PREDICTING FUTURE AGE-RELATED COGNITIVE DECLINE: PROCESSING SPEED AND FRONTAL LOBE FUNCTIONING

by

Melissa Hughes Kitner-Triolo

Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Psychology

APPROVED:

Helen J. Crawford, Ph.D., Chairperson	Joseph J. Franchina, Ph.D.
Martha Ann Bell, Ph.D.	Albert M. Prestrude, Ph.D.
Rosemary Blieszner, Ph.D.	Alan B. Zonderman, Ph.D.

May, 2000

Blacksburg, Virginia

KEY WORDS: CROSS-SECTIONAL AGING, LONGITUDINAL AGING, REACTION TIME, INHIBITION, INTERFERENCE, WORKING MEMORY, PREFRONTAL CORTEX

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Abstract

The present study assessed the impact of aging on cognitive functioning over six to 16 years in exceptionally healthy individuals (20 to 79 years) drawn from the Baltimore Longitudinal Study of Aging. The first study (N = 380 women, 757 men) examined the relationship between age and speed of processing as measured by five reaction time (RT) tasks (simple reaction time to complex reaction time involving varying amounts of inhibitory and working memory processing). Unlike previous research, this study additionally assessed the impact of processing speed, working memory, inhibitory processing, and interference RT measures in predicting future performance 6-16 years later (N=103) on (1) mental status (Blessed Information-Memory-Concentration, Mini-Mental State Examination), and prefrontal mediated neuropsychological tests (Trail Making A and B; verbal and category fluency; WAIS digits forward and backwards, California Verbal Learning Test proactive interference index). Regression analyses assessed which theoretical approach, speed of processing (Salthouse, 1996) or prefrontal cortex (Hasher & Zacks, 1988; West, 1996), better explained cognitive change.

Age-related cognitive slowing was observed for initial RT tasks. Especially among the oldest studied (62-79 years of age), slower speed of processing was accelerated by task complexity. Increases in response time were substantially steeper for older as opposed to younger participants. Men were faster than women were on simple RT and a RT task that involved inhibitory processing. A 6-9 year age decline in speed of processing only occurred among individuals over 60 years. RT omission and commission errors showed similar results.

Hierarchical regression analyses determined that RT tasks involving inhibitory control, working memory and interference were most predictive of future prefrontal-mediated cognitive performance (Trail Making B, digit span backwards, letter and category fluency). Prediction of the prefrontal outcome measures of Trail Making A and digit span forward performance from simple reaction time was mediated by the RT measures (inhibitory control, working memory and

interference), but not the other way around. Thus, the data most strongly support the Inhibitory Deficit (Hasher & Zacks, 1988) and Prefrontal Cortex Function (West, 1996) theories. There was little support for the processing speed theory (Salthouse, 1996).

To My Daughter,

Eliza Michelle Triolo

My Husband,

F. Anthony (Tony) Triolo, Jr.

And My Parents,

Mary E. Kitner and Walter E. Kitner

ACKNOWLEDGMENTS

I would like to thank my advisor and committee chairperson, Dr. Helen Crawford, for her continued encouragement and at times extra prodding, during the course of this research. Her willingness to accommodate the extra challenges of guiding my research long-distance, through e-mail and long-distance phone conversations, was crucial to the completion of my dissertation.

I would also like to thank the other members of my committee, Dr. Martha Ann Bell, Dr. Rosemary Blieszner, Dr. Joseph Franchina, Dr. Albert Prestrude, and Dr. Alan Zonderman, for their insightful comments, guidance and suggestions. I would particularly like to thank Alan Zonderman, from the National Institute on Aging, for agreeing to serve on my committee. His continued support, resources and statistical guidance made the completion of this dissertation possible.

My sincere gratitude also goes to the National Institute on Aging, Dr. David Arenberg for devising and implementing the reaction time research program, and especially the participants of the Baltimore Longitudinal Study of Aging (BLSA). The invaluable contribution the participants make to the BLSA through their participation is realized in the research findings that result.

I would finally like to thank my colleagues, friends and all of the members of my wonderful family, particularly my parents Mary and Walter Kitner, my husband Tony Triolo, and my sweet daughter Eliza Triolo. They sacrificed much over the past few years so that I could finish my degree. My family endured years of not asking: "How is it going?" My parents always knew I could do it and contributed in immeasurable ways with encouragement, sometimes with meals and help in taking care of my daughter. My husband took over many responsibilities so that I could devote more time to the completion of my degree. He constantly supported my efforts and urged me to push forward. My daughter, who has not known life without the sacrifices of living with a mother working on her doctoral degree, will finally receive the time with me that she deserves. It is to my daughter, my husband and my parents that I dedicate this dissertation as an illustration of what daughters, wives, mothers and women can achieve.

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Chapter 1: Introduction

A long-standing interest in aging research has been to determine why many memory and cognitive functions often decline as one gets older. Even more interesting is why there are individual differences in the rate of this decline, even within a healthy population of individuals. Until recently, a large portion of the decline in functions has been attributed to a generalized slowing in speed of processing (e.g., Salthouse, 1991, 1992a, 1992b, 1992c, 1993a, 1994a, 1994b, 1996; Salthouse & Babcock, 1991; Salthouse & Fristoe, 1995; Salthouse, Fristoe, & Rhee, 1996). However, additional research indicates memory and cognitive processes that engage prefrontal cortex functioning contribute to advancing age declines. Specifically, these include representational or working memory, resistance to interference, and inhibitory control (e.g., Daigneault, Braun, & Whitaker, 1992; Daigneault & Braun, 1993; Dempster, 1991, 1992, 1993; Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999; May & Hasher, 1998; West, 1996).

The purpose of this study was to conduct both cross-sectional and longitudinal examinations to determine whether age-related changes in speed of processing, working memory, inhibitory functioning and interference could predict future performance on tasks that are engaged by the prefrontal cortex. Toward this aim, this chapter reviews relevant literature related to the speed of processing theory (Salthouse, 1996) and prefrontal cortical theories of cognitive aging (Hasher & Zacks, 1988; West, 1996). Salthouse (1996) originally proposed that virtually all age-related cognitive declines could be attributed to a generalized slowing of simple cognitive functions, although recently he has begun to assess prefrontal functionality as well (Salthouse, Fristoe, McGuthry, & Hambrick, 1998; Verhaeghen & Salthouse, 1997). Additional proposed contributions to age-related cognitive decline are reviewed, specifically those involving inhibitory functions, susceptibility to interference and representational (working) memory. Both cognitive and physiological research has demonstrated that these prefrontal cortical functions develop throughout infancy and childhood (e.g., Bell & Fox, 1992; Chelune & Baer, 1986; Diamond, 1988, 1990a; Fox & Bell, 1990), and may be among the first to decline with advancing age (Daigneault et al., 1992; Davis, Cohen, Gandy, Colombo, VanDusseldorp, Simolke, & Romano, 1990; Earles, Connor, Frieske, Park, Smith, & Zwahr, 1997; Salthouse et al., 1996; Witkin & Goodenough, 1981).

In a subsequent section of the chapter, literature is reviewed that addresses the difficulties associated with elucidating age-related prefrontal changes based on tasks that measure more than one prefrontal function. Most of the tests that are currently available to measure prefrontal functioning measure more than one prefrontal function. This makes it difficult to tease apart the contribution of various prefrontal functions, namely inhibitory control, working memory and resistance to interference, and to assess their individual contribution to cognitive aging.

Finally, the hypotheses are stated after an outline of the present dissertation's design. It was designed to investigate change in speed of processing, inhibitory processing, working memory and interference. It was also designed to longitudinally predict future cognitive decline, as much as 6-to 16-years later. Most of the aging studies reviewed were cross-sectional in nature. As such, the uniqueness and strength of this dissertation was its longitudinal perspective.

Processing Speed: Reaction Time and Perceptual Speed

The most consistent and least controversial finding in aging research is that as people age, they become slower in most physical and mental functions (Salthouse, 1996). This slowing affects sensory-motor activity as well as cognitive and memory processing (Birren, Woods, & Williams, 1980; Cerella, 1985; Howard, Shaw, & Heisey, 1986; Long, 1985). The consistency of this finding has led some researchers to attribute much of the cognitive change associated with age to age-related slowing in processing speed (e.g., Fisk & Warr, 1996; Salthouse, 1991, 1992a, 1992b, 1992c, 1993a, 1994a, 1994b, 1996; Salthouse & Babcock, 1991; Salthouse & Fristoe, 1995; Salthouse et al., 1996).

In a review of the literature, Salthouse (1985) reported a median correlation of .45 between age and speed across numerous studies that investigated various behavioral and everyday tasks. These included the Wechsler Adult Intelligence Scale (WAIS) Digit-Symbol Substitution, Trail Making, both simple and choice reaction time, movement time, dialing a telephone, picking up coins, and zipping a garment. Even among educated, high functioning university professors ranging in age from 30 to 71 years old, Shimamura, Berry, Mangels, Rusting, and Jurica (1995) reported a correlation of .53 between age and reaction time performance. Therefore, reductions in speed affect many older individuals, even high functioning individuals who are still mentally active.

Simple reaction time declines approximately 20% from age 20 to 60 years of age (Birren et al., 1980; Waugh, Fozard, & Thomas, 1978; Welford, 1977). Depending on task complexity age-related differences in visual reaction time, using a lexical decision task, varied from 4 to 10 milliseconds per year for persons aged 30 to 70 years old (Madden 1989, 1992). In the Baltimore Longitudinal Study (BLSA) (the population from which the present investigation was drawn), Fozard, Vercruyssen, Reynolds, Hancock, and Quilter (1994) found changes at a rate of approximately 0.5 milliseconds per year in 20-90-year-olds for simple auditory reaction time. Declines of approximately 1.6 milliseconds per year occurred for a disjunctive auditory (go no-go) task. As such, the annual rate of change reported for disjunctive or choice reaction time tasks was more than two (Madden 1992) or three times (Fozard et al., 1994) larger than the rate of change for simple reaction time. In the university professor sample, there was a similar incremental increase in reaction time going from simple reaction time to two-choice reaction time to four-choice reaction time (Shimamura et al., 1995). Fozard and colleagues concluded that reaction time increased as "a direct function of task complexity and, presumably, the degree of mediation by higher regions in the central nervous system" (Fozard et al., 1994, p. 179). This suggests the involvement of working memory, inhibitory and interference mechanisms.

When compared with other cognitive functions (e.g., inductive reasoning, spatial orientation, numeric ability, verbal ability, and verbal memory), age declines in perceptual speed are observed to be among the greatest in both cross-sectional (Schaie, 1989, 1994; Schaie & Willis, 1993) and longitudinal (Schaie, 1989, 1994) studies. Schaie and colleague (Schaie, 1989, 1994; Schaie & Willis, 1993) reported extensively on both cross-sectional and longitudinal cognitive research from the Seattle Longitudinal Study. Cross-sectionally, Schaie and Willis (1993) found a 2.5 standard deviation age difference between older (67 or more years of age) and younger adults (mean age = 29 years old) for visual perceptual speed measures, but only a .75 standard deviation age difference for measures of verbal ability. Longitudinal studies (Schaie, 1989, 1994) revealed similar results. Perceptual speed measures were among those indicators that declined the most with advancing age, displaying a linear decline from the 20s to the 80s both cross-sectionally (Schaie, 1989, 1994; Schaie & Willis, 1993) and longitudinally (Schaie, 1989, 1994). When using perceptual speed to predict future cognitive changes, Schaie (1989) found that speed had a significant mediating effect on the relationship between age and the primary mental abilities of verbal meaning, spatial orientation, inductive reasoning and word fluency. These results are consistent with those of Salthouse and colleagues (Salthouse, 1991; 1992a; 1992b; 1993a; Salthouse et al., 1996) and others (Earles et al., 1997) that will be discussed later. Unlike the present dissertation, none of these studies assessed whether reaction time speed continued to contribute to predicted outcomes if measures of prefrontal functioning were entered prior to speed in regression and path analyses.

Sex differences were inconsistently observed. Fozard and colleagues (1994) found women were consistently slower than men were on measures of both simple and disjunctive auditory reaction time. In contrast, Schaie (Schaie, 1989; Schaie & Willis, 1993) found women consistently outperformed men on measures of visual perceptual speed. Yet, Madden (1992) found no sex differences on speeded measures. Fozard and colleagues found increased variability as age increased, whereas Schaie (Schaie, 1989; Schaie & Willis, 1993) did not. Schaie (Schaie, 1989; Schaie & Willis, 1993) did find great variability among individuals in their performance on the perceptual speed tasks, yet they did not find that variability increased with age.

The observed differences between men and women and variability across age of these two longitudinal studies may be due, in part, to differences in the tasks used and how they were aggregated. First, Fozard and colleagues (1994) used auditory reaction time tasks that required participants to respond either to both high and low tones (the simple reaction time task), or only to the high tones (the disjunctive go no-go task). Schaie's (Schaie, 1989; 1994; Schaie & Willis, 1993) perceptual speed measure was a composite of three visual comparison tasks: the Identical Pictures Test – search for which of five pictures were the same as a template; the Finding As Test – find five As located in 40 words; and the Number Comparison Test – indicating whether two multi-digit numbers were the same or different. Two of the tasks involved visual search before a response was made. Finally, Schaie's tasks involved more cognitive processing before a response was made, hence the term perceptual speed tasks, whereas Fozard and colleague's tasks involved a quick yes/no decision, hence the term reaction time tasks.

A linear decline in speed of processing from the 20s to the 80s and 90s was found for simple (Fozard et al., 1994; Madden 1992; Salthouse, 1993c), disjunctive (Fozard et al., 1994), choice reaction time (e.g., Madden 1992; Salthouse, 1993c) and perceptual speed (Schaie, 1989;

1994; Schaie & Willis, 1993) tasks. The sometimes observed quadratic trends were inconsistent and small in comparison to the linear trends (Salthouse, 1993c). Those who tested for both effects only found significant linear trends (Madden, 1992). Based on an analysis of five studies employing a variety of tasks (including word naming, visual search, lexical decision making, sentence completion, semantic relations and category membership decisions), Nebes and Madden (1988) found a consistent linear decline in reaction time associated with aging.

Reaction time errors also increased with age and longer reaction time (Fozard et al., 1994; Madden, 1992). Similarly, for seven visual discrimination reaction time tasks of comparable complexity levels, Swearer and Kane (1996) found a linear increase in older adults' reaction times and errors compared to younger adults. The differences were exacerbated as task difficulty increased. These results indicate it was unlikely that adults were trading increases in accuracy for decreases in speed with increased age.

In summary, research on the impact of age on reaction time and perceptual speed indicates that older adults typically exhibit generalized linear slowing for both auditory and visual domains. Age-related slowing is additionally sensitive to task complexity; reaction times can double or triple with increased complexity. The increase in reaction time and decrease in perceptual speed is apparently not attributable to an increase in accuracy (or cautiousness) because increases in reaction time and decreases in perceptual speed go hand in hand with increases in reaction time errors. Women tended to performed more slowly than age-matched men across the adult age span on reaction time tasks, but not on perceptual speed tasks.

The following sections evaluate three major theories that address the impact of aging on cognitive processes: (a) the processing-speed theory, (b) and the inhibitory deficit theory (c) the prefrontal cortex function theory.

The Processing-Speed Theory

To account for the consistent changes in age-related speed of processing, Salthouse (1996) proposed the processing-speed theory of cognitive aging. He postulated that many of the age differences in cognitive and memory functions were due to age-related declines in processing speed. There are two premises to the theory. First, variations in age-related speed of processing are at least partially the result of a limited set of general factors as opposed to a large set of specific factors. Second, speed of processing is an important mediator of the decline in a variety of cognitive processes with age.

Slower processing speed is not the sole determinant of age-related declines in cognitive functioning. Other age-related effects have also been hypothesized to account for cognitive declines (e.g., decline in working memory). Yet, a reduction in speed with advancing age for many cognitive functions is hypothesized to be a major cause of age-related declines observed for a variety of higher-level cognitive and memory tasks. In fact, much of the decline in working memory associated with aging has been attributed to slower processing speed (Salthouse, 1991, 1992a, 1992b, 1994; Salthouse & Babcock, 1991; Salthouse et al., 1996). More specifically, Salthouse (1992a, 1994a) attributed reductions in working memory to the rate by which information is activated in working memory rather than the speed with which information is lost from working memory.   Similarly, Fisk and Warr (1996) reported age-related changes in perceptual speed as well as declines in processing of the central executive and phonological loop systems of working memory, as proposed in Baddeley's model of working memory (Baddeley, 1986). They attributed aging effects of the central executive and phonological loop to be due largely to a slowdown in the speed by which information in the working memory system is activated.

The processing-speed theory of cognitive aging proposes two mechanisms that are responsible for the age-speed-cognition relationship: (1) the limited time mechanism, and (2) the simultaneity mechanism (Salthouse, 1996). According to the limited time mechanism, a reason for declines in cognition with age is that the speed with which relevant cognitive operations are performed is too slow for the task to be completed within the specified time period. The limited time mechanism is assumed to operate for both simple and complex cognitive tasks. With simple tasks, the speed with which relevant operations are performed is the main determinant of cognitive age declines. With more difficult tasks, where accuracy is affected by slower processing speed, more complex performance is a result of less complex, underlying operations. Because of the slower execution speed of these less complex operations, fewer products are available for the subsequent more complex processing. Thus, the slower processing speed of the less complex operations is evidenced in the poorer speed and accuracy of subsequent more complex operations.

The limited time mechanism was proposed to account for “the complexity effect, or the positive relation between task complexity and the magnitude of age differences in both speed and accuracy measures of task performance” (Salthouse, 1996, p. 404). Thus, Salthouse (1996) implicated processing speed to account for the complexity effect. However, in a prior study (Salthouse, 1992b) that assessed performance on tasks with three complexity levels, he also proposed that more difficult cognitive tasks placed a greater demand on working memory, and that in part contributed to the complexity effect. However, he still attributed much of the effect of working memory to slower processing speed.

A simultaneity mechanism involves the progressive decline of simultaneous information being available in working memory that is needed for higher level processing due to declines in memory processing with advancing age. A basic assumption is that “information decreases in availability (i.e., quantity or quality) over time as a function of either decay or displacement” (p. 405), or the information may simply no longer be relevant or accurate. In fact, Salthouse (1996) proposed that the simultaneity mechanism could be used to account for variations with age on tasks of working memory capacity. This was proposed because working memory can be thought of as involving the storage and processing of currently available information for task performance.

A host of different cognitive tasks were tested to assess the robustness of their processing-speed theory (e.g., Salthouse, 1991, 1992a, 1992b, 1992c, 1993a, 1993b, 1994a, 1994b, 1994c, 1996; Salthouse & Babcock, 1991; Salthouse & Fristoe, 1995; Salthouse et al., 1996). These studies typically employed one of two analytical procedures: path analyses and/or hierarchical regression. They evaluated speeded and self-paced (Salthouse, 1992a), verbal and non-verbal (Salthouse 1994a; Salthouse et al., 1996) tasks, as well as tasks varying in the complexity of the target (Salthouse, 1992b). Furthermore, they assessed functions proposed to engage frontal, temporal and parietal brain regions (Salthouse, 1993a; Salthouse et al., 1996).

Overall, these results consistently showed that the relationship between advancing age and cognitive decline is mediated by speed of processing. Hierarchical regression analyses demonstrated that the relationship between age and various fluid (as opposed to crystallized) cognitive functions (e.g., working memory, paired associate memory, free recall memory, reasoning, spatial abilities, and attentional tasks such as Trail Making) was drastically reduced after accounting for speed of processing. In some cases, age-related effects could be eliminated after controlling for speed of processing (Salthouse, 1992a, 1992b, 1993a, 1994a; Salthouse & Fristoe, 1995). Reductions in the age-working memory relationship were found after controlling for speed of processing for both speeded and self-paced working memory tasks (Salthouse, 1992a).

Even after controlling for speed of processing, several studies found there were still significant age-cognition relationships for some tasks that were more complex and required working memory (Salthouse 1992b; Salthouse & Fristoe, 1995). For example, performance on Trail Making B involves something unique as a result of the need to switch attention between numbers and letters, over and above that of speed of processing (Salthouse & Fristoe, 1995). In an investigation of tasks of varying difficulty, Salthouse (1992b) found that speed of processing produced a significant attenuating effect on easier task levels, whereas at intermediate and most complex levels working memory had a major impact. Tasks at the most complex level were also predicted by performance at the intermediate level of the task. Salthouse and colleagues (1996) performed a linear structural equation model of the attenuating effect that speed of processing had on the age-cognition relationship among various cognitive tasks (memory, reasoning, space, fluency). Paths from age to memory, reasoning, space and fluency measures were mediated by speed of processing. Additionally, there were independent paths going directly from age to memory and fluency that were not mediated by speed. Unlike the present dissertation, they did not assess the impact of inhibitory control, working memory and interference before the inclusion of reaction time.

In a meta analysis of 91 studies, Verhaeghen and Salthouse (1997) found similar results for relationships among speed of processing, working and episodic memory, spatial ability, reasoning and age. They submitted the correlation matrix among the variables generated from the meta-analysis to a linear structural equation model. Direct paths from age to primary/working memory, in addition to a path mediated through speed of processing, were obtained. Furthermore, paths from age to a general fluid intelligence factor and episodic memory were mediated through primary/working memory, independent of the path through speed of processing. Thus, it appears that speed of processing has a significant, and sometimes profound effect on various age-cognition relationships. However, from Salthouse's own work (Salthouse

1992b; Salthouse & Fristoe, 1995; Salthouse et al., 1996; Verhaeghen & Salthouse, 1997), it can also be said that there are other effects left to be accounted for (possibly working memory and attentional mechanisms). For instance, Salthouse and colleagues (1998) pointed to the task switching properties of the perceptual speed tasks they used to measure speed of processing as an independent and contributing factor in age-cognition relationships. Earles and colleagues (1997) additionally implicated interference in controlling a portion of the age-related variance in working memory. They found that even after accounting for speed of processing a measure of interference controlled a significant portion of the variance in working memory.

The mediating effect of speed on cognitive processes appears to be related to reductions in perceptual speed tasks that require mental substitutions or comparisons (i.e., Letter or Pattern comparison or Wechsler Adult Intelligence Scale-Revised: Digit Symbol Substitution). The mediating effect is not simply related to motor speed (i.e., tasks requiring simply drawing lines or copying symbols such as the Line Marking test or the Copying test) (Salthouse, 1993a; Salthouse et al., 1996). Salthouse (1993a) examined the attenuating effects of both motor and perceptual speed on age for composite measures of memory (paired associates, primacy, recency and asymptote measures) and cognition (primary mental abilities reasoning and space measures, integrative reasoning, and analogies). He found that perceptual speed had a greater attenuating effect on both memory and cognition tasks than did motor speed. Furthermore, after motor speed was controlled for, there continued to be a statistically significant relationship between age and perceptual speed. Most importantly, Salthouse et al. (1996) found a greater attenuation of the relationship between age and individual cognitive tasks after the control of perceptual comparison speed than after the control of motor speed. Specifically, the effect of age on a paired associates task was reduced from $R^2 = 0.261$ to $R^2 = 0.085$, after control of perceptual comparison speed, but it was only reduced to $R^2 = 0.123$ after control of motor speed. Similarly, the age effect was reduced more for a component of the Rey Auditory Verbal Learning Test (RAVLT) after the effect of perceptual speed was removed (from $R^2 = 0.220$ to $R^2 = 0.085$) than after the effect of motor speed was removed (from $R^2 = 0.220$ to $R^2 = 0.120$). These results indicate that a significant portion of the age-related slowing effects on cognitive function can be attributed to perceptual speed over and above the effect of motor speed.

Neurophysiological Evidence For Slower Speed of Processing and Decreased Frontal Lobe Functioning with Age

Neurophysiological studies of event-related potentials (ERPs) to auditory stimuli presented in various perceptual and attentional paradigms provide further support for Salthouse's processing-speed theory. In general, sensory nerve potentials decrease in amplitude and increase in latency during normal aging (e.g., Desmedt & Cheron, 1980). The impact of aging is seen in a slowing of ERPs, particularly those that occur 100 or more milliseconds after a stimulus. This robust finding has been observed for the auditory N100 (Amenedo & Diaz, 1999; Anderer, Pascual-Marqui, Semlitsch, & Saletu, 1998a, 1998b), N200 (Anderer, Semlitsch, & Saletu, 1996, 1998a, 1998b; Coyle, Gordon, Howson, & Meares, 1991; Ritter, Simson, Vaughan, & Friedman, 1979) and P300 (Anderer et al., 1996, 1998a, 1998b; Coyle et al., 1991; Donchin & Coles, 1988; Fabiani, Friedman, & Cheng, 1998; Johnson, 1986; Smulders, Kenemans, Schmidt, & Kok, 1999; Squires, Chippendale, Wrege, Goodin, & Starr, 1980; Syndulko, Hansch, Cohen, Pearce, Goldberg, Montan, Tortellotte, & Potvin, 1982). Studies of ERPs in patient populations (including dementia) indicate that delayed P300 latencies are a result of brain dysfunction (Gordon, Kraiuhin, Harris, Meares, & Howson, 1986; Patterson, Michalewski, & Starr, 1988; Squires et al., 1980; Syndulko et al., 1982). Findings of increased latencies in both older adults and patient populations indicate that normal adults evidence brain dysfunction with advancing age, in addition to increased slowing.

ERP deficits with advancing age have been observed in the frontal cortex (Amenedo & Diaz, 1999; Fabiani et al., 1998). Fabiani and colleagues (1998) examined the relationship between frontal and parietal P300 amplitude and performance on various neuropsychological measures of frontal lobe functioning (e.g., The Wisconsin Card Sorting Task [WCST], letter fluency, and the Boston Naming Test). They found greater P300a response of older adults in the frontal cortex as opposed to greater posterior P300b response in younger adults. The greater P300a amplitude indicates frontal lobe dysfunction due possibly to deficits "in the formation and/or maintenance of working-memory templates" (Fabiani et al., 1998, p. 699) or greater susceptibility to interference. Older adults with greater frontal P300a distributions performed more poorly on tests of frontal lobe functioning than did older adults with greater posterior P300b scalp distributions.

Amenedo and Diaz (1999) found that older adults had larger N100 peak amplitudes in the fronto-central regions than did younger adults. These data indicate compromised inhibitory functioning in older adults since similar abnormal N100s are found in individuals with frontal lobe lesions (Knight, Hillyard, Woods, & Neville, 1980). Younger children whose frontal lobes were not as well mylinated showed N100 differences when compared with older children whose frontal lobes had greater mylination (Bruneau, Roux, Guerin, Barthelemy, & Lelord, 1997).

Of particular interest to the proposed accelerated frontal lobe aging hypothesis is the separate but interconnected anterior and posterior attentional systems (Petersen, Robinson, & Morris, 1987; Posner, 1988; Posner & Petersen, 1990; Posner, Petersen, Fox & Raichle, 1988; Posner, Walker, Friedrich, & Rafal, 1984). The posterior attention system is responsible for shifting attention away from stimuli and reorienting to a target stimulus. It involves the posterior region of the parietal lobes (Mountcastle, 1978; Wurtz, Goldberg, & Robinson, 1980), the thalamus (Petersen et al., 1987) and more specifically the lateral pulvinar nucleus of the postereolateral thalamus (Petersen et al., 1987; Posner & Peterson, 1990), as well as the superior colliculus (Petersen et al., 1988). Damage to these three areas produces different types of deficits in shifting attention. Posterior parietal lobe damage results in a specific deficit in moving attention from a previous focus to a stimulus in a location contralateral to the lesion site (Posner et al., 1984). Thalamic lesions result in difficulty in orienting to a stimulus contralateral to the lesion when there are distracting stimuli in other locations (Petersen et al., 1987; Posner, 1988). Superior colliculus damage results in a generalized deficit in involuntary attention shifting ability (Posner & Petersen, 1990).

The anterior attention system, responsible for directed attention (e.g., target detection) and inhibition, involves the anterior cingulate gyrus (Posner et al., 1988) and prefrontal cortex. Posner and colleagues (1988) found increases in anterior cingulate blood flow corresponded to increases in the number of targets to be detected. Evidence that the anterior and posterior attention systems are interconnected, although they control different aspects of attention, comes from two lines of research (Posner & Petersen, 1990). First, the anterior cingulate has connections to both the dorsolateral prefrontal cortex (DLPFC) and the posterior parietal lobe (e.g., Goldman-Rakic, 1988). Second, findings from both patient (Posner, Inhoff, Friedrich, & Cohen, 1987) and normal (Posner, Sandson, Dhawan, & Shulman, 1989) populations indicate that deficits in visual orienting (thought to be controlled by the posterior attention system) correspond to less severe language (controlled by the lateral frontal cortex) deficits. Based on these results, Posner and Petersen (1990) concluded that there is possibly a "hierarchy of attention systems in which the anterior system can pass control to the posterior system when it is not occupied with processing other material" (p. 35).

In summary, ERP research supports the hypothesized general slowing down of processing speed and suggests a greater impact on frontal cortex processes associated with inhibitory processes, speed of cognitive processing, and tasks of sustained attention. Further evidence suggests that advancing age may impact the anterior attention system more strongly than the posterior attention system. This evidence is reviewed in the next section.

<u>Prefrontal Cortex Functions: Functions that First Build in Childhood and then are Among the First Functions to Decline with Age</u>

The frontal lobes are the last to develop both phylogenetically in the course of animal evolution (Fuster, 1989) and ontogenetically in the course of human development (Hudspeth & Pribram, 1992; Luria, 1973; Rakic, 1995; Thatcher, Walker, & Guidice, 1987). EEG research indicates a posterior to anterior progression in brain development (Hudspeth & Pribram, 1990). Receiving projections from the dorsomedial nucleus of the thalamus, the prefrontal cortex is noted for its reciprocal connections and feedback loops with both subcortical (limbic system) and posterior (sensory) cortical regions of the brain (Dempster, 1992, 1993; Luria, 1973). The frontal lobes receive projections from the limbic system related to internal states and posterior regions of the brain related to the external environment (Dempster, 1992, 1993; Lezak, 1983), and in turn provide projections to these same areas. The frontal lobes serve as attentional and inhibitory gatekeepers for sensory information reaching or not reaching higher cortical centers (Dempster, 1992, 1993; Fuster, 1989). As such, it has been suggested that the frontal lobes are where information converges and is integrated and acted upon (e.g., Dempster, 1992, 1993; Lezak, 1983).

Aging places a greater load on those functions controlled by the anterior attention system and the fronto-parietal network (e.g., Albert & Kaplin, 1980; Daigneault et al., 1992; Daigneault & Braun, 1993; Dempster, 1992; West, 1996). These are also the functions proposed to develop later in childhood brain development (Hudspeth & Pribram, 1992; Luria, 1973; Rakic, 1995;

Thatcher et al., 1987). Three major prefrontal cortex processes, to be reviewed below, are: (1) interference and inhibitory mechanisms of the prefrontal cortex (e.g., Dempster, 1991; 1992; 1993; Hasher & Zacks, 1988; Hasher et al., 1999; May & Hasher, 1998; Zacks & Hasher, 1997), (2) perseveration and working memory of the prefrontal cortex (e.g., Daigneault & Braun, 1993; Daigneault et al., 1992), and (3) interference, prospective memory and retrospective memory (including representation or working memory) of the prefrontal cortex (West, 1996; West & Bell, 1997).

Are-related declines are found for a number of prefrontal lobe mediated tasks including the Wisconsin Card Sorting Test (WCST), Field Dependence Tests, the Stroop Test, the Brown-Peterson Task, and selective attention tests (Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962; Davis et al., 1990; Dempster 1992, 1993; Haaland, Vranes, Goodwin, & Garry, 1987; Lee & Pollack, 1978; Welford, 1985). Similar deficits in performance were reported for patients with frontal lobe damage (Benson, Stuss, Naeser, Weir, Kaplan, & Levine, 1981; Stuss & Benson, 1984; Milner, 1963; 1964; Teuber, 1964; 1972) and children whose frontal lobes were not yet fully developed (Chelune & Baer, 1986; Comalli et al., 1962; Wise, Sutton, & Gibbons, 1975; Witkin & Goodenough, 1981). Age-related declines found on these tasks indicate that the prefrontal cortex of older adults is not functioning as well as it is in younger adults (Dempster, 1992, 1993).

Performance on the WCST, a test of set shifting and inhibitory processes that is often used as an index of the integrity of the prefrontal cortex (Heaton, 1981), is often impaired with aging. Patients with frontal lobe lesions (Milner, 1963, 1964) and older adults demonstrated greater difficulty in set shifting, as indexed by fewer numbers of category set shifts, than neurologically intact younger adults (Davis et al., 1990; Haaland et al., 1987). Older adults had more WCST perseverative errors than did young adults (Davis et al., 1990). Additionally, children produced fewer WCST perseverative errors and achieved more category set shifts as age increased from the first to the sixth grade (Chelune & Baer, 1986).

Older adults show a decreased ability to ignore irrelevant information and inhibit incorrect responses. Using measures of field dependence (Rod and Frame Test, Embedded Figures Test), research demonstrated an increased ability of children to ignore irrelevant information through the teenage years (Witkin & Goodenough, 1981). With advancing age, subsequent field independence declines were found (Lee & Pollack, 1978; Welford, 1985). Age-related declines were evident as early as the 50s (Lee & Pollack, 1978). Corresponding increases in field dependence were also found in frontal lobe lesion patients (Teuber, 1964, 1972).

The Stroop Test assesses interference to distracting stimuli and suppression of a prepotent response (Benson et al., 1981; Cohn et al., 1984; Comalli et al., 1962; Davis et al., 1990; Stuss & Benson, 1984; Wise et al., 1975). Performance on the Stroop Test increases through childhood, levels out in early adulthood (Comalli et al., 1962; Wise et al., 1975), and begins to decline after 65 years of age (Cohn et al., 1984; Comalli et al., 1962; Davis et al., 1990). Again, persons with frontal lobe damage show increased susceptibility to interference on the Stroop Test (Benson et al., 1981; Stuss & Benson, 1984).

Daigneault and colleagues (Daigneault et al., 1992; Daigneault & Braun, 1993) found that prior to 65 years of age deficits in performance occurred on a wide variety of prefrontal cortex measures (e.g., WCST, Self Ordered Pointing Test [SOPT], Porteus Mazes and Stroop test). Increases in perseveration occurred on some tasks (WCST, Porteus Mazes and Design Fluency). Daigneault and Braun (1993) found that early normal age-related declines in working memory, as assessed by the SOPT, could be attributed to declines in attentional, executive function processes. SOPT deficits were found for clustering strategies but not for encoding, storage, retrieval, or interference measures. Young participants (24-54 years old) made fewer errors and benefited more from a clustering strategy, while the middle-aged participants (55-64 years old) made more errors and were less likely to use a clustering strategy to perform the task. Since there were no significant differences between the two groups on time to perform the task, the poorer performance by middle-aged participants was not attributable to slower speed of processing but rather to an attentional deficit in the ability to shift between encoding and retrieval, and processing and storage.

In sum, the research reviewed in this section supports the proposed “last developed, first lost” hypothesis (Dempster, 1992; 1993). The prefrontal cortex is last to develop and often the first to show deficits due to advancing age.

Prefrontal Cortex Functions: The Inhibitory Deficit Theory of Cognitive Aging

In their seminal article that outlined an inhibitory deficit theory to cognitive aging, Hasher and Zacks (1988) proposed that early deficits of aging are attributed to declines in inhibitory attentional processes and an increased susceptibility to interference of the prefrontal cortex. Inhibitory attentional processes are impacted greatly, whereas more automatic attentional processes are not. Originally they proposed that inhibition served two functions in working memory: to allow only task relevant information access to working memory, and to inhibit or delete irrelevant task information from working memory. More recently, they (Hasher et al., 1999; May & Hasher, 1998) proposed an additional third inhibitory function: the restraint to perform strong, prepotent responses.

Selective attention and negative priming studies provide support for this theory. Older adults are less inhibited to respond to a target that was previously a to-be-ignored distracter (Hasher & Zacks, 1988; Zacks & Hasher, 1997). That older adults' reaction times were less affected by the previous distracter status of the current target suggested a deficit in inhibitory functioning (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991). When performing a reading task, older adults were more distracted than younger adults were by task irrelevant information (e.g., strings of letters, words, related phrases), especially if the distracting information was related to the information that was being read (Connelly, Hasher, & Zacks, 1991). Distracting effects were greater when the location was unpredictable than when distracting information (even highly meaningful information) was placed in predictable locations for older adults (Carlson, Hasher, Connelly, Zacks, 1995; Connelly & Hasher, 1993; Madden, 1983). Even when people were told to actively forget irrelevant information or information that was no longer relevant, older adults were still more likely than younger adults to report the irrelevant information (Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996). Irrelevant or no longer relevant information was especially difficult to inhibit if that information was a well-learned response to a situation, such as looking in the opposite direction when a cue was presented in the visual periphery (Butler, Zacks, & Henderson, 1996).

Age-related declines in working memory span are traditionally attributed to deficits in working memory capacity. Instead, Hasher and Zacks (Hasher et al., 1999; May, Hasher, & Kane 1999; Zacks & Hasher, 1997) provided evidence that these declines may be attributed to increases in susceptibility to interference. "It may well be that interference due to diminished inhibitory control results in the poorer working memory scores typically seen for older adults" (Zacks & Hasher, 1997, p. P276).

Prefrontal Cortex Functions: The Prefrontal Cortex Function Theory

Extending the work emphasizing prefrontal inhibitory and interference processes, West (1996) elucidated the impact of aging on memory processes. He demonstrated that those aspects of memory processing most associated with frontal lobe functioning, namely representational or working memory (memory used on-line while performing a task) are adversely impacted by age. Supportive evidence for localization of representational (working) memory to the prefrontal cortex comes from delayed response (DR) studies with non-human primates (Fuster, 1980), and the A-not-B task with human infants (Bell & Fox, 1992; Diamond, 1988; Fox & Bell, 1990). Persons with frontal lobe damage perform significantly poorer on working memory tasks (Stuss & Benson, 1987).

Non-human primates with prefrontal cortex damage were impaired in their ability to remember the location of a hidden reward after a short delay, even though they watched the reward being hidden (Diamond, 1990a; Diamond & Goldman-Rakic, 1989; Fuster, 1980). Similar results on the A-not-B task were found in human infants whose frontal lobes are still developing (Bell & Fox, 1992; Diamond, 1988, 1990; Diamond & Goldman-Rakic, 1989; Fox & Bell, 1990). Infants tended to return to a previously rewarded location after a delay, even though they saw the reward hidden in a different location (Bell & Fox, 1992; Diamond, 1988). The combination of having to rely on memory for the new location during the delay and the ability to inhibit a prepotent response combined to produce the effect, as the effect was not seen on the first trial of the task (hence no prepotent response) (Bell & Fox, 1992; Diamond, 1990b; Fox & Bell, 1990). Infants who were able to perform the A-not-B task after an increasing delay demonstrated frontal EEG power changes and increased coherence of anterior to posterior EEG (Bell & Fox, 1992, 1997; Fox & Bell, 1990). These results provide evidence that frontal lobe development is necessary for performance of the A-not-B task, which in turn provides evidence that frontal lobe development is important in the development of representational memory and inhibitory control.

Evidence for impairment of representational (working) memory with advancing age is found on a variety of working memory tasks: digit span (Gregoire & Van der Linden, 1997), Trails A and B (Salthouse et al., 1996; Salthouse & Fristoe, 1995), reading and computation spans (Earles et al., 1997; Salthouse & Babcock, 1991), and the SOPT (Daigneault et al., 1992; Daigneault & Braun, 1993).

According to West (1996), inhibition functions to influence performance in two related ways: (a) as a control of prepotent (though sometimes incorrect) responses (Dempster, 1991), and (b) as a means of sustaining attention on a task in the face of distracting stimuli (from both external sources and internally as reduced attention over time) to information that is relevant to the task at hand (Posner & Petersen, 1990; Stuss, 1991; Wilkins, Shallice, & McCarthy, 1987). Both of these have been localized to the dorsolateral prefrontal cortex (Diamond, 1990a; Posner & Rothbart, 1991).

Evidence for impairment in interference and inhibitory processes was found in studies of young children (Bell & Fox, 1992; Chelune & Baer, 1986; Comalli et al., 1962; Diamond, 1988, 1990b; Fox & Bell, 1990; Wise et al., 1975; Witkin & Goodenough, 1981), persons with frontal lobe damage (Benson et al., 1981; Milner, 1963; 1964; Stuss & Benson, 1984; Teuber, 1964; 1972) and aging adults (Cohn et al., 1984; Comalli et al., 1962; Earles et al., 1997; Haaland et al., 1987; Davis et al., 1990; Lee & Pollack, 1978; Welford, 1985). As presented earlier, studies with children provided evidence that functioning of inhibitory processes and resistance to interference increased as children became older until the teenage and early adult years. This was observed for the A-not-B task (Bell & Fox, 1992; Diamond, 1988; 1990b; Fox & Bell, 1990), the WCST (Chelune & Baer, 1986), measures of field dependence (Witkin & Goodenough, 1981), and the Stroop Test (Comalli et al., 1962; Wise et al., 1975). Older adults showed deficits on a range of inhibitory and interference tests including the WCST (Daigneault et al., 1992; Davis et al., 1990; Haaland et al., 1987), tests of negative priming (Hasher et al., 1991; Kane et al., 1994; Stoltzfus et al., 1993; Tipper, 1991), the Stroop Task (Cohn et al., 1984; Comalli et al., 1962; Davis et al., 1990), measures of field dependence (Lee & Pollack, 1978; Welford, 1985), a reading distraction task (Connelly et al., 1991), as well as other tasks of sustained attention and target detection (Parasuraman & Giambra, 1991; Parasuraman, Nestor & Greenwood, 1989; Quilter, Giambra, & Benson, 1983). Some inhibitory declines were observed to start before the age of 65 years old (Daigneault et al., 1992). Studies of persons with frontal lobe damage provided similar results, with deficits on the WCST (Milner, 1963, 1964), measures of field dependence (Teuber, 1964, 1972), and the Stroop Test (Benson et al., 1981; Stuss & Benson, 1984).

Although there is some debate as to which prefrontal regions are involved in inhibitory and interference processes, representational memory is typically found to be associated with the dorsolateral prefrontal cortex (DLPFC) (Alexander, Crutcher, & DeLong, 1990; Fuster, 1995; Mishkin & Manning, 1978; Wilson, O'Scalaidhe, Goldman-Rakic, 1993). Interference and inhibitory processes have been attributed to the DLPFC (Diamond, 1990b; Knight, 1991; Posner & Petersen, 1990) or the orbital prefrontal region (Fuster, 1989, 1990, 1995). Yet others attribute just interference to the orbital prefrontal region (Alexander et al., 1990; Mishkin & Manning, 1978).

Patients with damage to the orbital prefrontal region demonstrated increased proactive interference relative to controls, but their performance did not differ from controls on measures of prepotent response suppression, learning new information, and sustained attention for a short period of time (Stuss, 1991). Additionally, Earles and colleagues (1997) found that measures of inhibition (Stroop) and interference (a reading distraction task) controlled respectively, 27% and 49% of the age-related variance in working memory. After they controlled for variance related to speed of processing, age-related variance in working memory was still mediated by interference (a reading distraction task) but no longer was mediated by measures of inhibition (negative priming, Stroop).

Interference and inhibition act on different aspects of selective attention and may be localized to different prefrontal regions (Earles et al., 1997; May et al., 1995). Interference is proposed to act on the selection phase of the selective attention task when a person is trying to determine the appropriate stimulus among distracters. Inhibition is proposed to act on the response phase, after the person has already chosen among various stimuli and is trying to concentrate attention on the appropriate response while ignoring previously rejected responses (Earles et al., 1997; May et al., 1995). As West (1996) pointed out, inhibition of a prepotent response is localized to the DLPFC (Diamond, 1990a; Diamond et al., 1994). In contrast, return of attention to a new task and the control of interference from information that is no longer relevant to the new task (say irrelevant information from a previous task) is localized to the orbital prefrontal region (Fuster, 1980; 1989; 1990; Stuss, 1991).

West's (1996) model emphasizes the hierarchical nature of the prefrontal cortex. "At a general level, the prefrontal cortex supports the integration, formation, and execution of complex, novel behavioral structures or temporal gestalts (Fuster et al., 1985), which support the direction of behavior in an orderly, purposeful manner” (West, 1996, p. 282). West proposed four supplemental processes, three of which are supported by the DLPFC (retrospective or provisional memory, prospective memory, and inhibition of prepotent responses) and one by the orbital prefrontal region (interference control). Retrospective memory involves the on-line maintenance of information that is relevant to the task at hand (representational or working memory), whereas prospective memory prepares for a response, based on relevant internal and external information. Interference control acts to rid memory of irrelevant task-related information, and inhibition of a prepotent response acts to suppress internal prepotent responses and irrelevant, but attractive external stimuli from gaining control of the behavior.

Although interference on the one hand, and inhibition and representational (working) memory on the other, have been localized to different areas of the prefrontal cortex, it is obvious that the tasks used to measure these functions involve a great deal of overlap. The Stroop Test may be a test of suppression of a prepotent response due to the desire to read the printed word rather than the color of the ink in which the word is printed. Yet, it is also a test of interference because the printed word acts as interference and a distraction from reporting the color of the ink. The same can be said of the WCST. While the WCST tends to be a test of interference and distraction from other available options, it is also a measure of the ability to suppress an established prepotent response, to continue responding based on previous responding, and to shift attention. All of the above tasks also contain an aspect of representational (working) memory, as a measure of keeping the relevant information on-line while performing the task.

Tests of prefrontal cortex functions often draw upon various cognitive processes known to be localized to different regions in the prefrontal cortex (working memory and inhibition to the DLPFC and interference to the orbital prefrontal cortex). This confound makes it problematic for studies that have sought to separate out the contribution of these various functions and their impact on the aging brain. As a case in point, Daigneault and colleagues (Daigneault et al., 1992; Daigneault & Braun, 1993) reported that performance on some tests of prefrontal cortex functions (WCST, SOPT, Porteus Mazes, Stroop Test, measures of perseveration) showed decline before the age of 65 years old. Yet, because of the overlap in functions (and brain regions) tapped by these tests it is not clear whether working memory, inhibitory processes, interference, or a combination of the three contributed to the decline. Therefore, it is difficult to tell whether all functions are aging concurrently, or whether some begin to age before others, or possibly aging of some functions influences future aging of other functions.

An intriguing proposal is that aging declines in interference processes may predate declines in inhibitory processes (Earles et al., 1997). Only a longitudinal study will permit us to tease out differential declines in cognitive processing associated with age.

Summary

In summary, the reviewed research demonstrates that performance on tasks that place a greater load on working memory, and the anterior attention system processes of inhibition and interference are most sensitive to the effects of aging. A prefrontal cortex hypothesis of cognitive aging predicts that prefrontal functions such as working memory, interference experienced when switching attention, and inhibition of a prepotent response will deteriorate early in the course of aging. Therefore, corresponding declines on the following types of tasks should also be expected: backward digit span and SOPT (working memory), Trails B, the WCST and measures of proactive interference (interference), and the Stroop Color and Word Test (inhibition).

Additionally, speed of processing has a ubiquitous effect on many aging functions. It accounts for a large portion of the age-related change in a variety of cognitive and memory tasks (Earles et al., 1997; Salthouse 1991; 1992a, 1992b; Salthouse et al., 1996). However, even after controlling for the effects of speed of processing, the effects of working memory and interference processes still account for a portion of the age-related variance in cognitive decline (Earles et al., 1997; Salthouse 1992a; 1992b; Salthouse et al., 1996; Salthouse & Fristoe, 1995).

Salthouse attributed much of the decline in working memory to slower speed of processing. He concluded that "much of the age-related reduction in cognitive performance appears to be mediated by age-related reductions in working memory, which in turn appears to be largely mediated by age-related reductions in speed of processing" (Salthouse, 1992b, p. 912). However, in the very study where Salthouse (1992b) concluded that the reductions in working memory were due to declines in speed of processing, he found that performance varied independently based on working memory. For example, mean accuracy on various tasks (analogies, cube assembly, paper folding, reasoning) decreased and age trends were inversely related to the complexity of the cognitive task. Additionally, as task complexity increased, correlations between accuracy at each level of complexity and age increased. The most striking finding came from a hierarchical regression analysis in which speed of processing had the largest effect only on the easiest level (Salthouse, 1992b) and working memory on the intermediate and most complex levels of each task. As such, Salthouse (1992b) himself concluded that “much of the age-related differences in working memory appear to be mediated by age-related reductions in the speed of executing elementary operations…. (and) age-related reductions in processing speed contribute to impairments in working memory and to lowered performance in relatively simple cognitive tasks, and that the impairments in working memory are largely responsible for the difficulties experienced by older adults in more complex cognitive tasks” (p. 918).

Salthouse (1996) originally attributed reductions in working memory to previously observed declines in speed of processing for more difficult tasks (Salthouse, 1992b). From his account, it appeared that declines in working memory (and performance on easier levels of a task) provided a notable effect on the performance of more complex tasks. In contrast, speed of processing had a substantial effect on age-related declines on less complex tasks and less of an effect on more complex tasks. This effect was also noted in a study designed to investigate the influence of speed of processing on age differences in working memory (Salthouse, 1992a). The correlation between age and working memory retained statistical significance after adjusting for processing speed. Additional findings from Salthouse (Salthouse et al., 1996; Verhaeghen & Salthouse, 1997) provide evidence for the independent effect that working memory has on age-related cognitive decline. More recent work by Salthouse and colleagues (1998) implicates the prefrontal function of attention switching as a contributing factor.

Furthermore, results from path analyses (Salthouse et al., 1996; Verhaeghen & Salthouse, 1997) additionally demonstrated the specific and unique effect of age on memory, over and above the speed effect. Both Salthouse et al. (1996) and Salthouse and Fristoe (1995) reported a portion of the age-related variance in Trails B performance that is unique and independent of the effect of the age-related variance associated with performance on Trails A. While a portion of the variance in both Tails A and Trails B performance was affected by a general speed factor, performance was additionally found to result from the unique effect of alternating between number and letter on Trails B. Attention switching has since been implicated as an important factor in perceptual speed tasks (Salthouse et al., 1998). Therefore, while it does appear that a substantial effect of age-related cognitive declines can be attributed to slower speed of processing, there are additional specific effects that also contribute to cognitive declines with age.

In addition to or instead of speed of processing, the above review of the literature strongly support aging effects associated with three prefrontal cortex regions: (1) representational or working memory needed online while performing a task, (2) inhibition or suppression of prepotent responses, and (3) interference or distractibility from external and internal sources. The present study investigated how working memory, inhibition and interference, using both a cross-sectional and longitudinal design, predicted future prefrontal cortical functions (6-16 years later) from initial levels and changes in speed of processing, working memory, and interference. This approach permitted a teasing apart of the effects of speed of processing from the effects of working memory, inhibitory processes and interference. The present study employed five reaction time tasks that ranged from a simple speed test to more complex ones that involved attention set switching, working memory, and inhibitory processing.

Purpose of the Present Study and Hypotheses

The present study took advantage of as yet unanalyzed archival data obtained from men and women between the ages of 20 and 90 years old, who were recruited to participate in a longitudinal study of physical and psychological processing called the Baltimore Longitudinal Study of Aging (BLSA). The general purpose was to examine the influence of aging on cognitive functioning over 6 to16 years, and determine whether certain initial performance levels could predict differential cognitive decline over time. The aims of the study were to:

(1) examine age differences and age changes over a six-year time span in simple and complex reaction time (including inhibitory/working memory components) and reaction time errors to determine rate of change in men and women;

(2) determine whether reaction time and reaction time errors of men and women follow a similar course of change over a six year time span;

(3) examine rate of change in mental status and the prefrontal outcome measures of working memory, attention switching, interference, and inhibition over a four-or six-year time span, depending on outcome variable;

(4) determine whether initial simple reaction time, initial inhibitory/working (representational) memory measures, and initial reaction time commission errors (measure of interference) could predict mental status and the prefrontal cortical functions of working memory, attention switching, interference, and inhibition six to 16 years into the future;

(5) determine whether changes in simple reaction time, inhibitory/working (representational) memory, and reaction time commission errors (measure of interference) over six years could predict future change in overall mental status and working memory, attention switching, interference, and inhibition, 6 to 16 years into the future;

(6) determine which perspective – The processing speed theory proposed by Salthouse (Salthouse, 1996) or the Prefrontal Cortex Hypothesis (West ,1996) and inhibitory deficit theory (Hasher & Zacks, 1988) - best predicts future mental status, cognitive and memory performance, and future change in mental status, cognitive and memory performance, and

(7) determine which of the initial performance levels of the predictor variables and changes in the predictor variables (simple reaction time, inhibitory/working memory and interference) best predicts which of the outcome measures (mental status, attention, working memory, interference and inhibition).

Part One: Longitudinal Study of Reaction Time and Reaction Time Errors over Six Years

The first investigation evaluated hypothesized age-related changes in speed of visual processing over a 6-to 12-year time span that involved two (6 to 9 year change) test administrations. Five reaction time tasks were assessed: (1) press a hand held button every time a ‘0’ appeared; (2) press for a specific number embedded among other numbers (e.g., 3); (3) press for every odd number (or even number, depending on order given); (4) press for every odd number followed by an even number (or even number followed by an odd number, depending on order given); and (5) press for every odd number followed by another odd number, and every even number followed by another even number. The first task (press for ‘0’) was essentially a simple reaction time task, where one pressed every time the stimulus appeared. Tasks two through five included inhibitory processing and working memory in addition to reaction time, with tasks four and five incorporating the greatest amount of inhibition and working memory. They required one not only to detect a stimulus, but also to inhibit responding to competing stimulus-stimulus patterns (press for odd followed by even, but not for even followed by odd). They also required a greater amount of information to be held on-line in working memory while performing the task (press for odd followed by odd and even followed by even, rather than just pressing for a specific number).

Based upon prior studies using a variety of cognitive tasks (Birren et al., 1980; Fozard et al., 1994; Madden 1992; Salthouse, 1993c; Swearer & Kane, 1996; Waugh et al., 1978; Welford, 1977), it was expected that simple reaction time task speed would significantly decline over the 6- to 9-year period. Task speed that also included inhibitory processes and working memory was expected to decline more rapidly. Previous researchers found complex reaction time to decline twice to three times as much as simple reaction time (Fozard et al., 1994; Madden 1989; 1992). As such, it was expected that reaction time for tasks that also incorporated inhibition and working memory would decline at a rate that was closer to the rate of more complex reaction time tasks than to the rate of simple reaction time tasks.

Sex differences were also expected, namely that women would have slower responses than men would, with no interaction between sex and age. The expectation of men outperforming women was based on the work of Fozard and colleagues (1994) over that of Schaie (Schaie, 1989; 1994; Schaie & Willis, 1993) for two reasons. First, the present study drew participants from the same Baltimore project assessed by Fozard. Second, although Fozard and colleagues employed an auditory reaction time task and the present study employed a visual reaction time task, the tasks used were more similar to those of Fozard and colleagues than they were to those of Schaie.

Finally, a direct relationship between age, errors, and increased inhibitory and working memory processing was expected based on evidence for increased errors as a function of both task difficulty and age (Fozard et al., 1994; Madden, 1992; Swearer & Kane, 1996).

Part Two: Cross-Sectional and Longitudinal Reaction Time Performance as Predictors of Future Cognitive Change

Although many studies have examined the concurrent relationship between speed of processing and performance on a variety of cognitive and memory tasks, to date no one has attempted to predict future mental status, and cognitive and memory performance from reaction time performance. This investigation assessed the degree to which speed of processing is important in accounting for age-related cognitive decline. Specifically, it assessed whether initial reaction time and change in reaction time over six years could be used to predict future cognitive, memory, and ultimately prefrontal lobe functioning, 6 to 16 years into the future.

Based upon work by Salthouse and his colleagues (Salthouse, 1991, 1992a, 1992b, 1992c, 1993a, 1994a, 1994b, 1996; Salthouse & Babcock, 1991; Salthouse & Fristoe, 1995; Salthouse et al., 1996), speed of processing might account for a large proportion of coincident age-related variance in a variety of different cognitive and memory tasks. It was hypothesized that initial performance on the reaction time tasks, as well as change in reaction time performance (indices of speed of cognitive processing), would predict a significant portion of the variance in the prefrontal-associated outcome measures of attention, working memory, interference and inhibition. Furthermore, it was hypothesized that after adjusting for speed of processing future performance on measures of attention, working memory, interference and inhibition would be significantly predicted by (a) initial performance and change in performance on measures of inhibition and working memory measured by the more complex reaction time tasks, and (b) interference measured by reaction time commission errors.

Support for the contribution of inhibitory, working memory and interference processes on future age-related prefrontal cognitive decline comes from Hasher and Zacks (Hasher & Zacks, 1988; Hasher et al., 1999; May & Hasher, 1998; Zacks & Hasher, 1997), Daigneault (Daigneault & Braun, 1993; Daigneault et al., 1992) and West (West, 1996; West & Bell, 1997). They reported that representational (working) memory, interference and inhibition, all thought to largely involve prefrontal processes, are among the first to decline with advancing age. Additionally, Salthouse and his colleagues (Salthouse, 1992a; 1992b; Salthouse et al., 1996; Salthouse & Fristoe, 1995) demonstrated that after the effects of speed of processing have been controlled for, there were still consistent independent effects of working memory on cognitive functioning in older adults. Earles and colleagues (1997) also demonstrated significant effects of interference on age-related working memory decline after adjusting for speed of processing.

A series of hierarchical regression analyses were performed to determine which of the two major theories, the Processing-Speed Theory, or the Inhibitory Deficit Hypothesis and the

Prefrontal and Cortex Function Hypothesis, most adequately predicts future prefrontal cortical functioning. This was achieved by conducting a series of hierarchical regression analyses where the simple reaction time tasks (speed of processing) were entered first into the regression equation, followed by the inhibitory/working memory reaction time tasks, followed by the interference measures. A comparable series of regression analyses were also performed where the inhibitory/working memory reaction time tasks were entered first, followed by the interference measures, followed by the simple reaction time tasks. This allowed for an investigation of the independent effects of speed of processing, inhibitory/working memory and interference in predicting future cognitive performance. Entering speed of processing first into the initial set of regressions allowed for the assessment of the attenuating effect that speed of processing had on the ability to predict future prefrontal cognitive performance from inhibition/working memory and interference performance. Furthermore, by entering inhibitory/working memory and interference performance first into the second set of regressions, an assessment was made of the attenuating effects that inhibitory/working memory and interference performance had on the prediction of future prefrontal cognitive performance from speed of processing.

From a processing speed theoretical perspective, speed of processing is expected to account for a majority, if not all of the variance in future prefrontal-mediated cognitive performance because age-related cognitive decline can be primarily attributed to generalized cognitive slowing. In contrast, from a prefrontal cortex hypothesis, it would be expected that inhibition/working memory and interference measures would account for a majority of the variance in prefrontal-mediated cognitive performance. This would be expected because individuals with sharper declines in prefrontal cortical functions, served by the anterior attention system, are experiencing greater age-related cognitive decline. As such, those persons with poorer initial performance and a sharper decline over six years in functions controlled by the anterior attention system (e.g., inhibitory and working memory processes, and interference) would be expected to decline more rapidly on later prefrontal measures (e.g., backward digit span, attention switching, proactive interference, inhibition, fluency measures). Persons with better initial performance and small rates of decline in anterior attention system functions would experience a less rapid decline on later prefrontal measures.

With respect to declines in the prefrontal outcome measures, tasks placing greater demands on the prefrontal cortical functions of attention switching, interference, working memory and verbal fluency were expected to evidence greater impairment (e.g., Trails 'B', proactive interference, backward digit span, fluency measures) than those which placed fewer demands (e.g., Trails 'A', forward digit span). According to Daigneault (1992; Daigneault & Braun, 1993) Hasher and Zacks (1988; Hasher et al., 1999; May & Hasher, 1998) and West (1996), prefrontal functions are among the first to decline with advancing age. As such, it was expected that tasks that rely on prefrontal functions would decline more rapidly than tasks that had less reliance on prefrontal functions.

Furthermore, it was expected that tasks that placed greater demands on prefrontal cortical functioning (e.g., Trails 'B', proactive interference, backward digit span, fluency measures) would be better predicted by declines in functions controlled by the anterior attention system (e.g., inhibition, working memory, interference). In contrast, tasks that placed less of a demand on prefrontal cortical functions (e.g., forward digit span, Trails 'A', Stroop 'words' or 'colors'), would be better predicted by performance on simple reaction time tasks. Specifically, it was expected that the reaction time tasks that involve inhibitory/working memory (tasks four and five) would better predict (account for more of the age-related variance in) the outcome measures that involved working memory (backward digit span). The reaction time measures that involved interference (commission errors) would better predict the outcome measures that involved interference (Trails 'B', proactive interference). Finally, the reaction time task that involved simple reaction time (task one) would better predict the outcome measures that required less prefrontal processing (Trails 'A', forward digit span). These expectations are also based on the work of Daigneault (1992; Daigneault & Braun, 1993) Hasher and Zacks (1988; Hasher et al., 1999; May & Hasher, 1998), West (1996) and Salthouse (1996).

The expectation that simple reaction time would be a better predictor of tasks that required less prefrontal processing (e.g., Trails 'A', forward digit span) comes from the work of Salthouse (1992b). Salthouse (1992b) found that reductions in more complex versions of a task were in part a result of slower processing on less complex versions. It was additionally expected that simple reaction time would be a better predictor of overall mental status than would the prefrontal-mediated measures. According to Salthouse (1996), reduction in speed of processing, of which simple reaction time is a measure, is an indication of general cognitive processing. Mental status tests, by design, measure a cross section of cognitive processing (not just prefrontal processing), and as such measure a general process. Therefore, one might expect a measure of general cognitive slowing to more accurately predict a measure of overall cognitive functioning than would measures of specific prefrontal functioning.

Chapter 2: Method

Participants

The participants were drawn from the Baltimore Longitudinal Study of Aging (BLSA). Started in 1958 by Nathan Shock, the BLSA is a more than 40-year on-going study of normal aging designed to investigate normal age-related changes in a variety of physical and psychological functions. Selection for inclusion in analyses depended on the hypothesis investigated and the number of participants available.

Unlike many studies that ask for self-report of physical health, our participants were given physical exams at each testing period. As a result we were able to systematically evaluate the participants' physical health. Participants with a diagnosis of diseases that might affect vision (e.g., retinal detachment, glaucoma, cataracts, macular degeneration), reaction time (e.g., multiple sclerosis, arthritis), or brain functioning (e.g., strokes) before or at their initial reaction time assessment, were excluded from this investigation. The physical limitation exclusions resulted in 34% of the participants excluded for physical limitations. These exclusions were made based on research by Baltes and Lindenberger (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) who found that auditory and visual acuity measures accounted for 31% of the variance in intellectual functioning among older adults, compared with only 11% of the variance in intellectual functioning among younger adults. Participants with a diagnosis of dementia at any time during the study were also excluded. The exclusion based on dementia resulted in 8% of the participants excluded for dementia-related illnesses. Therefore, the participants used for this study were exceptionally healthy.

For the cross-sectional and longitudinal study of initial reaction time across ages and rate of age changes, normal participants with valid time 1 reaction time and reaction time error data were included in the analyses (n = 1017; 380 women, 757 men). See Table 1 for age breakdowns by year of first reaction time testing. The education level for this investigation (and the BLSA sample as a whole) was quite high, with many of the participants having at least a bachelor's degree and some having more than the equivalent of a doctoral degree (see Table 2).

For the cross-sectional and longitudinal analyses using reaction time and reaction time error performance to predict future cognitive performance and cognitive change, only those participants who had valid change data for both the reaction time measures and the cognitive outcome measures were included in the analyses. The number of participants available for most of the predictive analyses depended on the outcome variable used and ranged between 103 and 139. Table 2 presents a breakdown of participants by outcome variable.

Materials and Procedure

Reaction time tasks. To assess normal aging in reaction time, between the years of 1978 and 1992, BLSA participants were administered reaction time tasks designed to represent five levels of difficulty as part of a larger battery of cognitive tasks. Although the five tasks varied in their level of difficulty, they also varied in the amount of inhibitory processing and working memory needed to perform the tasks.

The first task (RT task 1) required simple detection of a target while the more difficult tasks (tasks 3-5) also required the participant to hold more targets in working memory as well as inhibit responding to no longer relevant targets. For the first and easiest of the five tasks, the participant was instructed to press a hand held push button, as quickly as possible, every time a ‘0’ randomly appeared. Every participant received this as the first reaction time task. The next three tasks were dependent on the specific counterbalanced order given to the participant. In addition, the subsequent four reaction time tasks required the participant to detect a target number or combination of target numbers presented one after the other along with distracter numbers.

The second task (RT task 2) required the participant to press the button every time a specific number was presented (e.g., 3). For the third task (RT task 3), the participant pressed the button for every odd number (or even number depending on the order assigned to the participant). The fourth task (RT task 4) required that the participant press every time an odd number was followed by an even number (or an even number followed by an odd number). And the fifth task (RT task 5), the one with the most inhibitory processing and highest working memory load, required the participant to press every time an odd number was followed another odd number, and every time an even number was followed another even number. All participants received this fifth and last task regardless of the order assigned to the participant.

For each reaction time task, a single digit number was presented at a rate of one digit per second with no inter-stimulus-interval. This was achieved by projecting each digit onto a three-inch by four-inch rectangular internal transparent window via computer control. This apparatus was specifically designed for the display of the reaction time tasks, in addition to displaying words, as part of the larger memory and reaction time battery. For task one, a ‘0’ appeared in the three-inch by four-inch window at random intervals. There were 15 targets presented each of the five RT tasks, and the numbers took up the entire surface area of the window (three-inches by four-inches). For tasks 2 through 5, the 15 targets were randomly embedded among 90 distracters, and each task was 90 seconds long. The targets took up the entire surface area of the display window. The reaction time was registered as soon as the hand held push button was depressed. Each target was presented for 1000 msec and participants were given up to 2000 msec to respond correctly when a target was presented. Additionally, responses occurring within the first 180 msec, for task one, and 200 milliseconds for tasks two through five, were considered to be anticipatory responses and excluded from analyses. Only reaction times for correct responses were recorded. The number of both omission and commission errors were also recorded.

The tasks were designed to be relatively short (90 seconds per task), with the same motor component and display time for all tasks (Arenberg, personal communication, 1998). The five tasks were part of a larger memory and reaction time battery not addressed in the present study. Prior to introducing the battery as a part of the regular BLSA testing, the tasks from the memory and reaction time battery were initially factor analyzed using a sample of 96 men from the BLSA cohort (Robertson-Tchabo & Arenberg, 1976). All five of the reaction time tasks loaded on a single information processing speed factor, which accounted for 27 % of the total variance after the factors were rotated. The reaction time tasks correlated significantly with age: $r = 0.41$, 0.51, 0.35, 0.36, and 0.23, respectively, $p < .01$).

The entire battery was given initially on a separate practice day to ensure that participants understood all tasks. Any questions or problems that the participant had were discussed on the practice day. Approximately 24 hours later, the actual test session was conducted where the entire set of five reaction time tasks were given again twice, interspersed with other tasks in the memory and reaction time battery. The mean of the two reaction time administrations was used in analyses.

The reaction time tasks were given on a six-year repeat schedule (5.95 -9.7 years from initial testing for the first repeat interval, and 11.9 -15.5 years from initial testing for the second repeat interval). Because only 29 participants received three administrations of the tests, analyses were limited to the first and second administrations.

Neuropsychological and cognitive tests. Since 1986, a neuropsychological battery has been given to all BLSA participants 70 years of age and older approximately every two years. Since 1990, participants 60 years and older were also given this battery every two years. The tests selected from this battery for inclusion in this study were designed to assess mental status, attention and attention switching and verbal fluency.

Both the Blessed Information-Memory-Concentration test (Fuld, 1978) and the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) are bedside mental status tests designed to assess overall cognitive functioning. The Blessed Information-Memory-Concentration test assesses orientation to person, place and time, attention and concentration (saying the months backwards, counting both forward and backwards), short and long term episodic memory (repeating and remembering a name and address after a short delay) and semantic memory for well learned information (e.g., mother's name, dates of World War I and World War II). Total numbers of errors (0 to 32) was the score for the Blessed Information-Memory-Concentration test. Blessed Dementia Scale scores, from which the Blessed Information-Memory-Concentration was derived, correlated positively with number of post-mortem plaque and tangle counts (Blessed, Tomlinson & Roth, 1968).

The Mini-Mental State Examination measures orientation to place and time, attention, repetition and short-term memory, both receptive and expressive (written) language and constructional praxis. Number correct (0 to 30) served as the score for the Mini-Mental State Examination. The Mini-Mental State Examination score was initially compared against neurologists' clinical evaluations of dementia or normal cognitive functioning.

The Mini-Mental State Examination measures some of the same cognitive components as the Blessed Information-Memory-Concentration test (orientation to place and time, attention, repetition and short-term memory for three words), yet there are also differences. For example, the Blessed Information-Memory-Concentration test measures long-term episodic and semantic memory, while the Mini-Mental State Examination measures both receptive and expressive (written) language, and constructional praxis.

The Trail Making Test (Trails A and Trails B) is designed to assess attention (Trails A) and attention switching (Trails B) and visuomotor scanning (both Trails A and Trails B) (Reitan, 1992). During Trails A, the participant was required to draw a line from one number to the next, in sequence, from numbers 1 to 25. For Trails B, the participant was again required to draw lines, but this time alternating between number and letter. Each time an error was made the participant was stopped, while the stopwatch was still running, and the participant had to correct him or herself. Time to completion (seconds) was the variable examined.

Verbal fluency measures are commonly used as indices of frontal lobe functioning (Lezak, 1983; Miller, 1985; Parkin & Lawrence, 1994). They measure a person's ability to spontaneously generate words within a specified time period. Two forms of verbal fluency were used for this study: letter fluency and category fluency. The letter fluency test is included in the Multilingual Aphasia Examination (Benton & Hamsher, 1976), while the category fluency test is an adaptation from the Boston Diagnostic Aphasia Examination (BDAE) category fluency test (Goodglass & Kaplan, 1972). Participants were asked to generated as many words as possible beginning with a specific letter (F, A, S) or category (fruits, animals, vegetables) within a specified period of time (60 seconds). Number of unique words generated was the variable measured.

Since 1993, an additional neuropsychological battery of tests has been given, on a two-year repeat schedule to every participant 50 years of age and older and to participants under the age of 50 years old, at least one time. The tests selected from this battery were designed to measure working memory and interference.

The Wechsler Adult Intelligence Scale-Revised (WAIS-R) Digit Span Forward and Backward tests (Wechsler, 1981) assess working (representational) memory needed while performing a task. During digits forward the participant repeated a series of single digit numbers at increasing digit span lengths. The length of the span of numbers ranges from three to nine digits. Two trials at each span were presented. The test was discontinued when the participant incorrectly repeated both trials at a specified span. If both trials in a span were correct a score of '2' was given, if one trial in a span was correct a score of '1' was given, if neither trail in a span was correct a score of '0' was given. Digits backward is similar to digits forward, except that the participant repeated a series of single digit numbers in reverse order. The length of the span of numbers ranges from two to eight digits. Total score for digits forward and digits backward were the variables measured.

The California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, & Ober, 1987) is a test of verbal learning and memory in which a list of 16 items (list A), representing 4 categories (fruits, tools, clothing, spices & herbs), are presented orally for recall over 5 learning trials. After the fifth learning trial, a second list (list B) was presented for recall once, that had two of the original categories overlapping (fruits, spices & herbs), but with new items. Without re-presenting the first list, the participant was then asked to recall the items from the first list (list A) again. This recall trial was followed by cued and delayed recall and recognition portions. These portions were not included in this study, and so will not be expanded upon here. The variable of interest in the present study was the index of proactive interference, which is defined as the percent total reduction in recall on list B relative to recall on trial 1 of list A ([total correct on list A trial 1 – total correct on list B] x 100 / total correct on list A trial 1).

Chapter 3: Results

The results are divided into two parts: (1) the longitudinal rate of change analyses for the reaction time (RT) and RT errors analyses; and (2) the predictive analyses using initial levels of simple RT, and RT that also involved inhibition, working memory and interference to predict future mental status and cognitive functioning.

Part One: Longitudinal Rate of Change in RT and RT Errors over Six Years: Data Analyses

The first set of longitudinal analyses assessed whether a change in age over six years in men and women is associated with a corresponding change in RT and RT errors over the same time period for the five RT tasks that varied in the amount of inhibition and working memory required. The rate of change analyses were performed using random-effects regression (mixed) models with sex and age at initial RT testing (5 levels) as between subjects fixed-effect factors, and RT task (5 levels) and time of testing (2 levels) as within subjects fixed-effect factors. Three separate mixed models were performed for the three dependent measures: RT, RT commission errors (a participant responded when s/he should not have), and RT omission errors (a participant did not respond when s/he should have).

The mixed model procedure used SAS's PROC MIXED program (Littell, Milliken, Stroup, & Wolfinger, 1996) to account for the special requirements of longitudinal data. The mixed model accommodates longitudinal data in three ways. First, the mixed model tests for both fixed and random effects, allowing for participants to have variable starting points (random intercepts) and variable slopes across time (random time effects). Second, participants who have only one data point can still be included in the analyses and contribute to the cross-sectional results, while those with two data points contribute to the longitudinal results. Finally, the model accounts for the inter-correlation among data points collected from the same person at different times.

The SAS PROC MIXED mixed model employs a successive backwise elimination regression procedure where higher order non-significant fixed effects are removed until the only terms left in the final model are significant. There are two reasons why non-significant fixed effects are left in the final model. First, lower order terms that are non-significant, but as part of a higher order term are significant, are retained in the model to make sure that the model is hierarchically well-formulated (Morrell, Pearson, & Brant, 1997). Second, because of the interest in examining longitudinal change over time, the variable called Time-Fixed (testing time 1 versus testing time 2) is kept in the model, even if non-significant, due to its usefulness in estimating RT change over time. More complete descriptions of mixed models are available from Singer (1998) and the SAS Institute (e.g., Littell et al., 1996).

The cross-sectional differences and longitudinal changes in RT and RT commission and omission errors were examined using the following fixed effects as covariates, for each of the three models. For illustrative purposes the effects are discussed for RT. Parallel analyses were performed for the RT commission and omission errors.

Initial Age: Age at initial RT testing, in years, was divided into five age groups: 20-31 years old, 32-41 years old, 42-51 years old, 52-61 years old, 62-79 years old. The age groupings were broken into approximate decade categories. The groupings were arranged to equalize the number of participants as much as possible across the age groups. Due to the small number of participants in the oldest age category, this group contained a 17-year interval. Table 1 presents the number and percentage of men and women in each of the five age groups.

Sex: Men's RT performance was considered in comparison to women's RT performance.

RT tasks: There were five levels of the RT tasks: task 1 - press for '0', task 2 - press for a specific number, task 3 - press for every odd (or even) number, task 4 - press for every odd followed by an even (or even followed by an odd) number, task 5 - press for every odd followed by another odd, and every even followed by another even number.

Time-Fixed: Time of testing (2 levels – initial testing and testing six to nine years later) evaluated the effects of longitudinal "age" changes on RT and RT errors.

Initial Age X Time-Fixed: The initial RT age by time interaction assessed differences in rate of change between time 1 and time 2 for the four age groups.

Sex X RT task: The sex by five RT tasks interaction assessed differences between men and women for each of the five RT tasks.

Initial Age X RT task: The initial RT age by five RT task interaction assessed differences among the five RT tasks for the four initial RT age groups.

Sex X Initial Age: The sex by initial age interaction assessed differences between men and women for the four initial RT age groups.

Sex X Time-Fixed: The sex by time interaction assessed differences in rate of change between time 1 and time 2 for men and women.

RT task X Time-Fixed: The five RT task by time interaction assessed variation in rate of change between time 1 and time 2 for the five RT tasks.

Mixed-Model Results: RT Fixed Effects

The final model included both of the between-subjects fixed-effect factors, initial age at RT testing and sex, and both of the within-subjects fixed-effect factors, the five RT tasks and time of testing, as significant. Table 3 presents a summary of the significant main effects along with the associated means and standard errors. The two-way interactions for initial age by the five RT tasks, initial age by time of testing and sex by the five RT tasks were also retained in the final model as significant: initial RT age x the five RT tasks: (F [16,4255] = 6.23, p < .0001); initial RT age x time of testing: (F [4,4255] = 2.96, p <. 02); sex by the five RT tasks: (F [4,4255] = 7.17, p < .0001]). The three-way interactions and the four-way interaction were not significant and therefore were not retained in the final model. Appendix A provides all main effect and interaction mean post-hoc comparisons with Bonferroni correction for multiple comparisons.

Figure 1 illustrates the differential impact of initial RT age and task complexity on RT; the means and standard errors are provided in Table 4. As expected, participants were faster on simple RT tasks than they were on more complex RT tasks. The increase in RT across task complexity was steeper for the older age groups than for the younger age groups.

There were no significant differences between any of the age groups for RT task 1 (simple reaction time). There were no significant differences among the three younger age groups for any of the five tasks and no significant differences between the two older age groups for any of the five tasks. Beginning with RT task 2, reaction time for the two older age groups clustered together and began to increase at a rate that was faster than for the three younger age groups beginning with RT task 2. The comparisons between the 20-31 year olds and the 52-61 year olds approached significance, and the comparison between the 20-31 year olds and the 62-79 year olds was significant at RT task 2 (RT task 2: 20-31 year olds vs. 52-61 year olds: t [4255] = 4.05, p = .06; RT task 2: 20-31 year olds vs. 62-79 year olds: t [4255] = -5.19, p < .0001). However, the comparisons between the 42-51 year olds and the 52-61 year olds, and the 42-51 year olds and 62-79 year olds were significant only for the two most difficult tasks (RT tasks 4: 42-51 year olds vs. 52-61 year olds: t [4255] = 3.84, p = .04; RT task 5: 42-51 year olds vs. 62-79 year olds: t [4255] = 5.18, p < .0001).

As expected, there were highly significant (p < .0001) although moderately low, correlations between initial RT age and initial RT for all five RT tasks: RT task 1: r = .27, p < .0001; RT task 2: r = .28, p < .0001; RT task 3: r = .31, p < .0001; RT task 4: r = .34, p < .0001; RT task 5: r = .23, p < .0001. Older participants were slower (increased RT) for each of the five RT tasks.

Only the oldest 62-79 year old age group showed a significant slowing in reaction time between times 1 and 2, t (4255) = 3.61 p = .0003. As shown in Figure 2, there were no significant differences between Time 1 and Time 2 for any of the other age groups. Additionally, there were no significant differences among the three youngest age groups, or the two oldest age groups at time 1 or time 2 (see Appendix A). However, RT for the 52-61 year olds was significantly slower than for the 42-51 year olds at both time 1 and time 2 (time 1: 42-51 year olds vs. 52-61 year olds: t [4255] = 3.33, p = .04; time 2: 42-51 year olds vs. 52-61 year olds: t [4255] = 3.45, p = .03). Again, the two older age groups clustered together at time 1 and time 2, and the three younger age groups clustered together at time 1 and time 2. The interaction and the significant time main effect presented in Table 3 were driven by the increase in reaction time from time 1 to time 2 for the oldest age group (62-79 year olds).

As seen in Figure 3, women were significantly slower than men for RT tasks 1 and 4 but there were no significant differences between men and women for tasks 2, 3 or 5 (RT task 1: t [5255] = 5.87, p < .0001; RT task 4: t [5255] = 5.82, p < .0001). Thus, women were slower than men for the simple reaction time task (RT task 1) and reaction time that involved inhibitory processing (RT task 4). Table 5 presents the means and standard errors.

Mixed-Model Results: RT Commission Error Fixed Effects

The final model for RT commission errors included the Initial RT age between subjects fixed-effect factor and both within subjects fixed-effect (the five RT tasks and time of testing) factors as significant. Table 6 provides a summary of the significant main effects along with the associated means and standard errors. The Initial RT age by RT task and sex by RT task two-way interactions were also retained as significant in the final model (initial RT age x RT task interaction: F [16, 4255] = 8.07, $p < .0001$; sex x RT task: F [4, 4255] = 5.49, $p < .0002$). Neither three-way nor four-way interactions were significant. Post-hoc comparisons are presented in Appendix B.

Figure 4 illustrates the differential impact of age and task complexity on RT commission errors. Means and standard errors are provided in Table 7. All of the age groups had a similar pattern of RT commission error performance until RT task 3. There were no significant differences between RT task 1 and RT task 2, or RT task 2 and RT task 3 for any of the age groups. There was a significant difference between RT task 1 and RT task 3 for each of the age groups except for the youngest (32-41 year olds: RT task 1 vs. RT task 3: t [4255] = 4.07, $p < .02$; 42-51 year olds: RT task 1 vs. RT task 3: t [4255] = 4.12, $p < .01$; 52-61year olds: RT task 1 vs. RT task 3: t [4255] = 4.15, $p < .01$; 62-79 year olds: RT task 1 vs. RT task 3: t [4255] = 5.47, $p < .0001$). The three younger groups continued to have similar increases in RT commission errors for tasks 4 and 5, and there are no significant differences among the three younger age groups at each of these two task levels. However, starting at RT task 4 the commission errors for the oldest two groups increased more sharply than the three younger groups. There were significant differences between both of the older age groups (52-61 year olds and 62-79 year olds) and the youngest age group (20-31 year olds) at RT task 4 and RT task 5 (RT task 4: 20-31 year olds vs. 52-61 year olds: t (4255) = -4.84, $p = .0004$; 20-31 year olds vs. 62-79 year olds: t (4255) = -9.60, $p < .0001$; RT task 5: 20-31 year olds vs. 52-61 year olds: t (4255) = -4.03, $p = .02$; 20-31 year olds vs. 62-79 year olds: t (4255) = -8.62, $p < .0001$). There were also significant differences between the oldest age group (62-79 year olds) and the 52-61 year olds for RT tasks 4 and 5 (RT task 4: 52-61 year olds vs. 62-79 year olds: t (4255) = -5.30, $p < .0001$; RT task 5: 52-61 year olds vs. 62-79 year olds: t (4255) = -5.10, $p < .0001$). Yet, there were no significant differences between the 52-61 year olds and the 42-51 year olds for either RT task 4 or RT task 5.

While age did not correlate significantly with reaction time commission errors on RT tasks 1, it did for the other four RT tasks: RT task 1: $r = .03$, n.s.; RT task 2: $r = .09$, $p < .02$; RT task 3: $r = .14$, $p < .0003$; RT task 4: $r = .29$, $p < .0001$; RT task 5: r =16, $p < .0001$. The strength of the relationship increased with the complexity of the task.

Figure 5 illustrates the impact of sex and task complexity on RT commission errors. See Table 8 for the means and standard errors. There were no significant differences between men and women for the individual RT tasks. The significant interaction is the result of a cross-over in RT commission errors between RT task 3 for women and RT task 4 for men, and between RT task 3 for men and RT task 4 for women (women RT task 3 vs. men RT task 4: t [4255] = 9.43, $p < .0001$; men RT task 3 vs. women RT task 4: t [4255] = 7.36, $p < .0001$).

Mixed-Model Results: RT Omission Errors Fixed Effects

The final model for RT omission errors included the Initial RT age between subjects' fixed-effect factor and the RT task within subjects' fixed-effect factor as significant. Table 9 presents a summary of the significant main effects and associated means and standard errors. The significant two-way interactions for Initial RT age by RT task and sex by RT task were also retained in the final model (Initial RT age x RT task interaction: F (16,4255) = 26.19, $p < .0001$; sex x RT task interaction: F (4, 4255) = 3.45, $p < .01$. Neither the three-way nor the four-way interactions were significant. Post-hoc mean comparisons are provided in Appendix C.

Figure 6 illustrates the differential impact of age and task complexity on RT omission errors. See Table 10 for means and standard errors. There are essentially no RT omission errors for RT tasks 1 through 3. However, beginning with RT task 4 the two oldest groups cluster together and begin to increase in omission errors at a faster rate than do the three younger age groups, who also cluster together. For RT task 4, the 52-61 year olds produced significantly more RT omission errors than the 32-41 year olds, though they did not produce more than the 41-52 year olds (RT task 4: 32-41 year olds vs. 52-61 year olds: t [4255] = 4.20, $p = .008$). For RT task 5, the 52-61 year olds also produced more omission errors than the 42-51 year olds (RT task 5: 42-51 year olds vs. 52-61 year olds: t [4255] = 6.99, $p < .0001$). The oldest age group produced significantly more RT omission errors than each of the other age groups did for both RT tasks 4 and 5. It should also be noted, that each of the age groups produced significantly more RT omission errors on task 5 than on the other tasks.

Correlations between age and omission errors were not significant for the first three RT tasks, but were for RT tasks 4 and 5: RT task 1: $r = -.04$, n.s.; RT task 2: $r = .01$, n.s.; RT task 3: $r = .05$, n.s.; RT task 4: $r = .31$, $p < .0001$; RT task 5: $r = .32$, $p < .0001$.

Figure 7 illustrates the impact of sex and task complexity on RT omission errors. Table 11 provides the means and standard errors. Again there were few errors until RT task 4. RT omission errors then rose dramatically for RT tasks 4 and 5 for both men and women. Furthermore, women evidenced a steeper increase in omission errors for RT task 4 than did men, yet error performance was the same for men and women for RT task 5 (men vs. women: RT task 4: t (4255) = -3.50, p = .02). Women produced more omission errors than did men for a RT task that involved considerable inhibitory processes, but they were similarly impacted by a RT task that involved considerable working memory.

Part Two: Predicting Prefrontal Outcome Measures from Speed of Processing, Inhibition, Working Memory and Interference

Preliminary Analyses Examining Cross-Sectional Differences and Longitudinal Changes in the Mental Status and Prefrontal Outcome Measures

Analyses were performed to examine differences in initial levels for the following outcome measures: the Blessed Information-Memory-Concentration errors; the Mini-Mental State Examination total number correct; total words summed across the three letter fluency tasks (F, A, S), and total words summed across the three category fluency tasks (fruits, animals, vegetables); time for Trails A and Trails B; total score for the WAIS-R digit span forward and digit span backward tasks; and the California Verbal Learning Test proactive interference variable ([total correct on list A trial 1 – total correct on list B] x 100 / total correct on list A trial 1). Separate one-way ANOVAs were performed on the outcome measures with age at initial RT testing (two levels) and sex as between subjects' factors and time as the repeated measures factor. The time factor examined changes between initial and most recent testing. For the BIMC, MMSE, fluency and Trail Making measures the change was between time 1 and time 4. For the WAIS-R digit span and California Verbal Learning Test interference measures the change was between time 1 and time 3. Age at initial RT testing was used to create the age breakdown to be consistent with the age breakdowns used for the longitudinal mixed model reaction time analyses, due to too few participants in some of the age groups. Some of the age categories used in the longitudinal rate of change in reaction time and reaction time errors mixed model analyses had to be consolidated for the cross-sectional and longitudinal prediction of prefrontal measures' analyses. The consolidation of the age categories resulted in two age groups. These age breakdowns differed depending on the outcome measure used. Due to differences in when the tests were started (CVLT and WAIS: digits forward and backward were started after the other outcome measures) too few participants were available in one of the age categories if the same convention was used to create the age breakdowns for all outcome measures. Table 12 presents the frequency of participants by age group.

These analyses were of interest in order to make selections for the subsequent regression analyses. Significant age differences were of interest because of subsequent analyses to account for age differences in the prefrontal outcome measures from the predictors of simple reaction time, inhibition, working memory and interference. Time effects (age changes) were important because only outcome measures with a significant time effect were included in the subsequent regressions predicting change in the outcome measures from change in RT and RT commission errors. Additionally, sex differences were of interest since sex was entered into the regression equation as a covariate for those outcome measures with a significant ANOVA main effect of sex. Table 13 presents a summary of significant effects for each task. Thus, they are not referred to in the text.

The older group of participants produced significantly more errors on the Blessed Information-Memory-Concentration Test than did the younger group of participants, but they did not differ on the Mini-Mental State Examination. Older participants took longer on Trails A and Trails B than younger participants. Similarly older participants had a shorter digit span forward than did younger participants, but they did not differ significantly on digits backward. Women generated more words than men did on category fluency. Men's digit span forward and backward were significantly greater than were the women's. Both letter and category fluency production declined from time 1 to time 2, while time to complete Trails B increased from time 1 to time 2.

<u>Initial Age Predicting Initial Levels of The Prefrontal Outcome Measures after Accounting for Initial Speed of Processing, Inhibition, Working Memory and Interference</u>

A series of forced forward entry regression analyses were performed using initial RT age, and initial levels of performance on measures of simple RT (RT task 1), RT that involved inhibition (RT task 4), RT that involved working memory (RT task 5) and RT commission errors (measures of interference) to predict future performance on tests of mental status and the prefrontal cortical functions of attention and attention switching, verbal fluency, working memory, and interference. In contrast to the preliminary ANOVA analyses presented in the previous section, age was left as a continuous variable for the regression analyses.

The actual RT predictor variables used for these analyses were RT task 1 (speed), RT task 4 (inhibition), RT task 5 (working memory), commission errors for RT 1 (the interference measure for the speed variable), commission errors for RT 4 (the interference measure for the inhibition variable), and commission errors for RT 5 (the interference measure for the working memory variable). These specific tasks were selected for the predictive analyses to be the most representative measures of the specific speed of processing and prefrontal functions of interest. RT task 1, a test of simple reaction time, was used as the measure of speed of processing. RT tasks 1 and 2 were not combined as a composite measure of simple reaction time because RT task 2 involved responding among other distracter numbers and RT task 1 did not. RT task 4 was used as the measure of inhibition because of the build up of inhibition from prepotent responses for RT tasks 1-3. RT task 5 was used as the working memory measure due to the additional working memory requirement of holding two chunks of information in memory (press for every odd followed by another odd and every even followed by another even).

The specific aim in performing these analyses was to determine which of two theories, the Speed of Processing theory (Salthouse, 1996) or the prefrontal cortex function Theory (e.g., West, 1996), more fully accounted for the relationship between age and future cognitive performance. This was achieved by performing regression analyses with forced forward entry, using initial age (age) at RT testing to predict initial performance on the mental status measures of the BIMC and MMSE and the prefrontal outcome measures of Trails A, Trails B, letter fluency, category fluency, CVLT: Interference, and WAIS: digit span forward and digit span backward. After entering age into the equation, speed was entered followed by inhibition (pressing a hand held button for every odd digit followed by an even digit), working memory (pressing for every odd digit followed by another odd digit, and every even digit followed by another even digit), and the interference variables (RT1 interference - commission errors for speed, RT4 interference - commission errors for inhibition and RT5 interference - commission errors for working memory). By performing the regression in this manner, it was possible to determine the effect that inhibition, working memory, and interference had on the relationship between age and mental status and the prefrontal outcome measures, after accounting for the effects of speed of processing.

Because initial RT testing date varied among participants by eight years, the actual date of initial RT testing was entered as a covariate after initial RT age, but before the other predictor variables. Initial RT testing to outcome prediction interval was also entered as a covariate due to variations in the prediction interval between initial RT testing and the outcome measures (between 6 and 12 years, or 8 and 16 years, depending on outcome measure). Additionally, for category fluency, digits forward and digits backward, sex was entered as a covariate due to the significant sex main effect for the preliminary ANOVAs.

Table 14 provides a summary of the results of the regression analyses predicting the mental status and prefrontal outcome measures, where RT task 1 (speed) was entered into the equation before RT task 4 (inhibition), RT task 5 (working memory) and the commission errors for RT tasks 1, 4, and 5 (interference measures). Surprisingly, age was not a significant predictor of either the mental status or prefrontal outcome measures. Speed was a significant predictor of Trails A and digits forward performance. Working memory was a significant predictor of both letter and category fluency performance. Interference for RT 5 was a significant predictor of Trails B and digits backward performance.

Parallel analyses were also performed, entering RT task 4 (inhibition), RT task 5 (working memory), and the commission errors for RT tasks 1, 4 and 5 (interference measures) into the regression equation ahead of RT task 1 (speed of processing) to determine the subsequent attenuating effect that these measures had on speed of processing and the relationship between age and the prefrontal outcome measures. Table 15 provides a summary of these results. Commission errors for RT5 (interference task 1) was a significant predictor of Trails B. RT task 5 (working memory) was a significant predictor of both letter and category fluency.

In comparing the results of the two parallel regression analyses, RT task 1 (speed) was a significant predictor of both Trails A and digits forward when entered before the prefrontal measures, yet it was not significant in either case when the prefrontal measures were entered first. Therefore, the significant effect of RT task 1 (speed) on Trails A and digits forward was accounted for by performance on the prefrontal measures.

Both letter and category fluency were predicted by RT task 5 (working memory), whether or not RT task 1 (speed) was entered first. In fact, entering RT task 1 (speed) into the equation first did not change the R-squared for either variable. Thus, RT task 5 (working memory) has an effect on both letter and category fluency that is independent of RT task 1 (speed). The same can be said for the effect of the commission errors for RT 5 (interference 3) on Trails B and digits backward. The significant effects and R-squared did not differ whether or not RT task 1 (speed) was entered first. It should be noted that a significant portion of the variance was accounted for by the inclusion of all of the variables in the model for category fluency, and digits forward and digits backward.

Initial Age Predicting Change in Levels of The Prefrontal Outcome Measures after Accounting for Change in Speed of Processing, Inhibition, Working Memory and Interference

Predictive analyses for the change measures were performed on those outcome variables for which time had a significant effect in the preliminary ANOVA analyses. Parallel regression analyses similar to those performed for initial levels on the predictor and outcome variables were performed, but this time change scores were used. Change analyses were performed for the following outcome variables: Blessed Information-Memory-Concentration Test errors, Trails A and B, category and letter fluency, and WAIS: digits backward. See Table 16 for a summary of the regression analyses with RT task 1 (speed) entered before the prefrontal predictor measures and Table 17 for the regression analyses with RT task 1 (speed) entered after the prefrontal predictor measures. Again, date of initial RT testing and the initial RT testing to initial outcome measure prediction intervals were entered as covariates after initial RT age, but before the change variables for the other predictor variables. Sex was also entered as a covariate for category fluency and digits backward.

Age at initial RT testing accounted for a significant portion of the variance in predicting future performance on Trails A Trails B and category fluency (see Table 16 and Table 17). Neither RT task 1 (speed) nor the RT prefrontal variables accounted for additional variance over and above the effect of age. This was the case whether RT task 1 (speed) was entered before or after the RT prefrontal measures. RT task 4 (inhibition) was a significant predictor of letter fluency. The amount of variance accounted for in letter fluency was the same whether it was entered before or after RT task 1 (speed).

The most interesting effect from this series of analyses involved the prediction of BIMC errors from RT task 1 (speed), commission errors for RT 4 (interference variable 2) and commission errors for RT 5 (interference variable 3). When RT task 1 (speed) was entered first into the regression equation it was not a significant predictor of BIMC errors. However, a significant amount of variance was accounted for by adding the commission errors for RT 4 (interference variable 2) measure after the RT task 1 (speed) variable. A trend ($p < .06$) was also found when the commission errors for RT 5 (interference variable 3) was entered, after entering both RT task 1 (speed) and the commission errors for RT 4 (interference variable 2). In contrast, when commission errors for RT 4 (interference variable 2) and commission errors for RT 5 (interference variable 3) were entered before RT task 1 (speed), neither was a significant predictor of BIMC errors, yet RT task 1 (speed) was a significant predictor (R-squared change = .04, $p < .05$). These results appear to indicate that both speed of processing and interference have independent effects on BIMC performance change. Again, it should be noted that the inclusion of all of the variables in the model for Trails A and digits accounted for a significant portion of the variance in digits backward.

Results Supporting The Processing Speed Theory of Cognitive Aging and the Inhibitory Deficit and Prefrontal Cortex Function Theories

Results Supporting the Processing Speed Theory of Cognitive Aging.

The only result providing support for the processing speed theory of cognitive aging of Salthouse (1996) comes from the regressions predicting change in the Blessed Information-Memory-Concentration mental status measure from change in RT task 1 (speed). RT task 1 (speed) did not account for a significant portion of the variance in Blessed Information-Memory-Concentration change scores if it was entered ahead of the RT prefrontal measures. It only accounted for a significant portion of the variance in Blessed Information-Memory-Concentration change scores when it was entered after the RT prefrontal measures. This is a curious finding and not expected based on regression analyses; thus, it only provides limited support for the theory.

Results Supporting the Inhibitory Deficit and Prefrontal Cortex Function Theories.

The majority of the support for predicting future initial prefrontal functioning and change in prefrontal functioning is based on the Inhibitory Deficit (Hasher & Zacks, 1988) and the Prefrontal Cortex Function Theories (West, 1996). Initial RT task 5 (working memory) performance accounted for a significant portion of the variance in both letter and category fluency whether it was entered before or after accounting for the effect of initial RT task 1 (speed) performance. Similar results were found for the initial commission errors for RT task 5 (interference variable 3) predicting initial performance on Trails B and digits backward. Entering in initial level for RT for task 1 (speed) did not influence the portion of variance accounted for in Trails B or digits backward. Results from the change analyses were similar to those of the initial level results. Change in RT task 4 (inhibition) accounted for a significant portion of the variance in letter fluency whether or not change in RT task 1 (speed) was entered first. These results provide support for the independent effect that inhibition, working memory and interference RT tasks have on predicting future initial performance and change in performance on the prefrontal measures of attention, attention switching, fluency, and working memory.

Initial RT task 1 (speed) performance accounted for a significant portion of the variance in both initial Trails A and digits forward performance when it was entered into the equation before the RT prefrontal measures. However, it did not account for a significant portion of the variance in either measure after accounting for the influence of the RT prefrontal measures. This indicates that the relationship between initial RT task 1 performance is mediated by the RT prefrontal measures.

Therefore, the results from the regression analyses provide greater support for the Inhibitory Deficit Theory (Hasher and Zacks, 1988) and Prefrontal Cortex Function Theories West (1996) than they do for the processing speed theory of Salthouse (1996).

Chapter 4: Discussion

This study confirmed the existence of age-related cognitive slowing among quite healthy older adults when compared to healthy younger adults. Especially among the oldest studied (62-79 years of age), slower speed of processing was accelerated by task complexity. Limited support for sex differences in speed of processing was obtained. Men were faster than women were for simple RT and one of several RT tasks that additionally involved inhibitory processing. There was minimal support for a 6-9 year age change in speed of processing across the adult age range. Longitudinal speed of processing decline only occurred for individuals over 60 years of age.

In this group of healthy individuals, the regression analyses determined that tasks involving inhibitory control, working memory and interference were most predictive of future prefrontal-mediated cognitive function. Thus, the data most strongly support the inhibitory deficit theory (Hasher & Zacks, 1988) and the prefrontal cortex function Theory (West, 1996). There was little support for the processing speed theory (Salthouse, 1996) in predicting future cognitive performance. RT measures that included inhibitory control, working memory and interference predicted future performance on Trail Making A and B, digit span backwards and letter and category fluency better than simple reaction time. Additionally, the RT measures that included prefrontal functions mediated the predictive relationship between speed of processing, and Trail Making A and digit span forward performance.

Part One: Longitudinal Rate of Change in RT and RT Errors over Six Years

This study assessed the influence of aging on RT speed, commission errors, and omission errors for five RT tasks that varied in complexity. In general, older participants were slower in RT and made more errors than younger participants. As anticipated, these differences varied as a function of the complexity of the five RT tasks. Each of the three reaction time measures is discussed separately below.

Reaction Time

As expected, participants were faster on the simple RT task and slower on the more complex RT tasks that taxed inhibitory processing and working memory. As the demand for increased inhibitory processing and working memory increased on the RT tasks, a more detrimental effect on older participants than on younger participants was observed. Specifically, differences among the age groups were non-significant for the simplest RT task that involved pressing a button each time ‘0’ randomly appeared on a view window. As the tasks introduced inhibitory processing and working memory components, it was evident that the two oldest age groups (52-61 year olds and 62-79 year olds) showed significantly greater slowing of RT than the younger age groups (20-31 year olds, 32-41 year olds and 42-51 year olds). These results are similar to the incremental increases in RT performance reported by others who investigated the influence of complexity on RT performance with age (e.g., Fozard et al., 1994; Madden, 1992; Salthouse 1992b; Shimamura et al., 1995). In those studies, age-related increases in complex RT (disjunctive and go no-go tasks) were consistently larger than age-related increases in simple RT.

The cross-sectional age difference findings outlined above correspond nicely with the findings of other cross-sectional studies (e.g., Fozard et al., 1994; Madden, 1989, 1992; Salthouse 1985; Schaie 1989, 1994; Schaie & Willis, 1993; Shimamura et al., 1995). However, an examination of change in RT over six years provided little support for short-term age-related changes in RT for all but the oldest age group (62-79 year olds). The 62-79 year old age group was the only group to exhibit a significant increase in RT from time 1 to time 2. The lack of a longitudinal age change in RT with age for all but the oldest age group is in contrast to the findings of another longitudinal study based on the same general population of participants (Fozard et al., 1994). By contrast, Fozard and colleagues found increases in both simple and disjunctive auditory RT over six years (three administrations), the same time period as used in the present study. There are several possible reasons for the discrepancies between the results of Fozard et al. (1994) and the present study. First, the tasks differed with respect to the modality used to assess RT and interstimulus interval differences. The present study employed a visual RT task, while Fozard and colleagues employed an auditory RT task. Of particular interest for future research is the question of whether the auditory modality is more vulnerable to aging effects than the visual modality.

Second, the RT task in the Fozard et al. (1994) study involved a longer delay between stimulus occurrences (J. Fozard, April, 17, 2000, personal communication), making it more of a vigilance task than the tasks used in present study. In the present study there was no interstimulus interval between target presentations for the more complex RT tasks. Third, while both involved simple and more complex RT tasks, the RT tasks for the present study were practiced approximately 24 hours before the actual test session. The exposure to the practice tasks may have helped familiarize the present participants to the tasks and possibly reduced performance anxiety as well so that they showed less deterioration.

Finally, our selection criteria were substantially more stringent than Fozard et al. (1994). Although both Fozard's study and the present investigation drew samples from the BLSA, their study included all participants who by self-report were in good to excellent health. In contrast, the present study made exclusions based on physical examinations performed by physicians, physician's assistants or nurse practitioners. Participants with visual deficits (e.g., retinal detachment, glaucoma, cataracts, macular degeneration), peripheral disabilities (multiple sclerosis, arthritis) and brain abnormalities (strokes) that might have influenced RT, as well as those with a diagnosis of dementia, were excluded. The only participants excluded from the Fozard et al. (1994) study were those who could not hear the tones presented at their loudest level. In the present investigation, we concluded that the actual physical examinations were more valid determinants of actual healthiness than the often-used self-reports. This conclusion was based upon evidence that the correlation between self-reported health and actual physical health is only .30 in the BLSA (A. Zonderman, May 9, 2000, personal communication).

The lack of a longitudinal age-speed of processing finding in the present study is also in contrast to the findings of Schaie (1989, 1994). Some of the same reasons for discrepancies between the present findings and the findings of Fozard and colleagues are applicable for the discrepancies with Schaie (1989, 1994). It should be noted that the participants in Schaie's longitudinal studies represented a broader cross-section of older adults than the present study, which drew heavily from more highly educated individuals. Additionally, speed of processing tasks employed by Schaie were perceptual speed tasks that require visual search and comparison. In contrast, even the more complex RT tasks employed in the present study that involved inhibitory processing and working memory required a yes or no decision in a limited amount of time (2 seconds).

The present study found that while there were cross-sectional age differences in response speed, actual longitudinal age changes among exceptionally healthy individuals were evident only for individuals who were 60 year of age and older at their first RT testing. It is evident that individuals who were over the age of 60 were on a significantly different age change trajectory than were individuals under the age of 60 years of age. Thus, within a very healthy group of adults, some shift in cognitive processing (possibly prefrontal cortical slowing as discussed below) occurred for individuals over the age of 60 years of age. This change is over and above the usual age-related physical and cognitive changes associated with advancing age.

Reaction time sex differences are quite inconsistent in the literature. In the present study, women were significantly slower in reaction time than men on two of the five RT tasks, the simplest RT task (RT1) and the task that required inhibition (RT4). Fozard and colleagues (1994) found that women were significantly slower on both simple and disjunctive (complex) RT tasks than were men in all the age ranges studied (20s – 90s). Both the present study and the Fozard et al. (1994) study employed simple and more complex RT tasks that involved quick yes/no decisions and responses, and found that women performed more slowly than men did on comparable tasks. In contrast, Schaie’s longitudinal research (1989, 1994) reported sex differences favoring women when employing perceptual speed tasks that involved visual search and more cognitive processing before a response was made. Finally, Madden (1992), who found no sex differences, employed a visual word discrimination-priming task to examine response speed. Therefore, whether studies find sex differences can in part be attributed to the type of task used and the cognitive requirements of the task. It is possible that women are differentially impaired on tasks that require simple response speed and inhibitory processing, but not on tasks that rely on greater explicit cognitive processing, such as working memory. This interpretation fits well with Schaie’s (1989, 1994; Schaie & Willis, 1993) finding that women outperformed men on the cognitively laden perceptual speed tasks. Most certainly future research needs to assess more closely the differential impact of aging on response speed, inhibitory processing, and working memory in men and women.

RT Commission and Omission Errors

There were few commission and omission errors for simple reaction time, regardless of age. However, errors increased with age as the RT tasks increased in complexity. When errors began to increase they increased at a faster rate for the two older age groups (52-61 year olds and 62-79 year olds) than they did for the three younger age groups (20-31 year olds, 32-41 year olds and 42-51 year olds). This clustering together of the two oldest age groups and the three youngest age groups is similar to the previously discussed RT response data. Commission errors did not become evident until the RT tasks began to increase in both inhibitory and working memory requirements. There were essentially no RT omission errors for the easiest tasks (RT tasks 1-3). Increases in commission errors occurred for RT tasks that possessed the greatest inhibition and working memory load (RT task 4 and RT 5). There was an incremental increase in omission errors beginning with RT tasks that involved a high level of inhibition (RT task 4). Additionally, there was another incremental increase in omission errors for the RT task that involved the highest level of working memory (RT task 5), especially for the two older age groups (52-61 year olds and 62-79 year olds).

Increases in RT errors corresponded to increases in response RT. This finding is consistent with those of other studies that reported corresponding increases in RT and RT errors (Fozard et al., 1994; Madden, 1992; Swearer & Kane, 1996). Swearer and Kane (1996) found that RT errors were exacerbated by increased task difficulty. Both the age and complexity findings support the conclusion that older adults did not trade accuracy (cautiousness) for speed. In the present study, it is possible that participants over the age of 60 years old were not given enough time to respond to the more complex tasks that involved inhibitory processing and working memory, and that is why omission errors increased with task complexity. Participants were only given 2 seconds to respond, and after 2 seconds, an omission error was recorded if a response was not made for the specific target. Had the older group of participants been given more time to respond they may have made fewer omission errors even on the more complex RT tasks.

In summary, support was found for cross-sectional RT age differences and longitudinal RT task differences varying in task complexity and inhibitory processing and working memory. Between subject comparisons showed that older groups of individuals may be slower than younger groups of individuals. But when the same participants were followed over time, it was strongly evident that healthy individuals became slower as they get older only after they reached their 60s.

In addition, support was found for the hypothesis that RT errors (both commission and omission) would increase with age and task complexity as measured by increased inhibitory processing and working memory. Both commission and omission errors increased as the RT tasks increased in inhibitory processing and working memory. These results are similar to those of other studies that reported increases in errors that correspond with increases in RT (Fozard et al., 1994; Madden, 1992; Swearer & Kane, 1996), exacerbated by increased task difficulty (Swearer & Kane, 1996). Therefore, these findings support the conclusion that older adults are not trading accuracy (cautiousness) for speed. However, it is not clear from the present study whether giving participants more time to respond would decrease at least some errors, namely omission errors.

Part Two: Predicting Prefrontal Outcome Measures from Speed of Processing, Inhibition, Working Memory and Interference

Cross-Sectional Differences and Longitudinal Changes in Mental Status: Comparison between Age, Sex, and Time of Testing

Two commonly used mental status measures for overall cognitive functioning level were employed as outcome variables in the present study: the Blessed Information-Memory-Concentration Test and the Mini-Mental State Examination. In the cross-sectional analysis, older participants had significantly more Blessed Information-Memory-Concentration errors than did younger participants, yet there were no age differences for the Mini-Mental State Examination. Within this group of healthy individuals, there was no observed decline in mental status on either test over six years of time in either the younger (42-61 year olds) or older (62-79 year olds) groups, nor were there any significant sex differences on them.

It is a common finding in the literature that cognitive functioning for a variety of fluid (as opposed to crystallized) abilities decreases with age (e.g., Baltes & Lindenberger, 1997; Hasher & Zacks, 1988; Lindenberger & Baltes, 1994; May et al., 1997; Schaie, 1989, 1994; Schaie & Willis, 1993; Salthouse, 1996; Verhaeghen & Salthouse, 1997; West, 1996; Zacks & Hasher, 1997). Therefore, it is at first surprising that neither of the tests designed to measure overall cognitive functioning in older adults evidenced change in six years, even in the oldest age group. However, when one considers that both measures of mental status used in the present study are typically used to assess dementia (e.g., Blessed et al., 1968; Erkinjuntti, Hokkanen, Sulkava, & Palo, 1988; Fillenbaum, Heyman, Wilkinson, & Hayner, 1987; Folstein et al., 1975; Thal, Grundman, & Golden, 1986), this finding is not as surprising. In fact, the age differences that were found on the Blessed Information-Memory-Concentration Test in such a homogenous, high cognitive functioning sample of normal individuals is testament to the Blessed Information-Memory-Concentration Test's ability to detect subtle changes in overall age-related cognitive functioning. This result extends the use of the Blessed Information-Memory-Concentration Test as more than just a diagnostic tool designed to detect cognitive deficits associated with dementia.

Cross-Sectional Differences and Longitudinal Changes in Prefrontal Tasks: Comparison between Age, Sex, and Time of Testing

The following outcome measures were chosen because the literature has shown that they engage prefrontal cortical processes: Trail Making A and B, letter and category fluency, WAIS: digits forward and digits backward and the California Verbal Learning Test (CVLT) interference measure. Whether age, sex or time of testing differences emerged was dependent upon the type of task employed. Attention and attention switching tasks (Trails A and Trails B, respectively) both demonstrated age differences. As expected based on previous research (e.g., Davies, 1968; Davies, Spelman, & Davies, 1981; Elias, Robbins, Walter, & Schultz, 1993; Reed & Reitan, 1963; Salthouse & Fristoe, 1995), older participants took longer to perform both tasks. There was also a significant time effect (longitudinal aging effects) for Trails B. This finding corresponds with expectations based on previous cross-sectional literature (Salthouse & Fristoe, 1995). Aging (time) effects are more likely on Trails B because it involves the additional component of switching attention back and forth from numbers to letters, over and above the attentional component of Trails A.

There were significant effects due to aging (time effect) for both letter and category fluency. Participants generated more words that began with specific letters and generated more words that were members of specific categories at time 1 than at time 2. Prior research is controversial with respect to cross-sectional age differences in normal samples of older individuals. Some studies find age differences on category fluency only (Kozora & Cullum, 1995) while others find age differences on letter fluency (Parkin & Lawrence, 1994), and still others find no differences related to age (Bolla, Lindgren, Bonaccorsy, & Bleeker, 1990). The age-associated change in verbal fluency found in the present study may in part be due to the longitudinal nature of the study. It is possible that age-related changes in verbal fluency are more likely to be evident when the same people are examined over time.

Age effects were evident for digits forward but not for digits backwards. Thus, as one aged shorter forward spans occurred. With respect to age differences on digit span, Gregoire and Van der Linden (1997) reported finding age differences on both digits forward and digits backwards. The present study employed the standard scoring instructions provided in the WAIS-R manual (Wechsler, 1981), while Gregoire and Van der Linden employed a variation in scoring where participants were given equal credit whether just one or both of the trials in a specified digit span length were correct. Another possible reason for discrepancies between the two studies involves differences in the way the age categories were broken down, the number of participants employed in the two studies and the way the tests were scored. The age range for participants in the Gregoire and Van der Linden (1997) study was 16–79 years old, while the age range in the present study was 32-79 years old at the time of initial RT testing, which was eight to 16 years prior to the digit span testing. Due to the reduced number of participants in specific age categories in the present study, participants were grouped into two categories: 32-51 years old versus 52-61 years old. The Gregoire and Van der Linden sample involved many more participants broken down into much smaller age categories. The difference in the way participants were categorized based on age, coupled with fewer number of participants in the present study could have contributed to the discrepancies in the results.

Women in the present study outperformed men for category fluency only. These data indicate that highly healthy-educated men and women do not demonstrate sex-related deficits in verbal fluency typically found in the more general population. Other studies reported women were better performers on letter fluency (Bolla et al., 1990) and other verbal tasks (Herlitz, Airaksinen, & Nordstrom, 1999; Maccoby & Jacklin, 1974). In addition, some studies reported sex differences on both category and letter fluency (Monsch, Bondi, Butters, Salmon, Katzman, & Thal, 1992). Still others reported minimal sex differences on both category and letter fluency tasks (Kozora & Cullum, 1995). The lack of a sex effect for letter fluency in the present study could in part be due to the high education and functioning of the participants as a whole.

In contrast to the verbal fluency findings, men had longer digit span forward and digit span backward spans than women. Sex differences in the present study could in part be attributed to the differential effects of inhibitory control for men and women. May, Hasher, and Kane (1999) implicate interference (and I would additionally include inhibition) and not working memory skills as having a major impact on memory for digit spans. They suggest that there is a build up of interference as one successively performs more trials on digit span because distracting information from previous trials increase with subsequent responding. It can also be suggested that inhibition increases with successive digit span trials because there are more prepotent responses to overcome. It is possible that women are more susceptible to the distracting effects of interference and thus have greater difficulty inhibiting previous prepotent responses. Because these effects are cumulative in memory span tasks and women are influenced more by inhibition, digit span is reduced. This interpretation is consistent with the finding from the present study that women were slower for the RT task that involved inhibitory processing.

Finally, there were no significant differences for sex, age or time of testing for the California Verbal Learning Test interference measure. Again, this result is likely the product of a high functioning sample.

Regression Analyses Assessing the Impact of Age, Before and After Accounting for Initial Speed of Processing, Inhibition, Working Memory and Interference.

Contrary to expectations based on the prior literature, age did not account for a significant portion of the variance in either the mental status measures (Mini-Mental State Examination, Blessed Information-Memory-Concentration Test) or any of the prefrontal attentional, interference, or working memory outcome measures.

The findings of the present study provide little support for a significant effect of speed of processing in predicting future age-related cognitive change. Thus, it provides very limited support for Salthouse's (1996) speed of information processing theory. Speed accounted for a significant, though small amount of the variance in predicting Trails A and WAIS: digits forward, only when it was entered into the regression equation ahead of the prefrontal outcome measures. When speed was entered in after the prefrontal outcome measures it was no longer a significant predictor of Trails A and WAIS: digits forward. This finding implies that prefrontal functioning level in predicting Trails A and WAIS: digits forward mediates speed of processing.

Salthouse and colleagues (e.g., 1992a, 1992b, 1993a, 1994a; Salthouse & Fristoe, 1995; Salthouse et al., 1998; Verhagaeghen & Salthouse, 1997) and others (Earles et al., 1997) found that speed of processing had an profound attenuating effect on performance for a variety of cognitive tasks in similar age groups. The amount of variance explained for by speed in the present study was substantially lower than that usually reported. For example, in the present study speed accounted for 11 % of the variance in Trails A performance and 13% of the variance in WAIS: digits forward performance. In contrast, in the Salthouse (1992b) study speed accounted for 39% of the variance in reasoning and 41% of the variance in analogies performance.

A contribution of this study is evidence that when one enters prefrontal outcome measures prior to speed, speed is no longer a significant predictor. Therefore, the effect that speed of processing has on cognition can be attenuated by accounting for the contribution of prefrontal functioning. In a somewhat similar study, Earles et al. (1997) found that some of the age-related variance in working memory was mediated by interference. They also found that most of the age-related variance in interference and inhibition was mediated by speed of processing. However, they did not investigate the mediating effect of speed of processing on working memory, in relation to the contribution that interference might have on working memory.

Results using the prefrontal measures to predict the mental status and attentional, interference and working memory outcome tasks were consistent whether they were entered before or after speed of processing. Working memory predicted a significant, though again small, portion of the variance for both fluency tasks (letters and categories), while the interference task for the fifth RT task predicted a significant amount of the variance in Trails B and WAIS: digits backward performance. This finding indicates that speed of processing does not have a significant mediating effect on the prediction of the prefrontal outcome measures from the prefrontal predictors. Again, these findings are different from those reported by Salthouse and colleagues (e.g., 1992a, 1992b, 1993a, 1994a; Salthouse & Fristoe, 1995; Salthouse et al., 1998; Verhagaeghen & Salthouse, 1997) and others (Earles et al., 1997).

Although the present findings do not support the Salthouse (1996) hypothesis that speed of processing mediates performance on various prefrontal measures, they do provide support for both the prefrontal cortex function theory of West (1996) and the inhibitory deficit theory of Hasher and Zacks (e.g., 1988; Hasher et al., 1999; May & Hasher, 1998). The influence of speed of processing in predicting Trails A and WAIS: digits forward performance was mediated by the prefrontal outcome measures. Therefore, it appears that for measures of attention (Trails A) and simple working memory (WAIS: digits forward), prefrontal functioning mediates the influence of speed of processing. This finding is similar to other research that found prefrontal performance is related to variability in prefrontal functions (e.g., Albert & Kaplan, 1980; Daigneault et al., 1992; Daigneault & Braun, 1993; Dempster, 1992; Earles, 1997; Hasher & Zacks, 1988; Hasher et al., 1991; West, 1996; West & Bell, 1997; Zacks & Hasher, 1994; Zacks et al., 1996). However, the fact that age was not a significant predictor of initial performance on either of the mental status or prefrontal measures makes this finding less clear. Again, the healthy sample used in the present study could partially account for the discrepancies.

Although the finding that prefrontal measures mediated the relationship between speed of processing and Trails A and WAIS: digit span performance supports prefrontal and inhibitory theories of aging, this finding does not support the previously presented hypotheses for the present study. Indeed it was expected that the effects of speed of processing would be mediated by the prefrontal measures, but this expectation was made for tasks such as Trails B and WAIS: digits backward, both of which have high attentional, interference and working memory components. It was expected that speed of processing would mediate the relationship between the mental status measures of overall cognitive functioning (Mini-Mental State Examination, Blessed Information-Memory-Concentration Test) and simple prefrontal tasks (Trails A and WAIS: digits forward). It is likely that the high functioning status of the participants in the present study contributed to the lack of findings. Research related to the involvement of intellectually changing activities as moderating the detrimental effects of aging demonstrate that keeping physically and mentally active as one ages can help ameliorate the detrimental effects of aging (Hultsch, Hertzog, Small, & Dixon, 1999). Thus, it is possible that the participants in this study do not demonstrate all of the common age-associated cognitive changes generally found when studying older individuals because they are healthy, high functioning individuals.

This study was the first known in the literature to assess how speed of processing and prefrontal measures predicted cognitive performance as much as six to 16 years into the future (depending on outcome measure used). None of the other longitudinal studies have employed the approach of predicting future cognitive change from performance on speed of processing and prefrontal-mediated tasks. While this is certainly a more rigorous test of any theory it can also be less powerful in that the number of participants included in the study is small. Unfortunately, this was the case with this study.

The more stringent screening criteria used in the present study is also a likely reason why the present study found no significant relationships between initial age and initial performance on any of the outcome variables. The participants used in this study were those who are examples of optimal aging, not necessarily normal aging. While it might be considered a limitation of this study by some, it is also a benefit. By selecting an extremely healthy sample of individuals I was able to assess the effect that speed of processing and prefrontal functioning has on the mental status and prefrontal attentional, interference, and working memory performance in the absence of significant disease. Therefore, any effects can be attributed to the variables studied and not uncontrolled physical or cognitive deficits. This is an important finding because it indicates that normal aging had no impact on the relationship between initial age and initial performance on the outcome measures.

Regression Analyses Assessing the Impact of Age, Before and After Accounting for Change in Speed of Processing, Inhibition, Working Memory and Interference.

When change scores were analyzed, age was a significant predictor of Trails A, Trails B and category fluency performance, and inhibition was a significant predictor of letter fluency performance. After entering in age for Trails A, Trails B and category fluency and inhibition for letter fluency, none of the other variables introduced to the equation were significant. Thus, none of these effects were influenced by the introduction of other variables. Therefore, for the change analyses it appears that the best predictors of future prefrontal processing were age (unmediated by speed and the prefrontal measures) and inhibition. These results are similar to those of others who found that both age and performance on prefrontal tasks relate to prefrontal functioning (e.g., Albert & Kaplan, 1980; Daigneault et al., 1992; Daigneault & Braun, 1993; Dempster, 1992; Earles, 1997; Hasher & Zacks, 1988; Hasher et al., 1991; West, 1996; West & Bell, 1997; Zacks & Hasher, 1994; Zacks et al., 1996).

An unexpected finding in the change analyses as that speed was a significant predictor of Blessed Information-Memory-Concentration Test performance after the effect of the prefrontal measures was accounted for, but not before the effect of the prefrontal measures was accounted for. In addition, the interference variable for RT task 4 and the interference variable for RT task 5 were also significant predictors of Blessed Information-Memory-Concentration Test performance, but only after the effect of speed was accounted for, not before speed was accounted for. At present there is no explanation for these results. It is possible that each was acting as a suppressor variable. “A suppressor variable is a variable that has a zero, or close to zero, correlation with the criterion but is correlated with one or more than one of the predictor variables. The inclusion of the suppressor variable in the analysis increases the partial correlation because it serves to suppress, or control for, irrelevant variance, that is, variance that is shared with the predictor and not with the criterion, thereby ridding the analysis of irrelevant variation, or noise" (Pedhauzer, 1982, p. 104). As such, it is possible that both speed and the interference variables were acting as suppressor variables. Beyond this, no explanation can be provided, but it is certainly worthy of further investigation.

Limitations of the Study and Future Directions

The stringent physical selection criteria used for this study that is repeatedly referenced as a benefit can also be referenced as a limitation. Although the exclusion of participants with physical limitations that might influence RT had the effect of producing a very healthy sample of individuals, it may have also decreased the generalizability of the findings. It is important to know how individuals age in the absence of disease, but unfortunately disease is a reality for many as they age. Therefore, a follow-up study will include participants with physical limitations who were excluded from this study to determine what effect physical limitations have on speed and prefrontal functioning. A future investigation will also examine the effect of other age-associated health limitations (e.g., hypertension, heart disease and diabetes), in addition to various stress indicator variables found in blood (e.g., cortical) on speed and prefrontal functioning.

A strength of the present study is the robustness of the findings based on a relatively small sample size used for the predictive analyses, due to the selection criteria employed. Restrictions based on physical functioning and cognitive status provided a clean but small, sample that in part resulted in the modest amounts of variance accounted for in the regression analyses, even for the significant effects. By including physical limitations into the regression model as a predictor in the next study, we will be able to increase the number of participants available for study as well as partition the variance along physical limitations.

Finally, the predictive nature of this study can be seen as a benefit, but it can also be seen as a limitation. As stated above a predictive study is a "true" test of the theory, but one also needs very robust results to find an effect. This was a predictive study where RT performance was used to predict future cognitive performance as much as 16 years into the future. Because this study was predictive there were fewer numbers of participants available for study. Therefore the study may have been less powerful because the number of participants included in the study was small. Another contributing factor was the wide time span for the predictive interval. The wide predictive interval possibly contributed to the lack of findings. A future study will adjust the predictive interval between the predictor variables and outcome measures to determine the optimal predictive interval.

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Appendix A

Reaction Time Post-Hoc Contrasts with Bonferroni Correction for Multiple Contrasts (Adj p)

Age	**Sex**	**RT**	**Visit**	**Age**	**Sex**	**RT**	**Visit**	**Estimate**	**SE**	**t**	**p**	**Adj p**
20-31				32-41				-14.0	6.8	-2.1	0.0398	0.3984
20-31				42-51				-21.6	7.5	-2.9	0.0039	0.0392
20-31				52-61				-47.5	7.1	-6.7	<.0001	<.0001
20-31				62-79				-65.3	7.2	-9.1	<.0001	<.0001
32-41				42-51				-7.5	6.8	-1.1	0.2678	1
32-41				52-61				-33.5	6.4	-5.2	<.0001	<.0001
32-41				62-79				-51.3	6.5	-7.9	<.0001	<.0001
42-51				52-61				-25.9	7.1	-3.7	0.0003	0.0026
42-51				62-79				-43.7	7.1	-6.1	<.0001	<.0001
52-61				62-79				-17.8	6.8	-2.6	0.0085	0.0846
	Men				Wmn			-21.5	4.4	-4.9	<.0001	<.0001
		1				2		-95.7	2.6	-36.7	<.0001	<.0001
		1				3		-167.5	2.6	-64.2	<.0001	<.0001
		1				4		-210.0	2.6	-80.5	<.0001	<.0001
		1				5		-332.1	2.6	-127.2	<.0001	<.0001
		2				3		-71.8	2.6	-27.5	<.0001	<.0001
		2				4		-114.3	2.6	-43.8	<.0001	<.0001
		2				5		-236.4	2.6	-90.6	<.0001	<.0001
		3				4		-42.5	2.6	-16.3	<.0001	<.0001
		3				5		-164.6	2.6	-63.1	<.0001	<.0001
		4				5		-122.1	2.6	-46.8	<.0001	<.0001
			1				2	-3.8	1.9	-2.0	0.0483	0.0483
20-31		1		20-31		2		-95.1	6.2	-15.4	<.0001	<.0001
20-31		1		20-31		3		-163.6	6.2	-26.4	<.0001	<.0001
20-31		1		20-31		4		-190.4	6.2	-30.7	<.0001	<.0001
20-31		1		20-31		5		-320.4	6.2	-51.7	<.0001	<.0001
20-31		1		32-41		1		-11.4	8.5	-1.4	0.1774	1
20-31		1		32-41		2		-107.1	8.5	-12.6	<.0001	<.0001
20-31		1		32-41		3		-175.9	8.5	-20.7	<.0001	<.0001
20-31		1		32-41		4		-210.9	8.5	-24.9	<.0001	<.0001
20-31		1		32-41		5		-334.3	8.5	-39.4	<.0001	<.0001
20-31		1		42-51		1		-20.8	9.3	-2.2	0.0249	1
20-31		1		42-51		2		-116.5	9.3	-12.6	<.0001	<.0001
20-31		1		42-51		3		-184.5	9.3	-19.9	<.0001	<.0001
20-31		1		42-51		4		-222.5	9.3	-24.0	<.0001	<.0001
20-31		1		42-51		5		-333.1	9.3	-35.9	<.0001	<.0001
20-31		1		52-61		1		-33.0	8.8	-3.7	0.0002	0.0555
20-31		1		52-61		2		-130.8	8.8	-14.8	<.0001	<.0001
20-31		1		52-61		3		-208.7	8.8	-23.6	<.0001	<.0001
20-31		1		52-61		4		-256.1	8.8	-29.0	<.0001	<.0001
20-31		1		52-61		5		-378.3	8.8	-42.8	<.0001	<.0001
20-31		1		62-79		1		-47.4	8.9	-5.3	<.0001	<.0001
20-31		1		62-79		2		-141.5	8.9	-15.8	<.0001	<.0001
20-31		1		62-79		3		-217.4	8.9	-24.3	<.0001	<.0001
20-31		1		62-79		4		-282.8	8.9	-31.6	<.0001	<.0001
20-31		1		62-79		5		-407.0	8.9	-45.5	<.0001	<.0001
20-31		2		20-31		3		-68.5	6.2	-11.1	<.0001	<.0001
20-31		2		20-31		4		-95.3	6.2	-15.4	<.0001	<.0001
20-31		2		20-31		5		-225.3	6.2	-36.4	<.0001	<.0001
20-31		2		32-41		1		83.7	8.5	9.9	<.0001	<.0001
20-31		2		32-41		2		-12.0	8.5	-1.4	0.1582	1
20-31		2		32-41		3		-80.8	8.5	-9.5	<.0001	<.0001
20-31		2		32-41		4		-115.8	8.5	-13.6	<.0001	<.0001
20-31		2		32-41		5		-239.2	8.5	-28.2	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31		2		42-51		1		74.3	9.3	8.0	<.0001	<.0001
20-31		2		42-51		2		-21.4	9.3	-2.3	0.021	1
20-31		2		42-51		3		-89.4	9.3	-9.6	<.0001	<.0001
20-31		2		42-51		4		-127.4	9.3	-13.7	<.0001	<.0001
20-31		2		42-51		5		-238.0	9.3	-25.7	<.0001	<.0001
20-31		2		52-61		1		62.1	8.8	7.0	<.0001	<.0001
20-31		2		52-61		2		-35.7	8.8	-4.1	<.0001	0.0158
20-31		2		52-61		3		-113.6	8.8	-12.9	<.0001	<.0001
20-31		2		52-61		4		-161.0	8.8	-18.2	<.0001	<.0001
20-31		2		52-61		5		-283.2	8.8	-32.1	<.0001	<.0001
20-31		2		62-79		1		47.7	8.9	5.3	<.0001	<.0001
20-31		2		62-79		2		-46.4	8.9	-5.2	<.0001	<.0001
20-31		2		62-79		3		-122.3	8.9	-13.7	<.0001	<.0001
20-31		2		62-79		4		-187.7	8.9	-21.0	<.0001	<.0001
20-31		2		62-79		5		-311.9	8.9	-34.9	<.0001	<.0001
20-31		3		20-31		4		-26.9	6.2	-4.3	<.0001	0.0045
20-31		3		20-31		5		-156.8	6.2	-25.3	<.0001	<.0001
20-31		3		32-41		1		152.1	8.5	17.9	<.0001	<.0001
20-31		3		32-41		2		56.5	8.5	6.7	<.0001	<.0001
20-31		3		32-41		3		-12.3	8.5	-1.5	0.1455	1
20-31		3		32-41		4		-47.3	8.5	-5.6	<.0001	<.0001
20-31		3		32-41		5		-170.8	8.5	-20.1	<.0001	<.0001
20-31		3		42-51		1		142.8	9.3	15.4	<.0001	<.0001
20-31		3		42-51		2		47.1	9.3	5.1	<.0001	0.0001
20-31		3		42-51		3		-20.9	9.3	-2.3	0.0242	1
20-31		3		42-51		4		-58.9	9.3	-6.4	<.0001	<.0001
20-31		3		42-51		5		-169.6	9.3	-18.3	<.0001	<.0001
20-31		3		52-61		1		130.6	8.8	14.8	<.0001	<.0001
20-31		3		52-61		2		32.7	8.8	3.7	0.0002	0.064
20-31		3		52-61		3		-45.1	8.8	-5.1	<.0001	<.0001
20-31		3		52-61		4		-92.5	8.8	-10.5	<.0001	<.0001
20-31		3		52-61		5		-214.8	8.8	-24.3	<.0001	<.0001
20-31		3		62-79		1		116.2	8.9	13.0	<.0001	<.0001
20-31		3		62-79		2		22.1	8.9	2.5	0.0135	1
20-31		3		62-79		3		-53.9	8.9	-6.0	<.0001	<.0001
20-31		3		62-79		4		-119.2	8.9	-13.3	<.0001	<.0001
20-31		3		62-79		5		-243.5	8.9	-27.2	<.0001	<.0001
20-31		4		20-31		5		-130.0	6.2	-21.0	<.0001	<.0001
20-31		4		32-41		1		179.0	8.5	21.1	<.0001	<.0001
20-31		4		32-41		2		83.3	8.5	9.8	<.0001	<.0001
20-31		4		32-41		3		14.5	8.5	1.7	0.0874	1
20-31		4		32-41		4		-20.5	8.5	-2.4	0.0158	1
20-31		4		32-41		5		-143.9	8.5	-17.0	<.0001	<.0001
20-31		4		42-51		1		169.6	9.3	18.3	<.0001	<.0001
20-31		4		42-51		2		73.9	9.3	8.0	<.0001	<.0001
20-31		4		42-51		3		6.0	9.3	0.6	0.5205	1
20-31		4		42-51		4		-32.1	9.3	-3.5	0.0005	0.1621
20-31		4		42-51		5		-142.7	9.3	-15.4	<.0001	<.0001
20-31		4		52-61		1		157.4	8.8	17.8	<.0001	<.0001
20-31		4		52-61		2		59.6	8.8	6.8	<.0001	<.0001
20-31		4		52-61		3		-18.3	8.8	-2.1	0.0387	1
20-31		4		52-61		4		-65.7	8.8	-7.4	<.0001	<.0001
20-31		4		52-61		5		-187.9	8.8	-21.3	<.0001	<.0001
20-31		4		62-79		1		143.1	8.9	16.0	<.0001	<.0001
20-31		4		62-79		2		49.0	8.9	5.5	<.0001	<.0001
20-31		4		62-79		3		-27.0	8.9	-3.0	0.0026	0.7669
20-31		4		62-79		4		-92.3	8.9	-10.3	<.0001	<.0001
20-31		4		62-79		5		-216.6	8.9	-24.2	<.0001	<.0001
20-31		5		32-41		1		309.0	8.5	36.4	<.0001	<.0001
20-31		5		32-41		2		213.3	8.5	25.1	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31		5		32-41		3		144.5	8.5	17.0	<.0001	<.0001
20-31		5		32-41		4		109.5	8.5	12.9	<.0001	<.0001
20-31		5		32-41		5		-13.9	8.5	-1.6	0.1002	1
20-31		5		42-51		1		299.6	9.3	32.3	<.0001	<.0001
20-31		5		42-51		2		203.9	9.3	22.0	<.0001	<.0001
20-31		5		42-51		3		135.9	9.3	14.7	<.0001	<.0001
20-31		5		42-51		4		97.9	9.3	10.6	<.0001	<.0001
20-31		5		42-51		5		-12.7	9.3	-1.4	0.1691	1
20-31		5		52-61		1		287.4	8.8	32.5	<.0001	<.0001
20-31		5		52-61		2		189.6	8.8	21.5	<.0001	<.0001
20-31		5		52-61		3		111.7	8.8	12.6	<.0001	<.0001
20-31		5		52-61		4		64.3	8.8	7.3	<.0001	<.0001
20-31		5		52-61		5		-57.9	8.8	-6.6	<.0001	<.0001
20-31		5		62-79		1		273.0	8.9	30.5	<.0001	<.0001
20-31		5		62-79		2		178.9	8.9	20.0	<.0001	<.0001
20-31		5		62-79		3		103.0	8.9	11.5	<.0001	<.0001
20-31		5		62-79		4		37.6	8.9	4.2	<.0001	0.008
20-31		5		62-79		5		-86.6	8.9	-9.7	<.0001	<.0001
32-41		1		32-41		2		-95.7	5.0	-19.1	<.0001	<.0001
32-41		1		32-41		3		-164.5	5.0	-32.8	<.0001	<.0001
32-41		1		32-41		4		-199.5	5.0	-39.8	<.0001	<.0001
32-41		1		32-41		5		-322.9	5.0	-64.4	<.0001	<.0001
32-41		1		42-51		1		-9.4	8.4	-1.1	0.2664	1
32-41		1		42-51		2		-105.1	8.4	-12.5	<.0001	<.0001
32-41		1		42-51		3		-173.0	8.4	-20.5	<.0001	<.0001
32-41		1		42-51		4		-211.1	8.4	-25.0	<.0001	<.0001
32-41		1		42-51		5		-321.7	8.4	-38.1	<.0001	<.0001
32-41		1		52-61		1		-21.6	7.9	-2.7	0.0065	1
32-41		1		52-61		2		-119.4	8.0	-15.0	<.0001	<.0001
32-41		1		52-61		3		-197.3	8.0	-24.8	<.0001	<.0001
32-41		1		52-61		4		-244.7	8.0	-30.8	<.0001	<.0001
32-41		1		52-61		5		-366.9	8.0	-46.2	<.0001	<.0001
32-41		1		62-79		1		-35.9	8.0	-4.5	<.0001	0.0024
32-41		1		62-79		2		-130.0	8.1	-16.1	<.0001	<.0001
32-41		1		62-79		3		-206.0	8.1	-25.5	<.0001	<.0001
32-41		1		62-79		4		-271.3	8.1	-33.6	<.0001	<.0001
32-41		1		62-79		5		-395.6	8.1	-49.0	<.0001	<.0001
32-41		2		32-41		3		-68.8	5.0	-13.7	<.0001	<.0001
32-41		2		32-41		4		-103.8	5.0	-20.7	<.0001	<.0001
32-41		2		32-41		5		-227.2	5.0	-45.3	<.0001	<.0001
32-41		2		42-51		1		86.3	8.4	10.2	<.0001	<.0001
32-41		2		42-51		2		-9.4	8.4	-1.1	0.2626	1
32-41		2		42-51		3		-77.4	8.4	-9.2	<.0001	<.0001
32-41		2		42-51		4		-115.4	8.4	-13.7	<.0001	<.0001
32-41		2		42-51		5		-226.0	8.4	-26.8	<.0001	<.0001
32-41		2		52-61		1		74.1	8.0	9.3	<.0001	<.0001
32-41		2		52-61		2		-23.7	7.9	-3.0	0.0027	0.8233
32-41		2		52-61		3		-101.6	8.0	-12.8	<.0001	<.0001
32-41		2		52-61		4		-149.0	8.0	-18.7	<.0001	<.0001
32-41		2		52-61		5		-271.2	8.0	-34.1	<.0001	<.0001
32-41		2		62-79		1		59.7	8.1	7.4	<.0001	<.0001
32-41		2		62-79		2		-34.4	8.0	-4.3	<.0001	0.0058
32-41		2		62-79		3		-110.3	8.1	-13.7	<.0001	<.0001
32-41		2		62-79		4		-175.7	8.1	-21.8	<.0001	<.0001
32-41		2		62-79		5		-299.9	8.1	-37.2	<.0001	<.0001
32-41		3		32-41		4		-35.0	5.0	-7.0	<.0001	<.0001
32-41		3		32-41		5		-158.4	5.0	-31.6	<.0001	<.0001
32-41		3		42-51		1		155.1	8.4	18.4	<.0001	<.0001
32-41		3		42-51		2		59.4	8.4	7.0	<.0001	<.0001
32-41		3		42-51		3		-8.6	8.4	-1.0	0.3096	1

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
32-41		3		42-51		4		-46.6	8.4	-5.5	<.0001	<.0001
32-41		3		42-51		5		-157.2	8.4	-18.6	<.0001	<.0001
32-41		3		52-61		1		142.9	8.0	18.0	<.0001	<.0001
32-41		3		52-61		2		45.1	8.0	5.7	<.0001	<.0001
32-41		3		52-61		3		-32.8	7.9	-4.1	<.0001	0.0108
32-41		3		52-61		4		-80.2	8.0	-10.1	<.0001	<.0001
32-41		3		52-61		5		-202.4	8.0	-25.5	<.0001	<.0001
32-41		3		62-79		1		128.6	8.1	15.9	<.0001	<.0001
32-41		3		62-79		2		34.4	8.1	4.3	<.0001	0.006
32-41		3		62-79		3		-41.5	8.0	-5.2	<.0001	<.0001
32-41		3		62-79		4		-106.9	8.1	-13.2	<.0001	<.0001
32-41		3		62-79		5		-231.1	8.1	-28.6	<.0001	<.0001
32-41		4		32-41		5		-123.4	5.0	-24.6	<.0001	<.0001
32-41		4		42-51		1		190.1	8.4	22.5	<.0001	<.0001
32-41		4		42-51		2		94.4	8.4	11.2	<.0001	<.0001
32-41		4		42-51		3		26.4	8.4	3.1	0.0017	0.5222
32-41		4		42-51		4		-11.6	8.4	-1.4	0.1679	1
32-41		4		42-51		5		-122.2	8.4	-14.5	<.0001	<.0001
32-41		4		52-61		1		177.9	8.0	22.4	<.0001	<.0001
32-41		4		52-61		2		80.1	8.0	10.1	<.0001	<.0001
32-41		4		52-61		3		2.2	8.0	0.3	0.7809	1
32-41		4		52-61		4		-45.2	7.9	-5.7	<.0001	<.0001
32-41		4		52-61		5		-167.4	8.0	-21.1	<.0001	<.0001
32-41		4		62-79		1		163.5	8.1	20.3	<.0001	<.0001
32-41		4		62-79		2		69.4	8.1	8.6	<.0001	<.0001
32-41		4		62-79		3		-6.5	8.1	-0.8	0.4197	1
32-41		4		62-79		4		-71.9	8.0	-8.9	<.0001	<.0001
32-41		4		62-79		5		-196.1	8.1	-24.3	<.0001	<.0001
32-41		5		42-51		1		313.5	8.4	37.2	<.0001	<.0001
32-41		5		42-51		2		217.8	8.4	25.8	<.0001	<.0001
32-41		5		42-51		3		149.9	8.4	17.8	<.0001	<.0001
32-41		5		42-51		4		111.8	8.4	13.3	<.0001	<.0001
32-41		5		42-51		5		1.2	8.4	0.1	0.8865	1
32-41		5		52-61		1		301.3	8.0	37.9	<.0001	<.0001
32-41		5		52-61		2		203.5	8.0	25.6	<.0001	<.0001
32-41		5		52-61		3		125.6	8.0	15.8	<.0001	<.0001
32-41		5		52-61		4		78.2	8.0	9.8	<.0001	<.0001
32-41		5		52-61		5		-44.0	7.9	-5.6	<.0001	<.0001
32-41		5		62-79		1		287.0	8.1	35.6	<.0001	<.0001
32-41		5		62-79		2		192.9	8.1	23.9	<.0001	<.0001
32-41		5		62-79		3		116.9	8.1	14.5	<.0001	<.0001
32-41		5		62-79		4		51.6	8.1	6.4	<.0001	<.0001
32-41		5		62-79		5		-72.7	8.0	-9.0	<.0001	<.0001
42-51		1		42-51		2		-95.7	6.1	-15.8	<.0001	<.0001
42-51		1		42-51		3		-163.7	6.1	-27.0	<.0001	<.0001
42-51		1		42-51		4		-201.7	6.1	-33.3	<.0001	<.0001
42-51		1		42-51		5		-312.3	6.1	-51.5	<.0001	<.0001
42-51		1		52-61		1		-12.2	8.7	-1.4	0.1615	1
42-51		1		52-61		2		-110.0	8.8	-12.6	<.0001	<.0001
42-51		1		52-61		3		-187.9	8.8	-21.4	<.0001	<.0001
42-51		1		52-61		4		-235.3	8.8	-26.8	<.0001	<.0001
42-51		1		52-61		5		-357.5	8.8	-40.8	<.0001	<.0001
42-51		1		62-79		1		-26.6	8.8	-3.0	0.0027	0.7951
42-51		1		62-79		2		-120.7	8.9	-13.6	<.0001	<.0001
42-51		1		62-79		3		-196.6	8.9	-22.1	<.0001	<.0001
42-51		1		62-79		4		-262.0	8.9	-29.5	<.0001	<.0001
42-51		1		62-79		5		-386.2	8.9	-43.5	<.0001	<.0001
42-51		2		42-51		3		-68.0	6.1	-11.2	<.0001	<.0001
42-51		2		42-51		4		-106.0	6.1	-17.5	<.0001	<.0001
42-51		2		42-51		5		-216.6	6.1	-35.7	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
42-51		2		52-61		1		83.5	8.8	9.5	<.0001	<.0001
42-51		2		52-61		2		-14.3	8.7	-1.6	0.1012	1
42-51		2		52-61		3		-92.2	8.8	-10.5	<.0001	<.0001
42-51		2		52-61		4		-139.6	8.8	-15.9	<.0001	<.0001
42-51		2		52-61		5		-261.8	8.8	-29.9	<.0001	<.0001
42-51		2		62-79		1		69.1	8.9	7.8	<.0001	<.0001
42-51		2		62-79		2		-25.0	8.8	-2.8	0.0048	1
42-51		2		62-79		3		-100.9	8.9	-11.4	<.0001	<.0001
42-51		2		62-79		4		-166.3	8.9	-18.7	<.0001	<.0001
42-51		2		62-79		5		-290.5	8.9	-32.7	<.0001	<.0001
42-51		3		42-51		4		-38.0	6.1	-6.3	<.0001	<.0001
42-51		3		42-51		5		-148.7	6.1	-24.5	<.0001	<.0001
42-51		3		52-61		1		151.5	8.8	17.3	<.0001	<.0001
42-51		3		52-61		2		53.6	8.8	6.1	<.0001	<.0001
42-51		3		52-61		3		-24.2	8.7	-2.8	0.0055	1
42-51		3		52-61		4		-71.6	8.8	-8.2	<.0001	<.0001
42-51		3		52-61		5		-193.9	8.8	-22.1	<.0001	<.0001
42-51		3		62-79		1		137.1	8.9	15.4	<.0001	<.0001
42-51		3		62-79		2		43.0	8.9	4.8	<.0001	0.0004
42-51		3		62-79		3		-33.0	8.8	-3.7	0.0002	0.0587
42-51		3		62-79		4		-98.3	8.9	-11.1	<.0001	<.0001
42-51		3		62-79		5		-222.6	8.9	-25.1	<.0001	<.0001
42-51		4		42-51		5		-110.6	6.1	-18.3	<.0001	<.0001
42-51		4		52-61		1		189.5	8.8	21.6	<.0001	<.0001
42-51		4		52-61		2		91.7	8.8	10.5	<.0001	<.0001
42-51		4		52-61		3		13.8	8.8	1.6	0.1152	1
42-51		4		52-61		4		-33.6	8.7	-3.8	0.0001	0.0368
42-51		4		52-61		5		-155.8	8.8	-17.8	<.0001	<.0001
42-51		4		62-79		1		175.1	8.9	19.7	<.0001	<.0001
42-51		4		62-79		2		81.0	8.9	9.1	<.0001	<.0001
42-51		4		62-79		3		5.1	8.9	0.6	0.5663	1
42-51		4		62-79		4		-60.3	8.8	-6.8	<.0001	<.0001
42-51		4		62-79		5		-184.5	8.9	-20.8	<.0001	<.0001
42-51		5		52-61		1		300.1	8.8	34.2	<.0001	<.0001
42-51		5		52-61		2		202.3	8.8	23.1	<.0001	<.0001
42-51		5		52-61		3		124.4	8.8	14.2	<.0001	<.0001
42-51		5		52-61		4		77.0	8.8	8.8	<.0001	<.0001
42-51		5		52-61		5		-45.2	8.7	-5.2	<.0001	<.0001
42-51		5		62-79		1		285.8	8.9	32.2	<.0001	<.0001
42-51		5		62-79		2		191.7	8.9	21.6	<.0001	<.0001
42-51		5		62-79		3		115.7	8.9	13.0	<.0001	<.0001
42-51		5		62-79		4		50.4	8.9	5.7	<.0001	<.0001
42-51		5		62-79		5		-73.9	8.8	-8.4	<.0001	<.0001
52-61		1		52-61		2		-97.8	5.4	-18.0	<.0001	<.0001
52-61		1		52-61		3		-175.7	5.4	-32.3	<.0001	<.0001
52-61		1		52-61		4		-223.1	5.4	-41.0	<.0001	<.0001
52-61		1		52-61		5		-345.3	5.4	-63.5	<.0001	<.0001
52-61		1		62-79		1		-14.4	8.4	-1.7	0.0863	1
52-61		1		62-79		2		-108.5	8.4	-12.9	<.0001	<.0001
52-61		1		62-79		3		-184.4	8.4	-21.9	<.0001	<.0001
52-61		1		62-79		4		-249.8	8.4	-29.7	<.0001	<.0001
52-61		1		62-79		5		-374.0	8.4	-44.5	<.0001	<.0001
52-61		2		52-61		3		-77.9	5.4	-14.3	<.0001	<.0001
52-61		2		52-61		4		-125.3	5.4	-23.0	<.0001	<.0001
52-61		2		52-61		5		-247.5	5.4	-45.5	<.0001	<.0001
52-61		2		62-79		1		83.5	8.4	9.9	<.0001	<.0001
52-61		2		62-79		2		-10.6	8.4	-1.3	0.2034	1
52-61		2		62-79		3		-86.6	8.4	-10.3	<.0001	<.0001
52-61		2		62-79		4		-151.9	8.4	-18.1	<.0001	<.0001
52-61		2		62-79		5		-276.2	8.4	-32.8	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
52-61		3		52-61		4		-47.4	5.4	-8.7	<.0001	<.0001
52-61		3		52-61		5		-169.6	5.4	-31.2	<.0001	<.0001
52-61		3		62-79		1		161.3	8.4	19.2	<.0001	<.0001
52-61		3		62-79		2		67.2	8.4	8.0	<.0001	<.0001
52-61		3		62-79		3		-8.7	8.4	-1.0	0.2973	1
52-61		3		62-79		4		-74.1	8.4	-8.8	<.0001	<.0001
52-61		3		62-79		5		-198.3	8.4	-23.6	<.0001	<.0001
52-61		4		52-61		5		-122.2	5.4	-22.5	<.0001	<.0001
52-61		4		62-79		1		208.7	8.4	24.8	<.0001	<.0001
52-61		4		62-79		2		114.6	8.4	13.6	<.0001	<.0001
52-61		4		62-79		3		38.7	8.4	4.6	<.0001	0.0013
52-61		4		62-79		4		-26.7	8.4	-3.2	0.0014	0.4309
52-61		4		62-79		5		-150.9	8.4	-17.9	<.0001	<.0001
52-61		5		62-79		1		331.0	8.4	39.3	<.0001	<.0001
52-61		5		62-79		2		236.9	8.4	28.2	<.0001	<.0001
52-61		5		62-79		3		160.9	8.4	19.1	<.0001	<.0001
52-61		5		62-79		4		95.6	8.4	11.4	<.0001	<.0001
52-61		5		62-79		5		-28.7	8.4	-3.4	0.0006	0.1834
62-79		1		62-79		2		-94.1	5.7	-16.5	<.0001	<.0001
62-79		1		62-79		3		-170.1	5.7	-29.8	<.0001	<.0001
62-79		1		62-79		4		-235.4	5.7	-41.2	<.0001	<.0001
62-79		1		62-79		5		-359.7	5.7	-63.0	<.0001	<.0001
62-79		2		62-79		3		-75.9	5.7	-13.3	<.0001	<.0001
62-79		2		62-79		4		-141.3	5.7	-24.8	<.0001	<.0001
62-79		2		62-79		5		-265.6	5.7	-46.5	<.0001	<.0001
62-79		3		62-79		4		-65.3	5.7	-11.5	<.0001	<.0001
62-79		3		62-79		5		-189.6	5.7	-33.2	<.0001	<.0001
62-79		4		62-79		5		-124.3	5.7	-21.8	<.0001	<.0001
20-31			1	20-31			2	-2.5	5.0	-0.5	0.613	1
20-31			1	32-41			1	-16.8	6.8	-2.5	0.013	0.5838
20-31			1	32-41			2	-13.8	7.2	-1.9	0.0574	1
20-31			1	42-51			1	-22.9	7.5	-3.1	0.0022	0.0983
20-31			1	42-51			2	-22.8	8.0	-2.9	0.0043	0.1921
20-31			1	52-61			1	-47.0	7.2	-6.6	<.0001	<.0001
20-31			1	52-61			2	-50.5	7.5	-6.8	<.0001	<.0001
20-31			1	62-79			1	-58.4	7.1	-8.3	<.0001	<.0001
20-31			1	62-79			2	-74.7	7.8	-9.5	<.0001	<.0001
20-31			2	32-41			1	-14.3	7.8	-1.8	0.0658	1
20-31			2	32-41			2	-11.2	8.2	-1.4	0.1699	1
20-31			2	42-51			1	-20.4	8.4	-2.4	0.0151	0.68
20-31			2	42-51			2	-20.2	8.8	-2.3	0.022	0.9879
20-31			2	52-61			1	-44.5	8.1	-5.5	<.0001	<.0001
20-31			2	52-61			2	-47.9	8.4	-5.7	<.0001	<.0001
20-31			2	62-79			1	-55.9	8.0	-7.0	<.0001	<.0001
20-31			2	62-79			2	-72.2	8.7	-8.3	<.0001	<.0001
32-41			1	32-41			2	3.1	3.8	0.8	0.4158	1
32-41			1	42-51			1	-6.1	6.9	-0.9	0.3759	1
32-41			1	42-51			2	-5.9	7.4	-0.8	0.4241	1
32-41			1	52-61			1	-30.2	6.5	-4.6	<.0001	0.0002
32-41			1	52-61			2	-33.6	6.9	-4.9	<.0001	<.0001
32-41			1	62-79			1	-41.6	6.4	-6.5	<.0001	<.0001
32-41			1	62-79			2	-57.9	7.3	-8.0	<.0001	<.0001
32-41			2	42-51			1	-9.2	7.4	-1.2	0.2133	1
32-41			2	42-51			2	-9.0	7.8	-1.1	0.2524	1
32-41			2	52-61			1	-33.3	7.0	-4.7	<.0001	0.0001
32-41			2	52-61			2	-36.7	7.3	-5.0	<.0001	<.0001
32-41			2	62-79			1	-44.7	6.9	-6.4	<.0001	<.0001
32-41			2	62-79			2	-61.0	7.7	-7.9	<.0001	<.0001
42-51			1	42-51			2	0.2	4.3	0.0	0.9663	1
42-51			1	52-61			1	-24.1	7.2	-3.3	0.0009	0.04

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
42-51			1	52-61			2	-27.5	7.6	-3.6	0.0003	0.0124
42-51			1	62-79			1	-35.5	7.2	-5.0	<.0001	<.0001
42-51			1	62-79			2	-51.8	7.9	-6.5	<.0001	<.0001
42-51			2	52-61			1	-24.3	7.7	-3.1	0.0017	0.0769
42-51			2	52-61			2	-27.7	8.0	-3.5	0.0006	0.0255
42-51			2	62-79			1	-35.7	7.7	-4.7	<.0001	0.0002
42-51			2	62-79			2	-52.0	8.4	-6.2	<.0001	<.0001
52-61			1	52-61			2	-3.4	3.8	-0.9	0.364	1
52-61			1	62-79			1	-11.4	6.8	-1.7	0.0947	1
52-61			1	62-79			2	-27.7	7.6	-3.6	0.0003	0.0123
52-61			2	62-79			1	-8.0	7.1	-1.1	0.266	1
52-61			2	62-79			2	-24.3	7.9	-3.1	0.0022	0.0973
62-79			1	62-79			2	-16.3	4.5	-3.6	0.0003	0.0139
	Men	1			Men	2		-103.3	3.2	-32.3	<.0001	<.0001
	Men	1			Men	3		-176.1	3.2	-55.1	<.0001	<.0001
	Men	1			Men	4		-210.2	3.2	-65.8	<.0001	<.0001
	Men	1			Men	5		-342.5	3.2	-107.2	<.0001	<.0001
	Men	1			Wmn	1		-32.2	5.5	-5.9	<.0001	<.0001
	Men	1			Wmn	2		-120.2	5.5	-21.9	<.0001	<.0001
	Men	1			Wmn	3		-191.0	5.5	-34.8	<.0001	<.0001
	Men	1			Wmn	4		-242.1	5.5	-44.1	<.0001	<.0001
	Men	1			Wmn	5		-353.9	5.5	-64.5	<.0001	<.0001
	Men	2			Men	3		-72.8	3.2	-22.8	<.0001	<.0001
	Men	2			Men	4		-106.8	3.2	-33.4	<.0001	<.0001
	Men	2			Men	5		-239.2	3.2	-74.8	<.0001	<.0001
	Men	2			Wmn	1		71.2	5.5	13.0	<.0001	<.0001
	Men	2			Wmn	2		-16.9	5.5	-3.1	0.0021	0.0927
	Men	2			Wmn	3		-87.7	5.5	-16.0	<.0001	<.0001
	Men	2			Wmn	4		-138.7	5.5	-25.3	<.0001	<.0001
	Men	2			Wmn	5		-250.6	5.5	-45.7	<.0001	<.0001
	Men	3			Men	4		-34.0	3.2	-10.7	<.0001	<.0001
	Men	3			Men	5		-166.4	3.2	-52.1	<.0001	<.0001
	Men	3			Wmn	1		144.0	5.5	26.2	<.0001	<.0001
	Men	3			Wmn	2		55.9	5.5	10.2	<.0001	<.0001
	Men	3			Wmn	3		-14.9	5.5	-2.7	0.0065	0.2911
	Men	3			Wmn	4		-65.9	5.5	-12.0	<.0001	<.0001
	Men	3			Wmn	5		-177.8	5.5	-32.4	<.0001	<.0001
	Men	4			Men	5		-132.3	3.2	-41.4	<.0001	<.0001
	Men	4			Wmn	1		178.0	5.5	32.4	<.0001	<.0001
	Men	4			Wmn	2		89.9	5.5	16.4	<.0001	<.0001
	Men	4			Wmn	3		19.1	5.5	3.5	0.0005	0.0226
	Men	4			Wmn	4		-31.9	5.5	-5.8	<.0001	<.0001
	Men	4			Wmn	5		-143.8	5.5	-26.2	<.0001	<.0001
	Men	5			Wmn	1		310.3	5.5	56.6	<.0001	<.0001
	Men	5			Wmn	2		222.3	5.5	40.5	<.0001	<.0001
	Men	5			Wmn	3		151.4	5.5	27.6	<.0001	<.0001
	Men	5			Wmn	4		100.4	5.5	18.3	<.0001	<.0001
	Men	5			Wmn	5		-11.5	5.5	-2.1	0.0364	1
	Wmn	1			Wmn	2		-88.1	4.1	-21.4	<.0001	<.0001
	Wmn	1			Wmn	3		-158.9	4.1	-38.7	<.0001	<.0001
	Wmn	1			Wmn	4		-209.9	4.1	-51.1	<.0001	<.0001
	Wmn	1			Wmn	5		-321.8	4.1	-78.3	<.0001	<.0001
	Wmn	2			Wmn	3		-70.8	4.1	-17.2	<.0001	<.0001
	Wmn	2			Wmn	4		-121.8	4.1	-29.6	<.0001	<.0001
	Wmn	2			Wmn	5		-233.7	4.1	-56.9	<.0001	<.0001
	Wmn	3			Wmn	4		-51.0	4.1	-12.4	<.0001	<.0001
	Wmn	3			Wmn	5		-162.9	4.1	-39.6	<.0001	<.0001
	Wmn	4			Wmn	5		-111.9	4.1	-27.2	<.0001	<.0001

Age = age at initial RT testing

Wmn = women
RT = the five RT tasks
Visit = time 1 versus time 2
Estimate = Mean difference in reaction time
SE = Standard Error
Adj p = Bonferroni Adjusted probability

Appendix B

RT Commission Error Post-Hoc Contrasts with Bonferroni Correction for Multiple Contrasts (Adj p)

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31				32-41				-0.1	0.1	-1.0	0.3	1.0
20-31				42-51				-0.1	0.1	-1.9	0.1	0.6
20-31				52-61				-0.2	0.1	-3.0	0.0	0.0
20-31				62-79				-0.5	0.1	-7.4	<.0001	<.0001
32-41				42-51				-0.1	0.1	-1.1	0.3	1.0
32-41				52-61				-0.1	0.1	-2.3	0.0	0.2
32-41				62-79				-0.4	0.1	-7.3	<.0001	<.0001
42-51				52-61				-0.1	0.1	-1.1	0.3	1.0
42-51				62-79				-0.3	0.1	-5.7	<.0001	<.0001
52-61				62-79				-0.3	0.1	-5.0	<.0001	<.0001
	Men				Wmn			0.0	0.0	0.1	0.9	0.9
		1				2		-0.1	0.0	-2.6	0.0	0.1
		1				3		-0.4	0.0	-9.2	<.0001	<.0001
		1				4		-0.9	0.0	-22.1	<.0001	<.0001
		1				5		-1.3	0.0	-31.5	<.0001	<.0001
		2				3		-0.3	0.0	-6.6	<.0001	<.0001
		2				4		-0.8	0.0	-19.5	<.0001	<.0001
		2				5		-1.2	0.0	-28.9	<.0001	<.0001
		3				4		-0.5	0.0	-12.9	<.0001	<.0001
		3				5		-0.9	0.0	-22.3	<.0001	<.0001
		4				5		-0.4	0.0	-9.4	<.0001	<.0001
			1				2	0.1	0.0	2.9	0.0	0.0
20-31		1		20-31		2		-0.1	0.1	-0.6	0.6	1.0
20-31		1		20-31		3		-0.3	0.1	-3.3	0.0	0.3
20-31		1		20-31		4		-0.5	0.1	-5.7	<.0001	<.0001
20-31		1		20-31		5		-0.9	0.1	-9.3	<.0001	<.0001
20-31		1		32-41		1		0.0	0.1	0.3	0.8	1.0
20-31		1		32-41		2		-0.1	0.1	-0.6	0.6	1.0
20-31		1		32-41		3		-0.3	0.1	-3.0	0.0	1.0
20-31		1		32-41		4		-0.6	0.1	-6.1	<.0001	<.0001
20-31		1		32-41		5		-1.2	0.1	-12.1	<.0001	<.0001
20-31		1		42-51		1		0.0	0.1	0.2	0.8	1.0
20-31		1		42-51		2		-0.1	0.1	-1.1	0.3	1.0
20-31		1		42-51		3		-0.4	0.1	-3.5	0.0	0.2
20-31		1		42-51		4		-0.7	0.1	-7.0	<.0001	<.0001
20-31		1		42-51		5		-1.2	0.1	-11.4	<.0001	<.0001
20-31		1		52-61		1		0.0	0.1	0.1	1.0	1.0
20-31		1		52-61		2		0.0	0.1	-0.4	0.7	1.0
20-31		1		52-61		3		-0.3	0.1	-3.4	0.0	0.2
20-31		1		52-61		4		-1.0	0.1	-10.3	<.0001	<.0001
20-31		1		52-61		5		-1.3	0.1	-12.9	<.0001	<.0001
20-31		1		62-79		1		0.0	0.1	-0.4	0.7	1.0
20-31		1		62-79		2		-0.2	0.1	-2.3	0.0	1.0
20-31		1		62-79		3		-0.5	0.1	-5.1	<.0001	0.0
20-31		1		62-79		4		-1.5	0.1	-14.9	<.0001	<.0001
20-31		1		62-79		5		-1.8	0.1	-17.2	<.0001	<.0001
20-31		2		20-31		3		-0.3	0.1	-2.7	0.0	1.0
20-31		2		20-31		4		-0.5	0.1	-5.1	<.0001	<.0001
20-31		2		20-31		5		-0.8	0.1	-8.7	<.0001	<.0001
20-31		2		32-41		1		0.1	0.1	0.9	0.4	1.0
20-31		2		32-41		2		0.0	0.1	0.0	1.0	1.0
20-31		2		32-41		3		-0.2	0.1	-2.4	0.0	1.0
20-31		2		32-41		4		-0.5	0.1	-5.5	<.0001	<.0001
20-31		2		32-41		5		-1.1	0.1	-11.6	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31		2		42-51		1		0.1	0.1	0.7	0.5	1.0
20-31		2		42-51		2		-0.1	0.1	-0.6	0.6	1.0
20-31		2		42-51		3		-0.3	0.1	-2.9	0.0	1.0
20-31		2		42-51		4		-0.7	0.1	-6.4	<.0001	<.0001
20-31		2		42-51		5		-1.1	0.1	-10.8	<.0001	<.0001
20-31		2		52-61		1		0.1	0.1	0.6	0.5	1.0
20-31		2		52-61		2		0.0	0.1	0.2	0.8	1.0
20-31		2		52-61		3		-0.3	0.1	-2.9	0.0	1.0
20-31		2		52-61		4		-1.0	0.1	-9.7	<.0001	<.0001
20-31		2		52-61		5		-1.2	0.1	-12.3	<.0001	<.0001
20-31		2		62-79		1		0.0	0.1	0.2	0.9	1.0
20-31		2		62-79		2		-0.2	0.1	-1.8	0.1	1.0
20-31		2		62-79		3		-0.5	0.1	-4.5	<.0001	0.0
20-31		2		62-79		4		-1.5	0.1	-14.4	<.0001	<.0001
20-31		2		62-79		5		-1.7	0.1	-16.7	<.0001	<.0001
20-31		3		20-31		4		-0.2	0.1	-2.4	0.0	1.0
20-31		3		20-31		5		-0.6	0.1	-6.0	<.0001	<.0001
20-31		3		32-41		1		0.3	0.1	3.5	0.0	0.1
20-31		3		32-41		2		0.3	0.1	2.7	0.0	1.0
20-31		3		32-41		3		0.0	0.1	0.3	0.8	1.0
20-31		3		32-41		4		-0.3	0.1	-2.8	0.0	1.0
20-31		3		32-41		5		-0.9	0.1	-8.9	<.0001	<.0001
20-31		3		42-51		1		0.3	0.1	3.2	0.0	0.5
20-31		3		42-51		2		0.2	0.1	1.9	0.1	1.0
20-31		3		42-51		3		-0.1	0.1	-0.5	0.6	1.0
20-31		3		42-51		4		-0.4	0.1	-4.0	<.0001	0.0
20-31		3		42-51		5		-0.9	0.1	-8.4	<.0001	<.0001
20-31		3		52-61		1		0.3	0.1	3.2	0.0	0.4
20-31		3		52-61		2		0.3	0.1	2.8	0.0	1.0
20-31		3		52-61		3		0.0	0.1	-0.3	0.8	1.0
20-31		3		52-61		4		-0.7	0.1	-7.2	<.0001	<.0001
20-31		3		52-61		5		-1.0	0.1	-9.7	<.0001	<.0001
20-31		3		62-79		1		0.3	0.1	2.7	0.0	1.0
20-31		3		62-79		2		0.1	0.1	0.8	0.5	1.0
20-31		3		62-79		3		-0.2	0.1	-2.0	0.0	1.0
20-31		3		62-79		4		-1.2	0.1	-11.8	<.0001	<.0001
20-31		3		62-79		5		-1.5	0.1	-14.2	<.0001	<.0001
20-31		4		20-31		5		-0.3	0.1	-3.6	0.0	0.1
20-31		4		32-41		1		0.6	0.1	5.9	<.0001	<.0001
20-31		4		32-41		2		0.5	0.1	5.0	<.0001	0.0
20-31		4		32-41		3		0.3	0.1	2.7	0.0	1.0
20-31		4		32-41		4		0.0	0.1	-0.4	0.7	1.0
20-31		4		32-41		5		-0.6	0.1	-6.5	<.0001	<.0001
20-31		4		42-51		1		0.6	0.1	5.4	<.0001	<.0001
20-31		4		42-51		2		0.4	0.1	4.1	<.0001	0.0
20-31		4		42-51		3		0.2	0.1	1.7	0.1	1.0
20-31		4		42-51		4		-0.2	0.1	-1.8	0.1	1.0
20-31		4		42-51		5		-0.6	0.1	-6.2	<.0001	<.0001
20-31		4		52-61		1		0.6	0.1	5.5	<.0001	<.0001
20-31		4		52-61		2		0.5	0.1	5.1	<.0001	0.0
20-31		4		52-61		3		0.2	0.1	2.0	0.0	1.0
20-31		4		52-61		4		-0.5	0.1	-4.8	<.0001	0.0
20-31		4		52-61		5		-0.7	0.1	-7.4	<.0001	<.0001
20-31		4		62-79		1		0.5	0.1	5.0	<.0001	0.0
20-31		4		62-79		2		0.3	0.1	3.0	0.0	0.8
20-31		4		62-79		3		0.0	0.1	0.3	0.8	1.0
20-31		4		62-79		4		-1.0	0.1	-9.6	<.0001	<.0001
20-31		4		62-79		5		-1.2	0.1	-11.9	<.0001	<.0001
20-31		5		32-41		1		0.9	0.1	9.4	<.0001	<.0001
20-31		5		32-41		2		0.8	0.1	8.5	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31		5		32-41		3		0.6	0.1	6.2	<.0001	<.0001
20-31		5		32-41		4		0.3	0.1	3.1	0.0	0.7
20-31		5		32-41		5		-0.3	0.1	-3.0	0.0	0.8
20-31		5		42-51		1		0.9	0.1	8.6	<.0001	<.0001
20-31		5		42-51		2		0.8	0.1	7.3	<.0001	<.0001
20-31		5		42-51		3		0.5	0.1	4.9	<.0001	0.0
20-31		5		42-51		4		0.2	0.1	1.4	0.2	1.0
20-31		5		42-51		5		-0.3	0.1	-3.0	0.0	1.0
20-31		5		52-61		1		0.9	0.1	8.9	<.0001	<.0001
20-31		5		52-61		2		0.9	0.1	8.5	<.0001	<.0001
20-31		5		52-61		3		0.5	0.1	5.4	<.0001	<.0001
20-31		5		52-61		4		-0.1	0.1	-1.5	0.1	1.0
20-31		5		52-61		5		-0.4	0.1	-4.0	<.0001	0.0
20-31		5		62-79		1		0.8	0.1	8.2	<.0001	<.0001
20-31		5		62-79		2		0.6	0.1	6.3	<.0001	<.0001
20-31		5		62-79		3		0.4	0.1	3.6	0.0	0.1
20-31		5		62-79		4		-0.6	0.1	-6.3	<.0001	<.0001
20-31		5		62-79		5		-0.9	0.1	-8.6	<.0001	<.0001
32-41		1		32-41		2		-0.1	0.1	-1.1	0.3	1.0
32-41		1		32-41		3		-0.3	0.1	-4.1	<.0001	0.0
32-41		1		32-41		4		-0.6	0.1	-8.0	<.0001	<.0001
32-41		1		32-41		5		-1.2	0.1	-15.6	<.0001	<.0001
32-41		1		42-51		1		0.0	0.1	-0.1	0.9	1.0
32-41		1		42-51		2		-0.1	0.1	-1.5	0.1	1.0
32-41		1		42-51		3		-0.4	0.1	-4.1	<.0001	0.0
32-41		1		42-51		4		-0.8	0.1	-8.0	<.0001	<.0001
32-41		1		42-51		5		-1.2	0.1	-12.9	<.0001	<.0001
32-41		1		52-61		1		0.0	0.1	-0.3	0.8	1.0
32-41		1		52-61		2		-0.1	0.1	-0.7	0.5	1.0
32-41		1		52-61		3		-0.4	0.1	-4.1	<.0001	0.0
32-41		1		52-61		4		-1.1	0.1	-11.8	<.0001	<.0001
32-41		1		52-61		5		-1.3	0.1	-14.7	<.0001	<.0001
32-41		1		62-79		1		-0.1	0.1	-0.7	0.5	1.0
32-41		1		62-79		2		-0.3	0.1	-2.9	0.0	1.0
32-41		1		62-79		3		-0.5	0.1	-5.9	<.0001	<.0001
32-41		1		62-79		4		-1.6	0.1	-16.9	<.0001	<.0001
32-41		1		62-79		5		-1.8	0.1	-19.5	<.0001	<.0001
32-41		2		32-41		3		-0.2	0.1	-3.0	0.0	0.9
32-41		2		32-41		4		-0.5	0.1	-6.9	<.0001	<.0001
32-41		2		32-41		5		-1.1	0.1	-14.5	<.0001	<.0001
32-41		2		42-51		1		0.1	0.1	0.8	0.4	1.0
32-41		2		42-51		2		-0.1	0.1	-0.6	0.5	1.0
32-41		2		42-51		3		-0.3	0.1	-3.2	0.0	0.4
32-41		2		42-51		4		-0.7	0.1	-7.1	<.0001	<.0001
32-41		2		42-51		5		-1.1	0.1	-12.0	<.0001	<.0001
32-41		2		52-61		1		0.1	0.1	0.7	0.5	1.0
32-41		2		52-61		2		0.0	0.1	0.3	0.8	1.0
32-41		2		52-61		3		-0.3	0.1	-3.2	0.0	0.4
32-41		2		52-61		4		-1.0	0.1	-10.9	<.0001	<.0001
32-41		2		52-61		5		-1.2	0.1	-13.8	<.0001	<.0001
32-41		2		62-79		1		0.0	0.1	0.2	0.8	1.0
32-41		2		62-79		2		-0.2	0.1	-2.0	0.1	1.0
32-41		2		62-79		3		-0.5	0.1	-5.0	<.0001	0.0
32-41		2		62-79		4		-1.5	0.1	-16.0	<.0001	<.0001
32-41		2		62-79		5		-1.7	0.1	-18.6	<.0001	<.0001
32-41		3		32-41		4		-0.3	0.1	-3.9	<.0001	0.0
32-41		3		32-41		5		-0.9	0.1	-11.5	<.0001	<.0001
32-41		3		42-51		1		0.3	0.1	3.2	0.0	0.4
32-41		3		42-51		2		0.2	0.1	1.8	0.1	1.0
32-41		3		42-51		3		-0.1	0.1	-0.8	0.4	1.0

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
32-41		3		42-51		4		-0.4	0.1	-4.7	<.0001	0.0
32-41		3		42-51		5		-0.9	0.1	-9.6	<.0001	<.0001
32-41		3		52-61		1		0.3	0.1	3.3	0.0	0.3
32-41		3		52-61		2		0.3	0.1	2.8	0.0	1.0
32-41		3		52-61		3		-0.1	0.1	-0.6	0.5	1.0
32-41		3		52-61		4		-0.7	0.1	-8.3	<.0001	<.0001
32-41		3		52-61		5		-1.0	0.1	-11.2	<.0001	<.0001
32-41		3		62-79		1		0.2	0.1	2.7	0.0	1.0
32-41		3		62-79		2		0.0	0.1	0.5	0.6	1.0
32-41		3		62-79		3		-0.2	0.1	-2.5	0.0	1.0
32-41		3		62-79		4		-1.2	0.1	-13.5	<.0001	<.0001
32-41		3		62-79		5		-1.5	0.1	-16.1	<.0001	<.0001
32-41		4		32-41		5		-0.6	0.1	-7.6	<.0001	<.0001
32-41		4		42-51		1		0.6	0.1	6.4	<.0001	<.0001
32-41		4		42-51		2		0.5	0.1	5.0	<.0001	0.0
32-41		4		42-51		3		0.2	0.1	2.4	0.0	1.0
32-41		4		42-51		4		-0.1	0.1	-1.5	0.1	1.0
32-41		4		42-51		5		-0.6	0.1	-6.4	<.0001	<.0001
32-41		4		52-61		1		0.6	0.1	6.7	<.0001	<.0001
32-41		4		52-61		2		0.6	0.1	6.2	<.0001	<.0001
32-41		4		52-61		3		0.2	0.1	2.8	0.0	1.0
32-41		4		52-61		4		-0.4	0.1	-5.0	<.0001	0.0
32-41		4		52-61		5		-0.7	0.1	-7.8	<.0001	<.0001
32-41		4		62-79		1		0.6	0.1	6.0	<.0001	<.0001
32-41		4		62-79		2		0.4	0.1	3.8	0.0	0.0
32-41		4		62-79		3		0.1	0.1	0.8	0.4	1.0
32-41		4		62-79		4		-0.9	0.1	-10.3	<.0001	<.0001
32-41		4		62-79		5		-1.2	0.1	-12.8	<.0001	<.0001
32-41		5		42-51		1		1.2	0.1	12.6	<.0001	<.0001
32-41		5		42-51		2		1.1	0.1	11.2	<.0001	<.0001
32-41		5		42-51		3		0.8	0.1	8.5	<.0001	<.0001
32-41		5		42-51		4		0.4	0.1	4.7	<.0001	0.0
32-41		5		42-51		5		0.0	0.1	-0.2	0.9	1.0
32-41		5		52-61		1		1.2	0.1	13.2	<.0001	<.0001
32-41		5		52-61		2		1.1	0.1	12.8	<.0001	<.0001
32-41		5		52-61		3		0.8	0.1	9.3	<.0001	<.0001
32-41		5		52-61		4		0.1	0.1	1.7	0.1	1.0
32-41		5		52-61		5		-0.1	0.1	-1.2	0.2	1.0
32-41		5		62-79		1		1.1	0.1	12.4	<.0001	<.0001
32-41		5		62-79		2		0.9	0.1	10.2	<.0001	<.0001
32-41		5		62-79		3		0.7	0.1	7.1	<.0001	<.0001
32-41		5		62-79		4		-0.4	0.1	-3.8	0.0	0.0
32-41		5		62-79		5		-0.6	0.1	-6.5	<.0001	<.0001
42-51		1		42-51		2		-0.1	0.1	-1.5	0.1	1.0
42-51		1		42-51		3		-0.4	0.1	-4.1	<.0001	0.0
42-51		1		42-51		4		-0.8	0.1	-8.1	<.0001	<.0001
42-51		1		42-51		5		-1.2	0.1	-13.0	<.0001	<.0001
42-51		1		52-61		1		0.0	0.1	-0.2	0.9	1.0
42-51		1		52-61		2		-0.1	0.1	-0.6	0.6	1.0
42-51		1		52-61		3		-0.4	0.1	-3.7	0.0	0.1
42-51		1		52-61		4		-1.1	0.1	-10.7	<.0001	<.0001
42-51		1		52-61		5		-1.3	0.1	-13.3	<.0001	<.0001
42-51		1		62-79		1		-0.1	0.1	-0.6	0.6	1.0
42-51		1		62-79		2		-0.3	0.1	-2.5	0.0	1.0
42-51		1		62-79		3		-0.5	0.1	-5.3	<.0001	<.0001
42-51		1		62-79		4		-1.6	0.1	-15.4	<.0001	<.0001
42-51		1		62-79		5		-1.8	0.1	-17.7	<.0001	<.0001
42-51		2		42-51		3		-0.3	0.1	-2.7	0.0	1.0
42-51		2		42-51		4		-0.6	0.1	-6.6	<.0001	<.0001
42-51		2		42-51		5		-1.1	0.1	-11.6	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
42-51		2		52-61		1		0.1	0.1	1.2	0.2	1.0
42-51		2		52-61		2		0.1	0.1	0.8	0.4	1.0
42-51		2		52-61		3		-0.2	0.1	-2.3	0.0	1.0
42-51		2		52-61		4		-0.9	0.1	-9.3	<.0001	<.0001
42-51		2		52-61		5		-1.2	0.1	-11.9	<.0001	<.0001
42-51		2		62-79		1		0.1	0.1	0.8	0.4	1.0
42-51		2		62-79		2		-0.1	0.1	-1.2	0.2	1.0
42-51		2		62-79		3		-0.4	0.1	-4.0	<.0001	0.0
42-51		2		62-79		4		-1.4	0.1	-14.0	<.0001	<.0001
42-51		2		62-79		5		-1.7	0.1	-16.4	<.0001	<.0001
42-51		3		42-51		4		-0.4	0.1	-3.9	<.0001	0.0
42-51		3		42-51		5		-0.8	0.1	-8.9	<.0001	<.0001
42-51		3		52-61		1		0.4	0.1	3.8	0.0	0.0
42-51		3		52-61		2		0.3	0.1	3.4	0.0	0.2
42-51		3		52-61		3		0.0	0.1	0.2	0.8	1.0
42-51		3		52-61		4		-0.7	0.1	-6.8	<.0001	<.0001
42-51		3		52-61		5		-0.9	0.1	-9.4	<.0001	<.0001
42-51		3		62-79		1		0.3	0.1	3.3	0.0	0.4
42-51		3		62-79		2		0.1	0.1	1.3	0.2	1.0
42-51		3		62-79		3		-0.2	0.1	-1.5	0.1	1.0
42-51		3		62-79		4		-1.2	0.1	-11.6	<.0001	<.0001
42-51		3		62-79		5		-1.4	0.1	-13.9	<.0001	<.0001
42-51		4		42-51		5		-0.5	0.1	-4.9	<.0001	0.0
42-51		4		52-61		1		0.7	0.1	7.5	<.0001	<.0001
42-51		4		52-61		2		0.7	0.1	7.1	<.0001	<.0001
42-51		4		52-61		3		0.4	0.1	4.0	<.0001	0.0
42-51		4		52-61		4		-0.3	0.1	-3.1	0.0	0.7
42-51		4		52-61		5		-0.6	0.1	-5.6	<.0001	<.0001
42-51		4		62-79		1		0.7	0.1	6.9	<.0001	<.0001
42-51		4		62-79		2		0.5	0.1	4.9	<.0001	0.0
42-51		4		62-79		3		0.2	0.1	2.1	0.0	1.0
42-51		4		62-79		4		-0.8	0.1	-8.0	<.0001	<.0001
42-51		4		62-79		5		-1.0	0.1	-10.3	<.0001	<.0001
42-51		5		52-61		1		1.2	0.1	12.2	<.0001	<.0001
42-51		5		52-61		2		1.2	0.1	11.8	<.0001	<.0001
42-51		5		52-61		3		0.9	0.1	8.7	<.0001	<.0001
42-51		5		52-61		4		0.2	0.1	1.7	0.1	1.0
42-51		5		52-61		5		-0.1	0.1	-1.0	0.3	1.0
42-51		5		62-79		1		1.2	0.1	11.5	<.0001	<.0001
42-51		5		62-79		2		1.0	0.1	9.5	<.0001	<.0001
42-51		5		62-79		3		0.7	0.1	6.7	<.0001	<.0001
42-51		5		62-79		4		-0.3	0.1	-3.3	0.0	0.3
42-51		5		62-79		5		-0.6	0.1	-5.7	<.0001	<.0001
52-61		1		52-61		2		0.0	0.1	-0.5	0.6	1.0
52-61		1		52-61		3		-0.3	0.1	-4.2	<.0001	0.0
52-61		1		52-61		4		-1.0	0.1	-12.4	<.0001	<.0001
52-61		1		52-61		5		-1.3	0.1	-15.4	<.0001	<.0001
52-61		1		62-79		1		0.0	0.1	-0.5	0.7	1.0
52-61		1		62-79		2		-0.2	0.1	-2.5	0.0	1.0
52-61		1		62-79		3		-0.5	0.1	-5.5	<.0001	<.0001
52-61		1		62-79		4		-1.5	0.1	-16.1	<.0001	<.0001
52-61		1		62-79		5		-1.8	0.1	-18.6	<.0001	<.0001
52-61		2		52-61		3		-0.3	0.1	-3.7	0.0	0.1
52-61		2		52-61		4		-1.0	0.1	-11.9	<.0001	<.0001
52-61		2		52-61		5		-1.3	0.1	-14.9	<.0001	<.0001
52-61		2		62-79		1		0.0	0.1	0.0	1.0	1.0
52-61		2		62-79		2		-0.2	0.1	-2.1	0.0	1.0
52-61		2		62-79		3		-0.5	0.1	-5.1	<.0001	0.0
52-61		2		62-79		4		-1.5	0.1	-15.7	<.0001	<.0001
52-61		2		62-79		5		-1.7	0.1	-18.2	<.0001	<.0001

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
52-61		3		52-61		4		-0.7	0.1	-8.2	<.0001	<.0001
52-61		3		52-61		5		-0.9	0.1	-11.3	<.0001	<.0001
52-61		3		62-79		1		0.3	0.1	3.2	0.0	0.4
52-61		3		62-79		2		0.1	0.1	1.1	0.3	1.0
52-61		3		62-79		3		-0.2	0.1	-1.9	0.1	1.0
52-61		3		62-79		4		-1.2	0.1	-12.4	<.0001	<.0001
52-61		3		62-79		5		-1.4	0.1	-14.9	<.0001	<.0001
52-61		4		52-61		5		-0.3	0.1	-3.1	0.0	0.7
52-61		4		62-79		1		1.0	0.1	10.4	<.0001	<.0001
52-61		4		62-79		2		0.8	0.1	8.3	<.0001	<.0001
52-61		4		62-79		3		0.5	0.1	5.4	<.0001	<.0001
52-61		4		62-79		4		-0.5	0.1	-5.3	<.0001	<.0001
52-61		4		62-79		5		-0.7	0.1	-7.7	<.0001	<.0001
52-61		5		62-79		1		1.3	0.1	13.1	<.0001	<.0001
52-61		5		62-79		2		1.1	0.1	11.0	<.0001	<.0001
52-61		5		62-79		3		0.8	0.1	8.1	<.0001	<.0001
52-61		5		62-79		4		-0.2	0.1	-2.6	0.0	1.0
52-61		5		62-79		5		-0.5	0.1	-5.1	<.0001	0.0
62-79		1		62-79		2		-0.2	0.1	-2.3	0.0	1.0
62-79		1		62-79		3		-0.5	0.1	-5.5	<.0001	<.0001
62-79		1		62-79		4		-1.5	0.1	-17.0	<.0001	<.0001
62-79		1		62-79		5		-1.7	0.1	-19.7	<.0001	<.0001
62-79		2		62-79		3		-0.3	0.1	-3.2	0.0	0.4
62-79		2		62-79		4		-1.3	0.1	-14.7	<.0001	<.0001
62-79		2		62-79		5		-1.5	0.1	-17.4	<.0001	<.0001
62-79		3		62-79		4		-1.0	0.1	-11.5	<.0001	<.0001
62-79		3		62-79		5		-1.3	0.1	-14.2	<.0001	<.0001
62-79		4		62-79		5		-0.2	0.1	-2.7	0.0	1.0
20-31			1	20-31			2	0.1	0.1	1.2	0.2	1.0
20-31			1	32-41			1	-0.1	0.1	-1.1	0.3	1.0
20-31			1	32-41			2	0.0	0.1	0.6	0.5	1.0
20-31			1	42-51			1	-0.1	0.1	-2.2	0.0	1.0
20-31			1	42-51			2	0.0	0.1	-0.1	1.0	1.0
20-31			1	52-61			1	-0.2	0.1	-2.6	0.0	0.4
20-31			1	52-61			2	-0.1	0.1	-1.5	0.1	1.0
20-31			1	62-79			1	-0.4	0.1	-6.8	<.0001	<.0001
20-31			1	62-79			2	-0.4	0.1	-5.3	<.0001	<.0001
20-31			2	32-41			1	-0.2	0.1	-2.0	0.0	1.0
20-31			2	32-41			2	0.0	0.1	-0.5	0.6	1.0
20-31			2	42-51			1	-0.2	0.1	-2.8	0.0	0.2
20-31			2	42-51			2	-0.1	0.1	-1.0	0.3	1.0
20-31			2	52-61			1	-0.3	0.1	-3.1	0.0	0.1
20-31			2	52-61			2	-0.2	0.1	-2.3	0.0	1.0
20-31			2	62-79			1	-0.5	0.1	-6.4	<.0001	<.0001
20-31			2	62-79			2	-0.5	0.1	-5.4	<.0001	<.0001
32-41			1	32-41			2	0.1	0.1	2.0	0.0	1.0
32-41			1	42-51			1	-0.1	0.1	-1.3	0.2	1.0
32-41			1	42-51			2	0.1	0.1	0.9	0.4	1.0
32-41			1	52-61			1	-0.1	0.1	-1.7	0.1	1.0
32-41			1	52-61			2	0.0	0.1	-0.6	0.6	1.0
32-41			1	62-79			1	-0.4	0.1	-6.3	<.0001	<.0001
32-41			1	62-79			2	-0.3	0.1	-4.7	<.0001	0.0
32-41			2	42-51			1	-0.2	0.1	-2.7	0.0	0.3
32-41			2	42-51			2	0.0	0.1	-0.6	0.5	1.0
32-41			2	52-61			1	-0.2	0.1	-3.1	0.0	0.1
32-41			2	52-61			2	-0.1	0.1	-2.1	0.0	1.0
32-41			2	62-79			1	-0.5	0.1	-7.0	<.0001	<.0001
32-41			2	62-79			2	-0.5	0.1	-5.6	<.0001	<.0001
42-51			1	42-51			2	0.1	0.1	2.2	0.0	1.0
42-51			1	52-61			1	0.0	0.1	-0.3	0.8	1.0

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
42-51			1	52-61			2	0.0	0.1	0.5	0.6	1.0
42-51			1	62-79			1	-0.3	0.1	-4.5	<.0001	0.0
42-51			1	62-79			2	-0.3	0.1	-3.4	0.0	0.0
42-51			2	52-61			1	-0.2	0.1	-2.2	0.0	1.0
42-51			2	52-61			2	-0.1	0.1	-1.3	0.2	1.0
42-51			2	62-79			1	-0.4	0.1	-5.8	<.0001	<.0001
42-51			2	62-79			2	-0.4	0.1	-4.7	<.0001	0.0
52-61			1	52-61			2	0.1	0.1	1.0	0.3	1.0
52-61			1	62-79			1	-0.3	0.1	-4.4	<.0001	0.0
52-61			1	62-79			2	-0.2	0.1	-3.3	0.0	0.0
52-61			2	62-79			1	-0.3	0.1	-4.8	<.0001	<.0001
52-61			2	62-79			2	-0.3	0.1	-3.8	0.0	0.0
62-79			1	62-79			2	0.0	0.1	0.2	0.8	1.0
	Men	1			Men	2		-0.1	0.0	-2.0	0.0	1.0
	Men	1			Men	3		-0.4	0.0	-9.0	<.0001	<.0001
	Men	1			Men	4		-0.8	0.0	-17.1	<.0001	<.0001
	Men	1			Men	5		-1.2	0.0	-23.6	<.0001	<.0001
	Men	1			Wmn	1		0.0	0.1	0.6	0.6	1.0
	Men	1			Wmn	2		-0.1	0.1	-1.2	0.3	1.0
	Men	1			Wmn	3		-0.3	0.1	-4.2	<.0001	0.0
	Men	1			Wmn	4		-0.9	0.1	-14.5	<.0001	<.0001
	Men	1			Wmn	5		-1.3	0.1	-21.5	<.0001	<.0001
	Men	2			Men	3		-0.3	0.0	-7.0	<.0001	<.0001
	Men	2			Men	4		-0.7	0.0	-15.1	<.0001	<.0001
	Men	2			Men	5		-1.1	0.0	-21.6	<.0001	<.0001
	Men	2			Wmn	1		0.1	0.1	2.2	0.0	1.0
	Men	2			Wmn	2		0.0	0.1	0.5	0.6	1.0
	Men	2			Wmn	3		-0.2	0.1	-2.5	0.0	0.5
	Men	2			Wmn	4		-0.8	0.1	-12.9	<.0001	<.0001
	Men	2			Wmn	5		-1.2	0.1	-19.9	<.0001	<.0001
	Men	3			Men	4		-0.4	0.0	-8.1	<.0001	<.0001
	Men	3			Men	5		-0.7	0.0	-14.6	<.0001	<.0001
	Men	3			Wmn	1		0.5	0.1	7.7	<.0001	<.0001
	Men	3			Wmn	2		0.4	0.1	6.0	<.0001	<.0001
	Men	3			Wmn	3		0.2	0.1	3.0	0.0	0.1
	Men	3			Wmn	4		-0.5	0.1	-7.4	<.0001	<.0001
	Men	3			Wmn	5		-0.9	0.1	-14.4	<.0001	<.0001
	Men	4			Men	5		-0.3	0.0	-6.5	<.0001	<.0001
	Men	4			Wmn	1		0.9	0.1	14.1	<.0001	<.0001
	Men	4			Wmn	2		0.8	0.1	12.4	<.0001	<.0001
	Men	4			Wmn	3		0.6	0.1	9.4	<.0001	<.0001
	Men	4			Wmn	4		-0.1	0.1	-1.0	0.3	1.0
	Men	4			Wmn	5		-0.5	0.1	-8.0	<.0001	<.0001
	Men	5			Wmn	1		1.2	0.1	19.3	<.0001	<.0001
	Men	5			Wmn	2		1.1	0.1	17.6	<.0001	<.0001
	Men	5			Wmn	3		0.9	0.1	14.6	<.0001	<.0001
	Men	5			Wmn	4		0.3	0.1	4.2	<.0001	0.0
	Men	5			Wmn	5		-0.2	0.1	-2.8	0.0	0.2
	Wmn	1			Wmn	2		-0.1	0.1	-1.7	0.1	1.0
	Wmn	1			Wmn	3		-0.3	0.1	-4.6	<.0001	0.0
	Wmn	1			Wmn	4		-0.9	0.1	-14.8	<.0001	<.0001
	Wmn	1			Wmn	5		-1.4	0.1	-21.6	<.0001	<.0001
	Wmn	2			Wmn	3		-0.2	0.1	-2.9	0.0	0.1
	Wmn	2			Wmn	4		-0.8	0.1	-13.1	<.0001	<.0001
	Wmn	2			Wmn	5		-1.3	0.1	-19.9	<.0001	<.0001
	Wmn	3			Wmn	4		-0.6	0.1	-10.2	<.0001	<.0001
	Wmn	3			Wmn	5		-1.1	0.1	-17.0	<.0001	<.0001
	Wmn	4			Wmn	5		-0.4	0.1	-6.9	<.0001	<.0001

Age = age at initial RT testing

Wmn = women
RT = the five RT tasks
Visit = time 1 versus time 2
Estimate = Mean reaction time
SE = Standard Error
Adj p = Bonferroni Adjusted probability

Appendix C

RT Omission Error Post-Hoc Contrasts with Bonferroni Correction for Multiple Contrasts (Adj p)

Age	Sex	RT	Visit	Age	Sex	RT	Visit	Estimate	SE	t	p	Adj p
20-31				32-41				-0.1	0.1	-1.3	0.2	1.0
20-31				42-51				-0.2	0.1	-2.2	0.0	0.3
20-31				52-61				-0.4	0.1	-5.1	<.0001	<.0001
20-31				62-79				-0.7	0.1	-9.3	<.0001	<.0001
32-41				42-51				-0.1	0.1	-1.2	0.2	1.0
32-41				52-61				-0.3	0.1	-4.4	<.0001	0.0
32-41				62-79				-0.6	0.1	-9.1	<.0001	<.0001
42-51				52-61				-0.2	0.1	-2.9	0.0	0.0
42-51				62-79				-0.5	0.1	-7.3	<.0001	<.0001
52-61				62-79				-0.3	0.1	-4.8	<.0001	<.0001
	Men				Wmn			-0.1	0.0	-1.7	0.1	0.1
		1				2		0.0	0.0	-0.4	0.7	1.0
		1				3		-0.1	0.0	-2.1	0.0	0.4
		1				4		-0.6	0.0	-13.6	<.0001	<.0001
		1				5		-2.1	0.0	-45.9	<.0001	<.0001
		2				3		-0.1	0.0	-1.7	0.1	0.9
		2				4		-0.6	0.0	-13.2	<.0001	<.0001
		2				5		-2.1	0.0	-45.5	<.0001	<.0001
		3				4		-0.5	0.0	-11.5	<.0001	<.0001
		3				5		-2.0	0.0	-43.8	<.0001	<.0001
		4				5		-1.5	0.0	-32.3	<.0001	<.0001
			1				2	0.1	0.0	1.8	0.1	0.1
20-31		1		20-31		2		0.0	0.1	0.2	0.8	1.0
20-31		1		20-31		3		-0.1	0.1	-0.6	0.5	1.0
20-31		1		20-31		4		-0.2	0.1	-1.6	0.1	1.0
20-31		1		20-31		5		-1.3	0.1	-11.9	<.0001	<.0001
20-31		1		32-41		1		0.0	0.1	0.3	0.8	1.0
20-31		1		32-41		2		0.0	0.1	0.2	0.8	1.0
20-31		1		32-41		3		0.0	0.1	-0.4	0.7	1.0
20-31		1		32-41		4		-0.3	0.1	-2.9	0.0	1.0
20-31		1		32-41		5		-1.6	0.1	-14.5	<.0001	<.0001
20-31		1		42-51		1		0.0	0.1	0.1	0.9	1.0
20-31		1		42-51		2		-0.1	0.1	-0.5	0.6	1.0
20-31		1		42-51		3		-0.1	0.1	-0.8	0.4	1.0
20-31		1		42-51		4		-0.5	0.1	-3.8	0.0	0.0
20-31		1		42-51		5		-1.7	0.1	-14.3	<.0001	<.0001
20-31		1		52-61		1		0.0	0.1	0.2	0.9	1.0
20-31		1		52-61		2		0.0	0.1	0.2	0.9	1.0
20-31		1		52-61		3		-0.1	0.1	-0.6	0.6	1.0
20-31		1		52-61		4		-0.7	0.1	-6.6	<.0001	<.0001
20-31		1		52-61		5		-2.5	0.1	-21.8	<.0001	<.0001
20-31		1		62-79		1		0.0	0.1	-0.2	0.9	1.0
20-31		1		62-79		2		0.0	0.1	-0.4	0.7	1.0
20-31		1		62-79		3		-0.1	0.1	-1.2	0.2	1.0
20-31		1		62-79		4		-1.3	0.1	-11.3	<.0001	<.0001
20-31		1		62-79		5		-3.3	0.1	-28.1	<.0001	<.0001
20-31		2		20-31		3		-0.1	0.1	-0.8	0.4	1.0
20-31		2		20-31		4		-0.2	0.1	-1.9	0.1	1.0
20-31		2		20-31		5		-1.3	0.1	-12.1	<.0001	<.0001
20-31		2		32-41		1		0.0	0.1	0.1	1.0	1.0
20-31		2		32-41		2		0.0	0.1	0.0	1.0	1.0
20-31		2		32-41		3		-0.1	0.1	-0.7	0.5	1.0
20-31		2		32-41		4		-0.3	0.1	-3.2	0.0	0.5

20-31	2	32-41	5	-1.6	0.1	-14.7	<.0001	<.0001
20-31	2	42-51	1	0.0	0.1	-0.1	0.9	1.0
20-31	2	42-51	2	-0.1	0.1	-0.7	0.5	1.0
20-31	2	42-51	3	-0.1	0.1	-1.0	0.3	1.0
20-31	2	42-51	4	-0.5	0.1	-4.1	<.0001	0.0
20-31	2	42-51	5	-1.7	0.1	-14.5	<.0001	<.0001
20-31	2	52-61	1	0.0	0.1	0.0	1.0	1.0
20-31	2	52-61	2	0.0	0.1	-0.1	1.0	1.0
20-31	2	52-61	3	-0.1	0.1	-0.8	0.4	1.0
20-31	2	52-61	4	-0.8	0.1	-6.8	<.0001	<.0001
20-31	2	52-61	5	-2.5	0.1	-22.0	<.0001	<.0001
20-31	2	62-79	1	0.0	0.1	-0.4	0.7	1.0
20-31	2	62-79	2	-0.1	0.1	-0.6	0.5	1.0
20-31	2	62-79	3	-0.2	0.1	-1.5	0.1	1.0
20-31	2	62-79	4	-1.3	0.1	-11.5	<.0001	<.0001
20-31	2	62-79	5	-3.3	0.1	-28.3	<.0001	<.0001
20-31	3	20-31	4	-0.1	0.1	-1.0	0.3	1.0
20-31	3	20-31	5	-1.2	0.1	-11.3	<.0001	<.0001
20-31	3	32-41	1	0.1	0.1	0.9	0.4	1.0
20-31	3	32-41	2	0.1	0.1	0.8	0.4	1.0
20-31	3	32-41	3	0.0	0.1	0.2	0.9	1.0
20-31	3	32-41	4	-0.3	0.1	-2.3	0.0	1.0
20-31	3	32-41	5	-1.5	0.1	-13.9	<.0001	<.0001
20-31	3	42-51	1	0.1	0.1	0.7	0.5	1.0
20-31	3	42-51	2	0.0	0.1	0.1	0.9	1.0
20-31	3	42-51	3	0.0	0.1	-0.2	0.8	1.0
20-31	3	42-51	4	-0.4	0.1	-3.3	0.0	0.3
20-31	3	42-51	5	-1.6	0.1	-13.7	<.0001	<.0001
20-31	3	52-61	1	0.1	0.1	0.8	0.4	1.0
20-31	3	52-61	2	0.1	0.1	0.8	0.5	1.0
20-31	3	52-61	3	0.0	0.1	0.0	1.0	1.0
20-31	3	52-61	4	-0.7	0.1	-6.0	<.0001	<.0001
20-31	3	52-61	5	-2.4	0.1	-21.2	<.0001	<.0001
20-31	3	62-79	1	0.0	0.1	0.4	0.7	1.0
20-31	3	62-79	2	0.0	0.1	0.2	0.9	1.0
20-31	3	62-79	3	-0.1	0.1	-0.7	0.5	1.0
20-31	3	62-79	4	-1.3	0.1	-10.7	<.0001	<.0001
20-31	3	62-79	5	-3.2	0.1	-27.5	<.0001	<.0001
20-31	4	20-31	5	-1.1	0.1	-10.2	<.0001	<.0001
20-31	4	32-41	1	0.2	0.1	1.9	0.1	1.0
20-31	4	32-41	2	0.2	0.1	1.8	0.1	1.0
20-31	4	32-41	3	0.1	0.1	1.2	0.2	1.0
20-31	4	32-41	4	-0.1	0.1	-1.3	0.2	1.0
20-31	4	32-41	5	-1.4	0.1	-12.9	<.0001	<.0001
20-31	4	42-51	1	0.2	0.1	1.6	0.1	1.0
20-31	4	42-51	2	0.1	0.1	1.0	0.3	1.0
20-31	4	42-51	3	0.1	0.1	0.7	0.5	1.0
20-31	4	42-51	4	-0.3	0.1	-2.4	0.0	1.0
20-31	4	42-51	5	-1.5	0.1	-12.8	<.0001	<.0001
20-31	4	52-61	1	0.2	0.1	1.7	0.1	1.0
20-31	4	52-61	2	0.2	0.1	1.7	0.1	1.0
20-31	4	52-61	3	0.1	0.1	1.0	0.3	1.0
20-31	4	52-61	4	-0.6	0.1	-5.0	<.0001	0.0
20-31	4	52-61	5	-2.3	0.1	-20.2	<.0001	<.0001
20-31	4	62-79	1	0.2	0.1	1.4	0.2	1.0
20-31	4	62-79	2	0.1	0.1	1.1	0.3	1.0
20-31	4	62-79	3	0.0	0.1	0.3	0.8	1.0
20-31	4	62-79	4	-1.1	0.1	-9.8	<.0001	<.0001
20-31	4	62-79	5	-3.1	0.1	-26.6	<.0001	<.0001
20-31	5	32-41	1	1.3	0.1	11.8	<.0001	<.0001
20-31	5	32-41	2	1.3	0.1	11.8	<.0001	<.0001

20-31	5	32-41	3	1.2	0.1	11.1	<.0001	<.0001
20-31	5	32-41	4	1.0	0.1	8.6	<.0001	<.0001
20-31	5	32-41	5	-0.3	0.1	-2.9	0.0	1.0
20-31	5	42-51	1	1.3	0.1	10.8	<.0001	<.0001
20-31	5	42-51	2	1.2	0.1	10.2	<.0001	<.0001
20-31	5	42-51	3	1.2	0.1	9.9	<.0001	<.0001
20-31	5	42-51	4	0.8	0.1	6.8	<.0001	<.0001
20-31	5	42-51	5	-0.4	0.1	-3.6	0.0	0.1
20-31	5	52-61	1	1.3	0.1	11.4	<.0001	<.0001
20-31	5	52-61	2	1.3	0.1	11.4	<.0001	<.0001
20-31	5	52-61	3	1.2	0.1	10.6	<.0001	<.0001
20-31	5	52-61	4	0.5	0.1	4.6	<.0001	0.0
20-31	5	52-61	5	-1.2	0.1	-10.6	<.0001	<.0001
20-31	5	62-79	1	1.3	0.1	10.7	<.0001	<.0001
20-31	5	62-79	2	1.2	0.1	10.5	<.0001	<.0001
20-31	5	62-79	3	1.1	0.1	9.7	<.0001	<.0001
20-31	5	62-79	4	0.0	0.1	-0.4	0.7	1.0
20-31	5	62-79	5	-2.0	0.1	-17.2	<.0001	<.0001
32-41	1	32-41	2	0.0	0.1	-0.1	0.9	1.0
32-41	1	32-41	3	-0.1	0.1	-0.9	0.4	1.0
32-41	1	32-41	4	-0.4	0.1	-4.1	<.0001	0.0
32-41	1	32-41	5	-1.6	0.1	-18.7	<.0001	<.0001
32-41	1	42-51	1	0.0	0.1	-0.2	0.9	1.0
32-41	1	42-51	2	-0.1	0.1	-0.8	0.4	1.0
32-41	1	42-51	3	-0.1	0.1	-1.2	0.3	1.0
32-41	1	42-51	4	-0.5	0.1	-4.5	<.0001	0.0
32-41	1	42-51	5	-1.7	0.1	-16.1	<.0001	<.0001
32-41	1	52-61	1	0.0	0.1	-0.1	0.9	1.0
32-41	1	52-61	2	0.0	0.1	-0.1	0.9	1.0
32-41	1	52-61	3	-0.1	0.1	-1.0	0.3	1.0
32-41	1	52-61	4	-0.8	0.1	-7.7	<.0001	<.0001
32-41	1	52-61	5	-2.5	0.1	-24.7	<.0001	<.0001
32-41	1	62-79	1	0.0	0.1	-0.5	0.6	1.0
32-41	1	62-79	2	-0.1	0.1	-0.7	0.5	1.0
32-41	1	62-79	3	-0.2	0.1	-1.7	0.1	1.0
32-41	1	62-79	4	-1.4	0.1	-12.9	<.0001	<.0001
32-41	1	62-79	5	-3.3	0.1	-31.6	<.0001	<.0001
32-41	2	32-41	3	-0.1	0.1	-0.8	0.4	1.0
32-41	2	32-41	4	-0.3	0.1	-4.0	<.0001	0.0
32-41	2	32-41	5	-1.6	0.1	-18.6	<.0001	<.0001
32-41	2	42-51	1	0.0	0.1	-0.1	0.9	1.0
32-41	2	42-51	2	-0.1	0.1	-0.7	0.5	1.0
32-41	2	42-51	3	-0.1	0.1	-1.1	0.3	1.0
32-41	2	42-51	4	-0.5	0.1	-4.5	<.0001	0.0
32-41	2	42-51	5	-1.7	0.1	-16.0	<.0001	<.0001
32-41	2	52-61	1	0.0	0.1	0.0	1.0	1.0
32-41	2	52-61	2	0.0	0.1	0.0	1.0	1.0
32-41	2	52-61	3	-0.1	0.1	-0.9	0.4	1.0
32-41	2	52-61	4	-0.8	0.1	-7.6	<.0001	<.0001
32-41	2	52-61	5	-2.5	0.1	-24.6	<.0001	<.0001
32-41	2	62-79	1	0.0	0.1	-0.4	0.7	1.0
32-41	2	62-79	2	-0.1	0.1	-0.7	0.5	1.0
32-41	2	62-79	3	-0.2	0.1	-1.6	0.1	1.0
32-41	2	62-79	4	-1.3	0.1	-12.8	<.0001	<.0001
32-41	2	62-79	5	-3.3	0.1	-31.5	<.0001	<.0001
32-41	3	32-41	4	-0.3	0.1	-3.2	0.0	0.5
32-41	3	32-41	5	-1.5	0.1	-17.8	<.0001	<.0001
32-41	3	42-51	1	0.1	0.1	0.6	0.6	1.0
32-41	3	42-51	2	0.0	0.1	-0.1	0.9	1.0
32-41	3	42-51	3	0.0	0.1	-0.4	0.7	1.0
32-41	3	42-51	4	-0.4	0.1	-3.8	0.0	0.0

32-41	3	42-51	5	-1.7	0.1	-15.3	<.0001	<.0001
32-41	3	52-61	1	0.1	0.1	0.7	0.5	1.0
32-41	3	52-61	2	0.1	0.1	0.7	0.5	1.0
32-41	3	52-61	3	0.0	0.1	-0.2	0.8	1.0
32-41	3	52-61	4	-0.7	0.1	-6.9	<.0001	<.0001
32-41	3	52-61	5	-2.4	0.1	-23.9	<.0001	<.0001
32-41	3	62-79	1	0.0	0.1	0.3	0.8	1.0
32-41	3	62-79	2	0.0	0.1	0.0	1.0	1.0
32-41	3	62-79	3	-0.1	0.1	-0.9	0.4	1.0
32-41	3	62-79	4	-1.3	0.1	-12.1	<.0001	<.0001
32-41	3	62-79	5	-3.2	0.1	-30.8	<.0001	<.0001
32-41	4	32-41	5	-1.3	0.1	-14.6	<.0001	<.0001
32-41	4	42-51	1	0.3	0.1	3.1	0.0	0.6
32-41	4	42-51	2	0.3	0.1	2.5	0.0	1.0
32-41	4	42-51	3	0.2	0.1	2.1	0.0	1.0
32-41	4	42-51	4	-0.1	0.1	-1.3	0.2	1.0
32-41	4	42-51	5	-1.4	0.1	-12.8	<.0001	<.0001
32-41	4	52-61	1	0.3	0.1	3.4	0.0	0.2
32-41	4	52-61	2	0.3	0.1	3.4	0.0	0.2
32-41	4	52-61	3	0.3	0.1	2.5	0.0	1.0
32-41	4	52-61	4	-0.4	0.1	-4.2	<.0001	0.0
32-41	4	52-61	5	-2.2	0.1	-21.3	<.0001	<.0001
32-41	4	62-79	1	0.3	0.1	2.9	0.0	1.0
32-41	4	62-79	2	0.3	0.1	2.6	0.0	1.0
32-41	4	62-79	3	0.2	0.1	1.7	0.1	1.0
32-41	4	62-79	4	-1.0	0.1	-9.6	<.0001	<.0001
32-41	4	62-79	5	-3.0	0.1	-28.2	<.0001	<.0001
32-41	5	42-51	1	1.6	0.1	14.9	<.0001	<.0001
32-41	5	42-51	2	1.5	0.1	14.2	<.0001	<.0001
32-41	5	42-51	3	1.5	0.1	13.9	<.0001	<.0001
32-41	5	42-51	4	1.1	0.1	10.5	<.0001	<.0001
32-41	5	42-51	5	-0.1	0.1	-1.1	0.3	1.0
32-41	5	52-61	1	1.6	0.1	15.9	<.0001	<.0001
32-41	5	52-61	2	1.6	0.1	15.9	<.0001	<.0001
32-41	5	52-61	3	1.5	0.1	15.0	<.0001	<.0001
32-41	5	52-61	4	0.8	0.1	8.3	<.0001	<.0001
32-41	5	52-61	5	-0.9	0.1	-8.8	<.0001	<.0001
32-41	5	62-79	1	1.6	0.1	15.0	<.0001	<.0001
32-41	5	62-79	2	1.6	0.1	14.8	<.0001	<.0001
32-41	5	62-79	3	1.5	0.1	13.8	<.0001	<.0001
32-41	5	62-79	4	0.3	0.1	2.6	0.0	1.0
32-41	5	62-79	5	-1.7	0.1	-16.2	<.0001	<.0001
42-51	1	42-51	2	-0.1	0.1	-0.7	0.5	1.0
42-51	1	42-51	3	-0.1	0.1	-1.0	0.3	1.0
42-51	1	42-51	4	-0.5	0.1	-4.5	<.0001	0.0
42-51	1	42-51	5	-1.7	0.1	-16.4	<.0001	<.0001
42-51	1	52-61	1	0.0	0.1	0.1	0.9	1.0
42-51	1	52-61	2	0.0	0.1	0.1	1.0	1.0
42-51	1	52-61	3	-0.1	0.1	-0.7	0.5	1.0
42-51	1	52-61	4	-0.8	0.1	-6.8	<.0001	<.0001
42-51	1	52-61	5	-2.5	0.1	-22.3	<.0001	<.0001
42-51	1	62-79	1	0.0	0.1	-0.3	0.8	1.0
42-51	1	62-79	2	-0.1	0.1	-0.5	0.6	1.0
42-51	1	62-79	3	-0.2	0.1	-1.4	0.2	1.0
42-51	1	62-79	4	-1.3	0.1	-11.6	<.0001	<.0001
42-51	1	62-79	5	-3.3	0.1	-28.7	<.0001	<.0001
42-51	2	42-51	3	0.0	0.1	-0.4	0.7	1.0
42-51	2	42-51	4	-0.4	0.1	-3.8	0.0	0.0
42-51	2	42-51	5	-1.7	0.1	-15.7	<.0001	<.0001
42-51	2	52-61	1	0.1	0.1	0.7	0.5	1.0
42-51	2	52-61	2	0.1	0.1	0.7	0.5	1.0

42-51	2	52-61	3	0.0	0.1	-0.1	0.9	1.0
42-51	2	52-61	4	-0.7	0.1	-6.2	<.0001	<.0001
42-51	2	52-61	5	-2.4	0.1	-21.7	<.0001	<.0001
42-51	2	62-79	1	0.0	0.1	0.3	0.7	1.0
42-51	2	62-79	2	0.0	0.1	0.1	0.9	1.0
42-51	2	62-79	3	-0.1	0.1	-0.8	0.4	1.0
42-51	2	62-79	4	-1.3	0.1	-11.0	<.0001	<.0001
42-51	2	62-79	5	-3.2	0.1	-28.1	<.0001	<.0001
42-51	3	42-51	4	-0.4	0.1	-3.5	0.0	0.1
42-51	3	42-51	5	-1.6	0.1	-15.4	<.0001	<.0001
42-51	3	52-61	1	0.1	0.1	1.0	0.3	1.0
42-51	3	52-61	2	0.1	0.1	1.0	0.3	1.0
42-51	3	52-61	3	0.0	0.1	0.2	0.8	1.0
42-51	3	52-61	4	-0.7	0.1	-5.8	<.0001	<.0001
42-51	3	52-61	5	-2.4	0.1	-21.4	<.0001	<.0001
42-51	3	62-79	1	0.1	0.1	0.7	0.5	1.0
42-51	3	62-79	2	0.0	0.1	0.4	0.7	1.0
42-51	3	62-79	3	-0.1	0.1	-0.5	0.6	1.0
42-51	3	62-79	4	-1.2	0.1	-10.7	<.0001	<.0001
42-51	3	62-79	5	-3.2	0.1	-27.8	<.0001	<.0001
42-51	4	42-51	5	-1.2	0.1	-11.9	<.0001	<.0001
42-51	4	52-61	1	0.5	0.1	4.3	<.0001	0.0
42-51	4	52-61	2	0.5	0.1	4.3	<.0001	0.0
42-51	4	52-61	3	0.4	0.1	3.5	0.0	0.1
42-51	4	52-61	4	-0.3	0.1	-2.6	0.0	1.0
42-51	4	52-61	5	-2.0	0.1	-18.1	<.0001	<.0001
42-51	4	62-79	1	0.4	0.1	3.9	0.0	0.0
42-51	4	62-79	2	0.4	0.1	3.6	0.0	0.1
42-51	4	62-79	3	0.3	0.1	2.7	0.0	1.0
42-51	4	62-79	4	-0.9	0.1	-7.6	<.0001	<.0001
42-51	4	62-79	5	-2.8	0.1	-24.6	<.0001	<.0001
42-51	5	52-61	1	1.7	0.1	15.5	<.0001	<.0001
42-51	5	52-61	2	1.7	0.1	15.5	<.0001	<.0001
42-51	5	52-61	3	1.6	0.1	14.7	<.0001	<.0001
42-51	5	52-61	4	1.0	0.1	8.6	<.0001	<.0001
42-51	5	52-61	5	-0.8	0.1	-7.0	<.0001	<.0001
42-51	5	62-79	1	1.7	0.1	14.7	<.0001	<.0001
42-51	5	62-79	2	1.7	0.1	14.5	<.0001	<.0001
42-51	5	62-79	3	1.6	0.1	13.6	<.0001	<.0001
42-51	5	62-79	4	0.4	0.1	3.4	0.0	0.2
42-51	5	62-79	5	-1.6	0.1	-13.8	<.0001	<.0001
52-61	1	52-61	2	0.0	0.1	0.0	1.0	1.0
52-61	1	52-61	3	-0.1	0.1	-1.0	0.3	1.0
52-61	1	52-61	4	-0.8	0.1	-8.1	<.0001	<.0001
52-61	1	52-61	5	-2.5	0.1	-26.5	<.0001	<.0001
52-61	1	62-79	1	0.0	0.1	-0.4	0.7	1.0
52-61	1	62-79	2	-0.1	0.1	-0.6	0.5	1.0
52-61	1	62-79	3	-0.2	0.1	-1.5	0.1	1.0
52-61	1	62-79	4	-1.3	0.1	-12.3	<.0001	<.0001
52-61	1	62-79	5	-3.3	0.1	-30.4	<.0001	<.0001
52-61	2	52-61	3	-0.1	0.1	-0.9	0.3	1.0
52-61	2	52-61	4	-0.8	0.1	-8.1	<.0001	<.0001
52-61	2	52-61	5	-2.5	0.1	-26.5	<.0001	<.0001
52-61	2	62-79	1	0.0	0.1	-0.4	0.7	1.0
52-61	2	62-79	2	-0.1	0.1	-0.6	0.5	1.0
52-61	2	62-79	3	-0.2	0.1	-1.5	0.1	1.0
52-61	2	62-79	4	-1.3	0.1	-12.3	<.0001	<.0001
52-61	2	62-79	5	-3.3	0.1	-30.4	<.0001	<.0001
52-61	3	52-61	4	-0.7	0.1	-7.2	<.0001	<.0001
52-61	3	52-61	5	-2.4	0.1	-25.6	<.0001	<.0001
52-61	3	62-79	1	0.0	0.1	0.5	0.6	1.0

52-61	3		62-79	2		0.0	0.1	0.2	0.8	1.0
52-61	3		62-79	3		-0.1	0.1	-0.7	0.5	1.0
52-61	3		62-79	4		-1.3	0.1	-11.5	<.0001	<.0001
52-61	3		62-79	5		-3.2	0.1	-29.6	<.0001	<.0001
52-61	4		52-61	5		-1.7	0.1	-18.4	<.0001	<.0001
52-61	4		62-79	1		0.7	0.1	6.7	<.0001	<.0001
52-61	4		62-79	2		0.7	0.1	6.5	<.0001	<.0001
52-61	4		62-79	3		0.6	0.1	5.5	<.0001	<.0001
52-61	4		62-79	4		-0.6	0.1	-5.3	<.0001	<.0001
52-61	4		62-79	5		-2.5	0.1	-23.3	<.0001	<.0001
52-61	5		62-79	1		2.5	0.1	22.7	<.0001	<.0001
52-61	5		62-79	2		2.4	0.1	22.4	<.0001	<.0001
52-61	5		62-79	3		2.3	0.1	21.5	<.0001	<.0001
52-61	5		62-79	4		1.2	0.1	10.7	<.0001	<.0001
52-61	5		62-79	5		-0.8	0.1	-7.4	<.0001	<.0001
62-79	1		62-79	2		0.0	0.1	-0.3	0.8	1.0
62-79	1		62-79	3		-0.1	0.1	-1.3	0.2	1.0
62-79	1		62-79	4		-1.3	0.1	-13.1	<.0001	<.0001
62-79	1		62-79	5		-3.3	0.1	-32.9	<.0001	<.0001
62-79	2		62-79	3		-0.1	0.1	-1.0	0.3	1.0
62-79	2		62-79	4		-1.3	0.1	-12.9	<.0001	<.0001
62-79	2		62-79	5		-3.2	0.1	-32.7	<.0001	<.0001
62-79	3		62-79	4		-1.2	0.1	-11.9	<.0001	<.0001
62-79	3		62-79	5		-3.1	0.1	-31.7	<.0001	<.0001
62-79	4		62-79	5		-2.0	0.1	-19.8	<.0001	<.0001
20-31		1	20-31		2	0.1	0.1	0.8	0.4	1.0
20-31		1	32-41		1	-0.1	0.1	-1.8	0.1	1.0
20-31		1	32-41		2	0.0	0.1	0.2	0.8	1.0
20-31		1	42-51		1	-0.2	0.1	-2.1	0.0	1.0
20-31		1	42-51		2	-0.1	0.1	-1.2	0.2	1.0
20-31		1	52-61		1	-0.4	0.1	-4.9	<.0001	<.0001
20-31		1	52-61		2	-0.3	0.1	-3.6	0.0	0.0
20-31		1	62-79		1	-0.6	0.1	-8.5	<.0001	<.0001
20-31		1	62-79		2	-0.7	0.1	-7.4	<.0001	<.0001
20-31		2	32-41		1	-0.2	0.1	-2.1	0.0	1.0
20-31		2	32-41		2	0.0	0.1	-0.5	0.6	1.0
20-31		2	42-51		1	-0.2	0.1	-2.4	0.0	0.8
20-31		2	42-51		2	-0.2	0.1	-1.6	0.1	1.0
20-31		2	52-61		1	-0.4	0.1	-4.5	<.0001	0.0
20-31		2	52-61		2	-0.4	0.1	-3.6	0.0	0.0
20-31		2	62-79		1	-0.7	0.1	-7.3	<.0001	<.0001
20-31		2	62-79		2	-0.7	0.1	-6.8	<.0001	<.0001
32-41		1	32-41		2	0.1	0.1	2.2	0.0	1.0
32-41		1	42-51		1	0.0	0.1	-0.6	0.6	1.0
32-41		1	42-51		2	0.0	0.1	0.2	0.8	1.0
32-41		1	52-61		1	-0.2	0.1	-3.6	0.0	0.0
32-41		1	52-61		2	-0.2	0.1	-2.3	0.0	1.0
32-41		1	62-79		1	-0.5	0.1	-7.5	<.0001	<.0001
32-41		1	62-79		2	-0.5	0.1	-6.4	<.0001	<.0001
32-41		2	42-51		1	-0.2	0.1	-2.2	0.0	1.0
32-41		2	42-51		2	-0.1	0.1	-1.3	0.2	1.0
32-41		2	52-61		1	-0.4	0.1	-4.8	<.0001	<.0001
32-41		2	52-61		2	-0.3	0.1	-3.6	0.0	0.0
32-41		2	62-79		1	-0.6	0.1	-8.2	<.0001	<.0001
32-41		2	62-79		2	-0.7	0.1	-7.3	<.0001	<.0001
42-51		1	42-51		2	0.1	0.1	0.8	0.4	1.0
42-51		1	52-61		1	-0.2	0.1	-2.7	0.0	0.3
42-51		1	52-61		2	-0.1	0.1	-1.6	0.1	1.0
42-51		1	62-79		1	-0.4	0.1	-6.2	<.0001	<.0001
42-51		1	62-79		2	-0.5	0.1	-5.6	<.0001	<.0001
42-51		2	52-61		1	-0.3	0.1	-3.0	0.0	0.1

42-51			2	52-61			2	-0.2	0.1	-2.1	0.0	1.0
42-51			2	62-79			1	-0.5	0.1	-6.1	<.0001	<.0001
42-51			2	62-79			2	-0.6	0.1	-5.6	<.0001	<.0001
52-61			1	52-61			2	0.1	0.1	1.1	0.3	1.0
52-61			1	62-79			1	-0.3	0.1	-3.7	0.0	0.0
52-61			1	62-79			2	-0.3	0.1	-3.5	0.0	0.0
52-61			2	62-79			1	-0.3	0.1	-4.2	<.0001	0.0
52-61			2	62-79			2	-0.4	0.1	-4.0	<.0001	0.0
62-79			1	62-79			2	0.0	0.1	-0.6	0.5	1.0
	Men	1			Men	2		0.0	0.1	-0.5	0.6	1.0
	Men	1			Men	3		-0.1	0.1	-1.8	0.1	1.0
	Men	1			Men	4		-0.5	0.1	-8.8	<.0001	<.0001
	Men	1			Men	5		-2.0	0.1	-36.2	<.0001	<.0001
	Men	1			Wmn	1		0.0	0.1	0.0	1.0	1.0
	Men	1			Wmn	2		0.0	0.1	0.0	1.0	1.0
	Men	1			Wmn	3		-0.1	0.1	-1.2	0.2	1.0
	Men	1			Wmn	4		-0.7	0.1	-10.4	<.0001	<.0001
	Men	1			Wmn	5		-2.1	0.1	-30.4	<.0001	<.0001
	Men	2			Men	3		-0.1	0.1	-1.3	0.2	1.0
	Men	2			Men	4		-0.5	0.1	-8.4	<.0001	<.0001
	Men	2			Men	5		-2.0	0.1	-35.8	<.0001	<.0001
	Men	2			Wmn	1		0.0	0.1	0.4	0.7	1.0
	Men	2			Wmn	2		0.0	0.1	0.3	0.7	1.0
	Men	2			Wmn	3		-0.1	0.1	-0.8	0.4	1.0
	Men	2			Wmn	4		-0.7	0.1	-10.1	<.0001	<.0001
	Men	2			Wmn	5		-2.1	0.1	-30.0	<.0001	<.0001
	Men	3			Men	4		-0.4	0.1	-7.1	<.0001	<.0001
	Men	3			Men	5		-1.9	0.1	-34.5	<.0001	<.0001
	Men	3			Wmn	1		0.1	0.1	1.4	0.2	1.0
	Men	3			Wmn	2		0.1	0.1	1.4	0.2	1.0
	Men	3			Wmn	3		0.0	0.1	0.2	0.9	1.0
	Men	3			Wmn	4		-0.6	0.1	-9.0	<.0001	<.0001
	Men	3			Wmn	5		-2.0	0.1	-29.0	<.0001	<.0001
	Men	4			Men	5		-1.5	0.1	-27.4	<.0001	<.0001
	Men	4			Wmn	1		0.5	0.1	7.0	<.0001	<.0001
	Men	4			Wmn	2		0.5	0.1	6.9	<.0001	<.0001
	Men	4			Wmn	3		0.4	0.1	5.7	<.0001	<.0001
	Men	4			Wmn	4		-0.2	0.1	-3.5	0.0	0.0
	Men	4			Wmn	5		-1.7	0.1	-23.4	<.0001	<.0001
	Men	5			Wmn	1		2.0	0.1	28.5	<.0001	<.0001
	Men	5			Wmn	2		2.0	0.1	28.4	<.0001	<.0001
	Men	5			Wmn	3		1.9	0.1	27.3	<.0001	<.0001
	Men	5			Wmn	4		1.3	0.1	18.1	<.0001	<.0001
	Men	5			Wmn	5		-0.1	0.1	-1.9	0.1	1.0
	Wmn	1			Wmn	2		0.0	0.1	-0.1	0.9	1.0
	Wmn	1			Wmn	3		-0.1	0.1	-1.3	0.2	1.0
	Wmn	1			Wmn	4		-0.7	0.1	-10.4	<.0001	<.0001
	Wmn	1			Wmn	5		-2.1	0.1	-30.1	<.0001	<.0001
	Wmn	2			Wmn	3		-0.1	0.1	-1.2	0.2	1.0
	Wmn	2			Wmn	4		-0.7	0.1	-10.3	<.0001	<.0001
	Wmn	2			Wmn	5		-2.1	0.1	-30.0	<.0001	<.0001
	Wmn	3			Wmn	4		-0.7	0.1	-9.1	<.0001	<.0001
	Wmn	3			Wmn	5		-2.1	0.1	-28.8	<.0001	<.0001
	Wmn	4			Wmn	5		-1.4	0.1	-19.7	<.0001	<.0001

Age = age at initial RT testing
Wmn = women
RT = the five RT tasks
Visit = time 1 versus time 2
Estimate = Mean reaction time

SE = Standard Error
Adj p = Bonferroni Adjusted probability

Table 1

Frequency of Men and Women by Age Group: Reaction Time Tasks Test-Retest Over 6-9 Years

	Men		Women	
Ages	Frequency	Percent	Frequency	Percent
20-31	90	14.13	77	20.26
32-41	155	24.33	106	27.90
42-51	116	18.21	61	16.05
52-61	145	22.76	72	18.95
62-79	131	20.57	64	16.84
Total N	637	100	380	100

Table 2

Mean Age and Education of Participants in the Prediction Analyses

Type of Analysis	N	Mean (SD) Age (yrs) at Initial Reaction Time Testing	Age Range (yrs)	Mean (SD) Education (yrs)	Education Range (yrs)
Reaction Time Predicting BIMC & MMSE Mental Status, Fluency & Trails A & B	103	58.17(6.67)	46-78	16.94(2.23)	10-20
Women	35	58.75(6.80)	47-78	16.17(2.42)	12-20
Men	68	57.88(6.62)	46-73	17.34(2.03)	10-20
Reaction Time Predicting CVLT: Interference and Digits Forward and Backward	139	51.45(8.87)	33-71	16.98(2.09)	10-21
Women	51	50.96(8.78)	34-68	16.67(2.05)	12-20
Men	88	51.74(8.96)	33-71	17.16(2.10)	10-21

BIMC = Blessed Information-Memory-Concentration Test
MMSE = Mini-Mental State Examination
Trails = Trail Making Test A and Trail Making Test B
CVLT = California Verbal Learning Test Proactive Interference Measure
Digits Forward & Backward = WAIS: Digits Forward and WAIS: Digits Backward

Table 3

Summary of Significant Reaction Time Main Effects for the Cross-Sectional and Longitudinal Rate of Change Analyses Using the Mixed Model

Significant Effects	F-value	Means in msec (SE) for Significant Main Effects
Age	F (4,4255) = 28.69**	20-31 yrs = 474.50 (5.29)
		32-41 yrs = 488.54 (4.33)
		42-51 yrs = 496.09 (5.31)
		52-61 yrs = 521.99 (4.80)
		62-79 yrs = 539.82 (4.88)
Sex	F (1,4255) = 23.96**	men = 493.45 (2.75)
		women = 514.92 (3.49)
RT Task	F (4,4255) = 4542.58**	RT task 1 = 343.12 (2.79)
		RT task 2 = 438.81 (2.79)
		RT task 3 = 510.62 (2.79)
		RT task 4 = 553.15 (2.79)
		RT task 5 = 675.24 (2.79)
Time of Testing	F (1,4255) = 3.90*	Time 1 = 502.28 (2.26)
		Time 2 = 506.09 (2.63)

*p < .05, ** p < .0001

Table 4

Reaction Time Means (in milliseconds) and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Impact of Age and Task Complexity on Reaction Time

Age at Initial RT Testing	Mean RT and Standard Errors (SE) in Milliseconds					
	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
20-31 yr olds	320.59	415.72	484.17	511.03	640.99	474.50
	(6.58)	(6.58)	(6.58)	(6.58)	(6.58)	(5.29)
32-41 yr olds	332.04	427.69	496.52	531.51	654.93	488.54
	(5.37)	(5.37)	(5.37)	(5.37)	(5.37)	(4.33)
42-51 yr olds	341.39	437.12	505.07	543.12	653.73	496.09
	(6.55)	(6.55)	(6.55)	(6.55)	(6.55)	(5.31)
52-61 yr olds	353.62	451.43	529.30	576.68	698.93	521.99
	(5.91)	(5.91)	(5.91)	(5.91)	(5.91)	(4.80)
62-79 yr olds	367.98	462.08	538.03	603.38	727.62	539.82
	(6.07)	(6.06)	(6.06)	(6.06)	(6.06)	(4.88)
Total Sample	343.12	438.81	510.62	553.15	675.24	
	(2.79)	(2.79)	(2.79)	(2.79)	(2.79)	

Note: RT task 1 = press for ‘0’
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 5

Reaction Time Means (in milliseconds) and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Differential Impact of Sex and Task Complexity on Reaction Time

	Mean RT and Standard Errors (SE) in Milliseconds					
Sex	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
Men	327.04	430.36	503.15	537.19	669.50	493.45
	(3.42)	(3.42)	(3.42)	(3.42)	(3.42)	(2.75)
Women	359.20	447.26	518.08	569.10	680.98	514.92
	(4.35)	(4.35)	(4.35)	(4.35)	(4.35)	(3.49)
Total Sample	343.12	438.81	510.62	553.15	675.24	
	(2.79)	(2.79)	(2.79)	(2.79)	(2.79)	

Note: RT task 1 = press for '0'
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 6

Summary of Significant Reaction Time Commission Error Main Effects for the Cross-Sectional and Longitudinal Rate of Change Analyses Using the Mixed Model

Significant Effects	F-value	Means in msec (SE) for Significant Main Effects
Age	F (4,4255) = 18.38**	20-31 yrs = 0.38 (0.05)
		32-41 yrs = 0.44 (0.04)
		42-51 yrs = 0.50 (0.04)
		52-61 yrs = 0.56 (0.04)
		62-79 yrs = 0.84 (0.04)
RT Task	F (4,4255) = 358.06**	RT task 1 = 0.02 (0.03)
		RT task 2 = 0.12 (0.03)
		RT task 3 = 0.38 (0.03)
		RT task 4 = 0.91 (0.03)
		RT task 5 = 1.29 (0.03)
Time of Testing	F (1,4255) = 8.52**	Time 1 = 0.58 (0.02)
		Time 2 = 0.50 (0.03)

*p < .05, ** p < .0001

Table 7

Reaction Time Commission Error Means and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Impact of Age and Task Complexity on Reaction Time Commission Errors

Age at Initial RT Testing	Mean RT and Standard Errors (SE) in Milliseconds					
	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
20-31 yr olds	0.02	0.08	0.34	0.57	0.91	0.38
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.05)
32-41 yr olds	0.00	0.08	0.31	0.61	1.20	0.44
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.04)
42-51 yr olds	0.00	0.14	0.39	0.76	1.22	0.50
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
52-61 yr olds	0.02	0.06	0.36	1.05	1.31	0.56
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
62-79 yr olds	0.06	0.26	0.54	1.56	1.79	0.84
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
Total Sample	0.17	0.12	0.39	0.91	1.29	
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	

Note: RT task 1 = press for ‘0’
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 8

Reaction Time Commission Error Means and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Differential Impact of Sex and Task Complexity on Reaction Time Commission Errors

	Mean RT and Standard Errors (SE) in Milliseconds					
Sex	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
Men	0.04	0.14	0.48	0.88	1.20	0.55
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
Women	0.00	0.11	0.29	0.94	1.37	0.54
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.03)
Total Sample	0.02	0.12	0.39	0.91	1.29	
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	

Note: RT task 1 = press for ‘0’
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 9

Summary of Significant Reaction Time Omission Error Main Effects for the Cross-Sectional and Longitudinal Rate of Change Analyses Using the Mixed Model

Significant Effects	F-value	Means in msec (SE) for Significant Main Effects
Age	F (4,4255) = 30.16**	20-31 yrs = 0.31 (0.05)
		32-41 yrs = 0.40 (0.04)
		42-51 yrs = 0.48 (0.05)
		52-61 yrs = 0.67 (0.05)
		62-79 yrs = 0.98 (0.05)
RT Task	F (4,4255) = 358.06**	RT task 1 = 0.01 (0.04)
		RT task 2 = 0.02 (0.04)
		RT task 3 = 0.10 (0.04)
		RT task 4 = 0.62 (0.04)
		RT task 5 = 2.09 (0.04)

*p < .05, ** p < .0001

Table 10

Reaction Time Omission Error Means and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Impact of Age and Task Complexity on Reaction Time Omission Errors

Age at Initial RT Testing	Mean RT and Standard Errors (SE) in Milliseconds					
	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
20-31 yr olds	0.02	0.00	0.08	0.09	1.29	0.32
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.05)
32-41 yr olds	0.00	0.00	0.07	0.34	1.62	0.40
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
42-51 yr olds	0.00	0.07	0.11	0.48	1.73	0.48
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.05)
52-61 yr olds	0.00	0.00	0.08	0.76	2.50	0.67
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.05)
62-79 yr olds	0.04	0.06	0.16	1.34	3.30	0.98
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.05)
Total Sample	0.01	0.02	0.10	0.62	2.09	
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	

Note: RT task 1 = press for ‘0’
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 11

Reaction Time Omission Error Means and Standard Errors (SE) for the Cross-Sectional Differences and Longitudinal Rate of Change Analyses: Differential Impact of Sex and Task Complexity on Reaction Time Omission Errors

	Mean RT and Standard Errors (SE) in Milliseconds					
Sex	RT task 1	RT task 2	RT task 3	RT task 4	RT task 5	Total Sample
Men	0.01	0.03	0.11	0.50	2.02	0.53
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Women	0.01	0.01	0.09	0.75	2.15	0.60
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.03)
Total	0.01	0.02	0.10	0.62	2.09	
Sample	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	

Note: RT task 1 = press for ‘0’
RT task 2 = press for a specific number (e.g., 3)
RT task 3 = press for every odd number (or every even number)
RT task 4 = press for every odd number followed by an even number (or every even number followed by an odd number)
RT task 5 = press for every odd number followed by another odd number and every even number followed by another even number

Table 12

Mental Status and Prefrontal Outcome Measures Included in the Regression Analyses: Frequencies of Men and Women by Age Group

Outcome measures: MMSE, BIMC, Fluency, Trails:

Age – at Initial	Men		Women	
Reaction time	Number	Percent	Number	Percent
42-61 yrs.	48	73	21	62
62-79 yrs.	18	27	13	38
Total N	66	100	34	100

Outcome measures: CVLT, Digits Forward & Backward:

Age - at Initial	Men		Women	
Reaction time	Number	Percent	Number	Percent
32-51 yrs.	39	45	25	50
52-79 yrs.	47	55	25	50
Total N	86	100	50	100

BIMC = Blessed Information-Memory-Concentration Test
MMSE = Mini-Mental State Examination
Trails = Trail Making Test A and Trail Making Test B
CVLT = California Verbal Learning Test Proactive Interference Measure
Digits Forward & Backward = WAIS: Digits Forward and WAIS: Digits Backward

Table 13

Summary of Significant ANOVA Effects for the Prefrontal Outcome Measures

Outcome Variable	Significant Effects	Means for Significant Effects
Overall Cognitive Functioning: Mental Status Measures:		
MMSE	age: F(1,95) = 0.81	42-61 yrs = 28.96 (1.14) 62-79 yrs = 28.74 (1.13)
	time: F(1,95) = 0.56	time 1 = 28.89 (1.06) time 2 = 28.77 (1.20)
BIMC	age: F(1,95) = 6.11*	42-61 yrs = 0.67 (0.96) 62-79 yrs = 1.28 (1.80)
	time: F(1,95) = 2.75	time 1 = .84 (.99) time 2 = .86 (1.77)
Prefrontal Interference, Working Memory and Attentional Tasks:		
CVLT: Interference	age: F (1,129) = .03	42-61 yrs = 4.49 (29.09) 62-79 yrs = 5.19 (33.11)
	time: F(1,129) = .05	time 4.44 (27.63) time 5.25 (34.42)
WAIS: Digits Forward	age: F(1,129) = 5.70*	32-51 yrs = 9.30 (1.91) 52-61 yrs = 8.28 (2.08)
	time: F(1,129) = 0.16	time 1: 8.75 (2.05) time 2: 8.83 (1.94)
	sex: F(1,129) = 7.36**	men: 9.36 (2.16) women: 8.21 (1.84)
WAIS: Digits Backward	age: F(1,129) = 1.35	32-51 yrs = 9.30 (1.91) 52-61 yrs = 8.28 (2.08)
	time: F(1,129) = 1.57	time 1 = 8.75 (1.09) time 2 = 6.59 (1.94)
	sex: F(1,129) = 6.56**	men: 8.69 (2.33) women: 7.54 (1.98)

Outcome Variable	Significant Effects	Means for Significant Effects
Prefrontal Attentional, Working Memory and Interference Tasks:		
Trails A	age: F(1,95) = 7.79**	42-61 yrs = 35.11 (11.88) 62-79 yrs = 42.46 (16.98)
	time: F(1,95) = 0.29	time 1 = 39.30 (12.53) time 2 = 38.28 (16.33)
Trails B	age: F(1,95) = 9.23**	42-61 yrs = 80.54 (29.26) 62-79 yrs = 101.06 (38.83)
	time: F(1,95) = 21.04***	time 1 = 82.15 (27.00) time 2 =99.45 (41.84)
Fluency: Letters	age: F(1,95) = 1.33	42-61 yrs = 16.34 (3.37) 62-79 yrs =15.50 (4.57)
	time: F(1,95) = 9.54 **	time 1: 16.55 (4.17) time 2: 15.33 (3.76)
Fluency: Category	age: F(1,95) = 3.03	42-61 yrs = 16.34 (3.21) 62-79 yrs = 15.25 (3.05)
	time: F(1,95) = 24.13***	time 1 = 16.71 (2.87) time 2 = 14.88 (3.39)
	sex: F(1,95) = 8.02**	men: 14.91 (3.19) women: 16.68 (3.07)

*p < .05, ** p < .01, ***p < .0001

BIMC = Blessed Information-Memory-Concentration Test
MMSE = Mini-Mental State Examination
Trails = Trail Making Test
CVLT = California Verbal Learning Test Proactive Interference Measure
Digits Forward & Backward = WAIS: Digits Forward and WAIS: Digits Backward

Table 14

Summary of Results Predicting Initial Levels of Mental Status and the Prefrontal Outcome Measures from Initial RT Age, and Inhibition, Working Memory and Interference After Accounting for the Attenuating Effects of Speed of Processing

Outcome Variable	Total R^2 Accounted for by the Model (Adj R^2)	Proportion of Variance Accounted for by Age			Additional Variance Accounted for After Adding: RT for Task 1 (Speed)			RT for Task 4 (Inhibition)			RT for Task 5 (Working Memory)		
		R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
MMSE	.06 (-.01)	.00	.00	.16	.01	.01	.92	.02	.01	.70	.02	.00	.08
BIMC	.10 (.01)	.03	.03	2.96	.04	.00	.21	.05	.01	.48	.06	.01	1.11
Trails A	.14 (.05)	.03	.03	2.59	.11	.04	4.79*	.11	.00	.29	.11	.00	.05
Trails B	.13 (.04)	.01	.01	1.21	.05	.03	3.25	.05	.00	.02	.06	.01	1.14
Fluency: Letters	.07 (-.02)	.00	.00	.01	.01	.00	.00	.01	.00	.37	.06	.05	5.03*
Fluency: Categories	.23** (.15)	.01	.01	.90	.15	.02	2.43	.15	.00	.00	.21	.06	6.81**
CVLT: Interference	.05 (-.02)	.00	.00	.17	.01	.00	.04	.01	.00	.06	.02	.00	.10
WAIS: Digits Forward	.15* (.08)	.02	.02	2.92	.13	.03	4.66*	.13	.01	1.25	.13	.00	.04
WAIS: Digits Backward	.15* (.09)	.00	.00	.46	.09	.00	.68	.10	.01	1.31	.10	.00	.43

* $p < .05$, ** $p < .01$

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Table 14 (con't)

Outcome Variable	Additional Variance Accounted for After Adding: Commission Errors for RT Task 1 (Interference 1)			Commission Errors for RT Task 4 (Interference 2)			Commission Errors for RT Task 5 (Interference 3)		
	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
MMSE	.03	.01	.87	.04	.01	1.18	.06	.02	1.81
BIMC	.07	.01	1.01	.09	.03	2.58	.10	.01	.57
Trails A	.11	.00	.08	.11	.00	.14	.14	.03	2.67
Trails B	.08	.02	1.91	.09	.01	.74	.13	.04	4.54*
Fluency: Letters	.06	.00	.09	.06	.00	.00	.07	.01	.77
Fluency: Categories	.21	.00	.19	.21	.00	.58	.23	.02	2.11
CVLT: Interference	.03	.02	2.22	.03	.00	.12	.50	.02	2.40
WAIS: Digits Forward	.14	.01	.93	.15	.01	1.42	.15	.00	.07
WAIS: Digits Backward	.10	.00	.11	.10	.00	.00	.15	.05	7.77**

*p < .05, ** p < .01

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Table 15

<u>Summary of Results Predicting Initial Levels of Mental Status and the Prefrontal Outcome Measures from Initial RT Age, and Speed of Processing After Accounting for the Attenuating Effects of Inhibition, Working Memory and Interference</u>

Outcome Variable	Total R^2 Accounted for by the Model (Adj R^2)	Proportion of Variance Accounted for by Age			Additional Variance Accounted for After Adding: RT for Task 4 (Inhibition)			RT for Task 5 (Working Memory)			Commission Errors for RT Task 1 (Interference 1)		
		R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
MMSE	.06 (-.01)	.00	.00	.16	.02	.01	1.46	.02	.00	.10	.03	.01	.89
BIMC	.09 (.01)	.03	.03	2.96	.04	.00	.15	.06	.01	1.21	.06	.01	.99
Trails A	.14 (.05)	.03	.03	2.59	.09	.02	2.45	.09	.00	.00	.09	.00	.11
Trails B	.13 (.04)	.01	.01	1.21	.02	.01	.64	.04	.01	1.45	.05	.02	1.77
Fluency: Letters	.07 (-.02)	.00	.00	.01	.01	.00	.31	.06	.05	4.92*	.06	.00	.08
Fluency: Categories	.23** (.15)	.01	.01	.90	.13	.00	.49	.20	.06	7.53**	.20	.00	.20
CVLT: Interference	.05 (-.02)	.00	.00	.17	.01	.00	.00	.01	.00	.12	.03	.02	2.21
WAIS: Digits Forward	.15* (.08)	.02	.02	2.92	.12	.02	3.47	.12	.00	.05	.12	.01	.87
WAIS: Digits Backward	.15* (.09)	.00	.00	.46	.10	.01	1.91	.10	.00	.44	.10	.00	.11

* $p < .05$, ** $p < .01$

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Outcome Variable	Additional Variance Accounted for After Adding: Commission Errors for RT Task 4 (Interference 2)			Commission Errors for RT Task 5 (Interference 3)			RT for Task 1 (Speed)		
	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
MMSE	.04	.01	1.11	.06	.02	1.84	.06	.00	.21
BIMC	.09	.03	2.78	.10	.01	.63	.10	.00	.26
Trails A	.09	.00	.33	.12	.03	2.65	.14	.02	2.33
Trails B	.07	.01	1.10	.11	.04	4.52*	.13	.02	2.06
Fluency: Letters	.06	.00	.01	.07	.01	.78	.07	.00	.22
Fluency: Categories	.22	.00	.39	.22	.02	2.09	.23	.01	1.49
CVLT: Interference	.03	.00	.05	.05	.02	2.23	.05	.01	.69
WAIS: Digits Forward	.13	.01	.95	.13	.00	.12	.15	.02	2.83
WAIS: Digits Backward	.10	.00	.00	.15	.05	7.89**	.15	.00	.03

* $p < .05$, ** $p < .01$

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Table 16

<u>Summary of Results Predicting Change in the Mental Status and the Prefrontal Outcome Measures from Initial RT Age, and Change in Inhibition, Working Memory and Interference After Accounting for the Attenuating Effects of Speed of Processing</u>

Outcome Variable	Total R^2 Accounted for by the Model (Adj R^2)	Proportion of Variance Accounted for by Age			Additional Variance Accounted for After Adding: RT for Task 1 (Speed)			RT for Task 4 (Inhibition)			RT for Task 5 (Working Memory)		
		R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
BIMC	.15 (.07)	.00	.00	.00	.05	.02	2.10	.05	.00	.06	.05	.00	.29
Trails A	.17* (.09)	.06	.06	5.87*	.13	.01	.89	.14	.02	1.90	.15	.00	.56
Trails B	.27**(.19)	.18	.18	21.72**	.24	.01	1.61	.25	.01	1.00	.25	.00	.00
Fluency: Letters	.13 (.05)	.02	.02	1.82	.03	.00	.34	.11	.08	8.31**	.12	.02	2.08
Fluency: Categories	.15 (.06)	.04	.04	3.84*	.14	.01	1.13	.14	.00	.19	.14	.00	.15
WAIS: Digits Backward	.11 (.00)	.00	.00	.46	.09	.00	.68	.10	.01	1.31	.10	.00	.43

[a] $p < .06$, * $p < .05$, ** $p < .01$

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Outcome Variable	Additional Variance Accounted for After Adding: Commission Errors for RT Task 1 (Interference 1)			Commission Errors for RT Task 4 (Interference 2)			Commission Errors for RT Task 5 (Interference 3)		
	R^2	$R^2\ \Delta$	F	R^2	$R^2\ \Delta$	F	R^2	$R^2\ \Delta$	F
BIMC	.08	.03	2.58	.12	.04	4.29*	.15	.03	3.55[a]
Trails A	.16	.01	.63	.16	.01	1.09	.17	.00	.26
Trails B	.26	.01	.81	.27	.01	1.71	.27	.00	.09
Fluency: Letters	.13	.00	.03	.13	.00	.22	.13	.01	.57
Fluency: Categories	.15	.00	.45	.15	.00	.51	.15	.00	.03
WAIS: Digits Backward	.10	.00	.11	.10	.00	.00	.15	.05	7.77**

[a] p < .06, p * < .05, ** p < .01

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Table 17

Summary of Results Predicting Change in the Mental Status and the Prefrontal Outcome Measures from Initial RT Age, and Change in Speed of Processing After Accounting for the Attenuating Effects of Inhibition, Working Memory and Interference

Outcome Variable	Total R^2 Accounted for by the Model (Adj R^2)	Proportion of Variance Accounted for by Age			Additional Variance Accounted for After Adding: RT for Task 4 (Inhibition)			RT for Task 5 (Working Memory)			Commission Errors for RT Task 1 (Interference 1)		
		R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
BIMC	.15 (.07)	.00	.00	.00	.03	.00	.14	.03	.00	.03	.06	.03	3.49
Trails A	.17* (.09)	.06	.06	5.87*	.14	.02	2.43	.14	.00	.25	.15	.01	.94
Trails B	.27* *(.19)	.18	.18	21.72**	.24	.01	1.57	.24	.00	.08	.25	.01	1.22
Fluency: Letters	.13 (.05)	.02	.02	1.82	.11	.08	8.76**	.12	.02	1.92	.12	.00	.07
Fluency: Categories	.15 (.06)	.04	.04	3.84*	.13	.00	.44	.13	.00	.00	.13	.00	.17
WAIS: Digits Backward	.10 (.00)	.00	.00	.09	.09	.00	.32	.10	.01	.71	.10	.00	.22

* p < .05, ** p < .01

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test

Outcome Variable	Additional Variance Accounted for After Adding: Commission Errors for RT Task 4 (Interference 2)			Commission Errors for RT Task 5 (Interference 3)			RT for Task 1 (Speed)		
	R^2	R^2 Δ	F	R^2	R^2 Δ	F	R^2	R^2 Δ	F
BIMC	.08	.02	2.05	.11	.03	2.97	.15	.04	4.19*
Trails A	.16	.01	.68	.16	.00	.27	.17	.01	.79
Trails B	.26	.01	1.09	.26	.00	.10	.27	.01	1.16
Fluency: Letters	.12	.00	.12	.13	.01	.58	.13	.00	.23
Fluency: Categories	.14	.01	.99	.14	.00	.04	.15	.01	.78
WAIS: Digits Backward	.10	.00	.07	.10	.00	.14	.11	.01	.64

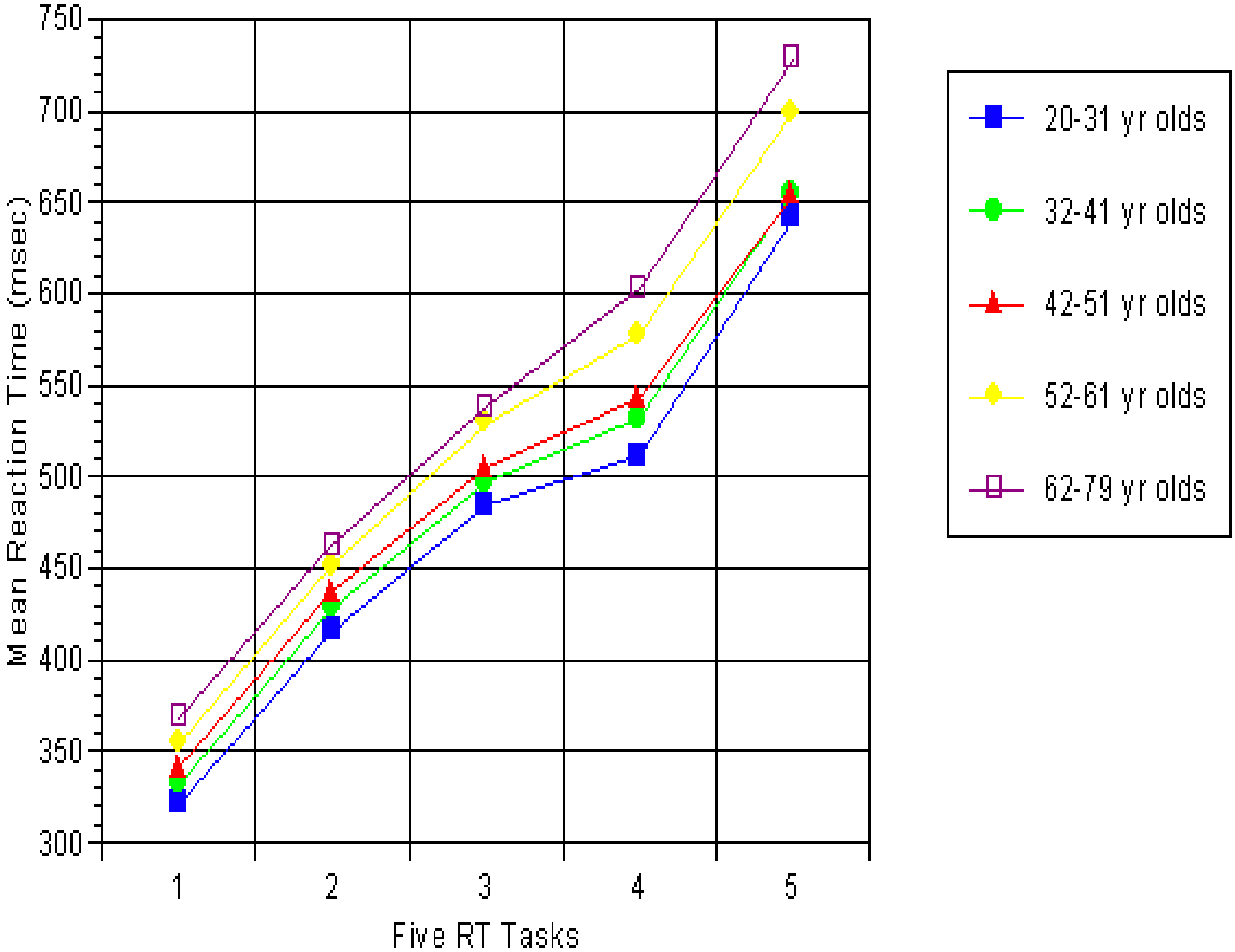
* $p < .05$, ** $p < .01$

Note: BIMC = Blessed Information –Memory-Concentration Test

MMSE = Mini-Mental State Examination

Trails = Trail Making Test

CVLT = California Verbal Learning Test



Note: RT task 1 = Press for '0'

RT task 2 = Press for a specific number

RT task 3 = Press for every odd number

RT task 4 = Press for every odd followed an even number

RT task 5 = Press for every odd followed by another odd and every even followed by another even

Figure 1.

Impact of Age on Mean RT Collapsed Across Time of Testing for the 5 RT Tasks Differing in Complexity

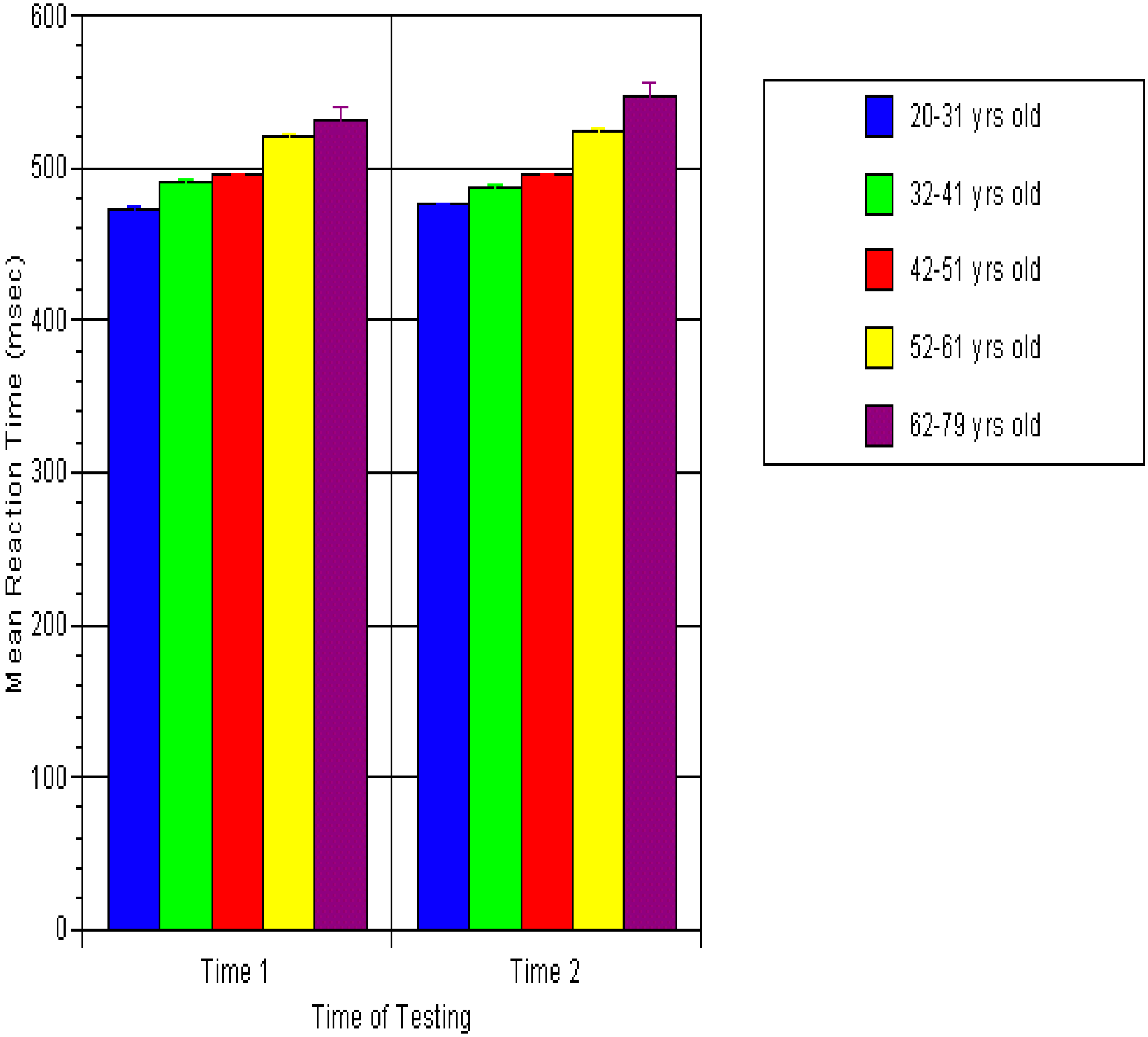
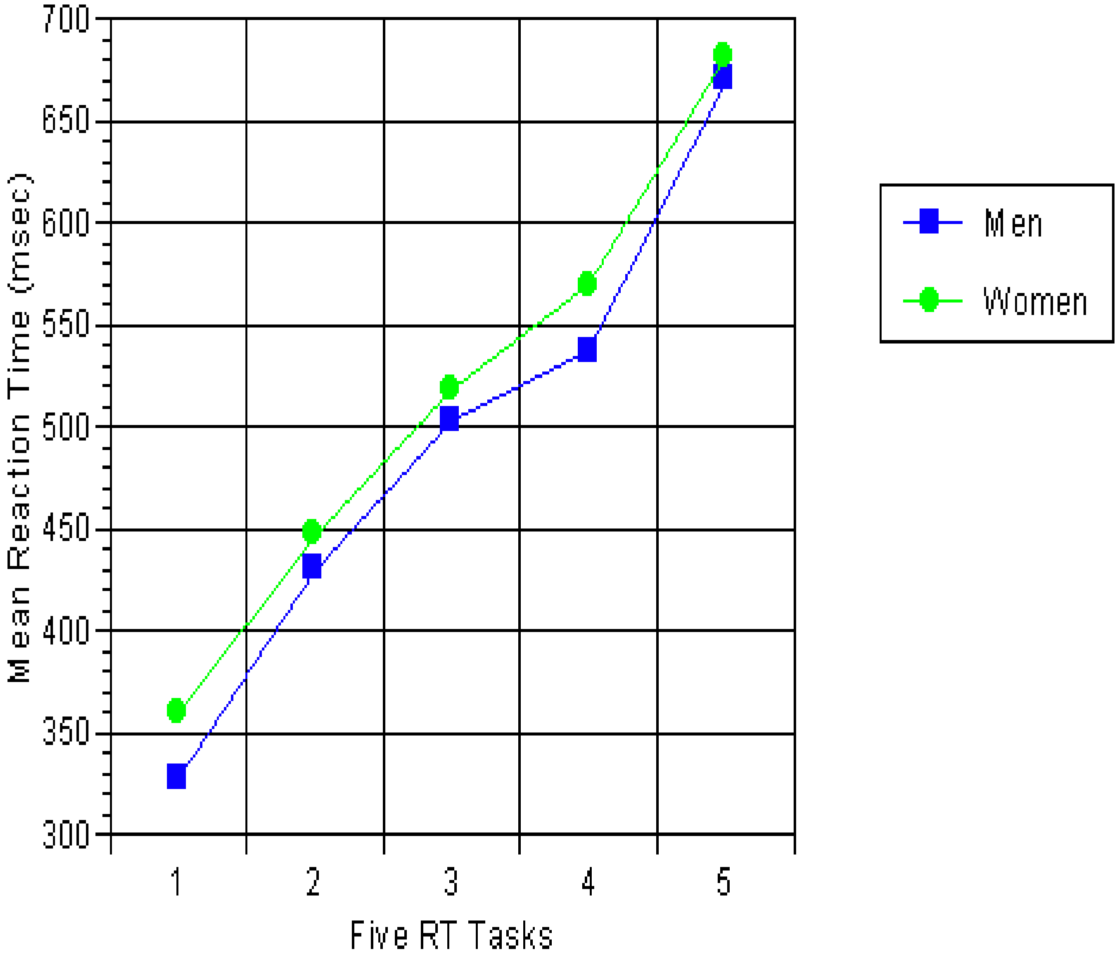


Figure 2.

Impact of Age and Mean RT Collapsed Across the Five RT Tasks: Initial and Follow-up 6 Years Later



Note: RT Task 1 = Press for '0'

RT Task 2 = Press for a specific number (e.g., 3)

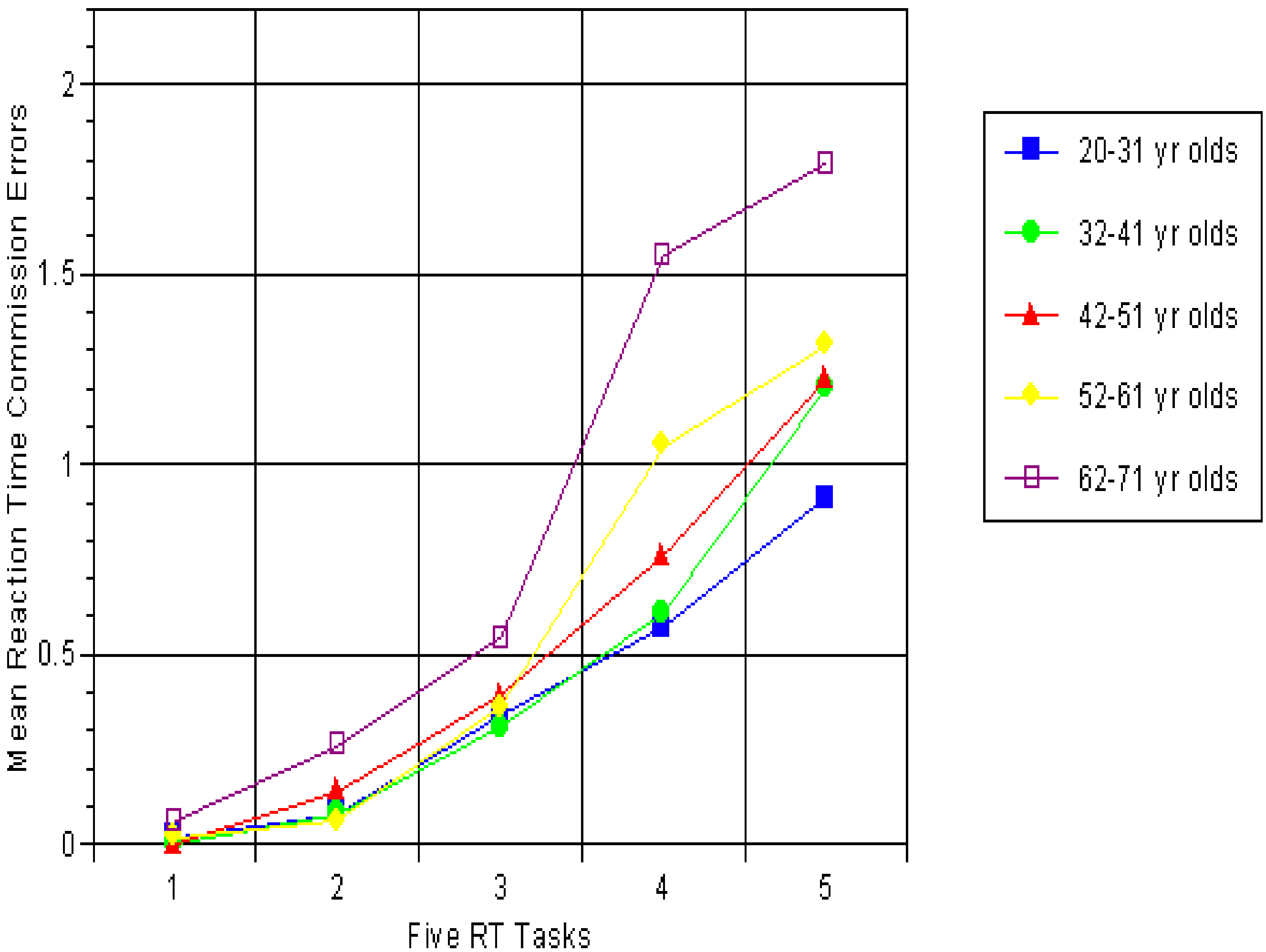
RT Task 3 = Press for every odd number

RT Task 4 = Press for every odd number followed by an even number

RT Task 5 = Press for every odd number followed by another odd number and every even number followed by another even number

Figure 3.

Potential Sex Differences on the 5 RT Tasks Collapsed Across both Times of Testing



Note: RT Task 1 = Press for '0'

RT Task 2 = Press for a specific number (e.g., 3)

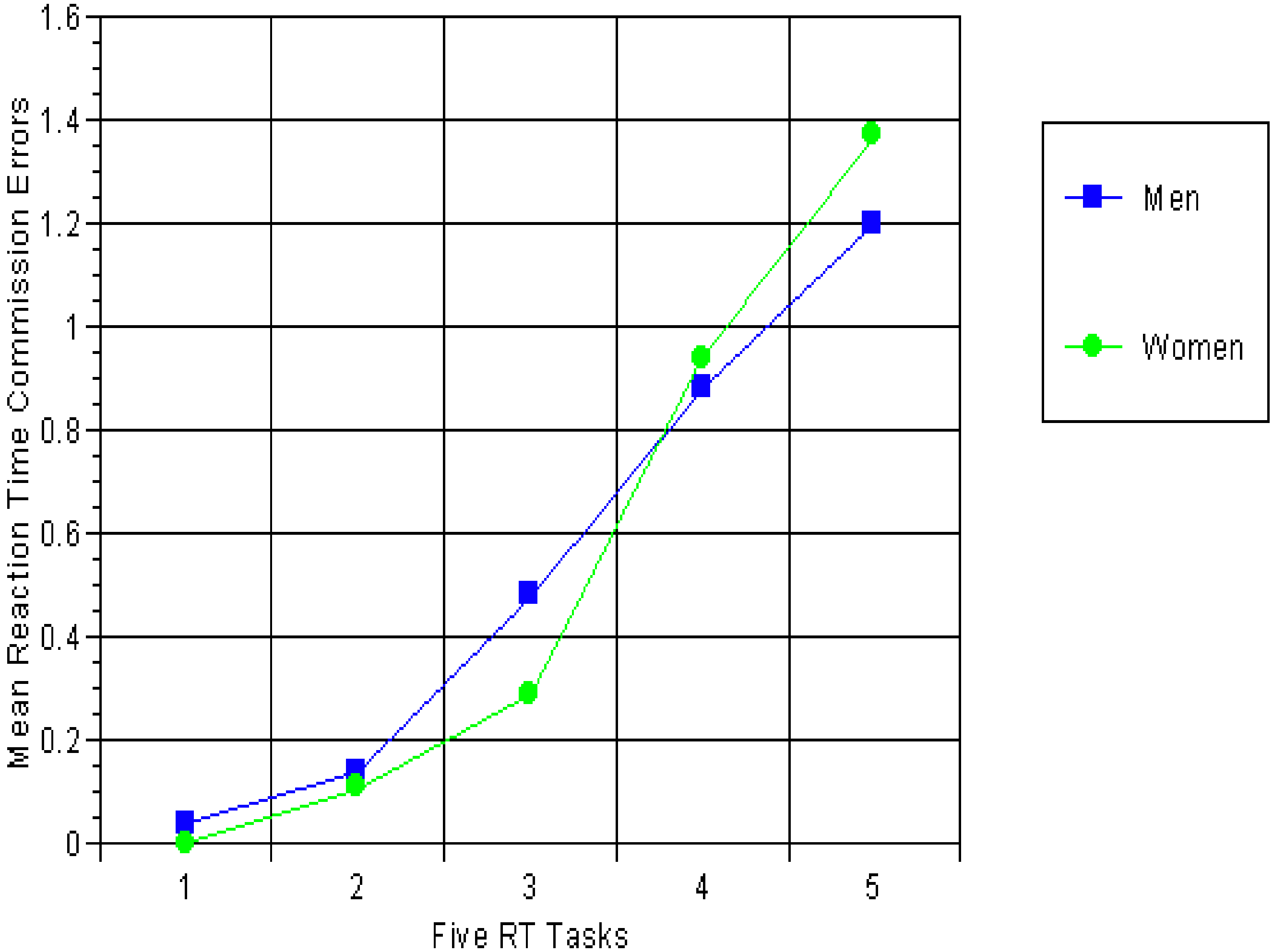
RT Task 3 = Press for every odd number

RT Task 4 = Press for every odd followed by an even number

RT Task 5 = Press for every odd followed by another odd and every even followed by another even number

Figure 4.

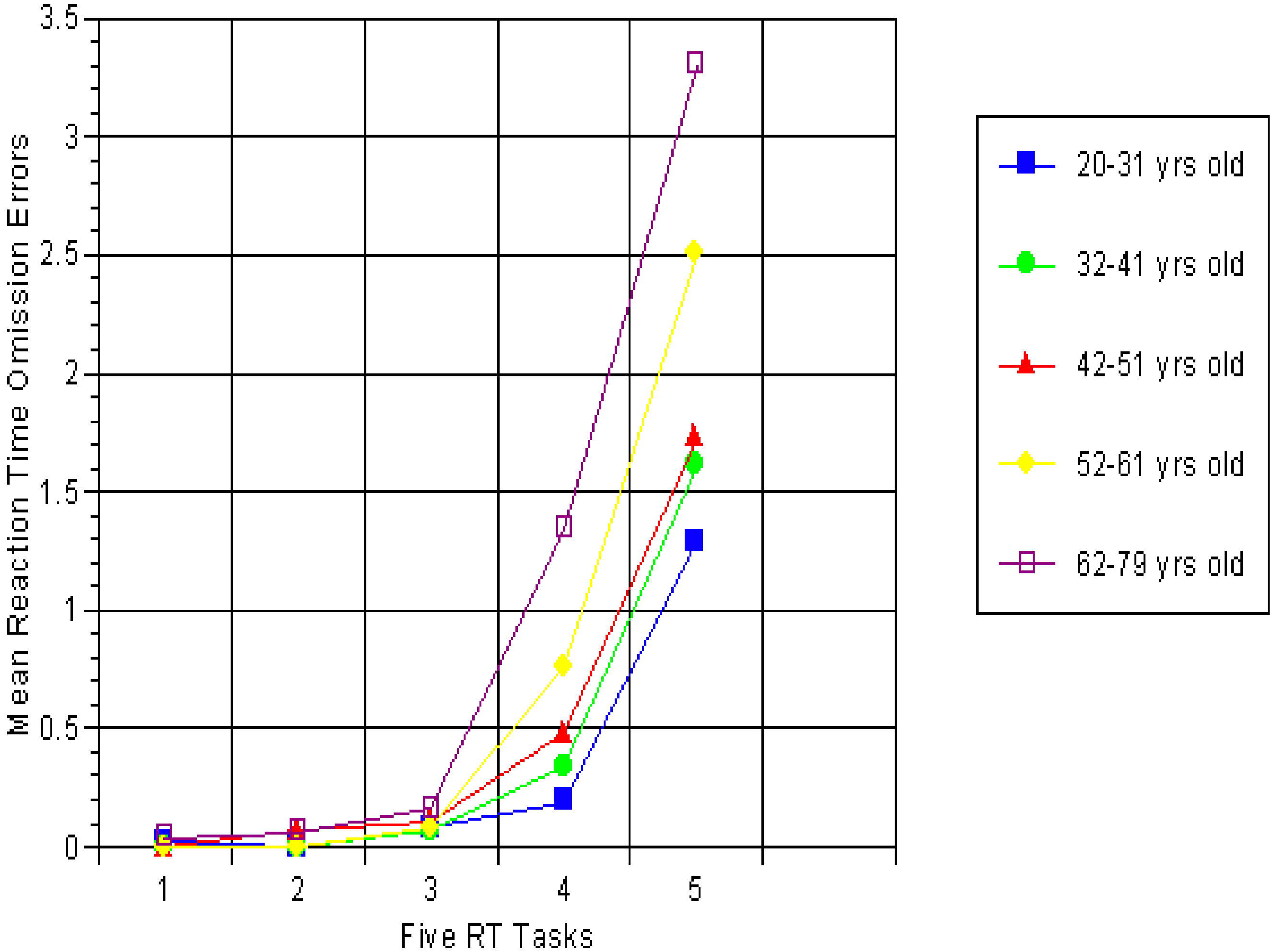
Impact of Age on Mean RT Commission Errors Collapsed Across Time of Testing for the 5 RT Tasks Differing in Complexity



Note: RT Task 1 = Press for '0'
RT Task 2 = Press for a specific number (e.g., 3)
RT Task 3 = Press for every odd number
RT Task 4 = Press for every odd followed by an even number
RT Task 5 = Press for every odd followed by another odd and every even followed by another even number

Figure 5.

Potential Sex Differences on Mean RT Commission Errors for the 5 RT Tasks Collapsed Across Time of Testing



Note: RT Task 1 = Press for '0'

RT Task 2 = Press for a specific number (e.g., 3)

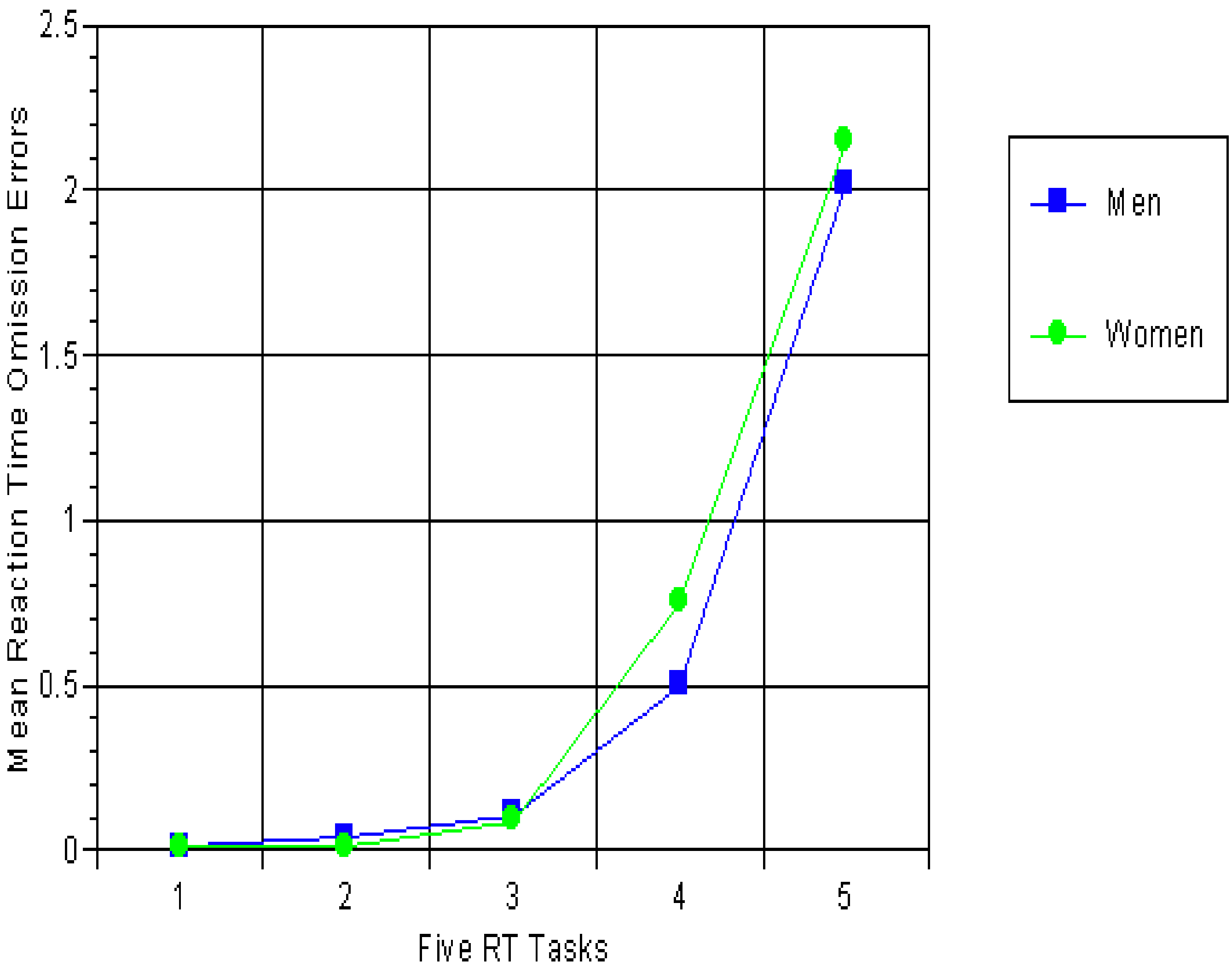
RT Task 3 = Press for every odd number

RT Task 4 = Press for every odd followed by an even number

RT Task 5 = Press for every odd followed by another odd and every even followed by another even number

<u>Figure 6.</u>

<u>Impact of Age on Mean Reaction Time Omission Errors Collapsed Across Time of Testing for the 5 RT Tasks Differing in Complexity</u>



Note: RT Task 1 = Press for '0'
RT Task 2 = Press for a specific number (e.g., 3)
RT Task 3 = Press for every odd number
RT Task 4 = Press for every odd followed by an even number
RT Task 5 = Press for every odd followed by another odd and every even followed by another even number

Figure 7.

Potential Sex Differences on Omission Errors for the 5 RT Tasks Collapsed Across Time of Testing

CURRICULUM VITAE

<u>Name:</u> Melissa H. Kitner-Triolo, Ph.D.

<u>E-mail address:</u> melissa@lpc.grc.nia.nih.gov

<u>Citizenship:</u> USA

<u>Education:</u>

1984 B.A., Towson State University (Psychology, Sociology), Towson, MD

1987 M.A., Towson State University (Experimental Psychology), Towson, MD

Thesis Topic: <u>Secretaries' and Their Supervisors' Attitudes Toward Computers</u>

2000 Ph.D., Virginia Polytechnic Institute and State University (Psychological Science)Blacksburg, VA.

Dissertation Topic: <u>Predicting Future Age-Related Cognitive Decline: Processing Speed And Frontal Lobe Functioning</u>

<u>Professional Experience:</u>

1983-85 Research Assistant, Psychology Department, Towson State University

1984 Researcher, Maryland Science Center

1984 Behavioral Statistics Teaching Assistant, Psychology Department, Towson State University.

1985-86 Assistant Head General Psychology Teaching Assistant, Psychology Department, Towson State University

1985-86 Statistical Analyst, Kids In Safety Seats Project, State of Maryland

1985-86 Research Assistant, Laboratory of Personality & Cognition, Gerontology Research Center, National Institute on Aging, National Institutes of Health, Baltimore

1986 Summer Research Fellow, Laboratory of Personality & Cognition, Gerontology Research Center, National Institute on Aging, National Institutes of Health, Baltimore

1986-87 Teaching Assistant, Psychology Department, Virginia Polytechnic Institute and State University

1987-89 Research Assistant, Psychology Department, Virginia Polytechnic Institute and State University

1989-pres Psychologist, Laboratory of Personality & Cognition, Gerontology Research Center, National Institute on Aging, National Institutes of Health, Baltimore

Societies

American Psychological Association

Maryland Gerontological Association

Cognitive Neuroscience Society

Honors and Awards

1978-80 House of Delegates Scholarship, State of Maryland

1984 Psi Chi National Honor Society in Psychology (chapter president)

1984 Outstanding Student in Psychology Award, Towson State University

1985 Who's Who Among Students in American Universities and Colleges

1985-86 Graduate Dean's Fellowship, Towson State University

1986 Summer Research Fellowship, Laboratory of Personality & Cognition, Gerontology Research Center, National Institute on Aging, National Institutes of Health

1986-87 Institutional Scholarship, Virginia Polytechnic Institute and State University

1991 Department of Health and Human Services, Employee of the Month Award

1994 Department of Health and Human Services, On the Spot Award

1997 Department of Health and Human Services, Special Act/Service Award

1998 Department of Health and Human Services, Employee of the Month Award

1999 Department of Health and Human Services, On the Spot Award

2000 Department of Health and Human Services, Employee Recognition Award

2000 Certificate In Gerontology, Virginia Polytechnic Institute and State University

Publications

1. Figler, M., Canoune, H. L., Kitner-Triolo, M. H. The effects of duration of territorial residence on aggression in convict cichlids. *Bulletin of the Psychonomic Society*. 1986; 24: 465-466.

2. Crawford, H. J., Kitner-Triolo, M. H., Clarke, S. W., & Brown, A. M. EEG activation patterns accompanying induced happy and sad moods: Moderating effects of hypnosis and hypnotic responsiveness level. *International Journal of Clinical and Experimental Hypnosis.* 1988; 36: 229. Abstract

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Papers and Posters Presented

1. Furukawa, J. M., & Kitner-Triolo, M. H. Cognitive processing capacity, age, teaching mode, word length and transfer effects in reading and spelling. Paper presented at the eighth annual conference, Eastern Educational Research Association. Virginia Beach, VA. February, 1985.

2. Crawford, H. J., Clarke, S. W., & Kitner-Triolo, M. H. EEG activity pattern differences in low and high hypnotizables: Reflections of cognitive strategy differences? Paper presented at the Fourth International Psychophysiology Conference. Prague, Czechoslovakia. September, 1988.

3. Crawford, H. J., Clarke, S. W., & Kitner-Triolo, M. H. EEG activation patterns accompanying induced happy and sad moods: Moderating effects of hypnosis and hypnotic responsiveness level. Paper presented at the annual scientific meeting of the Society for Clinical and Experimental Hypnosis (SCEH). Asheville, NC. November, 1988.

4. Kitner-Triolo, M. H., Crawford, H. J. & Clarke, S. W. Transient positive and negative experiences in stage hypnosis. Poster presented at the annual scientific meeting of the Southeastern Psychological Association. Washington, DC. March, 1989.

5. Clarke, S. W., Crawford, H. J., Kitner-Triolo, M. H., & Olesko, B. EEG correlates of emotions: Moderated by hypnosis and hypnotic levels. Paper presented at the annual conference of the American Psychological Association. New Orleans, LA. August, 1989.

6. Crawford, H. J., Kitner-Triolo, M. H., & Clarke, S. W. Transient positive and negative experiences in stage hypnosis participants. Paper presented at the annual scientific meeting of the Society for Clinical and Experimental Hypnosis (SCEH). ST. Louis, MO. November, 1989.

7. Brown, M. L., Clarke, S. W., Kitner-Triolo, M. H., & Crawford, H. J. Mathematics and visuo-spatial skills: Relationships and gender differences. Paper presented at the annual meeting of the Southeastern Psychological Association, Atlanta, GA. April, 1990.

8. Zonderman, A. B., Kitner-Triolo, M. H., & Costa, P. T., Jr. Personality changes predict diagnosis of dementia. Poster presented at the NIH poster day. Baltimore, MD. 1990.

9. Giambra, L. M., & Kitner-Triolo, M. H. Continuous association and the general slowing hypothesis, the fountain-head experiment revisited. Paper presented at the Cognitive Aging Conference. Atlanta, GA. April, 1996.