while maintaining the ProM intention was beyond what the working memory capacities of the participants could handle.

In order to more precisely determine the role of working memory in ProM performance Marsh and Hicks (1998) conducted a series of experiments in which participants performed ProM tasks that involved pressing a key whenever certain words were presented during a working memory on-going task. In each experiment participants concurrently performed tasks that differed in the extent to which demands were placed on the various components (i.e., central executive, phonological loop, and visuo-spatial sketch pad) included in Baddeley's model of working memory (1996; Baddeley & Logie, 1999). Relative to control conditions, ProM performance was worse when the concurrent tasks placed high demands on the central executive, but not when high demands were placed on the slave systems. The authors suggested that these results point to the importance of executive functions such as planning and monitoring in ProM.

Additional evidence for the role of executive function comes from a study conducted by Martin, Kliegel, and McDaniel (2003) in which participants were asked to perform a simple ProM task, a complex event-based ProM task, a complex time-based ProM task, and a highly complex multi-task ProM paradigm. The simple ProM task required participants to ask for the return of a personal item. The two complex ProM tasks required participants to respond to certain words (event-based) or at a certain time (time-based) while performing an on-going word rating task. The multi-task ProM paradigm required participants to perform several tasks according to rules that required a great deal of planning. In addition to the ProM tasks, participants also completed several tests of executive functioning (e.g., Wisconsin Card Sorting Test, Stroop, and Tower of London). Individual differences in executive functioning predicted performance on the complex ProM tasks, but not performance on the simplest ProM task. Presumably, the executive function tasks predicted complex ProM performance, because they both required cognitive control processes to a substantial degree. On the other hand, the executive function tasks did not predict performance on the simple ProM task, because it did not place high demands on cognitive control processes.

Theoretical Accounts of Prospective Memory

As mentioned earlier, typical ProM tasks involve a RetM component, in which the intention is encoded and maintained over some interval, and a ProM component, in which retrieval of the intention in the appropriate context is self-initiated (Einstein & McDaniel, 1996). A great deal of theoretical work attempting to differentiate between different types of ProM has focused on retrieval processes involved in the ProM component because retrieval processes vary substantially across ProM scenarios in the extent to which they are self-initiated. There are two dominant theories regarding retrieval processes in ProM: monitoring and multiprocess.

Monitoring theory. Smith (2003; see also, Smith & Bayen, 2004; Smith & Bayen, 2005), the most ardent supporter of monitoring theory, has proposed that after an intention is formed, events are continuously evaluated to determine if they are appropriate cues for retrieval of the intention. Preparatory attentional processes that facilitate the processing of ProM cues are engaged and maintained from the moment an intention is formed. Thus, from the perspective of this theory, once individuals have formed an intention, they are always in a retrieval mode and attentional and/or working memory processes are engaged to support monitoring. According to Smith and Bayen (2004), the sustained activation of preparatory attentional processes means that automatic processes do not play a role in the realization of intentions. In support of the monitoring view, several studies have shown that RT for on-going tasks was slower when there was a ProM load compared to conditions in which there was no ProM load (e.g. Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003). Furthermore, Marsh and Hicks (1998) reported that ProM performance suffered when the difficulty of the on-going task was increased. Presumably, performance would not have suffered if automatic processes were engaged, rather than processes supporting monitoring.

Multiprocess theory. In contrast to the strict monitoring view, McDaniel and colleagues (Einstein & McDaniel, 2005; McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004) have proposed a multiprocess theory that posits the involvement of both cue-focused processes (e.g., monitoring) and more efficient reflexive-associative processes in ProM. The cue-focused processes are hypothesized to rely on limited capacity systems that are supported by frontal cortex, such as the supervisory attentional system (SAS; Shallice & Burgess, 1991), or the central executive in Baddeley's working memory model (1996; Baddeley and Logie, 1999). Monitoring is one example of cue-focused processing, but because monitoring is so demanding of attention, it is hypothesized that another less demanding cue-focused process, perhaps similar to the processes involved in familiarity, is often utilized. This discrepancy-plus-search process evaluates the discrepancy between the actual and expected dynamics of processing when a ProM cue is encountered. When the discrepancy is sufficient, attention is then allocated to the task of determining what the ProM cue might signify (e.g. that an action is to be carried out). Reflexive-associative processes, in contrast with cue-focused processes, place few demands on limited capacity systems. Reflexive-associative processes rely on an automatic-associative memory system. This system takes input from consciously processed stimuli, which then interacts with the memory trace of the ProM cue that was created when the intention was initially formed. When an encountered cue interacts with the earlier memory trace of the cue to a sufficient extent, the intention reaches the level of conscious awareness.

The multiprocess theory assumes that reflexive-associative processes are the default and that various task characteristics and individual differences in cognitive ability determine whether cue-focused processes are engaged. McDaniel and Einstein (2000) identified several task characteristics that influence the extent to which cue-focused processes are utilized as opposed to reflexive-associative processes. One assumption that is important to the current study is that ProM tasks do indeed vary in the extent to which they rely on controlled processing; therefore, the presentation of those task characteristics identified by McDaniel and Einstein (2000) are summarized below.

The importance of the ProM component of the task is one factor that appears to determine whether cue-focused processes are in service. To be more specific, the more important the intention, the more likely it is that cue-focused processes will be relied upon. Kliegel, Martin, McDaniel, & Einstein (2001) found that when the importance of the ProM component was emphasized, participants were more likely to neglect to perform an on-going word rating task, but only when attention was divided. This suggests that when the importance of the ProM component was emphasized, monitoring processes were engaged at the expense of performance on the on-going task. Furthermore, Kliegel, Martin, McDaniel, and Einstein (2004) had participants perform a

ProM task that presumably engaged monitoring processes (viz., respond to words containing specific letters as opposed to the word itself) under standard and divided attention conditions and found that ProM performance was greater when the importance of the ProM cue was emphasized. Importantly, the effect of the importance manipulation was greatest when attention was divided.

The distinctiveness of the ProM cue is another task characteristic that influences whether cue-focused processes are engaged. Cues that are distinct or salient spontaneously capture attention and trigger an evaluation of the significance of the cue. Thus, cue-focused processes, such as monitoring, will play a more prominent role when the ProM cue is relatively indistinct than when it is salient. Consistent with this idea, McDaniel and Einstein (1993) reported that ProM was better when the cues used in their tasks were unfamiliar, and when the cues were distinctive relative to on-going task elements. Further support for this idea comes from the finding reported by McDaniel et al. (2004) that ProM performance was worse when cues were embedded in an on-going word rating task that contained previously studied words than when the words were new. Presumably the cue was less salient relative to previously studied words and more salient relative to new words.

The degree of semantic relatedness between the ProM cue and the intended action also influences the relative involvement of cue-focused and reflexive-associative processes. More specifically, the greater the semantic relatedness between the ProM cue and the intention, the more likely it is that reflexive-associative memory processes will deliver the intention to awareness. When the semantic relatedness between the ProM cue and the intention is weak, then the involvement of cue-focused processes will be necessary. To test this, McDaniel et al. (2004) gave participants ProM instructions that involved ProM cues and intentions that were either highly associated (e.g., spaghetti-sauce) or weakly associated (e.g., spaghetti-needle). Furthermore, half of the participants were given prior exposure to the words that would be used in the on-going word rating task and attention was divided for all participants on half of the trials. Prior exposure to the words used in the on-going task and dividing attention reduced ProM performance in the low association condition, in which limited capacity cue-focused processes were presumably involved, but not in the high association condition, in which automatic-associative processes were presumably more extensively involved.

Yet another task characteristic that influences the involvement of cue-focused and reflexive-associative processes pertains to focalization of processing, or the extent to which the on-going task requires attention to be placed on the ProM cue. When the on-going task requires focal processing of the ProM cue, then reflexive-associative processes are more likely to be involved. When the on-going task does not require focal processing of the ProM cue, then cue-focused processes are more likely to be involved. To test this, Einstein et al. (2005) had participants perform a ProM task that consisted of an on-going word categorization task and the intention to either respond when a particular word was presented (focal condition) or when a particular syllable occurred in a word (non-focal condition). ProM performance was higher in the focal condition than in the non-focal condition and responses to the on-going task items were faster in the focal condition than in the non-focal condition. These results suggest that the processes involved in ProM retrieval imposed a cost to performance on the on-going task in the non-focal condition, but not in the focal condition, consistent with the multiprocess view.

This notion of focalization of processing has also been couched in different terms by other researchers as well. For instance, van den Berg, Aarts, Midden, and Verplanken (2004) gave participants ProM instructions that were either categorical (non-focal) or specific (focal) in nature. They found that performance was better when specific instructions were given. Similarly, Meiser and Schult (2008) discussed their manipulations in terms of task-appropriate (i.e., focal) and task-inappropriate (i.e., non-focal) processing. They asked participants to remember to respond to either a category of animals or to palindromes during an on-going LDT. Presumably, responding to a category of animals involved more task-appropriate processing than responding to the palindromes. Consistent with the multiprocess account they found that increasing the attentional demands of the task impaired performance in the task-inappropriate condition, but not in the task-appropriate condition.

It may also be noted that although McDaniel and Einstein (2000) did not discuss the relevance of the multiprocess account to performance on time-based ProM tasks, given the requirement for self-initiated retrieval in such tasks, it seems clear that the theory would predict the involvement of controlled processes.

Age and Prospective Memory

The ProM literature is somewhat mixed with respect to identifying age-related differences. Early studies found that older adults actually performed better than younger adults (e.g., Maylor, 1990); however the tasks used were not subject to experimental control and older adults were more likely to use external cues than younger adults. When studies of age differences in ProM performance began to be conducted in the laboratory under controlled conditions, some failed to find any age differences (e.g., Einstein & McDaniel, 1990; Einstein et al., 1992, Exp. 1) whereas other studies did reveal age-related decrements (e.g., Einstein et al., 1992, Exp.2; Maylor, 1993). Despite these seemingly inconsistent findings, a pattern begins to emerge when task characteristics are considered. The literature regarding aging and ProM is reviewed below in the context of the task characteristics that appear to produce age differences.

Divided Attention

Much of the research mentioned below will make it abundantly clear that dividing attention often produces age differences in ProM performance. A study by Einstein, Smith, McDaniel, and Shaw (1997) is in accordance with that observation. They had participants perform an event-based ProM task either with or without a concurrently performed digit detection task. They found that younger adults performed better than older adults when attention was divided, but there was no age difference when attention was not divided. In follow-up studies they selectively divided attention during either encoding or retrieval. They reported age differences in both cases, but found that older adults were especially impaired when attention was divided at retrieval.

Naturalistic vs. Lab-based Prospective Memory Tasks

One variable that influences whether age differences in performance emerge is whether or not the ProM task is administered in a laboratory or in a more naturalistic setting. Contrary to what is sometimes found when ProM tasks are administered within a laboratory, older adults typically perform better than younger adults on naturalistic ProM tasks (i.e., those that are administered outside of a laboratory). Devolder, Brigham, and Pressley (1990) asked younger and older adults to telephone an answering machine twice a week for four weeks. On average, older adults completed two calls more than younger adults over the four week period. Similarly, Maylor (1990) reported that increasing age was associated with an increased likelihood of making requested telephone calls. Although, interestingly, this trend was only found in individuals who associated the calls with external cues (e.g., lunch time). Rendell and Thomson (1993) simulated a medication regimen for younger and older adults by having them press buttons at specific times over the course of two weeks. The older adults were more likely than younger adults to press the button on time, even though the older adults had poorer RetM.

Rendell and his colleagues (Rendell & Thomson, 1999; Rendell & Craik, 2000) have conducted studies to more methodically confirm the paradoxical findings between lab-based and naturalistic ProM tasks. Rendell and Thomson (1999) had younger and older adults enter the time in an electronic organizer four times a day for a week. Older adults outperformed younger adults regardless of the complexity of the schedule or whether or not external cues were used. These same participants also performed an event-based and a time-based ProM task within the laboratory. Contrary to what was found with the naturalistic tasks, younger adults performed better than the older adults on both the time-based and event-based ProM tasks administered in the lab. Rendell and Craik (2000) investigated the possibility that older adults might have more structured lives than younger adults; structure that affords them more and better opportunities to use strategies in support of ProM. In a first experiment participants played a board game designed to simulate real-world ProM situations that occur in daily living. Younger adults performed better in this game than older adults. In a second experiment the same participants were asked to perform ProM tasks that were supposed to be very similar to those encountered in the board game during the course of a week. In this naturalistic task older adults performed better than younger adults. Consistent with these paradoxical findings, a meta-analysis reported by Henry, MacLeod, Phillips, and Crawford (2004) also indicated that older adults perform worse on lab-based tasks, but better on naturalistic tasks. However, it should be noted that many of the tasks included in the meta-analysis as naturalistic were those conducted by Rendell and colleagues, and thus, the effect could be peculiar to their procedures or participant pool.

Habitual Prospective Memory

Older adults have particular trouble executing an intention on multiple occasions. Einstein et al. (1998) investigated habitual ProM by having participants respond to a ProM cue once during each of 11 trials, where a trial was the administration of a set of six on-going tasks. Attention was divided for some participants by having them perform a simultaneous digit monitoring task (DMT). Older adults were more likely than younger adults to fail to respond (error of omission) to cues on early trials, and more likely to respond too often (repetition error) on later trials. These differences were more pronounced when attention was divided. These results suggest that monitoring is necessary to some extent in habitual ProM tasks and that older adults are less able to utilize this monitoring process.

Recently, McDaniel, Bugg, Ramuschkat, Kliegel, and Einstein (in press) revisited the issue and replicated the finding that older adults are more likely to make repetition errors than young adults, even when given instructions that should have biased them against making repetition errors (viz. participants in one condition were told that it was better to fail to respond than to respond too often). Interestingly, McDaniel et al. also found that requiring the older adults to respond to the ProM cue in a complex manner reduced the number of repetition errors they made to that of young adults. It was suggested that the complex motor response facilitated better source monitoring by requiring more attention to be paid to the performance of the ProM task.

Time-based vs. Event-based Prospective Memory Tasks

Einstein, McDaniel, Richardson, Guynn, and Cunfer (1995) suspected that age differences in ProM performance should be pronounced for tasks that rely on self-initiated retrieval of the intention. Reasoning that time-based ProM tasks place more emphasis on self-initiated retrieval than event-based ProM tasks, they had younger and older participants perform ProM tasks that differed primarily in whether the ProM cue was time-based or event-based. As they expected, they found that younger adults performed better than older adults on the time-based version of the task, but not on the event-based version.

Park, Kidder, Morrell, and Mayhorn (1997) also had younger and older adults perform a time-based ProM task and an event-based ProM task. Like Einstein et al.

(1995), they reported superior performance by the younger adults on the time-based ProM task; however, younger adults also performed better than older adults on the event-based task. It should be noted that the effect of age was larger for the time-based task than for the event-based task.

Consistent with the findings of greater age-related deficits on time-based ProM tasks than event-based ProM tasks, a meta-analysis conducted by Henry, MacLeod, Phillips, and Crawford (2004) revealed that younger adults performed better than older adults on both time-based and event-based ProM tasks in the laboratory. Moreover, the effect size for age on time-based tasks ($r = -.39$) was slightly larger than that for event-based tasks as a whole ($r = -.34$), and substantially larger than that for event-based tasks that imparted relatively few demands on strategic control processes ($r = -.14$).

Number of Prospective Memory Cues

ProM tasks that involve multiple ProM cues are more likely to produce age differences than ProM tasks that involve one or only a few ProM cues. Einstein, Holland, McDaniel, and Guynn (1992) found that increasing the number of cues during an ongoing short-term memory task decreased ProM performance for both younger and older adults. There was no age difference when the intention was associated with only one cue; however, younger adults outperformed older adults when there were four cues. Einstein et al. suggested that there are two possible explanations for these findings. First, it is possible that older adults had more difficulty with the retrospective component of the task, and indeed, older adults recalled fewer cue items than younger adults at the end of the experiment. However, it was not possible to rule out a second possibility that the increase in complexity produced more difficulties for older adults in the ProM component of the task. Einstein et al. posited that if a certain activation threshold is required before a target event comes into awareness, then increasing the complexity of the task by adding cues reduces the activation of each single cue, resulting in lower performance. If the threshold is greater for older adults, age differences in performance would increase as the number of cues increase.

Target Distinctiveness

McDaniel and Einstein (2000) have suggested that highly distinct cues involuntarily capture attention and lead to a higher probability of intention retrieval than relatively indistinct cues. It might be expected, then, that age differences in ProM performance should be more likely when the ProM cue or target is distinct than when it is not distinct. Some evidence for this can be seen in the results reported by Einstein, McDaniel, Manzi, Cochran, and Baker (2000) who made ProM cue words distinct in their first experiment by presenting them in capital letters (the words of the on-going task were in lower-case) and less distinct in their third experiment by presenting them in lower-case letters. They did not find an age difference when the cue was distinct and participants were allowed to respond to the ProM cue immediately. Also, dividing attention under these conditions with a concurrently performed digit identification task had no effect on ProM performance. On the other hand, when the ProM cue was not distinct, dividing attention reduced ProM performance for older adults. Although a direct age comparison was not possible in that condition, given that cognitive performance is impaired more for older adults than younger adults when attention is divided (McDowd & Shaw, 2000), it seems reasonable to predict that the ProM performance of older adults would be lower than that of younger adults in situations where attention is divided and the ProM cue is not distinct.

Focalization of Processing

Age differences in ProM performance are more likely to occur when the on-going task does not focus processing on the ProM cue (e.g., responding to a syllable in a LDT rather than to a word) than when it does (e.g., responding to a particular word in a LDT). In the study by Park et al. (1997) mentioned above, a verbal working memory on-going task was used in which the visual background associated with the presentation of each word changed. The ProM component required participants to press a key when a particular background was presented. Thus, the on-going task of remembering words did not focus attention on the ProM cue. Although focalization of processing wasn't a variable of interest in their study, it is informative to note that they did report an age difference on this task whereas Einstein et al. (1995) found no age difference on their event-based task that involved an on-going task (a continuous memory span task) that focused processing on the ProM cue (the word *leopard*).

Maylor (1996) had younger and older participants perform an on-going task that required them to name famous faces. This on-going task, which required the participants to respond when a person wearing glasses was encountered, did not focus processing on the ProM component. As in the Park et al. (1997) study, focalization of processing was not a variable of interest, but younger adults did exhibit greater ProM performance on this task.

More recently Rendell, McDaniel, Forbes, and Einstein (2007) conducted a study to explicitly test the idea that age differences would be found when the on-going task does not focus processing on the ProM cue and would not be found when it did. They used methodology similar to that of Maylor (1996) which included an on-going task that required participants to name famous faces and to remember to respond when the picture of a face included some feature. In the focal condition participants responded when pictures of persons named John were presented and in the non-focal condition participants responded when pictures of people wearing eyeglasses were presented. Rendell et al. did indeed find a greater age difference when the on-going task did not focus attention on the ProM component than when it did focus attention on the ProM component.

Further support for the idea that age differences in ProM performance are largest when processing is non-focal comes from a meta-analysis conducted by Kliegel, Jager, and Phillips (2008) to test this very idea. They considered over 100 effect sizes (58 focal and 59 non-focal ProM tasks) and confirmed that age differences were indeed larger on non-focal ProM tasks, although they still found a small age difference on focal ProM tasks.

Delay

Introducing a delay between the presentation of the ProM cue and the opportunity to respond impairs ProM performance, and especially so for older adults. Einstein, McDaniel, Manzi, Cochran, and Baker (2000) demonstrated this when they investigated the effects of delay on ProM performance and found that a delay of as little as 10 seconds decreased memory performance for both older and younger adults, but more so for older adults. The effect of age in the delayed condition was especially pronounced when attention was divided. Similarly, McDaniel, Einstein, Stout, and Morgan (2003) showed that with a delay of only 5 seconds, older adults performed worse than younger adults. In a second experiment, divided attention was again shown to reduce performance in the delay condition and especially so for older adults. It was suggested that increasing age is associated with an impaired ability to maintain information in awareness.

It might be noted, as an aside, that these results are similar to findings in the working memory literature that indicate that preventing rehearsal of information results in lower performance (e.g., Myerson, Hale, Rhee, & Jenkins, 1999) for both younger and older adults. Some of Einstein et al.'s (2000) findings do support the notion that working memory is in part responsible for the age differences in delayed ProM retrieval. Specifically, they found that the age-related variance in delayed ProM performance was significantly reduced after taking working memory performance into account. However, it should be pointed out that age continued to explain a significant proportion of the variance in ProM performance in all but one condition; specifically, when the delay was 30 seconds and filled with another activity. It should also be pointed out that the Myerson et al. study failed to find evidence of age differences in the effect of preventing rehearsal. Thus, in terms of Baddeley's model, it is possible that it is age differences in the executive component of working memory, rather than a rehearsal component, that is responsible for the patterns observed in the regression analyses conducted by Einstein et al. (2000).

West's Frontal Lobe Theory of Cognitive Aging and the Role of Executive Control in Prospective Memory Performance

The frontal lobes are more susceptible to the damaging effects of age than any other areas of the brain (Moscovitch & Winocur, 1992; Raz, 2000). Furthermore, as was indicated above, ProM tasks vary in the extent to which they rely on various executive functions, depending on the nature of the on-going task and the ProM cue. The research reviewed above indicated that age differences are more likely on ProM tasks that presumably place greater demands on controlled processing (e.g., when non-focal processing of the ProM cue is required) than on tasks that rely on more automatic processing (e.g., when the ProM cue is highly salient). Thus, of the many theories of cognitive aging, those that implicate executive control are especially pertinent to the study of ProM and aging.

In his frontal lobe theory of cognitive aging, West (1996; see also, West, 2000; West, 2001) hypothesized that the pattern of spared and impaired cognitive abilities observed in older adults is a result of the pre-frontal cortex being especially susceptible to age-related deterioration. Thus, the frontal lobe theory predicts that cognitive abilities presumed to depend on frontal architecture, such as executive abilities, should show more impairment than those abilities depending on non-frontal architecture. Looked at another way, declines in frontally mediated tasks should occur before declines in non-frontally mediated tasks and declines in frontally mediated tasks should be greater in magnitude than declines in non-frontally mediated tasks.

Stemming partly from observations of the nature of age differences in ProM performance, West and his colleagues (West, 2001; West, Murphy, Armilio, Craik, & Stuss, 2002) later reasoned that age-related deficits in frontal cortex functioning result in increased fluctuations of executive control (although they have not explicitly stated the mechanism that ties the damaging effects of age on the frontal lobes to increased fluctuations of executive control). They pointed out research by Maylor (1996) who found that older adults were more likely to forget to respond (i.e., fail to respond to a ProM cue that had just previously elicited a correct response) than a younger comparison group. Forgetting to respond, West argued, suggested that the ProM intention failed to consistently guide behavior, and indicated that executive control processes failed more frequently in the older adults leading to poorer ProM performance.

They predicted that fluctuations in executive control would be reflected in intraindividual variability. Furthermore, they predicted that a consequence of age-related increases in fluctuations in executive control would be that age differences in intraindividual variability on tasks requiring more executive control would be greater than on tasks requiring less executive control. More specifically, the differences in intraindividual variability would be primarily reflected in differences in the skew of RT distributions. That is, RT distributions generated from tasks requiring a great deal of executive control would exhibit greater skew than those generated from tasks requiring less executive control. This, presumably, would be due to a greater frequency of lapses of attention (or lapses of intention as West has sometimes referred to it; see e.g., West et al., 2002) resulting in a greater number of RTs that are considerably longer than the modal RT. They further predicted that age differences in intraindividual variability would be the greatest for tasks requiring the most executive control. To test these hypotheses they compared the intraindividual variability in the RT of younger and older adults on immediate and one-back identification tasks. Consistent with their predictions, they found that, although intraindividual variability was similar for younger and older adults in the immediate identification task, the older adults showed greater performance variability than younger adults in the more executively demanding one-back identification task.

Aging and Intraindividual Variability

Historically, cognitive aging research has primarily focused on average levels of performance, largely dismissing the variability around those average levels of performance as uninteresting noise. Recently, however, there has been a growing interest in performance variability, especially in the variability of individual performance (e.g., MacDonald, Hultsch, & Dixon, 2003; Li, Huxhold, & Schmiedek, 2004; Luszcz, 2004; Martin & Hofer, 2004; Nesselroade, 2004; Nesselroade & Salthouse, 2004). Indeed, rather than being uninteresting noise, recent studies suggest that intraindividual variability is potentially a very important topic of study.

For example, intraindividual variability in RT predicts performance on non-speeded cognitive tasks. Hultsch, MacDonald, and Dixon (2002) had younger and older individuals perform four RT tasks. They used a method of calculating intraindividual variability which they claimed removed the effects of age, gender, practice, fatigue, and all interactions from the RT data. They found that older adults performed more variably than younger adults on all four RT tasks and that intraindividual variability predicted performance on working memory and episodic memory tasks for all age groups. Hultsch and his colleagues (McDonald, Hultsch, & Dixon, 2003) analyzed data collected from the same participants six years later and found that initial levels of intraindividual variability predicted the extent of decline in working memory and episodic memory performance. They also reported that intraindividual variability increased during the six-year period. In a similar vein, Rabbitt, Osman, Moore, and Stollery (2001) reported that the intraindividual variability of older adults on a variety of choice RT tasks predicted performance on the Cattell Culture Fair Intelligence Test.

Intraindividual variability also seems to be associated with neurological integrity. Strauss, MacDonald, Hunter, Moll and Hultsch (2002) reported that intraindividual variability in RT distinguished older individuals with dementia from those without dementia. Those with dementia exhibited greater intraindividual variability. Other evidence more directly suggests a relationship between intraindividual variability and the integrity of frontal architecture. Stuss and his colleagues (Stuss, Murphy, & Binns, 1999; Stuss, Murphy, Binns, & Alexander, 2003) have concluded that greater intraindividual variability on RT tasks might indicate the presence of frontal lobe lesions. This is particularly relevant to the study of cognitive aging because, as mentioned above, the finding that the frontal lobes are more prone to the damaging effects of aging than other areas of the brain has been well documented (Moscovitch & Winocour, 1992; Raz, 2000) and suggests that age-related increases in intraindividual variability in performance might be especially pronounced on tasks that rely on processes mediated by frontal cortex, such as executive control. This would be consistent with the findings of West et al. (2002) discussed above.

The existing literature regarding age differences in intraindividual variability suggests that older individuals do perform more variably than younger individuals on a variety of cognitive tasks. Indeed, current theoretical development seems to be proceeding under the assumption that older adults do perform more variably (e.g. Li et al., 1999). However, lest it seem a foregone conclusion that older adults will exhibit greater intraindividual variability in all aspects of cognitive performance, it should be noted that some findings are inconsistent with this view. For example, some studies have indicated that age differences in intraindividual variability are eliminated by controlling for age-related slowing (Myerson & Hale, 1993; Myerson, Robertson, & Hale, 2007; Robertson, Myerson, & Hale, 2006a; Robertson, Myerson, & Hale, 2006b; Shammi, Bosman, & Stuss, 1998). Also, Robertson et al. (2006a) found that older adults' non-speeded working memory performance was no more variable than that of younger adults. These reports of no age differences suggest that age differences in intraindividual variability may at least sometimes be the result of statistical artifacts (e.g., failing to adequately control for group differences in mean levels of performance), or systematic behavioral phenomena (e.g., practice and fatigue), or both. The contradictory findings in the literature might be the result of these extraneous sources of variability not being dealt with consistently from study to study.

It has been shown that mean levels of performance are confounded with the variability of performance (Hale et al., 1988). To the extent that mean levels of performance are not adequately controlled, errant or inadequately informed conclusions may be reached regarding age and performance variability. Figure 1 depicts the data from a same-different judgment task administered to older and younger adults by Robertson et al. (2006a) and illustrates the point. Older adults in this study did produce larger intraindividual standard deviations (SD's) than younger adults, but as can be seen, the function relating SD and mean RT was equivalent for both age groups. After taking this relationship into account there were no age differences in intraindividual variability. Similarly, Myerson, et al. (2007) measured the intraindividual variability of performance on a same-different judgment task using a variety of techniques and found no consistent evidence for greater variability in performance by older adults.

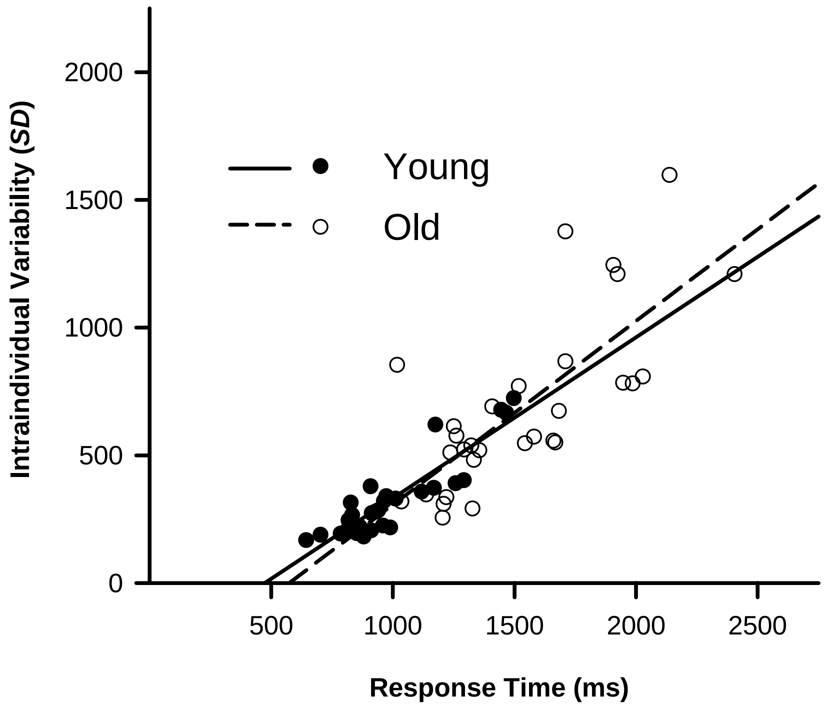

Figure 1. Relationship between intraindividual variability and response time for a same-different judgment task for young and older adults.

Another potential issue concerns the number of trials used to estimate intraindividual variability. Typically, small numbers of trials (e.g. approximately 50) are used in studies of intraindividual variability and aging. However, to accurately describe intraindividual variability in the cognitive performances of older adults, it is necessary to use a rather large number of trials (e.g., more than 300, depending on the analytic technique to be used). Older adults do not reach asymptotic levels of performance as quickly as younger adults and older adults typically benefit more from practice than younger adults. These age differences in the effects of practice and possibly fatigue mean that, if an insufficient number of trials have been administered to allow the performances of older adults to stabilize, or if statistical techniques are not employed to account for such differences, then estimates of intraindividual variability will be inflated. Beyond dealing with practice and fatigue effects, incorporating a large number of trials also affords the use of other techniques for assessing age differences in performance variability.

For example, including a large number of trials allows characteristics of the RT distributions of individuals to be analyzed graphically (e.g., quantile-quantile [Q-Q] plots) and to be fit with various distribution functions (e.g., ex-Gaussian). A characteristic of RT distributions that is relevant to the study of intraindividual variability, especially from the standpoint of fluctuations of executive control, is skew or shape. Comparing the skew of the RT distributions of older and younger individuals is one means of looking for age differences in an indicator of intraindividual variability that is not plagued by the relationship between average levels of performance and performance variability. (That is not to say that speed of performance cannot be correlated with the shapes of RT distributions; only that it need not be. In other words, slower individuals may produce distributions with greater skew than faster individuals, but the increased skew would not be caused by the slower performance. Something else would be causing both the slower performance and the increase in skew.) When the RT distributions of older individuals are skewed more than those of younger individuals, the implication is that the performances of older individuals are more variable than younger individuals than would be expected on the basis of age-related slowing. As pointed out above, it has been suggested that age differences in intraindividual variability, as indicated by more skew in the RT distributions of older adults, could be the result of decreased stability of executive control (West et al., 2002) or attentional deficits (Bunce, Warr, & Cochrane, 1993; Bunce, Barrowclough & Morris, 1996).

Inspecting Q-Q plots is one method of analyzing various characteristics of RT distributions. Q-Q plots have the advantage of being a simple and straightforward method of comparing the shapes of RT distributions, and therefore, the performance variability of younger and older individuals (Myerson, Adams, Hale, & Jenkins, 2003; Myerson et al., 2007; Ratcliff, Spieler, & McKoon, 2000). Furthermore, Q-Q plots do not assume a theoretical model as do some other potential methods (e.g., Diffusion Model; Ratcliff, 1979). Q-Q plots are constructed by plotting the RT quantiles of one group or individual (e.g., an older adult) as a function of the RT quantiles of a reference group (e.g., younger adults). A non-linear relationship between the two sets of quantiles would indicate a difference in the shapes of the two distributions being compared. Regarding age differences in intraindividual variability, if a second-order polynomial is fit to a Q-Q plot comparing an older adult's RT data with a younger adult's RT data, a positive quadratic coefficient would indicate that the distribution of the older adult's RTs is more positively skewed than that of the younger adult's (assuming the older adults quantiles are plotted on the ordinate). Myerson et al. (2007) recently put this method to use. They examined Q-Q plots comparing older adults to young adults who performed a same-different judgment task. In contrast to expectations, they found very little evidence that the older adults' distributions were more skewed than those of young adults, and if anything, the young adults' distributions were more skewed.

An additional method of describing several properties of an individuals' RT distribution is to fit statistical distribution functions to the individuals' RT data. Some of the properties that are described by the estimates of the parameters of these statistical distribution functions reflect performance variability and distribution shape, and these parameters can be compared across age groups. For instance, several researchers have examined the effects of various experimental manipulations on the parameters of the ex-Gaussian function (e.g., Hockley, 1984; Hohle, 1965; Myerson, et al. 2007; Ratcliff & Murdock, 1976; Spieler, Balota, & Faust, 1996). The ex-Gaussian function is the convolution of a Gaussian (i.e., normal) function and an exponential function. It has three parameters: *mu* is the mean of the Gaussian component, *sigma* is the SD of the Gaussian component, and *tau* is the mean and SD of the exponential component. It has been argued that the Gaussian component reflects non-decision aspects of a response and that the exponential component reflects controlled, decision related aspects of a response (Hohle, 1965; Schmiedek, Oberauer, Wilhelm, Suss, & Wittmann, 2007).

As already pointed out, some researchers have argued that the presence of a few especially long RTs in an individual's data, perhaps the result of occasional attentional lapses, failures of inhibition, or fluctuations in the efficiency of executive processing (e.g., Spieler, et al., 1996; West et al., 2002), influence the skew of RT distributions. Typically, researchers who apply the ex-Gaussian distribution interpret the *tau* parameter as a reflection of skew. Often what is found is that the *tau* parameters for older adults are larger than the *tau* parameters for younger adults (see e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Spieler et al., 1996; West, 1999; West et al., 2002). It would be tempting to suggest that such findings conclusively demonstrate greater variability in the performances of older individuals than in younger individuals. Unfortunately, some of these studies did not include sufficient numbers of trials to fit the ex-Gaussian function to the data of individuals and needed to combine the data of a few individuals (e.g., Spieler et al., 1996). Thus, although still quite informative, no firm conclusions about intraindividual variability can be made in these cases. Besides, it isn't clear that age differences in *tau* necessarily reflect age differences in the nature of cognitive processing beyond simple cognitive slowing. Simply slowing an individual's RTs by a constant, as would be the case given general slowing, would result in an increase in *tau*, while doing nothing to the skew of the distribution. A more appropriate approximation to the skew of an ex-Gaussian distribution is the ratio of the *tau* parameter to the *sigma* parameter (Heathcote, Brown, & Mewhort, 2002). The larger this ratio, the more skewed the distribution. Myerson et al. (2007) have recently reported that the older adults in their study involving a same-different judgment task actually tended to produce smaller ratios than the young adults.

Another statistical distribution function that can be used to characterize RT distributions is the three-parameter Weibull function (Weibull, 1951; Luce, 1986). It is useful descriptively because it has separate parameters (viz., *shift*, *scale*, and *shape*) that capture average performance information and performance variability information. Rouder, Sun, Speckman, Lu, and Zhou (2003) have suggested that group or condition differences in these parameters have a cognitive interpretation. The *shift* parameter is an estimate of the leading edge of the RT distribution, and differences in this parameter may reflect differences in peripheral processes. The *shape* parameter provides a quantification of the skew of the RT distribution. As the *shape* parameter approaches a value of 3.4 the Weibull is approximately normal (Logan, 1992). Lower values of the *shape* parameter would indicate more skew and therefore, greater intraindividual variability of performance. In addition to reflecting intraindividual variability, differences in this parameter reflect differences in the structure of central processes. Finally, the *scale* parameter is an estimate of the spread of the distribution. It may seem that the *scale* parameter is primarily a reflection of variability. However, differences in this parameter would reflect differences in the execution speed of central processes (at least when the *shape* parameter is equivalent across groups). The Weibull distribution has not yet been extensively applied to the study of cognitive aging. However, in at least one case (e.g., Myerson et al., 2007) younger adults actually produced distributions with smaller *shape* parameters (i.e. greater skew), on average, than older adults.

RATIONALE AND HYPOTHESES

The research reviewed above suggests that the more a ProM task relies on controlled processing the more likely it is that age differences will be found. This is consistent with West's (2001) executive control theory which proposes that selective age-related changes in frontal cortex result in decreased stability of executive control. This decreased stability of executive control in turn leads to several predictions regarding the intraindividual variability of performance on various aspects of ProM tasks. To date, these predictions have not been tested. Thus one goal of the current study was to evaluate the ability of West's theory to predict patterns of intraindividual variability of speeded cognitive performance associated with a variety of ProM conditions. An additional goal of the study was to determine whether individual differences in intraindividual variability predict ProM performance or account for age differences in ProM performance. Individual differences in cognitive processing speed (Salthouse, Berish, & Siedlecki, 2004), working memory and recognition memory (Cherry & LeCompte, 1999) and, executive function (Martin, Kliegel, & McDaniel, 2003) partly predict ProM performance; however, it is not known whether individual differences in intraindividual variability in cognitive performance predict ProM performance.

To accomplish these goals four key hypotheses that relate intraindividual variability in cognitive performance to ProM performance will be tested. Those hypotheses are as follows:

Hypothesis I: *The burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task and this increase is larger for tasks relying more on cue-focused (controlled) processes than those relying less on cue-focused processes.*

Hypothesis II: *The burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused (controlled) processes more for older adults than for younger adults.*

Hypothesis III: *Greater intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused (controlled) processes predicts worse ProM performance and accounts for age differences in ProM performance.*

Hypothesis IV: *Greater intraindividual variability in performance on a task that requires executive control predicts worse ProM performance on tasks that rely on cue-focused (controlled) processes and accounts for age differences in ProM performance.*

In order to test these hypotheses, ProM tasks were used that varied in the extent to which they required executive control. To that end, the theoretical framework put forth by McDaniel and Einstein (2000) provided an excellent guideline for developing the appropriate methodology. Recall that the multiprocess framework posits that ProM tasks engage cue-focused processes to varying degrees. These cue-focused processes rely on an executive attentional system that allows for monitoring of the ProM cue, interruption of the on-going task, and initiation of the processes required for executing the intention

(Einstein et al. 2005). In other words ProM tasks vary in the extent to which they require executive control.

Accordingly, the two experiments conducted for this study included ProM tasks that engaged executive control processes to varying degrees. A key purpose of Experiment 1 was to adjust the extent to which executive control processes are engaged by manipulating a characteristic of the on-going task (as opposed to the ProM cue). In this case, the degree to which an on-going LDT task focused attention on the ProM cue was varied. (A LDT task was used as the on-going task in both experiments because it allowed for the relative requirement for executive control to be easily manipulated while still allowing intraindividual variability and skew in speeded performance to be assessed.) Similarly, a principle purpose of Experiment 2 was to vary the degree to which executive control processes are engaged during ProM performance by manipulating a characteristic of the ProM cue (viz., the salience of the ProM target). The manipulations of Experiment 2 will lend some generality to the overall study, but more importantly, West's theory predicts that similar patterns of age differences in intraindividual variability in performance on the LDT should be observed regardless of whether the involvement of executive control processes is manipulated via the nature of the on-going task or the ProM cue. Thus, it was possible to compare the patterns of age differences found in the first experiment with those of the second experiment with the intent to explore the possibility of boundary conditions that might exist regarding the applicability of West's theory.

The LDT (whether performed alone, or with a ProM load) was also performed under conditions of full and divided attention. The purpose of this design component was to provide a means of confirming that cue-focused processes (rather than reflexive-associative) were supporting ProM performance when the LDT did not focus attention on the cue (non-focal condition) and when the ProM cue was not salient. To be more specific, when cue-focused processes are engaged, dividing attention should impair ProM performance, whereas performance should not be affected when reflexive-associative processes are sufficient (McDaniel et al., 2004).

The first two hypotheses of this study are pertinent to predicting the effects of a ProM burden on the intraindividual variability of performance on the on-going task. Regarding the key predictions being tested in this study, if *Hypothesis I* is correct, then the burden of a ProM intention should increase intraindividual variability in performance on the on-going LDT when processing is not focal (Experiment 1) or when the ProM cue is not distinct (Experiment 2), but not when processing is focal or the ProM cue is salient. If *Hypothesis II* is correct, then age differences in intraindividual variability on the on-going LDT should be greater when processing is not focal, when the ProM cue is not salient, or when attention is divided.

The last two hypotheses of this study pertain to individual differences in intraindividual variability and ProM performance. If *Hypothesis III* is correct, then age should not account for a significant portion of the variance in ProM performance after taking into account individual differences in intraindividual variability on the on-going LDT, which should predict ProM performance. In addition to the ProM load and divided attention conditions of the LDT, a two-back task, which has been hypothesized to require executive control (West et al., 2002), was administered to participants in both experiments to test *Hypothesis IV*. If *Hypothesis IV* is correct, then age should not account for a significant portion of the variance in ProM performance after taking into account individual differences in intraindividual variability in performance on the two-back task, which should predict ProM performance.

(It might seem odd to predict age differences in variability or a negative relationship between intraindividual variability and ProM performance given the lack of age differences reported in the Myerson et al. [2007] study discussed above. However, besides substantial task differences, the Myerson et al. study focused on only a few individuals, and may have lacked the power to detect small effect sizes. The current study will have the ability to detect an effect size smaller than what was possible in the Myerson et al. study. It should also point out that the absence of age difference would not preclude a relationship between intraindividual variability and ProM performance.)

In order to accurately measure intraindividual variability, participants in each experiment completed 400 trials (per condition) of the LDT, as well as, 400 trials of the two-back task. As will be seen, in most cases this number of trials allowed intraindividual variability to be assessed across a range of trials for which performance was predominantly stable (i.e., little influenced by practice or fatigue). Furthermore, an exponential decay function was fit to each participant's data to remove trends associated with practice and provide even cleaner measures of variability. The relatively large number of trials also allowed several different measures of intraindividual variability to be calculated which are sometimes missing from, or inadequately applied to other studies of variability and aging. More specifically, the ex-Gaussian function and the three-parameter Weibull function were fit to each individual's RT data. The *tau* to *sigma* ratios from the ex-Gaussian fits and the *shape* parameter estimates from the Weibull fits were taken as measures of skew (and intraindividual variability) for each individual. The validity of these measures of skew was bolstered by comparing them with the forms of individual Q-Q plots.

METHOD

The methodological protocol used in this study was approved by Washington University's Institutional Review Board and participants were treated in accordance with the ethical standards of the American Psychological Association (1992). The two experiments conducted for this study shared many procedural elements and these are described below. These general methods and procedures will be followed by those that are specific to each experiment.

Participants

Recruitment

Younger adult participants (18 to 25 years of age) were recruited through an undergraduate participant pool maintained by the psychology department at Washington University. To recruit undergraduate participants, descriptions of the proposed experiments were posted on a web page maintained by the psychology department. Older adults (over 65 years of age) were recruited from the older adult subject pool maintained by the Washington University psychology department's Aging and Development program. Potential older adult participants were contacted by phone and, after the study was described[1], asked if they would like to participate.

Screening

Each individual only participated in one of the two experiments. Upon initial contact, potential older adult participants were given a brief health pre-screen (see

[1] Participants were not exposed to any specific hypotheses or the prospective nature of the memory task prior to beginning the experiment.

Appendix A) to help ensure the absence of medical conditions known to affect cognitive performance and were excluded if they reported having certain neurological problems (e.g., stroke, Parkinson's disease), injuries (e.g., recent concussion), or depression. Young adults were given the same health pre-screen just prior to beginning the experiment. All participants later completed a health questionnaire (see Appendix B) to be used for descriptive and exploratory purposes. Near field visual acuity was tested using a Wormington Test Card (Gulden Ophthalmics, Elkins Park, PA), and participants who could not easily perceive the stimuli were excluded.

Apparatus

Testing was done in a quiet testing room. All tasks, excluding the vocabulary sub-test of the Wechsler Adult Intelligence Scale-III (WAIS-III; Psychological Corporation, 1997), were administered on a Windows based computer using E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA). Responses were made on a standard keyboard and RTs were recorded with one millisecond accuracy, with one exception. The exception is that responses to a DMT were vocal, and an experimenter recorded these responses by hand.

Tasks

Two-Back Task

For the two-back task participants were instructed to determine as quickly and as accurately as possible whether a number presented on the screen was the same as the one that was presented two trials previously. Participants pressed the "m" key to indicate that the number on the screen was the same and the 'v' key to indicate that it was different.

The sequence of events that occurred during the two-back task is depicted in Figure 2. All stimuli (viz. the digits 1 to 9) were presented in black Arial font of approximately 20 mm in height on a white screen background. The location of each number was jittered slightly to the left or to the right of the center of the monitor in an alternating manner, because pilot testing revealed that older adults were not able to achieve acceptable accuracy in a reasonable amount of time without this minimal spatial support. The commencement of the task was signaled by the word 'READY' that appeared in the center of the screen until participants pressed the spacebar. A blank white screen was presented for 750 ms before the first item was displayed. The first two items were displayed for 2000 ms each before being replaced by the third item, at which point participants were to begin responding. Participants were instructed to simply remember the first two items as a response would not be required until the third item had been presented. Once participants made a correct response the item disappeared and there was a randomly determined foreperiod duration of 500, 750, or 1000 ms before the next item was presented. On incorrect trials a brief 150 ms tone was sounded before the variable foreperiod duration began. The digits were presented in the same random order for all participants with the constraints that each digit appear an equal number of times, and that there be an equal number of same and different responses.

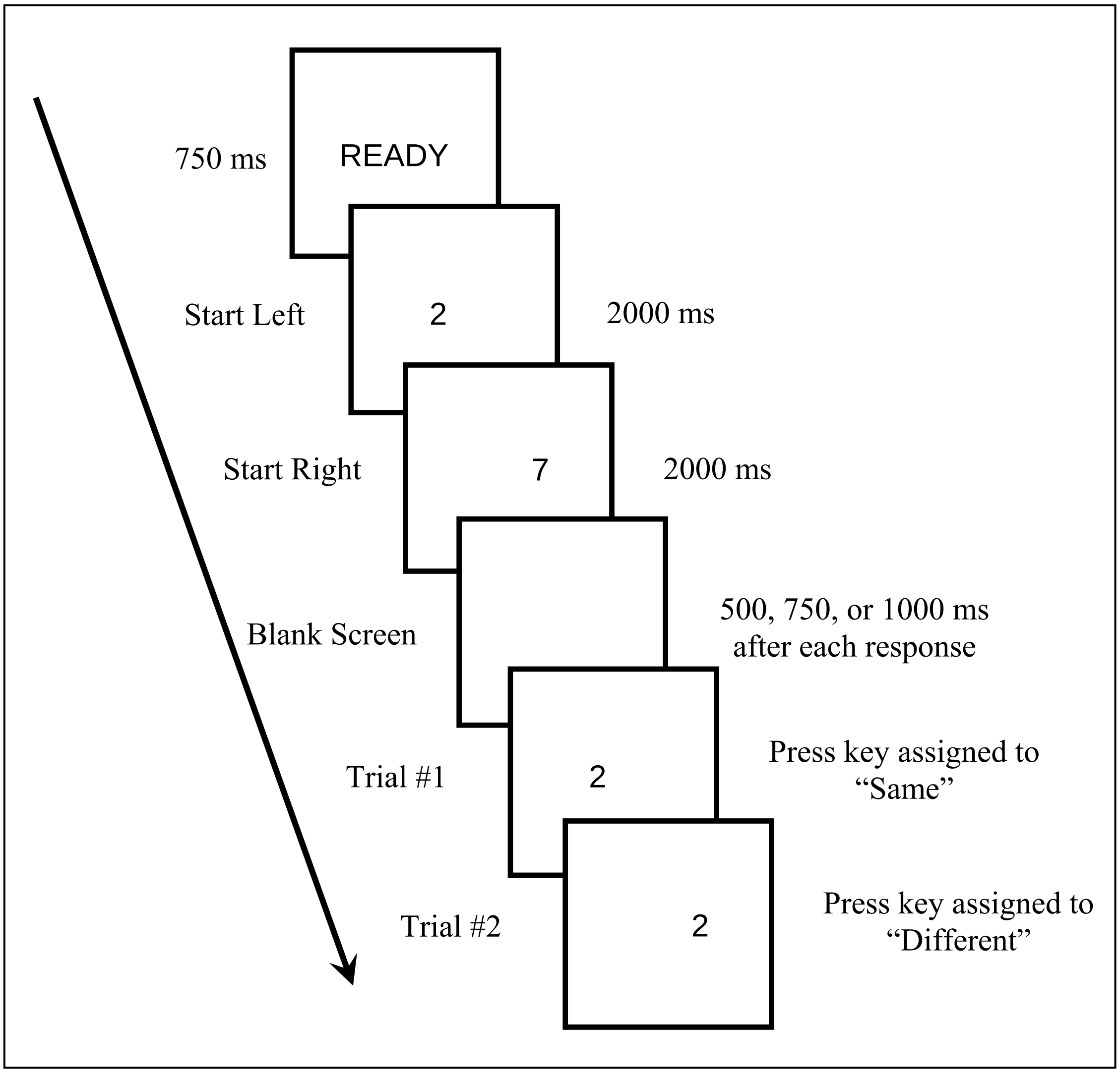

Figure 2. Representation of the sequence of events occurring during the two-back task.

Lexical Decision Task

For the LDT participants were asked to decide as quickly and accurately as possible whether a letter-string was an English word or a foil. The 'z' and '/' keys on the keyboard were used to indicate a choice. Unique sets of 50 words and 50 foils were used in each condition of an experiment, and the sets were counterbalanced across all conditions. The words were selected from a database created for the English Lexicon Project (ELP; Balota, Cortese, Hutchison, Neely, Nelson, Simpson, & Treiman, 2002). This database contains descriptive statistics on the words themselves (e.g., word length), as well as behavioral data for both speeded naming and lexical decision performance. With the exceptions noted below, the words were selected from this database in a quasi-random manner that resulted in each set being matched in terms of mean length (5.2 letters), standard deviation of length (1.1 letters), mean number of phonemes (4.3), mean log of the Hyperspace Analogue to Language (HAL) frequency (6.2), and standard deviation of log HAL frequency (0.3). The sets were also very closely matched in terms of mean accuracy (90%), mean RT (700 ms), and SD of RT (240 ms). The foils were also selected from the ELP and were created by replacing from 1 to 3 letters in real words contained in the database. Each set of foils was very closely matched to each other and to the word sets in terms of mean length, mean accuracy, mean RT, and SD of RT.

In both experiments, within each condition, one set of words and one set of foils (again, counterbalanced across conditions) was presented four times in random order. The words and foils were repeated the same number of times as the ProM targets so that the targets could not be identified on the bases of their greater frequency of occurrence alone. For each condition that included a ProM load some of the words were replaced with ProM targets according to the specific procedures described below. In these conditions, each presentation of a ProM target was separated by at least 40 trials.

The sequence of events that occurred during the standard version of the LDT (i.e., without a ProM load) are depicted in Figure 3. Regardless of condition, all stimuli were presented in black Arial font of approximately 10 mm in height against a white background and centered on the computer monitor. The commencement of the task was signaled by the word 'READY' that appeared in the center of the monitor until the participant pressed the spacebar. A blank white screen was presented for 750 ms before a red fixation cross (plus sign) was displayed. This fixation cross remained on the monitor for 300 ms and was followed by a variable foreperiod duration of 500, 750, or 1000 ms, which was in turn followed by a letter-string. The letter-string remained on the monitor until a response was made. After every response the letter-string disappeared and was replaced by a mask consisting of three rows of asterisks which remained on the screen for 700 ms before the next trial began. A brief 150 ms tone was sounded while the mask was displayed for incorrect trials. In conditions requiring ProM responses, either a word (e.g., 'z' key) or ProM (e.g., 'p' key) response was considered correct and a foil (e.g., / key) response was considered incorrect as all ProM cues involved words. No feedback was given regarding ProM errors.

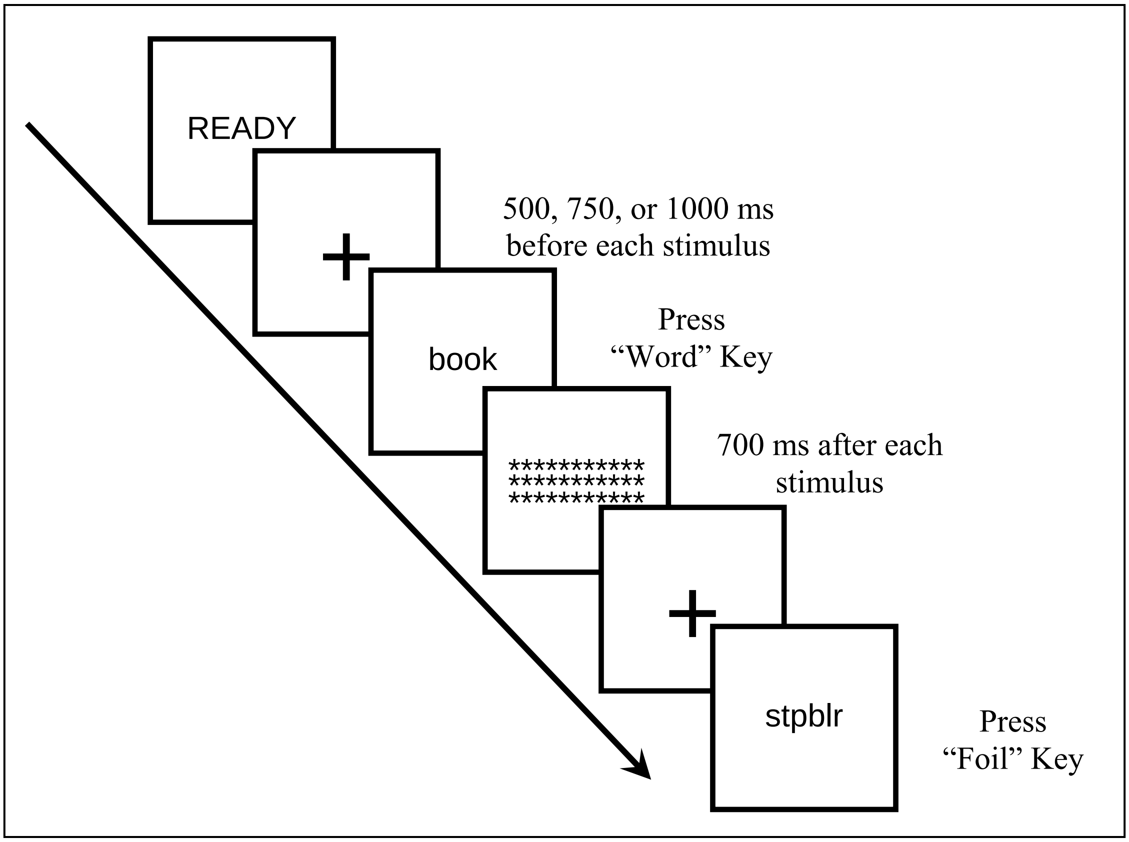

Figure 3. Representation of the sequence of events occurring during the standard conditions (no ProM load) of the lexical decision task.

Digit-Monitoring Task

For the secondary DMT participants were told that during some versions of the LDT they would hear digits from audio speakers near the computer spoken at approximately regular intervals and they were to indicate when two odd digits were repeated by saying aloud the word *repeat*. The digits were presented at the rate of one digit per trial and two consecutive odd digits were presented a total of 50 times during the LDT. (It might be noted that the rate of digit presentation varied both between subjects and within-subjects; however, this method ensured that all subjects were exposed to the same number of targets. The important point is that attention was divided between the LDT and the DMT.) The presentation of two consecutive odd digits occurred in the same random pattern for all participants with the constraint that it did not occur during the presentation of a ProM target.

General Procedure

Completion of all tasks in each experiment took approximately two hours. After providing informed consent, completing a demographic information form, health questionnaire, and visual acuity test, participants were given a brief overview of the tasks to be performed during the testing session. Participants were then given specific instructions and practice for the two-back task (10 practice trials), LDT (10 practice trials), and LDT with concurrent DMT (10 practice). If the tasks were not clearly understood during these practice trials, the practice was repeated. The tasks were clearly labeled so that participants knew what tasks they were about to perform and they were given the opportunity to review the instructions before each task if they found it necessary to do so.

From this point on in both experiments, the sequence of events differed depending on the order of task administration. All participants completed the two-back task and four conditions of the LDT. The four conditions of the LDT resulted from crossing two levels of an attention research factor (full or divided attention) with two levels of a ProM load research factor (no load or load). The order of task presentation was not completely counterbalanced because previous research on ProM using an on-going LDT (Einstein et al., 2005) has demonstrated that instructing participants to ignore ProM instructions does not remove the influence of a ProM load on RTs. Thus, a combination of orders was chosen that allowed the most relevant confounding order effects to be evaluated while still guarding some LDT conditions against the possibility of an incidental ProM burden. Table 1 provides the specific orders used. Half of the participants received the two-back task at the beginning of the experiment and half received it at the end of the experiment. The ProM conditions of the LDT always followed the non-ProM conditions and the order of presentation of the attention conditions was counterbalanced within each level of the ProM load factor (i.e., half of the participants began the non-ProM conditions with full attention and half will began with divided attention, and likewise for the ProM conditions).

Table 1

Order of Presentation for 2-back and Lexical Decision Task Conditions

	Order of Presentation				
Sequence	1st	2nd	3rd	4th	5th
1	2-Back	Standard	Div. Att.	ProM	ProM & Div. Att.
2	2-Back	Standard	Div. Att.	ProM & Div. Att.	ProM
3	2-Back	Div. Att.	Standard	ProM	ProM & Div. Att.
4	2-Back	Div. Att.	Standard	ProM & Div. Att.	ProM
5	Standard	Div. Att.	ProM	ProM & Div. Att.	2-Back
6	Standard	Div. Att.	ProM & Div. Att.	ProM	2-Back
7	Div. Att.	Standard	ProM	ProM & Div. Att.	2-Back
8	Div. Att.	Standard	ProM & Div. Att.	ProM	2-Back

Standard = LDT under full attention and without a ProM load.

Div. Att. = Divided Attention.

After receiving instructions and practice for all tasks participants performed either the two-back task or one of the non-ProM conditions of the LDT depending on the assigned sequence. Participants completed 406 trials (including 6 buffer trials) of the two-back task. When participants performed the LDT they were reminded that they would also be performing the DMT on either the first or second half of the trials. Participants completed 405 trials (including 5 buffer trials) of the LDT under full attention and 405 trials (including 5 buffer trials beginning with the onset of the DMT) under divided attention.

Next, participants were given the ProM instructions. Participants were told that an additional point of the study was to investigate memory for performing future actions. They were shown the ProM cues and then given specific instructions (see specific procedures below) on how to respond to the ProM target. To help ensure that participants remembered the ProM cues and instructions, they were asked to study the cues for 30 seconds. They were then quizzed on the cues and instructions. If they could not remember all the cues and instructions, they were asked to study them for an additional 30 seconds.

Participants were then told that before beginning the next administration of the LDT they would be given a short vocabulary test. The WAIS-III vocabulary test was administered and took approximately 15 minutes to complete. The completion time for the WAIS-III typically varies as a function of age group. Therefore, to ensure that the amount of time between learning the ProM instructions and beginning the on-going LDT task was approximately the same for both age groups, the on-going task did not begin until approximately 20 minutes after the ProM instructions were given, regardless of how much sooner the vocabulary test had been finished. After the vocabulary test, participants then completed another 405 trials of LDT task under full attention and 405 trials under divided attention.

After finishing the ProM load conditions of the LDT, participants were queried about the ProM task to ensure that they remembered the ProM targets and the required responses. If they could not freely recall all four ProM cues, they were provided with a list of 30 items (26 items were lures selected from the LDT word sets) which contained the ProM cues and were asked to identify the cues. Finally, for participants who completed the two-back task at the end of the session, they were informed that they would no longer need to remember the ProM targets. Although instructions to forget the ProM instructions are not always effective, the fact that the two-back task used numerals rather than letter-strings should have ensured that there was no incidental ProM load during this task, although the order used allowed for the assessment of this possibility.

Detailed Method: Experiment 1

Design and Participants

Forty-eight younger adults and 40 older adults participated in Experiment 1. The design for Experiment 1 was a 2 (age) X 2 (ProM target focalization) X 2 (attention) X 2 (ProM Load) mixed factorial with age and ProM cue focalization (focal, non-focal) being between-subjects factors, and attention (full, divided) and the addition of a ProM load to the on-going task being manipulated within-subjects.

Materials and Procedure

The key addition in Experiment 1 to the general procedures described above is that the focalization of the ProM cue was manipulated. Participants in the focal condition were given four ProM cues and were asked to press the 'p' key on the keyboard whenever any of these four cues were encountered. In the focal condition, each ProM cue was chosen from lists of exemplars of one of four categories: transportation (viz., *train, bicycle, moped, or boat*), tools (viz., *hammer, chisel, wrench, or pliers*), animals (viz., *zebra, camel, turtle, or lizard*), and apparel (viz., *coat, skirt, hat, or shirt*). For participants in this condition, each word chosen from these lists replaced an occurrence of four of the words in the sets constructed in the manner specified above. As previously mentioned, the words and non-words were presented four times, thus a ProM cue appeared 16 times (8 within each attention condition) and each word appeared in each attention condition an equal number of times. All participants in the non-focal condition were asked to press the 'p' key whenever they encountered words naming an object from the four categories above (viz., transportation, tools, animals, and apparel). For the non-focal condition all 16 words within the lists of exemplars only replaced one occurrence of a non-ProM cue word (8 within each attention condition and the assignment of the ProM cue words to either attention condition was counterbalanced across participants). In other words, the words in the lists of exemplars were not repeated in the non-focal condition. This arrangement ensured that participants in the non-focal condition were not able to associate the category with a particular word while at the same time keeping the number of occurrences of ProM cues the same for both the focal and non-focal conditions

(Einstein et al., 2005). It may be noted by some that the 16 ProM cue occurrences is more frequent than in some other ProM studies, but not unprecedented. For example, Einstein et al. (2000) included 16 ProM target occurrences and Kvavilashvili (1998) included 20 occurrences. Furthermore, Kelemen, Weinberg, Alford, Mulvey, and Kaeochinda (2006) have reported that the reliability of ProM tests improves as a function of the number of ProM targets. Having pointed that out, it is also important to weigh the benefit of increased reliability against the likelihood that too many targets may result in a test of vigilance. In that regard, it should be noted that the temporal spacing between ProM target occurrences is also similar to other studies (e.g., Smith, 2003). All other procedures were as stated in the general procedures. Figure 4 depicts the sequence of events that will occur during administration of the ProM conditions of the LDT in Experiment 1.

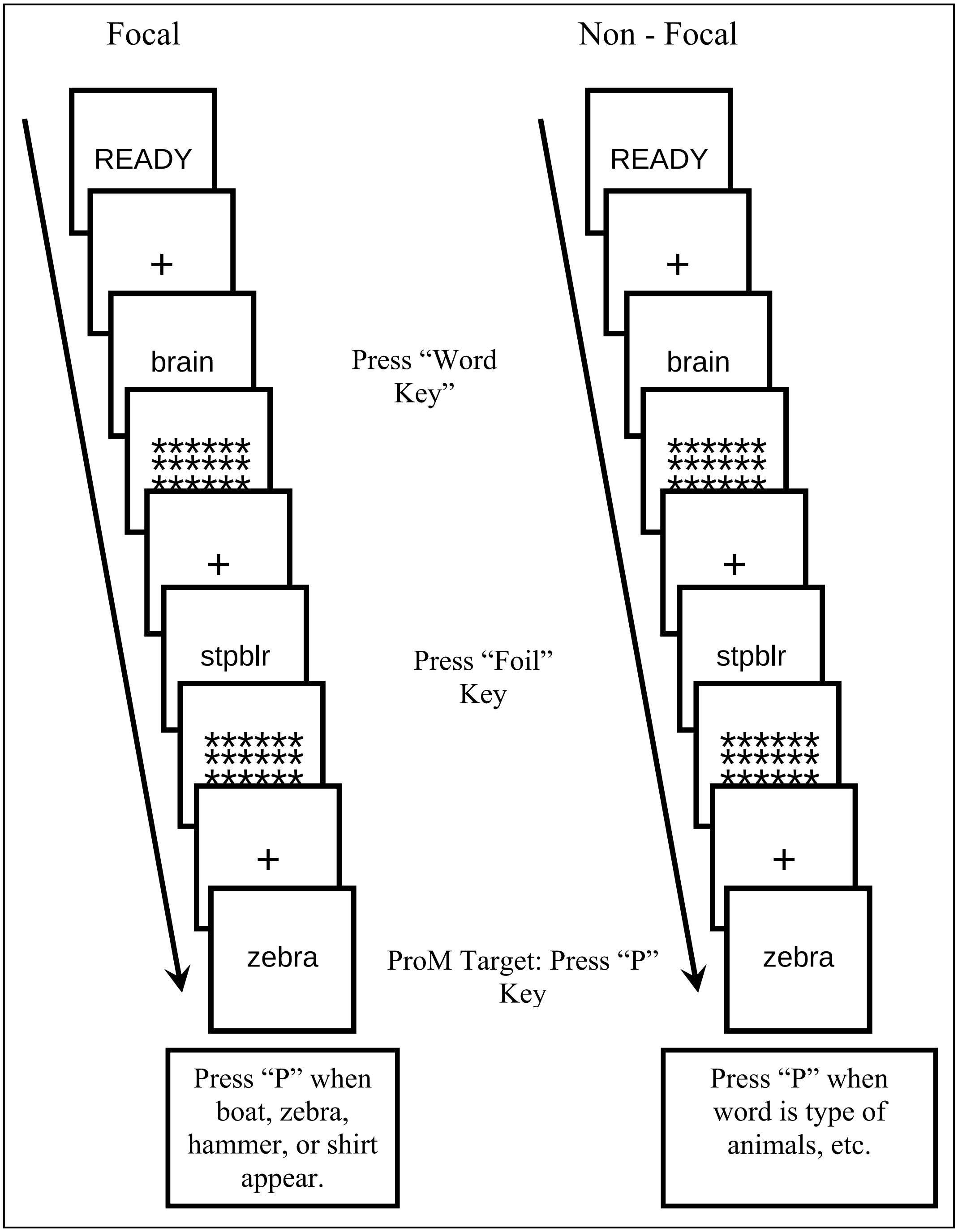

Figure 4. Representation of the sequence of events occurring during the ProM load conditions of the lexical decision task in Experiment 1.

Detailed Method: Experiment 2

Design and Participants

Forty-eight young adults and 40 older adults who meet the criteria stated in the general procedures detailed above participated in Experiment 2. The design for Experiment 2 was a 2 (age) X 2 (target salience) X 2 (attention) X 2 (ProM Load) mixed factorial. Age and target salience (low, high) were between-subjects factors, and attention (full, divided), and whether or not there was a ProM load present during the LDT were manipulated within-subjects. All participants also performed the two-back task.

Materials and Procedure

The key addition to the general procedures described above is that the salience of the ProM cue was manipulated. In the high salience condition, the ProM cue words (*bushwhack, flounce, furl*, & *tomtom*) had log HAL frequencies that were considerably lower than those of the other words in the on-going task (M = 1.39 for High Salience ProM cue words and M = 6.2 for the on-going task words). This fairly extreme difference in frequency between the ProM cue words and the on-going task words, as well as the relative unfamiliarity of the cue words (see e.g., McDaniel & Einstein, 1993) should have made the ProM cue words highly salient, much as presenting the cue words in all capital letters would. In the low salience condition, the ProM cue words (*jagged*, *nectar*, *pail*, & *tint*) had log HAL frequencies that were very similar to those of the other words in the on-going task (M = 6.2 for both Low Salience ProM cue words and the on-going task words). For each of the LDT conditions that included a ProM load, each occurrence of 4 randomly selected words was replaced with the four ProM cues. This replacement scheme resulted in each ProM cue word appearing in both attention conditions twice for each participant. Recall again that each letter-string was presented 4 times, so a ProM cue word appeared a total of 16 times (8 times in the full attention condition and 8 times in the divided attention condition). All other procedures were as stated in the general procedures.

RESULTS & DISCUSSION: EXPERIMENT 1

The analyses for Experiment 1 that test group differences (Hypotheses I & II) are reported first. More specifically, ProM performance will be examined first. Next, potential costs, in terms of RT, associated with the burden of a ProM load will be assessed. Then, analyses of RT distributions will be reported.

Analyses that assess the ability of individual differences (Hypotheses III & IV) in various aspects of on-going task performance and two-back task performance to predict ProM performance will be presented after the analyses of group differences.

Before proceeding to the ProM performance data, it is important to point out that performance on the DMT was fairly high as the grand mean proportion correct was 0.83 (*SD* = 0.11). There were no differences between age groups or between the focality conditions, nor were there any significant interactions; however, there was some evidence of a cost associated with a ProM burden. Specifically, although still fairly high, performance in the load condition (*M* = 0.81, *SD* = 0.16) was significantly lower than it was in the no-load condition (*M* = 0.85, *SD* = 0.15), $F(1, 84) = 11.07$, $p < .01$.

Prospective Memory Performance

A probability of .05 or less of making a type I error was considered acceptable for all statistical tests. Effect sizes are reported as partial η^2 values. One young adult could not remember the instruction to press the ‘p’ key upon encountering a ProM cue. Removing this individual did not affect the pattern of results in the analyses presented below. Also, three older adults (two in the focal condition and one in the non-focal condition) could only remember 3 out of the 4 ProM cues. Therefore, ProM performance was measured in terms of the conditional proportion of correct ProM responses, taking into account the total number of items remembered for each participant. This technique has been used by other researchers (see e.g. Einstein et al., 1992).

The conditional proportion correct measure was entered into a 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) mixed Analysis of Variance (ANOVA) in which age and focality were between-subjects factors and Attention was a within-subjects factor. The mean proportion correct values for each age group and condition are displayed in Figure 5. Surprisingly, there was not a main effect of age, F (1, 84) = 1.19, $p < .05$; although, the difference was in the expected direction (young: M = .42, SD = .26; old M = .36, SD = .27). There was a main effect of focality, F (1, 84) = 11.86, MSE = .141, $\eta^2 = .12$. Specifically, and as expected, ProM performance was higher in the focal condition (M = .49, SD = .33) than in the non-focal condition (M = .30, SD = .30). There was also a main effect of attention, F (1, 84) = 12.28, MSE = .049, $\eta^2 = .13$. ProM performance was higher when attention was full (M = .45, SD = .33) than when it was divided (M = .34, SD = .29). An attention X focality interaction was expected and it was significant, F (1, 84) = 4.75, MSE = .049, $\eta^2 = .05$. Follow-up analyses confirmed that this interaction was due to the fact that dividing attention did not affect performance in the focal condition ($t < 1$), whereas it lowered performance in the non-focal condition, t (43) = 4.14, $p < .001$. However, there was a significant age X focality X attention interaction, F (1, 84) = 6.21, MSE = *.141,* $\eta^2 = .07$. As can be seen in Figure 5, this 3-way interaction was due to a focality X attention interaction in the old [F

(1, 84) = 4.75, *MSE = .078,* η^2 = .14], but not in the young (*F* < 1). Dividing the attention of the older adults lowered their ProM performance in the non-focal condition, *t* (19) = 4.76, *p* < .001, but not in the focal condition.

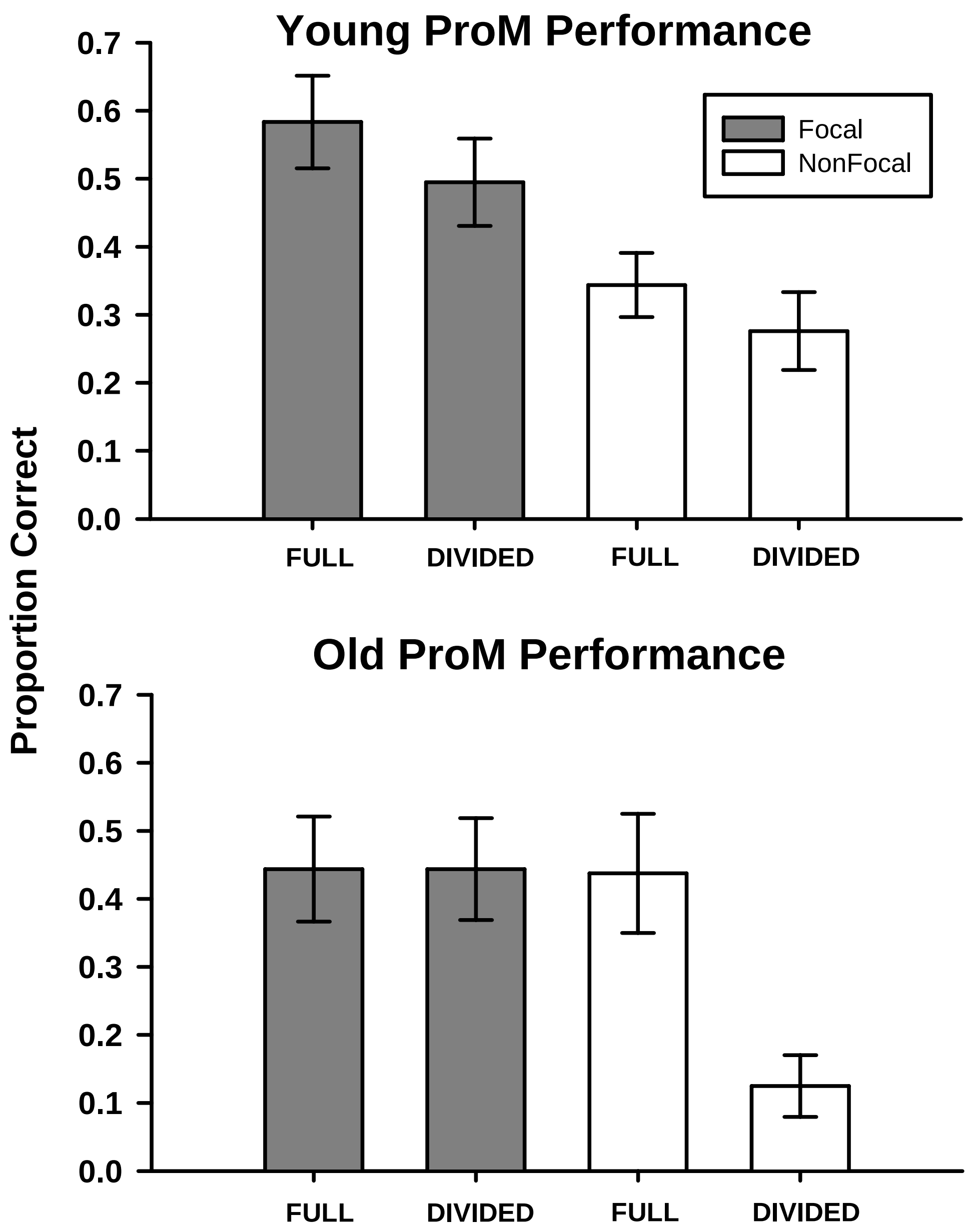

Figure 5. Mean conditional proportion of ProM targets correctly responded to by young adults (top panel) and older adults (bottom panel) as a function of Focality and Attention. Error bars are Standard Errors of the Mean.

On-Going Task Performance

Response Times associated with ProM cues and trials immediately following ProM cues were not included in the analyses that follow. This is because the RTs associated with those trials included the considerable amount of time it took to locate the correct ProM cue key (‘p’), and then relocate the key (‘m’) associated with the on-going LDT. Also, fairly lenient criteria were established to identify and remove RTs that were unreasonably fast (less than 150 ms) or slow (greater than 5,000 ms) from the data set. Similar criteria have been used by others (e.g., Heathcote, Brown, & Mewhort, 2000; Myerson, Robertson, & Hale, 2007). This should serve to ensure that task irrelevant responses (e.g. those associated with accidental button presses or pausing to ask a question) were not included in the analyses, while at the same time retaining as many task relevant responses as possible. This procedure resulted in 0.12% of trials being trimmed from the young adult data set and 0.58% from the older adult data set. Finally, only correct RTs were analyzed. Accuracy was high for both age groups ($M = .94$, $SD = .05$ young adults; $M = .97$, $SD = .03$ for older adults). Both median RTs and accuracy data for each condition and age group are presented in Table 2.

Table 2

Experiment 1: Average Median Response Time and Accuracy (Proportion Correct)

Condition	Full Attention		Divided Attention	
	Median RT	Accuracy	Median RT	Accuracy
		Lexical Decision Task		
Focal				
Young	596 (49)	.95 (.04)	872 (58)	.94 (.04)
Old	821 (132)	.97 (.05)	1115 (228)	.94 (.05)
Non-Focal				
Young	588 (57)	.94 (.06)	813 (228)	.93 (.06)
Old	780 (99)	.97 (.02)	1106 (347)	.97 (.02)
		Lexical Decision Task with ProM Burden		
Focal				
Young	656 (77)	.95 (.04)	806 (195)	.94 (.04)
Old	867 (177)	.98 (.02)	1080 (341)	.96 (.03)
Non-Focal				
Young	655 (102)	.93 (.07)	809 (272)	.92 (.06)
Old	878 (122)	.98 (.02)	1092 (379)	.97 (.02)

Note: Values in parentheses are standard deviations.

Given that the ProM load condition always followed the no-load condition, it was possible that any slowing, increase in variability, or increased skew in the ProM load condition relative to the no-load condition might have been due to simple fatigue effects, rather than the effect of a ProM burden. This possibility can be considered by viewing plots of RT as a function of trial number. Figures 6 and 7 depict such plots for both age groups and ProM conditions (i.e. load and no-load) for Full Attention and Divided Attention, respectively.

If fatigue was the primary factor behind slower performance in the ProM load condition, one would expect to find an appreciable (although perhaps nonlinear) increase in RT across trials for each condition. Instead, performance was quite stable (i.e. not showing a large positive or negative trend) for nearly all trials when under full attention. There was a noticeable positively accelerating nonlinearity in the first trials of the divided attention conditions that was more pronounced in the older adults, but performance reached asymptotic levels fairly rapidly. Thus, there was no evidence of systematic slowing associated with fatigue. Indeed, regression lines fit for each condition were all very slightly negative. The nature of the practice effects hinted at in the current data would only serve to mask the predicted differences in cost, variability, or distribution skew that may exist between the ProM conditions. (An exception would be if there was evidence for greater practice effects in the ProM load conditions than in the no load conditions, which there was not.)

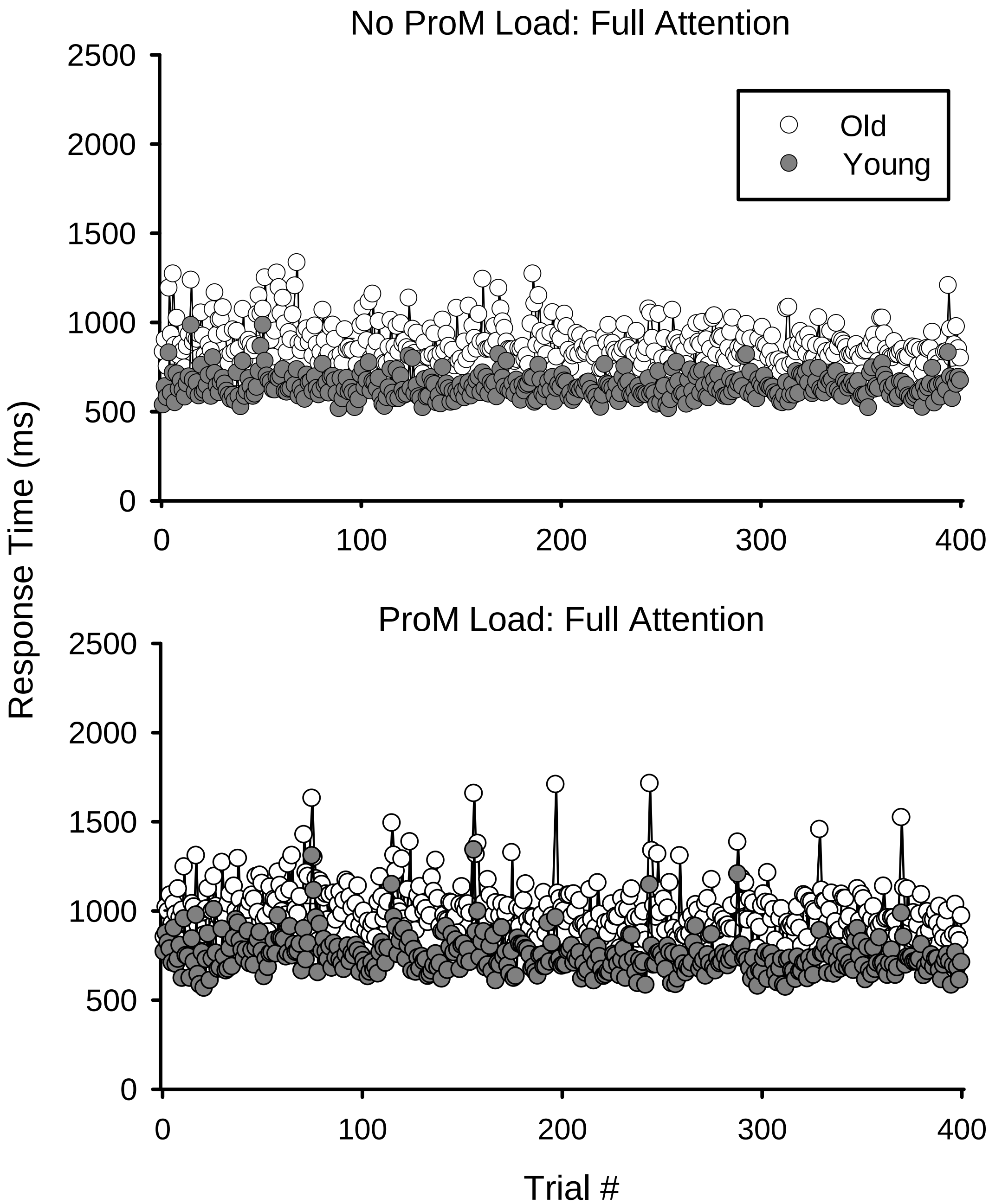

Figure 6. Response time on the lexical decision task as a function of trial number for young and older adults in the No-Load (upper panel) and Load (lower panel) conditions when attention was not divided.

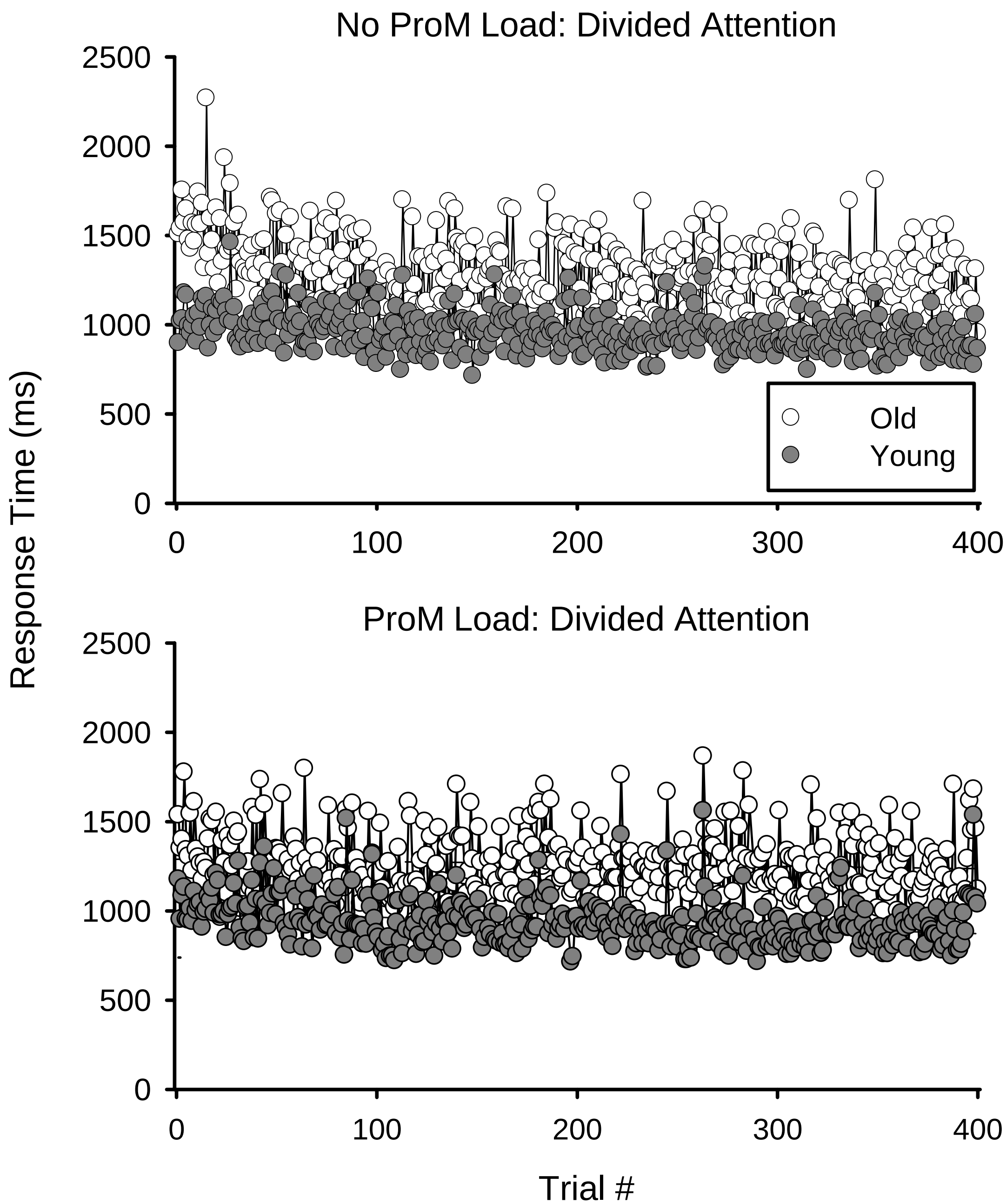

Figure 7. Response time on the lexical decision task as a function of trial number for young and older adults in the No-Load (upper panel) and Load (lower panel) conditions when attention was divided.

Cost of Prospective Memory Burden

Before proceeding with the following analyses, it should be pointed out that, because it was always necessary to present the ProM load condition after the no-load condition, the ProM factor was nested within the focality factor. Thus, the effect of focality on the LDT prior to administering the ProM instructions is irrelevant. Therefore, when interpreting analyses in which the focality factor was included, it was inappropriate to consider the main effect of focality, or any interactions involving focality that did not also include the ProM factor.

In order to obtain a more complete picture of the effect that the ProM burden had on the on-going LDT, the possibility of costs (i.e., the difference between the load and no-load conditions) associated with the burden of a ProM load was evaluated. Median RTs were entered into a 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA in which attention and ProM were within-subjects factors. Median RTs were used because they are less sensitive to outliers (Hays, 1994) and the skewed nature of RT distributions (Luce, 1986).

Older adults (M = 967, SD = 180) were slower than young adults (M = 724, SD = 180), F (1, 84) = 39.78, MSE = 129577, η^2 = .32. Performance was slower when attention was divided (M = 962, SD = 203) than when it was not (M = 730, SD = 69), F (1, 84) = 89.56, MSE = 52306, η^2 = .52. The main effect of ProM failed to reach significance; however, it was involved in an interaction with attention, F (1, 84) = 35.99, MSE = 5847, η^2 = .30. Specifically, performance was slower in the ProM load condition (M = 764, SD = 87) than in the no-load condition (M = 696, SD = 62) when attention was not divided, t (87) = 7.45, $p < .001$). In contrast, there was no significant difference between the ProM load condition (M = 946, SD = 212) and no-load condition (M = 977, SD = 211) when attention was divided, t (87) = 1.69, $p > .05$. There were no other significant main effects or interactions.

Although the omnibus test did not suggest that additional tests were needed, follow-up *t*-tests were nevertheless conducted separately for each age group and condition because of the potentially important information RT costs convey regarding the engagement of cue-focused processes. The follow-up analyses for the divided attention conditions are not reported here because there was an improvement, rather than a cost, in each case. The cost was significant in the full attention focal condition [$t(23) = 6.48$, $p < .001$] and full attention non-focal condition [$t(23) = 4.98$, $p < .001$] for young adults. The cost was significant at the trend level in the full attention focal condition [$t(19) = 1.79$, $p = .09$] and significant in the full attention non-focal condition [$t(19) = 6.48$, $p < .001$] for older adults.

Intraindividual Variability

Above, it was pointed out that the SD of RT increases as a function of mean levels of performance. Thus, if one wants to compare the intraindividual variability across groups that differ in mean levels of performance, that difference must be taken into account. The coefficient of variation (CV; an individual's SD divided by their mean) is one measure of variability that attempts to take mean levels of performance into account and has frequently been used in studies examining age differences in intraindividual variability (e.g., Hultsch et al., 2002). The CV can be thought of as a best guess at the slope of a line defined by a plot of SD as a function of the mean for an individual for a given task or condition. Of course, a line is defined by two points in space, and for the CV, one point is the individual's SD and mean, and the other is the origin. Thus, when comparing the CV of different individuals or groups, the assumption is that the line describing the relationship between SD and mean has an intercept that passes through the origin for all groups. This is clearly not the case for RT.

In the current study, this problem was solved by removing the value of the x-intercept of the line obtained by regressing SD on the mean RT from each individual's mean before calculating the CV. The parameter values for the regression equations are provided in the Table in Appendix C. This process simply shifted all of the data points to the left and forced the regression lines through the origin while preserving the slopes of the original data. Now the assumption of a common intercept through the origin is valid and the CV can be safely interpreted. Larger values reflect greater variability and lower values reflect less variability. Figure 8 depicts plots of each young and older individual's SD's in the full attention conditions as a function of their response times from which the x-intercepts have been removed. Figure 9 depicts the same, but for the divided attention conditions. It is worth pointing out that the slopes of the regression lines were nearly identical to the mean CVs provided in Table 3 for each age group and condition, recommending the validity of this method of calculating the CV. This is not the case when the typical method of calculating the CV is used. These modified CVs were entered into a 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA in which attention and ProM were within-subjects factors[2].

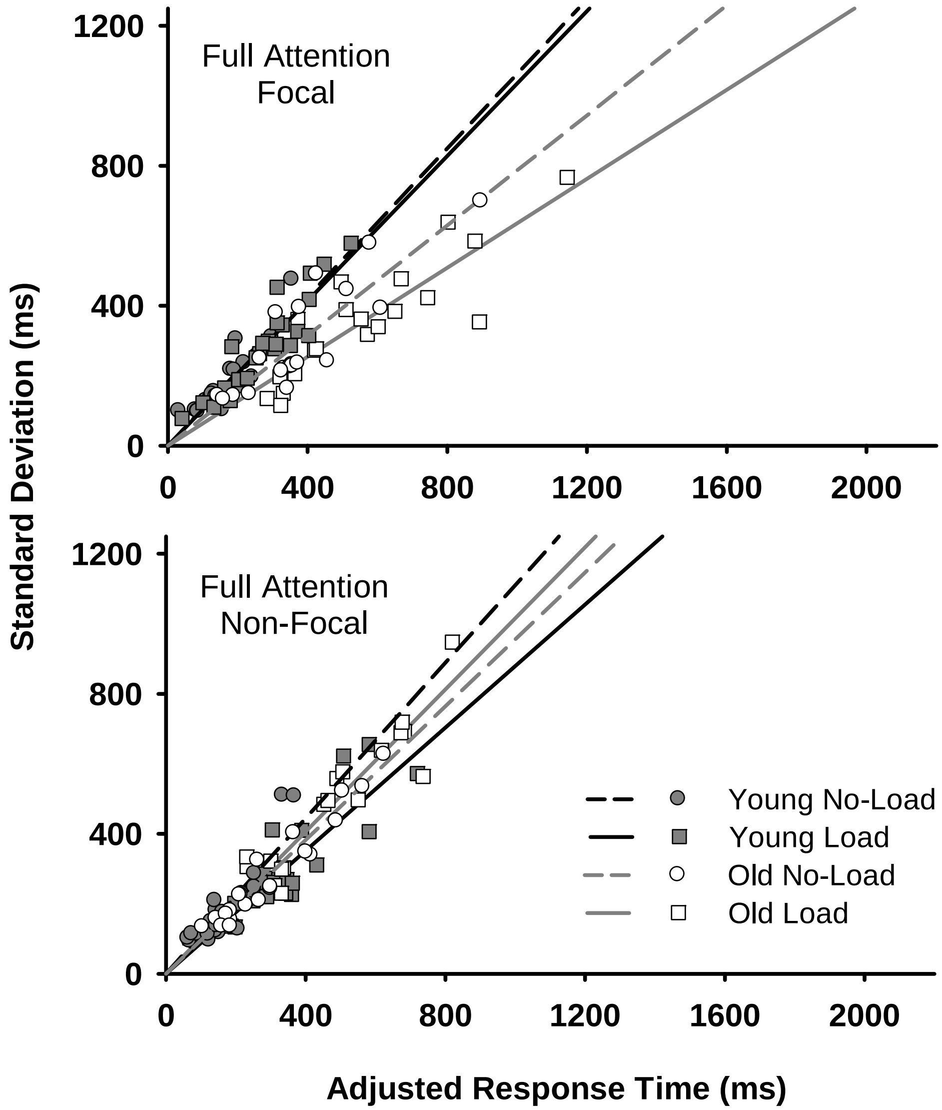

Figure 8. Individual standard deviations for young and older adults from each full attention condition plotted as a function of individual mean response time from which the x-intercept has been subtracted (see text). The lines are best-fitting regression lines. Participants in the focal condition are displayed in the top panel and participants in the non-focal condition are displayed in the bottom panel.

[2] One young participant had a mean RT in the full attention, no-load condition that was less than the estimated x-intercept, consequently producing an unreasonable negative coefficient of variation. This participant's data was not included in the analysis.

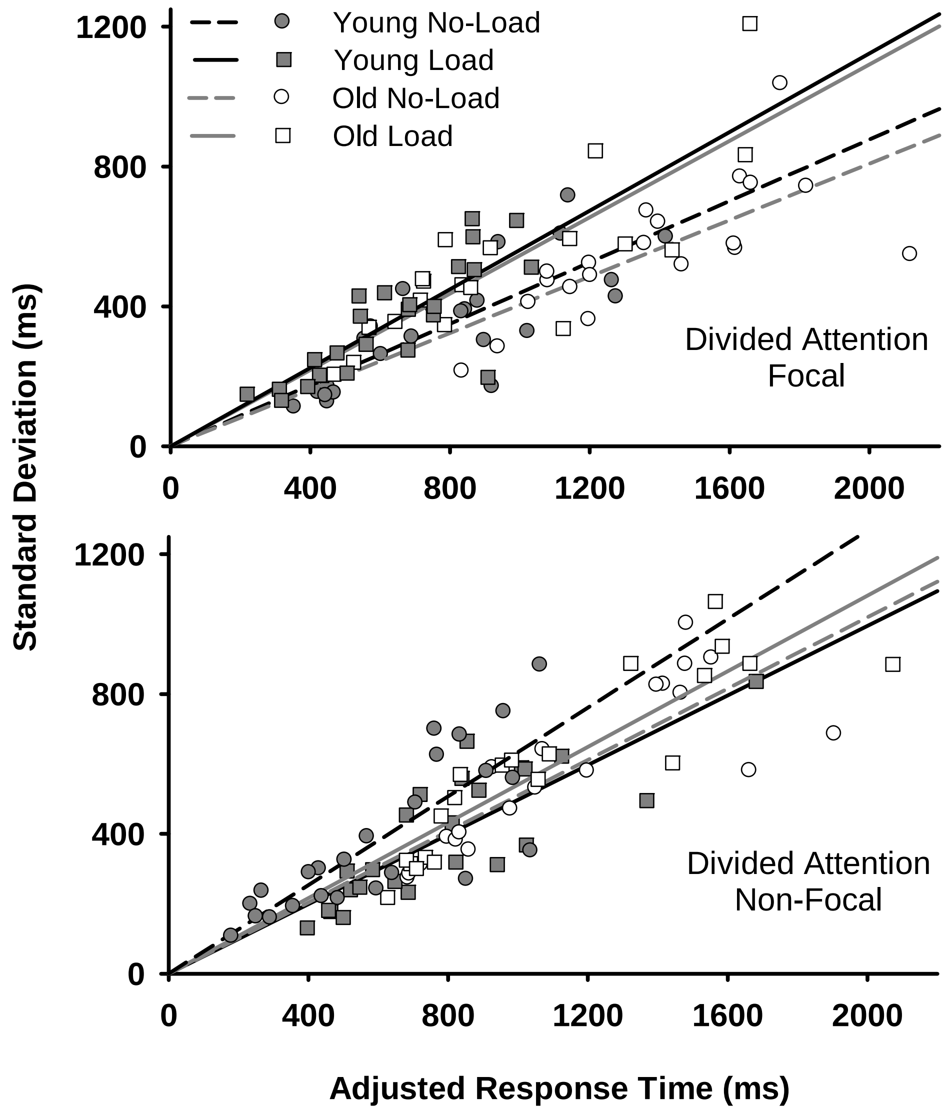

Figure 9. Individual standard deviations for young and older adults from each divided attention condition plotted as a function of individual mean response time from which the x-intercept has been subtracted (see text). The lines are best-fitting regression lines. Participants in the focal condition are displayed in the top panel and participants in the non-focal condition are displayed in the bottom panel.

Table 3

Experiment 1: Mean Coefficients of Variation

Condition	Full Attention	Divided Attention
	Lexical Decision Task	
Focal		
Young	1.14 (.50)	0.43 (.12)
Old	0.79 (.21)	0.40 (.08)
Non-Focal		
Young	1.10 (.29)	0.64 (.18)
Old	0.96 (.15)	0.50 (.09)
	Lexical Decision Task with ProM Burden	
Focal		
Young	1.08 (.27)	0.56 (.13)
Old	0.63 (.16)	0.54 (.12)
Non-Focal		
Young	0.87 (.19)	0.50 (.13)
Old	1.02 (.18)	0.53 (.10)

Note: Values in parentheses are standard deviations.

There was a main effect of age, F (1, 83) = 13.03, MSE = .087, η^2 = .14. This effect was in the opposite direction from what was expected. Young adults (M = 0.79, SD = 0.18) had larger CVs than older adults (M = 0.67, SD = 0.10). There was a main effect of attention, F (1, 83) = 273.30, MSE = .059, η^2 = .77. This was also in the opposite direction of what was expected as the full attention condition (M = 0.95, SD =

0.24) resulted in larger CVs than the divided attention condition (*M* = 0.51, *SD* = 0.11). There was a main effect of ProM [*F* (1, 83) = 5.55, *MSE* = .016, η^2 = .06] that was again in the opposite direction of what was expected. The CV was larger for the no-load condition (*M* = 0.75, *SD* = 0.19) than the load condition (*M* = 0.72, *SD* = 0.14).

There were several two-way interactions. There was a significant age X attention interaction, *F* (1, 83) = 8.95, *MSE* = .059, η^2 = .10. This was due to the fact that young adults (*M* = 1.05, *SD* = 0.30) had larger CVs than older adults (*M* = 0.85, *SD* = 0.15) in the full attention condition [*t* (85) = 3.64, $p < .01$]; whereas there was no difference between the young adults (*M* = 0.53, *SD* = 0.13) and older adults (*M* = 0.50, *SD* = 0.09) in the divided attention condition ($p > .05$). There was an age X ProM interaction, *F* (1, 83) = 12.92, *MSE* = .016, η^2 = .14. This was due to the CV being higher in the no-load condition (*M* = 0.83, *SD* = 0.23) than in the load condition (*M* = 0.75, *SD* = 0.15) for younger adults [*t* (46) = 3.84, $p < .01$]; whereas the difference between the no-load (*M* = 0.67, *SD* = 0.11) and load (*M* = 0.68, *SD* = 0.11) conditions was in the opposite direction and not significant for older adults ($p > .05$). There was a crossover interaction between the attention and ProM factors, *F* (1, 83) = 23.74, *MSE* = .019, η^2 = .22. The no-load condition (*M* = 1.00, *SD* = 0.33) had a larger CV than the load condition (*M* = 0.90, *SD* = 0.21) when attention was full [*t* (85) = 4.00, $p < .01$], but the no-load condition (*M* = 0.50, *SD* = 0.13) had a smaller CV than the load condition (*M* = 0.53, *SD* = 0.12) when attention was divided [*t* (85) = 3.61, $p < .01$]. There was a significant focality X ProM interaction, *F* (1, 83) = 9.32, *MSE* = .016, η^2 = .10. This interaction was due to the fact that the difference between the load (*M* = 0.70, *SD* = 0.21) and no-load (*M* = 0.69, *SD* =

0.28) conditions was not significant when processing was focal ($p > .05$), but the CV was actually smaller in the load condition ($M = 0.73$, $SD = 0.18$) than in the no-load condition ($M = 0.80$, $SD = 0.23$) when processing was non-focal [t (85) = 3.67, $p < .01$]. There was a three-way interaction involving the age, focality, and ProM factors, F (1, 83) = 24.10, $MSE = .016$, $\eta^2 = .23$. As can be seen in Figure 10, separate ProM (no-load, load) X focality (focal, non-focal) ANOVA's conducted for each age group revealed that the ProM x focality interaction was significant for the young adults [F (1, 45) = 25.60, $MSE = .021$, $\eta^2 = .36$], but not for the older adults ($p > .05$). Within the young adults, the ProM X focality interaction was due to the fact that the CV was actually larger in the no-load condition than in the load condition when processing was non-focal [t (46) = 6.10, $p < .01$], but there was no difference between the no-load and load conditions when processing was focal ($p > .05$).

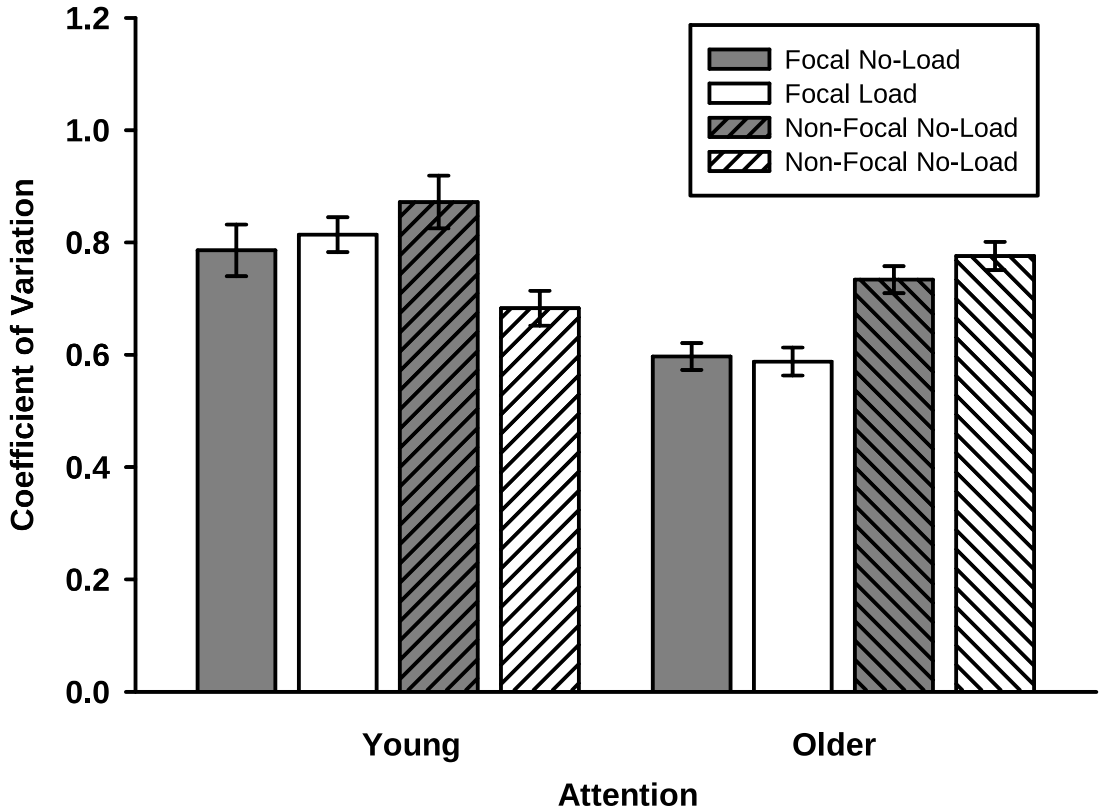

Figure 10. Mean coefficients of variation (± *SE*) for each level of focality and ProM and for each age group. Each mean is collapsed across the attention factor.

Finally, there was a three-way interaction between the attention, focality, and ProM factors, F (1, 83) = 13.73, MSE = .019, η^2 = .14. The means involved in this interaction are depicted in Figure 11. Separate ProM (no-load, load) X focality (focal, non-focal) ANOVA's were conducted for each attention condition to identify the nature of the interaction. There was a significant ProM X focality interaction when attention was divided [F (1, 83) = 81.83, MSE = .005, η^2 = .50], but not when attention was full (p

> .05). Within the divided attention condition, the nature of the ProM x focality interaction was due to the CV being significantly higher in the load than in the no-load condition when processing was focal [t (43) = 10.90, $p < .01$], but the CV was slightly lower in the load than in the no-load condition when processing was non-focal [t (42) = 2.89, $p < .01$].

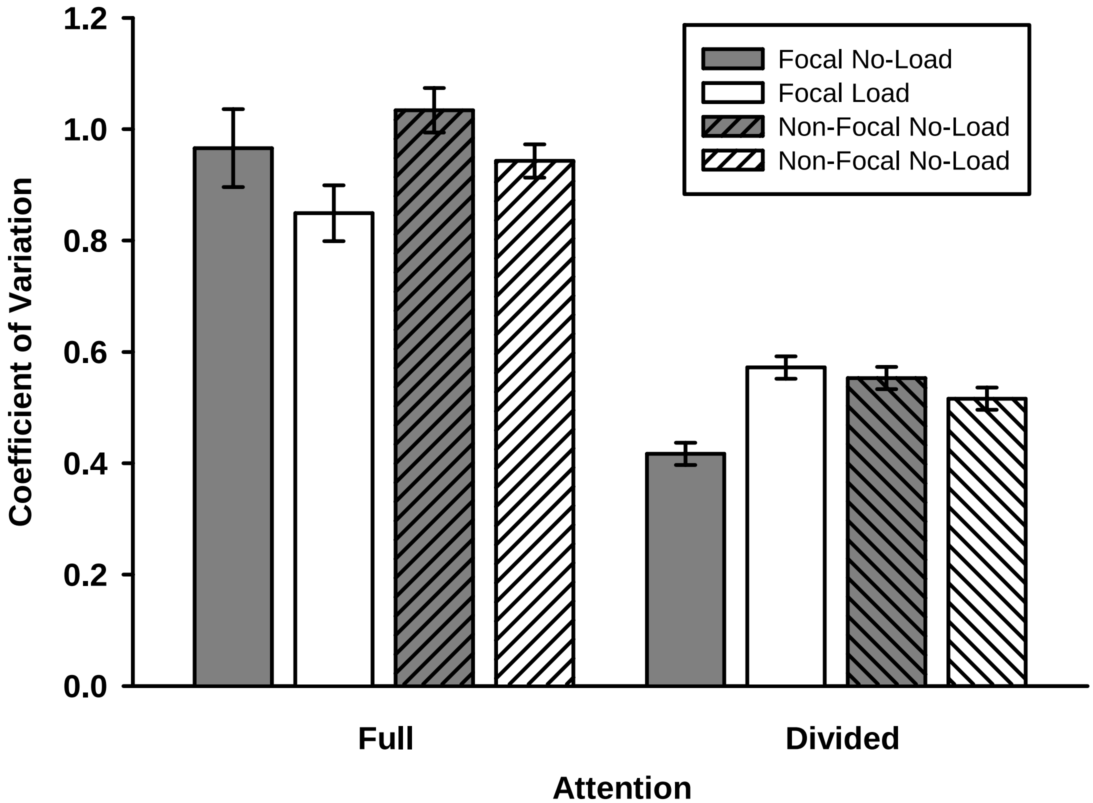

Figure 11. Mean coefficients of variation (± *SE*) for each level of attention, focality, and ProM. Each mean is collapsed across age.

Analyses of Response Time Distributions

Nonlinearities such as those observed in Figure 7 were removed from each individual's data before constructing Q-Q plots, or fitting the Weibull and ex-Gaussian functions for the analyses below. Typically, researchers have applied power functions to learning curves similar to those observed in the present data. However, Heathcote et al. (2000) have demonstrated that power functions only apply to aggregated data and not to data plotted as a function of individual trials. Instead, exponential decay functions better characterize learning and practice curves plotted as a function of trial. Therefore, an exponential decay function of the form $RT = a + b * e^{-c*trial\#}$ was applied to each individual's data separately for each condition. The mean of the original data was then added to the resulting residuals. This method allowed for the estimation of variability and skew parameters that are free of any trends associated with learning or practice that could artificially increase variability and/or skew. Unfortunately, when fitting this de-trended data, neither the estimated *mu* parameter of the ex-Gaussian function, nor the estimated *shift* parameter of the Weibull function, take into account any nonlinearity that may have been removed. Instead, they very closely approximate those parameter values of the original RT distribution and this should be kept in mind when interpreting the results below.

Quantile-Quantile plots. The potential influence of age, ProM, and focality on the shapes of RT distributions was first examined qualitatively by inspecting the Q-Q plots displayed in Figures 12 through 15. The parameters from the best fitting quadratic equations for each plot are provided in Table 4. As mentioned above, Q-Q plots are constructed by plotting the quantiles of one distribution against the quantiles of a reference distribution. In this case the mean quantiles (5th to 95th percentiles) of one set of distributions were plotted as a function of the mean quantiles of another set of distributions. The resulting Vincentized (after Vincent, 1912) distributions have approximately the same mean, variance, and shape as the average mean, variance, and shape of the individual distributions comprising the set (Myerson et al., 2007; Ratcliff, 1979).

Table 4

Parameter Values for Second-Order Polynomial Regression Equations Fit to Q - Q Plots

	Full Attention			Divided Attention		
Comparison	B_0	BX	BX^2 e-4	B_0	BX	BX^2 e-4
Old v. Young (Focal)	-94.96	1.61	-2.06	-324.34	1.94	-2.34
Old v. Young (Non-Focal)	124.79	0.88	4.45	-318.47	1.84	-0.86
			Focal LDT vs. LDT			
Young Adults	206.23	0.25	8.62	122.92	0.72	0.93
Older Adults	-115.24	1.29	-0.72	104.54	0.87	-0.07
			Non-Focal LDT vs. LDT			
Young Adults	49.60	0.62	6.91	106.61	0.72	1.25
Older Adults	0.02	0.78	4.19	101.01	0.81	0.79
			Non-Focal LDT vs. LDT			
Young Adults	-135.76	1.28	-1.15	-23.74	1.02	0.30
Older Adults	126.84	0.52	4.03	6.07	0.90	1.19

There are several patterns that can be observed in Q-Q plots that indicate the relative variability and shape of the distributions being compared (Myerson et al., 2007). First, if there is no difference between the distributions, then the data will fall along a diagonal line with a slope of one and an intercept of zero. Second, if one distribution is slowed relative to the other by a constant amount, then the data will fall along a line with a slope of one and either a positive or negative intercept. Third, if the data fall along a straight line with a slope different from one, then one distribution is magnified relative to the other (e.g. as would be expected in the case of age-related general slowing), although the shapes of the distributions would be the same. Fourth, if one distribution is more skewed than the other, then the data will fall along a curve rather than a straight line. A positively accelerating curve indicates that the distribution represented on the ordinate is more skewed, whereas a negatively accelerating curve indicates that the distribution represented on the abscissa is more skewed. Finally, it is also informative to note that increasing distance between data points as a function of quantile is indicative of the fact that at least one of the distributions is positively skewed. These outcomes are not mutually exclusive, and combinations are possible.

Figure 12 allows one to consider whether the burden of a ProM load increased skew when the ProM task involved focal cues. The top panel compares the RT distributions from the full attention focal ProM load condition with that from the full attention LDT for both young and older adults. The quadratic components for both age groups were very nearly zero, suggesting that the burden of a ProM load did not appreciably increase the skew of the RT distribution in this condition. The bottom panel of Figure 12 compares distributions from the divided attention ProM load condition with that from the divided attention LDT, again for both age groups. Once again, the plots suggest that the distributions had similar shapes.

Figure 13 allows one to consider whether the burden of a ProM load increased skew when the ProM task involved non-focal cues. The top panel of Figure 13 compares the RT distributions from the full attention non-focal ProM load condition with that from the full attention LDT for both age groups. There was very little nonlinearity; although, if anything, there was a tendency for the ProM load distribution to be slightly more skewed than the LDT distribution. The fact that performance was slower in ProM load conditions is evidenced by the slope being larger than one. The bottom panel of Figure 13 makes the same comparison as that in the top panel, but for divided attention. There is no clear evidence that one distribution was more skewed than the other.

Figure 14 allows one to consider whether RT distributions associated with non-focal ProM cues were more skewed than those associated with focal ProM cues. The top panel compares these two distributions for the full attention condition. The shapes of the distributions for young adults did not differ much, but the older adult data exhibited a tendency for the non-focal distributions to be slightly more skewed than the focal distributions. The bottom panel compares the focality conditions for divided attention. Again the young adult distributions did not seem to differ much. The quadratic parameter for the older adults was very nearly zero, but the slope being greater than one indicates that non-focal performance was slightly slower than focal performance.

Finally, Figure 15 allows one to ask whether the distributions of the older adults were significantly more skewed than those of young adults, separately for each condition involving a ProM burden. The top panel depicts the full attention conditions and the bottom panel shows the divided attention conditions. Older adults were clearly slower, as indicated by the larger than unity slopes, but the only case in which the quadratic component was positive was when the ProM cue was non-focal in the full attention condition.

Although inspecting these Q-Q plots is informative and, on the whole, do not suggest large differences in shape due to age, ProM burden, or focality, it is possible that the size of any differences are small enough to preclude unambiguous detection using such a gross level qualitative technique. The analyses of the ex-Gaussian and Weibull parameters below offer a quantitative approach.

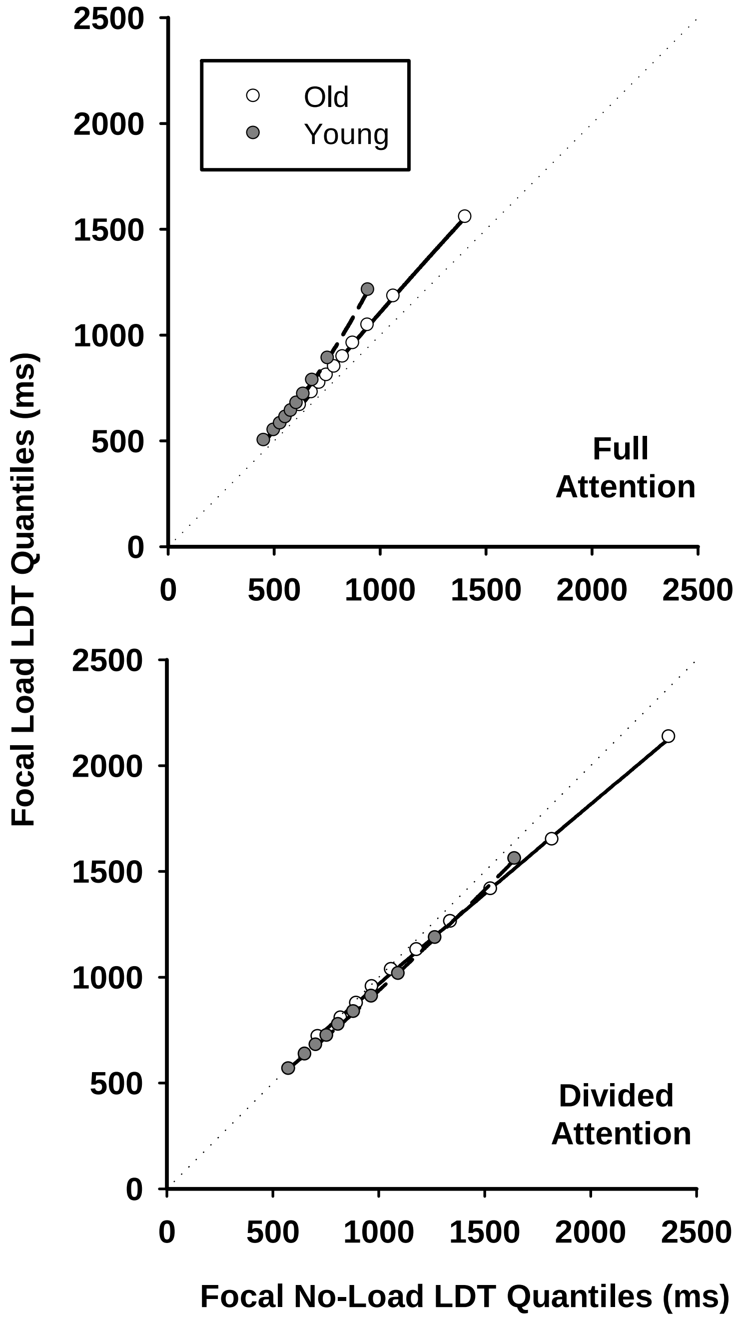

Figure 12. Average ProM load lexical decision task (LDT) quantiles plotted as a function of average no-load LDT quantiles for young and older participants in the focal condition. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

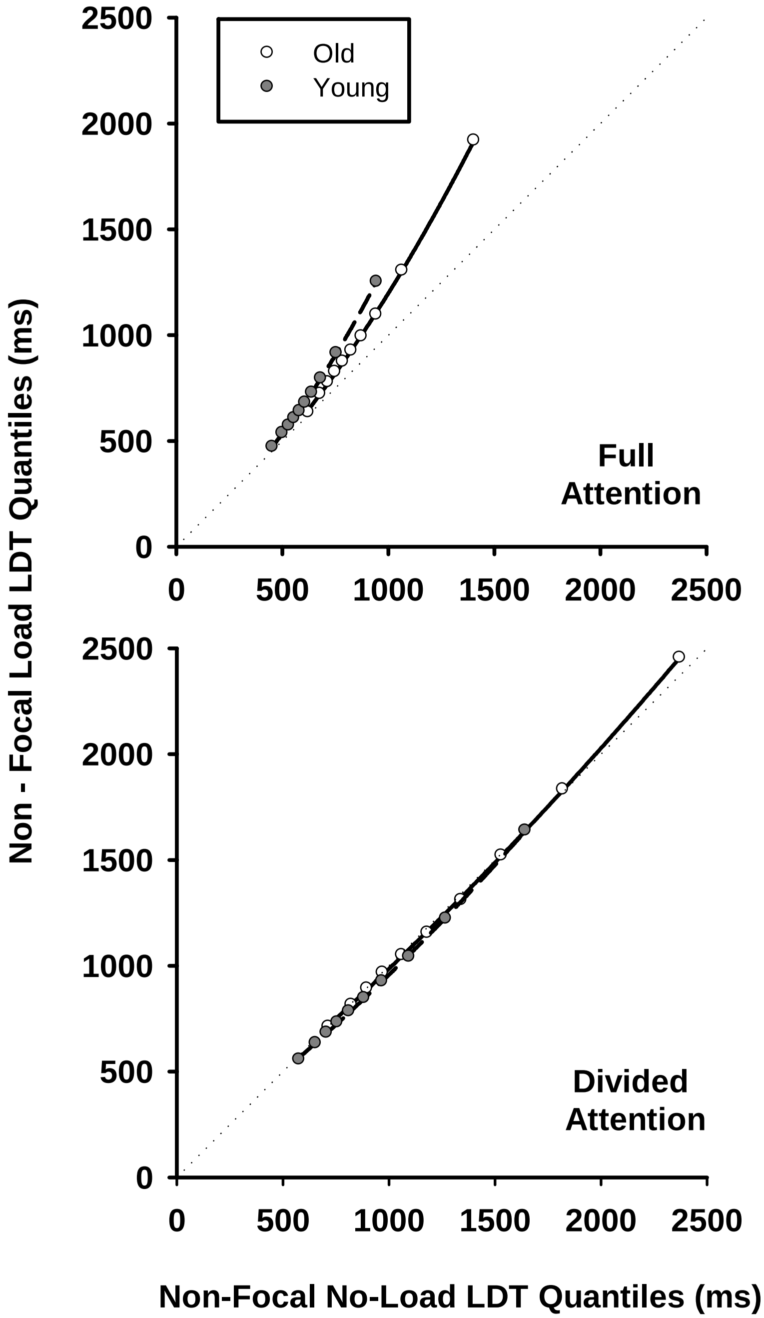

Figure 13. Average ProM load lexical decision task (LDT) quantiles plotted as a function of average no-load LDT quantiles for young and older participants in the non-focal condition. Data points represent the average 5^{th}, 15, …95^{th} percentiles. Dotted diagonal line is an equality line.

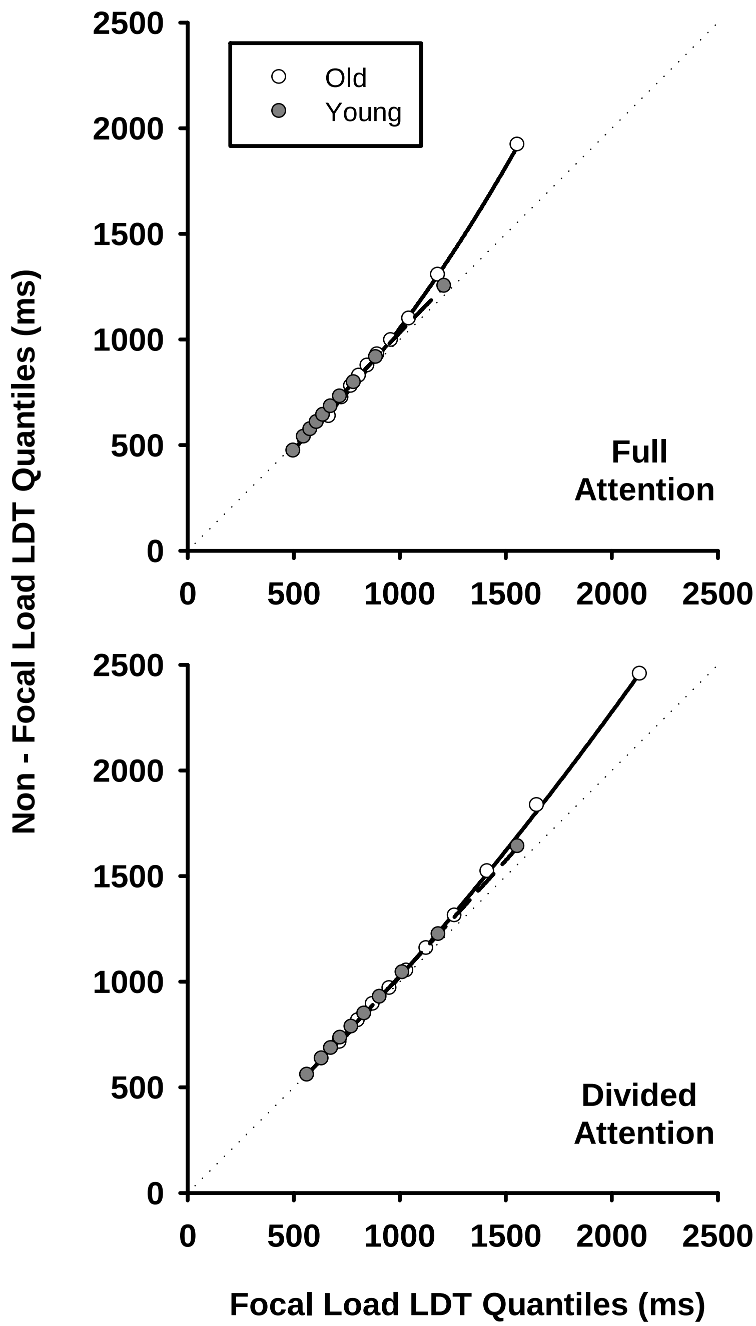

Figure 14. Average ProM load lexical decision task (LDT) quantiles for young and older participants in the non-focal condition plotted as a function of average load LDT quantiles for young and older participants in the focal condition. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

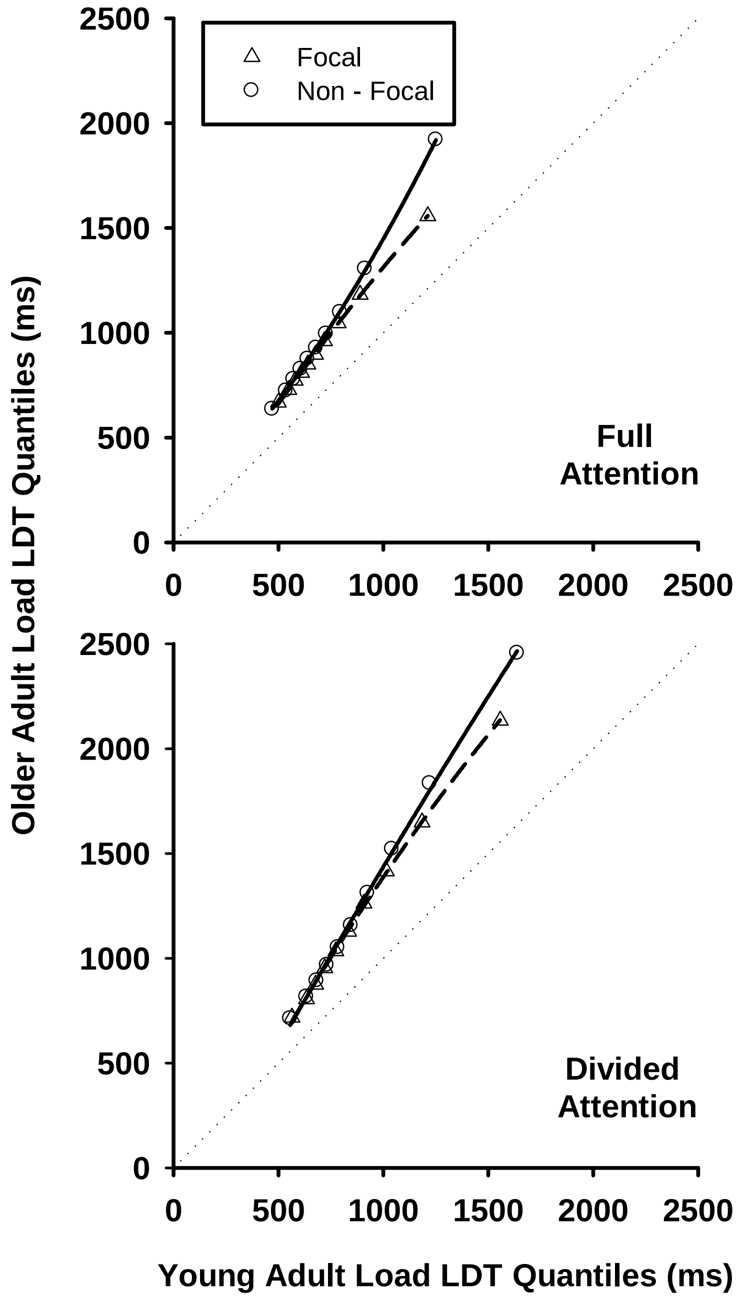

Figure 15. Average older adult ProM load lexical decision task (LDT) quantiles for the focal and non-focal conditions plotted as a function of average young adults load LDT quantiles for the focal and non-focal conditions. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

Ex-Gaussian parameters. The mean ex-Gaussian parameter values for the full attention conditions are provided in Table 5 and the parameter values for the divided attention conditions are provided in Table 6. For illustrative purposes, the figures in Appendix D display the histograms and best fitting ex-Gaussian functions for participants whose *mu*, *sigma*, *tau*, or *tau/sigma* values were near the median for their respective age group and for a given condition. Recall that the *mu* parameter represents the mean of the Gaussian component of an ex-Gaussian distribution. The *sigma* parameter reflects the SD of the Gaussian component. The *tau* parameter reflects the length of the right hand tail of the ex-Gaussian distribution and possibly the controlled, decision related aspect of responses. The mean of an ex-Gaussian distribution is equal to the sum of *mu* and *tau*. Each of the parameters were entered into 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA's in which attention and ProM were within-subjects factors.

Table 5

Mean ex-Gaussian Parameter Values for Full Attention Conditions

	mu	*sigma*	*tau*	*tau/sigma*
		Lexical Decision Task		
Focal				
Young	496 (29)	55 (11)	140 (59)	2.62 (1.15)
Old	661 (74)	62 (15)	239 (133)	3.98 (2.70)
Non-Focal				
Young	488 (33)	56 (21)	144 (78)	2.84 (1.93)
Old	635 (45)	59 (17)	225 (118)	3.88 (1.96)
		Lexical Decision Task with ProM Burden		
Focal				
Young	519 (40)	50 (15)	212 (97)	4.39 (1.93)
Old	690 (114)	62 (25)	272 (157)	4.53 (2.21)
Non-Focal				
Young	505 (56)	64 (38)	228 (106)	3.95 (1.72)
Old	671 (63)	88 (58)	426 (207)	4.63 (2.41)

Note: Values in parentheses are standard deviations.

Table 6

Mean ex-Gaussian Parameter Values for Divided Attention Conditions

	mu	*sigma*	*tau*	*tau/sigma*
		Lexical Decision Task		
Focal				
Young	654 (209)	97 (65)	309 (171)	3.86 (2.52)
Old	788 (247)	148 (120)	489 (196)	5.33 (4.08)
Non-Focal				
Young	585 (159)	75 (40)	347 (220)	5.65 (4.41)
Old	762 (244)	131 (113)	531 (221)	6.25 (4.22)
		Lexical Decision Task with ProM Burden		
Focal				
Young	591 (124)	67 (30)	308 (165)	5.30 (3.96)
Old	783 (225)	139 (155)	426 (207)	5.10 (3.05)
Non-Focal				
Young	589 (161)	84 (48)	330 (183)	4.27 (2.30)
Old	743 (199)	104 (101)	535 (262)	8.94 (11.56)

Note: Values in parentheses are standard deviations.

Older adults had larger *mu* parameters (M = 717, SD = 131) than young adults (M = 553, SD = 88), F (1, 84) = 48.64, MSE = 47947, η^2 = .37. The divided attention condition resulted in larger parameter values (M = 687, SD = 186) than the full attention condition (M = 583, SD = 54), F (1, 84) = 35.08, MSE = 26852, η^2 = .30. There was no effect of ProM; however, there was an attention X ProM interaction, F (1, 84) = 12.12, MSE =3962, η^2 = .13. This interaction was due to the ProM load condition resulting in a larger parameter value (M = 596, SD = 47) than the no-load condition (M = 570, SD = 72) when attention was not divided [t (87) = 4.36, p <.001], but no difference between the load (M = 677, SD = 179) and no-load conditions (M = 697, SD = 216) when attention was divided [t (87) = 1.50, p > .05]. No other main effects or interactions involving the *mu* parameter reached significance.

With respect to the *sigma* parameter, older adults (M = 99, SD = 60) produced larger parameter values than young adults (M = 68, SD = 25), F (1, 84) = 10.44, MSE = 7785, η^2 = .11. The divided attention condition resulted in larger parameter values (M = 106, SD = 80) than the full attention condition (M = 62, SD = 23), F (1, 84) = 28.84, MSE = 5830, η^2 = .26. The main effects of age and attention were qualified by an age X attention interaction, F (1, 84) = 5.34, MSE = 5830, η^2 = .06. This interaction was due to the fact that the parameter values for older adults (M = 68, SD = 26) and young (M = 56, SD = 19) adults did not differ significantly when attention was full [t (86) = 2.40, p > .05], whereas older adults (M = 130, SD = 110) produced larger parameter values than young adults (M = 81, SD = 40) when attention was divided [t (86) = 2.68, p < .05]. There was not a main effect of ProM; however, there was an attention X ProM interaction, *F* (1, 84) = 4.63, *MSE* =2370, η^2 = .05. This interaction was due to the fact that the ProM load condition (*M* = 65, *SD* = 39) resulted in larger values of *sigma* than the no-load condition (*M* = 58, *SD* = 17) when attention was full, *t* (87) = 1.9, *p* = .06; but when attention was divided, the ProM load condition (*M* = 96, *SD* = 91) resulted in a non-significantly smaller parameter value than the no-load condition (*M* = 110, *SD* = 95), *t* (87) = 1.51, *p* > .05. No other main effects or interactions involving the *sigma* parameter reached significance.

Regarding the *tau* parameter, older adults (*M* = 384, *SD* = 165) produced larger parameter values than young adults (*M* = 252, *SD* = 123), *F* (1, 84) = 18.26, *MSE* = 82793, η^2 = .18. The divided attention condition resulted in larger parameter values (*M* = 409, *SD* = 195) than the full attention condition (*M* = 227, *SD* = 111), *F* (1, 84) = 167.04, *MSE* = 17454, η^2 = .67. The main effects of age and attention were qualified by an age X attention interaction, *F* (1, 84) = 8.14, *MSE* = 17454, η^2 = .09. The nature of this interaction was that, although older adults (*M* = 272, *SD* = 138) produced larger parameter values than young adults (*M* = 181, *SD* = 81) in the full attention condition [*t* (86) = 3.67, *p* < .05], there was an even larger difference between older adults (*M* = 495, *SD* = 211) and young adults (*M* = 323, *SD* = 179) in the divided attention condition [*t* (86) = 4.06, *p* < .05]. The value of the *tau* parameter was larger when there was a ProM burden (*M* = 333, *SD* = 161) than when there was not (*M* = 303, *SD* = 138), *F* (1, 84) = 13.23, *MSE* = 5941, η^2 = .14. The main effect of ProM was qualified by interactions with both the attention factor [*F* (1, 84) = 46.42, *MSE* = 4571, η^2 = .36] and the focality factor [*F* (1, 84) = 5.62, *MSE* = 5941, η^2 = .06]. The ProM X attention interaction was due to their being a larger parameter value for the load (*M* = 262, *SD* = 143) than the no-load condition (*M* = 183, *SD* = 107) when attention was full [t (87) = 8.53, p <.001], but no difference between the load (*M* = 392, *SD* = 220) and no-load conditions (*M* = 411, *SD* = 220) when attention was divided, t (87) = 1.44, $p > .05$. The ProM X focality interaction was due to the fact that the ProM load condition (*M* = 361, *SD* = 244) produced larger parameter values than the no-load condition (*M* = 312, *SD* = 212) when processing was non-focal [t (86) = 3.61, $p < .01$], whereas there was not a significant difference between the ProM load (*M* = 304, *SD* = 209) and no-load (*M* = 294, *SD* = 175) conditions when processing was focal ($t < 1$). Finally, there was a three-way interaction between age, ProM, and focality, F (1, 84) = 6.30, *MSE* = 5941, $\eta^2 = .07$. As can be seen in Figure 16, separate ProM (no-load, load) X focality (focal, non-focal) mixed ANOVA's conducted for each age group confirmed that this interaction was due to the fact that there was not a two-way interaction between ProM and focality for the young adults ($F < 1$), but there was for the older adults, F (1, 38) = 7.53, *MSE* = 6528, $\eta^2 = .12$. The nature of the interaction within the older adults was that there was not a significant difference between the ProM load and no-load conditions when processing was focal [t (19) = 1.03, $p > .05$], but there was when processing was non-focal [t (19) = 2.57, $p < .05$]. No other main effects or interactions involving the *tau* parameter reached significance.

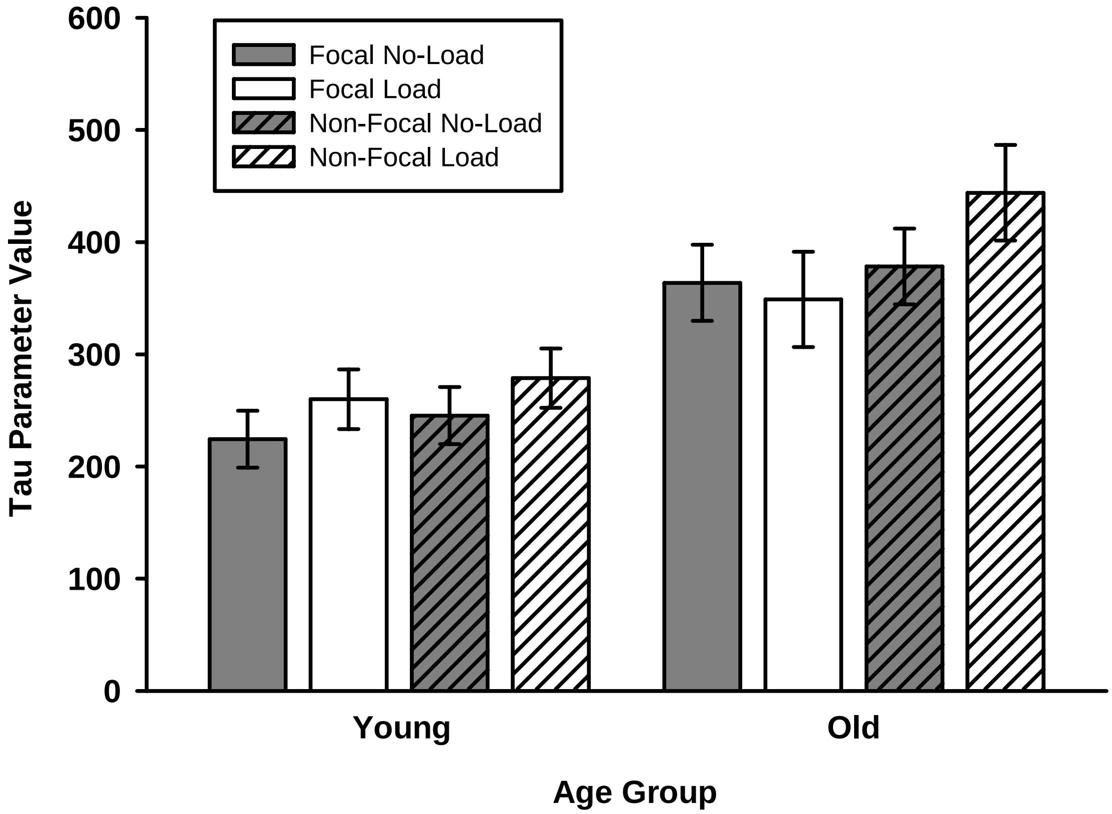

Figure 16. Mean *tau* parameter values (± *SE*) for each level of age, focality, and ProM. Each mean is collapsed across the attention factor.

With respect to skew, as indexed by the *tau/sigma* ratio, older adults (M = 5.33, SD = 2.97) produced larger ratios than young adults (M = 4.11, SD = 1.94), F (1, 84) = 5.37, MSE =24, η^2 = .06. The divided attention condition resulted in larger ratios (M = 6.90, SD = 4.01) than the full attention condition (M = 4.89, SD = 2.81), F (1, 84) = 14.37, MSE = 18, η^2 = .15. The ratio was larger when there was a ProM burden (M = 6.28, SD = 2.78) than when there was not (M = 5.51, SD = 2.95), F (1, 84) = 6.07, MSE =

10, η^2 = .07. There was a three-way interaction between age, ProM, and focality, *F* (1,84) = 5.87, *MSE* = 10, η^2 = .07. The means involved in this interaction are represented in Figure 17. Separate ProM (no-load, load) X focality (focal, non-focal) ANOVA's conducted for each age group revealed that the ProM X focality interaction was significant for the young adults [*F* (1,46) = 8.81, *MSE* = 4.13, η^2 = .16], but not for the older adults. The young adults in the focal condition produced a larger ratio when there was a ProM load (*M* = 4.85, *SD* = 2.47) than when there wasn't a ProM load (*M* = 3.24, *SD* = 1.34) [*t* (23) = 5.03, *p* < .001], but there was no difference between the load and no-load conditions when the ProM cue was non-focal (*t* < 1). None of the remaining main effects or interactions reached significance.

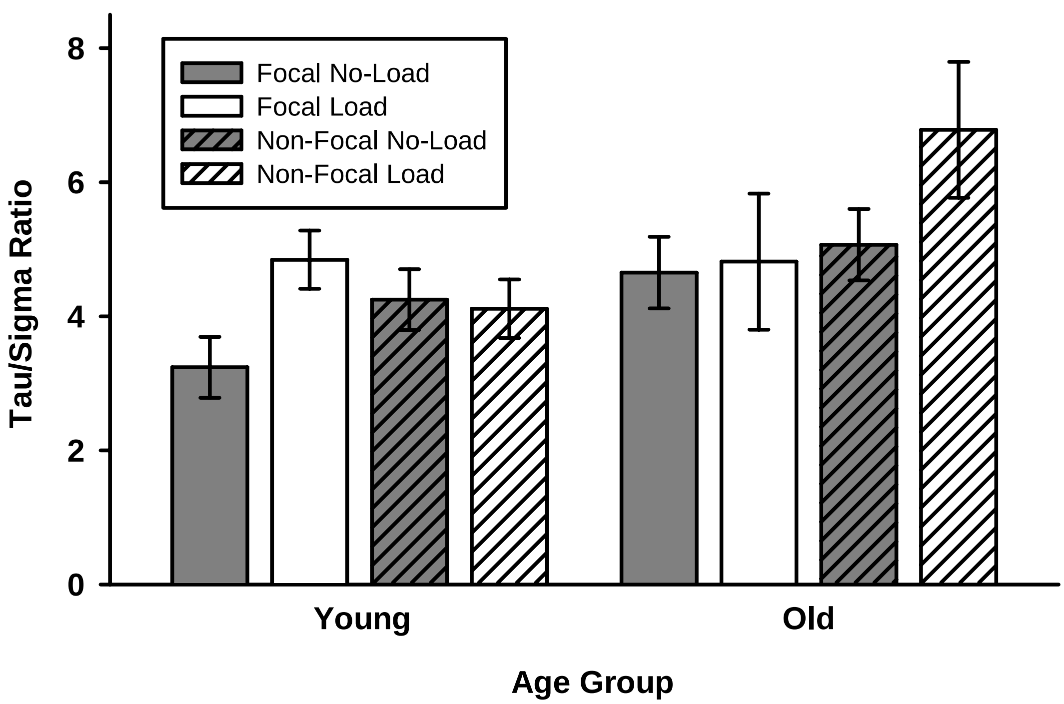

Figure 17. Mean *tau/sigma* ratios (± *SE*) for each level of age, focality, and ProM. Each mean is collapsed across the attention factor.

Weibull parameters. The mean Weibull parameter values for the full attention conditions are provided in Table 7 and the parameter values for the divided attention conditions are provided in Table 8. Again, for illustrative purposes, the Figures in Appendix E display the histograms and best fitting Weibull functions for participants whose *shift*, *scale* or *shape* parameter values were near the median for their respective age group and for a given condition. Recall that the *shift* parameter indicates the approximate location of the leading edge of a distribution and probably indicates a lower bound to the time taken to perform a given task. Thus, the value of the *shift* parameter would contain more information about peripheral and other non-controlled processes than the other parameters. Nonetheless, it should not be surprising to find condition differences in the *shift* parameter for tasks used in the current study. This is because processes such as those involved in the execution of a response would usually not be engaged until a decision had been made. The *shape* parameter reflects the skew of a distribution. The lower this parameter value, the more positively skewed the distribution. As mentioned above, differences in the *shape* parameter could indicate differences in the structure of cognitive processes. The *scale* parameter is a measure of the spread of the distribution. When the shapes of distributions are the same, differences in *scale* can be interpreted as differences in cognitive processing speed. Each of the parameters were entered into 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA's in which attention and ProM were within-subjects factors.

Table 7

Mean Weibull Parameter Values for Full Attention Conditions

	shift	*scale*	*shape*
		Lexical Decision Task	
Focal			
Young	420 (52)	221 (52)	1.84 (0.38)
Old	592 (79)	302 (113)	1.62 (0.29)
Non-Focal			
Young	404 (74)	232 (78)	1.90 (0.51)
Old	568 (58)	282 (92)	1.62 (0.31)
		Lexical Decision Task with ProM Burden	
Focal			
Young	471 (48)	248 (80)	1.49 (0.24)
Old	630 (100)	327 (153)	1.50 (0.28)
Non-Focal			
Young	433 (58)	294 (129)	1.58 (0.32)
Old	580 (56)	420 (204)	1.53 (0.28)

Note: Values in parentheses are standard deviations.

Table 8

Mean Weibull Parameter Values for Divided Attention Conditions

	shift	*scale*	*shape*
		Lexical Decision Task	
Focal			
Young	523 (120)	461 (266)	1.58 (0.46)
Old	598 (113)	703 (336)	1.56 (0.60)
Non-Focal			
Young	495 (116)	446 (216)	1.49 (0.50)
Old	623 (73)	687 (353)	1.29 (0.36)
		Lexical Decision Task with ProM Burden	
Focal			
Young	523 (105)	378 (177)	1.43 (0.30)
Old	611 (114)	624 (417)	1.45 (0.44)
Non-Focal			
Young	497 (138)	425 (230)	1.53 (0.40)
Old	644 (110)	643 (364)	1.29 (0.36)

Note: Values in parentheses are standard deviations.

Older adults had larger *shift* parameters (*M* = 606, *SD* = 75) than young adults (*M* = 471, *SD* = 74), *F* (1, 84) = 71.52, *MSE* = 22142, η^2 = .46. The divided attention condition resulted in larger parameter values (*M* = 564, *SD* = 106) than the full attention condition (*M* = 512, *SD* = 61), *F* (1, 84) = 32.17, *MSE* = 7338, η^2 = .28. The main effects of age and attention were qualified by an age X attention interaction, *F* (1, 84) = 7.87, *MSE* = 7338, η^2 = .09. Specifically, dividing attention resulted in larger parameter values (*M* = 619, *SD* = 97) than full attention (*M* = 592, *SD* = 99) for the older adults [*t* (38) = 2.19, *p* < .05]; however the difference between the divided attention condition (*M* = 510, *SD* = 111) and full attention condition (*M* = 432, *SD* = 54) was even larger for the young adults [*t* (46) = 5.80, *p* < .01]. The value of the *shift* parameter was larger when there was a ProM burden (*M* = 549, *SD* = 80) than when there was not (*M* = 528, *SD* = 77), *F* (1, 84) = 15.07, *MSE* = 2470, η^2 = .15. Finally, there was a ProM X attention interaction, *F* (1, 84) = 4.70, *MSE* = 2591, η^2 = .05. The ProM load condition resulted in a higher parameter value (*M* = 521, *SD* = 103) than the no-load condition (*M* = 488, *SD* = 107) when attention was not divided [*t* (87) = 5.43, *p* < .01], whereas there was no significant difference between the load (*M* = 563, *SD* = 131) and no-load (*M* = 555, *SD* = 119) conditions when attention was divided (*t* < 1). There were no other significant main effects or interactions involving the *shift* parameter.

With respect to the *scale* parameter, older adults produced larger parameter values (*M* = 498, *SD* = 225) than young adults (*M* = 338, *SD* = 133), *F* (1, 84) = 17.16, *MSE* = 130847, η^2 = .17. The divided attention condition resulted in larger parameter values (*M* = 546, *SD* = 285) than the full attention condition (*M* = 291, *SD* = 105), *F* (1, 84) =

109.46, *MSE* = 51874, η^2 = .57. The main effects of age and attention were qualified by an age X attention interaction, *F* (1, 84) = 9.85, *MSE* = 51874, η^2 = .11. Specifically, dividing attention resulted in larger parameter values (*M* = 664, *SD* = 351) than full attention (*M* = 333, *SD* = 130) for the older adults, *t* (38) = 7.55, *p* < .001. The difference between the divided attention condition (*M* = 427, *SD* = 212) and full attention (*M* = 249, *SD* = 76) condition was significant, but not as large for the young adults, *t* (46) = 7.04, *p* < .001. There was not a main effect of ProM, but there was a ProM X attention interaction, *F* (1, 84) = 35.00, *MSE* = 14925, η^2 = .06. The *scale* parameter value was larger when there was a ProM load (*M* = 318, *SD* = 155) than when there was not (*M* = 256, *SD* = 90) in the full attention condition, [*t* (87) = 4.78, *p* < .001], whereas there was a decrease between the load (*M* = 563, *SD* = 313) and no-load (*M* = 507, *SD* = 321) conditions when attention was divided [*t* (87) = 2.84, *p* < .01]. No other main effects or interactions involving the *scale* parameter reached significance.

Regarding the *shape* parameter, older adults had more skewed distributions (*M* = 1.48, *SD* = 0.25) than young adults (*M* = 1.61, *SD* = 0.31), *F* (1, 84) = 4.15, *MSE* = 0.33, η^2 = .05. Distributions were more skewed when there was a ProM load (*M* = 1.48, *SD* = 0.27) than when there was not (*M* = 1.61, *SD* = 0.36), *F* (1, 84) = 22.49, *MSE* = .07, η^2 = .21. There was an interaction between the age and ProM factors, *F* (1, 84) = 4.03, *MSE* = .07, η^2 = .05. Distributions tended to be more skewed when there was a ProM load (*M* = 1.44, *SD* = 0.26) than when there was not (*M* = 1.52, *SD* = 0.30) for older adults [*t* (38) = 1.86, *p* = .07], but the difference between the load (*M* = 1.51, *SD* = 0.28) and no –load (*M* = 1.70, *SD* = 0.39) conditions was even larger for young adults [*t* (46) = 4.95, *p* < .001].

Distributions were more skewed when attention was divided (*M* = 1.45, *SD* = 0.38) than when attention was full (*M* = 1.64, *SD* = 0.30), *F* (1, 84) = 21.40, *MSE* = .141, η^2 = .20. The main effect of attention was qualified by an interaction with ProM, *F* (1, 84) = 7.91, *MSE* = .07, η^2 = .09. In the full attention condition, distributions were more skewed when there was a ProM load (*M* = 1.53, *SD* = 0.28) than when there wasn't (*M* = 1.76, *SD* = 0.40), *t* (87) = 6.36, *p* < .001. The difference between the load (*M* = 1.43, *SD* = 0.34) and no-load (*M* = 1.48, *SD* = 0.50) conditions was not significant [*t* (87) = 1.20, *p* > .05] when attention was divided. Finally, the attention X ProM interaction was in turn qualified by a three-way interaction involving age, *F* (1, 84) = 4.13, *MSE* = .07, η^2 = .05. Figure 18 depicts the means involved in this interaction. To isolate the source of this interaction, separate attention X ProM ANOVA's were conducted for each age group. Although the pattern of the attention X ProM interaction was the same for both age groups, it was only significant for young adults, *F* (1, 46) = 12.60, *MSE* = .07, η^2 = .22, (*F* < 1 for older adults). No other main effects or interactions regarding the *shape* parameter reached significance.

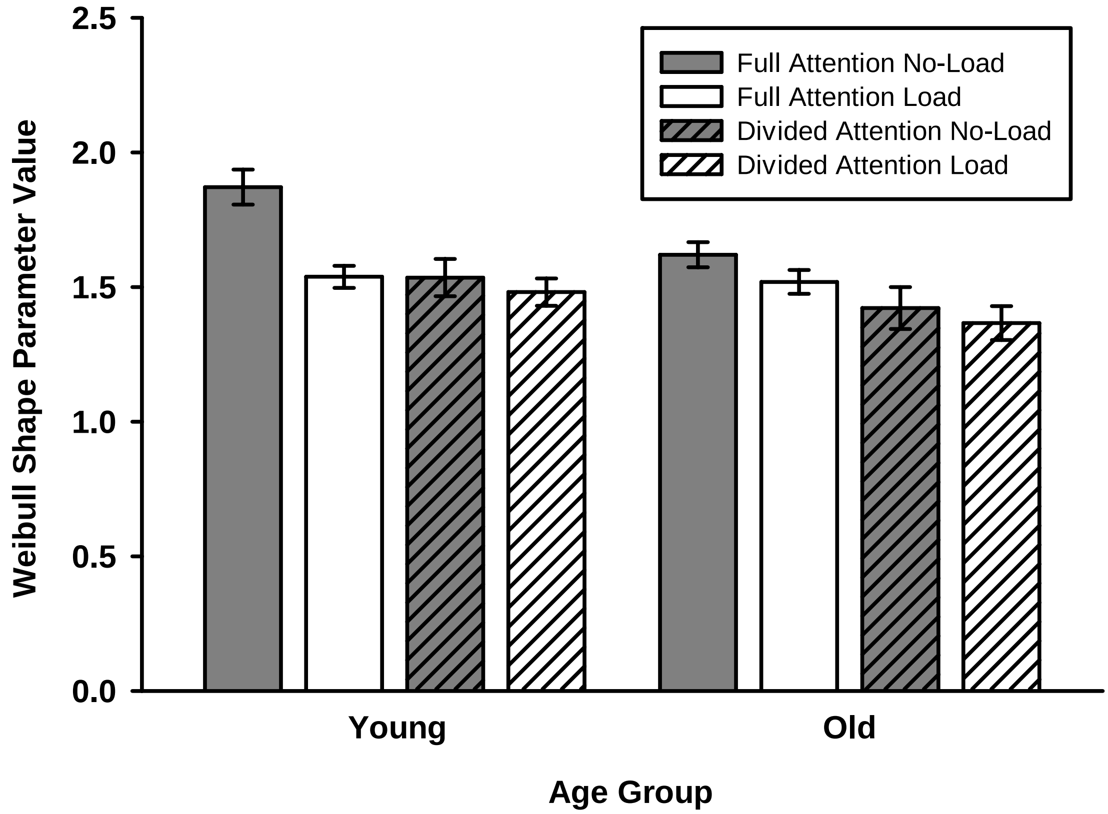

Figure 18. Mean Weibull *shape* parameter values (± *SE*) for each level of age, attention, and ProM. Each mean is collapsed across the focality factor.

Individual Differences

A series of hierarchical regression analyses were conducted to determine whether individual differences in processing speed and/or intraindividual variability predict ProM performance, or account for age differences in ProM performance where they exist. Age was dummy-coded such that young adults were assigned a code of 0 and older adults were given a code of 1. As will be seen, in some cases suppression was evident (see Tzelgov & Henik, 1991 for a full description of this phenomenon). Suppression is a phenomenon in which two predictor variables reduce variance in each other that is irrelevant to the criterion variable. Due to the recurrent presence of suppression, and for the sake of comprehensiveness, the order of entry was reversed in each of the analyses presented below, despite the fact that there weren't always age differences in ProM performance to account for. Separate analyses were conducted for each focality and attention condition[3]. Results of the hierarchical regression analyses for Experiment 1 are reported in the Tables in Appendix F. The results of these analyses are described below.

On-Going LDT Measure as a Predictor

Median response time. For exploratory purposes, although not critical to the hypotheses being investigated, median RT is nonetheless considered here as a predictor of ProM performance. The full attention conditions are considered first. When processing was focal, neither age nor median RT reliably predicted ProM performance when age was entered first. In contrast, suppression was observed when age was entered after median RT, as it reliably predicted an additional 9.0% of the variance in ProM performance. As age increased, ProM performance declined. In the non-focal condition,

[3] Separate analyses were conducted because the effects of Focality, Attention, and Age were assessed in the ANOVA's above and would be mostly redundant. Age was nonetheless included in these regression analyses, because that variable was important to the individual differences hypotheses. For fear that the interchangeability of ANOVA and multiple regression might lead to confusion regarding the necessity of the regression analyses, it should be noted that with the exception of the first step in which age was entered as the sole predictor, these regression analyses are not redundant with the ANOVA's reported above. In the case of the ANOVA's on the variability measures, the question was whether the mere presence of a ProM burden (regardless of ProM accuracy) altered various characteristics of performance on the on-going LDT task at the group level. In contrast, ProM accuracy was the dependent variable of interest in the regression analyses. It would have been quite possible to find an effect of ProM in the ANOVA's, yet find that the variability measures do not predict ProM performance in the regression analyses, and vice-verse. For example, consider a case in which there is little or no between-subjects variability within conditions, but considerable differences in a given dependent variable between conditions. The result would be a main effect in an ANOVA, but no predictive value of the individual differences variable in the regression analysis.

median RT reliably accounted for an additional 17.2% of the variance in ProM performance after controlling for age. As RT increased, so did ProM performance. This fact did not change when the order of entry was reversed, although the direction of the effect of age switched to become negative.

Turning now to the divided attention conditions, neither age nor median RT reliably predicted ProM performance in the focal condition, and reversing the order of entry did not change this fact. In contrast, in the non-focal condition median RT accounted for an additional 18.3% of the variance after taking into account age. As RT increased, so did ProM performance. Reversing the order of entry revealed a suppression effect. Median RT only accounted for 7.3% of the variance in ProM performance when entered first, and age continued to reliably predict ProM performance. Thus, age suppressed variance in median RT that was unrelated to variance in ProM performance.

Coefficient of variation. The same CV measure that was used above was also used for the individual differences analyses. Looking first at the full attention condition when processing was focal, neither age nor CV predicted ProM performance when age was entered into the equation first. This did not change when the order of entry was reversed. Regarding the non-focal full attention condition, CV did account for an additional 9.3% of the variance in ProM performance after controlling for age. Lower CV values were associated with greater ProM performance. However, when the order of entry was reversed, CV no longer accounted for a significant proportion of variance in ProM performance, and age still did not predict performance. Thus, a suppressive relationship between age and CV was also present. When attention was divided and processing was focal, neither age nor CV predicted ProM performance and this did not change when the order of entry was reversed. In the non-focal divided attention condition CV neither reliably predicted ProM performance nor did it account for age differences in ProM performance. However, there was again evidence of suppression as the amount of variance accounted for by age was 8.8% before controlling for CV, but 10.3% after controlling for CV.

Tau/sigma. The focality conditions for which attention was undivided are again considered first. After controlling for age, skew, as indexed by the ratio of *tau* to *sigma*, did not predict any additional variance in the focal condition, and this did not change when the order of entry was reversed. On the other hand, skew did account for a significant additional 8.3% of the variance in the non-focal condition after controlling for age. When the order of entry was reversed, the strength of the relationship between this skew measure and ProM performance actually decreased. This again suggests the presence of suppression in these analyses.

Regarding the conditions for which attention was divided, in the focal condition, skew did not reliably predict ProM performance after controlling for age and reversing the order of entry did not change this. In the non-focal condition skew again failed to predict ProM performance or appreciably reduce the amount of variance accounted for by age.

Weibull shape. Again, the conditions for which attention was undivided are considered first. Skew, as indexed this time by the Weibull *shape* parameter, did not predict ProM performance in either focality condition after controlling for age. Neither did the skew predict ProM performance when entered first.

Turning now to the focality conditions in which attention was divided, the *shape* parameter did not account for additional variance in ProM performance after controlling for age. However, focusing on the non-focal condition, when the order of entry was reversed, the additional amount of variance accounted for by age was reduced from 8.8% to 7.9% which was only significant at the trend level.

Two-Back Measure as a Predictor

The average median RT, proportion correct, CV, ex-Gaussian parameters, and Weibull parameters for each age group are provided in Table 13.

Table 9

Experiment 1: Median Response Time, Accuracy, Coeffecient of Variation, Ex-Gaussian Parameters, & Weibull Parameters for the Two-Back Task

Measure	Young	Old
Median RT	653 (120)	1167 (314)
Accuracy	0.94 (.05)	0.90 (.07)
CV	0.99 (.18)	0.87 (.18)
	Ex - Gaussian Parameters	
mu	421 (62)	718 (144)
sigma	92 (34)	174 (66)
tau	331 (167)	656 (362)
tau/sigma	3.93 (2.44)	3.79 (1.46)
	Weibull Parameters	
shift	310 (76)	535 (124)
scale	453 (162)	872 (381)
shape	1.63 (.33)	1.49 (.30)

Note: Standard deviations are in parentheses. Also, age differences for all measures except the *tau/sigma* ratio are significant at the .05 level.

Median response time. First considering the full attention conditions, neither age nor median RT reliably predicted ProM performance in the focal condition and this did not change when the order of entry was reversed. However, suppression was observed in the non-focal condition. Median RT accounted for a significant 15.5% of the variance in ProM performance when entered after age, which accounted for a non-significant 2.3% of the variance. ProM performance increased as median RT decreased. In contrast, when median RT was entered first, it accounted for a non-significant 2.4% of the variance and age reliably predicted 15.4% of the variance. However, the direction of the relationship between age and ProM performance was the opposite of what was expected. After controlling for median RT, ProM performance was actually better for older adults than young adults.

With respect to the divided attention conditions, neither age nor median RT reliably predicted ProM performance in the focal condition and this pattern did not change when the order of entry was reversed. In the non-focal condition, median RT did not reliably predict ProM performance after controlling for age, and no suppression was observed when the order of entry was reversed.

Coefficient of variation. Considering the full attention conditions first, neither age nor two back CV reliably predicted ProM performance. This was true for both focality conditions and both predictors still did not predict ProM performance when the order of entry was reversed. In the focal divided attention condition both age and two back CV failed to predict ProM performance and this did not change when the order of entry was reversed. In the non-focal divided attention condition two back CV did not account for a significant proportion of variance in ProM performance after controlling for age. However, two back CV did account for a significant 13% of the variance in ProM performance when entered into the equation first. In this case, an increase in two back CV was associated with an increase in ProM performance. Furthermore, the amount of variance accounted for by age was reduced to a non-significant 2.8%.

Tau/sigma. When attention was undivided, skew did not account for any additional variance in ProM performance for either Focality condition after controlling for age. Skew still did not predict ProM performance when entered into the equations first. When attention was divided, skew again failed to account for additional variance after controlling for age. When the order of entry was reversed skew did not predict ProM performance, although the effect of age that was present in the non-focal condition was reduced by 1.3% to 7.5% which was only significant at the trend level. However, the direction of the relationship between skew and ProM performance was the opposite of what was predicted.

Weibull shape. When attention was undivided, the Weibull *shape* parameter did not predict ProM performance for either focality condition regardless of whether it was entered after or prior to age. With respect to the focality conditions in which attention was divided, the *shape* parameter did not account for additional variance in ProM performance after controlling for age. When the order of entry was reversed, the *shape* parameter did not predict ProM performance or eliminate the effect of age that was present in the non-focal condition.

Summary & Discussion: Experiment 1

ProM performance in Experiment 1 was largely as expected. The main effect of age was not significant, but older adults did tend to perform worse than young adults. The failure to find an overall age difference in ProM performance or the expected age X focality interaction might be explained by age differences in the extent to which attention was placed on monitoring processes. This possibility has also been suggested by McDaniel, Einstein, and Rendell (2008) who reported that, although they did not find an age difference in performance on a non-focal ProM task, they did find greater costs to the on-going task for older adults than for young adults. Likewise, in the present study older adults tended to outperform young adults in the non-focal full attention condition, but at the same time, as can be seen in Table 2, they also tended to incur larger costs to performance on the on-going task in that condition than young adults.

As expected, ProM performance was worse when processing was non-focal than when it was focal, and dividing attention lowered performance. Furthermore, dividing attention reduced performance in the non-focal condition more than in the focal condition, and this was only the case for older adults. The fact that focality did not interact with attention in the young adults is not inconsistent with multiprocess theory when considered in the context of the three-way interaction with age. That is, it was expected that the focality X attention interaction would be more pronounced in the older adults than in the young adults.

Given that performance by young adults was only slightly over 50% in the full attention focal condition, it is possible that reflexive-associative processes were not sufficient to perform the focal ProM task conditions successfully. Low ProM performance by itself does not necessarily indicate that reflexive-associative processes were not relied on as it could have been the case that a strong associative link between the cue and intention was not formed during initial encoding. If this were the case, performance in the focal condition might be expected to be low even if reflexive-associative processes would otherwise have been sufficient. However, it should be pointed out that in the present study all but a very few participants remembered all four ProM cues. Furthermore, when evaluated separately for each age group and each full attention condition, the costs incurred in the focal condition were significant or approaching significance for both age groups suggesting that cue-focused processes were relied on to some extent. Of course, this explanation begs the question: why might participants have relied on cue-focused processes in the focal full attention condition? The answer may lie in the number of ProM cues. For example, Cohen, Jaudas, and Gollwitzer (2008) found that there was no cost to performance on a LDT when there were one or two targets, but there was when there were three or more targets. Likewise, Einstein et al. (2005) also found that a cost to on-going task performance was incurred when there were six targets, but not when there was only one target.

With respect to performance on the on-going LDT, although several anticipated main effects and interactions regarding median RT failed to reach significance, the data nonetheless were consistent with the multiprocess framework. Importantly, the ProM x focality interaction was at least in the expected direction. Specifically, the difference between the no-load (M = 821, SD = 253) and load (M = 858, SD = 279) conditions tended to be larger when processing was not focal than the difference between the no-load (*M* = 851, *SD* = 255) and load (*M* = 852, *SD* = 279) conditions when processing was focal. This, in conjunction with the ProM performance data, suggests that some type of cue-focused process was engaged more prominently in the non-focal condition than in the focal condition.

Also, the nature of the attention X ProM interaction may seem puzzling given that the effect of adding a ProM burden should have been greater when attention was divided than when it was not. Instead, there was an effect of ProM in the full attention condition, but not in the divided attention condition. This result was most likely due to practice effects associated with the digit monitoring task overwhelming any cost associated with the ProM load. (Recall the nonlinear aspect of the data depicted in Figure 7 that was most pronounced for older adults in the divided attention, no-load condition.) As suggested above, these practice effects do not invalidate conclusions made regarding the effects of ProM on intraindividual variability and skew. On the contrary, because intraindividual variability and skew are greater when performance is changing (in this case improving in the no-load conditions) than when performance is stable (e.g. in the load conditions) the practice effects would only obscure the effects of ProM. Thus, it is interesting, but not surprising that the attention X ProM interaction observed for the median RTs was also present in every Weibull and ex-Gaussian measure, with the exception of the *tau*/*sigma* ratio. Even in the *tau*/*sigma* ratio, the data were consistent with the pattern of the interaction in the other parameters. It seems that the effect of the

ProM burden was indeed obscured by the practice effects on the digit monitoring task for several different aspects of the RT distributions, not just median RT.

In addition to the unintended consequences of the digit monitoring task for performance on the on-going LDT, the pattern of ProM performance was also less than optimal for this experiment. That is, it would have been most favorable if performance in the full attention focal condition of the ProM task had been better with minimal age differences and no associated cost, thus indicating that reflexive-associative processes were primarily responsible. Nonetheless, what is most important with respect to West's frontal lobe theory of cognitive aging and the primary hypotheses of this study is the relative contribution of controlled processes to performance on a given task. These data are consistent with the expectation that the non-focal condition required controlled processing to a greater extent than the focal condition. Of course, the data are also consistent with the notion that controlled processes were required to a greater extent in the ProM load conditions than in the no-load conditions.

Turning now to the issue of performance variability, recall that there were two hypotheses related to group differences in intraindividual variability. The first hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task and this increase is larger for tasks relying more on cue-focused processes than those relying less on cue-focused processes. The second hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes more for older adults than for younger adults.

The CV measure yielded very interesting, if puzzling results that were not in agreement with the hypotheses of this study. The CV measure suggested that younger adults were more variable than older adults, full attention resulted in more variability than divided attention, and variability was greater when there was not a ProM load than when there was. Even the nature of the interactions was counter to expectations. For example, younger adults were more variable than older adults in the full attention condition, but there was not an age difference in the divided attention condition. Furthermore, the focality X ProM interaction indicated that variability was greater in the no-load than in the load condition when processing was non-focal. Also interesting was the fact that the experimental manipulations tended to have less impact on the older adults' variability than on the younger adults' variability, as suggested by the several interactions involving age.

As will be seen, these seemingly anomalous findings were also present in the second experiment and a possible explanation for the strange pattern will be offered in the general discussion below. For now, it should be pointed out that it was entirely possible to obtain these results for the CV measure while still finding the opposite effects for the skew measures. The CV is derived from the SD, and so it is a measure of relative dispersion. One distribution can be more disperse than another, but less skewed. That is, one distribution might be highly symmetrical with a large SD, whereas another might by highly asymmetrical with a small SD. (Think of a distribution in which every RT is the same with the exception of one outlier.) More importantly, as pointed out above, although West derived his theory from the assumption that older adults exhibit greater intraindividual variability in certain situations, that actually need not be the case for his predictions to hold. West's theory specifically predicts age differences in the skew of RT distributions.

The first approach used in this study to assess the relative skew of the RT distributions was the examination of the Q-Q plots. Visual inspection of the Q-Q plots appears to have been too insensitive a technique from which to base firm conclusions regarding the hypotheses of this study, or the effects of the independent variables on skew; however there were no flagrant discrepancies between the Q-Q plots and the skew relevant ex-Gaussian and Weibull parameters. Indeed, there were several points of agreement between the Q-Q plots and the other analyses. For example, age differences and attention differences in the lengths of the tails of the distributions were revealed by the *tau* parameter, and also by the greater increase in distance between successive quantiles of the relevant Q-Q plots.

The aspects of the ex-Gaussian and Weibull analyses that were the most relevant to the primary hypotheses of this study were the measures that indicated the degree of RT distribution skew; specifically, the *tau*/*sigma* ratio from the ex-Gaussian analysis, and the *shape* parameter from the Weibull analysis. It has already been pointed out that the *tau* parameter alone is not an optimal measure of skew because it primarily reflects the absolute length of the tail of a distribution. Consequently, *tau* is not appropriate for testing the hypotheses of this study. Nonetheless, the *tau* parameter results should also be reviewed here, because it is so often used by other researchers as a measure of skew.

The results regarding the *tau* parameter were consistent with what other researchers have found (e.g., Spieler et al., 1996; West, et al., 2002) and with what West would argue to be support for the frontal lobe theory. Older adults produced larger parameter values than young adults, *tau* was larger when attention was divided than when it was full, and *tau* was larger when there was a ProM load than when there was not a load. More importantly, the two way interaction involving age and attention, as well as the three-way interaction involving age, focality, and ProM would also typically be offered as support of frontal lobe accounts of cognitive aging. More specifically, the age X attention interaction was due to their being a larger age difference when attention was divided than when it was full. The age X focality X ProM interaction resulted from the effect of a ProM burden being larger when processing was non-focal than when processing was focal for older adults, but not for young adults. Thus, age differences in the *tau* parameter were more pronounced when controlled processes were presumably engaged. However, rather than indicate that older adults experienced more fluctuations in the efficiency of executive control, the age differences in *tau* more likely reflected the fact that older adults process information more slowly than young adults and this difference was exaggerated when controlled processes were engaged. The fact that the interactions involving age were not detected for either median RT or the *mu* parameter does not affect the validity of this conclusion, because simple slowing would result in group differences being magnified in the tails of the distributions. Thus, it is more likely that differences would be evident in *tau* than in *mu* or measures of central tendency.

Again, the measure that is more appropriate for investigating lapses of attention is the ratio of *tau* to *sigma*, which is a more fitting indicator of skew than *tau* alone. The *tau/sigma* ratio was greater when attention was divided than when it was not, which was to be expected if the engagement of controlled processes result in an increase in skew. Regarding the first hypothesis, the presence of a ProM burden did result in greater skew relative to the control condition; however, this effect was not larger for the focal condition than the non-focal condition. As mentioned in the general discussion below, one possible reason for this failure might be that there was not sufficient separation between the conditions in terms of the engagement of controlled processes to allow differences in skew to be detected. With respect to the second hypothesis, older adults did indeed produce larger ratios than young adults. However suggestive this age difference might be, this finding alone does not fully test the second hypothesis, and consequently, it does not support or challenge West's theory. What is needed to more fully corroborate West's theory is to find that age differences in skew increased as a function of the employment of controlled processes. There was a significant three-way interaction involving age, focality, and ProM, but it was traced to a significant focality X ProM interaction that existed only for the young adults and was due to there being a larger effect of ProM in the focal condition than in the non-focal condition. Putting aside the statistical nature of the interaction for a moment, it is difficult not to notice that Figure 17 reveals that the pattern of the data involved in this interaction was at least consistent with West's theory. That is, in contrast to what was found for the young adults, for older adults there was very little difference between the no-load and load conditions when processing was focal, whereas the *tau/sigma* ratio was greater when there was a ProM load and when processing was non-focal. Or, looked at another way, the largest age difference existed in the non-focal condition when there was a concurrent ProM load, the condition that should have engaged control processes to the greatest extent.

The Weibull *shape* parameter, the other measure appropriate for assessing skew and testing the frontal lobe theory, yielded results that were not wholly different from what was found for the *tau*/*sigma* ratio. Skew was greater when attention was divided than when it was full. Again, with respect to the first hypothesis, skew was greater when there was a ProM load than when there was not, but this effect was not influenced by focality. Regarding the second hypothesis pertaining to age differences, the *shape* parameter indicated that older adults had more skewed distributions than young adults; but, there were only two significant interactions (viz. the age X ProM and the age X attention X ProM) that were relevant to the hypotheses of the current study, and neither was in the predicted direction.

To sum up the RT distributional analyses for Experiment 1, the results of the various techniques were largely consistent with one another. On average, older adults' distributions were more skewed than those of young adults, dividing attention produced distributions with greater skew than full attention, and the presence of a ProM load increased the skew of distributions relative to situations in which there was no ProM load. The Q-Q plots for the full attention conditions were consistent with the notion that age differences in skew should be larger for the non-focal condition than for the focal condition.

Turning now to the individual differences analyses, suppression was present in many cases. This really shouldn't be surprising though, given that suppression often occurs (in the three-variable case) when one variable is positively associated with the other two while those are in turn negatively associated with one another (Tzelgov & Henik, 1991). In this case, with the exception of the *shape* parameter, the measures derived from the on-going LDT tended to be positively associated with both age and ProM accuracy, while age and ProM accuracy tended to be negatively associated with one another. In cases of suppression the zero-order correlations may be underestimated and partial regression coefficients more accurately reflect the true relationship.

Although not directly relevant to the key hypotheses, the regression analyses involving median RT from the on-going LDT were interesting in that they seem to reveal more about strategy and the nature of the ProM task than about the integrity or efficiency of cognitive processing. Even though, due to the practice effects associated with the divided attention conditions, the omnibus ANOVA's did not clearly reveal the expected patterns of cost associated with the burden of a ProM load, the regression analyses indicated that the more slowly individuals performed the LDT, the more ProM targets they responded to. Importantly, this relationship between speed and ProM performance was only significant in the non-focal condition. Thus, it seems that the individual differences analysis was successful at detecting the expected cost associated with the ProM load in the non-focal condition.

In contrast, the analyses involving the two-back median RT did suggest something about the integrity of cognitive processing. In this case median RT tended to be negatively associated with ProM performance, but only significantly so for the non-focal condition. This also supports the notion that the non-focal condition relied more on controlled processing as the two-back task also presumably relies to a large extent on controlled processing.

With respect to the issue of performance variability, recall that there were again two relevant hypotheses. The third hypothesis of this study was that intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes predicts ProM performance and accounts for age differences in ProM performance. The fourth hypothesis was that intraindividual variability in performance on a task that requires executive control predicts ProM performance on tasks that rely on cue-focused processes and accounts for age differences in ProM performance.

The analyses involving intraindividual variability as measured by the CV should be interpreted with caution, given the strange results obtained in the between-group analyses. With that in mind, the on-going LDT CV reliably predicted performance in the non-focal full attention condition; however, there were no age differences to account for in this condition. Thus, at least within the full attention conditions, the results partly supported the third hypothesis. The patterns of associations present in the divided attention conditions are, again, puzzling. Rather than being negatively associated with ProM performance, CV tended to by positively associated with ProM performance, although not significantly so. Regarding the fourth hypothesis, the two-back task CV reliably predicted performance in the non-focal divided attention condition and accounted for the age differences in that condition. However, CV was again positively, not negatively associated with ProM performance.

Concerning the related issue of RT distribution skew, it should be pointed out that, with respect to the individual differences analyses and their role in testing West's frontal lobe hypothesis, there was only one condition in which to explain age differences in ProM performance (viz. the non-focal divided attention condition), and consequently, to test the hypotheses of this study. However, West's theory also makes predictions about the relationship between RT distribution skew and ProM performance that are age invariant. Therefore, these analyses were potentially useful, despite the lack of expected age differences in ProM performance. Unfortunately, the only case in which a skew measure reliably predicted ProM performance was for the on-going LDT *tau*/*sigma* ratio in the non-focal full attention condition. In this case, greater skew was associated with worse ProM performance. Thus, just considering the full attention conditions, the pattern of results was largely consistent with the third hypothesis of this study in that individual differences in the *tau*/*sigma* ratio reliably predicted performance when processing was non-focal, but not when processing was focal. The fourth hypothesis was not supported as skew in two-back performance did not predict ProM performance in any condition.

RESULTS & DISCUSSION: EXPERIMENT 2

The organization of the results for Experiment 2 is the same as that for Experiment 1. Analyses testing group differences (Hypotheses I & II) will be presented first, and tests of individual differences (Hypotheses III & IV) will be presented last.

Once again, performance on the digit monitoring task was fairly high as the overall mean proportion correct was 0.83 (*SD* = 0.11). There were no significant differences between age groups, salience conditions, or ProM conditions, nor were there any interactions.

Prospective Memory Performance

Once again, a probability of .05 or less of making a type I error was considered acceptable for all statistical tests. Effect sizes are reported as partial η^2 values. Three older adults could not remember the instruction to press the 'p' key upon encountering a ProM cue. Removing these individuals did not affect the pattern of results in the analyses presented below. Also, three older adults (one in the high salience condition and two in the low salience condition) could not remember all 4 ProM cues. Thus, ProM performance was again measured in terms of the conditional proportion of correct ProM responses, taking into account the total number of items remembered for each participant.

The conditional proportion correct measure was entered into a 2 (age: young, old) X 2 (salience: high, low) X 2 (attention: full, divided) mixed ANOVA in which age and salience were between-subjects factors and attention was a within-subjects factor. The mean proportion correct values are displayed in Figure 19.

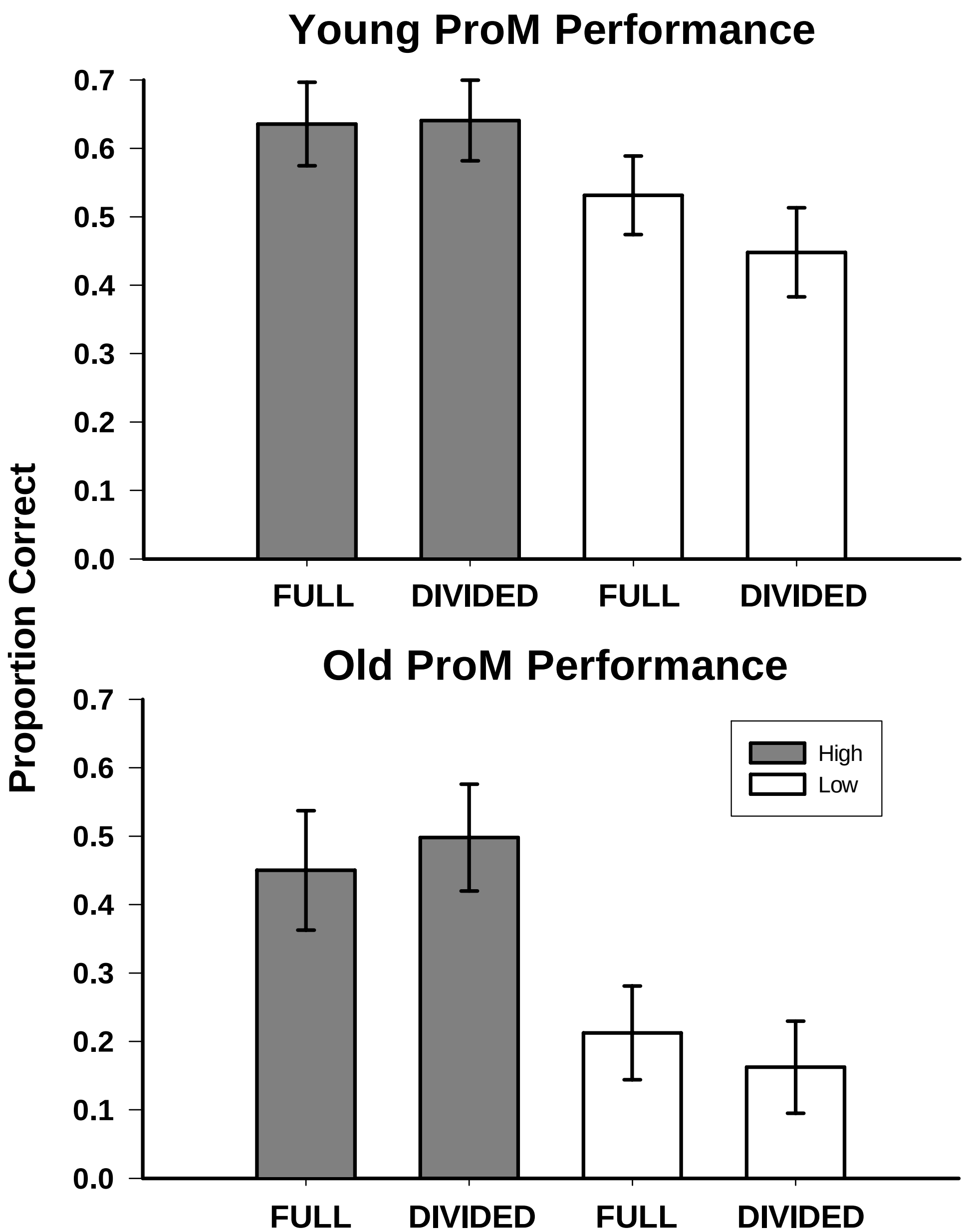

Figure 19. Mean conditional proportion of ProM targets correctly responded to by young adults (top panel) and older adults (bottom panel) as a function of Salience and Attention. Error bars are Standard Errors of the Mean.

There was a main effect of age, F (1, 84) = 13.99, $MSE = .169$, $\eta^2 = .14$. ProM performance was higher for young adults (M = .56, SD = .29) than for older adults (M = .33, SD = .29). There was a main effect of salience, F (1, 84) = 12.18, $MSE = .141$, η^2 = .13. Specifically, ProM performance was higher for high salience cues (M = .56, SD = .43) than for low salience cues (M = .34, SD = .39). There was not a main effect of attention ($F < 1$); however, the salience X attention interaction was significant at the trend level, F (1, 84) = 3.04, $p = .085$, $MSE = .141$, $\eta^2 = .04$. Planned t-tests confirmed that this interaction was due to the fact that dividing attention did not affect performance in the high salience condition ($t < 1$), whereas it lowered performance in the low salience condition, t (43) = 4.14, $p < .05$. There were no other significant interactions.

On-Going Task Performance

As in Experiment 1, RTs associated with ProM cues and trials immediately following ProM cues were not included in the analyses. The same criteria were also used to identify and remove RTs that were unreasonably fast (less than 150 ms) or slow (greater than 5,000 ms) from the data set. This procedure resulted in 0.12% of trials being trimmed from the young adult data set and 0.37% from the older adult data set. Finally, only correct RTs were analyzed. Both median RTs and accuracy data for each condition are presented in Table 18.

Table 10

Experiment 2: Average Median Response Times and Accuracy (Proportion Correct)

	Full Attention		Divided Attention	
Condition	Median RT	Accuracy	Median RT	Accuracy
	Lexical Decision Task			
High Salience				
Young	608 (79)	.95 (.04)	872 (332)	.95 (.04)
Old	847 (203)	.97 (.02)	1188 (462)	.95 (.03)
Low Salience				
Young	564 (64)	.93 (.04)	693 (189)	.92 (.05)
Old	798 (108)	.98 (.02)	1065 (279)	.96 (.03)
	Lexical Decision Task with ProM Burden			
High Salience				
Young	637 (70)	.94 (.03)	809 (236)	.95 (.03)
Old	849 (111)	.97 (.02)	1092 (350)	.96 (.02)
Low Salience				
Young	593 (70)	.92 (.04)	705 (230)	.93 (.04)
Old	800 (105)	.96 (.01)	931 (180)	.96 (.02)

Note: Values in parentheses are standard deviations.

As was the case in the first experiment, given that the ProM load condition always followed the no-load condition, it was again possible that any slowing, increase in variability, or increased skew in the ProM load condition relative to the no-load condition might have been due to simple fatigue effects, rather than the effect of a ProM burden.

Figures 20 and 21 depict plots of RT as f unction of trial for both age groups and ProM conditions (i.e. load and no-load) for Full Attention and Divided Attention, respectively.

Once again, if fatigue was the primary factor behind slower performance in the ProM load condition, one would expect to find an appreciable (although perhaps nonlinear) increase in RT across trials for each condition. In contrast, as can be seen in the figures, performance was quite stable (i.e. not showing a large positive or negative trend) for nearly all trials when under full attention. Similar to what was found in the first experiment there was a noticeable positively accelerating nonlinearity in the first trials of the divided attention conditions that was more pronounced in the older adults, but performance again reached asymptotic levels fairly rapidly. Thus, there was no evidence of systematic slowing associated with fatigue. Indeed, regression lines fit for each condition were all very slightly negative. As mentioned above, the nature of the practice effects hinted at in the current data would only serve to mask the predicted differences in cost, variability, or distribution shape that may exist between the ProM conditions.

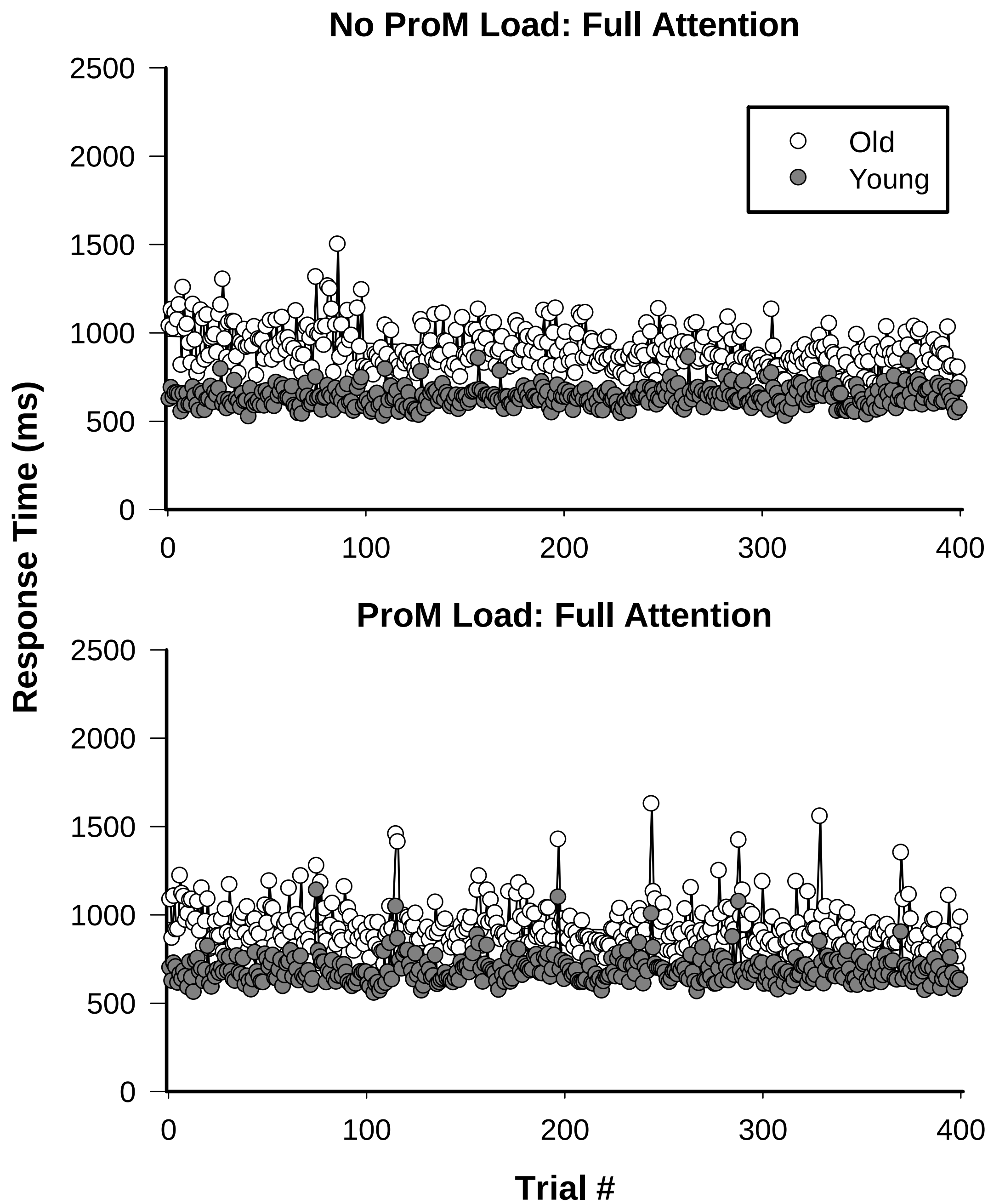

Figure 20. Response time on the lexical decision task as a function of trial number for young and older adults in the No-Load (upper panel) and Load (lower panel) conditions when attention was not divided.

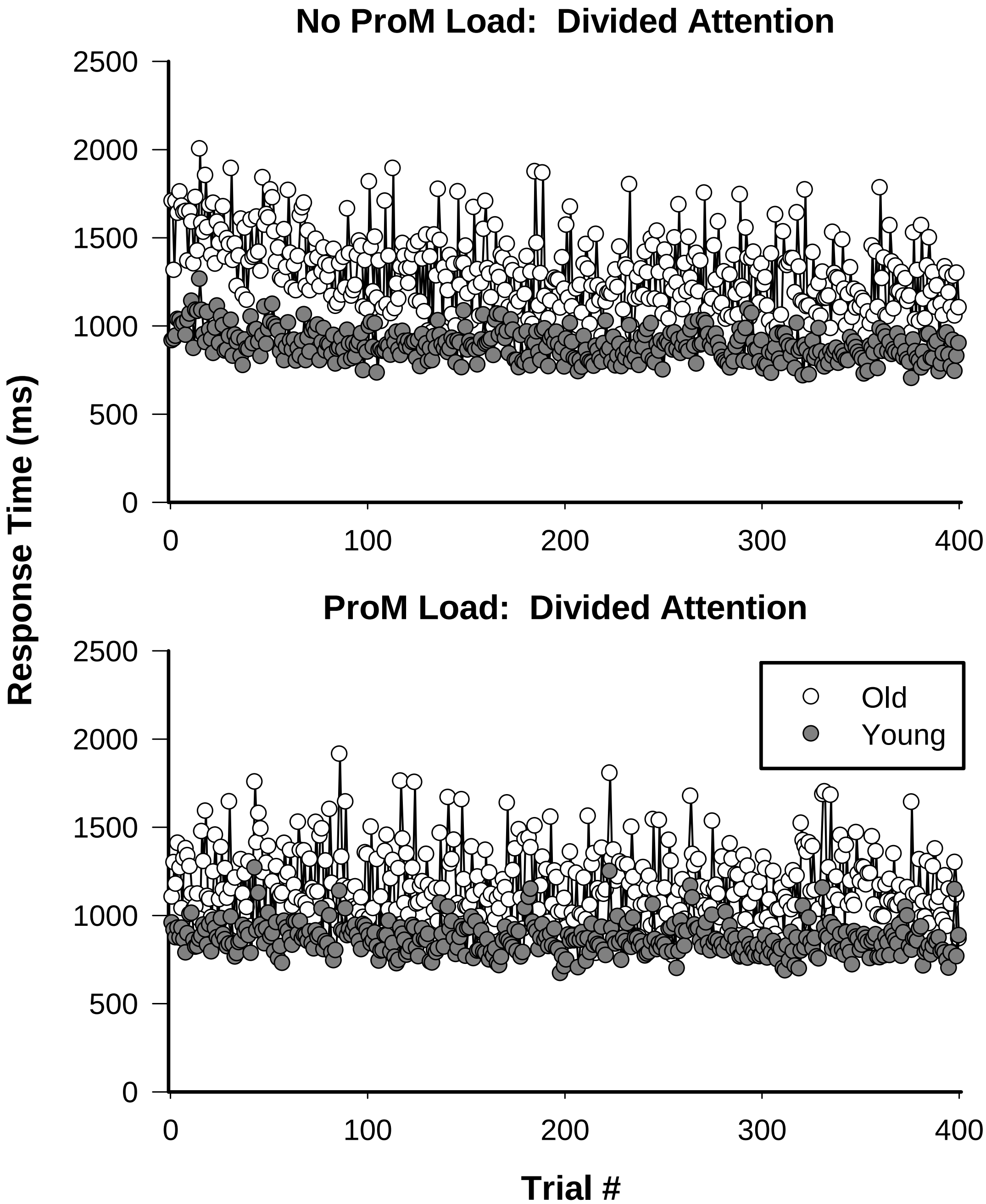

Figure 21. Response time on the lexical decision task as a function of trial number for young and older adults in the No-Load (upper panel) and Load (lower panel) conditions when attention was divided.

As was the case in the first experiment, due to the partially nested nature of the design, when interpreting analyses in which the salience factor is included, it is inappropriate to consider the main effect of salience, or any interactions involving salience that do not also include the ProM factor.

Cost of Prospective Memory Burden

Median RTs were entered into a 2 (age: young, old) X 2 (attention: full, divided) X 2 (ProM: no-load, load) X 2 (salience: high, low) mixed ANOVA in which attention and ProM were within-subjects factors. There was a main effect of age, F (1, 84) = 45.45, MSE = 130930, η^2 = .35. Older adults (M = 946, SD = 214) were slower than younger adults (M = 685, SD = 148). There was a main effect of attention, F (1, 84) = 79.73, MSE = 47054, η^2 = .49. Performance was faster when attention was undivided (M = 712, SD = 100) than when it was divided (M = 919, SD = 282). There was a main effect of ProM, F (1, 84) = 6.24, MSE = 10519, η^2 = .07. Performance was actually slower in the no-load condition (M = 829, SD = 212) than in the load condition (M = 802, SD = 162). However, the main effect of ProM was qualified by an attention X ProM interaction, F (1, 84) = 33.89, MSE = 4729, η^2 = .29. This interaction was due to the fact that performance was slower in the ProM load condition (M = 710, SD = 139) than in the no-load condition (M = 694, SD = 170) when attention was full [t (87) = 2.07, p < .05], but faster in the ProM load condition (M = 873, SD = 288) than in the no-load condition (M = 939, SD = 372) when attention was divided [t (87) = 3.78, p < .001]. The ProM factor also interacted with age, F (1, 84) = 7.07, MSE = 10519, η^2 = .08. Performance was slower in the no-load condition (M = 975, SD = 258) than in the load condition (M =

918, *SD* = 180) for older adults [t (43) = 3.02, $p < .01$], whereas there was no difference in performance between the no-load (*M* = 684, *SD* = 162) and load (*M* = 686, *SD* = 145) conditions for young adults ($t < 1$). Finally, there was an age X attention X ProM interaction, F (1, 84) = 4.71, *MSE* = 4729, $\eta^2 = .05$. The means involved in this interaction are represented in Figure 22. Separate Age X ProM ANOVA's conducted for each attention condition revealed that the age X ProM interaction was significant when attention was divided [F (1, 84) = 7.18, *MSE* = 12407, $\eta^2 = .08$], but not when attention was full ($p > .05$). Within the divided attention condition the age X ProM interaction was due to the fact that the effect of ProM was significant for older adults [t (39) = 4.27, $p < .001$], but not for young adults ($p > .05$).

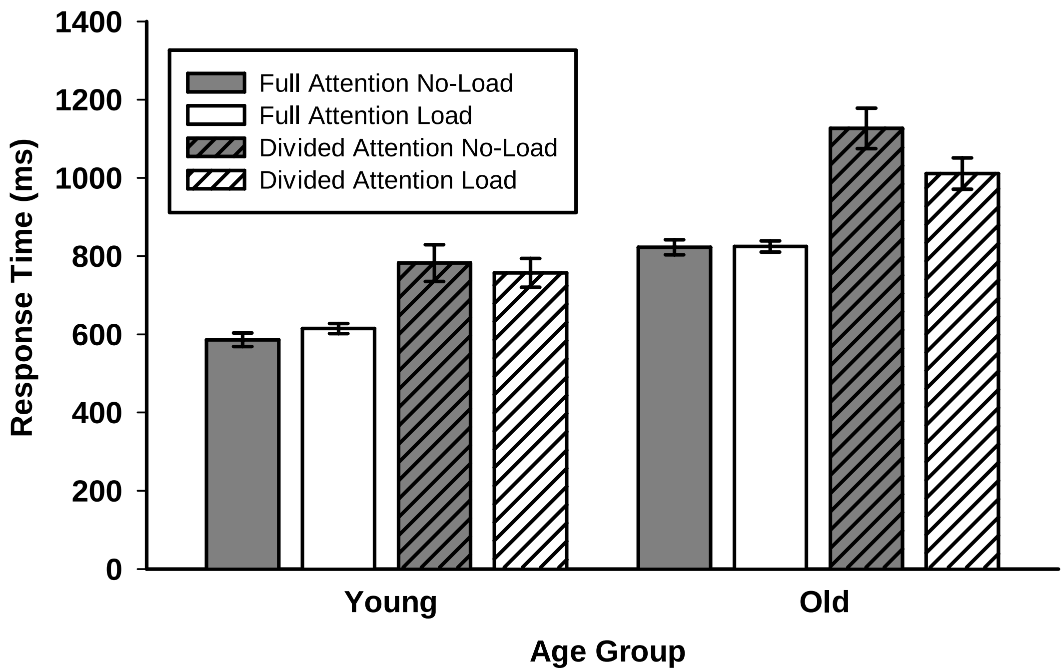

Figure 22. Mean median response time (± *SE*) for each level of attention and ProM for each age group. Each mean is collapsed across the salience factor.

Although the omnibus test again did not suggest that additional tests were necessary, follow-up *t*-tests were once more conducted separately for each age group and condition. As for the divided attention conditions, there was an improvement rather than a cost in each case except for the low salience condition for young adults, and this cost was not significant ($t < 1$) . The cost was significant in the full attention high salience condition [$t(23) = 2.56$, $p < .05$] and full attention low salience condition [$t(23) = 3.64$, $p < .01$] for young adults. There were no costs in either the high salience or low salience full attention conditions for the older adults (both *t*'s < 1).

Intraindividual Variability

The modified CV measure was again used to assess intraindividual variability. The parameter values of the SD on RT regression equations are provided in the table in Appendix G. Figure 23 depicts plots of each young and older individual's SD's in the full attention conditions as a function of their RTs from which the x-intercepts have been removed. Figure 24 depicts the same, but for the divided attention conditions. The mean CVs for each age group and condition are provided in Table 19.

Table 11
Experiment 2: Mean Coefficients of Variation

Condition	Full Attention	Divided Attention
	Lexical Decision Task	
High Salience		
Young	1.18 (.32)	0.37 (.11)
Old	0.76 (.13)	0.39 (.08)
Low Salience		
Young	0.72 (.17)	0.44 (.11)
Old	0.88 (.22)	0.56 (.09)
	Lexical Decision Task with ProM Burden	
High Salience		
Young	0.90 (.26)	0.37 (.12)
Old	0.78 (.13)	0.51 (.09)
Low Salience		
Young	0.75 (.15)	0.38 (.10)
Old	0.76 (.23)	0.69 (.11)

Note: Values in parentheses are standard deviations.

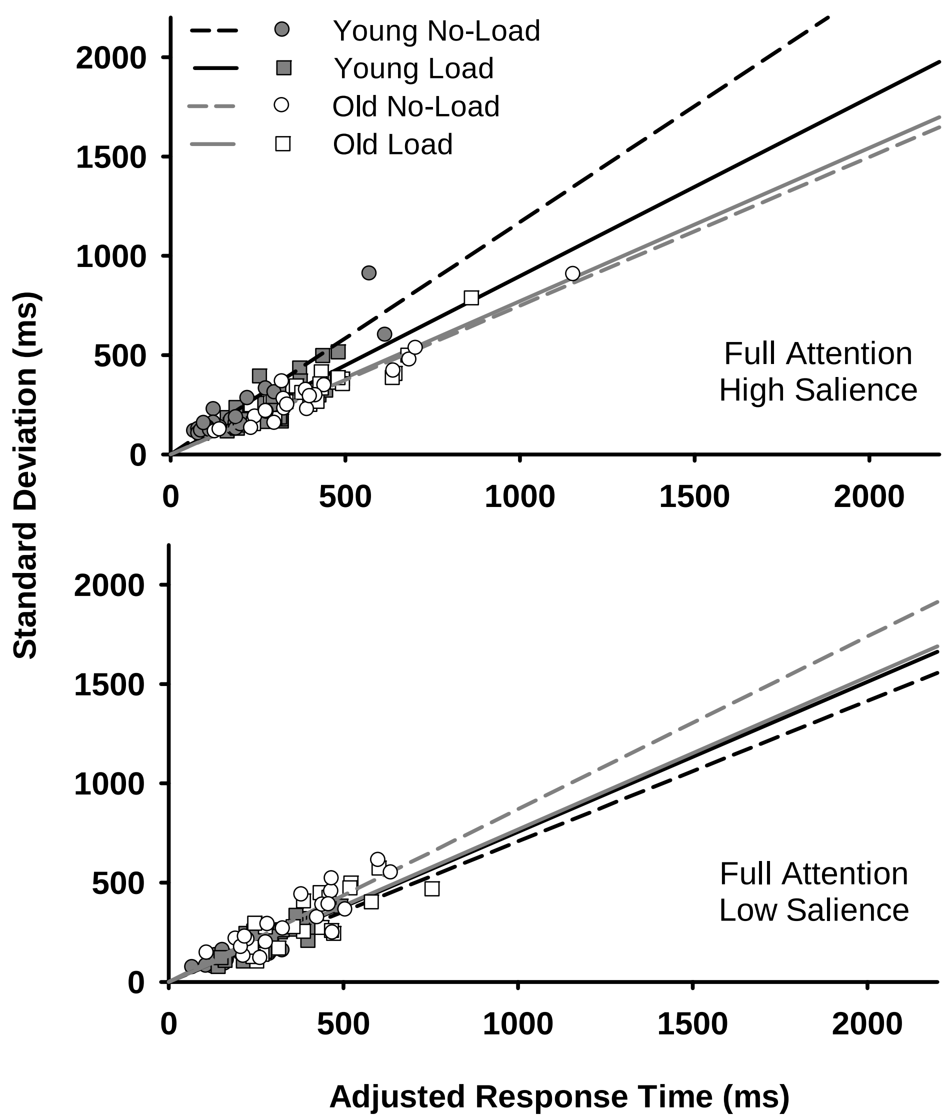

Figure 23. Individual standard deviations for young and older adults from each full attention condition plotted as a function of individual mean response time from which the x-intercept has been subtracted (see text). The lines are best-fitting regression lines. Participants in the high salience condition are displayed in the top panel and participants in the low salience condition are displayed in the bottom panel.

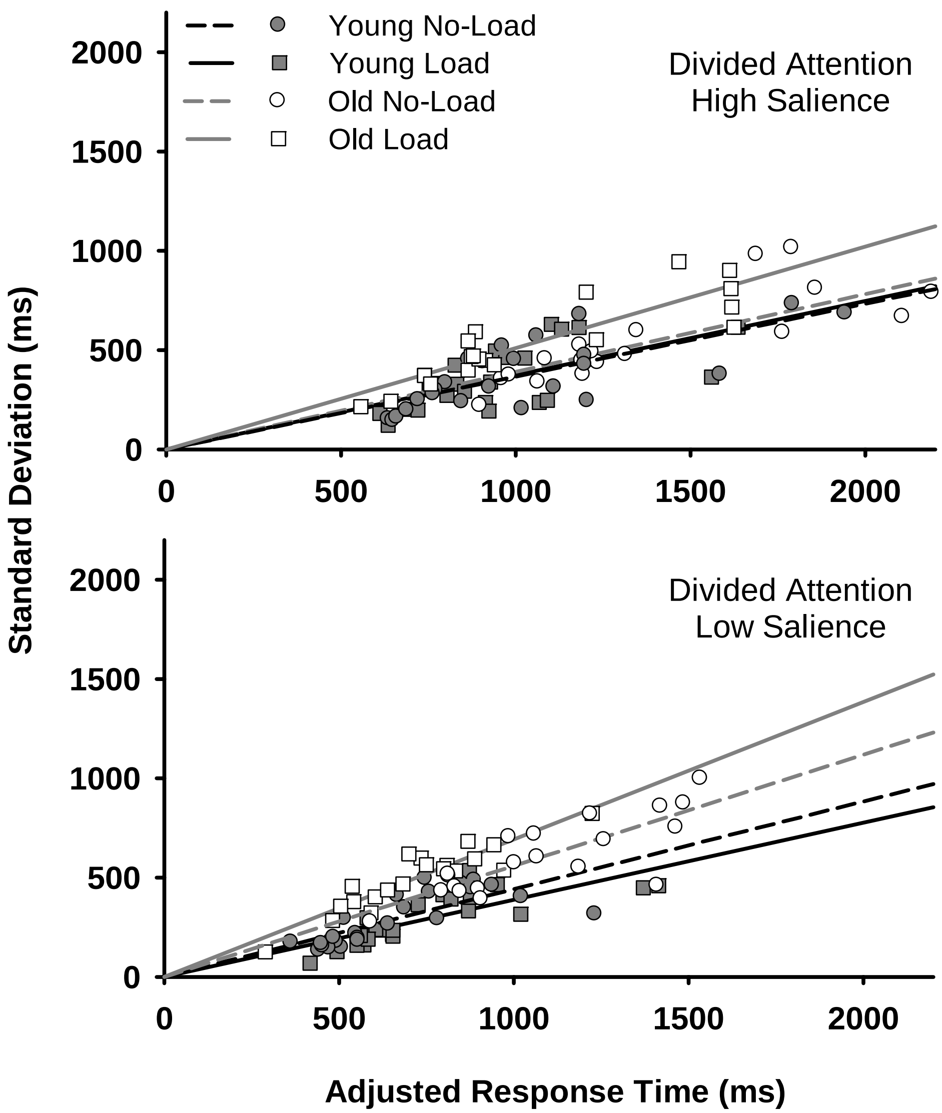

Figure 24. Individual standard deviations for young and older adults from each divided attention condition plotted as a function of individual mean response time from which the x-intercept has been subtracted (see text). The lines are best-fitting regression lines. Participants in the high salience condition are displayed in the top panel and participants in the low salience condition are displayed in the bottom panel.

The CVs were entered into a 2 (age: young, old) X 2 (focality: focal, non-focal) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA in which attention and ProM were within-subjects factors.

There was a main effect of attention, F (1, 83) = 12.42, MSE = .003, η^2 = .82. The full attention condition (M = 0.84, SD = 0.17) resulted in larger CVs than the divided attention condition (M = 0.46, SD = 0.09). The main effects of age and ProM both failed to reach significance (both p's > .05); however these factors were involved in several interactions.

There were several two-way interactions. There was a crossover interaction between the age and attention, F (1, 83) = 36.85, MSE = .003, η^2 = .31. In the full attention condition younger adults (M = 0.89, SD = 0.21) had larger CVs than older adults (M = 0.80, SD = 0.17), t (85) = 2.26, p < .05. On the other hand, in the divided attention condition younger adults (M = 0.39, SD = 0.10) had smaller CVs than older adults (M = 0.54, SD = 0.08), t (85) = 6.90, p < .001. There was also an interaction between age and ProM, F (1, 83) = 25.09, MSE = .001, η^2 = .23. This interaction was due to the fact that there was no difference between the CV of older adults (M = 0.65, SD = 0.10) and young adults (M = 0.68, SD = 0.16) in the no-load condition (p > .05); whereas the older adults (M = 0.68, SD = 0.11) had larger CVs than young adults (M = 0.60, SD = 0.14) in the load condition, t (85) = 3.04, p < .01. There was a significant attention X ProM interaction, F (1, 83) = 37.82, MSE = .001, η^2 = .31. This interaction was due to the fact that CV was higher in the no-load condition (M = 0.89, SD = 0.22) than in the load condition (*M* = 0.80, *SD* = 0.20) when attention was full [*t* (86) = 4.19, *p* < .001], but it was lower in the no-load condition (*M* = 0.44, *SD* = 0.10) than in the load condition (*M* = 0.49, *SD* = 0.10) when attention was divided [*t* (86) = 6.20, *p* < .001].

There were also two three-way interactions. There was a three-way interaction between the age, salience, and ProM factors, *F* (1, 83) = 18.90, *MSE* = .001, η^2 = .19. As can be seen in Figure 25, separate age (young, old) X ProM (no-load, load) ANOVA's conducted for each salience condition revealed that the age X ProM interaction was significant in the high salience condition [*F* (1, 46) = 41.19, *MSE* = .011, η^2 = .50], but not in the low salience condition (*F* < 1). The age X ProM interaction within the high salience condition was due to the younger adults having larger CVs than older adults when there was not a ProM load [*t* (41) = 4.42, *p* < .001], but no significant difference between the age groups when there was a ProM load (*p* > .05).

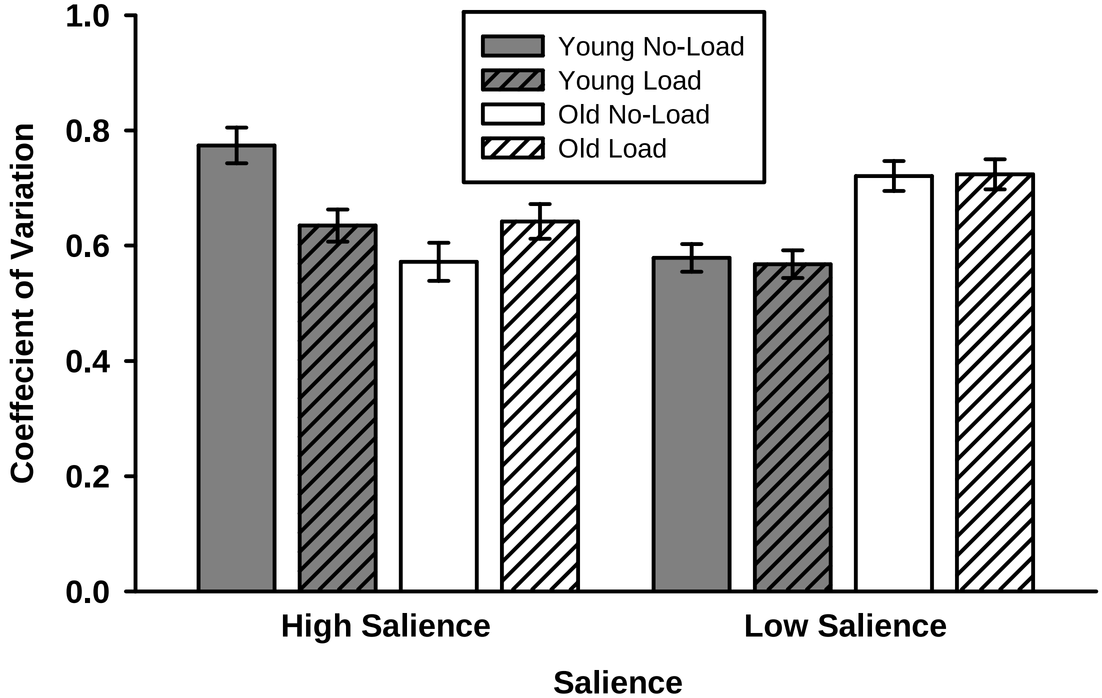

Figure 25. Mean coefficients of variation (± *SE*) for each age group, salience condition, and ProM condition. Each mean is collapsed across the attention factor.

There was also a three-way interaction between the attention, salience, and ProM factors, F (1, 83) = 6.28, MSE = .001, η^2 = .07. The nature of this interaction can be seen in Figure 26. Separate salience X ProM ANOVA's were conducted for each attention condition to localize the source of the interaction and revealed that the salience X ProM interaction was present in the full attention condition [F (1, 83) = 4.44, MSE = .018, η^2 = .05], but not in the divided attention condition (p > .05). Within the full attention condition, the salience X ProM interaction was due to the fact that the CV was larger in the no-load condition than in the load condition when the cue was salient [t (86) = 4.26, p

< .001], but the difference between the no-load and load conditions was not significant when the cue was not salient (p > .05).

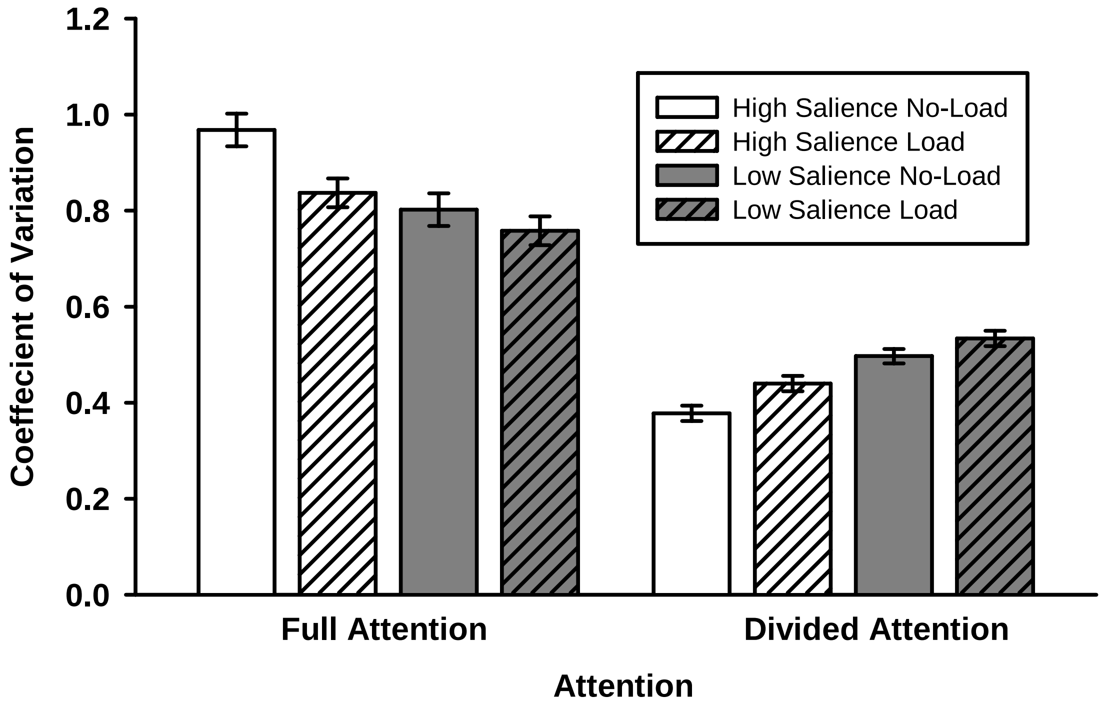

Figure 26. Mean coefficients of variation (± *SE*) for salience condition, level of attention, and ProM condition. Each mean is collapsed across the age factor.

Finally, all effects were qualified by a significant age X attention X salience X ProM interaction [F (1, 83) = 34.00, MSE = .001, η^2 = .29]; however, this interaction turned out not to be interpretable from a theoretical standpoint because the source of the interaction was traced to an attention X salience interaction that was present only in the young adults when there was no ProM load. As pointed out above, the effects of salience can only be interpreted in conjunction with the ProM factor. Given that the salience factor was manipulated between subjects, this interaction was likely the result of sampling bias despite efforts to guard against it using typical sampling strategies.

Analyses of Response Time Distributions

The same procedure used for Experiment 1 was used to remove nonlinearities, such as those observed in Figures 20 and 21, from each individual's data before constructing Q-Q plots, or fitting the Weibull and ex-Gaussian functions for the analyses below.

Quantile-Quantile plots. The Q-Q plots for Experiment 2 were constructed in the same manner as those for Experiment 1. The parameters from the best fitting quadratic equations for each plot are provided in Table 20. Figure 27 allows one to consider whether the burden of a ProM load increased skew when the ProM task involved high salience cues. The top panel compares the RT distributions from the full attention high salience ProM load condition with that from the full attention LDT for both young and older adults. The quadratic components for both age groups were very close to zero, suggesting that the burden of a ProM load did not appreciably increase the skew of the RT distribution in this condition. The bottom panel of Figure 27 compares distributions for the divided attention high salience ProM load condition with that form the divided attention LDT, again for both age groups. Once again, the plots suggest that the distributions had similar shapes as there was very little nonlinearity evident in either plot.

Table 12

Experiment 2: Parameter Values for Second-Order Polynomial Regression Equations Fit to Q - Q Plots

	Full Attention			Divided Attention		
Comparison	B_0	BX	BX^2 e-4	B_0	BX	BX^2 e-4
Old vs. Young (High Sal.)	-21.93	1.37	-0.10	-572.31	2.29	-3.05
Old vs. Young (Low Sal.)	18.84	1.24	1.34	-469.72	2.08	-0.51
	High Salience LDT vs. LDT					
Young Adults	131.40	0.56	5.15	106.20	0.81	1.15
Older Adults	-4.71	1.01	0.41	53.52	0.88	0.13
	Low Salience LDT vs. LDT					
Young Adults	140.27	0.54	3.74	168.56	0.59	0.97
Older Adults	81.42	0.81	0.74	208.70	0.52	1.07
	Low Salience LDT vs. High Salience LDT					
Young Adults	40.58	0.88	-0.28	91.88	0.74	0.12
Older Adults	86.48	0.81	0.36	162.91	0.61	1.08

Figure 28 allows one to consider whether the burden of a ProM load increased skew when the ProM task involved low salience cues. The top panel of Figure 28 compares the RT distributions from the full attention low salience ProM load condition with that from the full attention LDT for both age groups. There was very little nonlinearity evident; although, if anything, there was a very weak tendency for the ProM load distribution to be slightly more skewed than the LDT distribution. The bottom panel of Figure 28 makes the same comparison as that in the top panel, but for divided attention. There was a slight tendency for the ProM load distribution to be more skewed than the LDT distribution.

Figure 29 allows one to consider whether RT distributions associated with low salience ProM cues were more skewed than those associated with high salience ProM cues. The top panel compares these two distributions for the full attention condition. The shapes of the distributions were nearly identical for both age groups. The bottom panel compares the two salience conditions for divided attention. The young adult distributions did not seem to differ much; however, the older adult distributions showed some evidence of greater skew in the low salience condition than the high salience condition.

Finally, Figure 30 allows one to ask whether the distributions of the older adults were significantly more skewed than those of the young adults, separately for each condition involving a ProM burden. The top panel depicts the full attention conditions and the bottom panel shows the divided attention conditions. The larger than unity slopes indicate that older adults were slower than young adults; however, in no case was there overwhelming evidence that the shapes of the older adults distributions were more skewed than those of young adults.

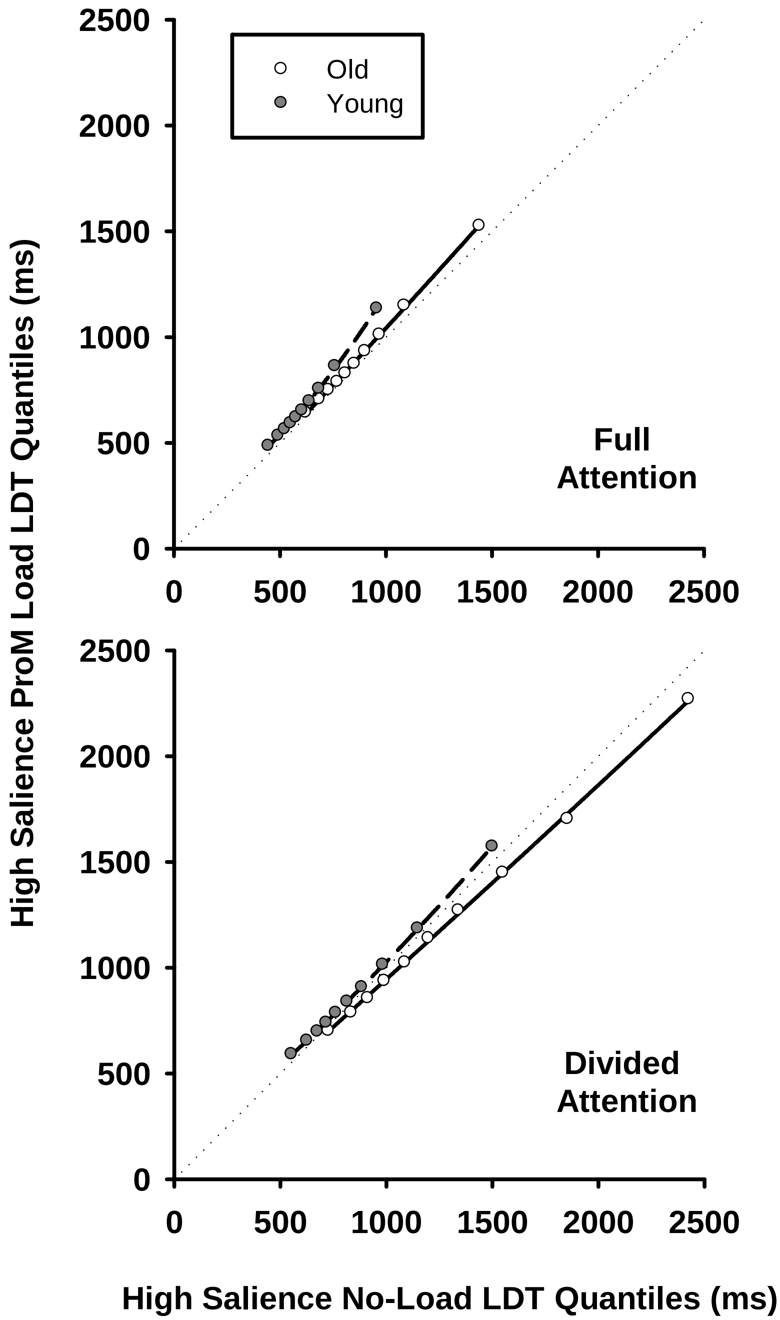

Figure 27. Average ProM load lexical decision task (LDT) quantiles plotted as a function of average no-load LDT quantiles for young and older participants in the high salience condition. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

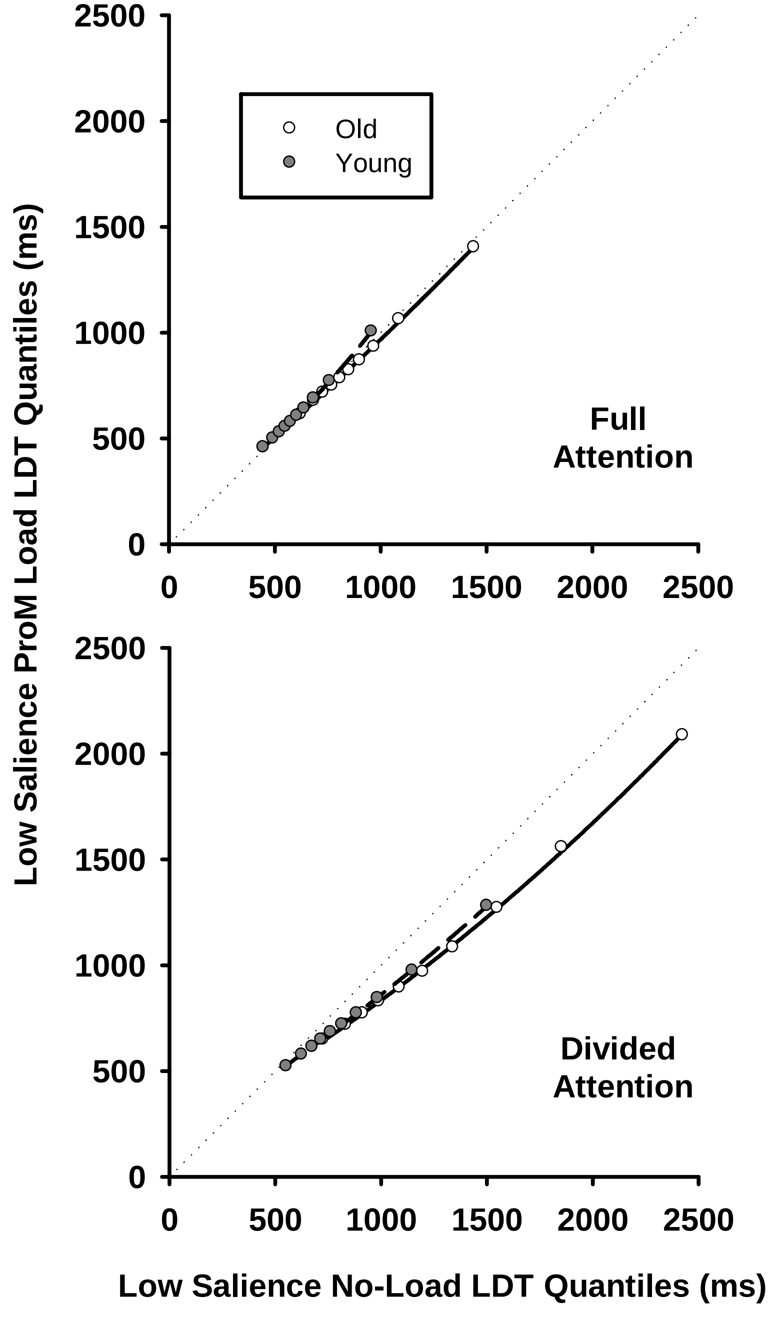

Figure 28. Average ProM load lexical decision task (LDT) quantiles plotted as a function of average no-load LDT quantiles for young and older participants in the low salience condition. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

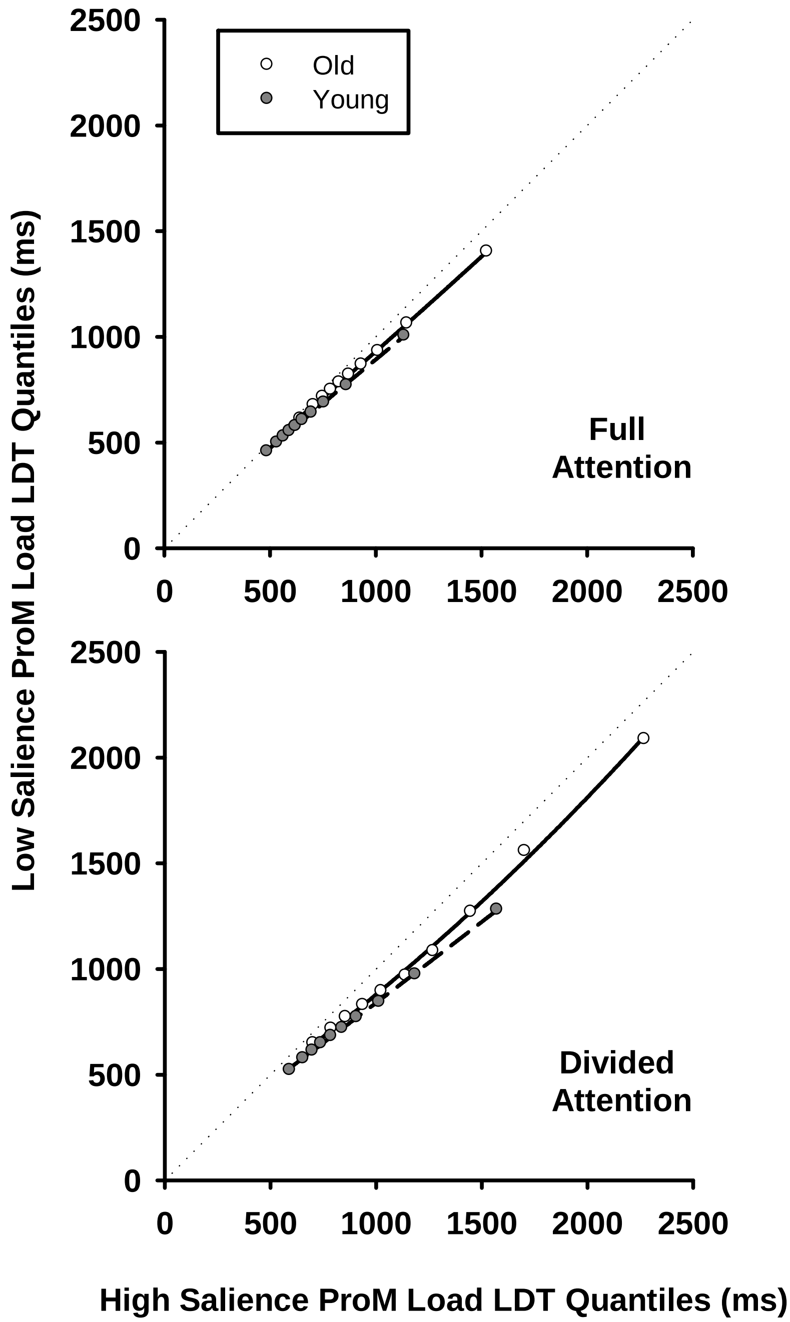

Figure 29. Average ProM load lexical decision task (LDT) quantiles for young and older participants in the low salience condition plotted as a function of average load LDT quantiles for young and older participants in the high salience condition. Data points represent the average 5th, 15, …95th percentiles. Dotted diagonal line is an equality line.

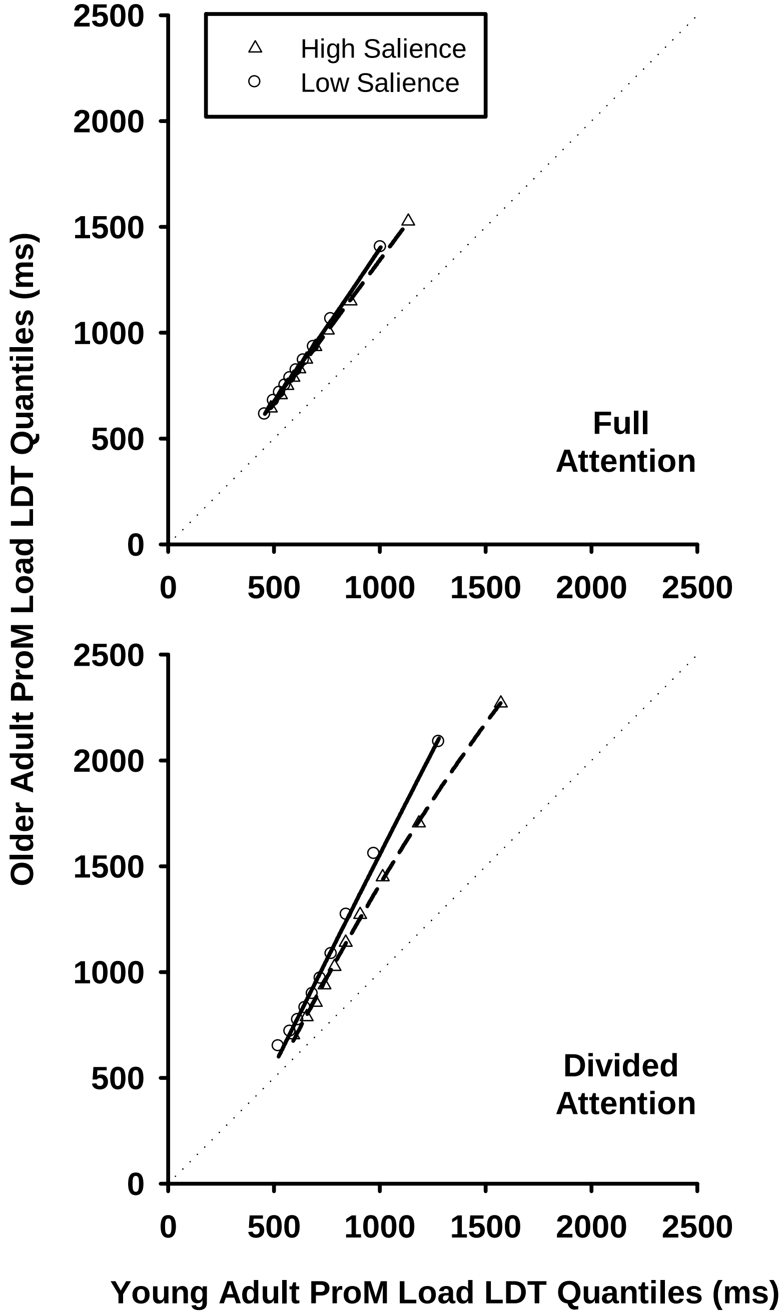

Figure 30. Average older adult ProM load lexical decision task (LDT) quantiles for the high salience and low salience conditions plotted as a function of average young adults load LDT quantiles for the high salience and low salience conditions. Data points represent the average 5^{th}, 15, …95^{th} percentiles. Dotted diagonal line is an equality line.

Ex-Gaussian parameters. The mean ex-Gaussian parameter values for the full attention conditions of Experiment 2 are provided in Table 21 and those for the divided attention conditions are provided in Table 22. The Figures in Appendix H display the histograms and best fitting ex-Gaussian functions for participants whose *mu*, *sigma*, *tau*, or *tau*/*sigma* values were near the median for their respective age group and for a given condition. Each of the parameters were entered into 2 (age: young, old) X 2 (salience: high salience, low salience) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA's in which attention and ProM were within-subjects factors.

Table 13

Experiment 2: Mean ex-Gaussian Parameter Values for Full Attention Conditions

	mu	*sigma*	*tau*	*tau/sigma*
		Lexical Decision Task		
High Salience				
Young	491 (66)	56 (15)	174 (162)	3.04 (2.04)
Old	668 (80)	68 (53)	253 (180)	3.80 (1.27)
Low Salience				
Young	473 (46)	50 (7)	123 (54)	2.47 (1.10)
Old	646 (46)	70 (28)	235 (108)	3.59 (1.69)
		Lexical Decision Task with ProM Burden		
High Salience				
Young	505 (47)	48 (15)	199 (78)	4.29 (1.92)
Old	671 (64)	68 (240	266 (127)	4.05 (1.43)
Low Salience				
Young	480 (45)	46 (11)	164 (57)	3.62 (1.26)
Old	644 (64)	65 (24)	235 (97)	3.70 (1.17)

Note: Values in parentheses are standard deviations.

Table 14

Experiment 2: Mean ex-Gaussian Parameter Values for Divided Attention Conditions

	mu	*sigma*	*tau*	*tau/sigma*
		Lexical Decision Task		
High Salience				
Young	657 (243)	94 (73)	324 (168)	4.71 (3.60)
Old	836 (294)	147 (123)	505 (238)	5.83 (6.94)
Low Salience				
Young	533 (144)	71 (34)	242 (124)	3.66 (1.83)
Old	736 (175)	143 (118)	532 (178)	6.49 (6.82)
		Lexical Decision Task with ProM Burden		
High Salience				
Young	613 (190)	69 (37)	301 (143)	5.06 (3.05)
Old	644 (64)	65 (24)	462 (188)	5.75 (3.39)
Low Salience				
Young	546 (172)	59 (34)	232 (106)	4.18 (1.63)
Old	659 (87)	78 (77)	437 (151)	7.87 (4.37)

Note: Values in parentheses are standard deviations.

With respect to the *mu* parameter, there was a main effect of age such that older adults produced larger parameter values (M = 537, SD = 117) than young adults (M = 702, SD = 108), F (1, 84) = 47.09, MSE = 50608, η^2 = .36. There was a main effect of attention due to the divided attention conditions (M = 668, SD = 188) producing larger parameter values than the full attention conditions (M = 572, SD = 57), F (1, 84) = 30.66, MSE = 25896, η^2 = .27. There was a main effect of ProM resulting from the no-load conditions (M = 630, SD = 130) producing larger parameter values than the load conditions (M = 610, SD = 104), F (1, 84) = 7.98, MSE = 4503, η^2 = .09. The main effect of ProM was qualified by interactions with both age [F (1, 84) = 6.08, MSE = 4503, η^2 = .07] and attention [F (1, 84) = 16.57, MSE = 3459, η^2 = .17]. The age X ProM interaction was characterized by no effect of ProM in the young adults (M = 539, SD = 117 for no-load; M = 536, SD = 107 for load; $p > .05$), but a larger parameter value in the no-load condition (M = 722, SD = 143) than in the load condition (M = 684, SD = 99) for the older adults, t (39) = 3.21, $p < .01$. The attention X ProM interaction was due to the fact that the no-load condition (M = 691, SD = 221) produced larger parameter values than the load condition (M = 645, SD = 171) when attention was divided [t (87) = 3.58, $p < .01$], whereas there was no significant difference between the no-load (M = 570, SD = 65) and load (M = 575, SD = 55) conditions when attention was undivided ($p > .05$). Finally, there was a three-way interaction between age, ProM, and attention, F (1, 84) = 4.08, MSE = 3459, η^2 = .05. This interaction is shown in Figure 31. Separate 2 (age: young, old) X 2 (ProM: no-load, load) ANOVA's were conducted for each attention condition to resolve this interaction. The age X ProM interaction was not significant for the full attention condition ($p > .05$), whereas it was for the divided attention condition [F (1, 84) = 5.63, MSE = 7171, $\eta^2 = .06$]. Within the divided attention condition, the interaction was due to the fact that the age difference in the *mu* parameter was larger in the no-load condition [t (86) = 3.98, $p < .001$] than in the load condition [t (86) = 3.51, $p < .01$]. There were no other significant main effects or interactions involving the *mu* parameter.

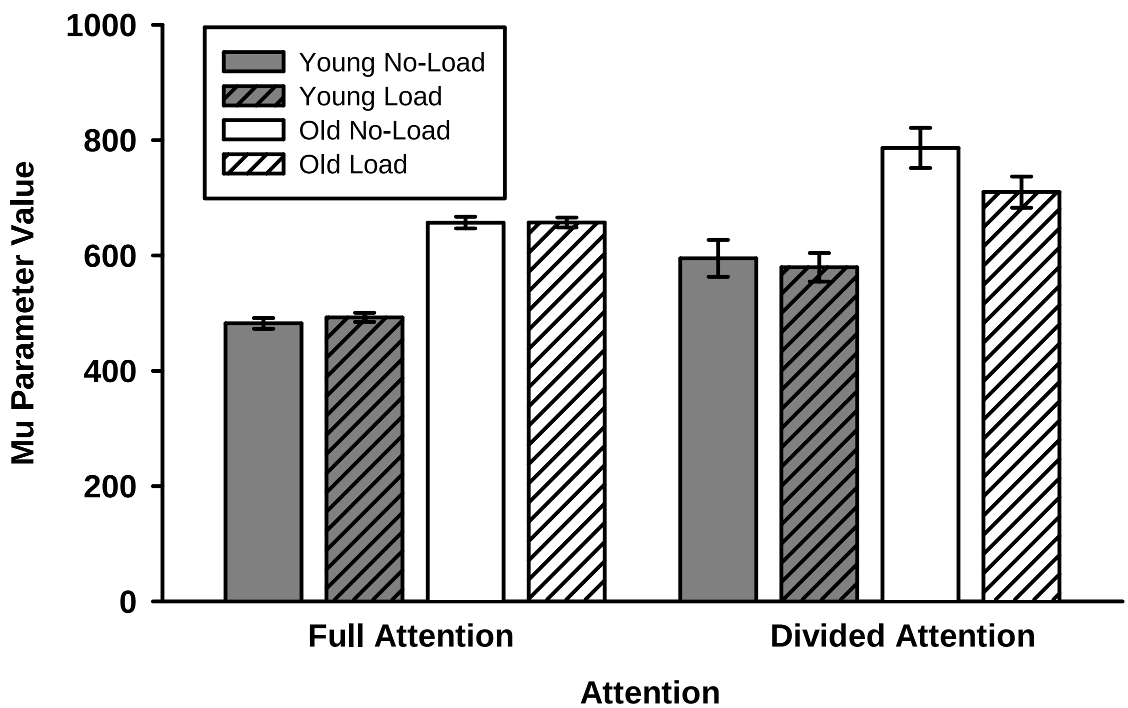

Figure 31. Mean ex-Gaussian *mu* parameter value (± *SE*) for each level of attention, ProM, and age group. Each mean is collapsed across the salience factor.

Regarding the *sigma* parameter, there was again a main effect of age, F (1, 84) = 12.87, MSE = 8413, η^2 = .13. Older adults (M = 97, SD = 64) produced larger parameter values than young adults (M = 62, SD = 22). There was a main effect of attention such that the divided attention conditions (M = 99, SD = 81) resulted in larger parameter values than the full attention conditions (M = 59, SD = 20), F (1, 84) = 26.49, MSE = 5379, η^2 = .24. There was a main effect of ProM such that the load conditions (M = 71, SD = 46) produced smaller parameter values than the no-load conditions (M = 87, SD = 52), F (1, 84) = 21.61, MSE = 1047, η^2 = .21. There was an age X attention interaction, F (1, 84) = 5.00, MSE = 5379, η^2 = .06. This was due to the fact that dividing attention had a larger impact on the parameter value for the older adults [M = 68, SD = 28 for full attention; M = 126, SD = 111 for divided attention; t (39) = 3.66, $p < .01$] than for the young adults [M = 50, SD = 10 for full attention; M = 73, SD = 41 for divided attention; t (47) = 4.07, $p < .001$]. There was a ProM X attention interaction, F (1, 84) = 8.23, MSE = 1534, η^2 = .09. This interaction was characterized by a significant decrease in *sigma* from the no-load (M = 113, SD = 92) to load (M = 85, SD = 83) conditions when attention was divided [t (87) = 3.98, $p < .001$], but no difference between the no-load (M = 61, SD = 30) and load (M = 57, SD = 19) conditions when attention was full ($p > .05$). There was an age X salience X ProM interaction that is depicted in Figure 32, F (1, 84) = 7.59, MSE = 1047, η^2 = .08. Separate 2 (salience: high, low) X 2 (ProM: no-load, load) ANOVA's were conducted for each age group to confirm the nature of the interaction. The salience X ProM interaction was not significant for the young adults ($p > .05$); however, it was for the older adults [F (1, 38) = 6.03, MSE = 1430, η^2 = .14]. Within the older adults, the interaction stemmed from the fact that there was no difference between the no-load and load conditions when the ProM cue was highly salient ($p > .05$), whereas the no-load condition produced larger parameter values than the load conditions when the ProM cue was low in salience, t (19) = 4.36, $p < .001$. There were no other significant interactions involving the *sigma* parameter.

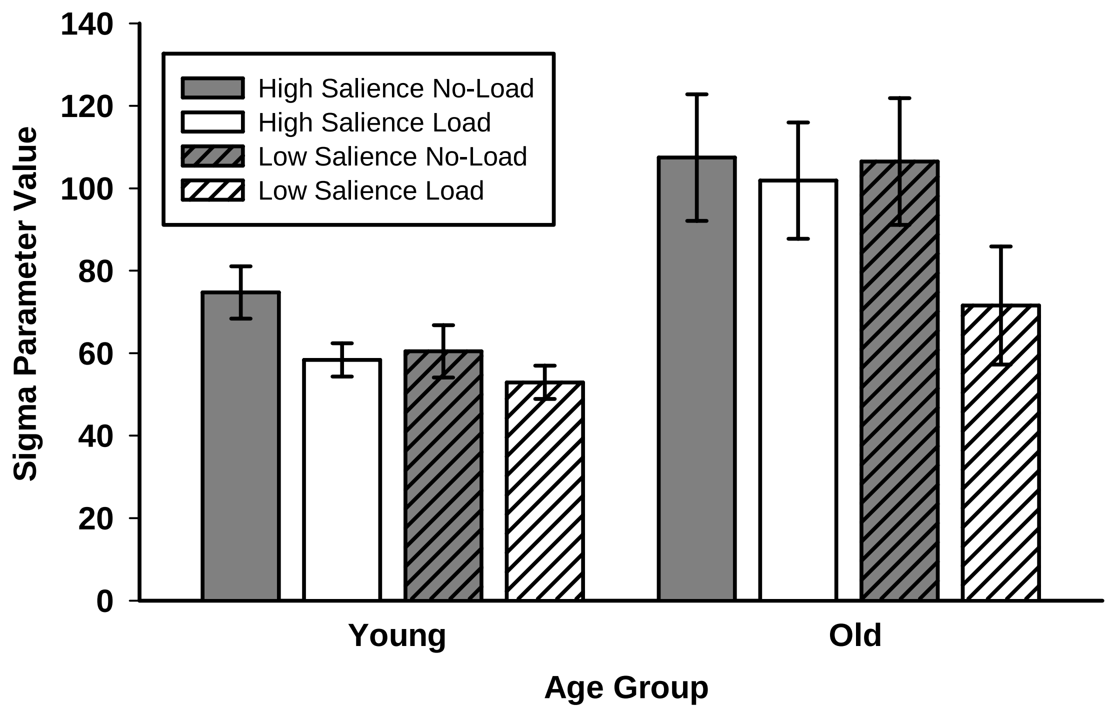

Figure 32. Mean ex-Gaussian *sigma* parameter value (± *SE*) for each salience condition, level of ProM, and age group. Each mean is collapsed across the attention factor.

As for the *tau* parameter, there was again a main effect of age, F (1, 84) = 34.19, MSE = 54246, η^2 = .29. Older adults (M = 366, SD = 138) produced larger parameter values than young adults (M = 220, SD = 95). There was a main effect of attention due to the divided attention condition (M = 379, SD = 158) producing larger parameter values than full attention condition (M = 206, SD = 106), F (1, 84) = 150.83, MSE = 17359, η^2 = .64. There was not a main effect of ProM, but there was an age X ProM interaction [F (1, 84) = 7.09, MSE = 4666, η^2 = .08] such that there was a non-significant tendency for the *tau* parameter to be larger in the load (M = 224, SD = 91) than in the no-load (M = 216, SD = 110) condition for young adults ($p > .05$); whereas, the load condition (M = 350, SD = 124) resulted in a significantly smaller parameter value than the no-load condition (M = 381, SD = 159) for older adults, t (39) = 2.69, $p < .05$. There was an age X attention interaction, F (1, 84) = 20.26, MSE = 17359, η^2 = .19. This was due to the fact that dividing attention had a larger impact on the *tau* parameter for older adults [M = 247, SD = 128 for full attention; M = 484, SD = 183 for divided attention; t (39) = 9.63, $p < .001$] than for young adults [M = 165, SD = 82 for full attention; M = 275, SD = 132 for divided attention; t (47) = 7.02, $p < .001$]. There was a ProM X attention interaction, F (1, 84) = 22.67, MSE = 3809, η^2 = .21. This interaction was characterized by the fact that there was no significant difference between the no-load (M = 196, SD = 134) and load (M = 216, SD = 92) conditions when attention was full ($p > .05$), but the no-load condition (M = 401, SD = 179) resulted in a larger parameter value than the load condition (M = 358, SD = 148) when attention was divided, t (87) = 4.28, $p < .001$. No other main effects or interactions reached significance.

Concerning the *tau*/*sigma* ratio, older adults (*M* = 5.14, *SD* = 2.24) produced more skewed distributions than young adults (*M* = 3.89, *SD* = 1.35), *F* (1, 84) = 10.50, *MSE* = 13, η^2 = .11. Dividing attention (*M* = 5.44, *SD* = 3.62) resulted in larger ratios than full attention (*M* = 3.57, *SD* = 1.29), *F* (1, 84) = 18.9, *MSE* = 16, η^2 = .18. There was also a main effect of ProM, *F* (1, 84) = 5.35, *MSE* = 6, η^2 = .06. The load condition (*M* = 4.82, *SD* = 1.74) resulted in more skewed distributions than the no-load condition (*M* = 4.20, *SD* = 2.56). Importantly, the age X attention interaction was significant at the trend level, *F* (1, 84) = 3.66, *MSE* = 16, η^2 = .04, *p* = .059. This interaction was characterized by the fact that older adults (*M* = 6.49, *SD* = 4.80) produced more skewed distributions than young adults (*M* = 4.40, *SD* = 2.17) in the divided attention conditions [*t* (86) = 2.70, *p* < .01], but not in the undivided attention conditions (*M* = 3.79, *SD* = 1.10 for older adults; *M* = 3.35, *SD* = 1.43 for young adults; *p* > .05). No other interactions reached significance.

Weibull parameters. The Figures in Appendix I display the histograms and best fitting Weibull functions for participants whose *shift*, *scale* or *shape* parameters were near the median for their age group and for a given condition. The mean Weibull parameter values for the full and divided attention conditions are provided in Tables 23 and 24, respectively. Each of the parameters were entered into 2 (age: young, old) X 2 (salience: high salience, low salience) X 2 (attention: full, divided) X 2 (ProM: no-load, load) mixed ANOVA's in which attention and ProM were within-subjects factors.

Table 15

Experiment 2: Mean Weibull Parameter Values for Full Attention Conditions

	shift	*scale*	*shape*
		Lexical Decision Task	
High Salience			
Young	416 (71)	253 (136)	1.81 (0.40)
Old	578 (93)	347 (283)	1.63 (0.27)
Low Salience			
Young	401 (56)	204 (36)	1.86 (0.41)
Old	558 (78)	316 (98)	1.80 (0.54)
		Lexical Decision Task with ProM Burden	
High Salience			
Young	458 (47)	237 (63)	1.49 (0.20)
Old	595 (64)	336 (127)	1.58 (0.40)
Low Salience			
Young	429 (55)	212 (48)	1.59 (0.26)
Old	565 (69)	303 (106)	1.69 (0.40)

Note: Values in parentheses are standard deviations.

Table 16

Experiment 2: Mean Weibull Parameter Values for Divided Attention Conditions

	shift	*scale*	*shape*
		Lexical Decision Task	
High Salience			
Young	537 (166)	450 (267)	1.56 (0.41)
Old	622 (205)	745 (458)	1.55 (0.50)
Low Salience			
Young	451 (110)	327 (146)	1.62 (0.35)
Old	576 (125)	707 (351)	1.34 (0.42)
		Lexical Decision Task with ProM Burden	
High Salience			
Young	545 (148)	362 (161)	1.42 (0.29)
Old	635 (89)	604 (367)	1.28 (0.25)
Low Salience			
Young	483 (143)	289 (135)	1.52 (0.22)
Old	594 (72)	486 (209)	1.25 (0.43)

Note: Values in parentheses are standard deviations.

Regarding the *shift* parameter, there was a main effect of age such that older adults (M = 590, SD = 73) produced larger parameter values than young adults (M = 465, SD = 88), F (1, 84) = 51.75, MSE = 26434, η^2 = .38. There was a main effect of attention, F (1, 84) = 22.16, MSE = 12081, η^2 = .21. The parameter value was larger in the divided attention condition (M = 555, SD = 126) than in the full attention condition (M = 500, SD = 59). There was a main effect of ProM, F (1, 84) = 10.23, MSE = 3560, η^2 = .11. The *shift* parameter was larger in the load condition (M = 538, SD = 81) than the no-load condition (M = 517, SD = 92). There was an age X attention interaction, F (1, 84) = 3.73, MSE = 12081, η^2 = .04. This interaction was due to there being a larger effect of attention in the young adults [M = 426, SD = 52 for full attention; M = 504, SD = 139 for divided attention; t (47) = 4.69, p < .001] than in the older adults [M = 574, SD = 65 for full attention; M = 607, SD = 108 for divided attention; t (39) = 2.00, p = .052].

With respect to the *scale* parameter, there was again a main effect of age, F (1, 84) = 26.07, MSE = 119363, η^2 = .24. Older adults (M = 481, SD = 229) produced larger parameter values than young adults (M = 292, SD = 106). There was a main effect of attention, F (1, 84) = 94.02, MSE = 45054, η^2 = .53. The *scale* parameter was larger in the divided attention condition (M = 496, SD = 264) than in the full attention condition (M = 276, SD = 115). There was a main effect of ProM, F (1, 84) = 35.29, MSE = 10512, η^2 = .30. The *scale* parameter value was larger in the no-load condition (M = 419, SD = 209) than in the load condition (M = 354, SD = 147). There was an age X attention interaction, F (1, 84) = 15.59, MSE = 45054, η^2 = .16. Specifically, dividing attention had a larger effect on the *scale* parameter for the older adults [M = 326, SD = 155 for full attention; *M* = 636, *SD* = 342 for divided attention; *t* (39) = 7.25, $p < .001$] than for the young adults [*M* = 226, *SD* = 64 for full attention; *M* = 357, *SD* = 171 for divided attention; *t* (47) = 6.12, $p < .001$]. There was an age X ProM interaction, *F* (1, 84) = 8.25, *MSE* = 10512, $\eta^2 = .09$. The *scale* parameter was smaller in the load condition (*M* = 275, *SD* = 94) than the no-load condition (*M* = 309, *SD* = 131) for young adults [*t* (47) = 2.73, $p < .01$], but the difference between the load (*M* = 432, *SD* = 192) and no-load (*M* = 529, *SD* = 274) conditions was even larger for the older adults [*t* (39) = 5.09, $p < .001$]. Finally, there was an attention X ProM interaction, *F* (1, 84) = 23.92, *MSE* = 11949, $\eta^2 = .22$. The *scale* parameter was smaller in the load (*M* = 435, *SD* = 230) than in the no-load (*M* = 557, *SD* = 319) condition when attention was divided [*t* (87) = 6.62, $p < .001$], but there was no difference between the load (*M* = 272, *SD* = 89) and no-load (*M* = 280, *SD* = 161) condition when attention was not divided ($p > .05$). No other main effects or interactions involving the *scale* parameter reached significance.

Regarding the *shape* parameter, there was a marginally significant ($p = .055$) main effect of age, *F* (1, 84) = 3.79, *MSE* = .192, $\eta^2 = .04$. Older adults (*M* = 1.52, *SD* = 0.23) produced more skewed distributions than young adults (*M* = 1.61, *SD* = 0.21). There was a main effect of attention, *F* (1, 84) = 25.98, *MSE* = .188, $\eta^2 = .24$. RT distributions were more skewed in the divided attention condition (*M* = 1.44, *SD* = 0.33) than in the full attention condition (*M* = 1.68, *SD* = 0.29). There was a main effect of ProM, *F* (1, 84) = 33.33, *MSE* = .076, $\eta^2 = .28$. RT distributions were more skewed in the load condition (*M* = 1.48, *SD* = 0.23) than in the no-load condition (*M* = 1.65, *SD* = 0.28). Finally, there was a three-way interaction between the age, attention, and ProM factors, *F* (1, 84) =

5.14, *MSE* = .082, η^2 = .06. The means involved in this interaction are represented in Figure 33. Separate 2 (attention: full, divided) X 2 (ProM: no-load, load) ANOVA's were conducted for each age group to resolve this interaction. The attention X ProM interaction was significant for young adults [F (1, 46) = 6.90, *MSE* = .053, η^2 = .13], but not for older adults ($p > .05$). Within the young adults the interaction was due to the fact that distributions were more skewed in the divided attention condition than in the full attention condition when there was not a ProM load [t (47) = 3.40, $p < .01$], but there was not a significant effect of attention when there was a ProM load ($p > .05$). No other interactions reached significance.

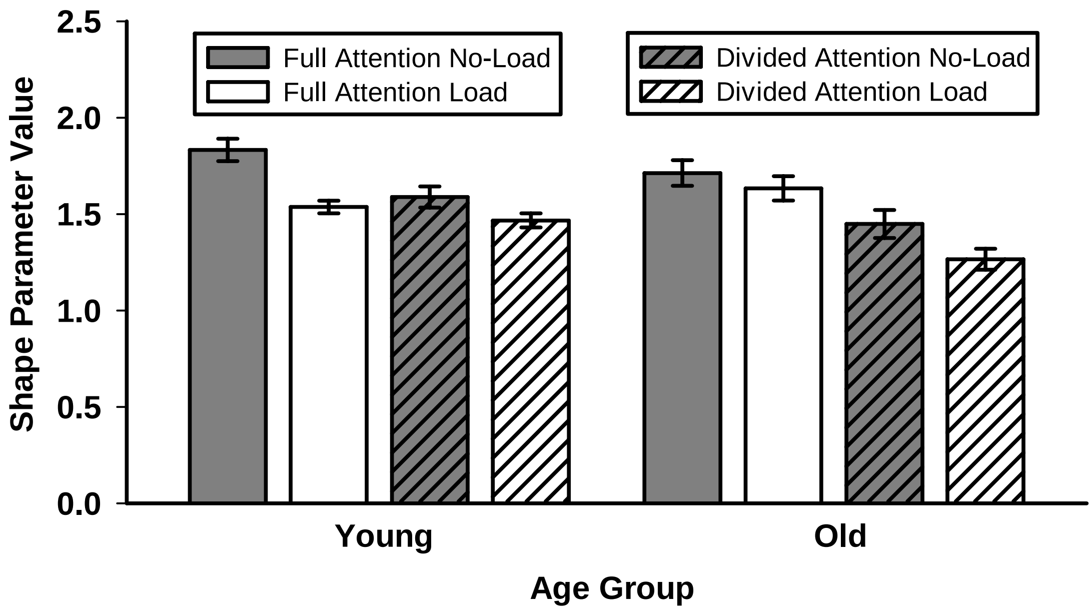

Figure 33. Mean Weibull *shape* parameter values (± *SE*) for each level of attention, ProM condition, and age group. Each mean is collapsed across the salience factor.

Individual Differences

As was done for Experiment 1, a series of hierarchical regression analyses were conducted for Experiment 2 to determine whether individual differences in processing speed and/or intraindividual variability predict ProM performance, or account for age differences in ProM performance where they exist. Age was again dummy-coded such that young adults were assigned a code of 0 and older adults were given a code of 1. As was the case in Experiment 1, in some instances suppression was evident, so the order of entry was reversed in each of the analyses presented below, despite the fact that there weren't always significant age differences in ProM performance to account for. Separate analyses were conducted for each salience and attention condition. Results of the hierarchical regression analyses are reported in the Tables in Appendix J. The results of these analyses are described below.

On-Going LDT Measure as a Predictor

Median response time. Once again, although not critical to the hypotheses being investigated, median RT is nonetheless considered here as a predictor of ProM performance, for exploratory purposes. The full attention conditions are considered first. In the high salience condition, median RT did not predict ProM performance after controlling for age. Median RT still did not predict ProM performance when entered first, but evidence of suppression was again present as the amount of variance accounted for by age actually increased slightly from 7.0% to 8.4% when entered second. In the low salience condition median RT did not predict ProM performance when entered after age, which accounted for 23.5% of the variance. Not surprisingly given the age differences in both ProM and median RT for this condition, median RT was negatively related to ProM performance when entered first. More interesting was the fact that entering median RT first did not eliminate the effect of age.

Turning now to the divided attention conditions, the proportion of variance accounted for in the high salience condition by median RT (7.2%) after controlling for age was significant at the trend level (p = .08). Specifically, slower speed on the on-going LDT tended to correspond with better ProM performance. Suppression was again evident when the order of entry was reversed. Median RT no longer reliably predicted ProM performance, but the proportion of variance accounted for by age actually increased from 5.0% to 10.1%, which was significant. With respect to the low salience condition, median RT accounted for a significant 8.1% of the variance after controlling for age, which accounted for 17.9% of the variance. Once again, slower speed on the on-going task was associated with better ProM performance. When median RT was entered before age, it accounted for very little variance (0.2%) in ProM performance, but the amount of variance accounted for by age increased to 25.8%. Thus, suppression was again a feature of the relationships between age, speed, and ProM performance.

Coefficient of variation. Regarding the full attention high salience condition, CV did not account for a significant proportion of variance in ProM performance after controlling for age. When the order of entry was reversed there was evidence of a suppressive relationship between age and CV as the proportion of variance accounted for by age increased from 7.0% when entered first to a significant 8.7% when entered second. As for the full attention low salience condition CV did not account for variance in ProM performance after controlling for age, nor did it account for age differences in ProM performance when entered into the equation first.

Turning now to the divided attention high salience condition, the same suppressive relationship observed for the full attention condition was seen here as well. That is, CV did not account for variance in ProM performance after controlling for age, and when the order of entry was reversed, the amount of variance accounted for by age increased from 5.0% when entered first to a marginally significant 8.3% when entered after CV. In the divided attention low salience condition CV did not account for a significant proportion of variance in ProM performance after controlling for age. When the order of entry was reversed CV accounted for a significant 8.1% of the variance, but age continued to account for a significant proportion of variance in ProM performance.

Tau/sigma. The salience conditions for which attention was undivided are again considered first. Neither age nor skew predicted ProM performance in the high salience condition, and this did not change when the order of entry was reversed. In the low salience condition, skew did not predict ProM performance after controlling for age. When the order of entry was reversed skew still did not predict performance and it did not eliminate the effect of age.

Regarding the conditions for which attention was divided, in the high salience condition neither age nor skew predicted ProM performance and this remained the case when the order of entry was reversed. As for the low salience condition, skew did not predict ProM performance after controlling for age. When the order of entry was reversed, skew still did not predict performance. The amount of variance accounted for by age was reduced slightly from 17.9% to a still significant 14.2%.

Weibull shape. Again, the conditions for which attention was undivided are considered first. In the high salience condition, neither age nor *shape* predicted ProM performance, and this did not change when the order of entry was reversed. In the low salience condition, *shape* did not predict performance after controlling for age. When the order of entry was reversed, age still predicted ProM performance, although the amount of variance accounted for by age was reduced slightly from 23.5% to a still significant 20.7%.

Turning now to the salience conditions in which attention was divided, neither age nor *shape* predicted ProM performance in the high salience condition and this was still the case when the order of entry was reversed. In the low salience condition, the amount of variance accounted for by *shape* (5.9%) was significant at the trend level (p = .08) after controlling for age. However, the relationship between *shape* and ProM performance was in the opposite direction of what was expected. As skew increased, ProM performance also increased. Furthermore, when the order of entry was reversed, *shape* no longer predicted ProM performance and the proportion of variance accounted for by age actually increased from a significant 17.9% to 23.4%, once again demonstrating the presence of suppression.

Two-Back Measure as a Predictor

The average median RT, proportion correct, coefficient of variation, ex-Gaussian parameters, and Weibull parameters for each age group are provided in Table 29.

Table 17

Experiment 2: Median Response Time, Accuracy, Coeffecient of Variation, Ex-Gaussian Parameters, & Weibull Parameters for the Two-Back Task

Measure	Young	Old
Median RT	620 (89)	1215 (372)
Accuracy	0.93 (.04)	0.88 (.09)
CV	1.05 (.20)	0.78 (.15)
	Ex - Gaussian Parameters	
mu	410 (49)	737 (163)
sigma	75 (21)	177 (96)
tau	299 (146)	680 (392)
tau/sigma	4.47 (3.97)	4.62 (5.25)
	Weibull Parameters	
shift	323 (45)	548 (112)
scale	393 (125)	901 (472)
shape	1.55 (.29)	1.49 (.25)

Note: Standard deviations are in parentheses. Also, age differences for all measures except the *tau/sigma* ratio and the *shape* parameter are significant at the .05 level.

Median response time. First considering the full attention conditions, neither age nor median RT predicted ProM performance in the high salience condition, and this did not change when the order of entry was reversed. In the low salience condition, median RT did not reliably predict performance after controlling for age. When the order of entry was reversed, median RT accounted for a significant 22.1% of the variance and was negatively associated with ProM performance. The amount of variance accounted for by age was reduced from a significant 23.5% to a non-significant 4.0%. Thus, this pattern likely reflects the fact that older adults perform worse on the ProM task and are slower on the two-back task.

With respect to the divided attention conditions, after controlling for age in the high salience condition, the amount of variance in ProM performance accounted for by median RT (6.9%) was significant at the trend level (p = .08). People who were slower on the two-back task tended to do better on the high salience ProM task. When the order of entry was reversed, median RT no longer predicted performance. The amount of variance accounted for by age actually increased from a non-significant 5.0% to a significant 11.9%, suggesting suppression. In the low salience condition median RT did not reliably predict ProM performance after controlling for age. When the order of entry was reversed median RT accounted for a significant 10.7% of the variance. The amount of variance accounted for by age was reduced from a significant 17.9% to 7.3%, which was significant at the trend level (p = .06).

Coefficient of variation. Looking first at the full attention high salience condition, after controlling for age, two back CV accounted for an additional 6.2% of the variance in ProM performance, which was significant at the trend level (p = .09). When the order of entry was reversed CV actually failed to predict ProM performance and the amount of variance accounted for age increased from 7.0% to a significant 13.2% of the variance, thus revealing suppression. No suppression was evident in the full attention low salience condition. Two-back CV did not account for a significant proportion of variance in ProM performance after controlling for age, nor did it significantly alter the amount of variance accounted for by age when the order of entry was reversed.

Turning now to the divided attention conditions, two back CV accounted for a marginally significant 8.1% of the variance in ProM performance in the high salience condition after controlling for age. In this case, an increase in two-back CV was associated with a decrease in ProM performance. Reversing the order of entry indicated suppression between age and two-back CV here as well. When entered first CV only accounted for a non-significant 0.4% of the variance, but the amount of variance accounted for by age increased from 5.0% to a significant 12.7%. In the divided attention low salience condition, two-back CV did not account for additional variance in ProM performance beyond that explained by age, nor did it significantly reduce the amount of variance accounted for by age when the order of entry was reversed.

Tau/sigma. When attention was undivided, skew accounted for a significant 9.4% of the variance in ProM performance in the high salience condition after controlling for age. There was no clear evidence of suppression in this case as skew also accounted for a significant 9.9% of the variance when entered before age, which still failed to reliably predict ProM performance. In the low salience condition, skew did not reliably predict ProM performance or account for age differences in ProM performance.

When attention was divided, neither age group nor skew accounted for ProM performance in the high salience condition and this remained the case when the order of entry was reversed. In the low salience condition, skew did not reliably predict ProM performance or account for age differences in ProM performance.

Weibull shape. When attention was undivided, *shape* accounted for a significant 9.4% of the variance in ProM performance in the high salience condition after controlling for age. There was no evidence of suppression in this case as the *shape* parameter also accounted for a significant 12.1% of the variance when entered before age, which still did not reliably predict ProM performance in this condition. In the low salience condition the *shape* parameter did not reliably predict ProM performance or account for age differences in ProM performance.

With respect to the ProM conditions in which attention was divided, neither age nor *shape* predicted ProM performance in the high salience condition, and this remained the case when the order of entry was reversed. As for the low salience condition, the *shape* parameter did not reliably predict ProM performance or account for age differences.

Summary & Discussion: Experiment 2

ProM performance in Experiment 2 was again largely as expected. The results were consistent with the multiprocess framework. As predicted, performance was better for high salience targets than for low salience targets. Furthermore, dividing attention didn't adversely affect performance for high salience targets, whereas, it did tend to lower performance for low salience targets. Older adults performed significantly worse than young adults, also as predicted. The expected age X Salience interaction failed to reach significance, however, a look at Figure 19 shows that the pattern of data was clearly in the anticipated direction. The failure to reach significance in this case may have been due to the fact that the older adults were very nearly at floor in the low salience divided attention condition. Once again, older adults performed worse than young adults in the condition that was intended to minimally engage cue-focused processes.

As was the case in Experiment 1, performance was again fairly low in what should have been the condition with the best performance (viz. the full attention high salience condition). Thus, as may have been the case in the first experiment, it is possible that reflexive-associative processes were not sufficient to perform any of the ProM task conditions successfully. Some support for this again comes from looking at the cost analyses for the full attention conditions. Specifically, although young adults had better ProM performance than older adults in both full attention salience conditions, the young adults incurred costs whereas the older adults did not. The fairly low performance in the low salience full attention condition isn't surprising because this condition in this experiment was very similar to the focal condition in Experiment 1, with the only difference being in the particular words that were used as ProM targets. Therefore, the number of cues is again a likely explanation for the overall low performance.

Regarding performance on the on-going LDT, the same unintended consequences of the digit monitoring task that were observed in Experiment 1 were also observed in Experiment 2. That is, there was a substantial practice effect observed for performance in the divided attention conditions that was more substantial for older adults than young adults. However, the attention X ProM interaction indicated that the expected burden of a ProM load was evident when attention was full, and there is no reason to think that the ProM load wouldn't also affect the speed of performance when attention is divided. As mentioned above, the practice effect in the divided attention conditions is likely obscuring the cost associated with the ProM load. This is also suggested by the attention X ProM load present in several of the other measures (viz. *mu*, *sigma*, *tau*, *scale*, and CV). Although the expected effect of the ProM burden on speed of performance seemed to be present, there was no evidence that the cost depended on whether the cues were salient or not.

Turning now to the issue of performance variability, it may be helpful to once again recall that there were two hypotheses related to group differences in intraindividual variability. The first hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task and this increase is larger for tasks relying more on cue-focused processes than those relying less on cue-focused processes. The second hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes more for older adults than for younger adults.

The CV measure again yielded puzzling results, but results that were consistent with what was found in the first experiment. For one, the CV measure indicated that performance was more variable when attention was full than when it was divided, the opposite of what was expected, but the same as what was found in the first experiment. Also, opposite of the prediction made by the first hypothesis, performance tended to be more variable when there was not a ProM burden than when there was, although not significantly so. As mentioned above, these curious findings will be discussed further in the general discussion. On the other hand, there were a couple of two-way interactions that were somewhat in congruence with second hypothesis of the study. Specifically, age interacted with both ProM and attention, such that older adults had larger CVs when there was a ProM load and when attention was divided, but not when attention was full or when there wasn't a ProM load. Although the age X ProM interaction was qualified by a three-way interaction involving the salience factor, this interaction did not necessarily violate expectations. That is, although the source of the three-way interaction was traced to an age X ProM interaction within the high salience condition that was in a surprising direction, it was still the case that older adults were more variable in the condition in which they were expected to be more variable (specifically, the low salience condition, but not the high salience condition). As mentioned in the summary of results for the first experiment, although the results of the CV analyses are interesting from the standpoint of comparison with other studies on intraindividual variability and aging, it is the analyses of the shapes of distributions that are most important to the hypotheses of the current study.

Once again, inspection of the Q-Q plots was too insensitive a technique to draw firm conclusions about the first two hypotheses of this study, or the effects of the various independent variables on the shapes of the RT distributions, but they were suggestive nonetheless. First, consistent with the first hypothesis, in all cases distributions appeared to be more skewed when there was a ProM load than when there was not. This was true even for the divided attention conditions in which practice effects were working against detection of the ProM effect. Second, comparisons between the salience conditions (when there was a ProM load) were also largely in agreement with multiprocess theory. The salience comparisons for the young adults were a little strange in that the low salience condition may have been ever so slightly less skewed than the high salience condition when attention was full. However, when attention was divided, the low salience condition yielded distributions that were more skewed than the high salience condition, as expected. Similarly, for the older adults, the low salience condition produced more skewed distributions than the high salience condition, and this difference in skew seemed to be even more pronounced when attention was divided. Finally, regarding age differences in the shapes of RT distributions, the Q-Q plots yielded mixed findings. The plots suggested that young adults actually had more skewed distributions than older adults when attention was divided. On the other hand, just considering the full attention conditions, older adults did appear to be more variable than young adults when the ProM cues were low in salience, but not when the cues were highly salient, consistent with the second hypothesis.

Although the Q-Q plots were informative, as was the case in the first experiment, the ex-Gaussian and Weibull analyses offered more quantitative tests of the hypotheses being tested in the current study. Once again, *tau* is mentioned here for comparison with earlier studies. Many of the findings regarding the *tau* parameter were yet again consistent with what has been found by other researchers (e.g., Spieler, 2001; Spieler et al., 1996; West et al., 2002). In particular, older adults produced distributions with longer tails than young adults and tails were longer when attention was divided than when it was full. The age X attention interaction characterized by a larger age difference in tail length when attention was divided than when it was full was also consistent with previous findings.

The more appropriate measures of skew, the *tau*/*sigma* ratio and Weibull *shape* parameter, replicated the finding in the previous experiment that dividing attention produces distributions that are more skewed than when attention is full. In partial support of the first hypothesis, both skew measures indicated that distributions were more skewed when there was a concurrent ProM burden than when there wasn't. However, none of the expected interactions with the salience factor reached significance. Regarding the second hypothesis, older adults did produce distributions that were more skewed than young adults. Consistent with West's theory, the age X attention interactions found for the *tau* parameter were also present for the *tau*/*sigma* ratio at the trend level. However, none of the other critical interactions involving age were significant.

Concerning the individual differences analyses, few aspects of the analyses were in agreement with expectations. It is interesting to note that on-going LDT Median RT only reliably predicted ProM performance in the low salience divided attention condition. (Median RT also reliably predicted ProM performance in the low salience full attention condition, but only when entered before age. Thus, median RT was primarily serving as a proxy for age in that case.) As seemed to be the case for the first experiment, the positive relationship between median RT and ProM performance after controlling for age is likely a reflection of strategy differences. That is, people who took more time on the LDT were more likely to notice the ProM targets.

Concerning the issue of performance variability, recall that there were two relevant hypotheses regarding individual differences. Once again, the third hypothesis of this study was that intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes predicts ProM performance and accounts for age differences in ProM performance. The fourth hypothesis was that intraindividual variability in performance on a task that requires executive control predicts ProM performance on tasks that rely on cue-focused processes and accounts for age differences in ProM performance.

With respect to both individual differences hypotheses, intraindividual variability on the on-going LDT and the two-back task, as reflected in the CV measure, failed to reliably predict ProM performance. Skew in the distributions of the on-going LDT, as represented by the *tau*/*sigma* ratio and the Weibull *shape* parameter, also failed to reliably predict ProM performance. However, partially consistent with the fourth hypothesis, skew in the distributions of the two-back task did reliably predict ProM performance in the high salience full attention condition. As skew increased, ProM performance decreased. Furthermore, although the age difference in ProM performance was marginal in this condition, entering skew before age did tend to reduce the amount of variance accounted for by age from 7.0% to 6.6% for *tau*/*sigma* and to 4.3% for the Weibull *shape* parameter. The fact that these relationships were only detected for the condition in which ProM performance was the best, in combination with the fact that performance was quite low for older adults in the other conditions, suggests that the failure to obtain such findings in the other conditions may have been due to restriction of range.

GENERAL DISCUSSION

The current study had two goals. The principal goal was to determine whether manipulating the involvement of executive control processes in ProM tasks would produce changes in various measures of intraindividual variability in a manner consistent with West's (1996; West, 2000; West et al., 2002) frontal lobe theory of cognitive aging. An additional goal of the study was to determine whether individual differences in various measures of intraindividual variability predict performance on ProM tasks that vary in the extent to which they require executive control, or whether they can account for age differences in ProM performance, also in a manner consistent with West's theory.

The multiprocess account of ProM (McDaniel & Einstein, 2000) was used as the framework within which to manipulate the degree to which the ProM tasks relied on executive control processes. In the first experiment, whether or not the on-going LDT focused processing on the ProM cues was manipulated. Controlled processes should have played a larger role when processing was non-focal as opposed to when it was focal. In the second experiment, the salience of the ProM cues relative to the other items in the on-going LDT was manipulated. In this case, controlled processes should have been more important for successful ProM performance when the ProM cues were not salient compared to when they were salient. Although few tasks, if any, are truly process pure, an attempt was made nonetheless to compare ProM conditions that relied primarily on reflexive-associative (automatic) processes with those that rely more on cue-focused (controlled) processes. This attempt was somewhat successful in that ProM performance was worse in both experiments for the conditions designed to rely to the greatest extent on cue-focused processes. However, as already noted, the relatively low performance in the conditions designed to rely primarily on reflexive-associative processes, as well as the observed costs to on-going performance, suggests that they also required cue-focused processes. Nevertheless, what is critical in terms of the hypotheses being tested is that one condition relied on cue-focused processes to a greater extent than the other condition, and this was achieved.

The plan of the study was organized around four key hypotheses which are re-stated and evaluated in turn below:

Hypothesis I

The first hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task and this increase is larger for tasks relying more on cue-focused processes than those relying less on cue-focused processes. This hypothesis was partially supported in both experiments. Recall that condition and age differences in intraindividual variability were expected to be reflected primarily in the skew of the RT distributions for the on-going LDT. In both experiments the *tau*/*sigma* ratio and the Weibull *shape* parameter indicated greater skew in the distribution of the LDT task when there was a concurrent ProM burden than when there wasn't. Thus, the burden of a ProM intention does increase the intraindividual variability (as indicated by skew) in performance on the on-going component of a ProM task that encourages the recruitment of cue-focused processes.

There are of course many possible explanations for the failure to find that skew increased more for the non-focal and low salience conditions than for the focal and high salience conditions. One is that there was not sufficient separation between the conditions in terms of the engagement of controlled processes to allow differences in skew to be detected. Of course, this is an obstacle that could be easily addressed in future studies by employing manipulations that more clearly differentiate tasks that rely on reflexive-associative from those that require cue-focused processes.

Regardless of the reasons for not finding all of the expected outcomes, the finding that the burden of a ProM intention increases the skew of RT distributions is important for the current study regarding tests of frontal lobe theories of cognitive aging such as West's (2001). This finding is consistent with the notion that controlled processes fluctuate over time and that these fluctuations are reflected in the skew of RT distributions. This is the first time that such a finding has been clearly demonstrated using appropriate measures of skew. The fact that this finding was obtained using more than one measure of skew makes it all the more convincing. But the question still remains whether older adults are more susceptible to fluctuations of executive control processes than young adults. That is, of course, the purpose of the second hypothesis.

Hypothesis II

The second hypothesis was that the burden of a ProM intention increases intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes more for older adults than for younger adults. This hypothesis was not supported. In fact, in most cases the effect of a ProM burden on the skew of distributions was larger for young adults than for older adults. This interaction is a little puzzling given that older adults had distributions that were more skewed than young adults in both studies.

Perhaps the failure to obtain a larger effect of a ProM burden for older adults was again because there was not sufficient separation between the conditions (at least for the older adults) in terms of the engagement of controlled processes to allow differences in skew to be detected. This notion stems from the fact that older adults tended to have distributions that were more skewed than young adults even in the full attention conditions when there was not a ProM burden (although not always significantly so). The LDT in the absence of a ProM burden or divided attention should have required the least out of all the conditions in the way of executive control and thus, in contrast to what was found, there should have been no evidence for age differences in this situation. One possible reason for the observed tendency is that the length (about 15 to 20 minutes per condition) and procedural nature (i.e. a serial choice RT procedure) of the task created a scenario in which processes required for sustained attention were burdened, and to a greater degree for older adults than young adults. Thus, perhaps even the simplest conditions (i.e., those without a ProM burden or divided attention) in this study engaged controlled processes (e.g. inhibitory control) to a substantial extent for older adults, thus partially obscuring the effect of a ProM burden for that age group and leading to the age differences predicted by frontal lobe accounts.

Admittedly, the data are mixed with respect to the question of age differences in the ability to sustain attention as measured by vigilance tasks. For example, Bunce (2001) reported that vigilance, as measured by sensitivity, decreased with age, and especially so when the stimuli used in the vigilance task were highly degraded. On the other hand, Berardi, Parasuraman, and Haxby (2001) reported no age differences in sensitivity on a vigilance task, even when the stimuli were highly degraded. However, most of the few studies on that topic have focused on non-speeded measures of vigilance, which is more important from an applied standpoint, but not necessarily from a theoretical point of view. That is, it is possible that the effects of aging on vigilance tasks are more likely to be revealed by features of speeded performance than by more practical aspects of performance, such as sensitivity.

Unfortunately, there seem to be no studies that adequately examine the question of age differences in speeded performance on vigilance tasks. Bunce et al. (1993; see also, Bunce, Barrowclough & Morris, 1996) based his idea of age-related increases in attentional blocks on older literature showing that attention fluctuates on tasks performed over prolonged periods (see e.g., Bertelson & Joffe, 1963; Bills, 1931; Broadbent, 1953). He reported that age was associated with an increase in the number of very long RTs which were presumed to be the product of failures in the ability to sustain attention or attentional blocks, but the task used included very few trials and was not a vigilance task. In contrast to the studies conducted by Bunce and colleagues, Salthouse (1993; Salthouse, 1998) found that controlling for age differences in individuals' fastest RTs accounted for the age differences in the slowest RTs. Salthouse thus concluded that the RT distributions of older individuals are simply shifted and magnified (i.e. they have the same shape) and do not show evidence of especially long tails that would be consistent with failures of sustained attention, or the presence of attentional blocks for that matter.

Regrettably, the studies by Salthouse did not include nearly as many trials as the present study. Therefore, those studies likely did not place as large a demand on sustained attention as the present study, and this could account for the discrepancy between that study and the current study. The study by Myerson et al. (2007) did use task procedures similar to those used in the present study (i.e. prolonged performance on a serial choice RT task), but as already noted, they found no evidence that older adults had distributions that were more skewed than those of young adults, despite the fact that they also used a serial choice RT procedure and included many more trials per condition than the present study. However, the difference between the Myerson et al. study and the current study may be due to differences in power. The effect size for the age difference was fairly small in the present study as the overall effect of age accounted for at most 11% of the total variance in skew. Although Myerson et al. clearly demonstrated that older adults were not more variable in terms of SD, that study focused on in-depth analyses of a relatively few individuals (9 per age group) , and may have lacked the power necessary to detect such a small effect in terms of RT distribution skew.

Regardless of the reasons, this particular aspect of the data does not support West's frontal lobe theory of cognitive aging. Having said that, there was one finding that suggests that the above rational for the lack of an age X ProM interaction may be valid; a finding that is also consistent with frontal lobe theories of cognitive aging. Specifically, an anticipated age X attention interaction was present for both measures of skew in the first experiment and was marginally significant in the second experiment. The effect of dividing attention was much greater for older adults than young adults.

This is also consistent with the explanation for the age X ProM interaction. The effect of dividing attention produced much larger effects on skew than did the presence of a ProM burden, and so the difference between the full attention conditions and the divided attention conditions in terms the requirement for controlled processes was substantial enough to produce the observed pattern of age differences.

Hypothesis III

The last two hypotheses explored the role that individual differences in intraindividual variability may have in ProM performance. The third hypothesis was that intraindividual variability in performance on the on-going component of a ProM task relying on cue-focused processes predicts ProM performance and accounts for age differences in ProM performance. The results were mixed regarding this hypothesis. Intraindividual variability in performance on the on-going LDT, in terms of both the CV measure and skew (as indexed by the *tau/sigma* ratio), predicted ProM performance in the non-focal full attention condition after controlling for age. Greater skew and greater variability was associated with poorer ProM performance in a condition that encouraged the engagement of executive control processes. However, there were no age differences to account for in this condition, and because variability did not predict ProM performance in the conditions that did produce age differences, this study was not able to demonstrate that individual differences in intraindividual variability in performance on the on-going task accounts for age differences in ProM performance.

Hypothesis IV

The fourth hypothesis was that intraindividual variability in performance on a task that requires executive control predicts ProM performance on tasks that rely on cue-focused processes and accounts for age differences in ProM performance. Support for this hypothesis was again limited. Skew in the RT distributions of performance on the two-back task predicted ProM performance in the full attention high salience condition after controlling for age. The marginally significant age differences in this condition were not accounted for by the *tau*/*sigma* ratio; however, entering the *shape* parameter before age substantially reduced the amount of variance predicted by age.

Regarding both of the individual differences hypotheses, the fact that the various indicators of intraindividual variability in speeded cognitive performance failed to predict ProM performance in many of the conditions is likely due to a combination of factors. One reason might be the result of the methodology used. The particular methodological features of this study only allowed the ProM performance data to be evaluated in terms of the relative adequacy of reflexive-associative and cue-focused processes for accurate execution of the tasks. That is, it was possible to conclude that the non-focal and low salience conditions required cue-focused processes to a greater extent than the focal and high salience conditions, but not that all participants in the non-focal and low salience conditions actually employed a monitoring strategy relying on cue-focused processes. Thus, the failure to consistently observe a predictive relationship between intraindividual variability and ProM performance may have partly been the result of too few individuals utilizing a monitoring strategy. In concordance with this idea is the fact that the one condition in which the predicted relationship was found (specifically the non-focal full attention) is also the one condition in which there was the greatest evidence that a monitoring strategy was being employed. That is, even though the focality X ProM interaction expected for the cost analyses in the first experiment was not significant, the non-focal full attention condition did produce the numerically largest cost for both young and older adults. It might seem that this idea is contradicted by the fact that the burden of a ProM load was shown to increase skew in situations other than the full attention non-focal condition. However, as already explained in footnote 3 above, it is quite reasonable to obtain such effects when looking for group differences, while simultaneously finding that the same variable has no predictive value in a regression model. Thought of another way, not everyone in the experiment had to engage controlled processes to perform the ProM tasks in order to produce the observed effect of a ProM burden. However, the fewer people that do engage controlled processes, the less likelihood there is that the measures of intraindividual variability would have predictive value.

Given that the ProM performance data suggested that all conditions required cue-focused processes to some extent, and the likelihood that not everyone employed a strategy that invoked cue-focused processes at all times and in every condition, the lack of consistently finding the predicted associations might be expected. Recall that the idea behind the individual differences hypotheses was that if levels of ProM performance are determined by the efficiency of controlled processes that fluctuate in time, then measures of those fluctuations should predict ProM performance. However, to the extent that controlled processes were not being engaged for the ProM tasks, it would be less likely to find that various indicators of fluctuations in controlled processes would be predictive of ProM performance.

Limitations and Considerations for Future Research

This study produced many valuable new findings, and also shed light on complications and questions that can arise when conducting research on this topic that may not have been anticipated in future studies. Naturally, these concerns should be addressed in future studies.

One very puzzling and interesting issue that arose was the unexpected findings regarding the CV measure. It was certainly odd that the CV analyses suggested that younger adults were more variable than older adults, even though analyses of the RT distributions suggested that the distributions of older adults were more variable than those of the young adults. Theoretically, measures of variability based on the SD do not necessarily have to be in agreement with measures of skew, but in this case the results were often in direct opposition, which seems unlikely. Moreover, not only were the effects of age in opposition, but the overall pattern of data was in opposition. That is, for the most part the CV measure indicated that increasing the engagement of executive control processes actually decreased variability. Given that these findings were so odd, data sets from other tasks used in other studies were also examined. These other tasks included visual search tasks that placed varying demands on controlled processes and seemed to involve an element of task switching (Robertson, Myerson, & Hale, 2006b), a same-different judgment task (Myerson et al., (2007), a go-no-go task, and a choice RT task (Hale, Myerson, & Robertson, 2001). When the CVs from these tasks were looked at in conjunction with those produced in the present study, a pattern seemed to emerge. Specifically, there was a strong tendency for CV values to be lower on tasks that divided attention or seemed to involve an element of task switching. If this is a reliable pattern, what might be causing it?

There is at least one possibility that might explain both the age differences and the task differences. In the case of age differences, suppose a task requires many separate steps and that these steps are each carried out with different inherent levels of variability. Suppose further that one or a few of these steps that are carried out with the greatest degree of variability are also the steps that are slowed the least by aging, such as sensorimotor processes. At the same time, assume that the many steps not associated with sensorimotor processing (i.e., central processes) are slowed the most by aging and are carried out with the least amount of variability. These assumptions would be consistent with something akin to a two-compartment model in which sensorimotor and central processes are unrelated and central processes are slowed to a greater extent than sensorimotor processes (e.g., Cerella, 1985; Myerson, Hale, Zheng, Jenkins, & Widaman, 2003). The result would be that the few highly variable steps would contribute relatively more to the total response time and total variability for young adults than for older adults, due to the fact that the total response time would be less for young adults. Thus, the young adults would produce larger CVs than older adults. The same reasoning can be applied to task differences by assuming that the more difficult task (e.g. a divided attention task) either involves more central steps than the simpler task (e.g. a full attention task), each step takes longer, or some combination of the two. The result would again be that the easier task would produce a larger CV than the more difficult task.

The preceding account, of course, is highly speculative at this point. Regardless of the reason for these findings, the pattern does seem to be real and not a statistical fluke because very different tasks performed by different samples seem to follow the same pattern. Thus, the matter certainly warrants further attention, especially because the CV and similar approaches are commonly used in studies of intraindividual variability and aging. It should be recalled, however, that in the present analyses, individual CVs were calculated using a group estimate of the x-intercept of the regression of SD on mean RT. Although this avoids some of the problems caused by calculating the CV when the regression line does not go through the origin, the use of a group correction to individual data may well introduce other problems. In addition, because individual RT distributions are skewed, the whole approach of using the CV in any form maybe open to question, given that the CV is based on the SD, which is more appropriate for normal distributions. Both the development of better measures of variability and further research using such measures are clearly needed to address these issues. Fortunately, as mentioned above, the concerns regarding the CV measure did not adversely affect the primary research questions of the current study because the ideas that were tested specifically pertain to the skew of RT distributions.

Another rather notable issue more directly impacting the research questions of this study was that the large practice effects observed for the divided attention conditions highlights the fact that careful thought must be given to this procedural aspect of ProM studies. When analyzing the shapes of distributions the nonlinearity resulting from practice effects can be removed, as was done in the present study. However, the practice effects do present a problem for the analysis of RT costs associated with a ProM burden as the improvements can overwhelm any costs. Future studies should carefully consider the amount of practice secondary tasks might require before asymptotic performance is reached. The size of the practice effect observed in this study was much larger than anticipated and would have required a substantial amount of practice to obtain more stable data, especially for older adults. Thus, tasks that place less severe demands on participants should be considered when shorter experimental sessions are required. Of course, the desire to limit the amount of practice required would need to be balanced against the need to demonstrate the effect of dividing attention on other aspects of performance as well.

Another limitation was the fact that ProM performance was quite low in this study. This was true for both age groups, but especially so for older adults. This may have adversely affected the ability to obtain the predicted relationships between the variability indicators and ProM performance and to more clearly demonstrate the involvement of either reflexive-associative or cue-focused processes. Related to this issue, future study designs should include manipulations that more optimally distinguish between ProM tasks that encourage the recruitment of reflexive-associative and cue-focused processes, thus creating a scenario that allows a more rigorous test of theories such as West's.

Yet another way that similar studies could be improved would be to incorporate the idea that whether or not cue-focused processes are recruited depends on whether or not participants choose a strategy that engages those processes. As pointed out above, individuals may rely on reflexive-associative processes despite the fact that cue-focused processes are required for optimal performance on a ProM task. Likewise, it is also possible that some individuals might choose to use a monitoring strategy that requires the engagement of cue-focused processes even when reflexive-associative processes would be adequate. Van den Berg et al. (2004) have also suggested that whether or not monitoring (cue-focused processes) is used is a matter of strategic choice. Thus, future studies investigating similar questions as the present study would do well to not only manipulate whether or not the ProM task requires cue-focused processes, but to also manipulate whether or not participants utilize a strategy that engages cue-focused processes. The anticipated results of such a study are provided in Table 34. This design aspect would address the problem of whether or not participants were always engaging cue-focused processes when they needed to be, which would also improve individual differences analyses.

Table 18

Hypothetical Outcomes of a Study Involving Forced Strategy Use

	Task Requirement					
Strategy	Cue - Focused			Reflexive - Associative		
	RT Cost	Variability	ProM	RT Cost	Variability	ProM
Cue - Focused	Yes	High	High	Yes	High	Optimal
Ref. - Associative	No	Low	Low	No	Low	High

Finally, the individual differences question should receive more attention. One excellent way to approach the issue would be to incorporate several independent speeded cognitive tasks for acquiring measures of intraindividual variability and many different measures of ProM performance so that multivariate analytic methods such as factor analysis or structural equation modeling can be used.

Conclusions

The current study yielded several important new findings. Regarding ProM, this is the first study to demonstrate that the presence of a ProM burden increases the amount of skew in the RT distributions of on-going tasks. Related to this, the present study also demonstrated that effects of a ProM burden can be revealed in several different components of RT distributions, while not being reflected in measures of central tendency. Thus, studies that couch questions in terms of costs may reach invalid conclusions if many different characteristics of the RT distribution are not examined. This is also the first study to show that fluctuations in executive control processes can be predictive of ProM performance.

With respect to West's frontal lobe theory of cognitive aging, this study did not support or contradict its application to age differences in ProM performance. Despite the inconclusive results regarding ProM performance, this study is nevertheless the first to support West's theory using appropriate measures of skew. In fact, it is the first study to clearly demonstrate that the distributions of older adults are more skewed than those of young adults.

Clearly, aging research based solely on measures of central tendency is outmoded. Likewise, theoretical development in the area of ProM cannot be comprehensive without giving consideration to the implications of performance variability.

REFRENCES

American Psychological Association. (1992). Ethical principles of psychologists and code of conduct. *American Psychologist, 47*, 1597-1611.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology Special Issue: Working Memory, 49A*, 80-115.

Baddeley, A. & Logie, R.H. (1999). Working memory: The multiple-component model. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control.* (pp. 28-61). New York, NY: Cambridge University Press.

Balota, D. A., Cortese, M. J., Hutchison, K. A., Neely, J. H., Nelson, D.,Simpson, G. B., & Treiman, R. (2002). *The English Lexicon Project: A web-based repository of descriptive and behavioral measures for 40,481English words and nonwords*. Accessed January 30, 2004, on the Washington University Web site: http://elexicon.wustl.edu

Balota, D.A., Cortese, M.J., Sergent-Marshall, S.D., Spieler, D.H., & Yap, M.J. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General*, *133*, 283-316.

Berardi, A., Parasuraman, R., & Haxby, J.V. (2001). Overall vigilance and sustained attention decrements in healthy aging. *Experimental Aging Research, 27*, 19-39.

Bertelson, P., & Joffe, R. (1963). Blockings in prolonged serial responding. *Ergonomics, 6*, 109-116.

Bills, A.G. (1931). Blocking: A new principle of mental fatigue. *American Journal of Psychology, 43*, 230-245.

Broadbent, D.E. (1953). Noise, paced performance, and vigilance tasks. *British Journal of Psychology, 44*, 295-303.

Buckner, R.L., Goodman, J., Burock, M., Rotte, M., Koustaal, W., Schacter, D., et al. (1998). Functional-anatomic correlates of object priming in humans revealed by rapid presentation event-related fMRI. *Neuron, 20,* 285-296.

Bunce, D.J. (2001). Age differences in vigilance as a function of health-related physical fitness and task demands. *Neuropsychologia, 39*, 787-797.

Bunce, D.J., Barrowclough, A., & Morris, I. (1996). The moderating influence of physical fitness on age gradients in vigilance and serial choice responding tasks. *Psychology and Aging, 11*, 671-682.

Bunce, D.J., Warr, P.B., & Cochrane, T. (1993). Blocks in choice responding as a function of age and physical fitness. *Psychology and Aging, 8*, 26-33.

Burgess, P.W., Quayle, A., & Frith, C.D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia, 39,* 545-555.

Burgess, P.W., Scott, S.K., & Frith, C.D. (2003). The role of the rostral frontal cortex (area 10) in prospective memory: A lateral versus medial dissociation. *Neuropsychologia, 41*, 906-918.

Cherry, K.E., & LeCompte, D.C. (1999). Age and individual differences influence prospective memory. *Psychology and Aging, 14*, 60-76.

Cerella, J. (1985). Information processing rates in the elderly. *Psychological Bulletin, 98*, 67-83.

Cockburn, J. (1995). Task interruption in prospective memory: A frontal lobe function? *Cortex, 31*, 87-97.

Cohen, A.L., Jaudas, A., & Gollwitzer, P.M. (2008). Number of cues influences the cost of remembering to remember. *Memory & Cognition, 36*, 149-156.

Devolder, P.A., Brigham, M.C., & Pressley, M. (1990). Memory performance awareness in younger and older adults. *Psychology and Aging, 5*, 291-303.

Duchek, J.M., Balota, D.A., & Cortese, M. (2006). Prospective memory and apolipoprotein E in healthy aging and early stage Alzheimer's disease. *Neuropsychology, 20*, 633-644.

Edwards, J.D., Pexman, P.M., Goodyear, B.G., & Chambers, C.G. (2005). An fMRI investigation of strategies for word recognition. *Cognitive Brain Research, 24*, 648-662.

Einstein, G.O., Holland, L.J., McDaniel, M.A., & Guynn, M.J. (1992). Age-related deficits in prospective memory: The influence of task complexity. *Psychology and Aging, 7*, 471-478.

Einstein, G.O., McDaniel, M.A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., et al., (2005). Multiple Processes in Prospective Memory Retrieval: Factors Determining Monitoring Versus Spontaneous Retrieval. *Journal of Experimental Psychology: General, 134*, 327-342.

Einstein, G.O. & McDaniel, M.A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 717-726.

Einstein, G.O. & McDaniel, M.A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G.O. Einstein, M.A. McDaniel, (Eds.), *Prospective memory: Theory and applications*. (pp.115-141). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Einstein, G.O. & McDaniel, M.A. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science, 14*, 286-290.

Einstein, G.O., McDaniel, M.A., Manzi, M., Cochran, B., & Baker, M. (2000). Prospective memory and aging: Forgetting intentions over short delays. *Psychology and Aging, 15*, 671-683.

Einstein, G.O., McDaniel, M.A., Richardson, S.L., Guynn, M.J., & Cunfer, A.R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 996-1007.

Einstein, G.O., McDaniel, M.A., Smith, R., & Shaw, P. (1998). Habitual prospective memory and aging: Remembering instructions and forgetting actions. *Psychological Science, 9*, 284-288.

Einstein, G.O., Smith, R., McDaniel, M.A., & Shaw, P. (1997). Aging and prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging, 12*, 479-488.

Hale, S., Myerson, J., & Robertson, S. (2001). [Age differences in speeded cognitive performance]. Unpublished raw data.

Hale, S., Myerson, J., Smith, G.A., & Poon, L.W. (1988). Age, variability, and speed: Between-subjects diversity. *Psychology and Aging, 3*, 407-410.

Hays, W. L. (1994). *Statistics* (5^{th} ed.). Orlando, FL: Harcourt.

Heathcote, A., Brown, S., & Mewhort, D.J.K. (2000). The power law repealed: The case for an exponential law of practice. *Psychonomic Bulletin and Review, 7*, 185-207.

Heathcote, A., Brown, S., & Mewhort, D.J.K. (2002). Quantile maximum likelihood estimation of response time distributions. *Psychonomic Bulletin & Review, 9*, 394-401.

Henry, J.D., MacLeod, M.S., Phillips, L.H., & Crawford, J.R. (2004). A Meta-Analytic Review of Prospective Memory and Aging. *Psychology and Aging, 19*, 27-39.

Hockley, W.E. (1984). Analysis of response time distributions in the study of cognitive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 598-615.

Hohle, R.H. (1965). Inferred components of reaction times as functions of foreperiod duration. *Journal of Experimental Psychology, 69*, 382-386.

Hultsch, D.F., MacDonald, S.W.S., & Dixon, R.A. (2002). Variability in reaction time performance of younger and older adults. *Journal of Gerontology: Psychological Sciences, 57B*, P101-P115.

Kelemen, W.L., Weinberg, W.B., Alford, H.S., Mulvey,E.K., & Kaeochinda, K.F. (2006). Improving the reliability of event-based laboratory tests of prospective memory. *Psychonomic Bulletin and Review, 13*, 1028-1032.

Kliegel, M., Jager, T., & Phillips, L.H. (2008). Adult age differences in event-based prospective memory: A meta-analysis on the role of focal versus nonfocal cues. *Psychology and Aging, 23*, 203-208.

Kliegel, M., Martin, M., McDaniel, M.A., & Einstein, G.O. (2001). Varying the importance of a prospective memory task: Differential effects across time- and event-based prospective memory. *Memory, 9*, 1-11.

Kliegel, M., Martin, M., McDaniel, M.A., & Einstein, G.O. (2004). Importance effects on performance in event-based prospective memory tasks. *Memory, 12*, 553-561.

Kucera, H. & Francis, W.N. (1967). *Computational analysis of present-day American English*. Providence: Brown University Press.

Kvavilashvili, L. (1987). Remembering intention as a distinct form of memory. *British Journal of Psychology, 78,* 507-518.

Kvavilashvili, L. (1992). Remembering intentions: A critical review of existing experimental paradigms. *Applied Cognitive Psychology Special Issue: Memory in everyday settings, 6*, 507-524.

Kvavilashvili, L. (1998). Remembering intentions: Testing a new method of investigation. *Applied Cognitive Psychology, 12*, 533-554.

Li, S. (2002). Cross-level unification: A computational exploration of the link between deterioration of neurotransmitter systems and dedifferentiation of cognitive abilities in old age. In L.G. Nilsson & H.J. Markowitsch (Eds.), *Cognitive neuroscience of memory,* (pp. 103-146). Seattle, WA: Hogrefe & Huber.

Li, S., Huxhold, O., & Schmiedek, F. (2004). Aging and Attenuated Processing Robustness: Evidence from Cognitive and Sensor motor Functioning. *Gerontology, 50*, 28-34.

Li, S., & Lindenberger, U. (1999). Cross-level unification: A computational exploration of the link between deterioration of neurotransmitter systems and dedifferentiation of cognitive abilities in old age. In L.G. Nilsson & H.J. Markowitsch (Eds.), *Cognitive Neuroscience of Memory,* (pp. 103-146). Seattle: Hogrefe & Huber.

Li, S., Lindenberger, U., & Frensch, P.A. (2000). Unifying cognitive aging: From neuromodulation to representation to cognition. *Neurocomputing, 32*, 879-890.

Li, S. & Sikstrom, S. (2002). Integrative neurocomputational perspectives on cognitive aging, neuromodulation, and representation. *Neuroscience & Biobehavioral Reviews, 26*, 795-808.

Logan, G.D. (1992). Shapes of reaction-time distributions and shapes of learning curves: A test of the instance theory of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 883-914.

Luce, R.D. (1986). *Response times: Their role in inferring elementary mental organization*. New York: Oxford University Press.

Luszcz, M.A. (2004). What's it all about: Variation and aging. *Gerontology, 50*, 5-6.

Mäntylä, T. (1996). Activating actions and interrupting intentions: Mechanisms of retrieval sensitization in prospective memory. In M. Brandimonte, G.O. Einstein, M.A. McDaniel, (Eds.), *Prospective memory: Theory and applications*. (pp.93-113). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Marsh, R.L., & Hicks, J.L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 336-349.

Marsh, R.L., Hicks, J.L., Cook, G.I., Hansen, J.S., & Pallos, A.L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 861-870.

Martin, M., & Hofer, S.M. (2004). Intraindividual variability, change, and aging: Conceptual and analytical issues. *Gerontology, 50*, 7-11.

Martin, M., Kliegel, M., & McDaniel, M.A. (2003). The involvement of executive functions in prospective memory performance of adults. *International Journal of Psychology, 38*, 195-206.

Maylor, E.A. (1990). Age and prospective memory. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 42*, 471-493.

Maylor, E.A. (1993). Aging and forgetting in prospective and retrospective memory tasks. *Psychology and Aging, 8*, 420-428.

Maylor, E.A. (1996). Age-related impairment in an event-based prospective-memory task. *Psychology and Aging, 11*, 74-78.

Maylor, E.A., Smith, G., Della Sala, S., & Logie, R.H. (2002). Prospective and retrospective memory in normal aging and dementia: An experimental study. *Memory & Cognition, 30*, 871-884.

McDaniel, M.A., Bugg, J.M., Ramuschkat, G.M., Kliegel, M., & Einstein, G.O. (in press). Repetition errors in habitual prospective memory: Elimination of age differences via complex actions or appropriate resource allocation. *Aging, Neuropsychology, and Cognition*.

McDaniel, M.A. & Einstein, G.O. (1993). The importance of cue familiarity and cue distinctiveness in prospective memory. *Memory, 1*, 23-41.

McDaniel, M.A. & Einstein, G.O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology, 14*, S127-S144.

McDaniel, M.A., Einstein, G.O., & Rendell, P.G. (2008). The puzzle of inconsistent age-related declines in prospective memory: A multiprocess explanation. In M. Kliegel, M.A. McDaniel, and G.O. Einstein (Eds.), *Prospective Memory: Cognitive, Neuroscience, Developmental, and Applied Perspectives* (pp. 141-160). Mahwah, NJ: Erlbaum.

McDaniel, M.A., Einstein, G.O., Stout, A., & Morgan, Z. (2003). Aging and maintaining intentions over delays: Do it or lose it. *Psychology and Aging, 18*, 823-835.

McDaniel, M.A., Glisky, E., Rubin, S.R., Guynn, M.J., & Routhieaux, B.C., (1999). Prospective memory: A neuropsychological study. *Neuropsychology, 13*, 103-110.

McDaniel, M.A., Guynn, M.J., Einstein, G.O., & Breneiser, J. (2004). Cue-Focused and Reflexive-Associative Processes in Prospective Memory Retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 605-614.

MacDonald, S.W.S., Hultsch, D.F., & Dixon, R.A. (2003). Performance variability is related to change in cognition: Evidence from the Victoria Longitudinal Study. *Psychology and Aging, 18*, 510-523.

McDowd, J.M. & Shaw, R.J. (2000). Attention and aging: A functional perspective. In F.I.M. Craik, & T.A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 221-292). Hillsdale, NJ: LEA.

Meiser, T., & Schult, J.C. (2008). On the automatic nature of the task-appropriate processing effect in event-based prospective memory. *European Journal of Cognitive Psychology, 20*, 290-311.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F.I.M. Craik, & T.A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315-372). Hillsdale, NJ: LEA.

Myerson, J., & Hale, S. (1993). General slowing and age invariance in cognitive processing: The other side of the coin. In J. Cerella, J. Rybash, W. Hoyer, & M.L.

Commons (Eds.), *Adult information processing: Limits on loss*, pp. 116-141. San Diego, CA: Academic Press.

Myerson, J., Adams, D.R., Hale, S., & Jenkins, L. (2003). Analysis of group differences in processing speed: Brinley plots, Q-Q plots, and other conspiracies. *Psychonomic Bulletin & Review, 10*, 224-237.

Myerson, J., Hale, S., Rhee, S.H., & Jenkins, L. (1999). Selective interference with verbal and spatial working memory in young and older adults. *Journal of Gerontology: Psychological Sciences, 54B*, P161-P164.

Myerson, J., Hale, S., Wagstaff, D., Poon, L.W., & Smith, G. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review, 97*, 475-487.

Myerson, J., Hale, S., Zheng, Y., Jenkins, L., & Widaman, K.F. (2003). The difference engine: A model of diversity in speeded cognition. *Psychonomic Bulletin & Review, 10*, 262-288.

Myerson, J., Robertson, S., & Hale, S. (2007). Aging and intraindividual variability in performance: Analyses of response time distributions. *Journal of the Experimental Analysis of Behavior, 88*, 319-337.

Nesselroade, J.R. (2004). Intraindividual variability and short-term change. *Gerontology, 50*, 44-47.

Nesselroade, J.R., & Salthouse, T.A. (2004). Methodological and theoretical implications of intraindividual variability in perceptual-motor performance. *Journals of*

Gerontology: Series B: Psychological Sciences and Social Sciences, 59B, P49-P55.

Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin & Review, 3*, 135-148.

Palmer, H.M., & McDonald, S. (2000). The role of frontal and temporal lobe processes in prospective remembering. *Brain and Cognition, 44*, 98-112.

Park, D.C., Kidder, D.P., Morrell, R.W., & Mayhorn, C.B. (1997). Effect of age on event-based and time-based prospective memory. *Psychology and Aging, 12*, 314-327.

Psychological Corporation (1997). *WAIS –III administration and scoring manual*. San Antonio: Harcourt Brace & Company.

Ratcliff, R., & Murdock, B.B. (1976). Retrieval processes in recognition memory. *Psychological Review, 86*, 190-214.

Rabbitt, P.M.A., Osman, P., Moore, B., & Stollery, B. (2001). There are stable individual differences in performance variability, both from moment to moment and from day to day. *The Quarterly Journal of Experimental Psychology, 54*A, 981-1003.

Ratcliff, R. (1979). Group reaction time distributions and an analysis of distribution statistics. *Psychological Bulletin, 86*, 446-461.

Ratcliff, R., Spieler, D., & McKoon, G. (2000). Explicitly modeling the effects of aging on response time. *Psychonomic Bulletin & Review,* 7, 1-25.

Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F.I.M. Craik, & T.A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 1-90). Mahwah, NJ: LEA.

Rendell, P.G., & Craik, F.I.M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology Special Issue: New Perspectives in Prospective Memory, 14*, S43-S62.

Rendell, P.G., McDaniel, M.A., Forbes, R.D., & Einstein, G.O. (2007). Age-related effects in prospective memory are modulated by ongoing task complexity and relation to target cue. *Aging, Neuropsychology, and Cognition, 14,* 236-256.

Rendell, P.G., & Thomson, D.M. (1993). The effect of ageing on remembering to remember: An investigation of simulated medication regimens. *Australasian Journal on Ageing Special Issue: Psychology and Ageing, 12*, 11-18.

Rendell, P.G., & Thomson, D. M. (1999). Aging and prospective memory: Differences between naturalistic and laboratory tasks. *Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 54B*, P256-P269.

Robertson, S., Myerson, J., & Hale, S. (2006a). Are there age differences in intraindividual variability in working memory performance? *Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 61B*, P18-P24.

Robertson, S., Myerson, J., & Hale, S. (2006b, November). *Does intra-individual variability in response times increase with age or when more shifts of attention* *are required?* Poster session presented at the annual meeting of the Psychonomic Society, Houston, TX.

Rouder, J.N., Sun, D., Speckman, P.L., Lu, J., & Zhou, D. (2003). A hierarchical Bayesian statistical framework for response time distributions. *Psychometrika, 68*, 589-606.

Salthouse, T.A., Berish, D.E., & Siedlecki, K.L., (2004). Construct validity and age sensitivity of prospective memory. *Memory & Cognition, 32*, 1133-1148.

Schmiedek, F., Oberauer, K., Wilhelm, O., Suss, H., & Wittmann, W.W. (2007). Individual differences in components of reaction time distributions and their relations to working memory and intelligence. *Journal of Experimental Psychology: General, 136*, 414-429.

Schretlen, D., Pearlson, G.D., Anthony, J.C., Aylward, E.H., Augustine, A.M., Davis, A., et al. (2000). Elucidating the contributions of processing speed, executive ability, and frontal lobe volume to normal age-related differences in fluid intelligence. *Journal of the International Neuropsychological Society, 6*, 52-61.

Shallice, T., & Burgess, P.W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain, 114*, 727-741.

Shammi, P., Bosman, E., & Stuss, D.T. (1998). Aging and variability in performance. *Aging, Neurosychology, and Cognition, 5*, 1-13.

Shum, D., Ungvari, G.S., Tang, W., & Leung, J.P. (2004). Performance of Schizophrenia Patients on Time-, Event-, and Activity-Based Prospective Memory Tasks. *Schizophrenia Bulletin, 30*, 693-701.

Shum, D., Valentine, M., & Cutmore, T. (1999). Performance of individuals with severe long-term traumatic brain injury on time-, event-, and activity-based prospective memory tasks. *Journal of Clinical and Experimental Neuropsychology, 21*, 49-58.

Simons, J.S., Scholvinck, M. L., Gilbert, S.J., Frith, C.D., & Burgess, P.W. (2006). Differential components of prospective memory? Evidence from fMRI. *Neuropsychologia, 44*, 1388-1397.

Smith, R. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 347-361.

Smith, R. & Bayen, U. (2004). A Multinomial Model of Event-Based Prospective Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 756-777.

Smith, R. & Bayen, U. (2005). The Effects of Working Memory Resource Availability on Prospective Memory: A Formal Modeling Approach. *Experimental Psychology, 52,* 243-256.

Spieler, D.H. (2001). Modeling age-related changes in information processing. *European Journal of Cognitive Psychology, 13*, 217-234.

Spieler, D.H., Balota, D.A., & Faust, M.E. (1996). Stroop performance in healthy younger and older adults and in individuals with dementia of the Alzheimer's type. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 461-479.

Strauss, E., MacDonald, S.W.S., Hunter, M., Moll, A, & Hultsch, D.F. (2002). Intraindividual variability in cognitive performance in three groups of older adults: Cross-domain links to physical status and self-perceived affect and beliefs. *Journal of the International Neuropsychological Society, 8*, 893-906.

Stuss, D.T., Murphy, K.J., & Binns, M.A. (1999). The frontal lobes and performance variability: Evidence from reaction time. *Journal of the International Neuropsychological Society, 5*, 123.

Stuss, D.T., Murphy, K.J., Binns, M.A., & Alexander, M.P. (2003). Staying on the job: the frontal lobes control individual performance variability. *Brain, 126*, 2363-2380.

Tzelgov, J., & Henik, A. (1991). Suppression situations in psychological research: Definitions, implications, and applications. *Psychological Bulletin, 109*, 524-536.

Van den Berg, S.M., Aarts, H., Midden, C., & Verplanken, B. (2004). The role of executive processes in prospective memory tasks. *European Journal of Cognitive Psychology, 16*, 511-533.

Wecker, N.S., Kramer, J.H., Wisniewski, A., Delis, D.C., & Kaplan, E. (2000). Age effects on executive ability. *Neuropsychology, 14*, 409-414.

Weibull, W. (1951). A statistical distribution function of wide applicability. *Journal of Applied Mechanics, 9*, 293-297.

West, R.L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*, 272-292.

West, R. (1999). Visual distraction, working memory, and aging. *Memory and Cognition, 27*, 1064-1072.

West, R. (2000). In defense of the frontal lobe hypothesis of cognitive aging. *Journal of the International Neuropsychological Society, 6*, 727-729.

West, R., Krompinger, J., & Bowry, R. (2005). Disruptions of preparatory attention contribute to failures of prospective memory. *Psychonomic Bulletin & Review, 12*, 502-507.

West, R., Murphy, K.J., Armilio, M.L., Craik, F.I.M., & Stuss, D.T. (2002). Lapses of intention and performance variability reveal age-related increases in fluctuations of executive control. *Brain and Cognition, 49*, 402-419.

APPENDIX A

Pre-participation Health Screen

"Before we can include you in the study we must ask you a few questions about your health. To protect your privacy, we will destroy your answers to these questions after determining your eligibility for this particular study. You are free not to answer a question if you feel it is objectionable." (Items in **Bold** are exclusion criteria.)

1) Has a doctor ever said you have one of the following:		
a) A stroke?	**Yes**	No
b) A transient ischemic attack?	**Yes**	No
c) A brain tumor?	**Yes**	No
d) A brain infection such as encephalitis or meningitis?	**Yes**	No
e) Epilepsy or seizures?	**Yes**	No
f) Multiple sclerosis?	**Yes**	No
g) Parkinson's disease?	**Yes**	No
h) Dementia?	**Yes**	No
2) Have you ever been diagnosed with any of the following:		
a) Depression?	Yes	No
(If yes) Are you currently in treatment or taking medications for depression?	**Yes**	No
b) Anxiety?	Yes	No
(If yes) Are you currently in treatment or taking medications for anxiety?	**Yes**	No
c) Schizophrenia?	**Yes**	No
d) Bipolar disorder (manic depression)?	**Yes**	No
3) Have you ever experienced any of the following:		
a) Concussion?	Yes	No
(If yes) Did this occur less than ten years ago?	**Yes**	No
b) Skull or facial fracture?	Yes	No
(If yes) Did this occur less than five years ago?	**Yes**	No
c) Head injury with loss of consciousness greater than five minutes, or that required an overnight hospitalization?	**Yes**	No
d) Loss of consciousness greater than 15 minutes other than during surgery?	**Yes**	No

4) Do you have any difficulty moving your fingers or arms?	**Yes**	No
5) Do you have trouble with your vision that makes it difficult to read ordinary print even when you have your glasses on?	**Yes**	No
6) Are you colorblind?	**Yes**	No

If participant is excluded on questions 1, 2, or 3: "Thank you for answering those questions. You mentioned that you have had ________________. Although we are not certain that it would affect your performance, we are being extra cautious to control for certain health criteria at this stage of testing. However, if we have future studies in which we are not excluding for medical reasons, may we contact you?"

If participant is excluded on questions 4, 5, or 6: "Thank you for answering those questions. Because the tests we are using for this study require _____________ we are unable to include you in the study. Would you still be interested in future studies that do not include these requirements?"

APPENDIX B

Health Questionnaire

This health questionnaire is used to match older and younger adults on certain health variables and, if necessary, to conduct further analyses if future research suggests that some of these health characteristics may confound the results of our research. As with any data collected, the information you provide is completely confidential and will not be attached to your name. You are free not to answer a question if you feel it is objectionable.

1. Medical Problems: Has a doctor ever said that you had any of the following disorders (check all that apply)?

_____ Glaucoma
_____ Cataracts Have you had corrective surgery?________________
_____ Heart Attack
_____ Congestive Heart Failure
_____ Hypertension
_____ Diabetes
_____ Kidney Disease
_____ Thyroid Disease
_____ Cancer What kind?___________________ Is your cancer in remission?________

_____ **If none of the above apply check here.**

2. Medications
   a. How many alcoholic beverages do you consume in an average week?___________________
   b. Please list any medications (prescription and over-the-counter) that you are taking and the purpose for each:

____
____
____
____
____

3. Health Rating

On the following scale, circle the number that best describes you current health, with 7 being excellent and 1 being poor:

(poor) 1 2 3 4 5 6 7 (excellent)

APPENDIX C

Table of Parameter Values for SD on RT Regression Equations for Experiment 1.

The no ProM load and Prom load conditions are reported in the top and bottom portions of the tables, respectively. The columns labeled B_0 contains the regression constant and the columns labeled B_1 contain the slopes of the regression lines. The values in parentheses are standard errors.

Table C1

Experiment 1: Parameter Values for Standard Deviation on Mean Response Time Regression Equations

	Full Attention		Divided Attention	
Condition	B_0	B_1	B_0	B_1
	Lexical Decision Task			
Focal				
Young	-496.30 (83.12)	1.06 (0.13)	-75.41 (72.96)	0.44 (0.07)
Old	-409.55 (98.65)	0.79 (0.11)	39.21 (119.60)	0.40 (0.09)
Non-Focal				
Young	-518.83 (86.60)	1.11 (0.14)	-207.23 (95.99)	0.63 (0.10)
Old	-537.02 (49.00)	0.96 (0.06)	-75.33 (111.34)	0.51 (0.08)
	Lexical Decision Task with ProM Burden			
Focal				
Young	-471.77 (73.69)	1.04 (0.10)	-156.48 (84.56)	0.56 (0.09)
Old	-258.23 (84.49)	0.64 (0.09)	-164.87 (107.12)	0.55 (0.08)
Non-Focal				
Young	-353.04 (82.09)	0.88 (0.11)	-68.78 (72.36)	0.50 (0.07)
Old	-589.00 (87.16)	1.12 (0.08)	-107.93 (86.82)	0.54 (0.06)

Note: Values in parentheses are standard errors.

APPENDIX D

Representative ex-Gaussian Probability Density Functions and Histograms: Experiment 1

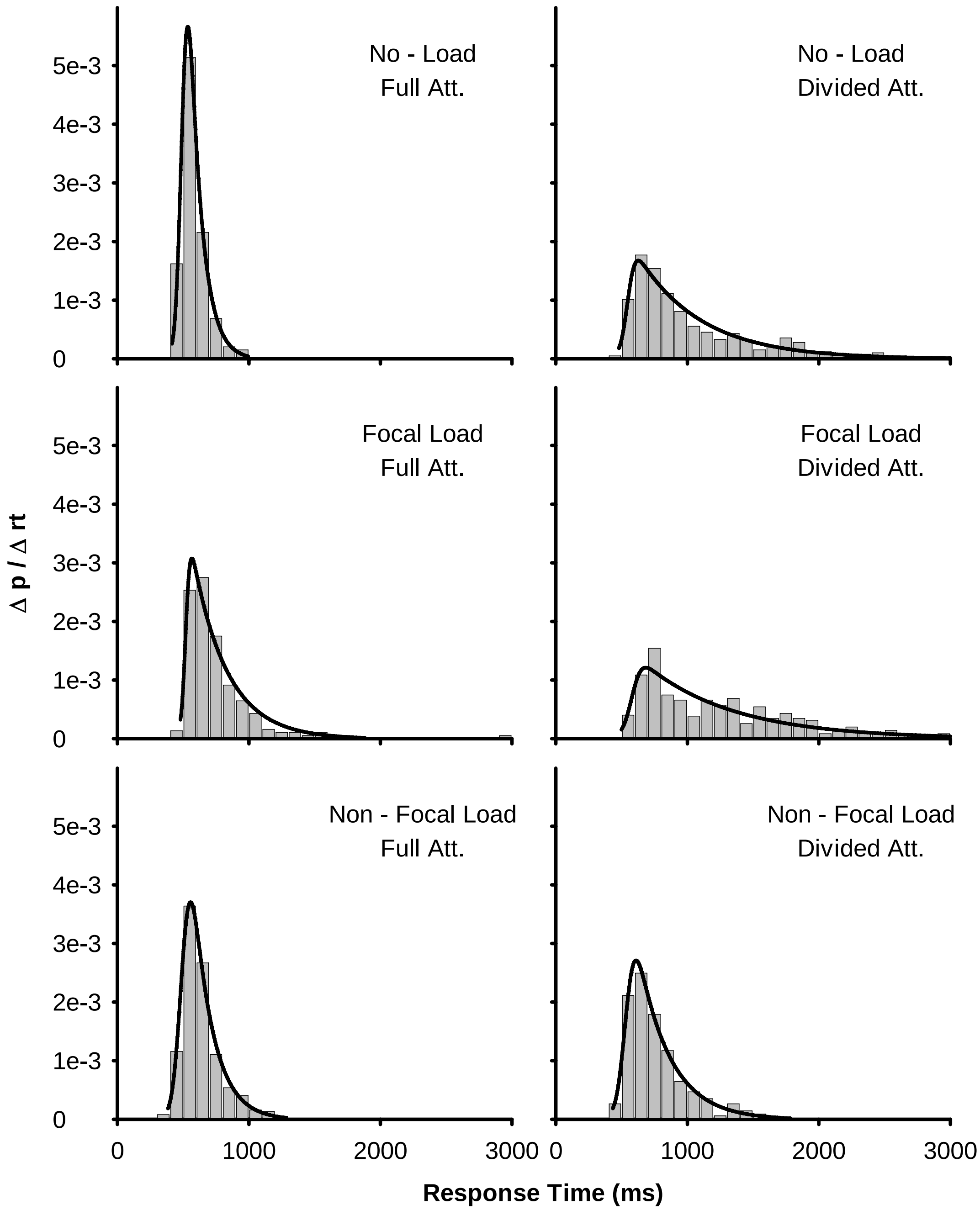

Figure D1. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *mu* parameters near the median for a given condition.

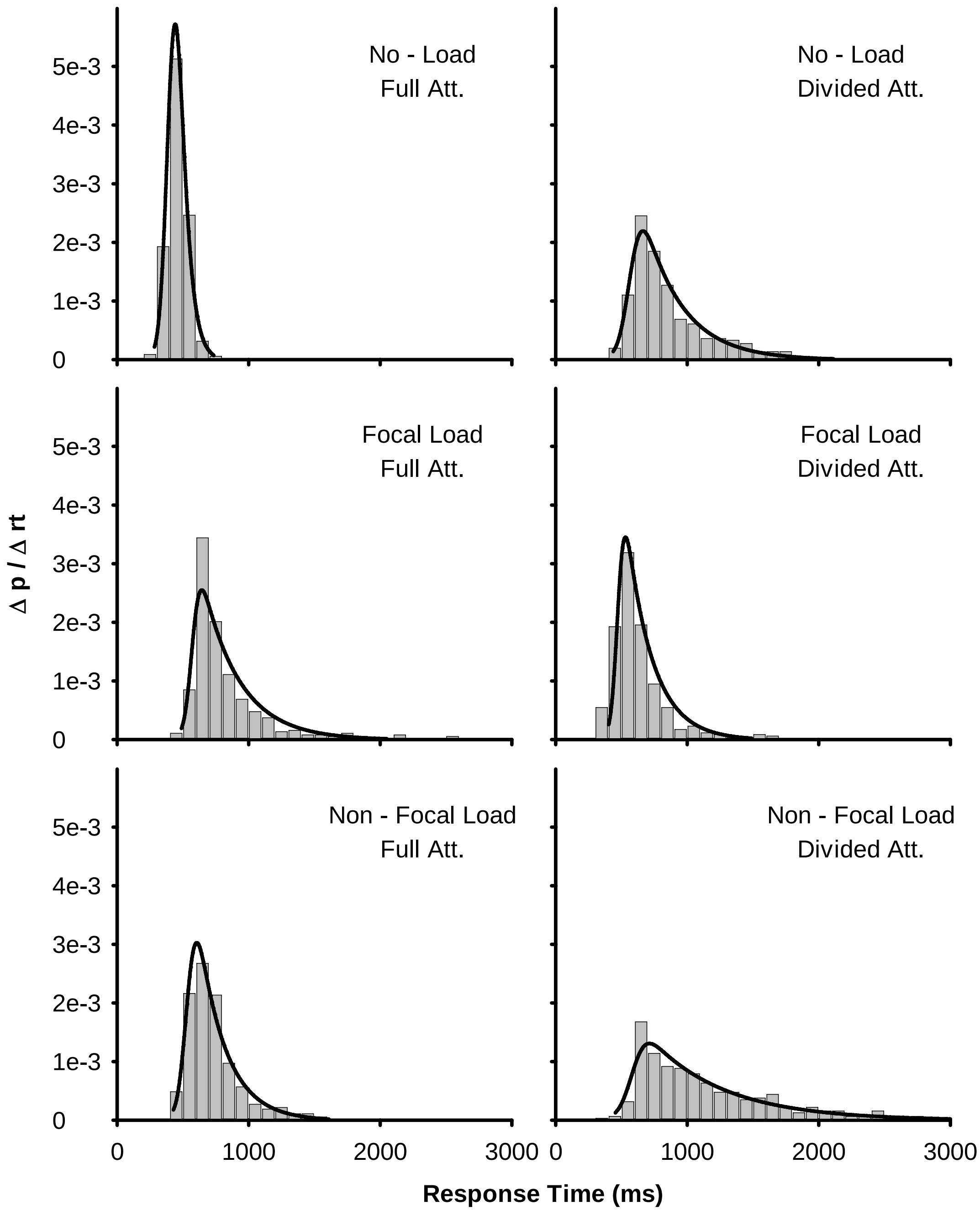

Figure D2. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *sigma* parameters near the median for a given condition.

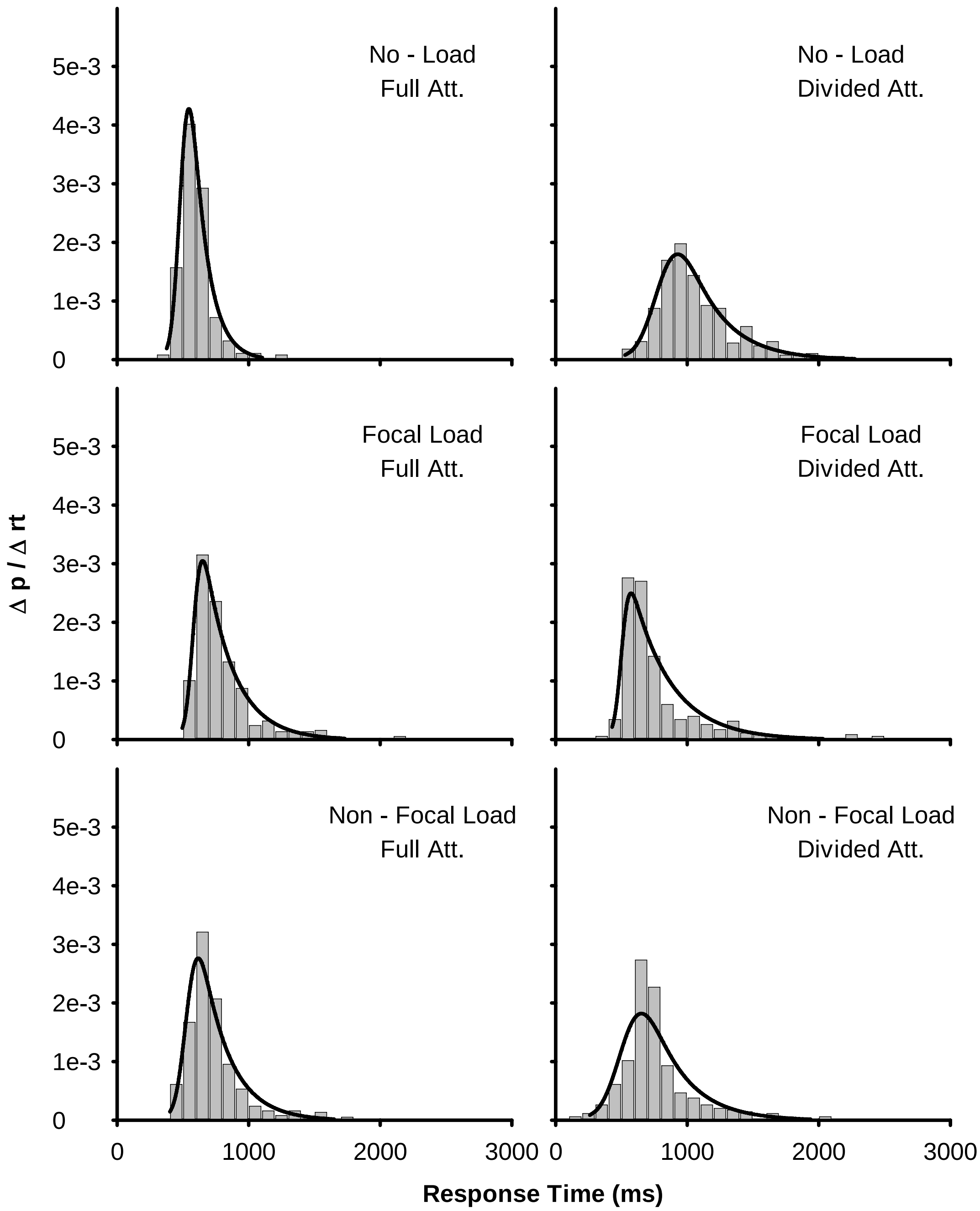

Figure D3. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *tau* parameters near the median for a given condition.

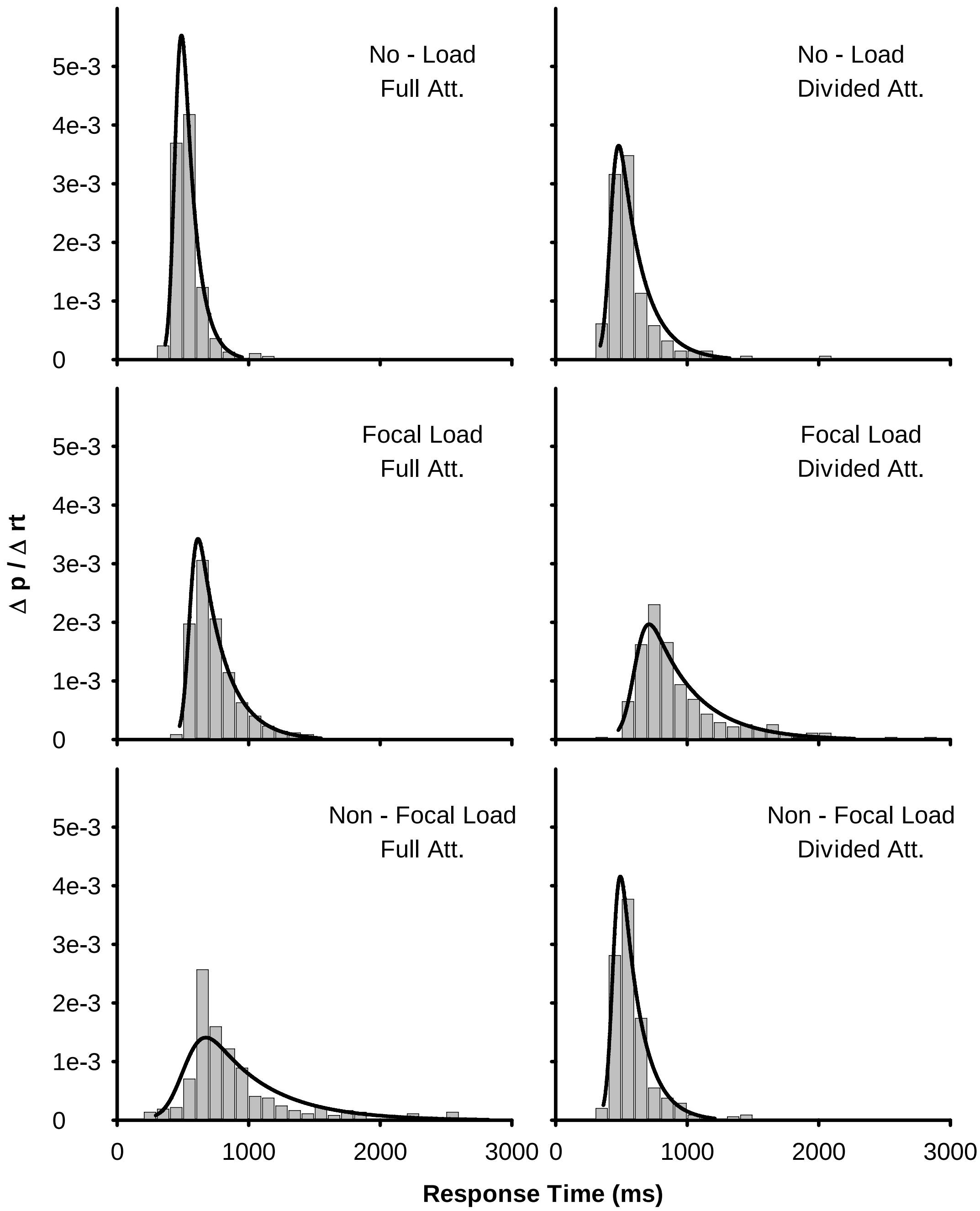

Figure D4. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *tau*/*sigma* ratios near the median for a given condition.

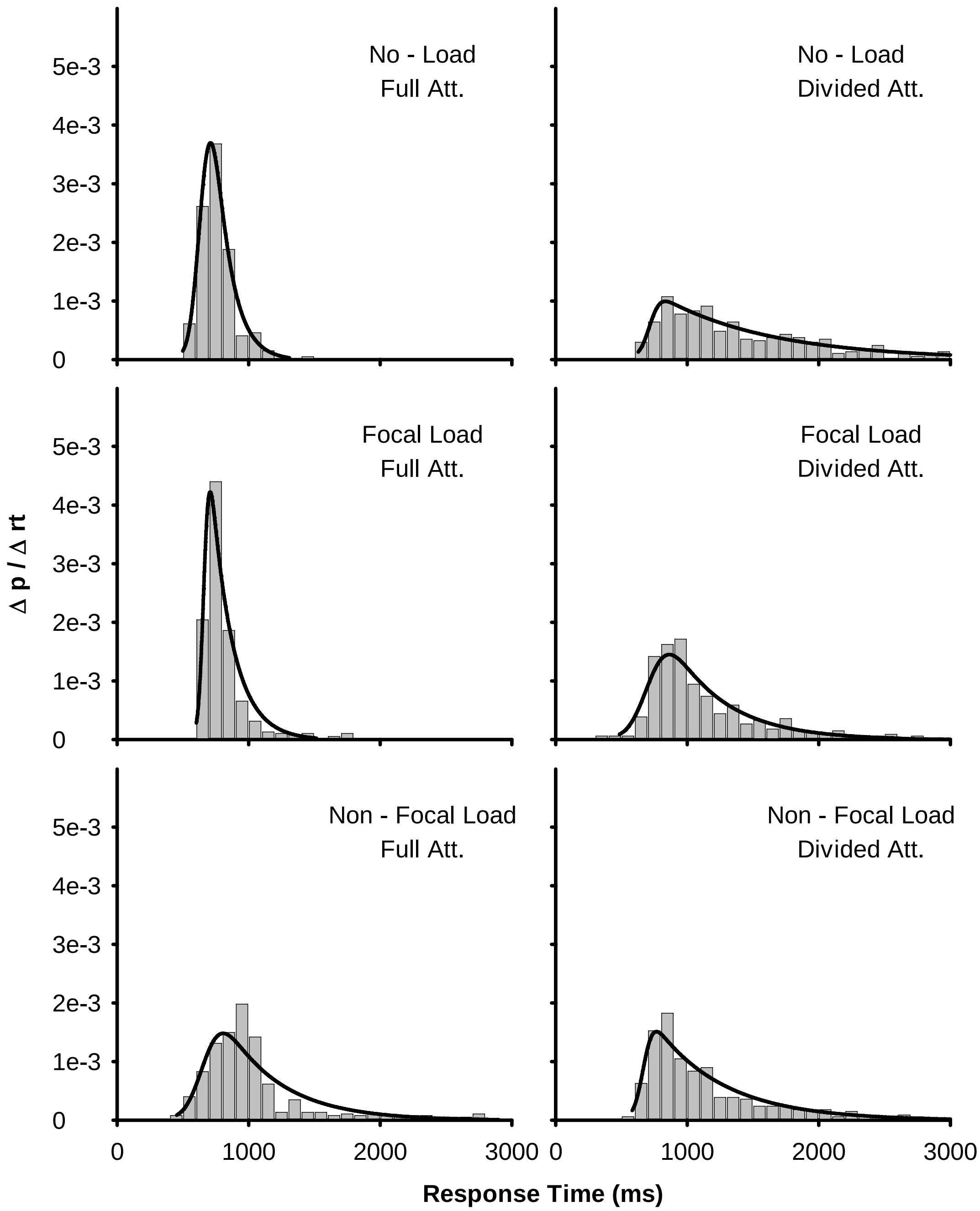

Figure D5. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *mu* parameters near the median for a given condition.

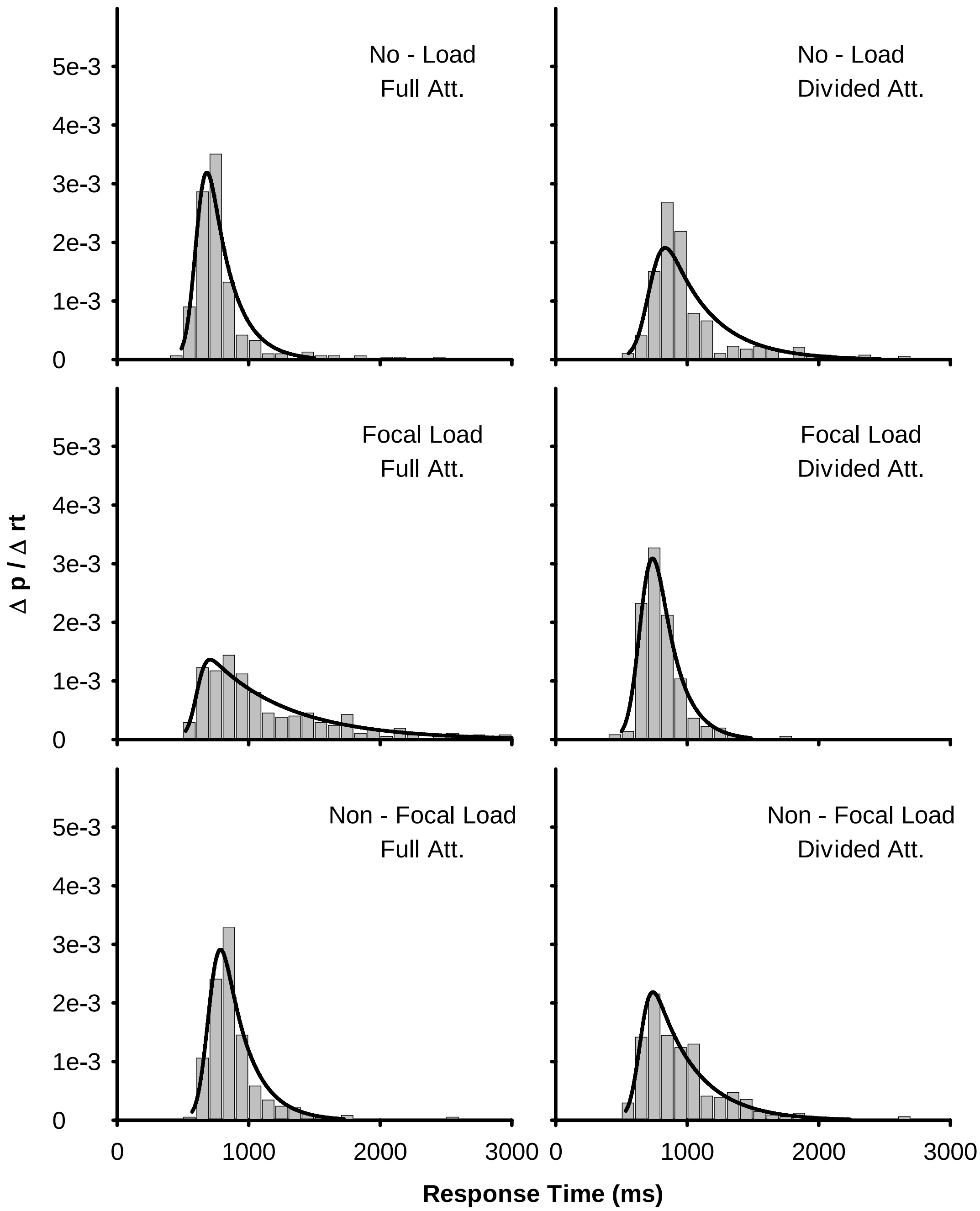

Figure D6. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *sigma* parameters near the median for a given condition.

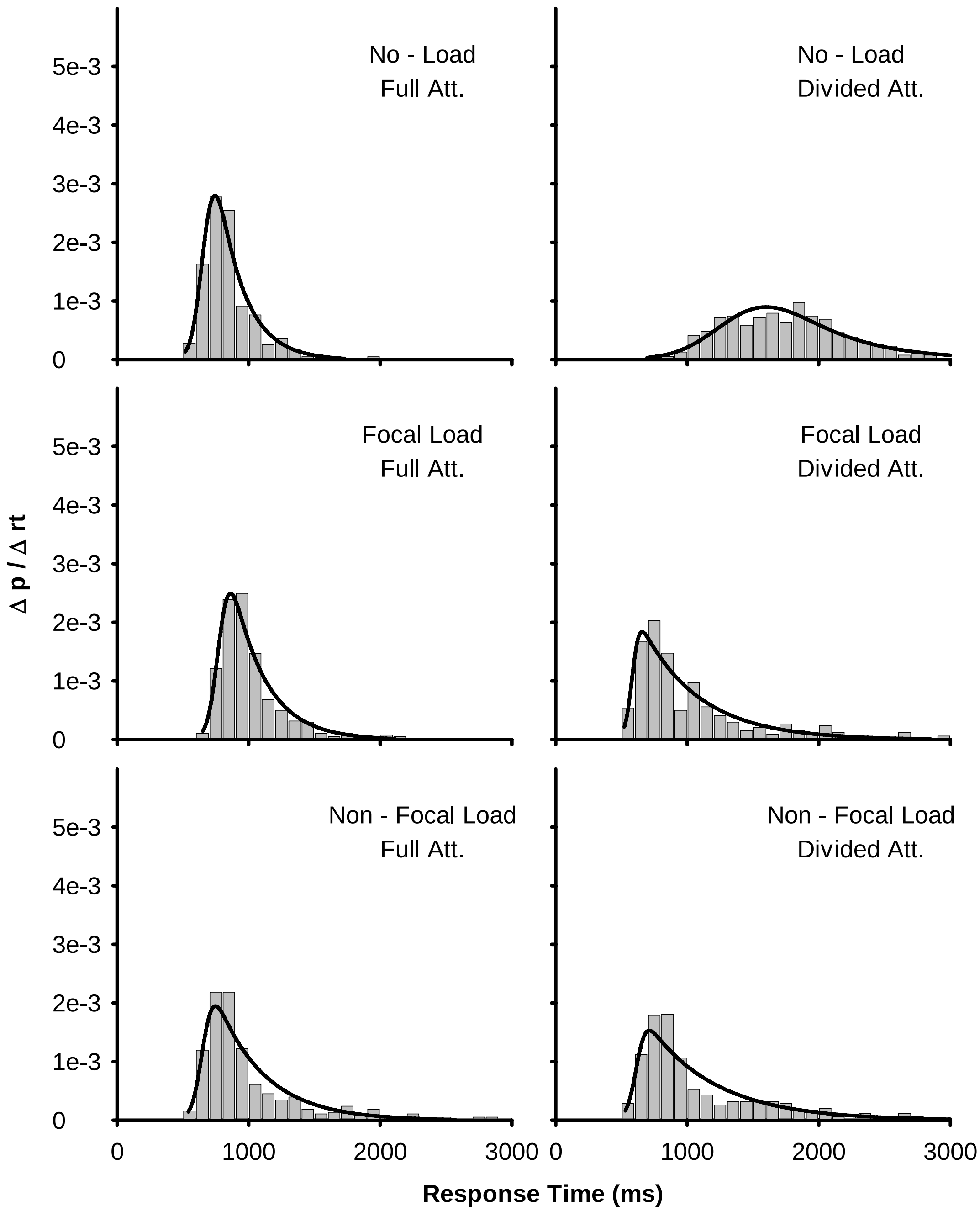

Figure D7. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *tau* parameters near the median for a given condition.

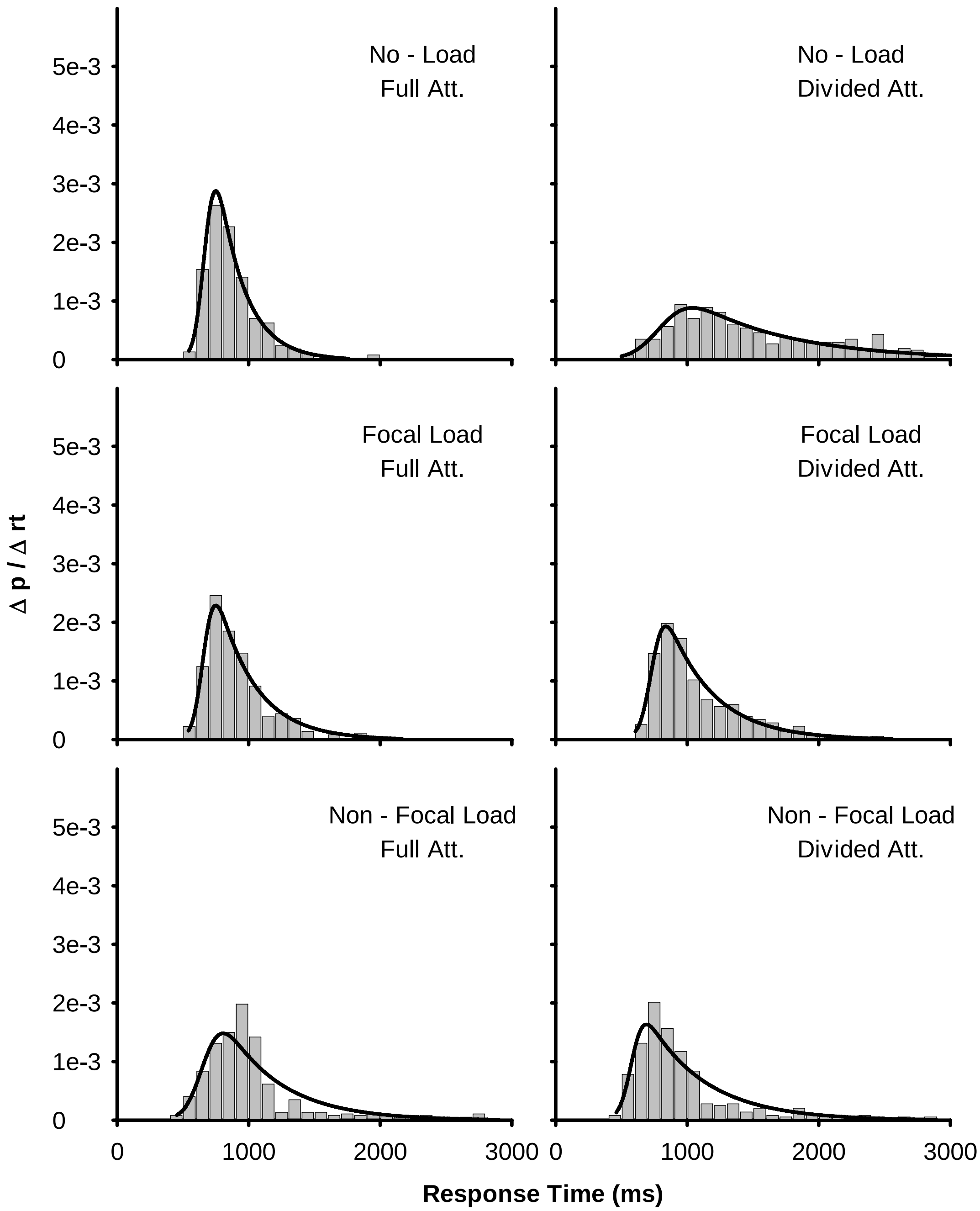

Figure D8. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *tau*/*sigma* ratios near the median for a given condition.

APPENDIX E

Representative Weibull Probability Density Functions and Histograms: Experiment 1

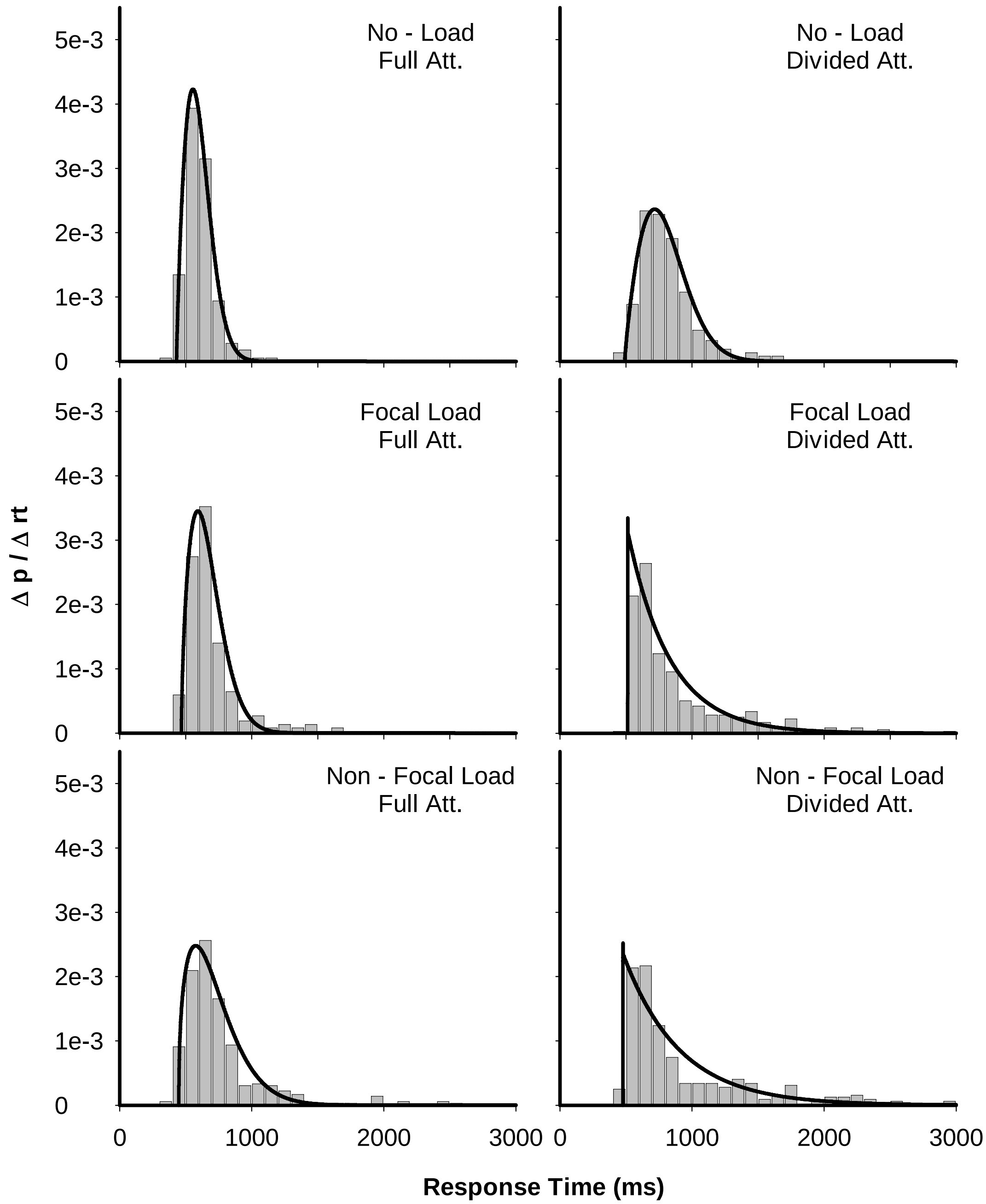

Figure E1. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *shift* parameters near the median for a given condition.

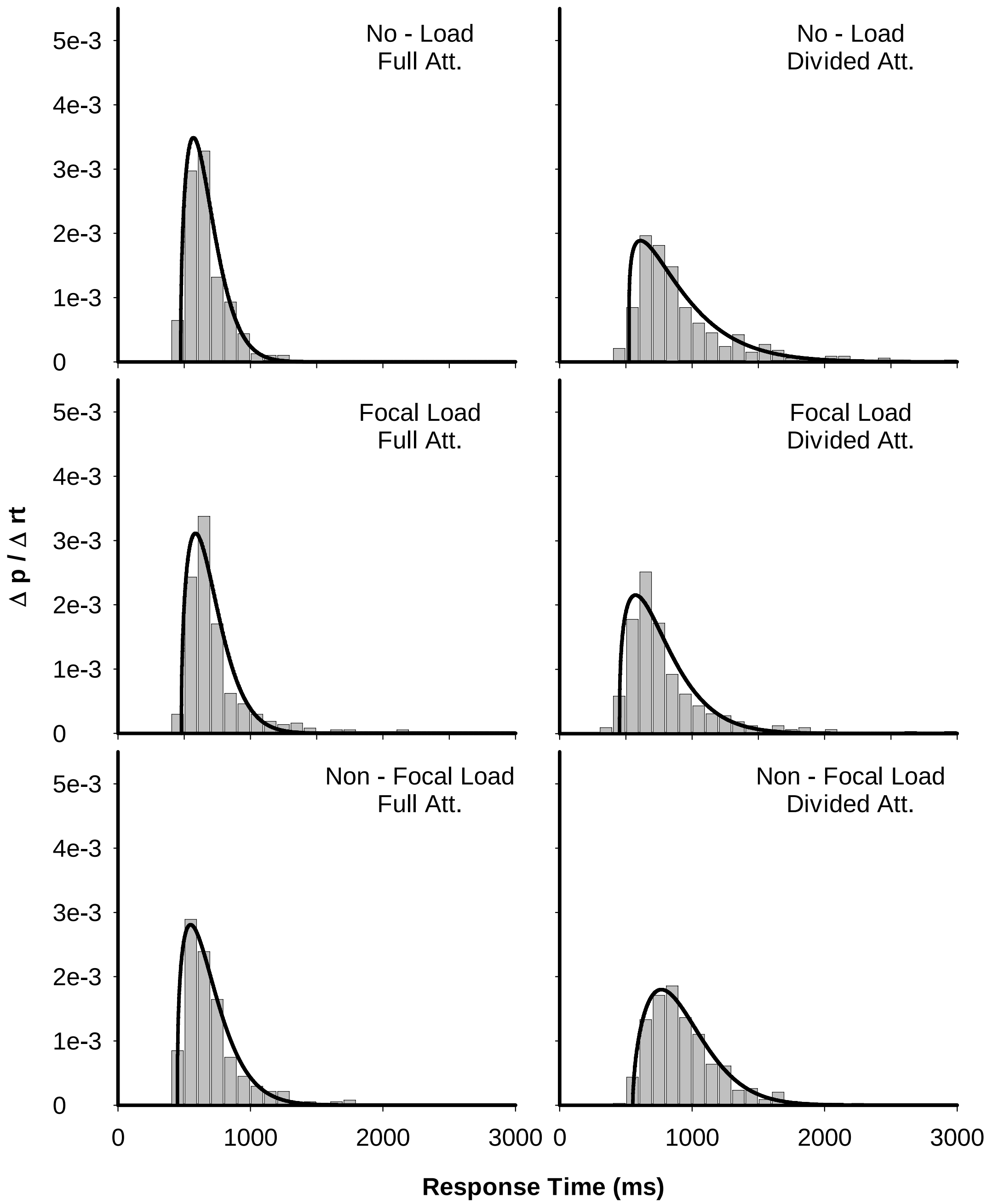

Figure E2. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *scale* parameters near the median for a given condition.

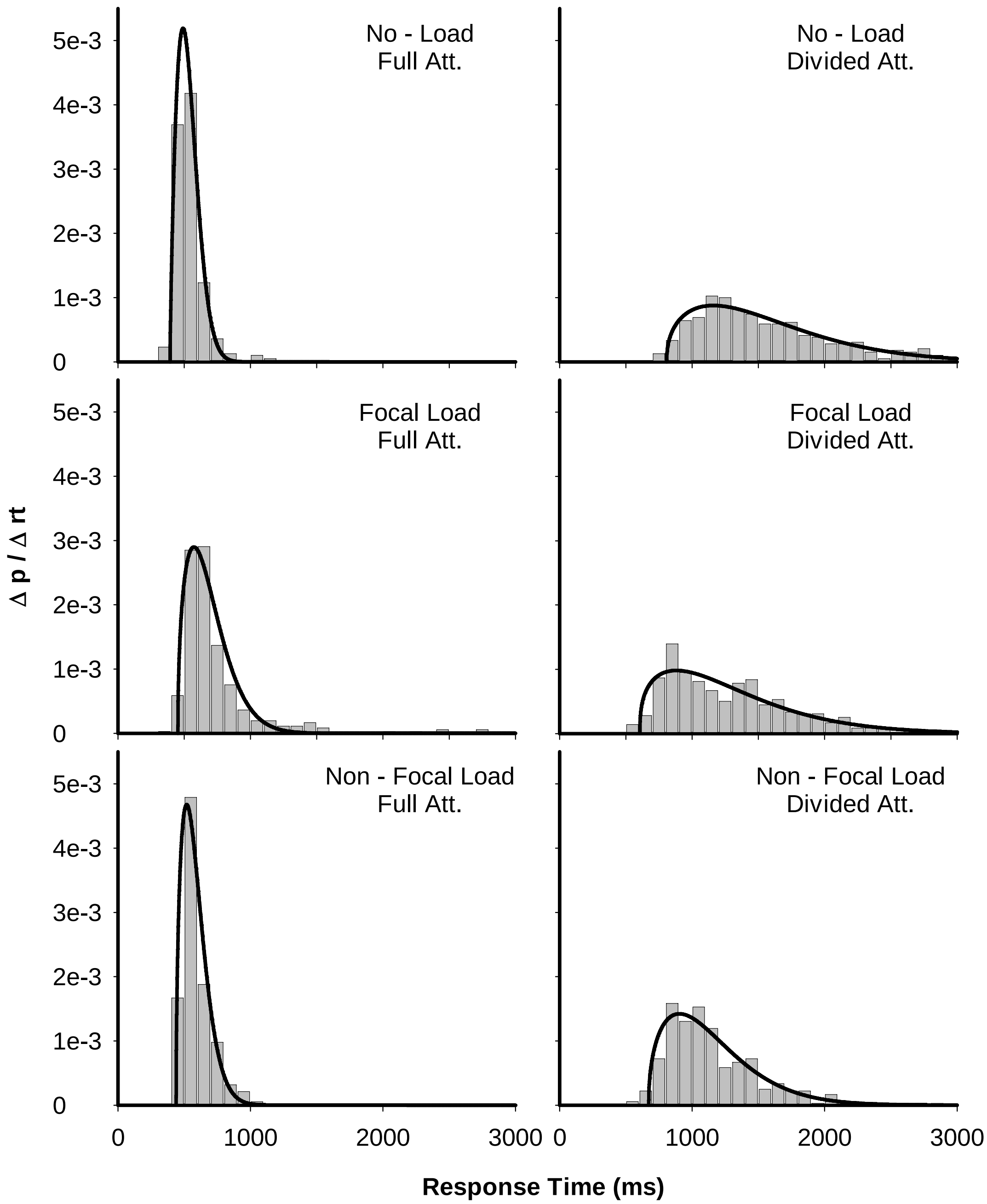

Figure E3. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *shape* parameters near the median for a given condition.

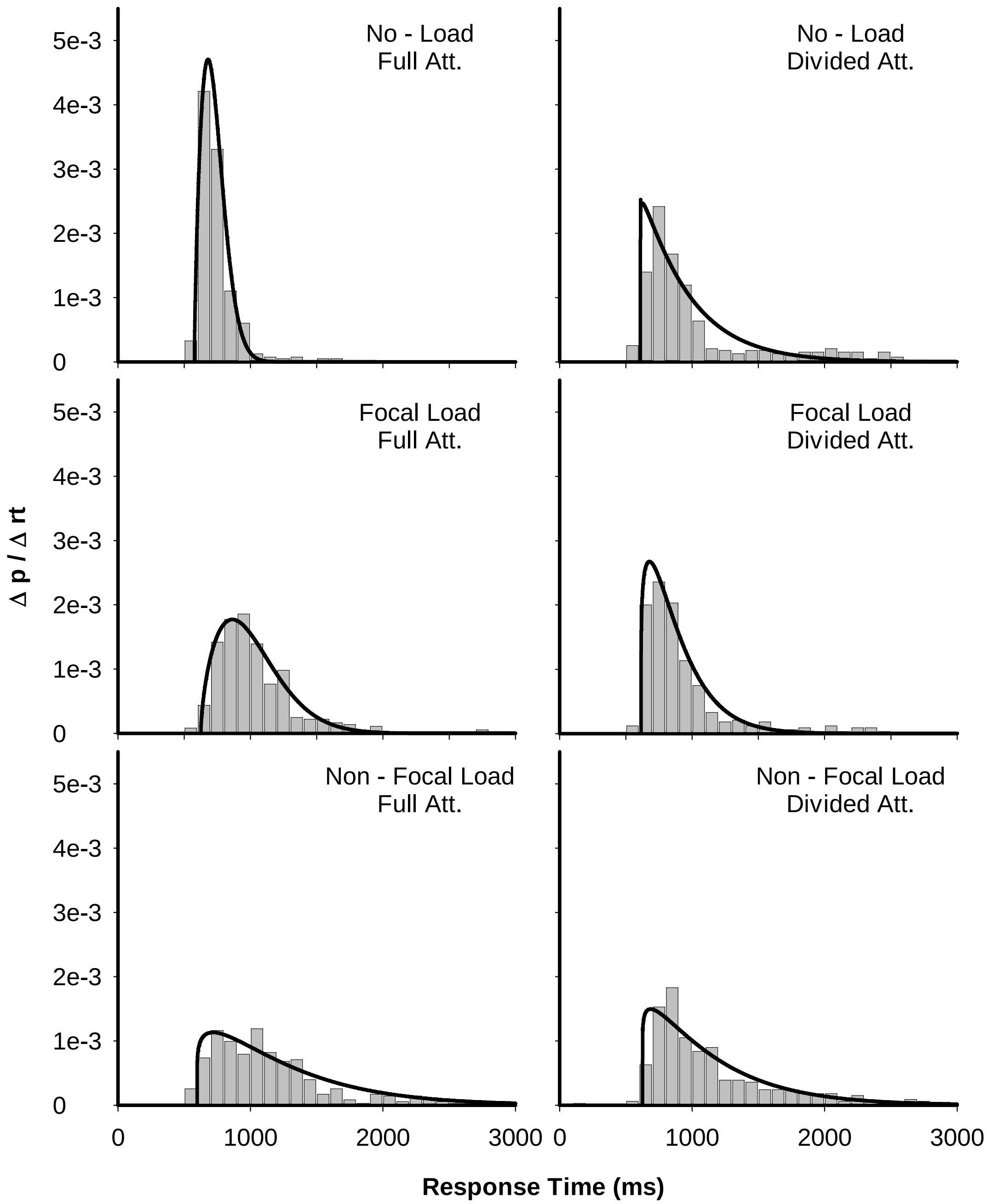

Figure E4. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *shift* parameters near the median for a given condition.

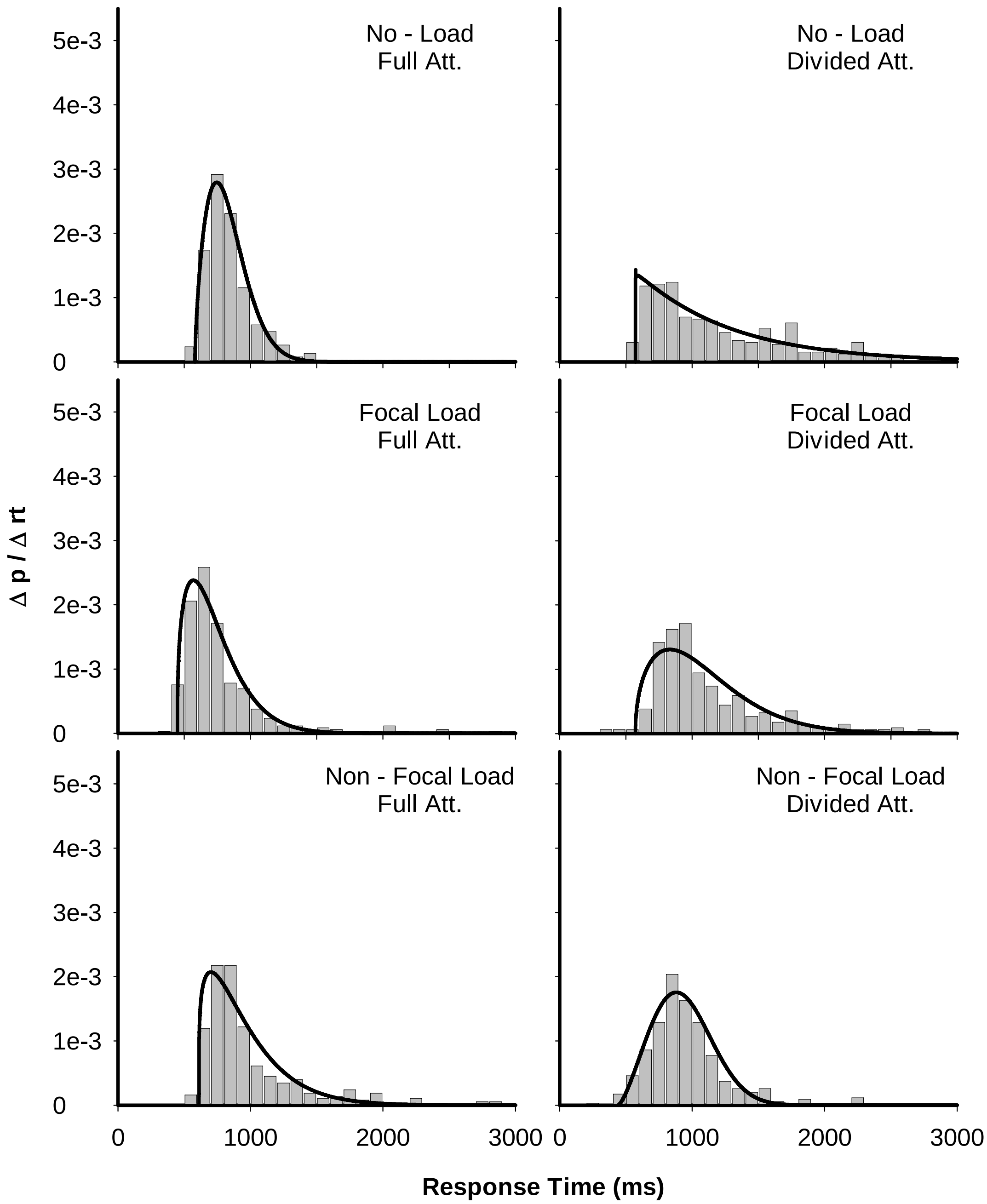

Figure E5. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *scale* parameters near the median for a given condition.

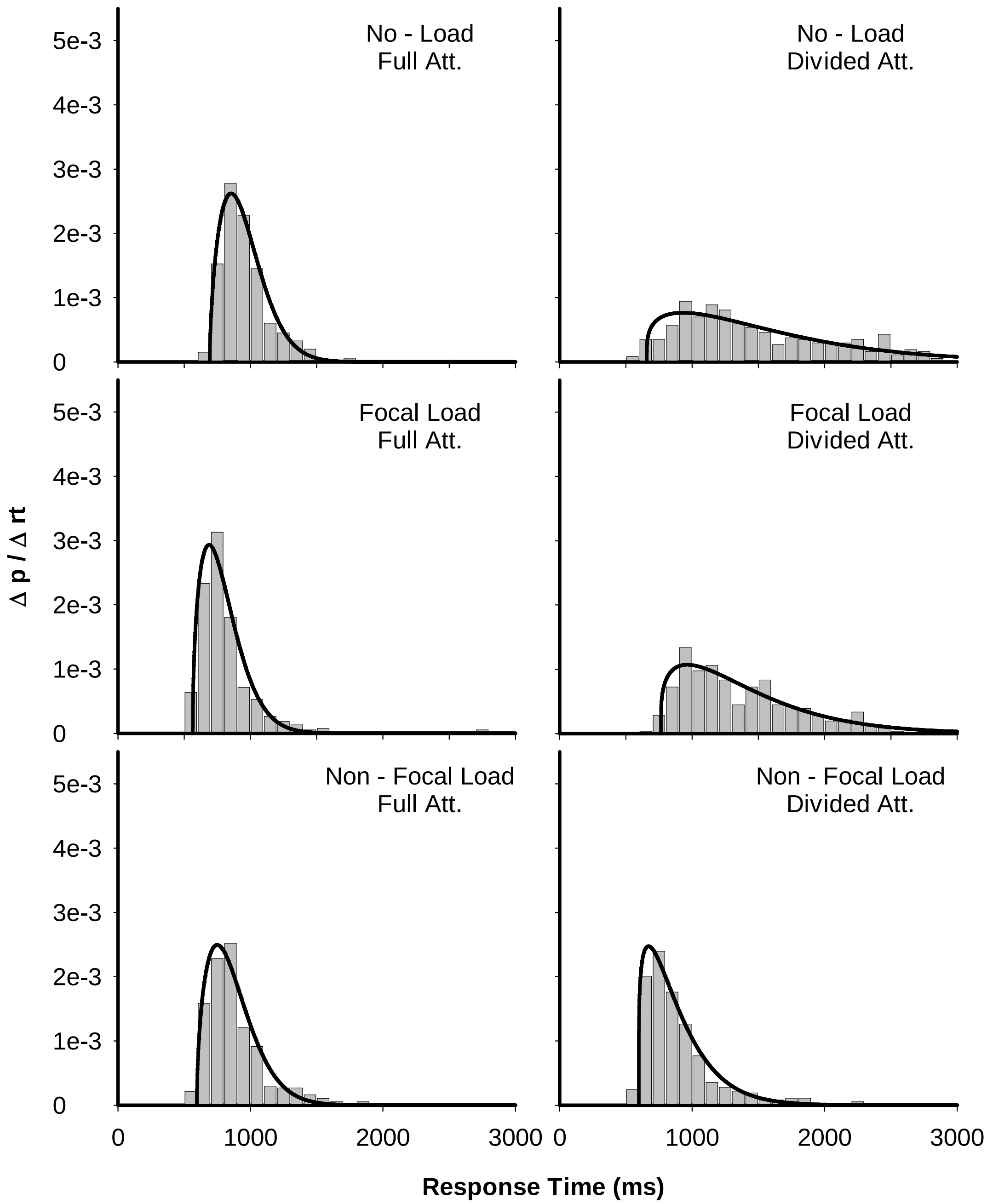

Figure E6. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *shape* parameters near the median for a given condition.

APPENDIX F

Summary Tables for Hierarchical Regression Analyses: Experiment 1

The full attention and divided attention conditions are reported in the top and bottom portions of the tables, respectively. The predictor variables added at each step are listed in the first column. The total *R*2 for each model at a given step is reported in the second column. The third column contains the increment in *R*2 associated with the addition of a given variable to the model. The *F* statistics testing the increment in *R*2, the associated degrees of freedom, and the *p* value for the increment in *R*2 are given in the fourth, fifth, and sixth columns, respectively. The seventh column contains the standardized regression coefficients. Those regression coefficients provided for the variables entered at the first step are identical to zero-order correlation coefficients, whereas the coefficients given for the variable added at the second step are partial regression coefficients.

Table F1

Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Median Response Time as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Median RT	0.092	0.050	2.25	1, 41	0.14	0.288
1. Median RT	0.002		0.08	1, 42	0.78	0.043
2. Age Group	0.092	0.090	4.08	1, 41	0.05	-0.388
Non - Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Median RT	0.194	0.172	8.73	1, 41	< 0.01	0.591
1. Median RT	0.158		7.88	1, 42	< 0.01	0.397
2. Age Group	0.194	0.036	1.85	1, 41	0.18	-0.272
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Median RT	0.007	0.000	0.01	1, 41	0.92	-0.019
1. Median RT	0.003		0.11	1, 42	0.74	-0.051
2. Age Group	0.007	0.004	0.17	1, 41	0.69	-0.072
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Median RT	0.271	0.183	10.3	1, 41	< 0.01	0.468
1. Median RT	0.271		3.33	1, 42	0.08	0.271
2. Age Group	0.520	0.197	11.09	1, 41	< 0.01	-0.486

Table F2

Summary of Hierarchical Regression Analyses of ProM Performance with On-Going Task Coefficient of Variation as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. CV	0.057	0.015	0.66	1, 41	0.42	-0.173
1. CV	0.003		0.14	1, 42	0.71	0.057
2. Age Group	0.057	0.054	2.36	1, 41	0.13	-0.327
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. CV	0.115	0.093	4.29	1, 41	0.05	-0.318
1. CV	0.061		2.72	1, 42	0.11	-0.247
2. Age Group	0.115	0.054	2.52	1, 41	0.12	0.244
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. CV	0.020	0.013	0.56	1, 41	0.46	0.116
1. CV	0.014		0.62	1, 42	0.44	0.120
2. Age Group	0.020	0.005	0.22	1, 41	0.64	-0.073
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. CV	0.114	0.027	1.23	1, 41	0.27	0.166
1. CV	0.011		0.48	1, 42	0.49	0.106
2. Age Group	0.114	0.103	4.76	1, 41	0.04	-0.326

Table F3

Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Tau/Sigma as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Tau/Sigma	0.051	0.009	0.39	1, 41	0.54	0.095
1. Tau/Sigma	0.088		0.33	1, 42	0.57	0.088
2. Age Group	0.226	0.044	1.88	1, 41	0.18	-0.209
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Tau/Sigma	0.106	0.083	3.83	1, 41	0.05	-0.293
1. Tau/Sigma	0.260		3.05	1, 42	0.09	-0.260
2. Age Group	0.326	0.038	1.76	1, 41	0.19	0.199
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Tau/Sigma	0.027	0.021	0.88	1, 41	0.35	0.145
1. Tau/Sigma	0.022		0.92	1, 42	0.34	0.147
2. Age Group	0.027	0.006	0.24	1, 41	0.62	-0.076
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Tau/Sigma	0.126	0.038	1.81	1, 41	0.19	0.205
1. Tau/Sigma	0.011		0.45	1, 42	0.51	0.103
2. Age Group	0.126	0.115	5.40	1, 41	0.03	-0.355

Table F4

Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Weibull Shape as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Shape	0.064	0.022	0.97	1, 41	0.33	-0.149
1. Shape	0.023		1.01	1, 42	0.32	-0.153
2. Age Group	0.064	0.041	1.79	1, 41	0.19	-0.202
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Shape	0.025	0.002	0.10	1, 41	0.75	0.049
1. Shape	0.001		0.05	1, 42	0.82	0.036
2. Age Group	0.025	0.024	1.00	1, 41	0.32	0.154
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Shape	0.013	0.007	0.27	1, 41	0.60	-0.081
1. Shape	0.007		0.29	1, 42	0.59	-0.083
2. Age Group	0.013	0.006	0.25	1, 41	0.62	-0.078
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Shape	0.088	0.000	0.00	1, 41	0.99	-0.001
1. Shape	0.008		0.35	1, 42	0.56	-0.091
2. Age Group	0.088	0.079	3.56	1, 41	0.07	-0.296

Table F5

Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Median Response Time as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Median RT	0.046	0.004	0.18	1, 41	0.67	-0.101
1. Median RT	0.040		1.74	1, 42	0.20	-0.199
2. Age Group	0.046	0.007	0.29	1, 41	0.60	-0.128
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Median RT	0.178	0.155	7.74	1, 41	< 0.01	-0.585
1. Median RT	0.024		1.03	1, 42	0.32	-0.155
2. Age Group	0.178	0.154	7.68	1, 41	< 0.01	0.582
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Median RT	0.007	0.000	0.01	1, 41	0.91	0.027
1. Median RT	0.003		0.11	1, 42	0.74	-0.051
2. Age Group	0.007	0.004	0.17	1, 41	0.68	-0.101
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Median RT	0.094	0.007	0.30	1, 41	0.59	-0.121
1. Median RT	0.075		3.40	1, 42	0.07	-0.274
2. Age Group	0.094	0.019	0.88	1, 41	0.36	-0.206

Table F6

Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Coefficient of Variation as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. CV	0.048	0.006	0.24	1, 41	0.63	0.078
1. CV	0.018		0.75	1, 42	0.39	0.132
2. Age Group	0.048	0.030	1.30	1, 41	0.26	-0.182
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. CV	0.028	0.006	0.24	1, 41	0.63	0.085
1. CV	0.000		0.00	1, 42	0.98	-0.003
2. Age Group	0.028	0.028	1.19	1, 41	0.28	0.190
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. CV	0.007	0.001	0.01	1, 41	0.93	0.015
1. CV	0.001		0.06	1, 42	0.81	0.038
2. Age Group	0.007	0.006	0.21	1, 41	0.67	-0.076
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. CV	0.130	0.042	1.98	1, 41	0.17	0.232
1. CV	0.102		4.77	1, 42	0.04	0.319
2. Age Group	0.130	0.028	1.31	1, 41	0.26	-0.188

Table F7

Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Tau/Sigma as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Tau/Sigma	0.043	0.001	0.04	1, 41	0.84	-0.030
1. Tau/Sigma	0.001		0.05	1, 42	0.82	-0.035
2. Age Group	0.043	0.042	1.80	1, 41	0.19	-0.205
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Tau/Sigma	0.079	0.057	2.53	1, 41	0.12	0.240
1. Tau/Sigma	0.049		2.16	1, 42	0.15	0.221
2. Age Group	0.079	0.030	1.35	1, 41	0.25	0.175
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Tau/Sigma	0.007	0.001	0.01	1, 41	0.92	0.016
1. Tau/Sigma	0.000		0.01	1, 42	0.93	0.015
2. Age Group	0.007	0.007	0.27	1, 41	0.61	-0.080
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Tau/Sigma	0.127	0.040	1.87	1, 41	0.18	0.200
1. Tau/Sigma	0.052		2.32	1, 42	0.14	0.229
2. Age Group	0.127	0.075	3.52	1, 41	0.07	-0.275

Table F8

Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Weibull Shape as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
Focal						
1. Age Group	0.042		1.85	1, 42	0.18	-0.206
2. Shape	0.047	0.005	0.22	1, 41	0.64	-0.076
1. Shape	0.000		0.00	1, 42	0.98	0.004
2. Age Group	0.047	0.047	2.04	1, 41	0.16	-0.232
Non-Focal						
1. Age Group	0.023		0.97	1, 42	0.33	0.150
2. Shape	0.024	0.002	0.08	1, 41	0.33	0.043
1. Shape	0.001		0.03	1, 42	0.87	0.025
2. Age Group	0.024	0.023	1.00	1, 41	0.32	0.155
			Divided Attention			
Focal						
1. Age Group	0.006		0.27	1, 42	0.61	-0.080
2. Shape	0.018	0.012	0.49	1, 41	0.49	-0.116
1. Shape	0.006		0.23	1, 42	0.63	-0.074
2. Age Group	0.018	0.013	0.53	1, 41	0.47	-0.120
Non-Focal						
1. Age Group	0.088		4.03	1, 42	0.05	-0.296
2. Shape	0.093	0.006	0.25	1, 41	0.62	-0.075
1. Shape	0.001		0.06	1, 42	0.80	-0.039
2. Age Group	0.093	0.092	4.14	1, 41	0.05	-0.305

APPENDIX G

Table of Parameter Values for SD on RT Regression Equations for Experiment 2.

The no ProM load and Prom load conditions are reported in the top and bottom portions of the tables, respectively. The columns labeled B_0 contains the regression constant and the colums labeled B_1 contain the slopes of the regression lines. The values in parentheses are standard errors.

Table G1

Experiment 2: Parameter Values for Standard Deviation on Mean Response Time Regression Equations

	Full Attention		Divided Attention	
Condition	B_0	B_1	B_0	B_1
	Lexical Decision Task			
High Salience				
Young	-565.16 (74.23)	1.17 (0.11)	13.94 (74.69)	0.37 (0.07)
Old	-386.63 (41.94)	0.75 (0.04)	38.69 (92.28)	0.39 (0.07)
Low Salience				
Young	-271.41 (59.39)	0.71 (0.10)	-49.78 (65.68)	0.44 (0.08)
Old	-454.30 (101.59)	0.87 (0.11)	-106.16 (123.50)	0.56 (0.10)
	Lexical Decision Task with ProM Burden			
High Salience				
Young	-379.78 (112.02)	0.90 (0.16)	11.64 (94.42)	0.37 (0.10)
Old	-376.83 (83.87)	0.77 (0.09)	-98.17 (85.62)	0.51 (0.07)
Low Salience				
Young	-272.72 (61.83)	0.76 (0.10)	-14.31 (51.93)	0.39 (0.06)
Old	-363.40 (126.84)	0.77 (0.14)	-265.16 (81.27)	0.69 (0.07)

Note: Values in parentheses are standard errors.

APPENDIX H

Representative ex-Gaussian Probability Density Functions and Histograms: Experiment 2

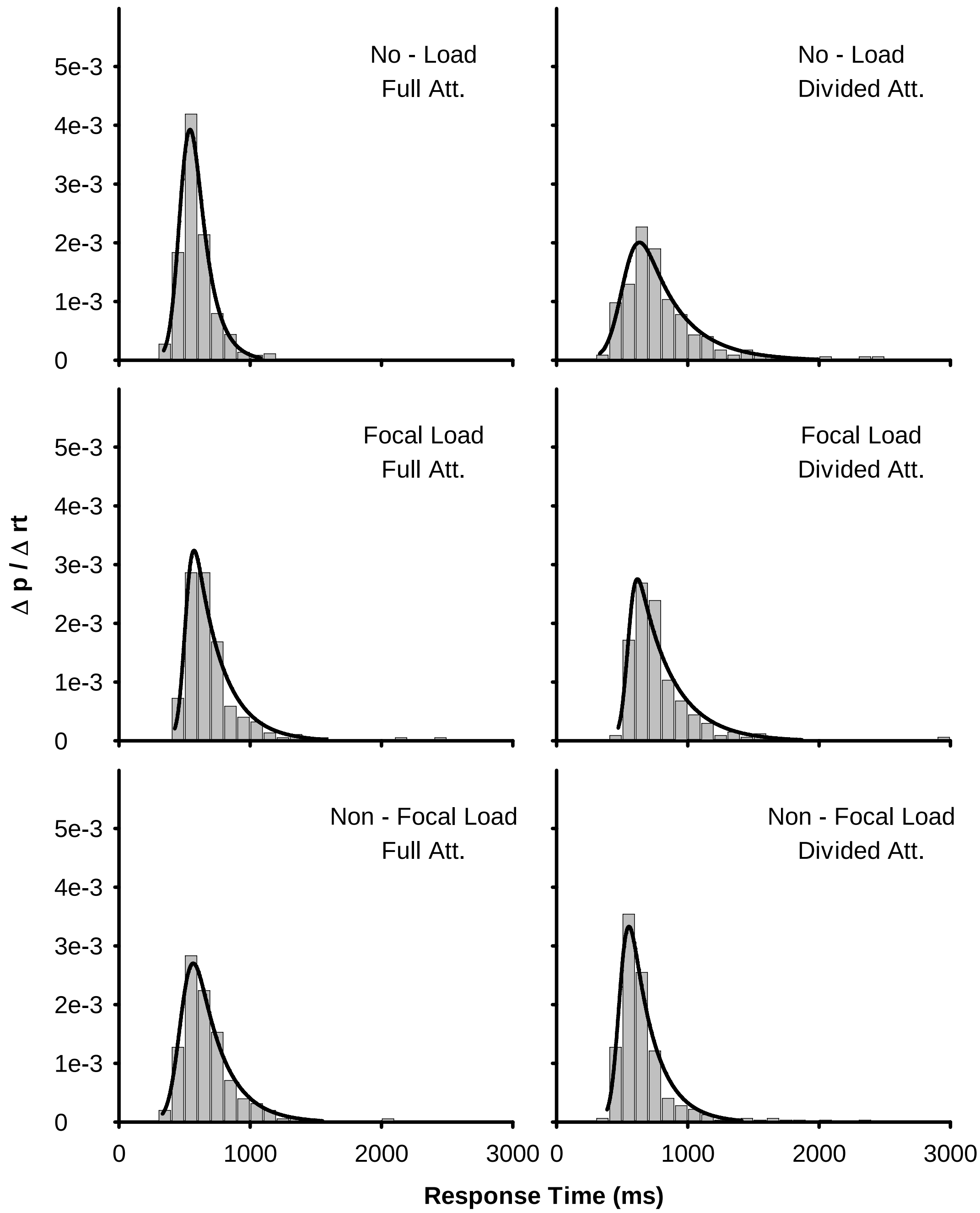

Figure H1. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *mu* parameters near the median for a given condition.

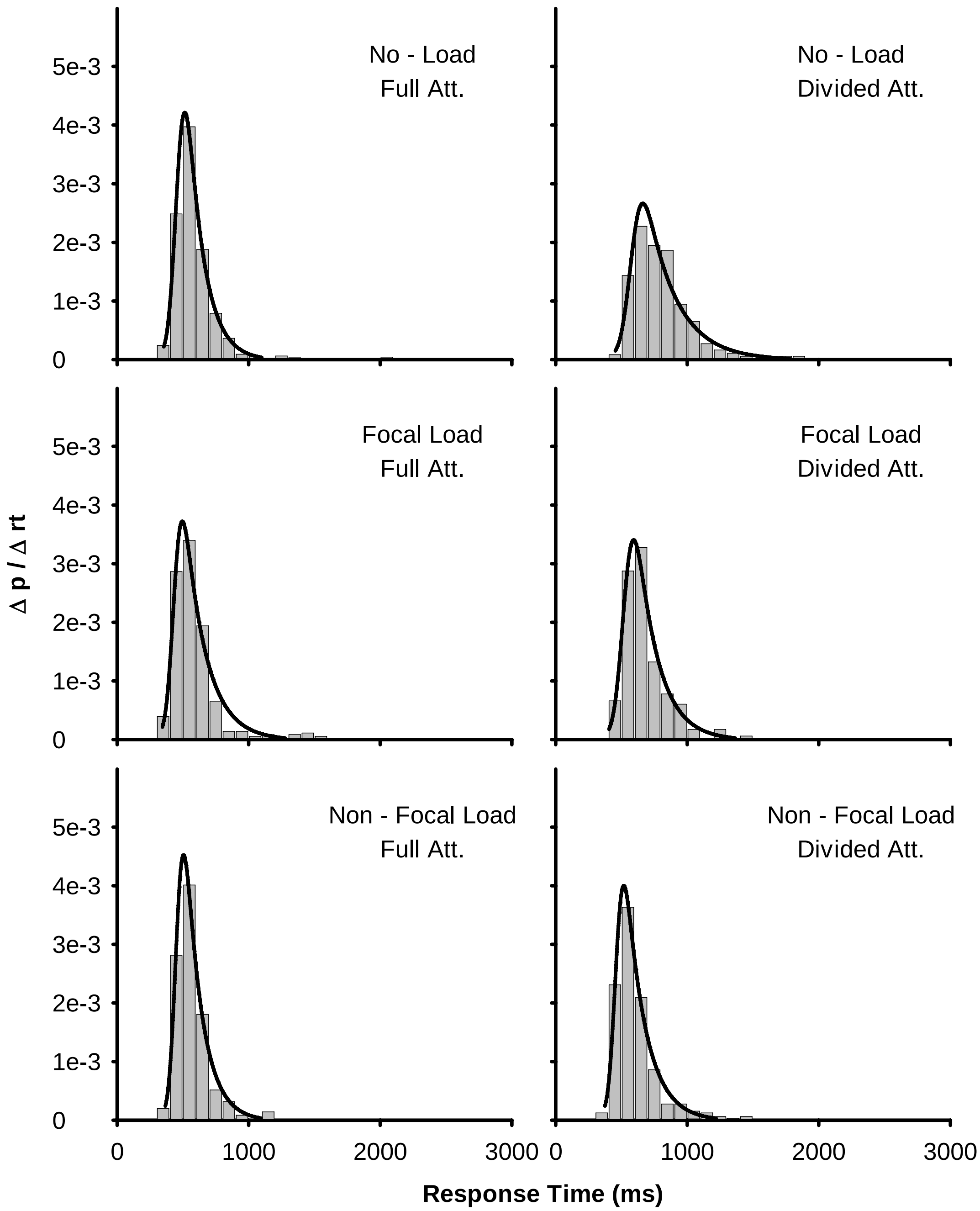

Figure H2. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *sigma* parameters near the median for a given condition.

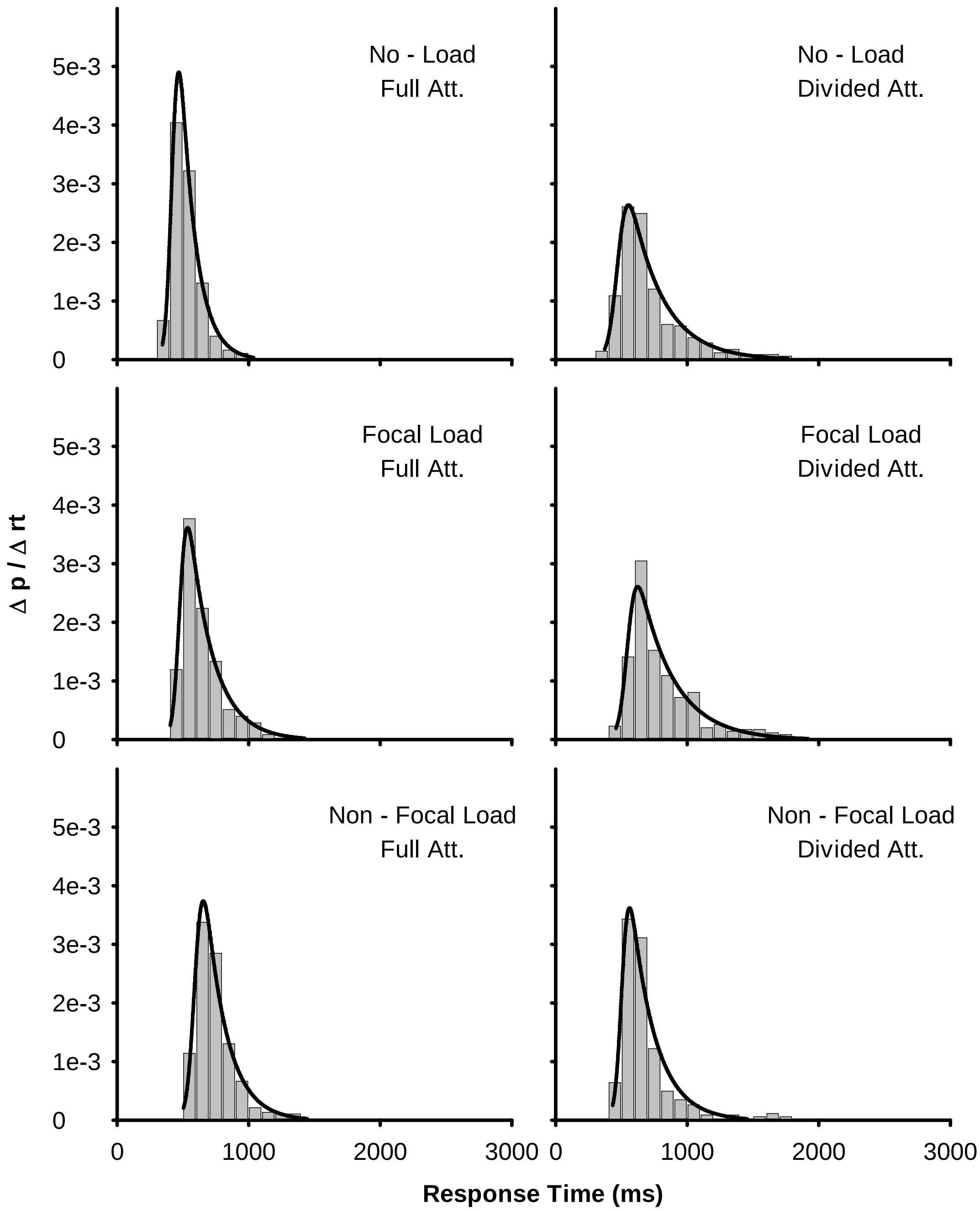

Figure H3. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *tau* parameters near the median for a given condition.

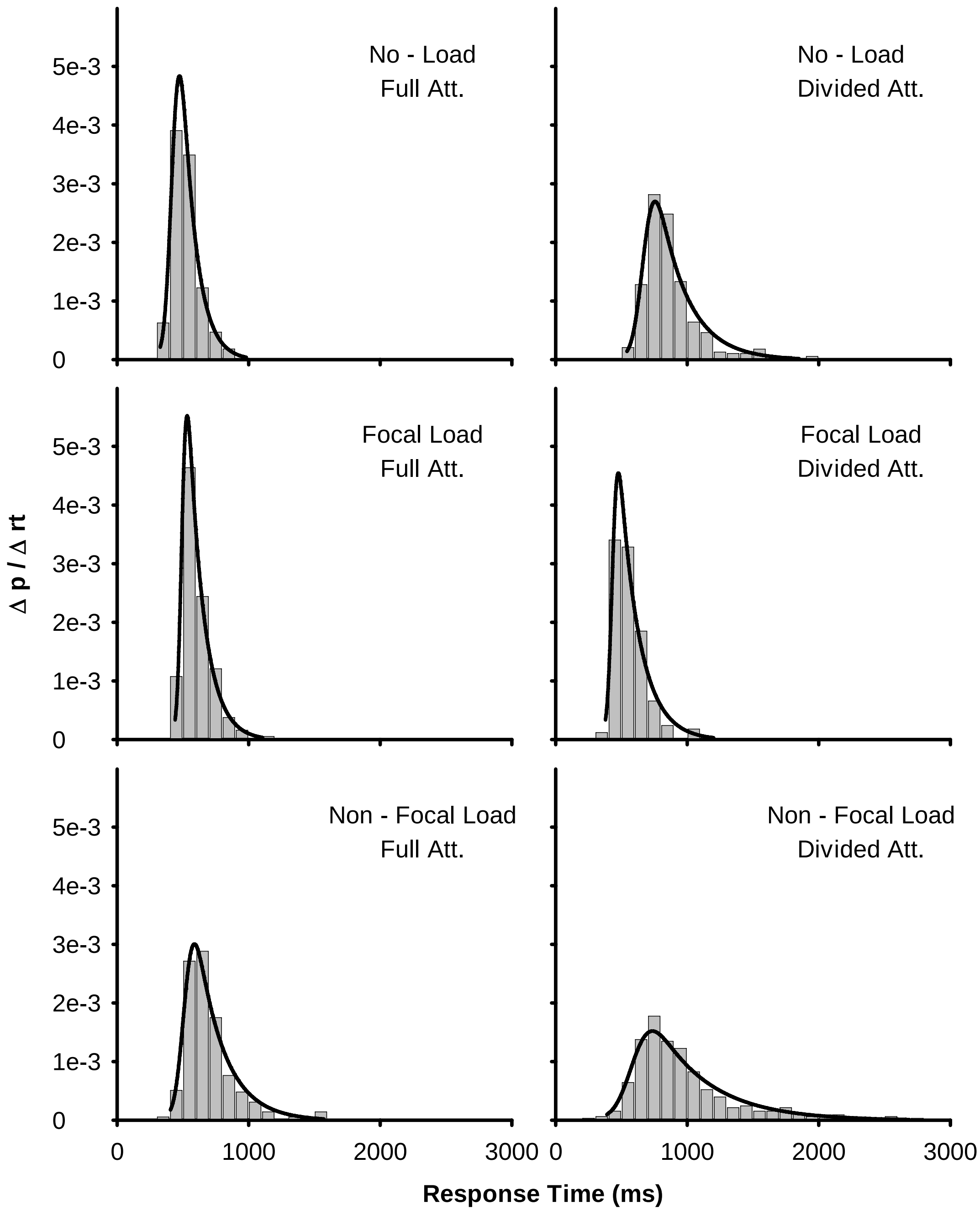

Figure H4. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual young participants who had *tau*/*sigma* ratios near the median for a given condition.

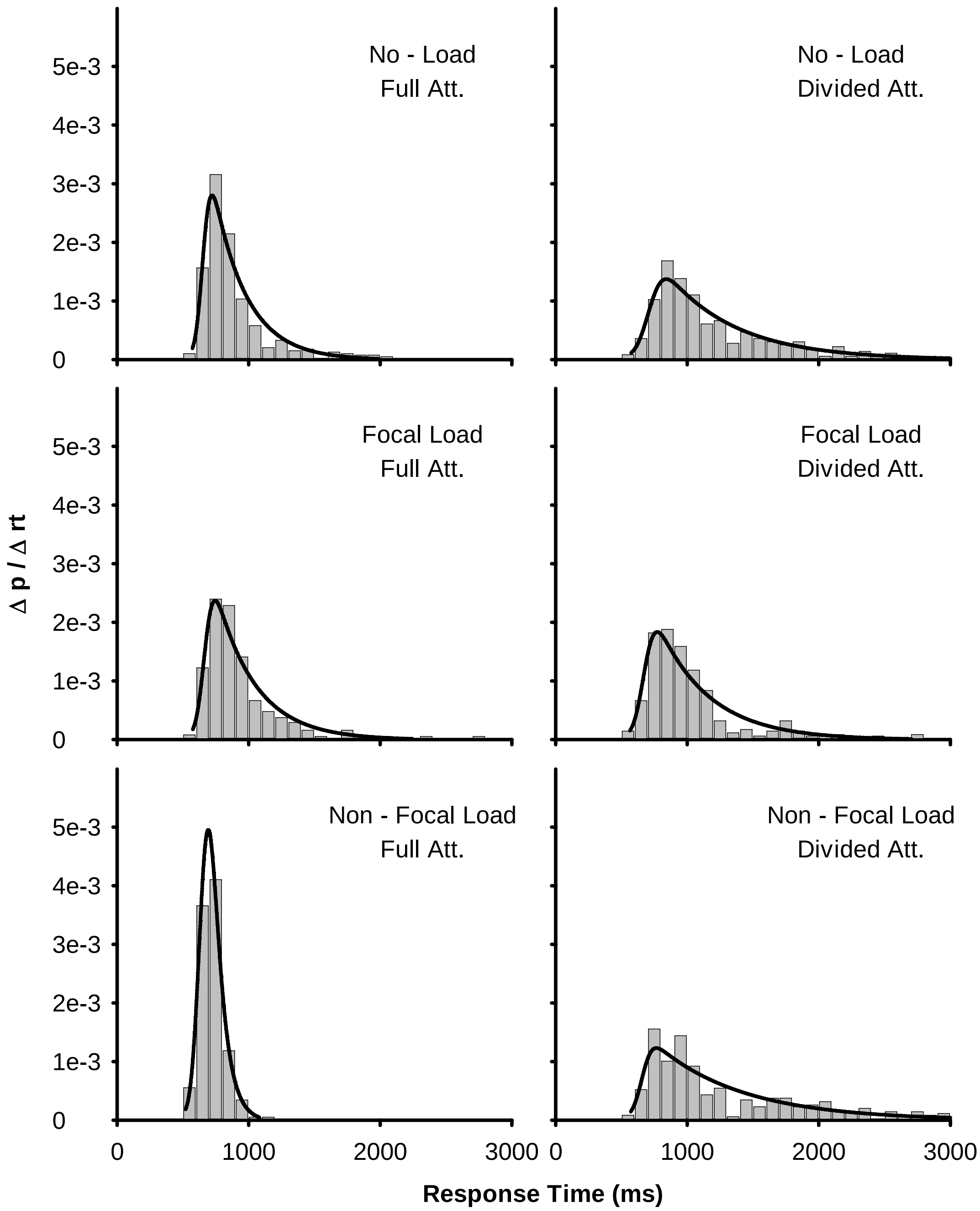

Figure H5. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *mu* parameters near the median for a given condition.

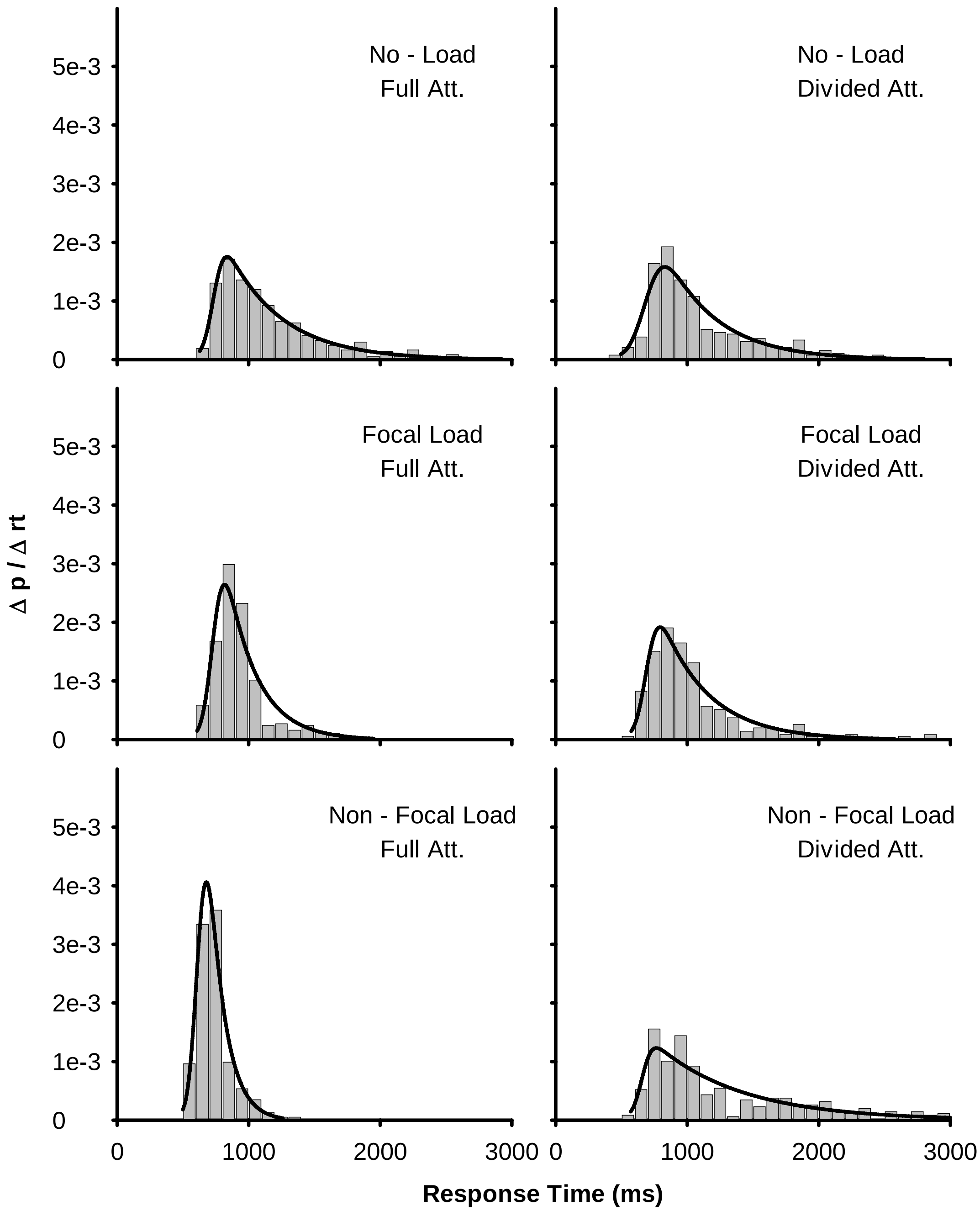

Figure H6. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *sigma* parameters near the median for a given condition.

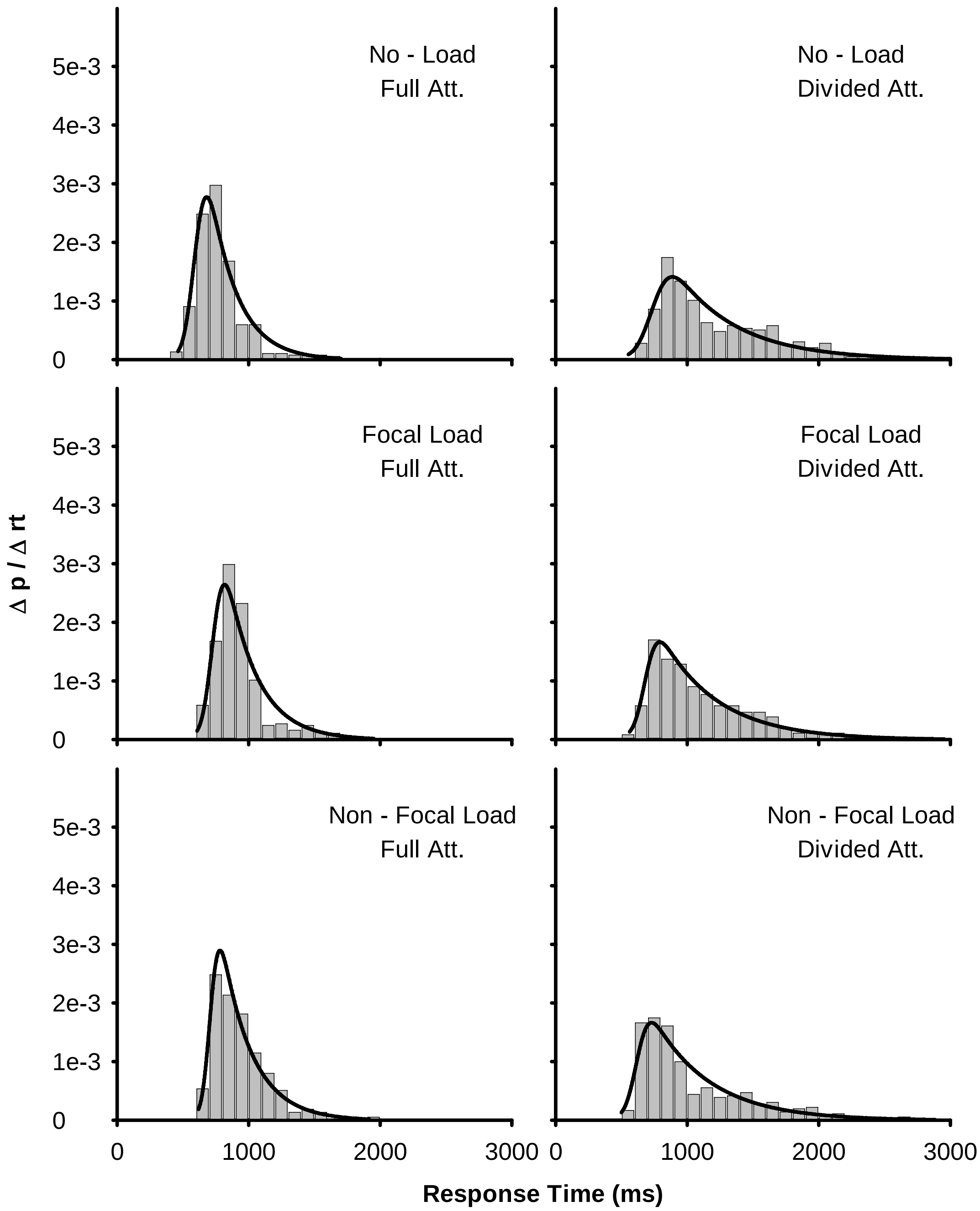

Figure H7. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *tau* parameters near the median for a given condition.

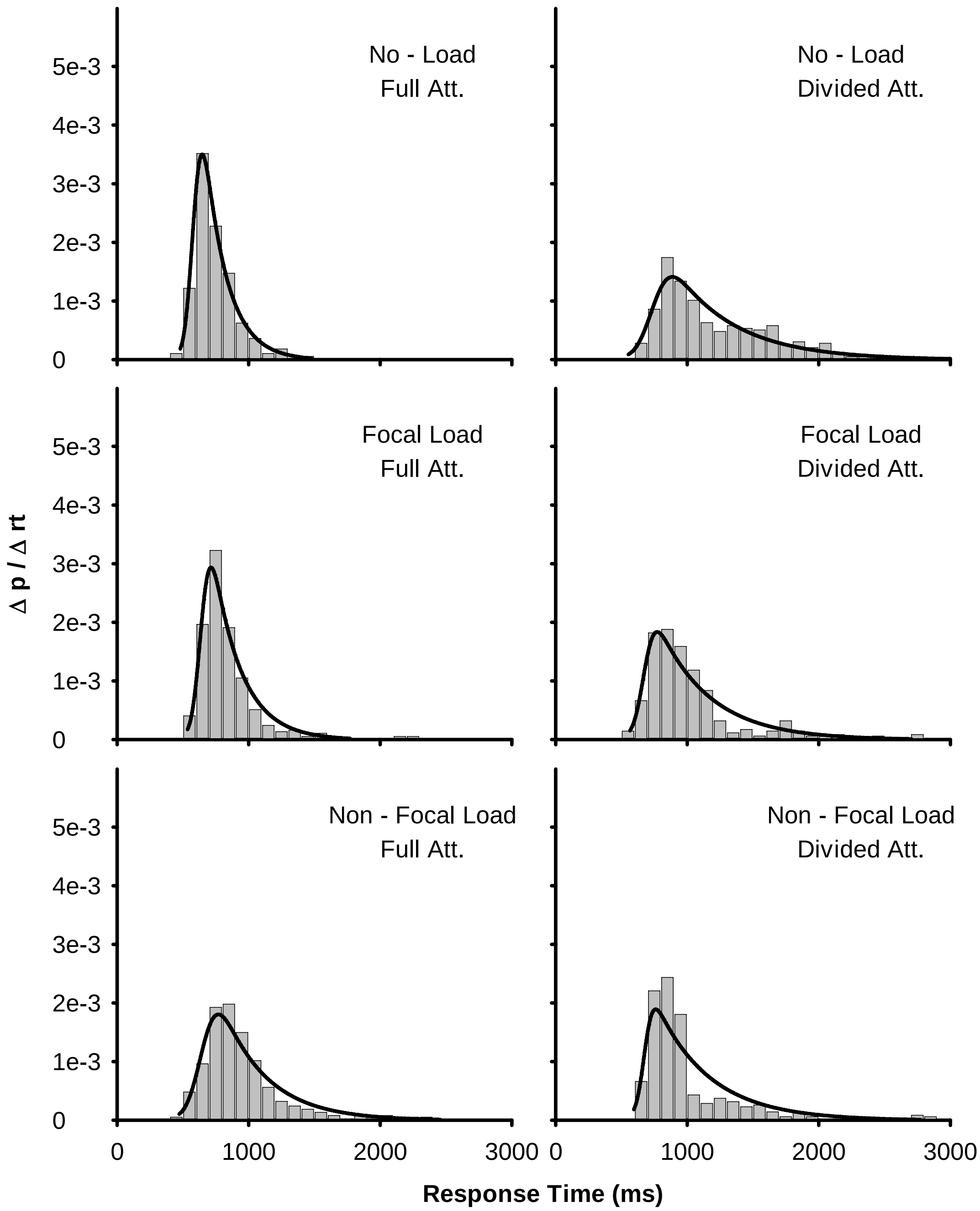

Figure H8. Fixed-width histograms with best-fitting ex-Gaussian density functions (solid curve) for response times of individual older participants who had *tau*/*sigma* ratios near the median for a given condition.

APPENDIX I

Representative Weibull Probability Density Functions and Histograms: Experiment 2

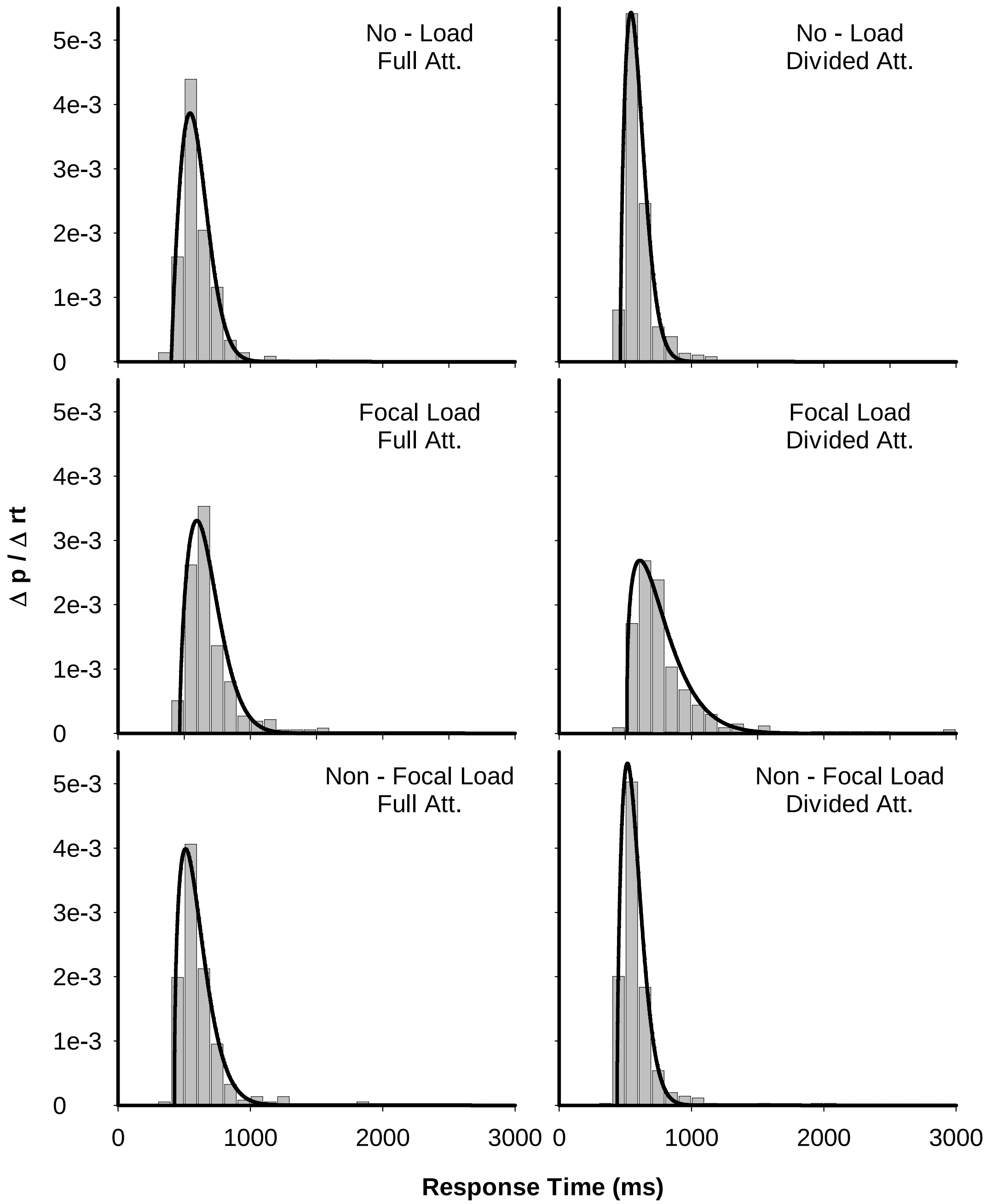

Figure I1. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *shift* parameters near the median for a given condition.

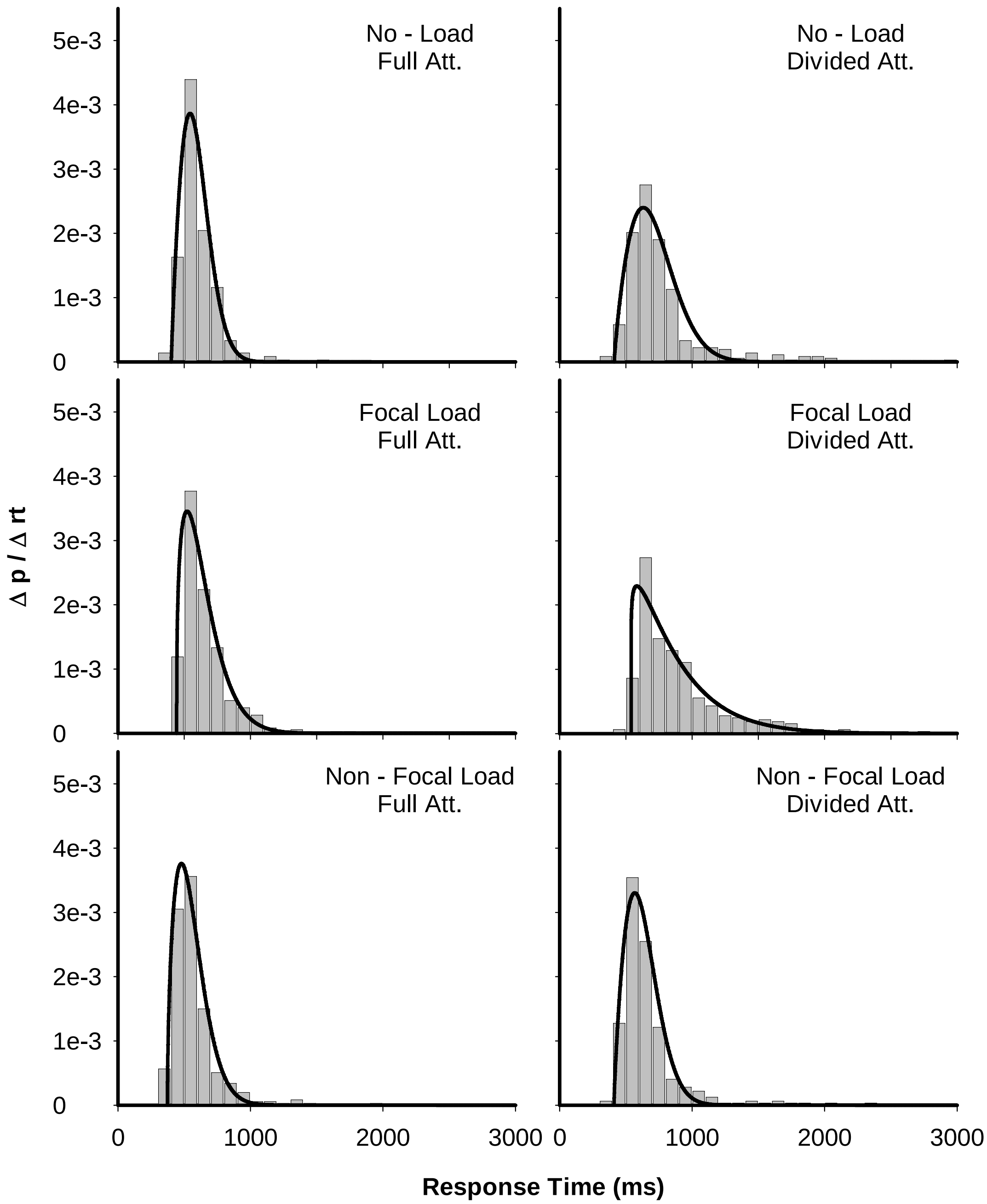

Figure I2. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *scale* parameters near the median for a given condition.

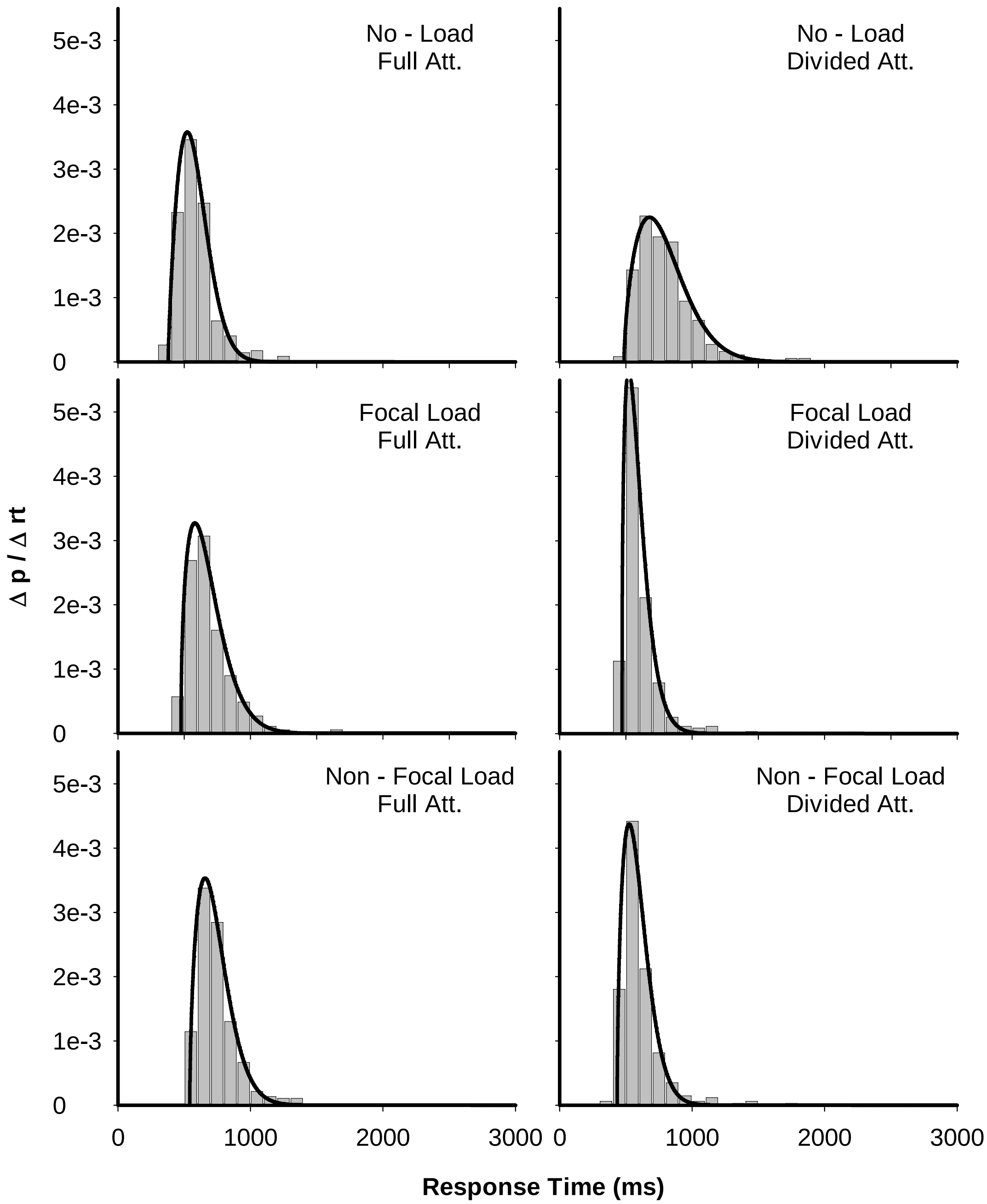

Figure I3. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual young participants who had *shape* parameters near the median for a given condition.

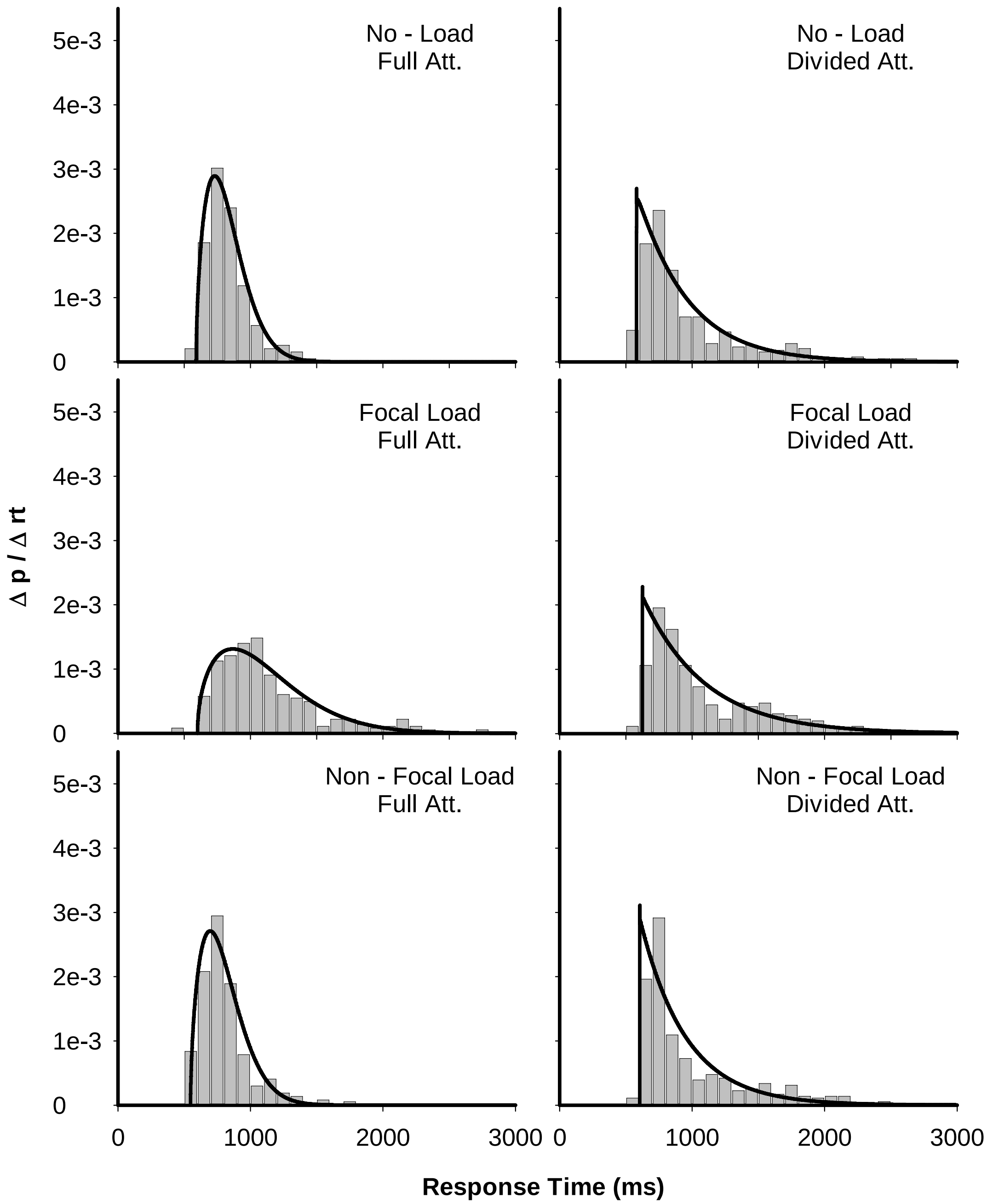

Figure I4. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *shift* parameters near the median for a given condition.

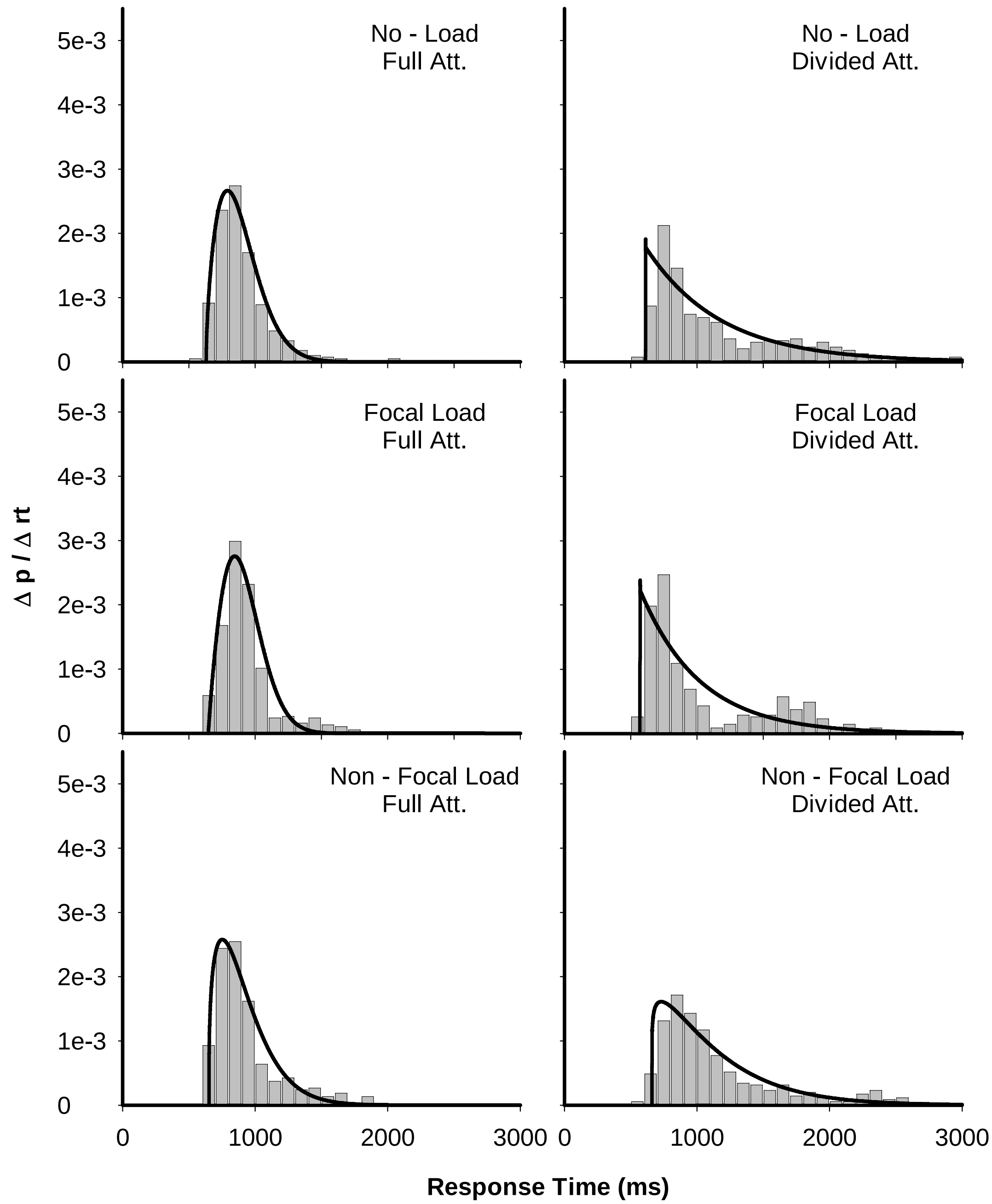

Figure I5. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *scale* parameters near the median for a given condition.

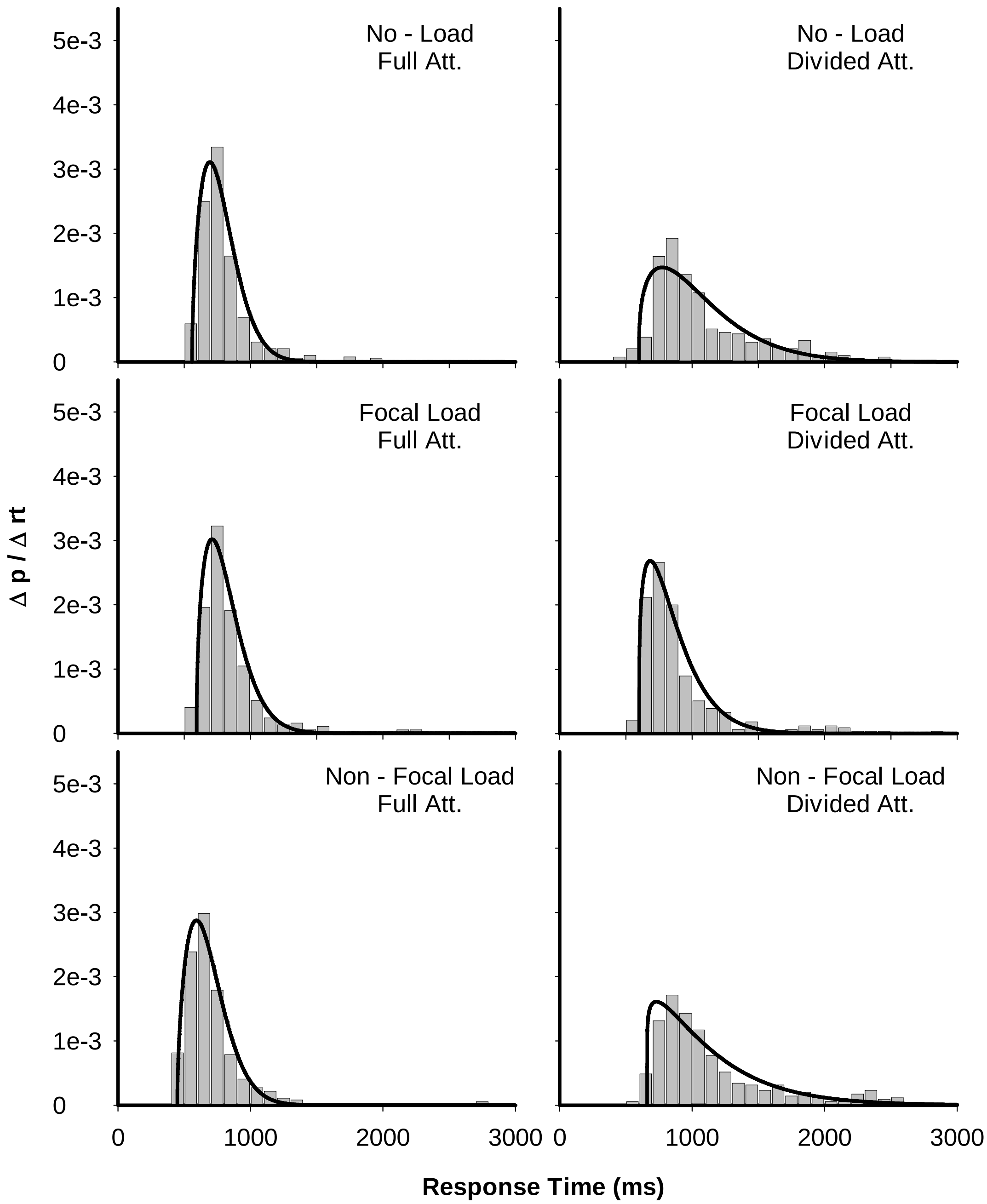

Figure I6. Fixed-width histograms with best-fitting Weibull density functions (solid curve) for response times of individual older participants who had *shape* parameters near the median for a given condition.

APPENDIX J

Summary Tables for Hierarchical Regression Analyses: Experiment 2

The predictor variables added at each step are listed in the first column. The total R^2 for each model at a given step is reported in the second column. The third column contains the increment in R^2 associated with the addition of a given variable to the model. The *F* statistics testing the increment in R^2, the associated degrees of freedom, and the *p* value for the increment in R^2 are given in the fourth, fifth, and sixth columns, respectively. The seventh column contains the standardized regression coefficients. Those regression coefficients provided for the variables entered at the first step are identical to zero-order correlation coefficients, whereas the coefficients given for the variable added at the second step are partial regression coefficients.

Table J1

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Median Response Time as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Median RT	0.095	0.024	1.10	1, 41	0.3	0.242
1. Median RT	0.011		0.45	1, 42	0.51	-0.103
2. Age Group	0.095	0.084	3.81	1, 41	0.06	-0.451
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Median RT	0.247	0.012	0.64	1, 41	0.43	0.170
1. Median RT	0.093		4.30	1, 42	0.04	-0.305
2. Age Group	0.247	0.154	8.39	1, 41	< 0.01	-0.616
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Median RT	0.121	0.072	3.34	1, 41	0.08	0.298
1. Median RT	0.020		0.86	1, 42	0.36	0.142
2. Age Group	0.121	0.101	4.73	1, 41	0.04	-0.355
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Median RT	0.260	0.081	4.46	1, 41	0.04	0.324
1. Median RT	0.002		0.08	1, 42	0.78	0.044
2. Age Group	0.260	0.258	14.3	1, 41	< 0.01	-0.580

Table J2

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Coefficient of Variation as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. CV	0.090	0.020	0.88	1, 41	0.36	-0.146
1. CV	0.003		0.12	1, 42	0.73	-0.053
2. Age Group	0.090	0.087	3.92	1, 41	0.05	-0.310
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. CV	0.235	0.000	0.00	1, 41	0.99	-0.002
1. CV	0.000		0.00	1, 42	0.93	-0.015
2. Age Group	0.235	0.235	12.60	1, 41	< 0.01	-0.485
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. CV	0.085	0.035	1.55	1, 41	0.22	0.222
1. CV	0.001		0.05	1, 42	0.83	0.033
2. Age Group	0.085	0.083	3.74	1, 41	0.06	-0.345
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. CV	0.195	0.016	0.79	1, 41	0.38	0.226
1. CV	0.081		3.69	1, 42	0.06	-0.284
2. Age Group	0.195	0.114	5.83	1, 41	0.02	-0.612

Table J3

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Tau/Sigma as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Tau/Sigma	0.081	0.010	0.46	1, 41	0.50	-0.102
1. Tau/Sigma	0.007		0.29	1, 42	0.59	-0.083
2. Age Group	0.081	0.074	3.30	1, 41	0.08	-0.273
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Tau/Sigma	0.253	0.018	1.01	1, 41	0.32	0.135
1. Tau/Sigma	0.014		0.60	1, 42	0.44	0.118
2. Age Group	0.253	0.239	13.15	1, 41	< 0.01	-0.490
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Tau/Sigma	0.053	0.003	0.12	1, 41	0.73	0.053
1. Tau/Sigma	0.001		0.03	1, 42	0.86	0.028
2. Age Group	0.053	0.052	2.25	1, 41	0.14	-0.229
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Tau/Sigma	0.180	0.001	0.03	1, 41	0.87	0.027
1. Tau/Sigma	0.038		1.68	1, 42	0.20	-0.196
2. Age Group	0.180	0.142	7.08	1, 41	0.01	-0.437

Table J4

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with On - Going Task Weibull Shape as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Shape	0.071	0.001	0.02	1, 41	0.90	0.020
1. Shape	0.000		0.02	1, 42	0.90	-0.020
2. Age Group	0.071	0.071	3.11	1, 41	0.09	-0.268
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Shape	0.256	0.021	1.17	1, 41	0.29	-0.147
1. Shape	0.049		2.16	1, 42	0.15	-0.221
2. Age Group	0.256	0.207	11.44	1, 41	< 0.01	
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Shape	0.074	0.024	1.07	1, 41	0.31	-0.161
1. Shape	0.009		0.37	1, 42	0.55	-0.094
2. Age Group	0.074	0.065	2.90	1, 41	0.10	-0.264
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Shape	0.238	0.059	3.16	1, 41	0.08	-0.262
1. Shape	0.004		0.18	1, 42	0.68	-0.064
2. Age Group	0.238	0.234	12.59	1, 41	< 0.01	-0.522

Table J5

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Median Response Time as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Median RT	0.073	0.003	0.13	1, 41	0.72	0.083
1. Median RT	0.028		1.23	1, 42	0.27	-0.169
2. Age Group	0.073	0.045	1.99	1, 41	0.17	-0.329
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Median RT	0.261	0.026	1.44	1, 41	0.24	-0.244
1. Median RT	0.221		11.93	1, 42	< 0.01	-0.470
2. Age Group	0.261	0.040	2.21	1, 41	0.14	-0.302
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Median RT	0.119	0.069	3.22	1, 41	0.08	0.409
1. Median RT	0.000		0.00	1, 42	0.99	-0.002
2. Age Group	0.119	0.119	5.54	1, 41	0.02	-0.536
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Median RT	0.180	0.001	0.01	1, 41	0.92	-0.022
1. Median RT	0.107		5.04	1, 42	0.03	-0.327
2. Age Group	0.180	0.073	3.63	1, 41	0.06	-0.407

Table J6

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Coefficient of Variation as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. CV	0.132	0.062	2.93	1, 41	0.09	-0.335
1. CV	0.000		0.00	1, 42	0.96	-0.007
2. Age Group	0.132	0.132	6.26	1, 41	0.02	-0.490
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. CV	0.239	0.003	0.18	1, 41	0.67	-0.071
1. CV	0.053		2.35	1, 42	0.13	0.230
2. Age Group	0.239	0.186	10.00	1, 41	< 0.01	-0.526
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. CV	0.131	0.081	3.83	1, 41	0.06	-0.384
1. CV	0.004		0.16	1, 42	0.69	-0.062
2. Age Group	0.131	0.127	6.00	1, 41	0.02	-0.481
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. CV	0.190	0.010	0.52	1, 41	0.48	-0.123
1. CV	0.025		1.10	1, 42	0.30	0.160
2. Age Group	0.190	0.164	8.31	1, 41	< 0.01	-0.494

Table J7

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Tau/Sigma as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Tau/Sigma	0.164	0.094	4.61	1, 41	0.04	-0.307
1. Tau/Sigma	0.099		4.59	1, 42	0.04	-0.314
2. Age Group	0.164	0.066	3.23	1, 41	0.08	-0.257
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Tau/Sigma	0.247	0.011	0.62	1, 41	0.44	0.107
1. Tau/Sigma	0.014		0.58	1, 42	0.45	0.117
2. Age Group	0.247	0.233	12.68	1, 41	< 0.01	-0.483
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Tau/Sigma	0.074	0.024	1.08	1, 41	0.30	0.157
1. Tau/Sigma	0.022		0.97	1, 42	0.33	0.150
2. Age Group	0.074	0.052	2.30	1, 41	0.14	-0.228
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Tau/Sigma	0.230	0.051	2.71	1, 41	0.11	0.226
1. Tau/Sigma	0.055		2.43	1, 42	0.13	0.234
2. Age Group	0.230	0.176	9.36	1, 41	< 0.01	-0.419

Table J8

Experiment 2: Summary of Hierarchical Regression Analyses of ProM Performance with Two Back Task Weibull Shape as a Predictor

Variable	R^2	ΔR^2	F	df	ΔR^2 p	β
			Full Attention			
High Salience						
1. Age Group	0.070		3.18	1, 42	0.08	-0.265
2. Shape	0.164	0.094	4.61	1, 41	0.04	0.311
1. Shape	0.121		5.79	1, 42	0.02	0.348
2. Age Group	0.164	0.043	2.13	1, 41	0.15	-0.211
Low Salience						
1. Age Group	0.235		12.91	1, 42	< 0.01	-0.485
2. Shape	0.241	0.005	0.30	1, 41	0.59	0.074
1. Shape	0.011		0.48	1, 42	0.50	0.106
2. Age Group	0.241	0.229	12.39	1, 41	< 0.01	-0.480
			Divided Attention			
High Salience						
1. Age Group	0.050		2.21	1, 42	0.15	-0.223
2. Shape	0.077	0.027	1.21	1, 41	0.28	0.168
1. Shape	0.041		1.78	1, 42	0.19	0.202
2. Age Group	0.077	0.037	1.63	1, 41	0.21	-0.194
Low Salience						
1. Age Group	0.179		9.19	1, 42	< 0.01	-0.424
2. Shape	0.214	0.034	1.78	1, 41	0.19	-0.185
1. Shape	0.024		1.05	1, 42	0.31	-0.156
2. Age Group	0.214	0.189	9.86	1, 41	< 0.01	-0.436