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Training And Transfer Of Attentional Control In Older Adulthood

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TRAINING AND TRANSFER OF ATTENTIONAL CONTROL IN OLDER ADULTHOOD

by

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Abstract

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Adulthood

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Recent research in cognitive aging has brought renewed interest to a decades old question. Can cognitive skills be trained, and if so, how widely does that trained skill transfer? Previous research has demonstrated that older adults are able to improve their performance on laboratory cognitive tests and in some cases these benefits can transfer to other similar tests (e.g. Kramer et al., 2004). A few cases have demonstrated transfer to more distal outcomes (Willis et al., 2006). This area of research is still in an early stage, and reports are mixed with regard to the efficacy of cognitive training. These mixed findings are obscured by differences in methodology and construct conceptualization. For example, many studies do not include a control condition, fail to consider practice effects as an account for posttest gains in test performance, or use outcome measures that lack a validated association with the targeted intervention.

This dissertation tested the transfer of cognitive training using an experimental approach that addressed previous limitations. A circumscribed set of cognitive variables representing processing speed, working memory, response distractor inhibition, and task switching were chosen to examine reliability, construct validity, and to characterize the training task.

Training-related gains in performance were demonstrated in a group of healthy older adults. Transfer of training-related gains was greater than practice-related improvement observed in a control group on a novel, but similar task. Transfer to more remote cognitive variables associated with the training task were examined and indicated a possible relationship between training and cognitive processing speed.

An important methodological aspect of this dissertation was the demonstration of the need to incorporate factor analytical approaches into the study of construct-level phenomena (e.g., attention), although large samples and high task reliability are prerequisite conditions for this approach and can be difficult to obtain. Further studies are needed to delineate the constructs associated with observed training gains and to specify the type and extent of transfer of training-related skills.

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CHAPTER 1: INTRODUCTION

As our older adult community grows over the next few decades it will be important for them to keep pace with their expectations. Older adults are choosing to remain in the workforce longer and to engage in more active lifestyles in retirement. Previous research has demonstrated that older adults are able to improve their performance on laboratory cognitive tests and in some cases these benefits can transfer to other similar tests and more distal outcome measures. This area of research is still in an early stage and reports are mixed with regard to the efficacy of cognitive training. The prevailing opinion is one of caution regarding generalizability. These mixed findings are obscured by differences in methodology and construct conceptualization. For example, many studies do not include a control condition, fail to consider practice effects as an account for posttest gains in test performance, or use outcome measures that lack a validated association with the targeted intervention.

Therefore, the mechanisms underlying these improvements (when found) are not well understood. It is not known if working on crossword puzzles is related to slower cognitive decline because it is a trait of people who tend to do well on other tests of cognition or if the crossword puzzles themselves boost an individual's skill on these other tests. If there is a causative relationship, it remains to be determined through what aspect of cognition it manifests. One goal of the present dissertation was to begin to answer some of these questions with an ultimate aim to keep our community living in independence and vitality with each advancing year.

In addition to a growing community of healthy older adults seeking to maintain vitality, the growth of age-related disease is increasing the functional limitations of our older adult community. The same cognitive training paradigms developed to improve performance among healthy older adults may also benefit those affected by disease. A second goal was, therefore, to characterize the aspects of cognition targeted and potentially improved through this training paradigm in order to facilitate its portability to other populations that may derive benefits.

This dissertation tested for the transfer of cognitive training using an experimental approach that improves upon previous limitations. A circumscribed set of cognitive variables were chosen to further establish the reliability and construct validity of relevant measures of cognition as well as their relationship to the training task. Training-related gains in performance were measured against a control condition, and transfer was examined.

CHAPTER 2: LITERATURE REVIEW

Overview

The scope and magnitude of age-related changes in cognition have been the focus of much research for the last 50 years (e.g., Balota, Dolan, & Duchek, 2000; Baltes & Schaie, 1974; Craik & Byrd, 1982; Salthouse 1996, 2004; Schaie, 1958, 2005). The first section of this chapter provides a brief overview of the findings on age-related changes in intelligence and memory--two aspects of cognition. Then age-related differences in basic mechanisms that may underlie more complex cognition are described. The next section discusses research that suggests a potential for cognitive plasticity in later life. Cognitive training studies developed in response to observed age-related declines in intelligence, memory, processing speed, and executive function are reviewed. Finally, the theoretical and methodological limitations of previous training studies are discussed along with the importance of continued work in the area of cognitive training.

Age-Related Changes in Cognition

Intelligence

Early psychometric studies of intelligence identified groups of abilities (Thurstone, 1938) as better descriptors than a single score such as g (Spearman, 1904). Horn and Cattell (1966) classified these abilities into two broad groupings named fluid and crystallized intelligence. Fluid abilities are closely linked to physiological functioning. They represent an individual's ability to think and act in situations that are novel and are, therefore, less reliant on the context of one's culture or educational attainment. Reasoning, episodic memory, and speed of processing are considered part of an individual's fluid abilities. Crystallized intelligence, on the other hand, is the accumulation of knowledge over the lifetime through formal education or life experience. It can be measured by verbal, semantic memory, numerical, or other factual information. Crystallized intelligence is related to physiological functioning indirectly through an individual's reliance on fluid abilities for the initial acquisition of content.

Age-related changes in intelligence tracked over 50 years as part of the Seattle Longitudinal Study show different trajectories of decline for fluid and crystallized abilities. Fluid abilities decline earlier and gradually in old age, and crystallize abilities remain fairly stable until the mid-70s and then decline precipitously (Schaie, 1996). A similar pattern of intellectual abilities decline was observed in the Berlin Aging Study (Lindenberger & Baltes, 1997). Recent work from the Victoria Longitudinal Study (Dixon, 2003) indicated, however, that age-related decline in intellectual abilities is not as clear cut and yoked to specific age points as the averaged longitudinal data suggest. In fact, there is considerable variability in absolute decline and the time course of decline from person to person.

Memory

Complaints of memory failures are prominent among older adults. Careful examination of the scope of memory deficits in older adults reveals that memory difficulties are specific to certain systems or processes (see Balota, Dolan, & Duchek, 2000, for a review). This understanding of the specificity of age-related change in memory depended on a refinement of the understanding of memory systems in general. Converging evidence over the past 30 years of research in animal, memory-disordered patient, and normal populations has distinguished important multiple divisions within the memory system (see Table 1 and Squire, 2004). The most prominent distinction is between memories that are available for conscious recollection and those that are not. Earlier conceptualizations dichotomized memory based on evidence of this distinction into explicit and implicit memory (Graf & Schacter, 1985), declarative and procedure knowledge (Cohen & Squire, 1980), and memory and habit (Mishkin, Malamut, & Bechevalier, 1984). Growing evidence of multiple biological systems related to memory performance that distinguished among aspects of nondeclarative memory led researchers to abandon a single term to describe memory that was not declarative and to adopt the umbrella term of *nondeclarative* memory to represent a number of independent systems. According to Squire (2004, p.173), "declarative memory is representational. It provides a way to model the external world, and as a model of the external world it is either true or false." Nondeclarative memory, in contrast, "is dispositional and is expressed through performance rather than recollection. Nondeclarative forms of memory occur as modifications within specialized performance systems." Nondeclarative systems are distinct and distributed in structures including the amygdala, cerebellum, striatum, neocortex, and reflex pathways. Forms of nondeclarative memory include priming and perceptual learning, simple classical conditioning, procedural (skill and habit) memory, and nonassociative learning.

Declarative memory is related to the medial temporal lobe and diencephalon, and it takes two broad forms--factual and event based. Factual (also called semantic) memory is a representation of facts about the world. Event-based (also called episodic) memory is the capacity to re-experience an event in the context in which it originally occurred. Thus, the distinction between semantic and episodic memory is that the consciously

Table 1 Divisions Within the Memory System		
Declarative		
	Episodic	Event-based; re-experience of event in the context in which it originally occurred
	Semantic	Factual; representation of facts about the world
Nondeclarative		
	Procedural	Skills and habits
	Priming	Facilitated performance on the basis of prior exposure
	Classical Conditioning	Exposing an organism to relations between events
	Nonassociative Learning	Behavioral change brought about by repeated exposure to a stimulus (E.g., sensitization)

recollected memory is yoked to specific contextual information in the case of episodic memory, whereas it is not for semantic memory. Further, episodic memory requires frontal lobe structures in addition to the medial temporal lobe structures that support both semantic and episodic memory (Shimamura & Squire, 1987). The experience of a memory is considered to be represented on multiple levels based on the coordination of these multiple parallel systems. Distinctions among the systems are found in experimentation that involves targeted disruption of individual systems. This disruption may occur from experimental manipulation (e.g., lesioned animal models) or by capitalizing on naturally occurring disruptions (e.g., patient models). Another naturally occurring change is the disruption to memory systems in old age.

Comparisons of young and older adults on tests of memory have found that older adults perform in a similar manner to young adults on tests of nondeclarative memory, whereas tests of declarative memory reveal robust age-related differences in performance (but see LaVoie & Light, 1994, for small but significant age effects in nondeclarative memory). Tests that require recollection from episodic memory show the greatest decline. Typically, semantic memory is preserved with healthy aging.

Within episodic memory further subdivisions of memory stores include sensory, short-term, and long-term memory. Sensory memory systems hold relatively unprocessed information from receptive systems such as the visual or auditory system for very brief durations. These early memory systems show very little age-related change (Kline & Orne-Rogers, 1978; Parkinson & Perry, 1980).

Similarly, few age differences are found in short-term memory. This form of memory involves the maintenance of small amounts of information over very short periods of time with low levels of interfering information. Under such circumstances young and older adults appear to perform similarly in both short-term memory capacity and rates of forgetting (Zacks, Hasher, & Li, 2000). A recent meta-analysis, however, found age differences on tests of simple verbal memory span, considered to be a measure of short-term memory (Bopp & Verahaeghen, 2005). Lustig and colleagues demonstrated that increasing the amount of proactive interference in a memory span task magnified the age effect. Thus, proactive interference, rather than a difference in memory capacity, may be an uncontrolled factor that explains mixed findings of age-related difference in simple memory span (Lustig, May, & Hasher, 2001). Age-related performance on working memory span measures (tasks that combine elements of simple span storage with the manipulation of information in the ongoing task), however, show robust decline with increasing age (Salthouse, 1991).

Long-term episodic memory is the context in which the largest age-related differences in memory have been most consistently reported. Memory failures for recently acquired names of people or places are common among healthy older adults (see Balota, Dolan, & Duchek, 2000, for a review). Experiments that require participants to remember items over various delays have reported absolute differences in memory capacity but age equivalence for retention of those items over time. In other words, older adults may store fewer items in memory than younger adults, but rates of forgetting the information that was stored is the same (Giambra & Arenberg, 1993; Park, Royal, Dudley, & Morrell, 1988).

Another important aspect of memory research is to consider the process of encoding, storing, and retrieving information in addition to the memory system involved.

This distinction among these processes of encoding, storage, and retrieval is supported by aging research. Encoding and retrieval processes reveal age-related differences in performance, whereas storage is relatively unchanged. Encoding is the process of consolidating information into memory. The greater the processing of information during learning, the more likely it will be remembered (Craik & Lockhart, 1972). Older adults process information at a shallower level than their younger counterparts (Craik & Byrd, 1982), and this has been proffered as an explanation for poorer memory performance. Retrieval deficits in aging are difficult to disentangle from the same processes that affect encoding, such as reduced effortful processing or increased interference effects (see Craik, 1986; Craik et al, 1995; Zacks, Hasher, & Li, 2000). Evidence that the intervening process of maintenance of information over delay (storage) remains fairly intact is further supported by the observation that older adults are able to benefit from cueing. The largest age effects are in free recall tests, and smaller effects of age are observed as more supporting information is presented (i.e., cued and recognition; Craik & McDowd, 1987).

In the following sections the discussion will focus on more recent work examining elementary processes or systems considered as potential mediators of age-related changes in complex behaviors such as intelligence and memory. The review will focus on evidence for age-related differences within these mechanisms rather than the body of literature establishing their mediating role in more complex cognition.

Mechanisms

Attention

Cohen (1993, p. 3) said, “Attention facilitates the selection of salient information and the allocation of cognitive processing appropriate to that information. Therefore, attention acts as a gate for information flow in the brain." With this ubiquity comes difficulty asserting specific contributions of attention independent of its reliance on, or relationship to, speed of processing, working memory, and inhibitory control. Nevertheless, the following review highlights important aspects of attention research as related to aging.

Attention can be considered in terms of how it is allocated. Two important aspects of controlled attention (see Shiffrin & Schnieder, 1977, and Norman & Shallice, 1980) are selective and divided attention. Selective attention has been operationally defined as performance in a condition in which multiple sources of information are possible for processing but only a subset are relevant. Performance in this condition is usually compared with one in which only relevant information is present. The Stroop color-word task is a common measure purported to tap selective attention (MacLeod, 1991). In this task one aspect of the stimulus (e.g., color) is processed while other aspects of the stimulus (e.g., word) are ignored. The interference comes from the similarity of the two aspects of the stimulus (e.g., the stimulus is a word that names a different color than the stimulus color). The notion is that the relative automaticity of reading the word interferes with color naming. Older adults tend to show greater susceptibility to this form of interference than younger adults, although the interpretation of the cause of the interference is contentious (Comalli, Wapner, & Werner, 1962; Earles et al. 1997; Hartley, 1993; Salthouse & Meinz, 1995; Spieler, Balota, & Faust, 1996).

Divided attention is the allocation of attention to two or more tasks concurrently. The ability to divide attention is often measured by performance changes on a single task associated with the addition of a second concurrent task. Age-related performance decrements are well established for dual-task situations (Craik, 1977; Kramer & Larish, 1996). The controversy arises over the explanation offered for this finding. One suggestion is that older adults have a specific impairment in the coordination of two or more tasks at a time. It is also possible that the age-related difficulty on more than one task is due to the combined difficulty of each component task and not due to the process of coordination.

Hartley (1992) originally asserted that dual task differences are caused by the affect of age on each of the component processes. In further examination of this assertion, however, Hartley and Little (1999) conducted a series of experiments in which they found no evidence for impairment in the ability of older adults to coordinate simultaneous tasks. The age differences found in their study appeared to relate to the degree of input and output interference in the task.

Continuing to address this question of whether robust age differences on dual tasks are specific to the coordination of two tasks or arise from component task difficulty, Salthouse, Fristoe, Lineweaver, and Coon (1995) predicted dual-task performance using age differences in the component tasks. Although age-related differences in dual task performance were reduced after including single task performance as a covariate, unique age-related variance in dual task remained. In other words, single task difficulty contributed to age-related differences in dual tasks but did not explain all of the age-related difference in dual task performance.

Tsang and Shaner (1998) conducted a study in which difficulty and structural similarity of the component tasks was manipulated as well as the priority of one task over the other (to test for flexibility of attention allocation). They concluded that there was an age-related deficit in dual task performance beyond that evidenced in the single tasks and proposed that this might be observed only when attentional demands are high. In addition, older adult's greater difficulty with the prioritization condition was interpreted as evidence for decreased flexibility of attentional control with age.

Verheaeghen and colleagues (2003) conducted a meta-analysis of dual task studies of aging and found that the age effect was additive but that it could not be accounted for by general slowing alone. Thus, they posited that the dual task (compared with single task) added another step for both the young and older adults and that this step was more costly for older adults.

Processing Speed

Measures of processing speed show robust age-related decline and account for large amounts of the age-related variance in other cognitive tests such as fluid intelligence, memory, and reading comprehension. This has led researchers to posit that age differences could be the consequence of general slowing within a cognitive system that is relatively constant across domains (Cerella, 1985; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1996).

Salthouse (1996) offered two possible mechanisms to explain the relationship between measures of processing speed and other aspects of cognition. First, there may be a time limitation for certain mental processes such that only early stages of processing are completed due to slowed execution and thus the computation is not fully carried out. Another possibility is that there is a necessary simultaneity of processing for certain tasks and that slowing could disrupt this interdependence among the processing streams in order to successfully carry out the computation. Both accounts incorporate findings of incorrect as well as delayed responses and further explain how slowed processing may not benefit simply from increased time on task for older adults.

Subsequent research has built upon the finding of general changes in performance due to slowing by adjusting for a slowing factor of approximately 1.5 compared with average young adult performance (Verhaeghen & Salthouse, 1997). More recently, Verhaeghan and colleagues (2003) voiced a methodological concern about the interpretation of complex tasks given to young and older adults. Participants of any age will typically perform a more difficult task slower. If it is true that all tasks will be affected by a multiplicative slowing factor of approximately 1.5 for older adults compared with younger adults, then slowing due to task complexity will be magnified by this constant age-related slowing factor. The implication of such an interaction of slowing due to task difficulty and age is that the relatively greater slowing demonstrated by older adults compared with younger adults on a more complex task may be sometimes misinterpreted as evidence for age-specific deficit that is more than simply a manifestation of task complexity and a constant slowing factor. Therefore, it is important to identify whether an observed age difference is due to the interaction of task difficulty and general slowing or if it is related to some other specific age-related deficit (Verhaeghan, Kliegl, & Mayr, 1997).

To address this concern Faust, Balota, Spieler, and Ferraro (1999) proposed a rate-amount model that predicts linear relationships between individuals that included global processing parameters based on large-scale group differences (such as differences in processing speed among young and older adults). They discussed several statistical approaches and argued for the utility of linear regression and *z* transformations to detect

Group x Treatment interactions in situations where group differences in information processing speed may obscure smaller effects.

Executive Function

Defining the construct. Stuss and Levine (2002) described executive function as a constellation of subprocesses coordinated to filter and manipulate information in the service of complex cognition. Despite attempts to give a broad, unifying definition to executive function, the complexity of this construct is apparent. Difficulty defining executive function comes, in part, from its clinical origin. Patients with frontal lobe injury and subsequent inability to regulate goal-directed behavior or emotion have been described as having impaired executive functioning (Shallice & Burgess, 1991; Stuss & Alexander, 2000). A lesion-based approach to define executive function is cumbersome because of the wide range of functions mediated by the frontal lobes and their extensive interconnections with other brain regions. Thus, executive functions are processes that influence many behaviors.

As an alternative to a lesion-based approach to define executive function, cognitive psychologists have used latent variable analysis (e.g., Miyake et al., 2000). This statistical approach identifies common variance across multiple measures purported to tap executive functions. This technique resolves common aspects of the tasks that purportedly relate to executive function and separates those from the unique task elements that are likely to recruit widespread brain systems. This approach has furthered our understanding of the interrelation among tasks considered to assess executive function, in some cases. It has also revealed relatively low correlations among tasks previously thought to be interchangeable.

Two areas of research considered under the general rubric of executive function that have important implications in aging research are working memory and inhibitory control.

Working memory. Working memory refers to the dynamic relationship between passive storage and active manipulation of information. Baddeley and Hitch's (1974) model of working memory refers to a central executive that coordinates information held in temporary storage systems. The storage system for auditory information is called the phonological loop. The storage system for visual information is called the visuospatial sketchpad. More recently, Baddeley (2000) added an episodic memory buffer to the theoretical model. Its purpose is to temporarily store information held in a multimodal code, which is capable of binding information from the subsidiary systems and from long-term memory into a unitary episodic representation.

The central executive is a control process in line with Norman and Shallice's (1986) supervisory attentional system. The central executive is charged with coordinating the subsidiary temporary storage systems to bind information from those systems together and switch among them as well as to switch among tasks or strategies. The central executive implies a unitary nature to the control process that has not been borne out in the literature (see Miyake et al, 2000). Broadly defined, however, this central executive is still considered to be the critical component that mediates the relationship between age and a wide variety of cognitive tasks (Engle, Kane, & Tulholki, 1999; Salthouse, 1996).

Working memory can be operationally defined in terms of a score on a working memory span task. Measures of working memory span such as reading span (Daneman

& Carpenter, 1980), listening span (Babcock & Salthouse, 1990), and computation span (Salthouse & Babcock, 1991) require participants to read or listen to a sentence for comprehension or solve a math problem while also storing a word or digit for later retrieval. Span is measured by the longest series a participant can accurately execute and retrieve. Age differences in working memory span are robust, and potential explanations for these differences include reduced processing resources (Craik, Morris, & Gick, 1990), decreased processing speed (Verhaeghaen & Salthouse, 1997), failure of inhibitory control (Hasher & Zacks, 1988), and increased difficulty coordinating complex tasks (Mayr & Kliegl, 1993).

Inhibitory control. Hasher and Zacks (1988) explained the reduced capacity for working memory in older adults by proposing a breakdown in inhibitory control. They built upon the framework of Norman and Shallice's (1986) model of attentional control and considered the key element to be the constraints imposed on what information is processed. For example, information entering working memory must be constrained such that only relevant information is able to gain access to processing. If irrelevant information is active, it must be deleted. Older adults are less efficient in this gating and deletion process. Words that were no longer relevant due to the context of the sentence persisted longer in older adults (Hartman & Hasher, 1991), and older adults required more time to reject a lure from an irrelevant memory set compared with younger adults (Oberauer, 2001). Further, there is evidence of disproportionate interference effects for older adults on nonmemory tasks such as in a picture-word interference paradigm (Duchek, Balota, Faust, & Ferraro, 1995) and the Stroop task. Older adults showed a disproportionate increase in interference on the Stroop color-word naming task compared with younger adults, consistent with an inhibitory failure in normal aging (Spieler, Balota, & Faust, 1996).

Kramer and colleagues (1994) examined age-related differences in inhibitory function across a number of tasks. They found support for specific, rather than general, effects of age on tasks purported to measure inhibition. Perseveration errors on the Wisconsin Card Sorting Test and stop-signal delays showed age-related deficits, whereas measures of response compatibility (i.e., Eriksen & Eriksen, 1974) and negative priming (see Tipper, 1985) did not. One interpretation of these data, suggested by the authors, is that inhibitory control tasks are not subserved by a unitary mechanism and that observed age-related differences are yoked to frontally mediated tasks of inhibition.

Friedman and Miyake (2004) used latent variable analysis in a sample of young adults to test the unity of a broad range of tasks considered to assess aspects of inhibition. They identified two latent variables--Response Distractor Inhibition and Resistance to Proactive Interference--based on the tasks they modeled. Response Distractor Inhibition included the following tasks: antisaccade, Eriksen flanker task, Stroop interference, stop signal, word naming (with interference), and shape matching (with interference). Proactive Interference included the following tasks: Brown-Peterson variant, paired associates task, and a cued recall task with interference. In addition to identifying this two factor structure among the tasks, the relationships among these factors and other measures of cognition such as task switching and reading span were examined. Task switching was found to be strongly associated with the Response Distractor factor and reading span was found to be associated with the Proactive Interference factor.

Cognitive Plasticity in Later Life

Behavioral Evidence

There is increasing evidence that cognitive decline associated with age may be mutable. Support for this position comes from the observation of practice effects on cognitive tasks (Benedict & Zgaljardic, 1998; Schaie, 1996). Despite poorer absolute performance when older adults are compared with young people, older adults show expected performance gains with practice. Improvement on memory, attention, and language tasks are evident from the first to second exposures of a test and across trials within a single testing session (e.g., Baron & Surdy, 1990). Despite baseline mnemonic differences, young and older adults can produce equivalent levels of recall with enough practice on a free recall list-learning task (Kahana, Howard, Zaromb, & Wingfield, 2002). In fact, a lack of performance gains may be a hallmark for disease-related cognitive decline (Boron, Turiano, Willis, & Schaie, 2007).

Another line of support for the position that cognitive changes related to age are not irreversible markers of a declining system can be found in recent work documenting performance variability within an individual. Cognitive decline associated with age is generally described in terms of mean levels of performance in a single instance across age cohorts (cross-sectional) or over time within the same cohort (longitudinal). Variability, however, is another important aspect of cognitive performance (Hultsch, MacDonald, & Dixon, 2002; West, 2001). In addition to an increase in performance variability across individuals with age, there are increases in across-trial intraindividual variability with age. Intraindividual variability has been implicated as an indicator of cognitive performance (Hultsch et al., 2002). Comprehensive documentation of interindividual variability across the range of tasks commonly used to characterize age trends is still needed. Salthouse (2007) examined within-person variability across a wide age range (18 to 97 years) of healthy adults for many cognitive and neuropsychological variables. He found large individual differences in variability that did not appear to be reliable and had few unique relations to age. Thus, single measurements may lack necessary precision and obscure longitudinal findings. Another recent study by Robertson, Myerson, and Hale (2006) did not find evidence for age-related increases in intraindividual variability on working memory spans. The authors suggested that the discrepant findings may be a statistical artifact of age-related slowing on measures of speeded performance.

Neuroimaging Evidence

There is a growing body of literature implicating the frontal brain networks in age-related cognitive change (e.g., Braver & Barch, 2002; Head, Raz, Gunning-Dixon, Williamson, & Acker, 2002; West, 1996). Recent neuroimaging studies have demonstrated that tasks purportedly measuring constructs such as working memory, controlled attention, and dual-task coordination reliably activate specific regions of the prefrontal cortex (e.g., Braver & Ruge, 2006; Erickson et al., 2007). Age and performance differences in task-related activation patterns have opened a new window into our view of changes in cognition with age.

Neuronal underpinnings of cognitive change with age were demonstrated to correlate with decreases in gray matter volume (e.g., Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; Head et al., 2002), white matter loss or loss of integrity of white matter (e.g., Madden et al., 2004), and metabolic disruption (e.g, Braver & Barch, 2002;

Castner & Goldman-Rakic, 2004). Although these findings are of great interest and relevance to an understanding of age-related deficits in memory and attention (among other aspects of cognition), the story has become more complex.

Logan and colleagues (2002) demonstrated the modulation of age-related underrecruitment of brain regions during different conditions of a memory task. When young and older participants were told to memorize words, younger adults performed better and activated regions critical for memory performance to a greater extent than did the older adults. Next, a strategy for memorization was provided in which participants were required to categorize the words to be remembered as either abstract or concrete. The memory performance of the older adults improved and activation of critical brain regions formerly underrecruited compared with younger adults increased. Although a pattern of underrecruitment of brain regions for older adults compared with younger adults does occur (e.g., Thomsen et al., 2004), evidence is accumulating that at least some regions are not necessarily lost and that activation can be modulated under certain strategic constraints.

Another source of observed cognitive improvement and thus further evidence of cognitive plasticity with age comes from studies of cardiovascular exercise. Colcombe and colleagues (2004) demonstrated in a 6-month longitudinal study that cardiovascular fitness (in the form of aerobic versus strength and toning fitness interventions) was associated with better performance on measures of cognitive control with coincident greater activity in task-relevant brain regions. Similar results from other human and animal laboratories (see Rosenzweig & Bennet, 1996, for a review of animal studies and Kramer, Bherer, Colcombe, Dong, & Greenough, 2004, for a review of both) have added to a growing interest in the study of interventions aimed to affect age-related differences in cognition.

Training Studies

Intelligence

The work of Willis and colleagues (e.g., 1986) from the Seattle Longitudinal Study distinguishes itself as both a well-designed training intervention and one that demonstrated improvement and transfer. Within the context of a longitudinal study participants received training over five 1-hour training sessions on strategies to improve performance on tests of inductive reasoning and spatial orientation. Improvements were observed for the trained tasks as well as other similar tasks, and these gains were maintained over a 7-year follow-up. An independent study highlighted the importance of accounting for practice effects in training studies and supporting evidence for the efficacy of reasoning training (Hayslip, 1989). Further, researchers from the Berlin Aging Study identified that reasoning training could be accomplished via strategies already in an older adults' repertoire; reliance on the trainer was not the crucial element for training success (Baltes, Kleigl, & Dittmann-Kohli, 1988).

Although researchers were able to find reliable demonstrations of improvement on cognitive tests with strategy training, an important question remained in the early studies. That is, the functional effect of improvement with training was not tested. In response to this need and to the methodological weakness of studies with little experimental control, a multisite randomized controlled single-blind trial with four treatment groups was initiated. Willis et al. (2006) reported on the results from a 5-year follow up. The four groups included memory, reasoning, and processing speed training groups and a control group. The training groups received 10 sessions of approximately 1 hour each. Cognitive tests were used to assess the specific training effects, and functional outcome measures were used to test the effect of improved cognition on everyday functioning. All training groups were successful to the degree that they showed improvement on other cognitive tests from the domain for which training was supplied. Improvements were not obtained in the untrained domains. Small but significant effects were found for instrumental activities of daily living. Age-related cognitive declines often lead to difficulty with instrumental activities of daily living. Thus, a lessening of the decline observed in individuals over 5 years was considered an important preventative outcome.

Memory

William James (1899, p. 161) foreshadowed current directions in cognitive training when he stated, "*the one who* THINKS *over his experiences most*, and weaves them into systematic relations with each other, *will be the one with the best memory.*" In other words, the more meaningful the material to be remembered and the more it is related to information already in one's knowledge, the better the chance that it will be recalled.

Contemporary memory training strategies make use of the same framework proposed by James and theoretically formalized by Craik and Lockhart (1972). Strategies such as the method of loci (Anschutz, Camp, Markley, & Kramer, 1985), pairing strategies such as name-face associations (Yesavage & Rose, 1984), or keyword techniques (Yesavage, Sheikh, Friedman, & Tank, 1990) have been applied with benefits if the individuals are not too impaired to learn and implement the laborious mnemonic procedures. A limitation of this training paradigm is that older adults often need extensive practice (Neely & Backman, 1993), and even after the skill is acquired they often do not spontaneously use the mnemonic strategy in a new situation (Anschutz et al., 1985). A meta-analysis of mnemonic training studies reported that mnemonic training improved memory in all groups with no particular approach distinguishing itself (Verhaeghen, Marcoen, & Gossens, 1992). Samples that demonstrated the most training improvements tended to be young-old adults. Old-old adults may need more practice to learn the strategies. Study duration (length of each session) was negatively associated with a training effect when duration exceeded 1.5 hours. This may reflect fatigue on the part of the participants.

Despite performance gains, the acquired mnemonic techniques are often abandoned in new situations. Some researchers have suggested that training of more fundamental processes may show greater generalization (Camp, 1993). Jennings and Jacoby (2003) conducted a training study in which they aimed to expand an older adults' ability to use controlled processes of recollection over greater and greater lags (intervening items in a list recognition task). At the beginning of training they observed that older adults were impaired with as few as one intervening item. By the end of 7 days of practice they were able to correctly recognize an item as old or new at a level typical for a younger adult with as many as 28 intervening items. The authors attributed the performance gains to the incremental difficulty of the task; they had a comparison group without that training feature. In a follow-up study (Jennings, Webster, Kleykamp, & Dagenbach, 2005) the training gains were transferred to tasks associated with frontal functioning such as working memory, speed of processing, and source monitoring.

Processing Speed

Despite substantial research on the relation between processing speed and many other cognitive abilities, there is a paucity of research on the training of processing speed. Notable, however, is the inclusion of processing speed training in the large study reported by Willis et al. (2006) and described in the section on intelligence training. In that study processing speed training produced gains on cognitive tasks within the same domain as well as on functional outcome measures of instrumental activities of daily living. A similar finding was reported in a study by Edwards et al. (2005). Improved processing speed led to improved performance on a useful field of view test as well as the instrumental activities of daily living measure.

A study targeting processing speed trained young and older men to increase processing speed by introducing time limits to a memory scanning dual task (Baron & Matilla, 1989). The typical age-related difference in performance was observed at the outset of the 44 hours of training. The authors reported that the time limit contingency reduced age differences to a greater degree than did task familiarity, even though both young and older adults improved with training under the time limits.

Executive Function

Recent studies aimed at training executive function in young and older adults have taken their lead from work reported by Green and Bavelier (2003, 2006). They reported transfer of skills from practice on a first-person shooter game to a number of attentional and perceptual tasks. These findings were similar to the earlier work of Gopher (1994), who used the computer game *Space Fortress,* also a maneuvering and shooting game, to train Israeli Air Force pilots. Improved flight performance was attributed to improved attentional control, although it was not directly tested.

In a recent attempt to replicate the findings of Green and Bavelier (2003), however, Boot and colleagues (2008) were unable to detect computer game-related skills transfer despite more participants, more training time, and a larger battery of transfer tasks. An important aspect of Boot and colleagues (2008) replication was that they tested participants on three occasions and accounted for expected practice effects before interpreting differences between the control and training groups. Failure to consider practice effects is a weakness of many training studies and was mentioned as a possible limitation in the original report by Green and Bavelier (2003).

Kramer and colleagues (1995) began a line of research examining the benefits of cognitive training in older adults by building on Gopher's work examining the training of complex skills. Gopher, Weil, and Siegel (1989) demonstrated the superiority of a training approach in which a task (computer game) was divided into subcomponents but presented to the participant in the whole task form with a changing emphasis placed on each of the subcomponents over the duration of the training. This changing emphasis approach yielded significantly better performance than playing the game for the same duration with no instruction. Kramer, Larish, and Strayer (1995) used the changing emphasis or *variable priority* approach in their study of training effects for dual task (or multitask) performance in young compared with older adults. The variable priority condition required participants to frequently shift their processing priorities between two concurrently performed tasks. This condition was contrasted with a fixed priority condition that required participants to treat both tasks as equally important in all of the dual task trials. The benefit of the variable priority approach over a typical unconstrained division between two tasks was demonstrated by faster mastery of the task and better performance on a transfer task of a similar dual task nature for both young and older adults.

Moreover, in follow-up studies, Kramer, Larish, Weber, and Bardell (1999) reported a diminished age effect with training and suggested that improvement on the training task with associated improvement on a novel task supported the position that dual task coordination is the targeted mechanism of the training and that older adults have a specific deficit in coordination. Of note, however, is that in the earlier study (Kramer et al., 1995) there was a variable priority training benefit across both age groups but no differential benefit for the older adults. The latter study (Kramer et al 1999) used a longer duration of training and not only reproduced the superiority of the variable priority training condition but also demonstrated a differential benefit for the older adults in the variable priority condition for the final training day. The increased cognitive demand was considered to be an important aspect of the task that led to the age effect in training benefit.

To clarify some potentially important elements of the variable priority training studies, the following is a description of the tasks and procedure used in Kramer et al. (1995). The training study included 30 older and 29 younger adults. The younger adult’s age ranged from 18 to 29 years. The older adult’s age ranged from 60 to 74 years. Half of each age group was assigned to the fixed priority condition and half of each age group was assigned to the variable priority condition. The entire training study was conducted over eight sessions. In Session 1 vision and general cognitive testing was conducted; Sessions 2 and 3 involved practicing single task versions of the to-be-trained dual task for 5 min blocks of 20 min each; at the end of Session 3 an additional 30 min of practice with the combined dual task was administered. Sessions 4 through 6 included ten 5-min blocks of dual task with two 5-min blocks of the single task of each. Sessions 7 and 8 tested for transfer in a new dual task, administered first as one 5-min block of each task followed by four 5-min blocks of the dual task.

In the dual task training (see Figure 1) participants monitored six continuously changing gauges and were instructed to reset each gauge when it reached a critical region. Each gauge was only visible for 1.5 s after its corresponding button was pressed. The construction of mental representations of the position and dynamics of the gauges were presumed to create a relatively difficult memory task. The second task (also presented in Figure 1) involved an alphabet arithmetic task in which participants indicated the letter associated with adding or subtracting positions in the alphabet. For example, the answer to the presented problem $H - 2 = ?$ is F. In addition to this computation, participants also indicated whether the answer in the just prior computation was greater or lesser with a key response.

In addition to the requirements of the two tasks, participants were instructed to use a feedback bar (see Figure 1) to guide task priority and for individualized performance feedback. The transfer tasks in this experiment had a visuospatial component (a box-stacking task similar to Tetris) and a memory component (paired associate recognition memory task). See Figure 2.

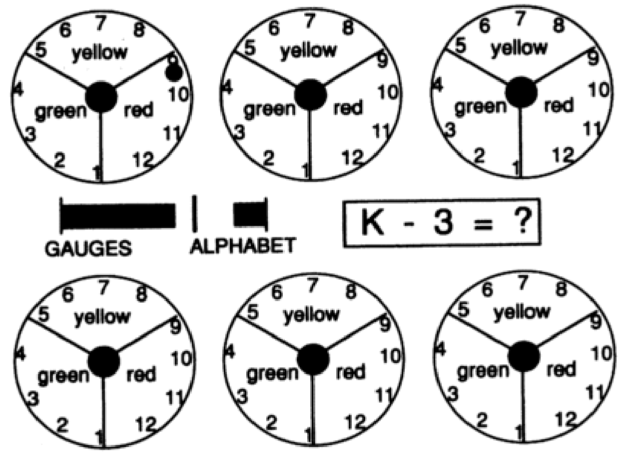


Figure 1. Training task from Kramer et al. (1995)

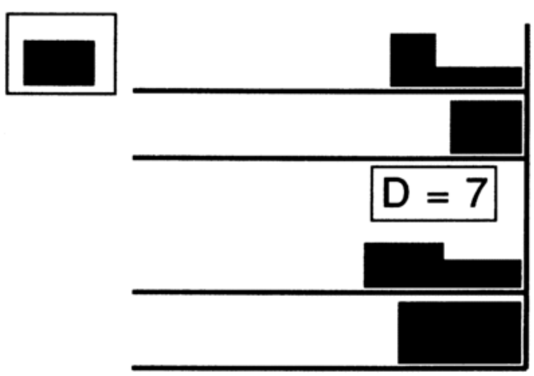


Figure 2. Transfer task from Kramer et al. (1995)

Older adults in the variable priority training group showed substantially greater learning of the alphabet-arithmetic task in the dual task conditions than did the younger participants. On the other hand, older adults in the variable priority training group showed less learning of the monitoring task in the dual task conditions than did the younger participants. It is interesting to note, however, that they did not find a significant age-related dual task deficit for either of the transfer tasks. These results do not provide an unequivocal answer to the question of whether age-related differences in dual task performance can be reduced or eliminated through training; they do suggest that these performance decrements may be reduced under some conditions.

The variable priority training strategy was more effective in improving performance in the dual task than in the single task version of the monitoring and alphabet-arithmetic tasks. The amount of improvement in the response speed measure across the younger and older adults in the single-task versions of the alphabet-arithmetic and monitoring tasks was approximately 7%. The comparable improvement scores for the dual task versions of the alphabet-arithmetic and monitoring tasks were approximately 17%. The disproportionate improvement in dual tasks compared with single tasks during training in conjunction with dual task specific transfer benefits observed with the scheduling and paired-associates tasks suggested that participants were acquiring task-coordination and management skills as a result of variable priority training.

Recent studies from this research group have varied task complexity and have continued to observe robust training-related improvements for young and older adults (Bherer, 2005, 2006). Although transfer of training benefits have also been demonstrated in both young and older adults, the lessening of the effects of age occurred only among the training studies that included extensive training (greater than 3 days) and at least one complex task with a memory load (Bherer, 2005, 2006). Further research has identified regions of the prefrontal cortex associated with task performance (Erickson, Colcombe, Wadhwa, Bherer, Peterson, & Scalf, 2007). Such areas have also been previously established to underlie aspects of attentional control (Erikson et al., 2005).

To account for their training data, Kramer and colleagues adopted a theoretical framework of age-associated decrease in the ability to manage and coordinate multiple processes, skills, and tasks. Their "task coordination and management hypothesis" (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Madden, 1986; Salthouse, 1984) is consistent with data that suggest that older adults have more difficulty than younger adults in switching rapidly between two tasks (Hawkins et al., 1992), preparing for one task while performing another task (Jennings et al., 2001), and performing one task while monitoring for a stimulus that indicates that an overt response should be aborted (Kramer et al., 1994). In each of these situations, they point out that successful performance depends on the coordination of multiple processes and task components.

Limitations of Training Studies

A next step in cognitive aging research, already underway, is to identify key processes contributing to more complex tasks pooled from various disciplines and to adopt a common language for their description. This approach will benefit training studies because of the reliance of these studies on assumptions about the underlying construct that is both the target of the intervention and the generalized outcome measure. The work of Miyake and colleagues (2002), for example, made an important contribution to this end when they used latent variable analysis to determine the amount of shared variance among three multidimensional neuropsychological tests with proposed underlying mechanisms of shifting, updating, and inhibition. This work, gathered from a large sample of undergraduates, does not directly translate to the behavior of older adults, but it creates a context for further studies and points out that even among a more homogenous sample (young adults) the mechanisms underlying previously grouped tasks can be further distinguished.

The adoption of latent variable techniques in the study of age-related changes in cognition championed by Salthouse and colleagues (e.g., Salthouse, 1991) has addressed concerns related to construct level ‘purity’ when a single task is used as a representative of a theoretical construct. The use of multiple tasks allows the researcher to partial out variance that is either task specific (e.g., visual vs. auditory testing format) or not of theoretical interest.

Recently Salthouse (2006) pointed out that those interested in examining interventions aimed to improve cognition in older adults are not adhering to a definition of age-related training improvement that he supports. He noted an important distinction that is obscured in reports of age-related cognitive training. First, an intervention might improve performance across all ages but not affect older adults differentially. In this case training is successful but is not age-specific. It is also possible for training to target a deficit that is specific to aging but not alter the aging process in its effect. In this case training is specific but does not affect the aging process. Salthouse held as the gold standard an intervention that affects the *trajectory* of *age-related* decline. The importance of this approach is in its appreciation of aging as a dynamic process. In other words, cognition changes over time. If the aim of a training study is to affect age-related cognitive decline, one must first identify an age-related deficit, then differentially affect that deficit with an intervention and then follow performance over time to document a change to the course of the aging process related to the intervention. He specified that an age-specific improvement in performance has not reached the level of his gold standard until it has been followed longitudinally and determined to have changed the course of decline. Thus, specificity alone cannot be interpreted as evidence for a trajectory change. The real world importance of Salthouse's distinction between trajectory and performance level change may be debatable, but it makes clear distinctions among studies that can assist in our interpretation of training effects. For example, correlational studies that clearly document associations between high levels of mental activity and resistance to cognitive decline (Schooler, 2006) do not fully address whether mental activity affects the aging process. These studies are, nonetheless, important practical contributions to our understanding of the relationships among mental activity and vitality.

Another important aspect of training is the implication, widely held in the area of education, that transfer of a trained skill to other contexts is possible. This issue, however, has been debated over several decades with little resolution. Barnett and Ceci (2002) presented a review that highlights the stark contrasts of scholarly opinion (from ubiquitous transfer to no evidence of any form of transfer) and outlined a framework to address the necessary methodological approach to compare and contrast past and future studies. The authors pointed out that researchers do not share the same definitions of transfer and clarified *far transfer* as transfer to a dissimilar context, whereas *near transfer* is transfer to a more similar context. They proposed that unclear findings are the result of a "lack of structure in the transfer debate and failure to specify the various dimensions that may be relevant to determining whether and when transfer occurs" (Barnett & Ceci, 2002, p. 3). In order to specify a framework of relevant dimensions and guard against perceived disagreements due to ill-defined terminology, failure to specify dimensional characteristics, or both, the researchers presented a taxonomy to provide structure to the question of whether and when transfer occurs. At a minimum, they proposed that the nature of the skill to be transferred, the performance change measured for the skill, and the memory demands of the transfer task used to measure it be evaluated. Furthermore, the distance between the training and the transfer contexts along multiple dimensions (including knowledge domain, physical context, temporal context, functional context, social context, and modality) should be identified.

With a few notable exceptions (Ball et al., 2002; Baltes et al, 1988; Willis & Schaie, 1986), research in cognitive training is still in its early development. Many standard methodological issues such as practice effects, construct validity, reliability, and experimental control need to be addressed. Further, sample characteristics such as age boundaries, health, IQ, and gender may play more than trivial roles in determining the results of prior training studies (Neely & Backman, 1993).

CHAPTER THREE: PURPOSE, RESEARCH DESIGN, AND HYPOTHESES

Purpose

Recent studies have demonstrated both behavioral and neuroimaging markers of cognitive improvement among older adults after extensive practice or training. There are equally compelling observations, however, that training benefits do not transfer to novel tasks and do not manifest in observable real world improvements. Studies aimed to address the generalizability of cognitive training have met with criticism due to limitations in study design (modeling practice effects in pre- and posttests), construct validity, and test reliability. All of these may critically influence observed training benefit and generalization. Variable priority training (broadly referred to as multitask training) has well-established, but not widely replicated benefits in both younger and older adults. The theoretical framing of variable priority training leans towards a general skill training in task coordination, task switching, or, in more general terms, *attentional control*. The association with general task coordination, switching, or attentional control has not been tested directly. Further, basic mechanisms that may account for variance in response to the variable priority training remain poorly specified measurement models.

The purpose of this dissertation was twofold. The first goal was a characterization of the training task. A measurement model that included a priori constructs of processing speed, working memory, and response-distractor inhibition was tested to determine the relationship among these latent variables and the performance on the variable priority training task. The association between the training task and a standard switching task was also tested.

The second purpose of this dissertation was focused on training and transfer. The first goal was to replicate the training benefit documented by Kramer and colleagues (1995) in a multiple task, variable priority training paradigm. The second goal was to examine two levels (near and far) of transfer of training benefit. The near transfer was tested with an equivalent, but not identical multitask; the far transfer was tested on a switching task.

Research Design

The study was divided into two partially overlapping testing arms. In the first arm 105 healthy older adults aged 60 to 70 years were administered a 2-hour cognitive battery (including a first exposure to the training task). A subset of 41 participants were recruited into the second arm of the study and participated in five additional 1-hr sessions of cognitive training. One half (n = 20) of the participants in the training study were randomly assigned to the training condition and participated in five 1-hour sessions of multitask training. The remaining 21 participants were in the control condition and participated in five 1-hour sessions of directed internet exploration. After completion of the five days of training (training and control groups) each participant returned for 2 hrs of transfer testing and post testing on the cognitive battery. See study design schematic, Figure 3.

Hypotheses

Hypothesis 1: Factor analysis to confirm three factor structure of the cognitive battery

Confirmatory factor analysis should reveal a three-factor structure of Processing Speed, Working Memory, and Response-Distractor Inhibition with nontrivial correlations

Figure 3. Study design schematic. Session 1 was scheduled in the first week. Sessions 2 through 6 were scheduled over week 2. Session 7 was scheduled in week 3. This design was repeated with approximately 5 participants enrolled in training and control sessions (sessions 2 through 6) per week until a total of 41 participants were tested (20 in training condition, 21 in control condition). One half of training participants were administered Version 1 of the training task on sessions 1-6 and then Version 2 on session 7. The other half were administered Version 2 on sessions 1-6 and Version 1 on session 7. An additional 64 participants were tested on the cognitive battery (session 1 only) for a total of 105 participants tested on the cognitive battery. One half of the 64 additional participants were administered Version 1 and one half were administered Version 2 of the training task.

among the factors. Reliability and construct validity were estimated in this new sample of 105 people.

Prior estimates of reliability or construct validity had been established in similar samples and are described in the description of each measure. Likewise, each of the three factors (Processing Speed, Working Memory, and Response-Distractor Inhibition) was derived in previous studies using the same or similar indicator variables. Response-Distractor Inhibition is the least well-established factor. It emerged from an exploratory factor analysis conducted by Friedman and Miyake (2004) aimed to describe aspects of inhibition. It included the following measures: antisaccade, Eriksen flanker task, Stroop interference, stop signal, word naming (with interference), and shape matching (with interference). This study tested the factor structure using antisaccade, Eriksen flanker task, and Stroop interference.

Hypothesis 2: Construct validity of the training task

Performance on the training task was expected to be predicted by the Response-Distractor Inhibition factor. Similarly, the switching task was expected to share variance with the Response-Distractor Inhibition factor and to predict performance on the training task.

Returning to Friedman and Miyake's (2004) factor analysis, in addition to identifying a two-factor structure among their selected tasks of inhibitory control, they tested the relationships among the factors and other measures of cognition such as task switching and reading span. Task switching was strongly associated with Response-Distractor Inhibition. Likewise, Kramer and colleagues (1995) suggested that variable priority training affects task coordination or task-switching ability. Thus, a strong relationship among performance on the variable priority training task and the Response Distractor Inhibition factor and task switching was hypothesized.

Hypothesis 3: Plasticity of performance over the training week

The training group was expected to show improvements in accuracy and speed of response from the initial testing and across 5 days of practice. Hypotheses 3 and 4 satisfy a conceptual replication of the body of work by Kramer and colleagues (e.g., Kramer et al., 1999; Bherer et al., 2005).

Hypothesis 4: Near transfer to novel multitask.

As demonstrated in earlier studies by Kramer and colleagues (1995), trainining benefits were expected to tranfer to other novel multitask situations. This transfer should be in addition to gains due to practice with a graphic interface and mouse. Thus, the training group was expected to perform better than the control group on the near transfer of a novel multitask.

Hypothesis 5: Far transfer to cognitive variables

For those factors or individual cognitive variables that are associated with the training task (based upon Hypothesis 2), training-related performance improvement was examined by comparing group (training vs. control) by performance differences at post test. It was expected that some factors or individual variables that are associated with the training task would also show improvement with training.

CHAPTER 4: METHOD

Participants

Power

For the first arm designed to test the measurement model and associations among the factors of the model, a confirmatory factor analysis with 21 parameters required at least 105 participants to ensure adequate power using the convention of 5 to 10 observations per parameter. This sample size also provided sufficient power (.86) to test associations of moderate effect size (r = .30) between the factors and the training and switching tasks.

The second arm of the study tested training benefit and transfer using a subset of the 105 participants in the first arm. Kramer and colleagues (1995) obtained moderate to large effects for training. With a moderate effect size of .25 a sample size of 20 participants was sufficient to obtain an 80% probability of detecting training improvement across 5 days. Another 21 participants were recruited into the control condition.

In pilot studies some participants conformed to the prioritization condition better than others; some did not appear to use the prioritization condition at all. Due to concerns about the affect of adherence to the study protocol on the power to detect a training effect a few additional steps were taken. The prioritization condition was programmed in the study to be a more salient stimulus, and extensive instructions and cueing to use the prioritization were given in the first session of training. Adherence to prioritization was monitored and demonstrated by measuring the proportion of adherence to the task priority goal across participants (see Figure 4).

Participant Characteristics

Participants ranged in age from 59 to 70 years ($M = 64.73$, $SD = 2.57$) with no difference in age between the training and the control groups $t(39) = 0.04$, $p > .05$. This age range was selected based on reports of maximal training gains in the 60-year-old age group (Verhaeghen et al., 1992) as well as observation of greater training gains and closer adherence to priority instructions among the 60- to 70-year-old pilot participants.

Participants were recruited from the Washington University psychology department's older adult volunteer pool. Exclusion criteria included history of neurological illness (e.g., stroke, transient ischemic attack, traumatic brain injury, dementia, Parkinson's disease, loss of consciousness for more than 5 min, seizure), psychiatric illness (e.g., major depression, bipolar disorder, schizophrenia), alcohol and/or substance abuse, chemotherapy or radiation therapy, cardiac bypass surgery, myocardial infarction, color blindness, uncorrectable severe vision deficits, uncontrolled diabetes, uncontrolled thyroid disorders, or major surgery within the past month. In addition, participants were excluded if they were taking any neuroleptic or psychoactive medication at the time of testing. Three participants were not eligible due to cardiac bypass surgery, and one participant was not eligible due to Parkinson's disease.

In a telephone screening call, participants were administered the Short Blessed Orientation and Memory Scale (Katzman et al., 1983) as a screening for possible dementia. Participants with a score of six or greater were not included. All participants screened met inclusion criteria on the Short Blessed Orientation and Memory Scale.

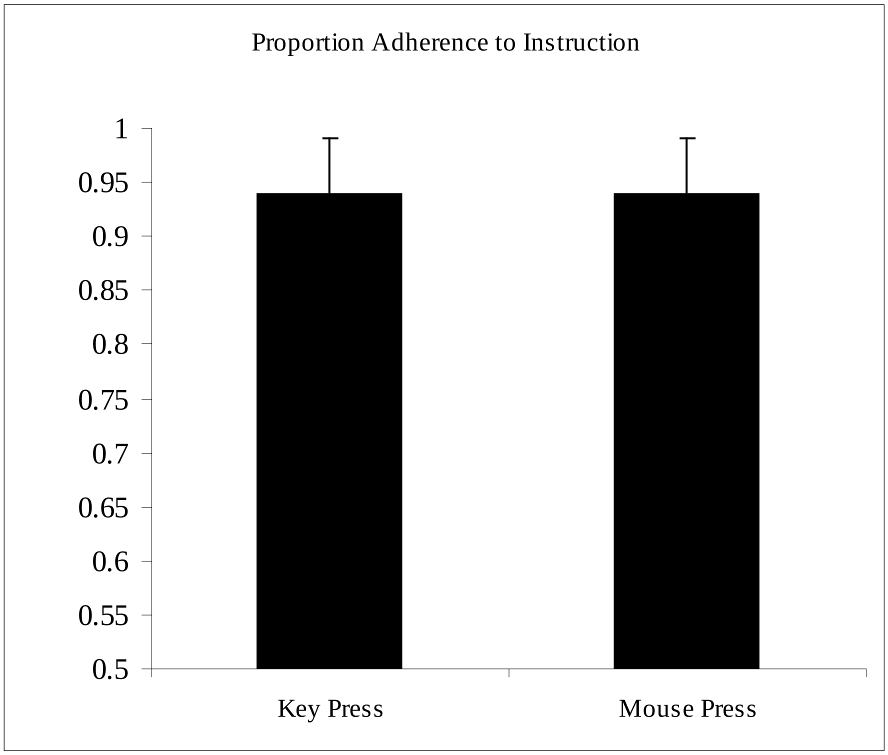


Figure 4. Mean proportion adherence across participants to task priority goal.

Participants were also screened for depression using the Geriatric Depression Scale (Yesavage & Sheikh, 1986). Participants with a score of 11 or greater were not included. Four participants scored greater than 11 on the Geriatric Depression Scale. They were informed that they were not eligible for participation in the study at this time and were provided contact details for an outpatient psychological counseling center.

Education ranged from 12 to 22 years (M = 16.12, SD = 2.79) and did not differ between the training and control groups, $t(39) = 0.61$, $p > .05$. Similarly, a measure of self-reported health and a test of corrected vision were administered, and all participants met minimum criteria of corrected 20/30 vision and self-reported good health. See Table 2 for means and standard deviations by group.

Materials

Cognitive Battery

Processing Speed. Each of the three hypothesized constructs was measured with three indicators. The first measure of speed was a computerized task of simple reaction time (RT; Appendix A, p.112). Participants were instructed to make a manual response when an arrow appeared on the computer screen; 10 practice trials were administered before the 40 test trails. Median RT for correct responses was entered into subsequent analyses.

A paper-and-pencil test of processing speed was also administered (i.e., Pattern Comparison; Salthouse & Babcock, 1991). Participants compared patterns of symbols and judged the similarity of pattern pairs (Appendix B, p.113). Three practice items were administered before the 30 test items. Participants were instructed to work as quickly as they could. The score on this test was number of items correctly completed within the

Table 2

Means and Standard Deviations of Demographic Variables by Group (Training vs. Control)

Measure	*M*	*SD*
Age		
Training	64.75	2.27
Control	64.71	2.88
Education		
Training	15.85	2.80
Control	16.38	2.82

Note. Comparisons of the Geriatric Depression Scale and Short Blessed Test of Orientation are not reported due to high cut-off for study inclusion. All participants self-reported good health.

allotted time of 60 s. Estimated reliability for this measure of .94 was derived by boosting split-half correlations by the Spearman-Brown formula (see Salthouse & Babcock, 1991).

For the third measure of processing speed, a standardized paper-and-pencil test of processing speed that required the transcription of symbols based on a number key was administered (i.e., Digit Symbol; Wechsler, 1997). The score was the number of items correctly completed in 120 s. Test-retest stability for this measure ranges from .90 to .93 for older adults aged 55 to 74 years included in the WAIS-III standardization sample (Wechsler, 1997).

Working Memory. Three computerized tasks of working memory were administered. In the Operation Span (Ospan; Unsworth, 2005) participants solved an equation to determine if a provided answer was correct or false. After each computation a letter was presented for later recall. Each component of the task was given separately during a practice session. Speed to read sentences was determined during the practice, and 2.5 SD was then added to create a time limit for the experimental session. If a participant did not respond before the time limit that item was scored as an error.

There were three trials for each of 3, 4, 5, 6, and 7 trial lengths yielding a total of 75 math problems to perform and 75 letters to recall. The order of set size was random for each participant. Ospan score was used in subsequent analyses (Unsworth, 2005) and was obtained by summing all perfectly recalled trials, ignoring order of the letters recalled. For example, if a participant correctly recalled 3 letters from a trial length of 3, 4 letters from a trial length of 4, and 3 letters from a trial length of 4, the score would be

3 + 4 + 0 = 7. Scores could range from 0 to 75. This measure has well-documented reliability with an average coefficient alpha of .80 (Kane et al., 2004).

Administration of the Reading Span task (Rspan; Turner & Engle, 1989) was the same as for Operation Span, but in Reading Span participants read a sentence and determined if it made sense or not. After each sentence a letter was presented for later recall. Again, there were five sets of each trial length (3 to 7 items) totaling 75 letters and 75 sentences. The Rspan score (see Unsworth, 2005) used in subsequent analyses was obtained in the same way as the Ospan score. This measure has well-documented reliability with coefficient alphas and split-half correlation in the .70 to .90 range and is also stable across time. Test-retest correlations for operation span and reading span over minutes to months have been observed in the .70 to .80 range (Conway et al., 2005).

The third measure of working memory, the two-back test, required the participant to press a key to indicate if a single viewed letter was the same or different from the letter presented two prior. Single lowercase letters on the computer screen were presented one at a time until a response was made or 800 ms elapsed; 18 practice items were presented before 72 test items. The score was percent correct. Reliability for the n-back task has been reported to be .84; this reliability estimate is based on the three-back version in Kane, Conway, Miura, and Colflesh (2007).

Response-Distractor Inhibition. Three computerized tasks of interference or inhibitory control were administered. The first was an antisaccade task measuring the ability to override a prepotent response to look in the direction of a stimulus presented to left or right of a fixation point. Participants looked at a central fixation until a cue was presented to either the right or the left of fixation for 175 ms. The task was to look away from that peripheral cue in order to determine the identity of the target presented on the opposite side of fixation from the cue. The target was either a *Q* or an O, presented for 375 ms and then covered by a visual mask (i.e., ####”). The mask remained until the participant pressed either the *Q* or the *O* to indicate the target letter. Ten seconds were allowed before the trial was recorded as an error due to omission; 10 practice trials were administered before 80 test trials. The score was proportion correct. Friedman and Miyake (2004) reported reliability estimate of .87 based on antisaccade errors (no prosaccade condition was administered) adjusting split-half correlations with the Spearman-Brown prophecy formula.

The second task was a version of the Eriksen flanker task (Eriksen & Eriksen, 1974) in which participants pressed a button as quickly as they could to identify the direction of the central arrow. The arrows remained on the screen until the participant made a response. In the response incompatible condition the flanking arrows pointed in the opposite direction of the central arrow, and in the compatible condition they pointed in the same direction; 10 practice trials were administered before 80 test trails. RTs of correct responses for each participant were converted to standardized scores and then the average standardized score for each condition (compatible and incompatible) was computed. The average standardized RT for the incompatible condition for each participant was entered in subsequent analyses. Friedman and Miyake (2004) reported a split-half reliability estimate of .59 for a flanker interference effect derived from the difference in reaction time between a response incompatible distractor condition and a no distractor condition.

Finally, the Stroop word-color naming test was administered. Participants named the color of the ink of words presented on the screen. The words were either incongruent with the ink color (the word *yellow* presented in blue letters), congruent (the word *blue* presented in blue letters), or neutral (the word *lawyer* presented in blue letters), and the three conditions were intermixed across trials. Ten intermixed practice trials were administered before 120 intermixed test trials of each condition were presented (40 incongruent, 40 congruent, 40 neutral) with a break after the 40^{th} and 80^{th} trials. Interstimulus interval was 1000 ms. The stimulus remained on the screen until a response was made. Text was Courier New, 18pt. RTs of all correct responses for each participant were converted to standardized scores, and then the average standardized score for each condition (incongruent, congruent, and neutral) was computed. The average standardized RT for the incongruent condition for each participant (using the congruent condition as the baseline) was entered into subsequent analyses. Friedman and Miyake (2004) reported a split-half reliability estimate of .80 for the Stroop task based on the RT difference between incongruent and neutral color word conditions.

Switching task. A switching task, not included in the factor analysis, was included due to the hypothesized relationship between multitask performance and task switching. This task was adapted from the work of Minear and Shah (2008). A number letter pair (e.g., 31A) was presented centrally on the computer screen. In the first block of 10 practice and 60 test trials participants attended only to the number. The cue *odd* appeared in the upper left corner of the screen to indicate the participant was to press a left key (D) if the number was odd; the cue *even* appeared in the upper right corner of the screen to indicate the participant should press a right key (K) if the number was even. Responses were made with the pointer fingers of each hand.

The second block of 10 practice and 60 test trials required the participant to indicate if the letter was a consonant or a vowel. The cues, *consonant* and *vowel*, were presented in the left and right corners of the computer screen and the same D and K keys were employed. These two tasks were combined to represent the no-switch condition.

In contrast, the third block of 10 practice and 60 test trials included both odd versus even and constant versus vowel judgments. The participant monitored the cue labels and responded to the number or letter based on the cues (odd and even or consonant and vowel); however, the pattern of cue switch was predictably every two trials. RTs of correct responses for each participant across all blocks were converted to standardized scores. Then the average standardized score for each condition (no switch and switch) was computed. The average standardized RT for the switch condition for each participant was entered into subsequent analyses. There is no reliability information for this task.

Multitask Training

Overview

Game Maker 7.0 software was used for task development; administration was on a Sony PCG-72GL laptop computer. The display was 20 cm by 27 cm. Responses were recorded via three number keys (1, 2, and 3) on the keyboard located in the upper left position of the keyboard, the space key (located centrally), and an external infrared mouse positioned on a large mouse pad to the right of the computer. This arrangement was the same regardless of hand dominance and both hands were used for responding (left hand for the numbers and the right hand for the mouse. All participants were comfortable with the mouse in the right hand and did not express a preference for a left sided mouse.

As shown in the upper portion of Figure 5, the training task consisted of two distinct tasks performed concurrently, the *number-summing* task presented in the center of the screen and the *flower-cutting* task. These tasks were developed to serve as alternate forms to those used by Kramer et al. (1995). They were designed to have both the memory and visuospatial demands in addition to the key aspects of the variable priority and individualized feedback included in the original multitask training. Pilot testing of the two multitasks is reported in Chapter 5.

Number Summing

A 4 cm by 4 cm white box with 2.5 cm by 1.5 cm blue numbers was presented centrally on the display. Participants pressed one of three number keys (1, 2, or 3) to indicate the correct value when the displayed numbers (presented serially in the center of the white box) were summed. Summing was continuous so that the displayed number advanced with the key press by the participant. The space bar could be used to advance to the next number without entering a value. If 1,500 ms elapsed without a key press, the number advanced and the response was logged as a miss. Numbers were presented from a pseudorandom list generated by the experimenter with constraints that the summed value equal 1, 2, or 3 in all instances, that no numbers repeat consecutively, and that all presented numbers were single digits. Negative values were included in the presentation list but not among possible solutions. Response categories included correct, wrong, miss,

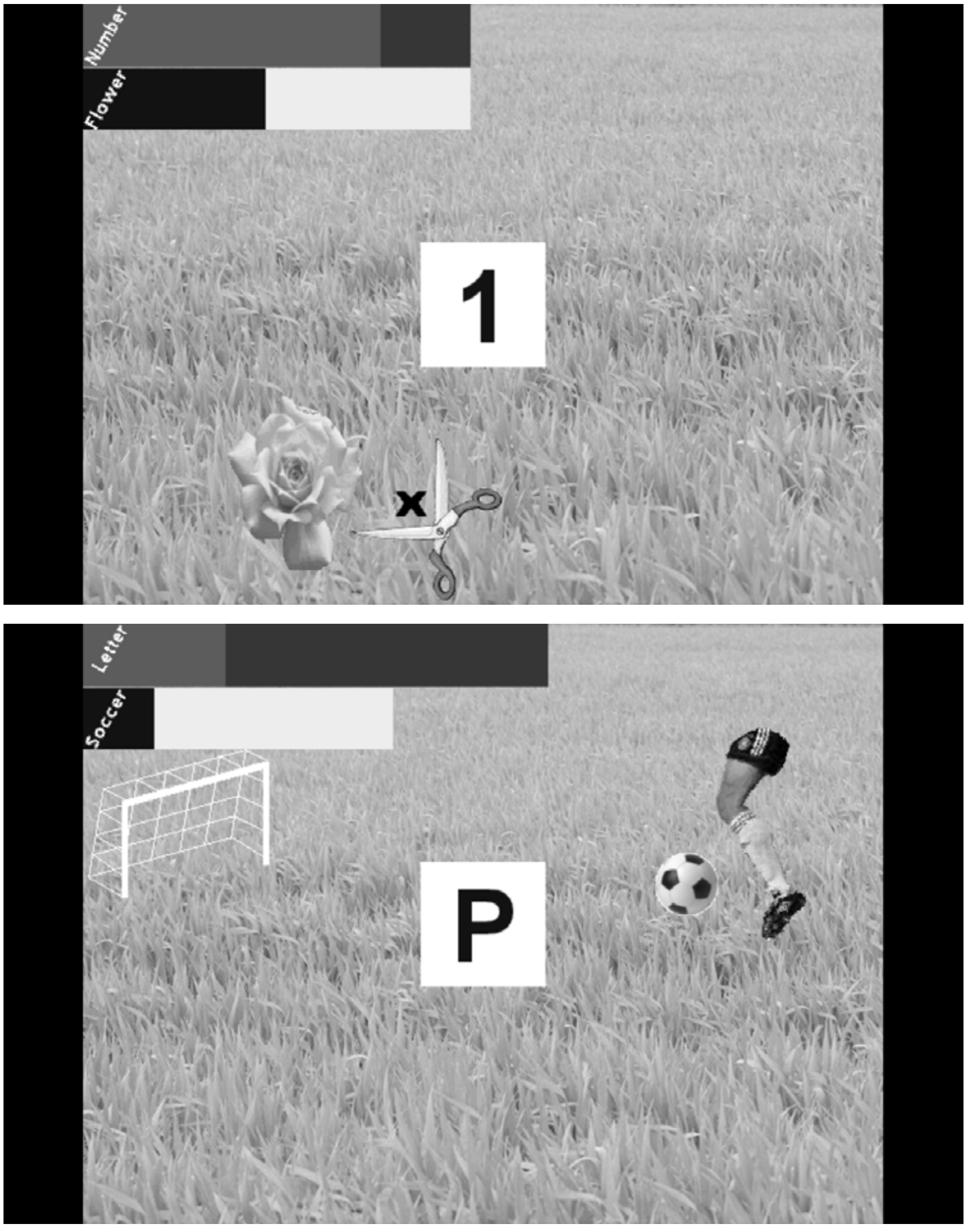


Figure 5. Multitask. The upper figure shows Version 1 and the lower figure shows Version 2. Task A is the central task (number or letter). Task B is the peripheral task (flower or soccer).

and spacebar. For each response the latency was recorded, and after each response the timer was reset. Two scores from this task were used in the data analyses: number of correct key presses per minute and median RT for correct key presses.

Flower Cutting

A 6 cm by 4 cm flower image was presented at a random location on the screen (constrained not to reappear in the center of the screen or the same location consecutively) and remained in that location until the participant “cut” it with the scissor cursor or 1500 ms elapsed, after which time the flower disappeared from the screen and reappeared at another location. The scissor cursor was a 6 cm by 5 cm pair of cartoon scissors with a central *X* placed between the blades of the scissors for proper positioning over the flower. The mouse controlled the position of the scissors, and the left button of the mouse changed the image of the scissors to closed. The category of response (*hit* if over the flower, *clicked not on flower* if over any other location on the screen) was recorded, along with the time interval from the presentation of the flower until the response. If the flower was not accurately cut after 1,500 ms, the flower disappeared and a *miss* was logged. Only hits and misses reset the timer. If the participant *clicked not on flower*, the error was logged but the trial did not advance and the timer continued until either a hit or miss (>1,500 ms) occurred. Two scores from this task were used in the data analyses: number of correct mouse presses per minute and median RT for correct mouse presses.

Variable Task Priority and Feedback

In addition to the number-summing and flower-cutting tasks, a third element of task prioritization with feedback monitoring was included in the training. Two rectangular bars of equal height were stacked on top of each other in the upper left corner of the display. The top bar represented feedback and priority for the number-summing task (Task A), and the bottom bar represented the same for the flower-cutting task (Task B). The bars were labeled and color coded such that the number task was colored green and red and the flower task was colored blue and yellow.

The stacked bars were 4.5 cm in height and varied in length: 5.5, 10.5, 13.5, 16, or 21 cm. The length of the bars depended on the priority condition. They were generated to create yoked priorities indicating the emphasis of Task A (first number) compared with Task B (second number): 20:80, 40:60, 50:50, 60:40, 80:20 A length of 5.5 cm for the top bar corresponded to a length of 21 cm for the bottom bar, 10.5 cm with 16 cm, 13.5 cm with 13.5 cm, 16 cm with 10.5 cm, and 21 cm with 5.5 cm. Each priority condition was set to a fixed time interval of 3,000 ms and repeated 12 times in a pseudorandom order constrained so that no priority was repeated consecutively.

Feedback was displayed using the color contrast of green or red and blue or yellow. Feedback was calculated based on the RT of the previous five responses for each task separately. This value was then modified based on the priority level and the participant's baseline performance from a single task calibration condition. If participants performed at the same level as baseline (proportional to the priority level at the time) then the bar was either completely green (for the number-summing task) or completely blue (for the flower-cutting task). If they were slower, then the amount of green (or blue) in the bar was less and the red (or yellow) was revealed. Participants were instructed to attempt to keep the bar completely filled with green or blue.

An alternate version of the multitask (lower portion of Figure 5) was developed to assess transfer benefit. It had the same properties as the training task, but the specific materials differed such that an alphabet task was substituted for the number-summing task. Participants entered the distance a letter was away from the preceding letter in the alphabet (e.g., H is 3 units away from K). A soccer task was substituted for the flower-cutting task. The scissors were replaced with a leg, and the flower was replaced with a soccer ball. The object was to kick the soccer ball through the goal (aiming was not necessary).

Across all multitasks each component ran concurrently, and participants were free to give a response for either task. The task took approximately 45 min. The number of trials depended on participant response.

Procedure

Data for the first goal of the study (characterization of the training task) were collected in a 1.5-hr testing session that included the cognitive battery. The tasks were in the following order for all 105 participants: multitask (Version 1 and Version 2 were counterbalanced across participants), Digit Symbol, flanker task, two back, simple RT, antisaccade task, operation span, pattern comparison, Stroop, reading span, and switching task. Breaks were given between tasks as needed.

For the 20 participants assigned to the training study the training protocol consisted of five 1-hr sessions of multiple task training. The version (Version 1 [number summing/flower] or Version 2 [alphabet/soccer]) of the multitask used during training was the same version of the task the participant was administered in Session 1 as part of the cognitive battery. The control protocol consisted of five 1-hr sessions of directed internet exploration. Participants used a new handout each day to learn about different internet resources (e.g. Google chat; uploading photos; searching for specific information online). Participants reported (short questionnaire) on the activities undertaken during each session at the end of each hour. Although no formal assessment of degree of engagement in the internet activity was conducted, all participants completed the questionnaires, which required them to engage in the task by looking up information on the internet or performing a function (photo upload, Google chat) and anecdotal feedback on the activities were positive.

Both the training and control groups underwent a 1.5 hr follow-up session of the transfer multitask (Version 2 if Version 1 was administered at Session 1 or Version 1 if Version 2 was administered at Session 1) and the cognitive battery. Participants received $10 per hour of participation.

Statistical Analyses

The goal of Hypothesis 1 was to aggregate tasks of processing speed, working memory, and inhibition in order to characterize the multitask training task in terms of constructs with uniquely shared variance rather than task specific similarities. Confirmatory factor analysis is a reasonable approach to aggregate the data and to further test the predicted factor structure based on the work of previous exploratory and confirmatory factor analytic studies (e.g. Friedman & Miyake, 2004; Salthouse, 1996; Salthouse, & Meinz, 1995) that have established relationships among tasks of processing speed, working memory, and aspects of inhibition.

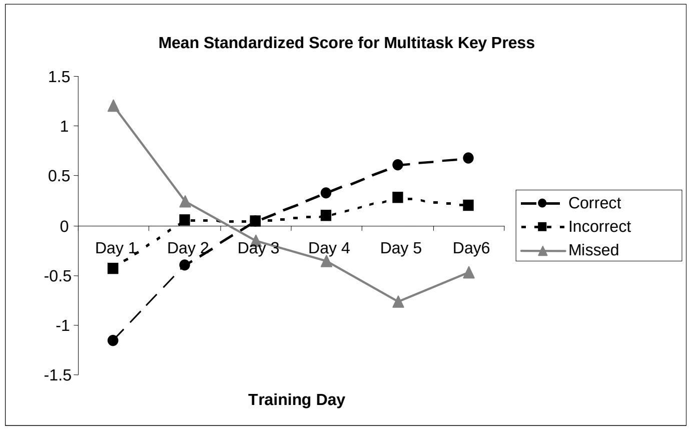
The model fit of the confirmatory analysis was tested, estimated reliability was evaluated, and the nature of each indicator variable was reviewed for adherence to established expectations. For example, means were reviewed to determine if basic predictions of longer RTs for incongruent versus congruent conditions of response-distractor tasks were met. To the extent that the necessary a priori expectations were not met, adjustments were made to subsequent analyses.

The goal of Hypothesis 2 was to validate the predicted construct represented by the multitask training. Multitask performance measures were tested within the CFA for association with the obtained factors from Hypothesis 1. In addition, given Kramer and colleagues' (1995) suggestion that multitasking is related to task switching and task coordination, task switching was also characterized as it related to the factors obtained in Hypothesis 1. In addition to testing the relationship between the cognitive factors obtained through the CFA and the multitask training variables and tasking switching separately, the direct relationship among task switching and multitask performance was tested.

The goal of Hypothesis 3 was to replicate the findings of Kramer and colleagues (Bherer, et al., 2005; Kramer et al., 1999), who found that older adults improved on measures of multitask performance with practice. They examined performance over several sessions beginning with the first exposure to the multitask. Although these past studies documented steep improvements from the first to second session, additional gains in performance were observed across several sessions. The current study included the pretest (first exposure) and five training days in the analyses to examine performance as a function of session. Performance gain as a function of session was graphed to demonstrate the trajectory of improvement across session (see Figure 6). Mixed analyses of variance including task version as a between subjects independent variable and time (the six sessions) as a within subjects independent variable were conducted for each multitask performance measure to test for improvement across sessions and any effect of version on training gains.

Hypothesis 4 was a replication of the work of Kramer and colleagues (1995). Near transfer of training improvements were tested using an alternate version of the training task in Session 7. The effect of version was again tested explicitly within these analyses of variance by including both task version and group (training vs. control) as between subjects independent variables for each performance measure. The goal of these analyses was to identify version specific effects, if any, and to identify training related performance gains were better in the training group than in the control group.

Hypothesis 5 was a test of far transfer of training-related performance improvement on the multitask to improvement on other cognitive measures. This hypothesis was more exploratory than the previous four hypotheses because of the limited sample size in the training arm of the study. In contrast with the effects of training and near transfer found in the studies of Kramer and colleagues (e.g. Kramer et al., 1999), the effects of far transfer are often small, if observed (Barnett & Ceci, 2002). A larger sample in the training arm was beyond the resources available for this study.



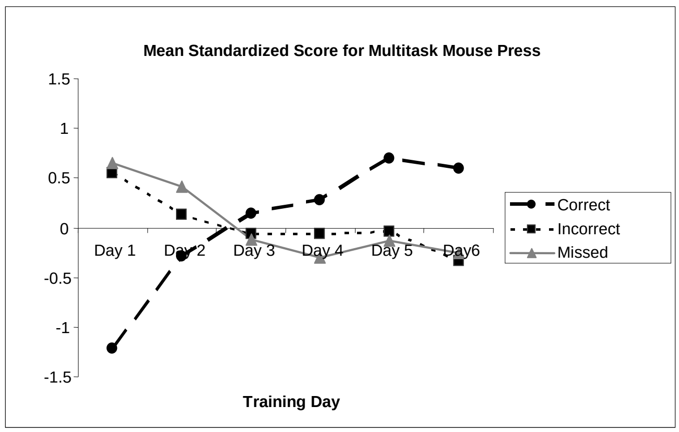


Figure 6. Performance on the multitask key press (upper panel) and mouse press (lower panel) collapsed across versions.

Training-related performance improvement on more distant tasks was examined by comparing group (training vs. control) performance differences at post test for each of the tasks on factors found to be related to measures from the multitask training task in the analyses conducted for Hypothesis 2. Tasks representing a given factor were not aggregated into a common variable because the sample size was too limited to extract only common variance.

This study examined the extent of training and tranfer within a group of older adults but did not test the effect of age on performance because of the restricted range of the sample (age 59 to 70).

CHAPTER 5: PILOT STUDIES

To determine the feasibility of a conceptual replication of the work of Kramer and colleagues (1995), a study was conducted using the multiple task training procedure described in the previous chapter. Individuals monitored a feedback bar that provided individualized speed and accuracy information and set variable priority goals while performing two concurrent tasks.

For 7 older adults (aged 62 to 85 years) latency to respond for correct trials of the summing and the flower-cutting task improved across days, $F(4, 24) = 5.03$, $p < .01$, $\eta^2 = .46$, and $F(4, 24) = 3.37$, $p < .05$, $\eta^2 = .36$, respectively. Accuracy for the summing task and the flower-cutting task also improved across days, $F(4, 24) = 7.80$, $p < .05$, $\eta^2 = .57$, and $F(4, 24) = 8.30$, $p < .001$, $\eta^2 = .58$, respectively. Priority condition (20:80, 40:60, 50:50, 60:40, 80:20) did not correlate with time spent on each task. A qualitative review of individual data revealed two participants with no apparent correlation with priority condition, whereas the majority was biased towards the easier flower-cutting task but did modulate performance based on the priority condition. Instructions were modified to emphasize the importance of the priority condition, and feedback bars were modified for increased saliency (see Methods). Instructions were modified from a verbal instruction script and assistance during the practice trials to a power point presentation with instruction for each task and the feedback bars separately before the administration of assisted practice trials. The size of bars were increased and the incremental update of the display of the bars was modified so that they appeared to be moving either to fill up or to empty rather than updating after a longer duration and in greater chunks. The apparent "movement" of the bars rather than a stepwise updating was thought to increase saliency.

Qualitative feedback from participants was encouraging. Most participants did not find the task tiresome, and some inquired about copies of the program to continue practicing after the training hour. One person said she wouldn't want to do the study again, but all others reported that longer sessions or more sessions would be tolerable. A suggestion was made to increase the size of the keyboard. In this pilot study a laptop was used, and the keys were smaller than on the standard desktop keyboard. So, an additional keyboard was available for use in the larger project.

The second multitask developed to be equivalent to the one using the flower-cutting and number-summing tasks was also tested. Four participants aged 60 to 70 years completed the same training protocol of five 1-hr session across consecutive days. One participant was excluded from the analysis after revealing recent concerns about memory loss, disorganized thinking, and possible psychiatric symptomatology. She requested therapy and was given a referral. The remaining three participants demonstrated increased accuracy and speed of response. Latency to respond for correct trials of the letter and the soccer task improved across days, $F(4, 8) = 18.71$, $p < .001, \eta^2 = .90$, and $F(4, 8) = 6.16$, $p < .01$, $\eta^2 = .76$, respectively. Accuracy for the letter task and the soccer task also improved across days, $F(4, 8) = 6.06$, $p < .01$, $\eta^2 = .75$, and $F(4, 8) = 12.28$, $p < .01$, $\eta^2 = .86$, respectively. This additional pilot study again demonstrated that older adults were willing and able to complete a 5-day training protocol and improved on the tasks across the 5 days.

CHAPTER SIX: RESULTS

Hypothesis 1: Factor analysis to confirm three factor structure of cognitive battery.

Means and standard deviations for the measures from the cognitive battery for the 105 participants are shown in Table 3. The correlations among the measures in the cognitive battery are shown in Table 4. Confirmatory factor analysis was used to test for a three-factor structure of Processing Speed, Working Memory, and Response-Distractor Inhibition with nontrivial correlations among the factors. The fit for a three factor model was evaluated using LISREL software (Joreskog & Sorbom, 2005) and multiple fit indices including the χ^2 statistic, the root mean square error of approximation (RMSEA), and Bentler's comparative fit index (CFI). These indices were selected because they represent different types of fit: absolute fit (χ^2 and RMSEA) and incremental fit (CFI) and are also sensitive to model misspecification (i.e., models that lack necessary parameters or cluster the variables inappropriately) while also being relatively insensitive to small sample size (i.e., $N < 150$; Hu & Bentler, 1998).

The χ^2 statistic measures the degree to which the covariances predicted by the model differ from the observed covariances. Therefore, a small χ^2 statistic indicates no statistically meaningful difference between the covariance matrix generated by the model and the observed matrix and suggests a satisfactory fit. The RMSEA is a measure of goodness of fit. A close fit is indicated by a RMSEA of .05 and below; .08 suggests marginal fit, and .10 suggests poor fit (Browne & Cudeck, 1993). Others allow more freedom and regard an RMSEA of < .06 as indicative of good fit (Newsom, 2005).

Incremental (also known as comparative or relative) fit indices compare the fit of a model with the fit of a baseline model that specifies no common variance among the indicators;

Table 3

Means and Standard Deviations of Measures in Cognitive Battery (N = 105)

Measure	*M*	*SD*
Switch (standardized RT)	.91	.16
Speed		
Simple RT (ms)	298.55	46.21
Pattern Comparisons (no. correct)	27.67	4.78
Digit Symbol (no. correct)	64.46	15.76
Working Memory		
Operation Span	28.02	19.90
Reading Span	29.83	19.31
N Back (percent correct)	60.54	7.22
Response Distractor Inhibition		
Antisaccade (proportion correct)	.73	.19
Flanker Incompatible (standardized RT)	.42	.15
Stroop Incongruent (standardized RT)	-.04	.12

Table 4

Correlations of Measures in Cognitive Battery

Measure	2	3	4	5	6	7	8	9	10
1. Simple RT (A)	**-.21**	**-.31**	**-.20**	-.15	**-.28**	**-.22**	**-.24**	-.16	**-.23**
2. Pattern Comparison (A)		**.37**	**.34**	**.44**	.12	**.25**	.18	.04	**.26**
3. Digit Symbol (A)			**.26**	**.29**	.13	**.33**	.08	.16	**.32**
4. Operation Span (B)				**.73**	**.30**	**.35**	-.04	**.38**	**.24**
5. Reading Span (B)					**.30**	**.40**	.08	**.33**	**.28**
6. Two Back (B)						**.35**	-.05	.05	**.26**
7. Antisaccade (C)							.10	.06	**.33**
8. Flanker (C)								-.14	.05
9. Stroop (C)									.02
10. Switch									

Note: Correlations $\geq$ .20 are significant at alpha = .05 and are shown in bold.

A = Processing Speed factor, B = Working Memory factor, C = Response-Distractor Inhibition factor. Switch task not included in factor analysis.

that is, the measured variables are uncorrelated (Hoyle, 1995; Newsom, 2005). The Comparative Fit Index (CFI; Bentler, 1990) is normed so that values must be between 0 and 1, and the higher the value the better the fit.

The three-factor model was not a good fit for the data, χ^2 (24) = 43.95, p <.01, in terms of the χ^2 statistic. RMSEA was.08, indicating marginal fit; the 90% percent confidence interval was .04 to .12. The CFI was .92, which was within adequate range.

Table 5 shows the estimated reliabilities of the measures used to assess each of the three factors. Reliabilities for the measures of inhibition were low, ranging from .00 to .06. The estimates for the measures for the other two factors varied from high to moderate with only one indicator with low reliability per factor: two back (.13) for Working Memory and simple RT (.19) for Processing Speed. Table 5 also includes a reliability estimate for the switching task, which was not included in the factor analysis. The reliability estimate was generated as part of a later analysis (see Hypothesis 2). In addition to low observed reliability, the Stroop task did not reveal the expected effect of incongruent condition slower than congruent or neutral. This unexpected result is thought to be due to a technical error. See Table 6.

Based on these results inhibition was removed from the model and a two-factor model of Processing Speed and Working Memory was tested. The two-factor model provided a reasonably good fit to the data, χ^2 (8) = 11.34, p = .18; RMSEA = 0.07, 90% confidence interval was 0.00 to 0.14); and CFI = 0.98. Processing Speed and Working Memory were correlated *(r* = -.64). See Figure 7 for the measurement model of these two factors.

Table 5

Reliability of Measures in Cognitive Battery

Measure	Reliability
Switch	.77
Processing Speed	
Simple RT	.19
Pattern Comparison	.34
Digit Symbol	.39
Working Memory	
Operation Span	.69
Reading Span	.78
Two Back	.13
Response-Distractor Inhibition	
Antisaccade	.06
Flanker	.00
Stroop	.04

Table 6

Means and Standard Deviations of the Switch task and Response Distractor Measures as a Function of Condition (N = 105)

Measure	*M*	*SD*
Switch (RT ms)		
Pure Block	966.45	430.11
Switch Block	2201.05	754.63
Response Distractor Inhibition		
Antisaccade (proportion correct)*	.73	.19
Flanker (RT ms)		
Compatible	662.32	120.23
Incompatible	771.92	126.57
Stroop (RT ms)		
Congruent	1006.55	231.76
Incongruent	1005.21	236.10
Neutral	1022.22	241.76

*Antisaccade did not have a prosaccade condition. This was the same procedure used in Freidman and Miyake (2004).

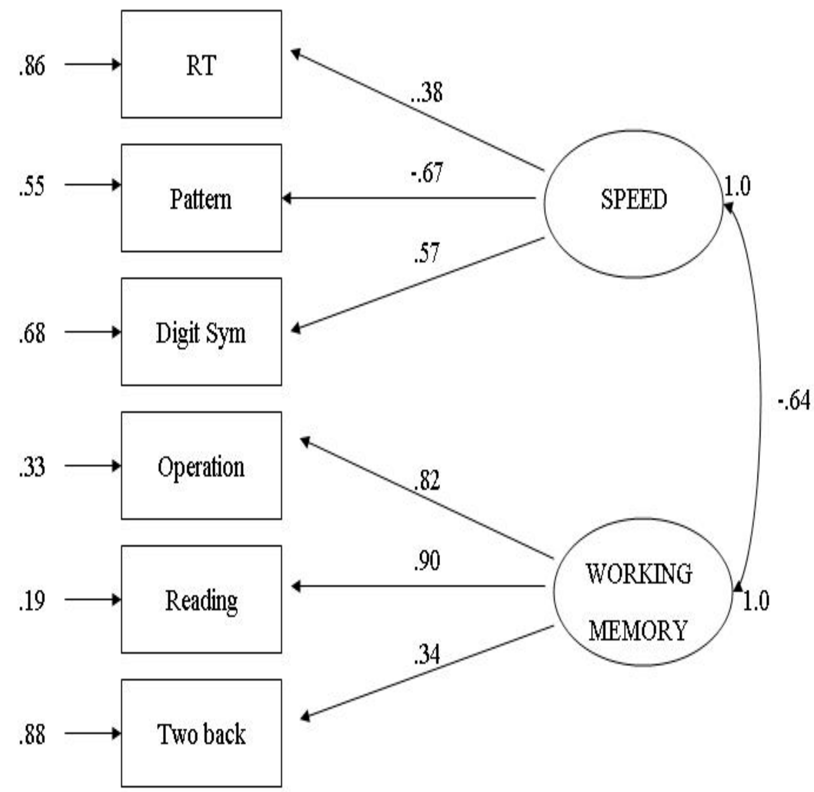


Figure 7. Measurement Model of Working Memory and Processing Speed

Hypothesis 2: Construct validity of the training task

The correlations among the measures in the cognitive battery and the four performance measures of the training task for all 105 participants at the first assessment are shown in Table 7. Performance on the training task in the first session was expected to be significantly correlated with the Response-Distractor Inhibition factor; however, this factor was removed from the measurement model due to the low reliability of the indicators. Correct key press per minute, mouse press per minute, key RT, and mouse RT were entered into the two-factor CFA measurement model. See Table 8 for the *t* values and standardized factor loadings for each training performance measure. Correct key RT was the only measure significantly associated with a factor. The standardized factor loading of correct key RT on Processing Speed was .58. No measures were significantly associated with Working Memory.

Based on previous work by Kramer and colleagues (1995), performance on the switching task was expected to correlate with the training task. As estimated in this analysis, the switching task had good reliability (.77, Table 4). As shown in Table 7, at initial assessment the switching task was moderately correlated (r = .33) with the key press per minute but not with the other training task measures. It was hypothesized that the switching task would be related to the Response-Distractor factor. Even though the Response-Distractor factor did not remain in the model, the switching task was entered into the measurement model with paths from the remaining factors of Working Memory and Processing Speed. See Table 9 for the *t* values and standardized factor loadings for the switch task (standardized RT of switch block trials standardized across pure and switch trials for each participant). The standardized factor loading of the switch task on Processing Speed was -.46. The switch task was not significantly associated with Working Memory.

Table 7

Correlation of Measures in Cognitive Battery with Multitask Performance (N =105)

Measure	Key press	Mouse press	Key RT	Mouse RT
1. Simple RT (A)	**-.26**	-.15	**.28**	.06
2. Pattern Comparison (A)	**.27**	.13	**-.32**	-.12
3. Digit Symbol (A)	**.23**	.01	**-.27**	-.10
4. Operation Span (B)	**.39**	**.25**	**.29**	-.13
5. Reading Span (B)	**.34**	**.20**	-.18	-.14
6. Two Back (B)	**.45**	**.22**	**-.24**	-.08
7. Antisaccade (C)	**.43**	.17	-.17	-.11
8. Flanker (C)	.06	.09	-.07	-.17
9. Stroop (C)	.06	.09	-.03	-.13
10. Switch	**.33**	.16	-.10	-.14

Note: Correlations ≥ .20 are significant at alpha = .05 and are shown in bold. A = Processing Speed factor; B = Working Memory factor; C = Response-Distractor Inhibition factor. Switch task not included in factor analysis.

Table 8

Standardized Factor Loadings for Training Measures on Working Memory and Processing Speed Factors (N =105)

Factor	Key press	Mouse press	Key RT	Mouse RT
Processing Speed				
Factor loading	-0.27	0.28	**0.58**	-0.08
t (12)	-1.54	1.66	**2.91**	-0.47
Working Memory				
Factor loading	0.27	0.01	0.11	0.13
t (12)	1.73	0.06	0.57	0.70

Note: *t* value $\geq$ 2.18 is significant at alpha = .05 and is shown in bold.

Table 9

Standardized Factor Loadings for Switching Task

on Processing Speed and Working Memory Factors

(N = 105)

Factor	Switching
Speed	
Factor loading	**-0.46**
t (12)	**-2.47**
Working memory	
Factor loading	.03
t (12)	.15

Note: *t* value $\geq$ 2.18 is significant at alpha = .05 and is shown in bold.

Correlations among the switching task and individual cognitive variables proposed to form a Response-Distractor Inhibition factor were conducted post hoc due to the failure to obtain this factor in the CFA. There was only one moderate correlation ($r = .33$) with the antisaccade task. No relationship was found with the flanker task. The switching task correlated moderately with measures of processing speed and working memory, ranging from .23 to .33 across all measures (see Table 4).

Hypothesis 3: Plasticity of performance over the training week

The four measures from the training task were examined for changes that occurred during training of the 20 participants in the training condition. For each of the four measures each participant's scores from the pretest and the five training sessions (within participant performance) were first converted to *z* scores to eliminate individual differences in speed.

Mixed analyses of variance including task version as a between subjects independent variable and time (the six sessions) as a within subjects independent variable were conducted for each of the four measures. In all four analyses the sphericity assumption was violated; therefore the Greenhouse-Geisser correction was applied. Because the scores were standardized within participants, the effect of version always produced an F of 0.

The results of the within portion of the four analyses are shown in Table 10. There was a main effect of time on each measure, but no interaction between version and time.

Table 10

Within Subjects Portion of Mixed Analysis of Variance of Standardized Measures from Pretest and Training Sessions for Training Group (N =20)

Source	*df* [a]	MS	*F*	*p*	η^2
		Key press per minute			
Time	1.84	48.82	159.16	<.0001	.90
Version x Time	1.84	0.09	0.29	.73	
Error 2	33.07	0.31			
		Mouse press per minute			
Time	2.07	42.27	128.10	<.0001	.88
Version x Time	2.07	0.06	0.18	.84	
Error 2	37.29	37.39			
		Key RT			
Time	2.51	22.42	24.09	<.0001	.57
Version x Time	2.51	0.68	0.73	.52	
Error 2	45.18	0.93			
		Mouse RT			
Time	1.66	46.36	61.11	<.0001	.77
Version x Time	1.66	0.22	0.28	.71	
Error 2	29.89	0.76			

[a] Greenhouse-Geisser correction

That is, the pattern of change over the sessions did not vary as a function of version of the task. Therefore the means and standard deviations for the standardized scores from the four measures collapsed over version are shown in Table 11. The effect of training (time) on each measure was significant (Table 10) and in the predicted direction of improved performance over time. For Task A (key press) participants increased the number of correct keys pressed per minute over the six sessions with a large effect size of $\eta^2 = .90$. Median RT per key press response decreased over time, again with the substantial effect size of $\eta^2 = .57$. For Task B (mouse hits), participants increased the number of correct mouse hits per minute over the six sessions with a large effect size of $\eta^2 = .88$. Median RT per mouse hit decreased over time, again with a large effect size of $\eta^2 = .77$.

Hypothesis 4: Transfer to Novel Multitask (Near Transfer)

Analyses of variance including task version and group (training vs. control) as between subjects independent variables were conducted for each performance measure (correct key press per minute, mouse hit per minute, key RT, and mouse RT) obtained on the novel multitask administered at posttest. Scores were standardized within version collapsing across training and control groups. Table 12 shows that there was a main effect of group for key press per minute, mouse press per minute, and mouse RT but no interactions between version and group. That is, the difference between groups did not vary as a function of version of the task. Because the scores were standardized within version, the effect of version produced *F*s of 0, which are omitted from Table 12.

The means and standard deviations for the four standardized measures collapsed over version are shown for each group in Table 13. The training group demonstrated more key presses per minute, mouse presses per minute, and faster mouse RT on the

Table 11

Means (and Standard Deviations) of Standardized (Within Each Participant) Scores from Pretest and Five Training Sessions for Scores collapsed across Task A and Task B in the Training Group (N = 20)

	Key press	Mouse press	Key RT	Mouse RT
Pretest	-1.64 (.17)	-1.71 (.35)	1.29 (.64)	1.64 (.65)
Training session				
1	-.52 (.26)	-.36 (.47)	.38 (.71)	.31 (.67)
2	.11 (.33)	.19 (.33)	-.04 (.69)	-.29 (.37)
3	.41 (.33)	.37 (.29)	-.30 (.46)	-.38 (.25)
4	.71 (.26)	.70 (.17)	-.51 (.55)	-.58 (.23)
5	.92 (.40)	.81 (.28)	-.81 (.65)	-.71 (.29)

Table 12

Analyses of Variance of Performance Measures on the Novel Transfer Multitask Administered at Posttest

Source	*df*	MS	*F*	*p*	η^2
		Key press per minute			
Group	1	4.70	5.20	<.05	.12
Group x Version	1	0.98	1.08	.30	
Error	37	0.90			
		Mouse press per minute			
Group	1	6.73	7.81	<.01	.17
Group x Version	1	.48	0.56	.46	
Error	37	.86			
		Key RT			
Group	1	.96	0.95	.33	
Group x Version	1	.64	0.64	.43	
Error	37	1.01			
		Mouse RT			
Group	1	3.87	4.13	<.05	.10
Group x Version	1	.59	0.63	.43	
Error	37	.94			

Effect size reported for significant effects only.

Table 13

Means (and Standard Deviations) of Standardized Performance Measures (within Version) on the Novel Multitask Administered at Posttest to the Training and Control Groups

Measure	Training (n = 20)	Control (n = 21)
Key press	0.34 (1.00)	-0.33 (0.87)
Mouse hit	0.41 (.98)	-0.39 (0.84)
Key RT	-0.15 (0.83)	0.15 (1.11)
Mouse RT	-0.31 (0.74)	0.30 (1.11)

novel multitask than the control group. Although the training group had faster key RTs than did the control group, the difference was not significant.

Hypothesis 5: Far Transfer to Cognitive Variables.

As reported in the analyses related to Hypothesis 2, measures from the training task were correlated at pretest with the switching task and with the Processing Speed factor. Therefore, mixed analyses of variance comparing the training and control groups at pretest (session 1) and posttest (session 7) were conducted for the switching task and the three measures from the Processing Speed factor (Simple RT, Pattern Comparison, and Digit Symbol). Table 14 shows the means and standard deviations for each of these measures for the training and controls groups at pretest and posttest. There were no significant effects for the switching task: group, $F(1, 39) = 2.32$, $p = .14$; session, $F(1, 39) = 1.42$, $p = .24$; Group x Session, $F(1, 39) = 0.32$, $p = .58$. For simple RT there were significant effects of group, $F(1, 39) = 3.95$, $p = .05$, $\eta^2 = .098$, and session (pretest to posttest) for simple RT, $F(1,39) = 16.50$, $p = .001$, $\eta^2 = .29$, that were qualified by a significant Group x Session interaction, $F(1, 39) = 4.09$, $p = .05$, $\eta^2 = .10$. Unexpectedly, both groups were slower (rather than faster) at posttest, but the slowing from session 1 to session 7 was less pronounced in the training group (298 vs. 310 ms) than in the control group (308 vs. 344 ms). For Pattern Comparison the group effect was not significant, $F(1, 39) = 1.87$, $p = .18$, but session was, $F(1, 39) = 4.36$, $p = .04$, $\eta^2 = .10$. The Group x Session, however, was not significant, $F(1, 39) = 0.48$, $p = .49$. Both groups improved slightly. For Digit Symbol the group effect approached significance, $F(1, 39) = 3.27$, $p = .08$, $\eta^2 = .08$, and the effect of session was significant, $F(1, 39) = 5.31$, $p = .03$, $\eta^2 = .12$. The Group x Session interaction also approached significance,

Table 14

Means (and Standard Deviations) of Four Cognitive Measures at Pretest and Posttest for the Training and Control Groups

Time	Training	Control
	Switch RT[a]	
Pretest	0.92 (0.20)	0.98 (0.10)
Posttest	0.90 (0.10)	0.94 (0.12)
	Simple RT	
Pretest	298.33 (32.99)	308.02 (50.47)
Posttest	310.12 (30.18)	343.70 (41.01)
	Pattern Comparison	
Pretest	29.20 (4.30)	27.33 (3.62)
Posttest	30.20 (4.46)	28.33 (3.31)
	Digit Symbol	
Pretest	52.50 (12.02)	64.81 (16.67)
Posttest	63.70 (17.52)	66.00 (15.27)

[a] Standardized across all blocks; standardized RT reported here from switch block only.

$F(1, 39) = 3.47$, $p = .07$, $\eta^2 = .08$. As predicted, scores improved at posttest and more so in the training group (52.50 vs. 63.70) than the control group (64.81 vs. 66.00).

CHAPTER SEVEN: DISCUSSION

The purpose of this study was to characterize the cognitive constructs associated with variable priority training and to test a replication of a variable priority task for training and transfer effects in a group of healthy older adults. The goal of replication and assessment of transfer effects was accomplished successfully. Characterization of the cognitive constructs associated with the task less so; this partial success will be addressed first.

Constructs Associated with the Training Task

When dealing with cognitive constructs that are anticipated to have shared variance, it is preferable to interpret the unique variance at the construct level rather than to interpret associations at the task level (see Friedman, Miyake, et al., 2004, for a discussion of latent variable approach). Most cognitive tasks have a moderate proportion of variance that can be attributed to individual differences in processing speed (Salthouse, 1996). For example, it was demonstrated in this study that the constructs of working memory and speed were correlated. Therefore, task level associations, although a useful first step in small samples, must be interpreted with caution due to problems of task impurity when the goal is to make subtle distinctions among constructs such as speed versus aspects of executive function.

The a priori model of Processing Speed, Working Memory, and Response-Distractor Inhibition hypothesized in this study was not supported by the data. The attempt to assess response-distractor inhibition failed because two of the three tasks purported to be associated with the construct had very low reliabilities according to the measurement model. Of note, the antisaccade and flanker tasks were not measured in the same way as Freidman and Mikaye (2004) and reliability estimates were based on the CFA not split-half correlations. In addition, the third response-distractor task, the Stroop task, was not included in subsequent analyses due to a technical error in task administration.

A two-factor model including Processing Speed and Working Memory was supported, however. Therefore only the relation between the training task and the two constructs of speed and working memory could be tested. The training task was associated with processing speed but not working memory, despite modest associations of the training task with the individual tasks associated with working memory. This finding of unique variance associated with processing speed and not with working memory supports Salthouse's (1996) explanation for the relationship between measures of processing speed and other aspects of cognition. According to his theory, the shared variance among the measures of processing speed and working memory may be explained by a time limitation for certain mental processes such that only early stages of processing are completed due to slowed execution; thus the computation is not fully carried out. Alternatively, there is a necessary simultaneity of processing for certain tasks, and slowing could disrupt this interdependence among the processing streams necessary to carry out the computation successfully. Both accounts incorporate findings of incorrect as well as delayed responses and further explain how slowed processing may not benefit simply from increased time on task.

Once the variance associated with these proposed mechanisms is accounted for, the relationship between the training task and working memory was no longer significant. Thus the relationships among the training task and the measures of processing speed include some shared aspect of the working memory tasks as can be seen in the moderate correlation between processing speed and working memory. It is important to note that Salthouse's own work (Salthouse, 2007) has demonstrated that there are unique aspects of complex tasks that cannot be attributed to an effect of general slowing. It appears, however, that the relationships examined in this study did not assess those aspects of executive function and are best described by the simpler theory proposed in Salthouse's earlier works. Working memory, therefore, may not be related because the apparent relationship is due to the shared variance with processing speed and not unique variance related to the executive component of this more complex task.

It is still possible that performance on the training task is related to other aspects of executive function distinct from speed or working memory. Because of the failure to obtain standard distractor effects in the Stroop task, and the low-reliability of the flanker task, the role of response-distractor inhibition remains unclear.

Replication of Kramer et al. (1995)

The multitask training effect first demonstrated by Kramer and colleagues (1995) was successfully replicated in a new sample of healthy older adults using a task developed based on the recommendations of Kramer et al. (1995) to include a working memory load and variable priority constraints as well as individualized feedback. Substantial effect sizes across training days with increased accuracy and decreased reaction times on all components of the multitask were similar to previous findings.

Similar to the anecdotal findings reported by Kramer et al. (1995), individuals found the task very challenging at first; thus a detailed instruction was developed. A few individuals stated that the task was tedious. It was also striking that other participants requested versions of the task to take home after the study was completed because of perceived benefit and stated enjoyment. There was no attrition from the training study once participants began the first training day (session 2). Still, there may be individual differences in how likely it is that older adults will agree to undergo such training.

As expected, both the training and control groups improved from pretest (session 1) to posttest (session 7). Across several training task performance measures, however, the training effect was larger than the practice effect modeled by the improvement in the control group in the test of near transfer of training to a novel multitask See Table 14 for group (training versus control) comparisons. Individuals in the training group outperformed individuals in the control group on the novel version of the task at posttest. Thus, training transferred beyond the benefit of the specific materials used. For example, familiarity with number summing or determining the distance two letters are apart from each other in the alphabet is expected with practice on that task. The test of near transfer of training indicated that individuals who trained on number summing, for example, outperformed the control group on the alphabet task. This demonstrated a training effect that was not specific to the task materials.

Kramer and colleagues (1999) proposed that multitask training-related performance benefit is related to improved switching or manipulation of multiple tasks. Although, it is reasonable to assume a relationship based on the nonspecific transfer of performance on a complex task (such as number summing), this study's characterization of the training task identified processing speed as a strongly associated construct and did not identify a unique contribution from working memory. Therefore, it is likely that the training improves cognitive processing speed in the context of a complex task, rather than training a unique aspect of that task that is independent of speed. It has been demonstrated that older adults can improve processing speed with practice (Baron & Matilla, 1989; Edwards et al., 2005; Willis et al., 2006) and that improved processing speed leads to improved performance on a test associated with driving ability as well as improved performance on a measure of instrumental activities of daily living. Of note, the more distal measure of improvement on instrumental activities of daily living was demonstrated in a large sample and observed as a relative lessening of performance decline over time compared with a control group, rather than absolute improvement.

Far Transfer

A key aspect of training that is often difficult to demonstrate empirically is transfer to other more distant tasks. Thus, a further test of the extent of transfer of training effects examines performance on cognitive tests that have a greater degree of difference in form from the training task (e.g., purported to represent a particular aspect of cognition, different task instructions, or pencil-and-paper based). This type of transfer also tests hypotheses about *what* aspect of cognition improves with training, to the degree that a given test may implicate a cognitive construct.

An indication of far transfer was suggested for one cognitive measure. Individuals in the training group demonstrated a trend towards differentially better performance than the control group on a measure of processing speed (Digit Symbol). Recall that at pretest the training task was related to the processing speed construct. Thus, the finding that training on the complex multitask improved performance on a measure of speed supports the notion that more fundamental processes are amenable to training within the context of a complex task. This approach is not new; improved processing speed was reported in the studies described by Willis and colleagues (2006).

Far transfer is anticipated to be a smaller effect than the training effect or a near transfer to a similar task, and so it is not surprising that previous studies documenting these more remote outcomes of training included large sample sizes. It is possible that the limited size of this study constrained the ability to identify more remote indicators of training-related improvement.

This study is unique in its ability to lend support to the notion that the underlying mechanism responsible for the near transfer of training benefit from one complex task to a different complex task is the more fundamental aspect of cognition, namely processing speed. This support, however, is limited given the mixed findings on measures of processing speed. Recall that training led to slower rather than faster performance on a simple reaction time measure, although training had an attenuating effect on that performance decline. There was no effect of training on a measure of speeded judgment of pattern similarity. On another measure of processing speed that involved speeded coding of number-symbol pairs there was a trend in the direction of improved performance among the training group. From these results it appears as though processing speed may be affected by the training, but interpretation is complicated by possible multiple factors influencing changes in performance. For example, there may be a tradeoff between fatigue effects (as seen in the simple reaction time task) and improvements seen on a more complex processing speed measure. The lack of consistency calls for further testing before a clear interpretation can be proposed. A larger set of processing speed measures capturing several versions of simple reaction time and more complex measures would allow for a detailed interrogation and parsing of possible training effects on speeded measures.

Kramer and colleagues (1997) proposed that multitask performance depends on an individual’s ability to switch between several tasks. Given this hypothesis, performance on the multitask should be related to other measures of task switching, and improvements in multitasking with training should be observed to transfer to performance on other switching tasks. This position was not supported. It is, however, important to note that the measure of task switching also shared variance with measures of processing speed. If improvement on the switching task was observed, the relative contribution from shared variance with processing speed versus a unique task-switching component should be tested. This study indicates that larger samples with more indicators of a task-switching construct would be required.

Limitations

A methodological limitation of this study was the poor reliability of some of the measures in the cognitive battery. Previous studies that reported higher reliability estimates also had larger numbers of trials for each task (Freidman & Miyake, 2004). Feasibility in terms of the length of the cognitive battery limited the number of trials per task, and this change may have affected the observed reliability. As a result the relationship among measures of the same construct and associations across constructs may have been attenuated.

Another methodological concern is that of construct validity. Moderate correlations were observed among some measures of the same purported construct. Salthouse (2009) argued that cognitive constructs such as processing speed, working memory, and executive function are expected to be moderately correlated, and therefore a standard should be set to look for large correlations when seeking to identify measures within the same construct. Given this rule of thumb, the training task does not appear to be described by any one of the constructs proposed, although it shares some variance with many measures.

This study demonstrated the importance of accounting for practice effects as evidenced by improved performance in the control group with differential benefit in the training group on only select measures of the training tasks and cognitive measures. Long term effects with additional follow-up assessment after the immediate posttest was not assessed. Little is known about the time course of the benefits of training on the task itself or other outcome measures of near and far transfer.

Future Directions

Several lines of research could build upon the information learned from this study. Further work to characterize the cognitive constructs related to the training task and training-related improvement is needed. In the past several years cognitive researchers have made important inroads to better differentiate the construct of executive function and to describe the unique versus shared variance among cognitive constructs of speed, working memory, and other aspects of executive function. This area, however, remains in an early stage of development and lacks clear specification and replication of studies that identify tasks that can be used to represent a given construct with a high degree of confidence. As this basic research moves forward, more complex tasks that are suspected to be related to several aspects of cognition can be better characterized.

The rationale for this study was that older adults have deficits in certain aspects of cognition including processing speed, working memory, and other executive functions and therefore may benefit from training that could potentially enhance these areas of cognition. All participants in this study were healthy, active older adults in the seventh decade of life, many with high levels of education and experience with cognitive testing as participants in other studies (not of training). It remains to be seen if similar benefits of training can be obtained in people who are older, less educated, or naive with regard to cognitive assessment. Further, there are patient populations (both young and old) with specific impairments in similar areas of cognition for whom training might be beneficial. For example, individuals with cardiovascular disease have cognitive deficits in processing speed and aspects of executive function. Patients with these deficits may benefit from training, especially if transfer to functional performance can be demonstrated.

The issue of functional performance leads to another line of research that would extend the scope of the current study. Outcome measures need to be developed to test the hypothesis that there is potential functional improvement with training. These measures will likely have some of the same methodological obstacles that were encountered in the laboratory cognitive measures, including the need for ground work to address test reliability and construct validity. There are a few studies investigating ecologically valid outcome measures for cognitive training (e.g., Ball et al., 2002; Willis et al., 2006), but more work is needed as research questions are asked that involve assumptions about the transfer of a construct from training tasks to proximal outcomes (cognitive tasks) to more distal outcomes (such as time to nursing home placement or other measures of functional independence such as managing finances, driving, managing medication, or caretaking). The aforementioned studies have tested for an effect of training in select cognitive domains on distal outcomes but the *assumptions* about how training may transfer to these outcome measures has not been systematically addressed. In other words, it is still not clear if we are testing the training effect of oranges to oranges or apples to oranges. As these lines of research are further developed and the methodological underpinnings are better specified (see Barnett & Ceci, 2002 for methodological framework and review), it will be possible to interpret with greater confidence the outcome of targeted questions that address the efficacy and generalizability of cognitive training interventions.

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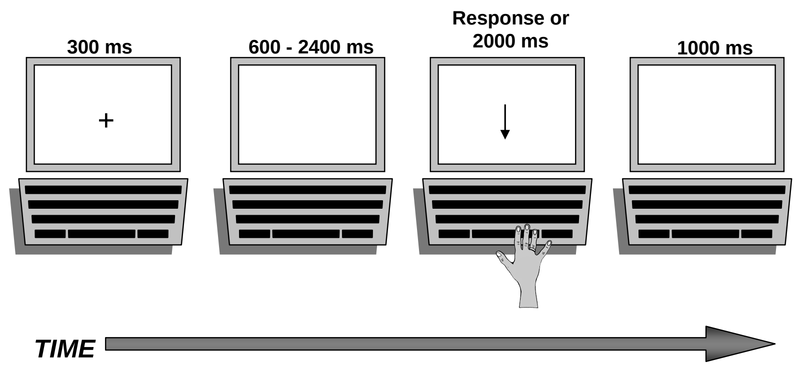
APPENDIX A



Stimuli and apparatus in the simple RT task.

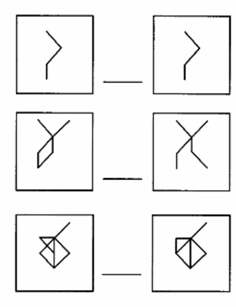
Appendix B.

ID # ___

Pattern Comparison

In this test you will be asked to determine whether two patterns of lines are the same or different. If the two patterns are the SAME, write an S on the line between them. If they are DIFFERENT, write a D on the line. Please try to work as rapidly as you can, writing an answer to each pair of line patterns.

Try the following examples.



Please do not turn the page until instructed to do so.

Sample Pattern Comparison. Reproduced with permission from the Salthouse laboratory.