ATTENTION IN NORMAL AGING AND ALZHEIMER'S DISEASE

A Thesis Submitted to

the College of Graduate Studies and Research

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy

in the Department of Psychology

University of Saskatchewan

Saskatoon

By

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Abstract

A large body of research has investigated various aspects of attention in normal aging and Alzheimer's disease (AD). Most of the previous studies have shown that divided attention, the ability to attend to two tasks or stimuli simultaneously, declines in both normal aging and AD. In a recent study of attention, Baddeley, Baddeley, Bucks, and Wilcock (2001) reported findings that contrast with other divided attention research. Specifically, they found no effects of aging on divided attention. Taken in combination with their findings of age and AD effects on other aspects of attention, the authors concluded that age-equivalent results on divided attention tasks support the theory that attentional control should be viewed as a fractionated system. Study 1 considered methodological differences between the divided attention tasks used by Baddeley et al., and the tasks used by researchers who have reported age-related differences. Specifically, the effects of task difficulty on age effects were examined. Young, middle-aged, and older adults were compared on a dual-task procedure that combined a secondary visuomotor task (box joining) with a primary verbal task (month reciting) administered at two levels of difficulty. Results showed a significant Age x Task Difficulty interaction. That is, differences among age groups were proportionately greater in the difficult dual-task condition versus the easy condition, suggesting that age-related declines in divided attention may only be detected if tasks are sufficiently difficult.

Study 2 examined attention in normal aging and AD. Young adults, older adults, and early-stage AD patients were compared on tasks of selective attention, focal attention, and divided attention, with each task administered at two levels of difficulty. Similar Group x Task Difficulty interaction effects were detected for all attentional tasks, a finding which is more consistent with a general-purpose model than a fractionated model of attention. Study 3 considered attentional tasks from a clinical perspective. Specifically, the attentional tasks utilized in Study 2 were examined with respect to their ability to correctly classify individuals with early-stage AD and normal older adults. Findings showed that all attentional tasks successfully discriminated patients from cognitively healthy older adults, with one task of divided attention showing particularly impressive sensitivity and specificity. Findings of the three studies are discussed with regard to their implications for future research and clinical practice.

Acknowledgements

Many people deserve thanks for their guidance and support throughout my years in graduate school and the completion of this dissertation. First, thanks to my supervisor, Dr. Margaret Crossley, for always being available to help and for providing such a wonderful example for me to follow. Thanks also to the faculty and staff of the Department of Psychology and to the members of my committee for all of their helpful suggestions and contributions to my dissertations. My committee consisted of Dr. Jamie Campbell, Dr. Lorin Elias, and Dr. Andrew Kirk. Thanks to Dr. Joan McDowd for serving as the external examiner for my dissertation defense.

A big thank you is owed to my family. I would not have been able to make it through the many challenges of graduate school without their constant and unwavering support. Finally, I would like to thank Leah for being there for me throughout the many highs and lows of graduate school.

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Attention in Normal Aging and Alzheimer's Disease

This dissertation examines attentional functions in normal aging and Alzheimer's disease (AD) by reviewing the literature and describing three studies. The studies were conducted to increase knowledge about attentional changes in normal aging and AD and to address theoretical and clinical questions that have been unresolved by research to date. From a theoretical perspective, the primary objective of these studies was to contribute to the growing body of literature and to advance understanding about the neuropsychological organization of attentional functions by investigating how they are affected in aging and AD. From a clinical perspective, the aim was to determine if knowledge about attention in AD can be used to help differentiate early-stage AD from normal aging. Baddeley proposed that attentional control is a primary function of the central executive, which is a key component of his model of working memory. The following general overview provides a description of this model and a summary of research examining the central executive and attention in normal aging and AD. Following this overview, the three studies comprising this dissertation are described. Study 1 provides an investigation of the effects of age and task difficulty on divided attention ability. In Study 2, the effects of normal aging and Alzheimer's disease on various domains of attention are considered. Finally, Study 3 examines the attentional performance of healthy older adults and AD patients from a clinical perspective to determine if tasks of attention can contribute to the identification of AD in the early stages.

Baddeley's Model of Working Memory

The term "working memory" has been used to describe the cognitive process of holding and manipulating information for a brief amount of time as a task is performed. The working memory model, originally proposed by Baddeley and Hitch (1974), described working memory as a multi-component system capable of both storing and manipulating information, and central to several complex cognitive activities.

Baddeley and Hitch's (1974) early model proposed that working memory is a non-unitary system, made up of multiple, specialized components. Specifically, Baddeley and Hitch suggested that working memory is comprised of a central executive supervisory system and at least two "slave systems" which are specialized for processing and temporarily maintaining information within a particular domain. The articulatory loop was postulated to maintain verbal information through subvocal rehearsal while the visuo-spatial sketchpad was thought to perform a similar function for visual information through visualization of spatial material (Baddeley, 1986). These specialized components of cognition allow humans to comprehend and mentally represent their immediate environment, to retain information about their immediate past experience, to support the acquisition of new knowledge, to solve problems, and to formulate, relate, and act on current goals (Baddeley & Logie, 1999). In addition to the three components of working memory originally proposed by Baddeley and Hitch (1974), Baddeley's current model of working memory has been expanded to include a fourth component, the episodic buffer (Baddeley, 2000) which has been proposed as providing an interface between the slave systems and long term memory.

Converging lines of research have provided solid evidence supporting the separateness of the three originally proposed working memory subcomponents, and particularly for the proposed "slave systems". For example, the articulatory loop and visuo-spatial sketchpad have been dissociated through the demonstration of selective interference effects found in normal adults in dual-task paradigms, whereby interference is greater when both tasks are thought to rely on the same "slave system" (Baddeley, 1986; Logie, 1995). Other supporting evidence for these specialized subcomponents of working memory comes from research that has shown selective sparing and impairments in the slave systems in brain injured patients (Della Sala & Logie, 1993), and differential rates of development for the three working memory components in children.

Both the phonological loop and the visuospatial sketchpad have been extensively investigated, and research has supported the idea that these slave systems may be further divisible into at least two subcomponents. Baddeley (1986) proposed the phonological loop is comprised of both a passive phonological store, which retains phonological representations of verbal information which decay with time, and an active rehearsal process that can offset the decay by restoring the fading phonological representations. According to Baddeley and Hitch (1995), there are four main clusters of evidence supporting the concept of the phonological loop: (1) the phonological similarity effects, in which immediate serial recall is impaired when items are similar in sound (Conrad & Hull, 1964); (2) the irrelevant speech effect, in which spoken material that the participant is instructed to ignore impairs immediate verbal serial recall (Colle & Welsh, 1976); (3) the word length effect, which sees immediate memory span systematically declining with the spoken length of the remembered items (Baddeley, Thomson, & Buchanan, 1975); and (4) articulatory suppression, in which requiring participants to utter an irrelevant sound during immediate serial recall impairs performance and eliminates the word length effect (Baddeley, Lewis, & Vallar, 1984).

The visuospatial sketchpad component of working memory is thought to be responsible for the processing and storage of visual and spatial information, and for other types of input that can be recoded into forms that specify visual and spatial coordinates (Baddeley, 1986). According to Baddeley and Hitch (1995), this component, which operates independently of the phonological loop, is needed in the model of working memory to account for evidence that visuospatial and verbal working memory involve separate resources. Logie (1995) has investigated the visuospatial sketchpad and proposed that, like the phonological loop, it can be divided into passive and active processes, which have been termed the "visual cache" and the "inner scribe" respectively. Baddeley and Hitch suggest that a primary piece of evidence supporting the existence of the visuospatial sketchpad is demonstrated by selective interference effects, whereby secondary visuospatial tasks disrupt performance on other spatial tasks to a greater extent than the disruption seen on other nonspatial tasks. For example, Baddeley, Grant, Wight, and Tompson (1975, as cited in Baddeley & Hitch, 1995) found that performance on a spatial task was disrupted by a concurrent visuospatial pursuit tracking task, but not by a non-spatial, abstract task, supporting the concept of an independent visuospatial sketchpad with limited processing resources.

The Central Executive of Working Memory

Baddeley's concept of the central executive is modeled on the construct of the supervisory attentional system, first proposed by Norman and Shallice (1980) to explain goal-directed and consciously controlled behaviour. Initially, the central executive was described as a non-specific homunculus and was assumed to be comprised of a pool of general purpose processing capacity that could be used to support either control processes or supplementary storage (Baddeley & Hitch, 1974). Later, Baddeley (1986) suggested that the central executive is the control center of the working memory system, responsible for selecting and operating various control processes. This conceptualization of the central executive assumes that it has a limited amount of processing capacity, some of which may be devoted to short-term storage of information. In addition, Baddeley (1986, 1996) postulated that the central executive is capable of “off-loading” storage demands onto the phonological loop and visuospatial sketch pad.

More recent research has led to further developments and modifications of Baddeley’s conceptualization of the central executive of working memory. For instance, Baddeley and Hitch’s (1974) original working assumption that the central executive’s pool of general purpose processing capacity can be used to support either control processes or supplementary storage has since been revised. It is no longer assumed that the central executive itself performs a memory storage function. Instead, increases in storage capacity beyond that which can be managed by the slave systems are thought to result from accessing long term memory or other subsystems. Both theoretical and empirical factors have led to these modifications in the concept of the central executive. From a theoretical perspective, Baddeley and Logie (1999) proposed that by giving the central executive the capacity to supplement and mimic the capacities of the slave systems, the proposed central executive would be too powerful and flexible to be investigated productively.

From an empirical perspective, research has attempted to specify the roles of the central executive and to identify the tasks it needs to perform and how it achieves them. Gathercole (1994) argued that the central executive’s roles fall into two broad categories: (1) control activities, including the control of attention and the ability to regulate information flow through the working memory system; and (2) storage and processing capabilities, including retrieval from long-term memory, maintenance rehearsal, and the storage and processing of linguistic material. Similarly, Baddeley (1996), and Baddeley and Logie (1999) proposed that the central executive plays a key role in the control and regulation of the working memory system and in performing a variety of executive functions, including coordinating the two slave systems and activating representations within long term memory. Most importantly for the present research, it was proposed that the central executive plays a primary role in controlling attentional processing including the focusing, switching, and dividing of attention. In keeping with these multifaceted models, Baddeley (1996) proposed that the central executive should be conceptualized as a fractionated system consisting of several subsystems.

Working Memory and the Central Executive in Normal Aging

Normal aging is accompanied by declines in a range of cognitive abilities, especially those abilities that involve speed, novelty, and complexity (see Craik & Salthouse, 2000 for a detailed review). One proposed explanation for this age-related deterioration in cognitive performance is a reduction in a general-purpose processing resource (Salthouse, 1988). Based on this explanation, the ability to perform novel, complex tasks is more susceptible to the effects of aging because of the greater demands such tasks place on the age-sensitive processing resource (Salthouse, 1992).

According to Fisk and Warr (1996), the functioning of working memory declines with increasing age, and is associated with the age-related decrements that are seen in many aspects of cognitive performance. This is consistent with other research that has demonstrated poorer performance among older adults when compared with young adults on a range of measures designed to assess working memory functioning (e.g., Salthouse, 1994). Two primary explanations have been proposed to account for the working memory changes associated with normal aging. Firstly, it has been proposed that the age-associated decline in working memory functioning reflects a decline in the processing resources of the central executive (e.g., Baddeley, 1996). In contrast, Salthouse (1994) argues that these age-associated differences can be explained by age differences in processing speed rather than by differences in cognitive resources, and suggests that some construct related to processing speed needs to be incorporated into explanations proposed to account for age differences in working memory.

The effects of normal aging on each of the three proposed subcomponents of working memory have been investigated. Firstly, in terms of the functioning of the phonological loop, much of the research investigating age differences has focused on rate of articulation, which has implications for the number of items that can be rehearsed in the subvocal rehearsal component of the phonological loop. For example, procedures include the use of articulatory suppression techniques, which are thought to interfere with the subvocal rehearsal of verbal information. Gerhand (1994, as cited in Phillips & Hamilton, 2001) reported significant age differences favoring younger adults on a digit span task performed alone, but no age differences in digit span when articulatory suppression was used to prevent subvocal rehearsal. The authors concluded that slow subvocal rehearsal may underlie age differences in simple verbal memory tasks. Other techniques used to investigate rate of articulation have reached similar conclusions, and according to Phillips and Hamilton, the majority of evidence suggests an age-associated slowing in rate of articulation.

Secondly, regarding the functioning of the visuo-spatial sketchpad, not a great deal of research has directly examined age-related differences. However, some studies using imagery tasks which are thought to rely upon the visuospatial sketchpad have been conducted, and age differences favouring younger adults have been reported (Phillips & Hamilton, 2001). Phillips and Hamilton point out that most tasks that have been used to investigate visuospatial sketchpad functioning have also involved an executive component, making it difficult to determine whether age differences are due to the functioning of the sketchpad or of the central executive.

Finally, in terms of the central executive, Baddeley (1986) argued that this component of working memory is particularly compromised in older adults compared with the slave systems, and a wealth of evidence has been gathered in support of this argument (see Phillips & Hamilton, 2001 for review). For instance, young adults have been shown to outperform older adults on a range of neuropsychological measures thought to assess executive and attentional functions.

Working Memory and the Central Executive in AD

A substantial body of previous research has established that early-stage AD is associated with declines in working memory functioning. In particular, it has been suggested that the central executive component of working memory is impaired in individuals with AD, while the functioning of the phonological loop and visuospatial sketchpad may be relatively spared, at least in the early stages of the disease (Baddeley, 1986; Morris, 1994; Morris & Baddeley, 1988). Thus, in attempts to further current understanding of the central executive, many researchers have relied on comparing and contrasting the performance of AD patients with that of normal older adults on executive tasks. Perhaps most notably, a number of studies have investigated central executive functioning in AD patients by examining their ability to divide their attention between two tasks simultaneously.

In one early study, Baddeley, Logie, Bressi, Della Sala, and Spinnler (1986) explored the hypothesis that AD is associated with a particular impairment in central executive functioning by comparing AD patients with age-matched and young controls on dual-task procedures. Participants were asked to perform a primary pursuit tracking task concurrently with each of three secondary tasks: (1) an articulatory suppression task; (2) a reaction time task; and (3) a digit span task. In order to control age or AD associated individual differences on the pursuit tracking task, the difficulty of the task was adjusted so that performance under single task conditions was equivalent across participants. A similar strategy was used to equate participants' single task performance on the digit span task, while individual differences on the articulatory suppression and reaction time tasks were not controlled.

Results of this study demonstrated that across all combinations of tasks, AD patients were significantly more impaired than age-matched controls on the pursuit tracking task following the addition of the secondary tasks. While only a small dual-task effect was detected for the articulatory suppression task, more dramatic effects were seen when the reaction time and digit span tasks were added to the pursuit tracking task. In contrast, when the age-matched control group was compared with young controls, little or no differential disruption in performance was detected under dual-task conditions. The authors concluded that these results support the hypothesis of a particular central executive impairment in AD.

Belleville, Peretz, and Malenfant (1996) compared young adults, older adults, and AD patients on a variety of working memory tasks to investigate the patterns of working memory impairment associated with both normal aging and AD. One major objective of this study was to investigate whether the differences between normal aging and AD are quantitative in nature, with AD patients showing similar but more extreme deficits, or whether qualitative differences also exist between these groups. Findings showed that AD was associated with decreased performance on tasks thought to rely on central executive functioning, while normal aging was not. The author also reported that as task demands were increased, AD patients became increasingly impaired, which was presented as an argument for the deficit being at the level of the central executive. However, this study also found that AD patients showed deficits in phonological processing, whereas normal older adults did not. This pattern of results suggests that there are both quantitative and qualitative differences between normal aging and AD, and provides evidence contradicting the idea of aging and AD being on the same continuum.

Comparison of Attentional Functions of the Central Executive of Working Memory in Normal Aging and Alzheimer's Disease

As described earlier, Baddeley, Baddeley, Bucks, and Wilcock (2001) investigated the proposed fractionation of the central executive's attentional processes by comparing AD patients with older adults and young control participants on three domains of attention: focal attention, selective attention, and divided attention. Two levels of task difficulty or complexity were used to assess each of these attentional domains. The authors suggested that qualitatively similar effects of task difficulty, age, and AD across the three attentional domains would support the unitary attentional hypothesis, whereas different patterns of results would support the idea of a fractionated executive system.

Baddeley et al. (2001) reported differing patterns of results across the three domains of attention. Specifically, they found that while both aging and AD were associated with declines in focal attention and selective attention, divided attention was affected only by AD. Although the authors presented the finding of age equivalent divided attention performance as a crucial piece of evidence supporting a fractionated executive system, this finding contradicts a large body of previous research suggesting that normal aging is in fact associated with declines in divided attention performance (Craik, 1977; Crossley & Hiscock, 1992; Kramer & Larish, 1994). For example, a meta-analysis of 54 experiments comparing younger and older adults on dual-task performance found that age differences were reliable (Kieley, 1990, as cited in Hartley, 1992).

In keeping with Baddeley's recent work, Perry and Hodges (1999) argued that attention is best conceptualized as a fractionated system which is divisible into several subsystems that perform separate but interrelated functions. For example, it has been proposed that different attentional processes may be responsible for functions such as orienting and focusing attention, filtering out distracting information, and dividing attention. According to Rogers (2000), focused attention refers to the ability to concentrate on a single stimulus in a known location, and sustained attention refers to focusing attention over an extended time period. Selective attention refers to the ability to attend to relevant information, while ignoring irrelevant information (McDowd & Shaw, 2000), and divided attention refers to the ability to perform two or more tasks concurrently, or to attend to multiple stimuli simultaneously (Rogers, 2000). Sarter and Turchi (2002) suggested that divided attention reflects the ability to share the available processing resources between multiple and competing perceptual tasks or cognitive processes.

Perry and Hodges (1999) argued that this division of attentional processes into separable, inter-related subsystems allows for more thorough investigation of age- and AD- associated attentional changes by enabling researchers to investigate similarities and differences among the proposed subsystems.

Attention in Normal Aging

Focused attention. Earlier studies reported that the ability to focus attention remains relatively intact in healthy older adults when compared with younger controls (Wright & Elias, 1979; Madden, 1982). However, directly contradicting this finding, Baddeley, Baddeley, Bucks and Wilcock (2001) reported that normal aging was associated with poorer performance on a reaction time task used as a measure of focused attention abilities.

Sustained attention. Findings from the majority of previous research investigating sustained attention indicate that normal aging is not associated with declines in performance (e.g., Giambra & Quilter, 1988). In a more recent study, Berardi, Parasuraman, and Haxby

(2001) reported that the ability to sustain attention was equivalent in young, middle-aged, and older participants under conditions requiring both automatic and effortful stimulus processing.

Selective attention. Researchers have used a variety of procedures in investigations of age-related changes in selective attention, with perhaps the most commonly-used procedures being visual search tasks, in which participants must locate certain items among an array of distracting items (Rogers, 2000). Previous research has yielded mixed findings with regards to the effects of normal aging on visual search task performance. While many studies have reported age-related deficits on visual search tasks (see McDowd & Shaw, 2000 for a review), some researchers have suggested that age-related differences may depend on the novelty of the target and distracter information. Clancy and Hoyer (1994) compared young adults with middle aged adults on visual search tasks and reported no age-associated differences when stimuli were familiar, but found that middle-aged adults performed more poorly when stimuli were unfamiliar. Although this study did not include older adults, the findings suggest a further need to investigate the effects of familiarity and complexity on the selective attention abilities of all age groups.

The Stroop colour-word task, which requires participants to process one aspect of a stimulus word (the colour in which the word is printed) while ignoring another aspect of the same stimulus (the word itself), has also been used frequently as a measure of selective attention. Studies that have investigated age-associated differences have typically shown that older adults are more susceptible to interference effects than younger adults (see McDowd & Craik, 2000 for a review).

Divided attention. As described earlier, previous studies regarding the effects of normal aging on the ability to divide attention provide contradictory evidence. Divided attention has typically been investigated through dual-task paradigms, in which study participants are required to divide their attention between two concurrent tasks and the interference on each task is measured. Past dual-task research, using a variety of different procedures and methodologies, has generally established that normal aging is associated with a gradual decline in divided attention abilities (Craik, 1977; Kramer and Larish, 1996).

There have, however, been exceptions to the finding that aging is associated with a decline in dual-task processing, particularly by researchers concerned by the methodologies used in the majority of early dual-task studies. For instance, Somberg and Salthouse (1982) noted that previous literature on aging and divided attention had not taken age differences in single-task performance into account. They conducted two experiments comparing young and older participants on a dual-task procedure involving two relatively simple component tasks. In these experiments, the authors reported no age differences in divided attention ability independent of single-task performance level. However, in a later project involving three independent studies which used more complex component tasks, Salthouse, Rogan, and Prill (1984) did find that older adults were more disadvantaged than younger controls under dual-task conditions. Similarly, in a study that used a simulated driving task to assess age differences in divided attention, Ponds, Brouwer, and van Wolffelaar (1988) adjusted single-task difficulty to an equivalent level for each participant and reported that older adults showed a decreased ability to divide attention when compared with young and middle-aged adults.

McDowd and Craik (1988) suggested that the negative findings of Somberg and Salthouse (1982) could be explained by the relatively simple component tasks, which were thought to involve shallow or automatic processing. McDowd and Craik investigated whether age-related decrements in divided attention increase as task demands become greater. In their experiments, task difficulty was manipulated and strong evidence for an age-related decrement in divided attention performance was found, especially as the difficulty of the tasks was increased. Subsequent dual-task studies have also demonstrated interactions between age and task difficulty. That is, while age differences have been minimal or completely absent when the component tasks are relatively easy or automatic, older adults are disproportionately disadvantaged as one or both tasks become more difficult (e.g., Crossley & Hiscock, 1992; Lorsbach & Simpson, 1988; McDowd & Craik, 1988).

Attention in Alzheimer's Disease

In addition to its commonly known effects on memory, research has demonstrated that AD is associated with impairments in other cognitive functions, including a range of central executive and attentional functions. In a recent review, Perry and Hodges (1999) provided evidence of a substantial and broad impairment of attention and central executive processes in AD patients, and concluded that attentional and dysexecutive impairments might be the first non-memory cognitive functions to be affected by AD. However, the authors suggested that not all components of attention are equally affected in early stage AD, with some components being more susceptible to the disease effects than others.

Focused attention. Previous studies have used simple or choice reaction time paradigms to compare AD patients with healthy older adults. Lafleche and Albert (1995, as cited in Perry & Hodges, 1999) found that mildly impaired AD patients showed non-significant slowing on a choice reaction time task, whereas Reid et al. (1996) reported that AD patients did perform significantly more poorly on a simple reaction time task. As noted by Perry and Hodges, the comparison of these findings is questionable because the simple and choice reaction time tasks were performed by separate groups of patients. In a study that did compare these two tasks in the same participants, Pate et al. (1994) compared normal older adults with AD patients and reported that simple reaction time was impaired in patients with mild dementia, but not in those described as ‘very mild’ dementia patients. In contrast, choice reaction time was affected in both mild and very mild dementia patients, suggesting that the increased difficulty of the choice reaction time task improved sensitivity to early-stage dementia.

Sustained attention. Perry and Hodges (1999) reported that, although the number of previous studies of sustained attention was limited, the majority have shown relatively unimpaired sustained attention abilities in patients with mild AD. This preservation of performance is reportedly found most consistently when experimental tasks involve using reaction time measures to assess sustained attention performance (as in instruments such as the Continuous Performance Test, Rosvold et al., 1956).

According to Perry and Hodges (1999), the conclusion that sustained attention is unimpaired in AD patients contradicts clinical observation of AD patients in everyday situations, which suggests that many AD patients have difficulty sustaining attention while performing activities. Contradictory results have been obtained by researchers by asking AD patients to discriminate targets from non-targets over a relatively long duration (e.g., Brazelli, Cocchini, Della Sala, & Spinnler, 1994). Results of such studies have demonstrated that as time on the task is increased, AD patients have more difficulty accurately discriminating targets from non-targets than do healthy older adults.

Selective attention. As in studies of normal aging, two procedures that have been used to investigate selective attention in AD are visual search tasks and the Stroop paradigm (Perry & Hodges, 1999). It has been demonstrated that visual search tasks can discriminate between AD patients and healthy older adults (Della Sala, Laiacona, Spinnler, & Ubezio, 1992). However, in their study, Della Sala et al. did not analyze the effects of AD severity, and Perry and Hodges postulate Della Sala et al.'s visual search task may not be sensitive to the early stages of the disease. With regard to the Stroop paradigm, Perry and Hodges suggest that it is a particularly sensitive test to the effects of AD. However, they note that is unclear whether the difficulty that AD patients have on this task reflects a specific impairment in selective attention, or whether it simply reflects the inherent difficulty in the task. Overall, Perry and Hodges concluded that current evidence suggests that selective attention is negatively affected even in the very early stages of AD.

Divided attention. Perry and Hodges (1999) state that the majority of previous studies of divided attention (as measured using dual-task procedures) have demonstrated no difference between AD patients and healthy controls when tasks are performed separately, but a disproportionate decline in performance among AD patients when tasks are combined and performed concurrently. When task difficulty has been manipulated, the decline in performance seen in AD patients on difficult tasks has been demonstrated to be even greater. According to Perry and Hodges, it is presently unclear at what stage of the disease process AD patients begin to exhibit impairments in divided attention abilities. While it seems clear that patients in the moderate and severe stages are markedly impaired in their ability to divide attention, some research has suggested that divided attention impairments in mild stage AD patients may be minimal or absent (e.g., Greene, Hodges, & Baddeley, 1995).

Other research has shown that attentional changes in AD may depend on the tasks used to assess attentional abilities. Specifically, on well-rehearsed and routine tasks that require few attentional resources, early stage AD patients may perform at a comparable level to that of healthy older adults. In contrast, on non-routine, non-automatic tasks requiring the coordination and allocation of attentional resources, AD patients are more likely to demonstrate impairments in performance (Crossley, Hiscock, & Beckie Foreman, 2004). Baddeley and his colleagues have suggested that such impairments can be attributed to a breakdown in the central executive of working memory, and in particular to the component of the central executive that coordinates and allocates attentional resources during non-routine tasks (Baddeley, 1996; Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Greene, Hodges, & Baddeley, 1995).

Description of Studies

A number of methodological differences were noted between the dual-task procedures described by Baddeley et al. (2001) and other studies that have reported results. Perhaps most notably, Baddeley et al. did not manipulate the level of dual-task difficulty in the typical manner and assessed dual-task performance at only one level of difficulty. As described by others (e.g., McDowd & Craik, 1988; Crossley & Hiscock, 1992), manipulation of dual-task complexity might be necessary in order to detect age differences that are not evident if only relatively simple tasks are included.

Study 1 was designed to further investigate the effects of normal aging on divided attention and, in doing so, to contribute to normal aging dual-task literature and increase theoretical understanding of the nature of the central executive. A main objective was to challenge evidence provided by Baddeley et al. (2001) in support of their view that the central executive should be considered as a fractionated system. A second objective of Study 1 was to develop hypotheses regarding the reasons for the discrepant dual-task findings of Baddeley et al. compared with previous normal aging research which has shown consistent age effects. Young, middle-aged, and older adults were compared on a modified version of Baddeley's dual-task paradigm. The modified version was designed to allow for manipulation of task difficulty in keeping with previous research, and to address other methodological concerns.

There were two primary objectives of Study 2. First, Study 2 was designed to contribute to current understanding about attentional changes in both normal aging and Alzheimer's disease. Consistent with the recommendations of Perry and Hodges (1999), multiple attentional domains were assessed using a single sample of participants. Specifically, young adults, older adults, and early-stage AD patients were compared on easy and difficult tasks of focused attention, selective attention, and divided attention. A second objective of Study 2 was to contribute to theoretical knowledge regarding the organization of the central executive. Specifically, the aim was to assess whether the pattern of performance for older adults and AD patients was similar or different across attentional domains, thereby lending support either to the proposed fractionation of attentional processes or to the view of attention as a unitary construct.

In addition to the theoretical knowledge gained by investigating attentional changes in normal aging and AD, a number of authors have discussed potential practical implications of this area of research (e.g., Baddeley et al., 2001; Crossley, Hiscock, & Beckie Foreman, 2004). For example, if the attentional changes associated with aging and AD can be reliably differentiated, it may lead to the development of new diagnostic tools that can improve the accuracy of AD diagnoses at an earlier stage of the disease process. The primary objective of Study 3 was to assess the value of attentional measures in contributing improved diagnostic accuracy of Alzheimer's disease. Specifically, we assessed the sensitivity and specificity of four newly developed attentional measures, both individually and in combination, in classifying AD patients and cognitively healthy older adults.

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Study 1: Task Difficulty Mediates Age Effects on Divided Attention

Normal aging is accompanied by declines in a range of cognitive abilities, especially those abilities that involve speed, novelty, and difficulty (see Craik & Salthouse, 2000 for a comprehensive overview). One proposed explanation for this age-related deterioration in cognitive performance is a reduction in a general-purpose processing resource (Salthouse, 1988). In order to investigate this hypothesized age difference in processing resources, many researchers have relied on tasks that assess the ability to divide attention between simultaneous stimuli or tasks.

Processing capacity can be estimated by measuring the degree of interference when attention is divided among activities. For example, in dual-task paradigms, the interference on one or both tasks is measured, based on single-task performance, as the two tasks are performed simultaneously. Dual-task studies have yielded conflicting results regarding the effects of aging on divided attention abilities. On one hand, many researchers have argued that age effects on divided attention are clearly established. For example, based on early research, Craik (1977) concluded that, "one of the clearest results in the experimental psychology of aging is the finding that older adults are more penalized when they must divide their attention" (p. 391). Similarly, almost twenty years later, Kramer and Larish (1996) stated that "one of the best exemplars of a mental activity in which large and robust age-related differences have been consistently obtained is dual-task processing" (p. 83). A large number of studies have consistently documented increased dual-task costs in normal aging (for meta-analyses and reviews, see Hartley & Little, 1999; McDowd & Shaw, 2000; Verhaeghen & Cerella, 2002; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003).

On the other hand, some researchers, particularly those concerned by the methodologies used in many early dual-task studies, have argued that observed age effects during dual task performance can be explained by other factors, such as failure to control for age differences in single-task performance (Somberg & Salthouse, 1982). They conducted dual-task experiments comprised of relatively simple tasks and reported no age differences in divided attention ability independent of single-task performance level.

McDowd and Craik (1988) suggested that age-equivalency during dual-task performance could be explained by the relatively simple or automatized nature of component tasks. They conducted experiments that manipulated task difficulty and reported strong evidence for an age-related decrement in divided attention performance, in direct relation to the difficulty of the tasks. Studies investigating the effects of divided attention on memory performance have shown that dividing attention has only minimal effects on retrieval but dividing attention during encoding results in large reductions in memory performance relative to encoding under full attention conditions, with older adults being particularly susceptible to dual-task interference (Anderson, Craik, & Naveh-Benjamin, 1998; Craik, Govani, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). The differential effects at encoding versus retrieval are presumably due to the effortful processing required by encoding tasks, in contrast to retrieval task which are relatively automatized. Other dual-task studies have also demonstrated significant Age x Task Difficulty interactions. That is, while age differences have been minimal or completely absent when the component tasks are relatively easy or automatic, older adults are disproportionately disadvantaged as one or both tasks are designed to be more difficult (e.g., Crossley & Hiscock, 1992; Lorsbach & Simpson, 1988).

More recently, Baddeley and colleagues have used dual-task procedures to investigate age- and illness-related effects on the central executive of working memory. In particular, they have investigated whether the declines in attentional control of executive function seen in normal aging and Alzheimer Disease (AD) result from a single global deficit (i.e., the unitary attentional hypothesis), or whether attentional control can be fractionated, with some aspects of attention being more vulnerable than others. For example, Baddeley, Baddeley, Bucks, and Wilcock (2001) investigated this question by comparing Alzheimer's disease patients with healthy older adults and young control participants on three domains of attention: focused attention, selective attention, and divided attention. They reported that while both aging and AD were associated with declines in performance on the focused attention and selective attention tasks, divided attention was affected only by AD and not by normal aging. The authors used these findings to support their hypothesis that attentional control, or the central executive of working memory, should be viewed as a fractionated system. Of note, however, their finding of age equivalent divided attention performance contradicts the age effects reported in much of the previous dual-task literature.

Interestingly, although Baddeley et al. (2001) included task difficulty as an independent variable in their design, they did not manipulate difficulty in a manner consistent with most previous studies in this area. Specifically, in their paradigm, the simple or easy task was defined as the single-task condition and the complex or difficult task as the dual-task condition. Therefore, performance was assessed at only one level of dual-task complexity. As described by others (e.g., Crossley & Hiscock, 1992; Crossley, Hiscock, & Beckie-Forman, 2004; McDowd & Craik, 1988), manipulation of dual-task difficulty is essential to detect age differences that may be minimal or absent when relatively simple tasks are combined in dual-task combinations.

When comparing young and older adults using dual-task methodology, it is common to observe age differences in performance on the component tasks during single-task trials. There is currently no consensus among dual-task researchers regarding the optimal procedures by which to control for these age differences on single-task performance. One method that has been utilized in some previous studies (e.g., Baddeley, Logie, Bressi, Della Sala, & Spinnler, 1986; Korteling, 1993; Salthouse et al.,1984; Somberg & Salthouse, 1982) involves adjusting the conditions in the dual-task situation for each participant according to his/her performance in the single-task situation. Although this method offers the advantage of providing direct control over performance, it is difficult to obtain reliable measures of single-task performance (Salthouse, Fristoe, Lineweaver, & Coon, 1995) or to ensure comparability of dual-task demands. Alternatively, other dual-task studies (e.g., Crossley et al., 2004; Crossley & Hiscock, 1992) have controlled for age differences in single-task performance by holding task conditions constant across age groups, and using computational adjustments (i.e., decrement scores or ratio scores) that measure interference in relation to single-task performance.

The use of different methods to control for age differences in single-task performance can lead to conflicting results regarding the effects of age on divided attention (Levitt, Fugelsang, & Crossley, 2006; Salthouse et al., 1995). For example, the method used by Baddeley et al. (2001) to control for single-task performance differences may have contributed to their finding of age-equivalency in divided attention. Their dual task paradigm combined a speeded visuomotor task and a digit span task. Participants were required to cross out a chain of boxes while repeating span-length sequences of random digits read by the examiner over a two-minute trial. The length of the digit span for each participant was the highest level at which performance was perfect over three trials and, therefore, the length varied among participants. When adjusting dual-task conditions for each participant according to his/her single-task performance on the cognitive task it is difficult to establish the equivalence of cognitive tasks across participants. Using percent decrement scores to equate participants on single task performance ensures similar levels of task complexity among participants in all groups.

The present study was designed to further investigate the contribution of task difficulty to age-effects on divided attention, with a focus on developing possible explanations for the discrepant findings of past dual-task research, including those of Baddeley et al. (2001). Young, middle-aged, and older adults were compared on a dual-task paradigm that was designed to be similar in nature to the paradigm used by Baddeley et al. (2001), but that allowed for manipulation of task difficulty in a manner similar to that of previous studies reporting age-related differences. Specifically, we used a continuous box-joining task in combination with a continuous verbal generation task (i.e., reciting the months of the year) that was administered at two levels of difficulty (i.e., recitation of months forward vs. recitation of months backwards) during both single- and dual-task trials. To control for age differences in the rate of single task performance on box-joining and easy and difficult verbal recitation, we administered identical single- and dual-task combinations to all participants, and directly measured age-related differences in performance prior to computing decrement scores as a measure of dual-task interference. To contribute to the relatively sparse literature on divided attention in the middle aged-years, the present study included a middle-aged group in addition to the young adult and old adult groups. Studies of aging and divided attention that have included middle-aged adults have reported conflicting results. For example, Ponds, Brouwer, and van Wolffelaaer (1998) reported no differences between young and middle-aged adults in divided attention, suggesting that this ability is preserved until late adulthood. In contrast, Crossley and Hiscock (1992) described linear effects of age on dual-task performance, indicating a decline in divided attention ability starting in middle-age.

In keeping with our past research and with a model of age-related declines in processing resources, it was predicted that task difficulty would have a significant mediating effect on age differences in divided attention. That is, in addition to significant age and task difficulty main effects, we expected a significant Age Group x Task Difficulty interaction. Specifically, it was predicted that older adults would be disproportionately disadvantaged by an increase in task demands (i.e., while box-joining and reciting the months of the year backwards) when compared with the younger age groups. Based on the results of other studies using similar paradigms (Crossley & Hiscock, 1992; Crossley et al., 2004), we hypothesized that dual-task interference effects would be detected primarily for the secondary, visuomotor task (box joining) while performance on the primary task (month reciting) was expected to be relatively preserved and age insensitive in the dual task condition.

Methods

Participants

Following approval by the University of Saskatchewan Research Ethics Board (Behavioral), participants were recruited from community settings (e.g., university campus, churches, libraries, seniors centres, gyms, etc.) using posters and published advertisements. Healthy adults of all ages were invited to participate in a study of memory, attention, and aging. The final sample consisted of 86 participants, including 28 young adults (*M* = 27.6 yrs; range = 20-37; 13 males, 15 females), 29 middle-aged adults (*M* = 51.5 yrs; range = 40-63; 15 males, 14 females), and 29 older adults (*M* = 71.7 yrs; range = 65-82; 14 males, 15 females). All participants reported good general health and were screened according to the following criteria:

(1) Visual and auditory acuity. Participants were required to have normal or corrected to normal vision and audition.

(2) Physical health. Participants were excluded from this study if they reported serious health conditions (e.g., stroke, serious head injury, multiple sclerosis) deemed likely to interfere with performance on the experimental tasks or neuropsychological test battery. A greater number of participants in the older group (i.e., 14 of 29) reported joint problems (i.e. arthritis, rheumatism, and/or bursitis), than in the middle-aged (6 of 29) or young (2 of 28) groups, *chi square* (2) = 19.05, $p < .01$. All participants were screened for normal peripheral hand functioning as reflected by age-appropriate performance for all participants on a test of manual dexterity (i.e., Grooved Pegboard Test; Matthews & Klove, 1964).

(3) General Cognitive Status: Performance on a neuropsychological test battery (described below) ensured that participants' cognitive status was within normal range.

With regard to education, there was a significant difference among the age groups in years of education, F (2, 83) = 3.95, $p < .05$, with the younger group reporting significantly more years of education (M = 15.4 years, SD = 2.5) than the older group (M = 13.1 years, SD = 3.5). The middle-aged group fell in between, reporting 14.6 years (SD = 3.4) of education. Importantly, as described in the results section, there were no age group differences in performance on neuropsychological tests considered to be good indicators of general intellectual ability. Consequently, concerns about possible confounds due to the expected age differences in education were minimized.

Materials

Neuropsychological Test Battery. To meet the requirements of a larger research project, all participants completed a battery of neuropsychological tests including the Peabody Picture Vocabulary Test – Revised (PPVT-R, Dunn & Dunn, 1981), and the reading subtest of the Wide Range Achievement Test – III (WRAT-III; Jastak & Wilkenson, 1997), both considered to be good indicators of general intellectual ability (Lezak, 1995). Memory abilities were assessed using the Delayed Word Recall Test (DWRT; Crossley & Foreman, 1995) in addition to the Logical Memory and Visual Reproduction subtests of the Wechsler Memory Scale – Revised (WMS-R; Wechsler, 1987). Measures of attention and working memory consisted of the Trail Making Test (Reitan, 1992), the Symbol Digit Modalities Test (SDMT; Smith, 1982), and Digit Span forward and backward (Wechsler Adult Intelligence Scale – Revised; Wechsler, 1981). Measures of phonemic fluency (Controlled Oral Word Association Test; COWAT; Benton & Hamsher, 1989), semantic fluency (Animal Naming; Spreen & Strauss, 1997), and visuomotor speed and manual dexterity (Grooved Pegboard Test; Matthews & Klove, 1964) were also included.

At the time of testing, participants completed a demographic questionnaire that included measures of self-perceived memory change (Squire & Zouzounis, 1988) and depressive symptoms (Center for the Epidemiological Studies of Depression Scale; CES-D; Radloff, 1977), in addition to questions about age, ethnicity, education, health, and lifestyle.

Procedure

Participation consisted of one session of approximately 2 hrs during which participants read and signed the informed consent form, and completed the questionnaire, neuropsychological tests, and experimental procedures.

The experimental tasks consisted of single-task control trials and dual-task trials at two levels of difficulty. Potential practice effects were controlled for by administering each of the single tasks (e.g., box-joining, month forward reciting, month backward reciting) both before and after the dual-task trials. For single task month reciting and for dual task trials, order of presentation of easy and difficult trials was counterbalanced to control for practice and/or fatigue effects. Composite scores consisting of an average of the two single-task control trials were then calculated for use in analyses. Instructions and stimuli for the dual task procedure are presented in Appendix A.

Box-joining. The box-joining task involved a modification of procedures first described by Baddeley, Della Sala, Papagno, and Spinnler (1997). For each box-joining trial, participants were presented with an 8.5 x 11 inch sheet of paper on which were printed eighty 1 cm^2 boxes joined by lines and arranged along a winding path. Participants were instructed to draw a line joining the boxes as quickly as possible, ensuring that their lines touched the insides of the boxes. Prior to the initial single-task box-joining trial, an untimed practice trial was administered to ensure that participants understood the task. For each of the two single-task box-joining trials, participants were told that they had 20 s to connect the boxes as quickly and accurately as possible, and that if they joined all 80 boxes, to start again at the beginning and continue joining boxes until the experimenter indicated that the trial was over. For each trial, the total number of boxes correctly joined (i.e., completely touched boxes in the correct sequence) was recorded. A composite box-joining score was then calculated, consisting of the average number of boxes joined across the two (i.e. pre- and post-dual task) single-task box-joining trials.

Month Reciting. Participants were asked to recite the months of the year continuously at two levels of difficulty. Firstly, they were asked to recite the months of the year forward, as quickly and clearly as possible (i.e., "January, February, March,…, etc."). This task has been shown to be highly practiced and automatized for most people, and to require few attentional resources during dual-task performance (Crossley & Hiscock, 1992; Crossley et al., 2004). Prior to the initial single-task month forward trial, participants completed an untimed practice trial of 18 months to ensure complete understanding of the task. For each of the two single-task month-forward trials, participants were instructed that they had 20 s to recite as many months as possible. The number of months correctly recited (i.e., correct months in correct order) was recorded for each trial. Months recited in the incorrect order or omitted were counted as errors and were not included in the total month reciting score.

Secondly, participants were asked to recite the months of the year backward, as quickly and clearly as possible (i.e., "December, November, October,…, etc"). This task is assumed to be more difficult and unpracticed for most people, and to draw more heavily on attentional processing resources than does reciting the months forward. Prior to the initial month-backward trial, an untimed practice trial of 18 months was administered to ensure understanding of the task. For each single-task month-backward trial, participants were instructed that they had 20 s to recite as many months backward as possible. The number of months correctly recited (i.e., correct months in correct reverse order) was recorded for each trial.

Dual-Task Trials. After completing initial box-joining and month-reciting single-task trials, participants performed the tasks simultaneously, with one trial each for the simple (i.e., box-joining and months forward) and difficult (i.e., box-joining and months backward) conditions. Prior to administration of each dual-task trial, an untimed practice trial was administered to ensure proper understanding of the tasks.

In the simple dual-task condition, participants were asked to join the boxes while reciting the months forward as quickly and accurately as possible during a 20 s trial. Similarly, the difficult dual-task condition consisted of a 20 s trial during which participants performed the box-joining task while reciting the months backward. In both dual-task conditions, the experimenter emphasized to participants that both tasks were equally important. Performance was measured in terms of number of boxes correctly joined and number of months correctly recited during each 20 s dual-task trial.

Results

Neuropsychological Testing

In general, neuropsychological testing yielded predictable age similarities and differences across a range of measures (see Table 1). Specifically, as expected, on the Peabody Picture Vocabulary Test-Revised and the Wide Range Achievement Scale – Reading Subtest, which are the age-stable indicators of verbal intelligence, scores were equivalent across all three age groups ($p > .05$). Similarly, performance on the Controlled Oral Word Association (COWA) Test was age-stable. Age-equivalent results were also obtained on the Center for Epidemiological Studies of Depression Scale (CES-D; Sawyer Radloff, 1977) ($p > .05$).

In contrast, as expected, increasing age was associated with poorer performance across a variety of attentional measures, including the Trail Making Tests A, $F(2, 83) = 17.10$, $p < .001$, and B, $F(2, 83) = 19.45$, $p < .0015$, and the Symbol Digit Modalities Test Written Version, $F(2, 83) = 34.33$, $p < .001$, and Oral Version, $F(2, 83) = 41.78$, $p < .001$. Similar age differences were detected on measures of memory, such as the Delayed Word Recall Test, Short Delay, $F(2, 83) = 15.01$, $p < .001$, and Long Delay, $F(2, 83) = 24.88$, $p < .001$; Logical Memory I, $F(2, 83) = 9.30$, $p < .001$, and II, $F(2, 82) = 10.42$, $p < .001$; and Visual Reproduction I, $F(2, 83) =$

12.76, $p < .001$, and II, $F(2, 83) = 22.32$, $p < .001$. Age differences were also detected on a measure of semantic fluency (Animal Naming), $F(2, 83) = 12.93$, $p < .001$, and on the Grooved Pegboard Test for both dominant, $F(2, 80) = 29.50$, $p < .001$, and non-dominant hands, $F(2, 80) = 26.87$, $p < .001$. Unexpectedly, age groups performed equivalently on the Digit Span Backward Subtest of the WAIS-R, but there was a significant age difference detected on the Digit Span Forward Subtest, $F(2, 83) = 3.36$, $p < .05$. This contrasts findings of a recent meta-analysis showing higher age-sensitivity for the backward digit span than for short-term memory span (Bopp & Verhaeghen, 2005), and was the only anomaly on this standardized battery of neuropsychological tests.

Increasing age was also associated with a greater likelihood to self-report deterioration in cognitive function compared with four years earlier $F(2, 81) = 8.74$, $p < .001$. Based on the results obtained from neuropsychological testing and the questionnaires administered, it was concluded that the present young, middle-aged, and older age samples represent an accurate approximation of population age differences in cognitive functioning. For a complete summary of all neuropsychological test results, see Table 1.

Experimental Results

Single-task box-joining. The average number of boxes joined during the 20 s single task trials for the 3 groups are shown in Table 2. A one-way Analysis of variance (ANOVA) revealed a significant effect of age group on number of boxes joined, $F(2, 83) = 31.29$, $p < .001$. Post hoc analysis using Tukey's Honestly Significant Difference (HSD) with alpha set at .05 showed significant differences between all age groups. As expected, the young group ($M = 87.8$, $SD = 16.5$) joined the highest number of boxes, followed by the middle-aged ($M = 74.7$, $SD = 14.7$) and the older groups ($M = 54.1$, $SD = 17.4$).

Single-task month reciting. The average number of months recited by each age group in the simple (i.e., months forward) and difficult (i.e., months backward) single-task month reciting conditions is shown in Table 2. Single-task month reciting data were analyzed in a 3 x 2 (Age Group x Task Difficulty) ANOVA, with repeated measures in the last factor. Firstly, as expected, a main effect of task difficulty was detected, $F(1, 83) = 629.50$, $p < .001$, with all age groups reciting significantly more months in the forward condition ($M = 52.7$ months, $SD = 11.9$) than in the backward condition ($M = 22.4$ months, $SD = 6.5$). Secondly, a main effect of age group was detected, $F(2, 83) = 5.70$, $p < .01$. Post hoc comparisons using Tukey's HSD with alpha set at .05 showed significant differences between all three groups, with young adults reciting the highest number of months, followed by middle-aged and older adults (see Table 2 for descriptive statistics). This result was consistent across both simple and difficult conditions, as no Age Group x Task Difficulty interaction was detected in single-task month reciting performance.

Dual-task box-joining. To account for the age differences that were expected and confirmed on single task performance, interference in dual-task conditions was expressed as a percent decrement score. A decrement score allows for an assessment of the proportional change in an individual's performance during dual-task conditions relative to his/her performance during the single-task conditions (Crossley et al., 2004; Crossley & Hiscock, 1992). For box-joining, percent decrement scores for both easy (i.e., box-joining combined with month-forward reciting) and difficult (i.e., box-joining combined with month-backward reciting) dual-task conditions were calculated and are displayed in Table 2. Data were analyzed in a 3 x 2 (Age group x Task Difficulty) repeated measures ANOVA. This analysis revealed a significant main effect of task difficulty, $F(1, 83) = 285.62$, $p < .001$, and a significant Age Group x Task Difficulty interaction, $F(2, 83) = 6.21$, $p < .005$. No main effect of age group was detected, $p > .05$.

Across groups, box-joining decreased by 11.4% in the easy dual-task condition, with no significant group difference. Box joining decreased by 48.7% in the difficult dual-task condition, relative to the single-task box-joining rate. Although no main effect of age group was detected, the Age Group x Task Difficulty interaction revealed that the difference in percent decrement scores between easy and difficult dual-task conditions was greater for older adults (5.9% in easy condition vs. 53.6% in difficult condition; difference = 47.7%), than for middle-aged (13.6% in easy condition vs. 48.4% in difficult condition; difference = 34.8%) and younger adults (14.8% in easy condition vs. 43.9% in difficult condition; difference = 29.1%).

To more thoroughly investigate the Age Group x Task Difficulty interaction detected in the main analysis, data were reanalyzed, firstly with the older adult group and then with the young adult group excluded. When data were analyzed with the older adult group excluded, only a main effect of task difficulty was detected, $F(1, 55) = 167.74$, $p < .001$, while the interaction between age and task difficulty failed to reach significance. When the young adult group was excluded, no main effect of age was detected, but both the main effect of task difficulty, $F(1, 56) = 222.11$, $p < .001$, and the Age Group x Task Difficulty interaction, $F(1, 56) = 5.40$, $p < .05$ remained significant.

Dual-task month reciting. Interference on the dual-task months forward and months backward reciting tasks was expressed as percent decrement scores (i.e., the proportional change in score relative to the single task conditions), and analyzed in a 3 x 2 (Age Group x Task Difficulty) repeated measures ANOVA. This analysis revealed only a significant main effect of task difficulty, $F(1, 83) = 11.50$, $p < .005$, indicating that, across age groups, the percent decrement score was greater on the difficult month reciting tasks (i.e., months backward) (M = 17.0%) than on the easy month reciting task (i.e., months forward) (M = 9.8%). As expected, dual-task interference effects on the month reciting tasks were not sensitive to age and were smaller compared to the dual task interference effects on the box joining task

Discussion

The present experiment utilized a dual-task procedure to investigate the contribution of task difficulty to age differences in divided attention ability. Consistent with previous research (e.g., Crossley & Hiscock, 1992; McDowd & Craik, 1988), results of the present study suggest that age differences in dual-task performance are strongly influenced by the difficulty of the component tasks. Whereas young, middle-aged, and older adults produced relatively low levels of interference during dual-task performance when the component tasks were relatively simple and automatized, older adults exhibited disproportionate interference effects on the box-joining task when simultaneously performing the difficult months-backward reciting task. Consistent with previous studies (Crossley & Hiscock, 1992; Crossley, Hiscock, & Beckie-Foreman, 2004), interference effects were observed on the secondary visuomotor task (box joining) while performance on the primary month reciting task was relatively well preserved under dual task conditions. The finding that age differences were detected only in the complex dual-task condition underscores the importance of considering task difficulty when interpreting the results of studies investigating age differences in divided attention ability.

Based on the present study and other previous research, it is clear that task difficulty plays an important role in determining whether age differences are detected during performance of divided attention tasks, and should be considered by future researchers using dual-task methodologies to investigate age or disease effects on divided attention. .

In addition to comparing young and older adults, the present study included a middle-aged adult group. When older adults were removed from the analyses, there were no statistically significant differences detected between young and middle-aged adults, suggesting that divided attention abilities are preserved through middle age, at least using this combination of primary and secondary tasks. However, this finding contrasts the results of other similar dual-task research (Crossley & Hiscock, 1992) which has suggested linear effects of age. Future researchers investigating dual-task performance in normal aging should be encouraged to include middle-aged adults to help clarify divided attention abilities in this age group.

Baddeley et al. (2001) reported age differences on tasks of selective attention and focused attention but age equivalency on a task of divided attention. In the same study, it was demonstrated that the effects of Alzheimer’s disease were both quantitatively and qualitatively similar across all three attentional domains. Baddeley and colleagues argued that the differing pattern among the three domains of attention provides crucial evidence supporting a theory of fractionated executive processes.

In contrast to Baddeley et al’s (2001) findings of age equivalent performance on divided attention, the present study demonstrates age differences when component tasks are sufficiently difficult. Findings of this study contrast a crucial piece of evidence, namely the finding of Baddeley et al. of preserved divided attention abilities in normal aging, supporting the view of the central executive as a fractionated system. In fact, when viewed alongside the findings reported by Baddeley et al. regarding age differences in selective and focused attention, the results of the present study are more consistent with the view of attention as a single, global resource. Other research has also demonstrated qualitatively similar effects of age and Alzheimer’s disease on dual-task performance. For instance, Crossley et al. (2004) investigated dual-task performance in older adults and early stage AD patients using component tasks of varying complexity, and argued that the pattern of results was qualitatively similar across groups, thus supporting the global resource hypothesis.

The conflicting findings across studies demonstrate that variations in dual-task methodology can lead to dramatically different results and conclusions regarding age- and disease-related effects on divided attention. When findings are used to support or dispute a broader theory of executive control, the implications of conflicting findings across studies are substantial. Theories regarding the nature of executive control will be strengthened if findings are consistent across studies even when methodological differences are present.

To this end, there is a need for additional research using a range of methodologies and paradigms to assess the effects of age and disease (e.g., A.D.) on attentional processes. Research utilizing multiple paradigms and investigating multiple attentional domains within the same study will be of particular value and will contribute to theory development without depending on the questionable assumption of subject and procedure equivalency across studies (Perry & Hodges, 1999). As demonstrated by the present study, it is clear that task difficulty plays a mediating role in the detection of divided attention age differences. Findings that describe an absence of age group differences on attentional tasks may be due to low sensitivity of the tasks at a particular level of difficulty. Thus, future research using dual-task paradigms as part of larger investigations of attentional control should include tasks and procedures that allow for the manipulation of task difficulty and the measurement of the effects of difficulty across two or more levels.

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Table 1. Average (SD) neuropsychological test scores and self-ratings of memory and mood for young, middle-aged, and older participants.

	Young	Middle-aged	Older	*p*-values
N	28	29	29	
Neuropsychological Tests				
PPVT-R[a]	161.2 (7.7)	164.7 (7.8)	162.3 (10.6)	NS
WRAT Reading[b]	48.0 (5.0)	49.1 (5.6)	48.6 (4.1)	NS
Trail Making Test[c]				
Part A	19.6 (4.8)	31.4 (17.6)	38.4 (10.5)	$p < .001$
Part B	46.6 (16.0)	70.6 (31.5)	90.5 (28.7)	$p < .001$
SDMT[d]				
Written	61.9 (10.9)	50.8 (8.7)	40.0 (10.2)	$p < .001$
Oral	73.3 (13.7)	56.2 (9.8)	46.1 (10.1)	$p < .001$
Digit Span[e]				
Forward	6.5 (1.0)	6.5 (1.4)	5.8 (1.4)	$p < .05$
Backward	5.0 (1.3)	4.5 (1.5)	4.5 (1.1)	NS
Logical Memory[f]				
I	30.6 (6.8)	27.0 (6.6)	22.6 (7.7)	$p < .001$
II	27.3 (8.4)	22.3 (8.0)	17.4 (7.9)	$p < .001$

Table 1 (cont'd)

	Young	Middle-aged	Older	*p*-values
Visual Reproduction[g]				
I	35.2 (4.0)	34.4 (4.1)	29.4 (6.0)	$p < .001$
II	27.3 (8.4)	22.3 (8.0)	17.4 (7.9)	$p < .001$
Delayed Word Recall[h]				
Short Delay	6.9 (1.7)	6.4 (1.8)	4.2 (2.3)	$p < .001$
Long Delay	6.8 (1.7)	5.5 (1.8)	3.1 (2.4)	$p < .001$
Grooved Pegboard[i]				
Dominant	58.3 (7.2)	70.4 (14.8)	89.5 (20.7)	$p < .001$
Non-dominant	67.7 (9.9)	77.8 (14.3)	103.0 (29.9)	$p < .001$
COWA[j]	39.7 (9.0)	40.3 (12.1)	38.3 (9.5)	NS
Animal Naming[k]	23.1 (5.0)	21.8 (3.7)	17.3 (4.9)	$p < .001$
Self-Ratings				
Memory[l]	1.2 (7.7)	-3.6 (5.6)	-5.5 (4.9)	$p < .001$
Mood (CES-D)[m]	7.5 (7.0)	7.5 (6.8)	6.0 (6.0)	NS

Notes. . [a] The Peabody Picture Vocabulary Test – Revised is scored out of a total of 175. [b] The Wide Range Achievement Test (3rd Edition) Reading subtest is scored out of a total of 57.[c] Scores for the Trail Making Test Part A are the number of seconds taken to sequentially join numbers in a random array; scores for Part B are the number of seconds taken to alternately join number and letter sequences; the higher the score the poorer the performance. [d] The Symbol

Digit Modalities Test scores are the number of correctly decoded symbol-digit pairs in 90 s intervals; the oral version always follows the written version and requires the participant to say the correct numbers while the examiner records their responses. [e] The Digit Span Forward score is the total number of digits accurately reported immediately following presentation by the examiner; the Backward score is the total number of digits reported in the reverse order. [f] The Logical Memory I score is the total number of components recalled immediately following the oral presentation of two brief stories with a maximum score of 50. The Logical Memory II score is the total number of components recalled from the two stories following a 30 minute delay, with a maximum score of 50. [g] The Visual Reproduction I score is the total number of components recalled immediately following presentation of four designs. The Visual Reproduction II score is the total number of components recalled from the four designs following a 30 minute delay. [h] The Delayed Word Recall scores are the number of words, out of a total of 10 rehearsed words, that are freely recalled following 5 min (Short Delay) and 30 min (Long Delay) delays. [i] The Grooved Pegboard Score is the number of seconds taken to place all pegs in the pegboard. [j] The Controlled Oral Word Association Test scores are the total number of words beginning with the letters “C”, “F”, and L” reported in three 1-min trials. [k] The Animal Naming score is the total number of animals named during a 1-min trial. [l] The Self-Rating of Memory scale contains 15 items and scores range from + 30 (maximum improvement over the past five years) to – 30 (maximum loss over the past five years). [m] Scores from the Centre of Epidemiological Studies of Depression Scale range from 0 to 60; scores above 15 are considered clinically relevant.

Table 2. Mean (SD) number of boxes joined and months recited and average percent decrement scores during easy and difficult dual-task conditions for young, middle-aged, and older adults.

	Young			Middle-aged			Older		
	M	SD	Range	M	SD	Range	M	SD	Range
Number of Boxes joined									
Single-task	87.8	16.5	64 -134	74.7	14.7	41 - 98	54.1	17.4	23 - 93
Easy Dual-task	74.5	20.5	31 - 108	64.2	18.0	23 - 94	49.9	15.4	23 - 94
% decrement	14.8	18.4	-7 - 75	13.6	17.8	-19 - 53	5.9	14.2	-23 - 32
Difficult dual-task	47.6	16.7	17-80	38.4	15.9	16 - 81	24.7	14.2	6 - 80
% decrement	43.9	21.8	6 - 83	48.4	17.9	13 – 74	53.6	17.6	14-85
Months forward recited									
Single-task	56.9	12.2	31 - 76	52.7	12.7	23 - 79	48.6	9.6	29 - 67
Easy dual-task	52.5	14.1	21 - 73	47.3	12.5	20 – 67	42.4	9.6	23 - 63
% decrement	8.2	10.0	-10 - 32	10.4	9.4	-9 - 34	10.7	12.9	-10 - 39

Table 2 (con't)

	Young			Middle-aged			Older		
	M	SD	Range	M	SD	Range	M	SD	Range
Months backward recited									
Single-task	24.8	7.1	12 - 39	22.5	5.9	8 – 34	19.9	5.9	6 - 33
Difficult dual-task	20.5	7.1	7 - 27	18.9	5.1	7 – 27	16.0	6.1	6 - 31
% decrement	17.7	16.8	-14 - 50	15.2	15.6	-14 – 43	18.3	21.2	-27 - 63

Study 2: Attention in Normal Aging and Alzheimer's Disease

It has generally been accepted that the early stage of Alzheimer's disease (AD), the most commonly diagnosed form of dementia, is characterized primarily by impairment in memory, with other cognitive domains affected later in the disease process. However, research in the last decade has indicated that deficits in attention are also present in the earliest stages of the disease. For example, Parasuramen and Greenwood (1998) argued that attention deficits likely occur concurrently or immediately following memory problems in AD. In a review of attention and executive processes in AD, Perry and Hodges (1999) also concluded that deterioration in attention occurs early in AD and precedes changes in other non-memory functions such as language, praxis, and visuospatial abilities. Importantly, Perry and Hodges described a number of different subtypes of attention and concluded that these are not all affected in the same way during the early stages of the disease. Focused attention, selective attention, and divided attention are the attentional subtypes most relevant to the current study.

Focused attention refers to the ability to focus or concentrate on a single stimulus in a known location (Rogers, 2000). Baddeley, Baddeley, Bucks, and Wilcock (2001) used simple and choice reaction time tasks to investigate the effects of age and AD on focused attention. They found that increasing age was associated with slower reaction times, but they found no clear evidence of an impact of AD on focused attention over and above the normal age effects. Other research using similar methodologies has produced mixed results (McElree, 2001). One possible explanation for the inconsistent findings is that the effects of age and AD on focused attention might be dependant on task complexity.

Selective attention refers to a variety of cognitive processes that involve attending to certain stimuli while ignoring or filtering distracting information (Fernandez-Duque & Black, 2008; Perry & Hodges, 1999). Activities drawing on selective attention abilities might include searching for the face of a friend in a crowd or attending to a conversation in a loud environment. Experimentally, visual search tasks, in which participants must locate certain target items among an array of non-target or distracting items, are easily administered and commonly used to assess selective attention ability (Brodeur, Trick, & Enns, 1997; Rogers, 2000; Wolfe, 2003). As with focused attention, research on selective attention has yielded mixed findings, at least with regards to the effects of normal aging on visual search task performance. While many studies have reported age-related deficits (see McDowd & Shaw, 2000 for a review), some researchers have suggested that age differences depend on the familiarity and complexity of the target and distracter information (Clancy & Hoyer, 1994).

The majority of studies suggest that selective attention is sensitive to AD (e.g., Duckheck, Hunt, Ball, Buckles, & Morris, 1997; Pignatti et al., 2005). Studies using visual search tasks to assess the impact of AD on selective attention have demonstrated that AD patients are abnormally slow on these tasks compared to healthy older adults, but it is unclear if this is due to general slowing or to a specific impairment of some aspect of selective attention (Della Sala, Laiacona, Spinnler, & Ubezio, 1992, Foster, Behrmann, & Stuss, 1999; Takes, Muir, Jones, Bayer, & Snowden, 2004). Investigations of selective attention in AD using other paradigms have also shown impairment, but it is unclear whether these are universally present in AD (Perry & Hodges, 1999).

Divided attention has been defined as the ability to perform two tasks at once (Greenwood & Parasuraman, 1997), or as the “sharing of attention by focusing on more than one relevant stimulus or process at one time” (Perry & Hodges, 1999). Normal aging research has yielded contradictory evidence regarding age effects on divided attention, although the bulk of the research indicates reliable age-related declines. The effect of AD on divided attention is less controversial, and there is general agreement that impairments in divided attention occur consistently and predictably in the early stages of the disease (Perry & Hodges, 1999). This finding is based on a substantial body of research, with studies typically measuring divided attention using dual-task paradigms, which involve concurrent performance of two component tasks. In an early study in this area, Baddeley, Della Sala, Logie, and Spinnler (1986) designed a dual-task procedure which combined a primary pursuit tracking task with a secondary digit span task. The dual-task interference effects of the latter task on pursuit tracking were significantly greater in AD patients than in healthy older adults. This finding of impaired divided attention in AD has been confirmed by a number of other studies using a variety of different dual-task methodologies (e.g., Camicioli, Howieson, Lehman, & Kaye, 1997; Crossley, Hiscock, & Beckie Forman, 2004; Nebes & Brady, 1989). Studies examining the effects of disease progression on divided attention have shown that dual-task impairments may be absent in the very earliest stages of AD (Greene, Hodges, & Baddeley, 1995; Perry, Watson, & Hodges, 2000), but become greater as the disease progresses (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Tinklenberg, Taylor, Peabody, Redington, & Gibson, 1984).

Changes in divided attention in early AD appear to depend on the component tasks used in the dual-task paradigm (e.g., Crossley et al., 2004). Specifically, if tasks are well-rehearsed and require few attentional resources, early stage AD patients will perform at a comparable level to that of healthy older adults. In contrast, on non-routine, non-automatic tasks requiring the coordination and allocation of attentional resources, AD patients are more likely to demonstrate impairments in performance (Crossley et al., 2004). Baddeley and his colleagues have suggested that such impairments can be attributed to a breakdown in the central executive of working memory, and in particular to the component of the central executive that coordinates and allocates attentional resources during non-routine tasks (Baddeley, 1996; Baddeley et al., 1991; Greene, Hodges, & Baddeley, 1995). This is in contrast to other researchers who have argued that reduced divided attention performance in AD is due to a decline in general-purpose processing resources (Craik, Morris, & Gick, 1990; Crossley et al., 2004; Hartman, 1991, Morris, 1986) or a general reduction in cognitive processing speed (Salthouse, 1996).

Perry and Hodges (1999) suggested that research utilizing multiple paradigms and investigating multiple attentional domains within the same study is of particular value in terms of theory development. For example, Baddeley et al. (2001) reported research showing differential effects of AD and normal aging on the various attentional domains (i.e., focused, selective, and divided) using tasks that were administered at two levels of difficulty. Specifically, both normal aging and AD were associated with declines in selective attention. For the focused attention task, age-related declines in performance were detected but there was no significant effect of AD over and above that of normal aging. In contrast, divided attention performance was affected only by AD, with no decline in divided attention performance associated with normal aging. That is, young and older adults performed equivalently on the divided attention tasks after controlling for age-related differences in performance on the component tasks. Baddeley et al. (2001) concluded that this differing pattern of results across focused, selective, and divided attention tasks supported the model of a fractionated attentional system as opposed to a single unitary resource.

Baddeley and colleagues (2001) presented the finding that young and older adults performed equivalently on divided attention tasks as a crucial piece of evidence supporting their new model of the central executive as a fractionated attentional system. However, this finding contradicts a large body of previous dual-task research which has generally established that normal aging is associated with a gradual decline in divided attention abilities (Batsakes & Fisk, 2000; Crossley & Hiscock, 1992; Kramer & Larish, 1996, Kramer, Larish, & Strayer, 1995; Kramer, Larish, Weber, & Bardell, 1999; Li, Lindenberger, Freund, & Baltes, 200l; Lindenberger, Marsiske, & Baltes, 2000; McDowd & Craik, 1988; Tsang & Shaner, 1998). In fact, Craik (1977) concluded that “one of the clearest results in the experimental psychology of aging is the finding that older adults are more penalized when they must divide their attention” (p. 391). Similarly, almost twenty years later, Kramer and Larish (1996) stated that “one of the best exemplars of a mental activity in which large and robust age-related differences have been consistently obtained is dual-task processing” (p. 83).

Manipulation of task difficulty level is necessary to detect age differences that are minimal if relatively simple component tasks are combined in a dual-task procedure (e.g., Crossley et al., 2004; Crossley & Hiscock, 1992; Lorsbach & Simpson, 1988; McDowd & Craik, 1988). Although Baddeley et al. (2001) included task difficulty as an independent variable in their design, they did not manipulate difficulty in a manner consistent with most previous studies in this area. Specifically, in their paradigm, the simple or easy task was defined as the single-task condition and the complex or difficult task as the dual-task condition. Therefore, performance was assessed at only one level of dual-task complexity.

Notably, the average age of the young adult sample included in Baddeley et al.’s (2001) study was 38.4 years, which is substantially older than samples used in most dual-task studies that have reported age differences. For example, the mean age of McDowd and Craik’s (1988) young adult sample was 19.4 years, while Korteling (1994), and Crossley and Hiscock (1992) used young groups with mean ages of 27 years and 30 years respectively. Dual-task studies that have included a middle-aged group in addition to young and older groups (e.g., Crossley &

Hiscock, 1992; Lindenberger et al., 2000) report dual-task decrements that are already present in middle-aged adults, although this finding has been contradicted by other dual-task research (Corney & Crossley, in review). In general, these results suggest that the deterioration in divided attention ability may begin by middle age, necessitating the use of control subjects who are younger than those used by Baddeley et al. in order to detect age differences.

When comparing young and old adults on dual-task performance, it is common for age differences in performance on the component tasks to be present during single-task trials. There is currently no consensus among dual-task researchers regarding the optimal procedure to control for age differences on single-task performance. One method that has been utilized in several previous studies (e.g., Baddeley et al., 1986; Korteling, 1993; Salthouse et al.,1984; Somberg & Salthouse, 1982) involves adjusting the conditions in the dual-task situation for each participant according to his/her performance in the single-task situation. Although this method offers the advantage of providing direct control over performance, it is difficult to obtain reliable measures of single-task performance (Salthouse, Fristoe, Lineweaver, & Coon, 1995). Alternatively, other dual-task studies (e.g., Crossley et al., 2004; Crossley & Hiscock, 1992) have taken age differences in single-task performance into account by holding task conditions constant across age groups, and using calculations of interference effects (i.e., decrement scores or ratio scores) during dual-task performance to control for single-task age differences.

The use of different methods to control for age differences in single-task performance can lead to conflicting results regarding the effects of age on divided attention (Levitt, Fugelsang, & Crossley, 2006; Salthouse et al., 1995) and might explain Baddeley et al.'s (2001) findings of age equivalent performance. When adjusting dual-task conditions for each participant according to his/her single-task performance on the cognitive task it is difficult to establish the equivalence of cognitive tasks across participants. Using statistical rather than procedural methods to control for differences in single task performance ensures similar levels of dual-task complexity among participants in all groups.

The primary objective of the present study was to further understanding about attentional processes, both in normal aging and in AD, by comparing young adults, healthy older adults, and early-stage AD patients on a range of attentional measures. Specifically, in keeping with the procedures described by Baddeley et al. (2001), tasks thought to involve selective attention, focused attention, and divided attention were administered to each of three groups, with each attentional domain administered at two levels of difficulty. For divided attention, two dual-task paradigms were designed to allow for manipulation of task difficulty in a manner similar to that of previous dual-task studies reporting age-related differences. Group differences in the rate of single task performance on the component tasks were controlled for by using statistical procedures (i.e. percent decrement scores) rather than by adjusting single task difficulty to equate performance across groups. It was hypothesized that for each attentional measure administered, equivalent interactions between group and level of difficulty across all tasks and all three groups would be detected. Such a qualitatively similar pattern of results would provide evidence contradicting a fractionated model of attentional processes, as proposed by Baddeley at al., and would be consistent with a conceptualization of attention as a unitary construct or processing resource.

Method

Participants

Individuals with early-stage Alzheimer's disease (AD) took part in this study along with groups of healthy young and older adults. Prior to participants being recruited, this study was approved by the University of Saskatchewan Research Ethics Board (Behavioral). AD patients consisted of 19 individuals (7 males, 12 females) who were assessed at the Rural and Remote Memory Clinic and received a consensus diagnosis of early-stage AD. The Rural and Remote Memory Clinic is an interprofessional clinic where patients undergo neuropsychological assessment as well as comprehensive assessments in neurology, physical therapy, and neuroradiology for suspected dementia. AD patients had an average age of 73.6 years (*SD* = 7.2, age range = 63 to 86 years).

Thirty young adult (15 males, 15 females) and 30 older adult (15 males, 15 females) normal control participants were included in this study. Older adults were recruited by mailing invitations to participate in the study to members of the Saskatoon Council on Aging, a non-profit organization with programs and services for seniors in Saskatoon, SK. Normal older adults had an average age of 76.3 years (*SD* = 6.9, age range = 62 – 88). Young adult control participants were recruited by posters placed in community settings (e.g., university campus, fitness centres) that requested volunteers for a study on aging and attention. Young adults had an average age of 27.2 years (*SD* = 5.1, range = 18-39).

Average years of education differed significantly among the three groups, $F(2, 76) = 33.52$, $p < .05$. As expected, young adults, on average, had significantly more years of education (17.97, *SD* = 2.76) than the other two groups. Comparison of AD patients and normal older adults showed that the latter group had significantly more years of education with an average of 14.3 years (*SD* = 3.6), compared to the AD group with an average of 10.8 years (*SD* = 3.26). This finding of lower years of education for the AD group was expected as research has shown that lower levels of education are associated with increased incidence of AD (Prencipe, Casini, Ferretti, Lattanzio, Fiorelli, & Culasso, 1996; Qiu, Backman, Winblad, Aguero-Torres, & Fratiglioni, 2001).

A large majority of participants (75 out of 79) reported English as their first language, while the four exceptions all described English as their current preferred language. In terms of racial background, seventy-six participants were Caucasian, two participants were Asian and one participant was of Native/Metis descent. Participants met predetermined criteria for visual and auditory acuity (i.e., hearing and vision were either normal or corrected-to-normal with hearing aids and/or glasses). Participants were included in the study if they were determined to be "normally healthy" and were excluded if they reported medical, neurological, psychiatric, or developmental conditions that could interfere significantly with higher brain functions. For example, participants were included if they reported controlled hypertension (n = 17), diabetes (n = 4), or stomach trouble (n = 10) whereas no participant reported a history of stroke, Parkinson's disease, or epilepsy. Informed written consent was obtained from all participants (consent form presented in Appendix B).

Procedures

Neuropsychological test battery

In addition to the experimental tasks described below, participants completed a short battery of standardized neuropsychological tests. Specific tests for this study were selected based on standard clinical protocol at the Rural and Remote Memory Clinic. Tests included the Modified Mini-Mental State Examination (3MS; Teng & Chui, 1987), a cognitive screening instrument scored out of 100 which also allows one to generate a score out of thirty for the Mini-Mental State Examination (MMSE; Folstein at al., 1975). Participants also completed the reading subtest of the Wide Range Achievement Test – III (WRAT-III; Jastak & Wilkinson, 1997), and the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998) which was designed to screen for dementia in older adults. The RBANS consists of subtests assessing the cognitive domains of immediate and delayed memory, attention, visuospatial/constructional abilities, and language. Other neuropsychological tests administered included the Trail Making Test (A & B; Reitan, 1992) as well as the Digit Symbol Coding and Symbol Search subtests of the Wechsler Adult Intelligence Scale – 3^{rd} Edition (WAIS-III; Wechsler, 1997). Participants also completed a questionnaire designed to collect demographic information and health history. A self-report measure (Centre for Epidemiological Studies of Depression Scale, CES-D; Radloff, 1977) was used to screen for depression because of the association between depression and decreased dual-task performance in the geriatric population (Nebes et al., 2001).

Selective Attention

Selective attention was assessed using a visual search task (see Appendix C for instructions, recording form, and stimuli). Participants were presented with a series of 8.5 x 11 sheets of paper on which were printed 150 underlined letters (10 lines of 15 letters each) printed in Times New Roman Font, size 24. Each group of letters contained 20 Zs distributed in quasi-random order (0 - 3 Zs per row). The task was introduced and demonstrated with the following instructions:

> In this next task, I would like you to cross out all of the Zs in groups of letters, like this (experimenter demonstrates two rows of letters). Go across the rows this way (experimenter indicates left to right). This first one is for practice. Use your pencil to cross out all of the Zs. Now you try.

Participants then completed an untimed practice trial requiring them to cross out 12 Zs embedded among six rows of 13 letters each. Errors of omission and commission were pointed out by the experimenter and participants were assisted if necessary in making corrections prior to the experimental trials being initiated.

After practice was complete and task demands clearly understood, each participant completed a total of four experimental trials, two trials at each of two levels of difficulty. Consistent with the difficulty manipulation described by Baddeley et al. (2001), Zs were embedded among dissimilar, curved letters (e.g., O, P, C, D, etc), in the easy selective attention condition, while in the difficult condition, Zs were embedded among more similar, angular letters (e.g., K, L, W, N, etc). This manipulation of task difficulty has been previously shown to result in slower processing and a higher error rate (Neisser, 1964 as cited in Baddeley et al., 2001). Prior to each experimental trial, the following instructions were provided by the examiner: "Work across the rows this way (indicate left to right) crossing out all the Zs in this group of letters. Work as quickly and carefully as you can and tell me when you are finished. Ready? Go!"

Participants were randomly assigned to one of two orders of task presentation. Order one consisted of one easy trial, followed by two difficult trials, and finally a second easy trial. Order two followed the opposite pattern. Each trial was timed by the experimenter using a stopwatch, and the times to completion and total number of errors of omission and commission for each trial were scored and recorded.

Focused Attention

Focused attention was assessed using a computerized reaction time task at two levels of task difficulty (see Appendix D for instructions and recording form). Apparatus for the focused attention task consisted of a laptop computer programmed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) to administer the focused attention task. The computer was connected to a symmetrical, two button computer mouse which was mounted to a plastic board with brackets to inhibit movement of the mouse during the trials. Consistent with the procedures described by Baddeley et al. (2001), difficulty was manipulated by administering simple and choice reaction time tasks to all participants. In the easy condition, which was the simple reaction time task, participants were asked to press the left mouse button as rapidly as possible following the presentation of a circle on the screen. A picture of a circle was attached to the board on the left side of the mouse to remind participants which button to press. Prior to two blocks of 20 trials being administered, a block of five practice trials were introduced with the following instructions:

> In this next task, you will see some shapes appear on this computer screen and I want you to press a button as quickly as you can each time you see a shape. Place your hand here so that your index finger rests on the middle part of the mouse. For the first few times, you will only see circles. When you see a circle appear, press this button (experimenter indicates left button) as quickly as you can. The circle will disappear and you should return your finger to the centre of the mouse, wait for the next circle, and again press the button as quickly as you can. Keep doing this until more instructions appear on the screen. The first few are for practice. Ready? Go.

The practice trial and subsequent experimental trials were initiated by the experimenter using a computer key press. For the two blocks of experimental trials, each consisting of 20 trials, participants were told:

Now we will do it again, but it will go on for a little bit longer than during the practice. Each time you see a circle on the screen, press the circle button as quickly as you can. The circle will disappear and you should return your finger to the centre and get ready for the next one.

The difficult focused attention condition consisted of a choice reaction time task whereby participants were required to press one of two buttons depending on the stimulus presented. Apparatus were identical to those described above and stimuli were similar except that half the shapes presented were circles and half were squares. Shapes were presented in a random order. Participants were instructed to press the left mouse button in response to circles being presented and the right mouse button in response to squares being presented. Pictures of a circle and a square were attached to the board with Velcro adjacent to the appropriate mouse button.

For both easy and difficult focused attention tasks, the length of time between trials varied from 1.33 s to 4.00 s. Participants were randomly assigned to one of two administration orders, with half of participants completing the two blocks of 20 easy focused attention task trials first, followed by the difficult task, and the other half completing the tasks in the reverse order. Participants' reaction times were measured using the computer software program and were later recorded along with the number of errors made (i.e., number of times an incorrect button was pressed).

Divided Attention I (Box Joining and Month Reciting)

See Appendix E for a sample of instructions, recording form, and stimuli for this task.

Box Joining. The box-joining task involved a modification of procedures first described by Baddeley, Della Sala, Papagno, and Spinnler (1997). For each box-joining trial, participants were presented with an 8.5 x 11 inch sheet of paper on which were printed eighty 1 cm^2 boxes joined by lines and arranged along a winding path. Prior to the initial single-task box-joining trial, a practice trial of 20 s (or longer if required for complete task understanding) was administered to ensure that participants understood the task. Participants received instruction from the experimenter, which consisted of the following:

> I would like you to start here (indicate first box) and draw a line joining these boxes as quickly as you can, like this (experimenter demonstrates). Now you try. Make sure your line goes through each of the boxes. If you get all the way to the end, keep your line going through the start and go around again. Remember to do it as quickly as you can and keep going until I tell you to stop. Go ahead.

After the practice trial, any errors were corrected and further instruction was provided, if necessary, prior to commencement of the experimental trials. Participants completed a total of two experimental single-task box-joining trials, one each before and after the dual task trials had been completed. For each single task trial, participants were told that they had 20 s to connect the boxes as quickly and accurately as possible until told to stop, and that if they joined all 80 boxes, they should start again at the beginning and continue joining boxes until the experimenter indicated that the trial was over.

Month reciting. Participants were asked to recite the months of the year continuously at two levels of difficulty. First, in the easy month reciting condition, they were asked to recite the months of the year forward, as quickly and clearly as possible This task has been shown to be highly practiced and automatized for most people, and to require few attentional resources during dual-task performance (Crossley & Hiscock, 1992; Crossley et al., 2004). For the difficult month reciting condition, participants were asked to recite the months of the year backward, as quickly as possible. This task is assumed to be more difficult and unpracticed for most people, and to draw more heavily on attentional processing resources than does reciting the months forward.

The easy month reciting condition was introduced with the following instructions: "Now I would like you to recite the months of the year in the forward direction as quickly as you can - January, February, March, and so on. When you get to December, go back to January and start over again. Keep going until I tell you to stop."

Prior to the initial single-task month-forward trial, participants completed an untimed practice trial of 18 months to ensure complete understanding of the task. If necessary, further instruction and practice were provided. For each of the two experimental single-task month-forward trials, participants were reminded that they had 20 s to recite as many months as possible.

The difficult month reciting task was introduced and demonstrated with the following instructions: "Now I would like you to recite the months of the year in the reverse order as quickly as you can. Start with December, and go backward, November, October, and so on. If you make it all the way to January, go back to December and start over again."

Prior to the initial single-task month-backward reciting trial, an untimed practice trial of 18 months was administered to ensure understanding of the task. Further instruction and practice were provided, if necessary, to ensure that the task was properly understood. For each single-task month-backward trial, participants were reminded that they had 20 s to recite as many months backward as possible.

Dual-task. The dual-task procedures consisted of box joining in combination with each of the month reciting tasks described above. Easy dual-task trials consisted of box joining in combination with the month-forward reciting task. This procedure was introduced and demonstrated with the following instructions:

> Now I would like you to do some more box joining and month reciting, but at the same time. I would like you to recite the months forward while also joining boxes. You should do both tasks as fast as you can, and remember that both tasks are equally important.

Prior to administration of the experimental dual-task trials, an untimed practice trial was administered to ensure proper understanding of the tasks. Additional instructions and practice were then provided, if necessary, to ensure full understanding of the task requirements. Participants then completed two 20-s experimental trials which were each preceded by a reminder of the task instructions.

For the difficult dual-task procedure, participants were instructed to complete the box joining task in combination with the month-backwards reciting task. The experimenter provided the following instructions:

> Now I would like you to do some more box joining and month reciting, but at the same time. I would like you to recite the months backward while also joining boxes. You should do both tasks as fast as you can, and remember that both tasks are equally important.

Prior to administration of two experimental dual-task trials, an untimed practice trial was administered to ensure proper understanding of the tasks. After the practice trial any errors were corrected and additional instructions and practice were provided, if necessary, to ensure complete understanding. Two experimental dual-task procedures were then completed, with each trial being preceded by a reminder of the task instructions

Experimental Design. All participants completed a total of ten 20-s experimental trials, two single-task trials for each of the three component tasks and four dual-task trials, two at each difficulty level. Participants were randomly assigned to one of two orders for completing the trials. Order one was as follows: (a) box joining single task, trial 1, (b), forward month reciting single task, trial 1, (c) backwards month reciting single task, trial 1, (d) easy dual-task trials 1 & 2, (e) difficult dual-task trials 1 & 2, (f) box joining single task, trial 2, (g) backwards month reciting single task, trial 2, (h) forward month reciting single task, trial 2. Order two consisted of (a) box joining single task, trial 1, (b), backwards month reciting single task, trial 1, (c) forward month reciting single task, trial 1, (d) difficult dual-task trials 1 & 2, (e) easy dual-task trials 1 & 2, (f) box joining single task, trial 2, (g) forward month reciting single task, trial 2, (h) backwards month reciting single task, trial 2.

After each single and dual-task trial, total number of boxes joined and/or total number of months correctly recited were recorded. Scores were averaged over the two trials for each component task and for the two levels of dual task difficulty. Percent decrement scores (i.e., the proportional change in performance when tasks are performed under dual-task versus single task conditions) were calculated using the following equation:

Decrement score = (single task score – dual task score) / single task score x 100%

Resulting percent decrement scores were used describe the interference effects associated with performing the tasks under dual-task conditions, with higher scores indicating greater interference.

Divided Attention II (Alternate Key Finger Tapping and Number Reciting)

See Appendix E for a sample of instructions, recording form, and stimuli for this task.

Finger tapping. Apparatus for the finger tapping task consisted of a symmetrical, two-button computer mouse mounted on a plastic board which was designed to secure the mouse and inhibit any movement during finger tapping. The mouse was mounted using plastic brackets and an armrest was mounted on the other end of the board to inhibit participants' arm movement during the tapping trials. When the mouse was secured in place, the end of the mouse faced the armrest.

The computer mouse was connected to a laptop computer and E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) was used to program the computer to generate 15-s finger tapping trials and to count the total number of taps in each trial. Trials were initiated by the experimenter using a computer key press and simultaneously instructing the participant to "go".

The finger tapping task was first demonstrated by the examiner as participants were given the following instructions:

> I would like you to tap these two mouse buttons, back and forth, as quickly as possible, like this (examiner demonstrates). Rest your arm here like this, place your hand flat on the board and try not to move any fingers except your index finger. The first time will be for practice. Start with the left button and remember to tap back and forth as quickly as you can. Keep going until I tell you to stop.

Participants were then asked to place their arm in the armrest so that their index fingers were within tapping distance of both mouse buttons. A 15-s practice trial was administered to ensure participant understanding of the task. If required to ensure complete understanding, further explanation and practice were provided. For the experimental trials, instructions consisted of, "Good work. Let's try it again and this time the computer is going to count how many taps you make, so try to do it as fast as you can, until I tell you to stop. Ready? Go."

Number reciting. The number reciting task was administered at two levels of task difficulty. For the easy number reciting condition, participants were asked to recite numbers, starting with one and counting forwards by ones. This task is assumed to be highly practiced and automatized for most participants and therefore to require few attentional resources. Participants were instructed:

> Now I would like you to do some counting by one's. Starting with the number one, please count aloud by one's for me as fast as you can, 1, 2, 3, and so on. This first time is for practice. Ready? Go.

After a 15-s practice trial, any errors were corrected by the examiner and, if necessary, further practice trials were administered to ensure complete understanding of the task. For the experimental trials, participants were told, "Good work. Let's try it again, and this time I am going to record how many numbers you get, so count aloud as fast as you can. Start with the number one. Ready? Go!" Experimental trials lasted 15 s and were timed by the examiner who said "Stop" at the end of a trial.

For the difficult number reciting task, participants were asked to start with the number 70 and to count backwards by two's as quickly as possible during 15-s trials. This task is assumed to be less automatized and more effortful, and therefore to require more attentional resources than counting forwards by ones. Instructions given by the experimenter for difficult month reciting were, "I would like you to count backwards by two's. Starting with the number 70, please count backwards by 2's like this: 70, 68, 66, 64, and so on." Prior to the experimental trials, a 15-s practice trial was administered after which errors were corrected and additional practice trials were administered, if necessary, to ensure complete task understanding. For the experimental trials, participants were told, "Let's try it again, but this time I'm going to record how many numbers you get, so count aloud as fast as you can. Remember to count quickly, but clearly, starting with the number 70 and counting backwards by 2's. Ready? Go." Experimental trials lasted 15 s and were timed by the experimenter who said "Stop" at the end of each trial.

Dual-task. The dual-task procedures consisted of finger tapping in combination with each of the number reciting tasks described above. Easy dual-task trials consisted of finger tapping in combination with counting by one's. This procedure was introduced and demonstrated with the following instructions:

> Now I would like you to count by one's as fast as you can while also tapping as fast as you can (experimenter demonstrates). Now you give it a try and remember that both tasks are equally important. Starting with the number one, count by ones as fast as you can, like 1, 2, 3, while also tapping as fast as you can, starting with the left mouse button. Go ahead.

A 15-s practice trial was then administered and further instructions and practice were provided if necessary to ensure full understanding of the task requirements. Participants then completed two experimental dual-task trials which were introduced with the following instructions:

> Now we'll tap and count by 1's once again. Remember to do both tasks as quickly and accurately as you can and remember that both tasks are equally important. Start with the number 1 and count by one's while you are tapping. Ready? Go.

For the difficult dual-task procedure, experimental trials were preceded by a practice trial which was introduced with the following:

> Now I would like you to count backwards from 70 by 2's as fast as you can while also tapping as fast as you can, like this (experimenter demonstrates). Now you give it a try and remember that both tasks are equally important. Staring with the number 70, count

backwards by 2's as fast as you can, like 70, 68, 66, while also tapping as fast as you can starting with the left mouse button. Again, start with the number 70. Go ahead.

After the 15-s practice trial, any errors were corrected and additional instructions and practice were provided if necessary to complete understanding. Two experimental dual trials were then administered, with participants being told:

Once again, please count backwards from 70 by two's as fast as you can, while also tapping as fast as you can, until I say stop. Remember, both task are equally important. Start with the number 70 and count backwards by two's while you're tapping. Ready? Go.

Experimental Design. All participants completed a total of ten 15-s experimental trials, two single-task trials for each of the three component tasks and four dual-task trials, two at each difficulty level. Participants were randomly assigned to one of two orders for completing the trials. Order one was as follows: (a) finger tapping single task, trial 1, (b), easy number reciting single task, trial 1, (c) difficult number reciting single task, trial 1, (d) easy dual-task trials 1 & 2, (e) difficult dual-task trials 1 & 2, (f) finger tapping single task, trial 2, (g) difficult number reciting single task, trial 2, (h) easy number reciting single task, trial 2. Order two consisted of (a) finger tapping single task, trial 1, (b), difficult number reciting single task, trial 1, (c) easy number reciting single task, trial 1, (d) difficult dual-task trials 1 & 2, (e) easy dual-task trials 1 & 2, (f) finger tapping single task, trial 12, (g) easy number reciting single task, trial 2, (h) difficult number reciting single task, trial 2.

After each trial, total number of taps and/or total numbers correctly recited were recorded. Scores were averaged over the two trials for each component task and for the two levels of dual task difficulty. Percent decrement scores (i.e., the proportional change in performance when tasks are performed under dual-task versus single task conditions) were calculated and used to describe the interference effects associated with performing the tasks under dual-task conditions.

Results

Data Cleaning

Variables were examined for the assumptions of normality and, if violated, a transformation was performed as outlined in Tabachnick and Fidell (2001). Specifically, a square root transformation was performed on the focused attention average reaction time score to reduce positive skewness and kurtosis. Analyses run with and without the transformations did not show any significant differences; therefore, for ease of interpretation, data presented below are based on the untransformed data.

Neuropsychological Test Results

Neuropsychological testing yielded the expected group differences on the 3MS, MMSE, and RBANS (see Table 1 for a summary of neuropsychological test scores). Although the Digit Symbol Coding and Symbol Search subtests of the WAIS-III and the Trail Making Test (B) were completed by all young adult and older adult participants, they were not completed by a majority of AD group participants due to time limitations during their clinical assessments, or an inability to complete the task in the case of Trail Making Test (B). These data were therefore not included in the analyses and only age differences between the young and older adult control groups are reported. Mean scores for the AD group on the cognitive screening measures (3MS and MMSE) are at or near cutoff for dementia indicating a relatively mild stage of dementia. On the Wide Range Achievement Test – 3rd Edition (WRAT-3; Jastak & Wilkenson, 1997) Reading Subtest, which is generally recognized as an age-stable (although not dementia-stable) indicator of verbal intelligence, the AD group scored significantly lower than the other two groups ($p < .05$). Scores on the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) above 16 are considered indicative of clinically significant symptoms of depression. Comparison of young adults, older adults, and AD patients on the CES-D showed equivalent results with the means for all three groups falling below this clinical cutoff score. Specifically, young adults had an average CES-D score of 7.3 (SD = 6.0, Range = 0 – 24), older adults had an average score of 9.2(SD = 6.1, Range = 0 – 22), and AD patients had an average score of 11.7 (SD = 6.0, Range = 2 – 27). A total of eight participants had CES-D scores above 15, the recommended cutoff for depression. This included two young adults, three older adults, and three early-stage AD patients. The analyses of the experimental attentional tasks were run first including and then excluding participants who were above cutoff for depression on the CES-D. Comparisons between these two sets of analyses showed that exclusion of these participants had no impact on the results and the analyses described below therefore include participants with CES-D scores above cutoff.

Correlational analyses showed that the difficult versions of the experimental attentional tasks were significantly associated with one another and the vast majority of the standardized neuropsychological tests administered. Correlation coefficients are displayed in Table 2. The experimental attentional tasks were analyzed via a series of 2 x 2 (two groups x two levels of difficulty) Analyses of Variance (ANOVAs) comparing the performance of young adults with normal older adults, and the performance of normal older adults with early-stage AD patients.

Selective Attention

Selective attention performance was measured primarily by time to completion although errors of omission and commission were also considered. Average seconds to completion and average number of errors for the easy and difficult selective attention tasks are displayed for each group in Table 3 and Figures 1 and 2. Separate 2 x 2 Analyses of Variance (ANOVA; two groups x two levels of difficulty) were conducted to determine the effects of age, AD and task difficulty on selective attention performance.

Age effects on time to completion. First, comparing young adults with normal older adults on total time to completion, there was a significant main effect of age group, $F(1, 58) = 26.92$, $p < .001$, with young adults requiring less time than normal older adults to complete the selective attention tasks across difficulty levels. There was also a significant main effect of task difficulty, $F(1, 58) = 217.73$, $p < .001$; across age groups, participants required significantly less time to complete the easy versus the difficult task. A significant Age Group x Task Difficulty interaction was also detected, $F(1, 58) = 14.69$, $p < .001$, that qualified the main effects for age and difficulty. This interaction effect was due to the difference between young and older adults being proportionally greater for the difficult task compared to the easy task.

AD effects on time to completion. Regarding the comparison between normal older adults and early-stage AD patients on time to completion, there was a significant main effect of group, $F(1, 47) = 5.47$, $p < .05$, with normal older adults completing the task in less time than AD patients across both difficulty levels. A main effect of task difficulty was also detected, $F(1, 47) = 291.47$, $p < .001$, with the combined participants requiring less time to complete the easy compared to the difficult selective attention task. In addition, the Group x Task Difficulty interaction was significant, $F(1, 47) = 12.72$, $p < .005$, qualifying the interpretation of the main effects. This interaction was attributable to disproportionate slowing by AD patients on the difficult selective task, despite group equivalency in performance on the easy selective attention task.

To control for the previously noted difference in education level between the AD patients and normal older adults, data including these two groups were re-analyzed via Analysis of Covariance (ANCOVA), with years of education entered as a covariate. After adjustment for education, the main effects of group, $F(1, 46) = 4.03$, $p < .05$, and difficulty level $F(1, 46) = 10.02$, $p < .01$, as well as the Group x Difficulty interaction, $F(1, 46) = 15.79$, $p < .001$, remained significant. There was no significant main effect of education, $F(1, 46) = 0.00$, $p > .05$, and no Education x Difficulty interaction effect, $F(1, 46) = 2.75$, $p > .05$.

Errors of commission and omission. No participants made errors of commission (i.e., crossing out a letter other than a Z) on the simple selective attention task and only 6 participants made errors of commission on one or both trials of the difficult task. Although these data were not analyzed via ANOVA, it is notable that the AD group accounted for five of the six participants making errors of commission, with the other error in the normal older adult group. In terms of errors of omission (i.e., number of Zs not crossed out), young adults were compared with older adults in a 2 x 2 ANOVA which revealed significant main effects of group, $F(1, 58) = 8.56$, $p < .005$, and task difficulty, $F(1, 58) = 15.97$, $p < .001$, as well as a significant Group x Difficulty interaction, $F(1, 58) = 8.15$, $p < .05$, which qualified the main effects. Normal young and older adults make an equivalent number of errors of omission during the easy task while older adults made significantly more omissions during the difficult task.

When normal older adults were compared with AD patients on omission errors, there were significant main effects of group, $F(1, 47) = 6.47$, $p < .05$, and task difficulty, $F(1, 47) = 16.64$, $p < .001$, but no significant interaction effect, $F(1, 47) = 0.50$, $p = .482$. AD patients made more errors than normal older adults at both difficulty levels, with no relative increase in omission errors during the difficult task.

Focused attention

The primary measurement of focused attention was mean reaction time across all trials, although number of errors made was also considered. For each group, mean reaction times and total number of errors per 20-trial block in the easy and difficulty focused attention conditions are displayed in Table 4 and Figures 3 and 4.

Age effects on reaction time. ANOVA comparing young adults and normal older adults showed a significant main effect of age group, $F(1, 58) = 42.48$, $p < .001$, with younger adults having a faster reaction time than normal older adults at both difficulty levels. There was also a significant main effect of task difficulty, $F(1, 58) = 605.78$, $p < .001$, indicating faster reaction times across groups for the easy focused attention task compared to the difficult task. A significant Age Group x Task Difficulty interaction, $F(1, 58) = 46.14$, $p < .001$, qualified the main effects, with normal older adults showing a disproportionate increase in reaction time in the difficult versus easy task when compared with the young adults.

AD effects on reaction time. ANOVA indicated the expected significant main effects of group, $F(1, 47) = 5.35$, $p < .05$, and task difficulty, $F(1, 47) = 29.72$, $p < .001$. In addition, the Group x Task Difficulty interaction was significant, $F(1, 47) = 13.40$, $p = .005$; there was no significant difference in reaction time between the AD and normal older adult groups on the easy focused attention task, but significantly slower reaction times for the AD group on the difficult task.

When the comparison between normal older adults and AD patients was re-analyzed with years of education entered as a covariate, the main effect of group was no longer significant, $F(1, 46) = 2.08$, $p > .05$, but the main effect of task difficulty $F(1, 46) = 27.92$, $p < .001$, and the Group x Task Difficulty interaction effect, $F(1, 46) = 6.72$, $p < .05$, remained significant. There was no significant main effect of education, $F(1, 46) = 1.26$, $p > .05$ and no Education x Difficulty interaction effect, $F(1, 46) = 1.35$, $p > .05$.

Errors for simple and difficult focused attention. Errors were rare on the simple focused attention task, with only 6 participants making errors on one or both blocks of twenty trials (four from the older adult group, two from the AD group). Errors on the difficult focused attention were more frequent, with 48 percent of participants (27 % of young adults, 60 % of normal older adults, 58 % of AD patients) making errors on one or both blocks of 20 trials. ANOVA comparing young adults with older adults on number of errors made per block of twenty difficult focal attention trials showed significantly more errors for the older adult group, $F(1, 58) = 6.58$, $p < .05$. A similar comparison between older adults and AD patients showed no group differences in terms of errors made, $F(1, 47) = 0.54$, $p = 0.47$.

Divided Attention I (Box Joining and Month Reciting)

Data for single-task trials of the two component single tasks (box joining and month reciting) are displayed in Table 5. As expected, a one-way ANOVA comparing young and older adults showed a significantly higher number of boxes joined for the young adult group, $F(1, 58) = 38.09$, $p < .001$. Young adults also recited significantly more months than older adults during both simple $F(1, 58) = 12.40$, $p < .01$, and difficult single-task trials, $F(1, 58) = 24.36$, $p < .001$. Comparisons between older adults and AD patients showed a similar pattern of results, with older adults joining more boxes, $F(1, 47) = 30.00$, $p < .001$, and reciting more months during both easy, $F(1, 47) = 7.47$, $p < .01$ and difficult, $F(1, 47) = 23.32$, $p < .001$, single task trials.

Average box joining and month reciting scores during the dual-task trials are displayed in Table 4. Decrement scores are summarized both in Table 4 and in Figures 3 and 4.

Age effects on box joining and month reciting decrement scores. ANOVA revealed a significant main effect of task difficulty, $F(1, 58) = 204.00$, $p < .001$, with both young adults and normal older adults showing a larger percent decrement score in the difficult dual-task condition. There was no main effect of age group, $F(1, 58) = 1.62$, $p = .208$, but the Group x Task Difficulty interaction was marginally significant, $F(1, 58) = 3.95$, $p = .052$. As shown in Figure 3 this interaction effect is attributable to a disproportionate increase in decrement score for the older adults in the difficult dual-task condition.

For the month reciting decrement score there was a significant main effect of task difficulty, $F(1, 58) = 18.31$, $p < .001$, but no significant effect of group, $F(1, 58) = .699$, $p = .41$, and no interaction effect, $F(1, 58) = .005$, $p = .95$. As shown in Figure 4, dual-task decrement scores for the month reciting task were equivalent between young and older adults with both groups showing greater interference effects for the difficult versus the easy dual-task trials.

AD effects on box joining and month reciting decrement scores. ANOVA revealed main effects on box joining decrement scores of group, $F(1, 47) = 10.79$, $p < .01$, and task difficulty, $F(1, 47) = 302.67$, $p < .001$. There was also a significant interaction effect, $F(1, 47) = 10.01$, $p = .01$, that qualified the main effects. As expected both groups showed greater interference during the difficult dual-task trials. As shown in Figure 3, percent decrement scores differed between groups for both the easy and difficult dual tasks, but AD patients showed a greater proportional decrease in box joining rate during the difficult task when compared with normal older adults. When years of education was added to the analysis as a covariate, main effects of group, $F(1, 46) = 11.83$, $p < .01$, and task difficulty, $F(1, 46) = 34.41$, $p < .001$, as well as the interaction effect, $F(1, 47) = 4.73$, $p < .05$, remained statistically significant. There was no main effect of years of education, $F(1, 47) = 1.37$, $p > .05$, and no significant interaction between education and task difficulty, $F(1, 47) = 1.28$, $p > .05$.

Comparing normal older adults with AD patients in terms of dual-task decrement scores for the month reciting task, there was a significant main effect of group, $F(1, 47) = 7.57$, $p < .01$, with AD patient showing higher percent decrement scores ($M = 14.3\%$, $SD = 12.1$) than older adults ($M = 5.0\%$, $SD = 11.2$) across both levels of task difficulty. There was no significant main effect of task difficulty, $F(1, 47) = 1.47$, $p < .23$, and no interaction between group and level of difficulty, $F(1, 47) = 2.40$, $p < .13$.

Divided Attention II (Alternate Key Finger Tapping and Number Reciting)

Data for single-task trials of the two component single tasks (finger tapping and number reciting) are displayed in Table 6. As expected, a one-way ANOVA comparing young and older adults showed a significantly faster rate of finger tapping for the young adult group, $F(1, 58) = 80.19$, $p < .001$. Young adults also recited significantly more numbers than older adults during both simple, $F(1, 58) = 23.73$, $p < .001$, and difficult single-task trials, $F(1, 58) = 55.55$, $p < .001$. Comparisons between older adults and AD patients showed a higher rate of single task finger tapping for the older adult group, $F(1, 47) = 6.64$, $p < .05$. For the easy number reciting single-task, there were no group differences in numbers recited, $F(1, 47) = 1.13$, $p = .29$, while for the difficult number reciting single-task, older adults recited significantly more numbers per trial than AD patients, $F(1, 47) = 21.52$, $p < .001$.

Average finger tapping, number reciting, and dual task decrement scores are displayed in Table 5.

Age effects on finger-tapping and number reciting decrement scores. Comparison between young adults and older adults showed significant main effects of age group, $F(1, 58) = 8.36$, $p < .01$, and task difficulty, $F(1, 58) = 30.09$, $p < .001$, as well as a significant Age Group x Task Difficulty interaction effect, $F(1, 58) = 15.76$, $p < .001$. This interaction was attributable to equivalent performance between young adults and healthy older adults in finger tapping decrement in the easy dual-task condition, with a disproportionate increase in decrement score for older adults compared to younger adults in the difficult dual-task condition.

For the number reciting decrement score there was a significant main effect of task difficulty, $F(1, 58) = 1.27$, $p < .005$, but no significant effect of group, $F(1, 58) = .937$, $p = .34$, and no interaction effect, $F(1, 58) = .036$, $p = .85$. As shown in Figure 7, dual-task decrement scores for the number reciting task were equivalent between young and older adults with both groups showing greater interference effects for the difficult versus the easy dual-task trials.

AD effects on finger-tapping and number reciting decrement scores. For finger-tapping decrement scores, the comparison between normal older adults and AD patients showed significant main effects of group, $F(1, 47) = 38.97$, $p < .001$, and task difficulty, $F(1, 47) = 178.44$, $p < .001$, as well as a significant interaction effect, $F(1, 47) = 27.94$, $p < .001$. AD patients showed greater interference than normal older adults during both easy and difficult dual-tasks, with the difference being proportionally greater in the difficult dual-task. When years of education was added to the analysis as a covariate, main effects of group, $F(1, 46) = 25.87$, $p < .001$, and task difficulty, $F(1, 46) = 23.44$, $p < .001$, as well as the Group x Task Difficulty interaction, $F(1, 47) = 15.87$, $p < .001$, remained statistically significant. There was no main effect of years of education, $F(1, 47) = 0.28$, $p > .05$, and no significant interaction between education and task difficulty, $F(1, 47) = 1.47$, $p > .05$.

Comparison of normal older adults with AD patients on dual-task decrement scores for the number reciting task showed a significant main effect of task difficulty, $F(1, 47) = 4.40$, $p < .05$, with both groups showing greater number reciting decrements in the difficult dual task condition. There was no significant main effect of group, $F(1, 47) = .015$, $p = .90$, and no interaction effect, $F(1, 47) = .272$, $p = .61$. As shown in Figure 7, dual-task decrement scores for the number reciting task were equivalent between older adults and AD participants with both groups showing greater interference effects for the difficult versus the easy dual-task trials.

Discussion

This study investigated the effects of normal aging and early stage AD on three domains of attention. The purpose of the study was to further understanding about attention in aging and AD as well as to investigate evidence for the proposed fractionation of attentional processes.

In addition to experimental attentional tasks, participants completed a battery of standardized neuropsychological tests which included a cognitive screening test and tests of memory, attention, language, and visuospatial/constructional abilities. This battery clearly differentiated between young and older adults, with young adults scoring higher on the MMSE and all other tests. Comparison between normal older adults and AD patients showed that performance of AD patients on the MMSE was significantly lower than that of healthy older adults but above the level generally used as the cutoff for dementia. This, together with a low level of variability in MMSE scores among the AD sample, indicates a relatively homogeneous AD group in terms of being in the early stage of the disease. On other neuropsychological tests, the performance of normal adults was consistently stronger than the performance of AD patients across all tests administered except for a test of constructional abilities (RBANS Figure Copy). Although data for two subtests from the WAIS-III that involve attention (Digit Symbol-Coding and Symbol Search) were incomplete in the AD group because of time constraints during the clinical assessment, the attention measures in the RBANS (Digit Span and Coding) provided a comparison between the older adult group and the AD adults on standardized measures of attention and revealed the expected differences. Participants completed a depression screening questionnaire (CES-D) that showed no group differences, with all three groups scoring below the level considered to be clinically relevant (Radloff, 1977). This is of particular importance, as depression has been shown to lead to decreased performance on attention tasks both in healthy adults (Goudemand & Rousseaux, 1998; Nebes et al., 2001) and in AD patients (Nakaaki, Murata, Sato, Shinagawa, Tatsumi, Hirono, & Furukawa, 2007).

In terms of the experimental measures, participants completed tasks of selective attention and focused attention as well two tasks of divided attention. Each task was administered at two levels of difficulty. As argued by Baddeley et al. (2001), differing patterns of results across the attentional paradigms would support the proposed fractionation of attentional processes, whereas a similar pattern of results – that is, an equivalent interaction between group and difficulty level across all three groups and all four tasks – would be more consistent with the unitary attentional hypothesis.

Comparison between young adults and older adults revealed a consistent pattern of results across all four attentional tasks. Specifically, there was an interaction between age group and task difficulty indicating relatively small group differences when tasks were easy, and more substantial differences when tasks were difficult. Comparison between normal older adults and early-stage AD patients revealed an identical pattern, with an interaction between group and difficulty across all tasks. AD patients and older adults differed in terms of years of education but inclusion of this variable as a covariate had no impact on results and education was not significantly associated with attention performance. Although these findings do not necessarily rule out the fractionation of attention (under a fractionated model, various aspects of attention could be separate yet still affected in similar ways by aging and AD), the unitary attentional hypothesis offers a more parsimonious account for the pattern of results detected.

Overall, results for the divided attention tasks are generally consistent with previous research which has shown age and AD effects when tasks are difficult despite relatively preserved performance when tasks are automatized (Corney & Crossley, Study 1; Crossley & Hiscock, 1992; Crossley, Hiscock, & Beckie Foreman, 2004; McDowd & Craik, 1988). Dual task interference effects were evident primarily on the secondary box joining task while performance on the primary month reciting tasks was relatively unaffected in the dual task.

Findings of this study contrast with the findings of Baddeley et al. (2001) who reported differing patterns of results across attentional domains. Closer comparison between the results of our study and those of Baddeley et al. shows generally consistent results for selective and focused attention but a major difference in the findings for divided attention. Specifically, Baddeley et al. found no effects of normal aging on divided attention, whereas our finding of age differences in divided attention was consistent with the majority of previous normal aging studies.

Discrepancies between the results of our study and the study described by Baddeley et al. (2001) are likely due to methodological differences. Perhaps most significantly, this study highlighted the important mediating effect of task difficulty in detecting age-related reductions in divided attention performance. Although Baddeley et al. considered task difficulty as an important variable, they did not manipulate difficulty in a typical manner and therefore considered only one level of dual-task difficulty. In contrast, our procedures allowed for the establishment of baseline single task performance, and for the assessment of dual-task performance at two levels of difficulty. This is consistent with the previous studies that have demonstrated the significant interaction between age group and task difficulty (McDowd & Craik, 1988; Crossley & Hiscock, 1992; Crossley et al., 2004).

Because data for the AD patients were collected during clinical assessments, time and other practical considerations limited our ability to explore the wide range of potential factors that may affect performance on attentional tasks. For example, age and AD effects on the attention tasks were demonstrated; however, it is important to note that these tasks were likely novel for most participants and we did not consider the potential effects of practice and/or training on our attentional tasks. Research using other attentional tasks has demonstrated that practice and training can significantly improve divided attention performance in young and older adults (Ruthruff, Johnston, & Van Selst, 2001; Kramer et al., 1995; Bherer et al., 2005), but it is unclear if these effects generalize to the attentional task used in the present study. Gothe, Kliegl, and Oberauer (2007) found that the effects of practice on divided attention tasks differed for young and older adults and suggested that these results indicate a qualitative difference between the groups in how they approach dual-task situations. Further research into the effects of practice and training on attention may lead to interventions and strategies to improve performance in both healthy older adults and AD patients.

Another factor not fully investigated in this study is task emphasis; although participants were instructed for both dual-tasks that each component task was equally important, task emphasis was not manipulated and it is therefore not possible to determine with certainty that all participants were emphasizing both tasks equally. Although some dual-task studies manipulated task emphasis and showed that emphasizing one task over another is not necessary for eliciting dual-task interference (Crossley & Hiscock, 1992; Crossley et al., 2004; Levy & Pashler, 2001), it would be of interest to investigate task emphasis manipulations using our dual task procedures.

Our early stage AD sample was relatively homogeneous in terms of performance on the MMSE and other neuropsychological tests, making it impossible to examine the effects of disease progression. In contrast, the patient sample described by Baddeley et al. (2001) showed more variability in cognitive performance, allowing some preliminary conclusions about the effect of disease progression on attentional performance. Specifically, they separated their AD group into two groups based on MMSE score and found that lower MMSE scores were associated with poorer performance on attentional tasks.

Although the current study was designed primarily from a theoretical perspective, findings also have potential practical and clinical implications. From a practical perspective, understanding of attentional changes in normal aging and AD may provide insights into functional abilities that are associated with attention. For example, dividing attention while walking has been shown to interfere with ambulation in AD patients (Camicoli, Howieson, Lehman, & Kaye, 1997) and research has shown that divided attention tasks provide valid predication of falls in older adults (Verghese et al., 2002). Attentional performance in aging and AD also has important implications for driving in these populations. Ponds, Brouwer, and van Wolffelaar (1988) found that normal aging was associated with reduced performance on a divided attention task designed to simulate everyday driving. Ducheck, Hunt, Ball, Buckles, and Morris (1997) argued that selective attention is related to driving ability in AD and that further examination of the ability of selective attention tasks to predict driving difficulties would be of importance.

Clinically, the finding of impairments in attention for AD patients compared with normal older adults indicates that it may be possible to use attentional tasks to aid in the identification of AD in its early stages. Gorus, De Raedt, Lambert, Lemper, and Mets (2006) found that the deterioration in selective attention in early AD can be used to discriminate between patients and matched controls. They concluded that attention measures may provide complimentary cognitive evidence for the diagnosis of AD. Other recent research has investigated whether attentional measures can be used to identify AD in its preclinical stages. In a longitudinal study, Rapp and Reischies (2005) followed 187 initially normal older adults over a four year period and found that tests of attention and executive function administered at baseline were able to discriminate individuals who developed AD from those who had not four years later. As understanding about the effects of early AD on attention increases, further research more closely investigating the ability of attentional measures to contribute to early diagnosis will be important.

In summary, the present study examined attentional performance on easy and difficult tasks in young adults, older adults, and AD patients. A consistent pattern of results was found across tasks of selective attention, focused attention, and divided attention. These findings contradict evidence from previous studies for the proposed fractionation of attention and are generally more consistent with the conceptualization of attention as a single, unitary construct. The differences across studies are likely related to key methodological differences and have significant implications for the strength of theories regarding the nature of attention and executive control.

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Table 1

Mean (SD) Neuropsychological Test Scores of Young Adults, Older Adults, and AD Patients

	Young Adults	Older Adults	AD Patients
CES-D	7.3 (6.0)$_a$	9.2 (6.1)$_a$	11.7 (6.0)$_a$
MMSE	29.9 (0.4)$_a$	28.6 (1.9)$_b$	24.6 (1.7)$_c$
3MS	99.4 (1.1)$_a$	96.5 (3.3)$_b$	78.4 (7.2)$_c$
WRAT-3 Reading	50.6 (2.7)$_a$	49.5 (4.5)$_a$	43.5 (6.5)$_b$
RBANS List Learning	31.0 (3.9)$_a$	23.7 (5.7)$_b$	17.2 (4.2)$_c$
RBANS Story Memory	19.5 (4.0)$_a$	16.2 (4.6)$_b$	9.7 (4.0)$_c$
RBANS Figure Copy	19.1 (1.4)$_a$	16.8 (2.9)$_b$	16.3 (2.1)$_b$
RBANS Line Orientation	18.8 (1.3)$_a$	16.2 (3.7)$_b$	13.0 (4.4)$_c$
RBANS Picture Naming	9.9 (0.3)$_a$	9.5 (0.6)$_b$	9.1 (0.7)$_c$
RBANS Semantic Fluency	24.5 (5.7)$_a$	19.7 (5.5)$_b$	14.8 (4.3)$_c$
RBANS Digit Span	11.8 (2.1)$_a$	9.2 (1.8)$_b$	8.1 (1.7)$_c$
RBANS Coding	58.1 (14.2)$_a$	39.9 (8.7)$_b$	24.8 (8.5)$_c$
RBANS List Recall	7.7 (1.7)$_a$	4.6 (2.3)$_b$	0.2 (0.4)$_c$
RBANS List Recognition	19.9 (0.3)$_a$	19.1 (1.1)$_b$	16.0 (2.4)$_c$
RBANS Story Recall	11.2 (1.0)$_a$	8.0 (2.9)$_b$	1.2 (1.7)$_c$
RBANS Figure Recall	17.4 (2.6)$_a$	11.0 (4.5)$_b$	2.6 (3.3)$_c$
Trail Making Test A	17.8 (6.1)$_a$	32.6 (10.8)$_b$	67.3 (27.0)$_c$
Trail Making Test B*	42.3 (6.3)$_a$	92.3 (38.4)$_b$	147.8 (51.9)$_c$

Symbol Search	46.9 (6.3)$_a$	24.9 (7.4)$_b$
Digit Symbol Coding	92.0 (20.3)$_a$	56.4 (11.4)$_b$

Note. Means in the same row that do not share subscripts differ at $p < .05$

*Not all participants in the AD group completed the Trail Making Test B (n = 11)

Table 2

Correlation Coefficients between Difficult Versions of Primary Experimental Attentional Measures and Standardized Neuropsychological Tests

Task	Selective Attention	Focal Attention	Divided Attention I	Divided Attention II
Selective Attention	1.00*	0.63*	0.34*	0.51*
Focal Attention	0.63*	1.00*	0.25*	0.56*
Divided Attention I	0.34*	0.25*	1.00*	0.55*
Divided Attention II	0.51*	0.56*	0.55*	1.00*
MMSE	-0.49*	-0.60*	-0.41*	-0.63*
3MS	-0.51*	-0.68*	-0.53*	-0.77*
RBANS Subtests				
List Learning	-0.53*	-0.64*	-0.49*	-0.74*
Story Memory	-0.41*	-0.48*	-0.41*	-0.71*
Figure Copy	-0.35*	-0.39*	-0.08	-0.27**
Line Orientation	-0.35*	-0.47*	-0.33*	-0.49*
Picture Naming	-0.37*	-0.36*	-0.19	-0.43*
Semantic Fluency	-0.41*	-0.48*	-0.53*	-0.54*
Digit Span	-0.45*	-0.37*	-0.37*	-0.51*
Coding	-0.67*	-0.65*	-0.52*	-0.62*
List Recall	-0.60*	-0.64*	-0.51*	-0.86*

List Recognition	-0.41*	-0.57*	-0.42*	-0.68*
Story Recall	-0.57*	-0.62*	-0.47*	-0.81*
Figure Recall	-0.54*	-0.56*	-0.52*	-0.80*
Trail Making Test A	0.55*	0.58*	0.52*	0.71*
Trail Making Test B***	0.62*	0.74*	0.39*	0.67*
Symbol Search	-0.66*	-0.69*	-0.44*	-0.64*
Digit Symbol-Coding	-0.53	-0.62*	-0.32**	-0.50*

* Correlation is significant at the 0.01 level (2-tailed)

** Correlation is significant at the 0.05 level (2-tailed)

*** Not all participants in the AD group completed the Trail Making Test B (*n* = 11)

Table 3

Mean (SD) time to completion and total number of errors of omission and commission during easy and difficult selective attention tasks for young adults, older adults, and AD patients.

	Young Adults	Older Adults	AD Patients
Easy Selective Attention			
Time to Completion	22.1 (6.8)$_a$	29.3 (5.7)$_b$	32.3 (8.7)$_b$
Errors of Commission	0.0 (0.0)$_a$	0.0 (0.0)$_a$	0.0 (0.0)$_a$
Errors of Omission	0.2 (0.3)$_a$	0.2 (0.4)$_a$	0.7 (0.8)$_b$
Difficult Selective Attention			
Time to Completion	27.4 (7.5)$_a$	38.3 (7.9)$_b$	46.1 (10.8)$_c$
Errors of Commission	0.0 (0.2)$_a$	0.2 (0.5)$_a$	0.00 (0.00)$_a$
Errors of Omission	0.2 (0.4)$_a$	0.7 (0.6)$_b$	1.4 (1.7)$_c$

Note. Means in the same row that do not share subscripts differ at $p < .05$.

Figure 1. Average time to completion for easy and difficult selective attention tasks for young adults, older adults and AD patients.

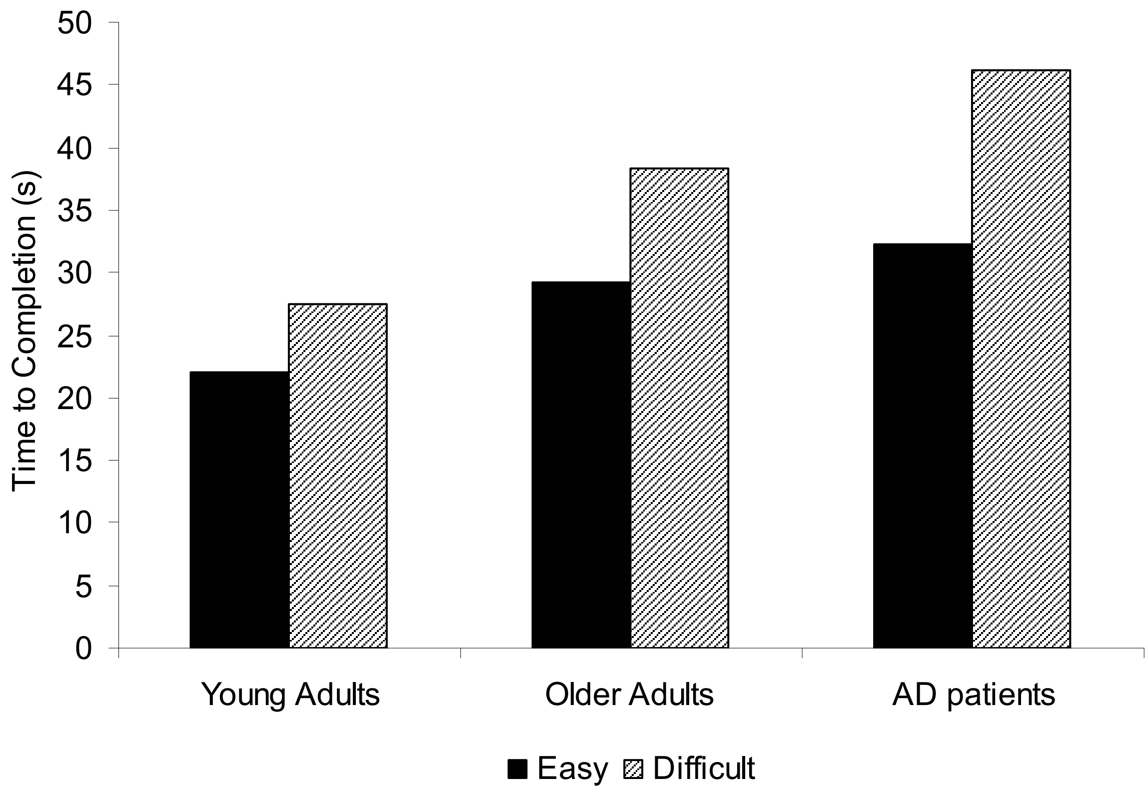


Figure 2. Average number of errors of omission for easy and difficult selective attention tasks for young adults, older adults, and AD patients.

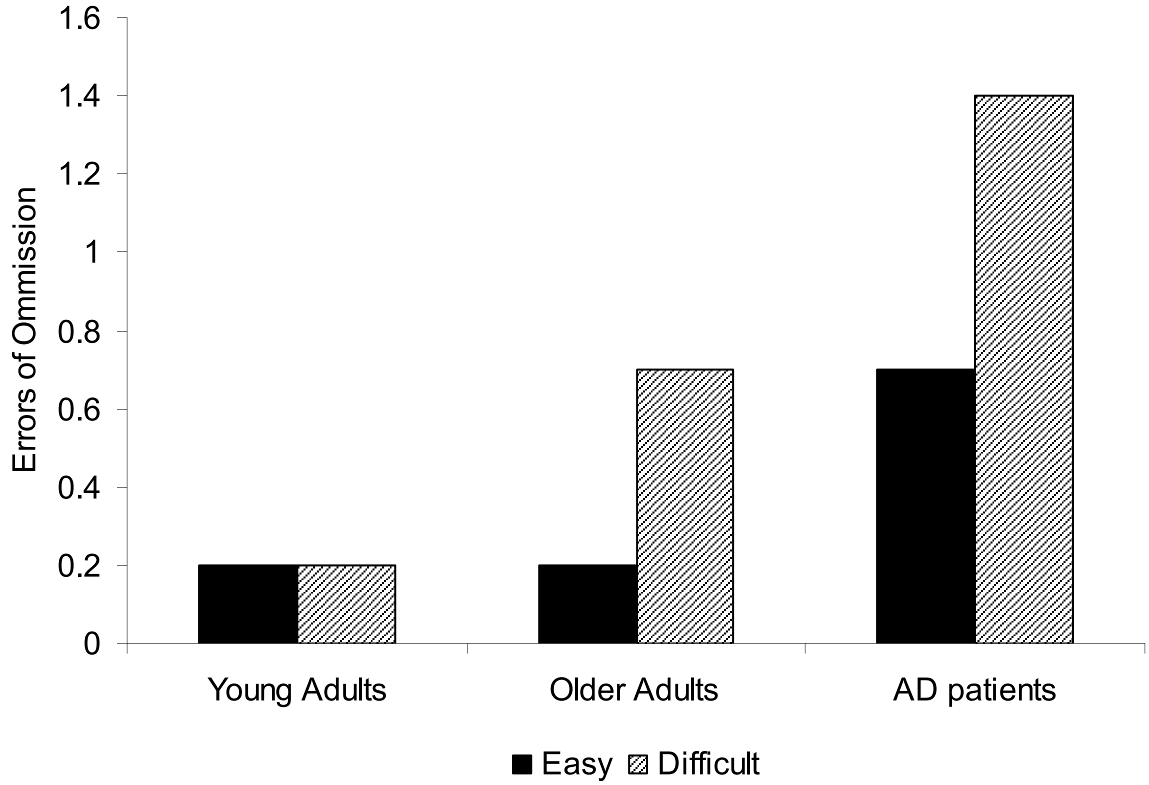


Table 4

Mean (SD) reaction time in milliseconds and total number of errors per 20-trial block during easy and difficult focused attention tasks for young adults, older adults, and AD patients

	Young Adults	Older Adults	AD Patients
Easy Focused attention			
Reaction Time	370.8 (37.1)$_a$	453.6 (101.7)$_b$	479.3 (155.1)$_b$
Errors	0.00 (0.00)$_a$	0.2 (0.1)$_a$	0.1 (0.2)$_a$
Difficult Focused attention			
Reaction Time	503.1 (53.4)$_a$	686.7 (117.5)$_b$	860.9 (274.5)$_c$
Errors	0.2 (0.33)$_a$	0.6 (0.6)$_b$	0.7 (0.8)$_b$

Note. Means in the same row that do not share subscripts differ at $p < .05$.

Figure 3. Average reactions times for easy and difficult focused attention trials in young adults, older adults, and AD patients

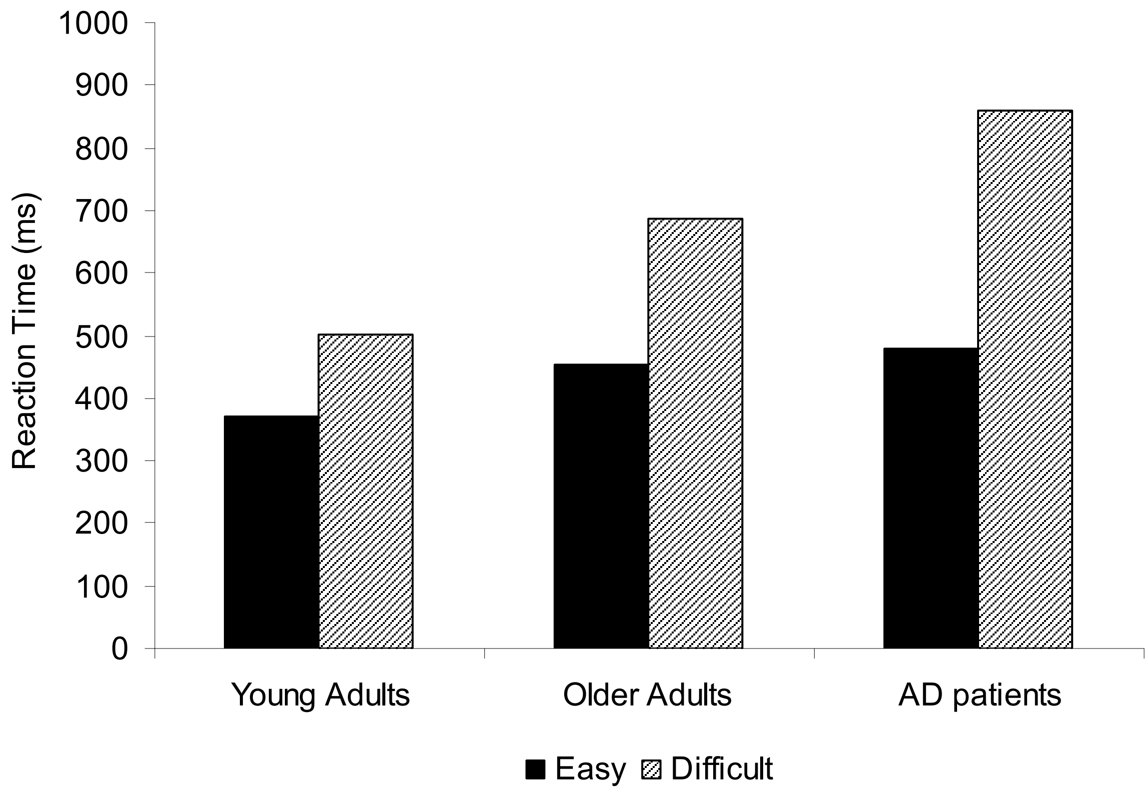


Table 5

Mean (SD) number of boxes joined and months recited, and average percent decrement scores during easy and difficult dual-task conditions for young adults, older adults, and AD patients

	Young Adults	Older Adults	AD Patients
Number of Boxes joined			
Single-task	94.9 (24.3)$_a$	64.1 (12.7)$_b$	43.1 (13.6)$_c$
Easy Dual-task	84.4 (25.2)$_a$	56.3 (14.2)$_b$	36.1 (11.4)$_c$
% decrement	11.0 (15.5)$_a$	11.6 (15.5)$_a$	16.1 (12.0)$_a$
Difficult dual-task	59.3 (22.7)$_a$	34.4 (14.2)$_b$	13.5 (4.8)$_c$
% decrement	37.7 (18.7)$_a$	47.0 (19.1)$_b$	67.1 (10.6)$_c$
Months forward recited			
Single-task	55.1 (9.7)$_a$	46.6 (8.9)$_b$	40.3 (5.8)$_c$
Easy dual-task	54.5 (12.0)$_a$	46.8 (11.0)$_b$	34.4 (8.8)$_c$
% decrement	2.1 (8.7)$_a$	0.0 (9.4)$_a$	14.9 (17.0)$_b$
Months backward recited			
Single-task	27.6 (6.5)$_a$	20.0 (5.4)$_b$	12.7 (4.7)$_c$
Difficult dual-task	24.1 (6.0)$_a$	17.8 (5.8)$_b$	11.3 (4.6)$_c$
% decrement	11.9 (11.9)$_a$	10.1 (18.9)$_b$	13.7 (22.4)$_c$

Note. Means in the same row that do not share subscripts differ at $p < .05$.

Figure 4. Mean percentage decrement in box joining score, relative to single-task box joining, as a function of group and level of dual-task difficulty.

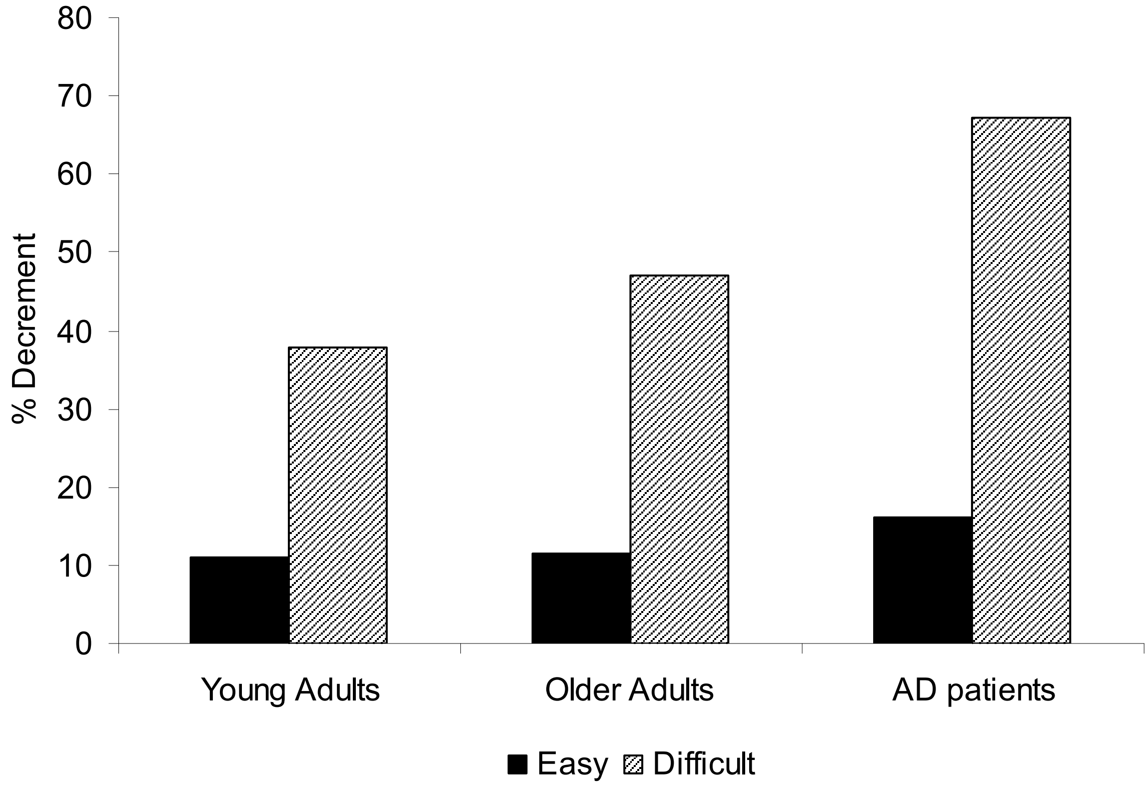


Figure 5. Mean percentage decrement in dual-task month reciting, relative to single-task month reciting, as a function of group and level of dual-task difficulty.

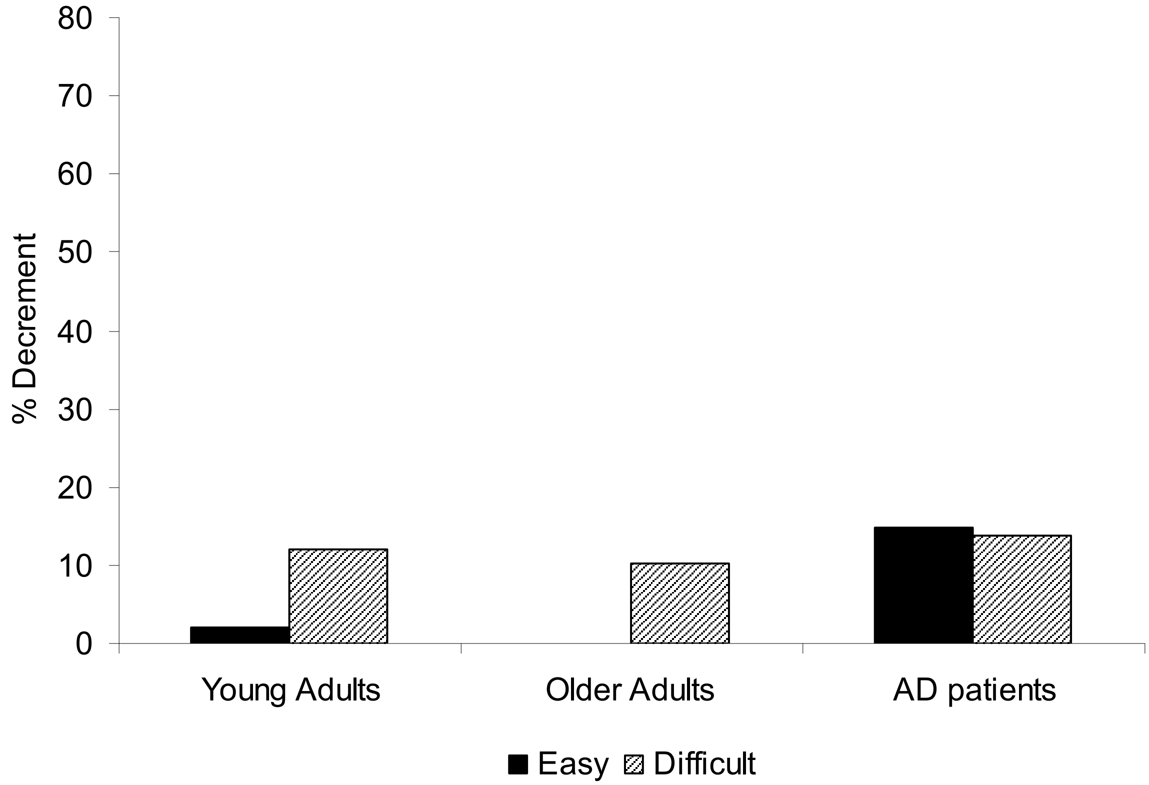


Table 6

Mean (SD) number of finger taps and numbers recited, and average percent decrement scores during easy and difficult dual-task conditions for young adults, older adults, and AD patients

	Young Adults	Older Adults	AD Patients
Number of Finger Taps			
Single-task	81.3 (8.7)$_a$	61.5 (8.4)$_b$	54.8 (9.5)$_c$
Easy dual-task	74.5 (11.7)$_a$	55.3 (11.1)$_b$	42.5 (8.2)$_c$
% decrement	8.4 (10.9)$_a$	9.8 (14.2)$_a$	21.9 (11.3)$_b$
Difficult dual-task	72.2 (9.7)$_a$	44.1 (15.3)$_b$	18.6 (5.3)$_c$
% decrement	11.4 (9.0)$_a$	28.9 (21.9)$_b$	65.9 (7.4)$_c$
Easy numbers recited			
Single-task	49.6 (6.8)$_a$	41.5 (6.0)$_b$	39.7 (5.6)$_b$
Dual-task	48.8 (8.3)$_a$	41.6 (7.4)$_b$	39.1 (6.4)$_b$
% decrement	1.7 (9.2)$_a$	-0.2 (9.2)$_a$	1.5 (10.5)$_a$
Difficult Numbers Recited			
Single-task	25.6 (4.9)$_a$	16.8 (4.3)$_b$	11.5 (3.1)$_b$
Dual-task	23.5 (4.2)$_a$	16.1 (4.3)$_b$	10.7 (2.8)$_b$
% decrement	7.6 (8.4)$_a$	6.4 (11.0)$_a$	5.4 (18.1)$_a$

Note. Means in the same row that do not share subscripts differ at $p < .05$.

Figure 6. Mean percentage decrement in finger tapping score, relative to single-task tapping rate, as a function of group and level of dual-task difficulty.

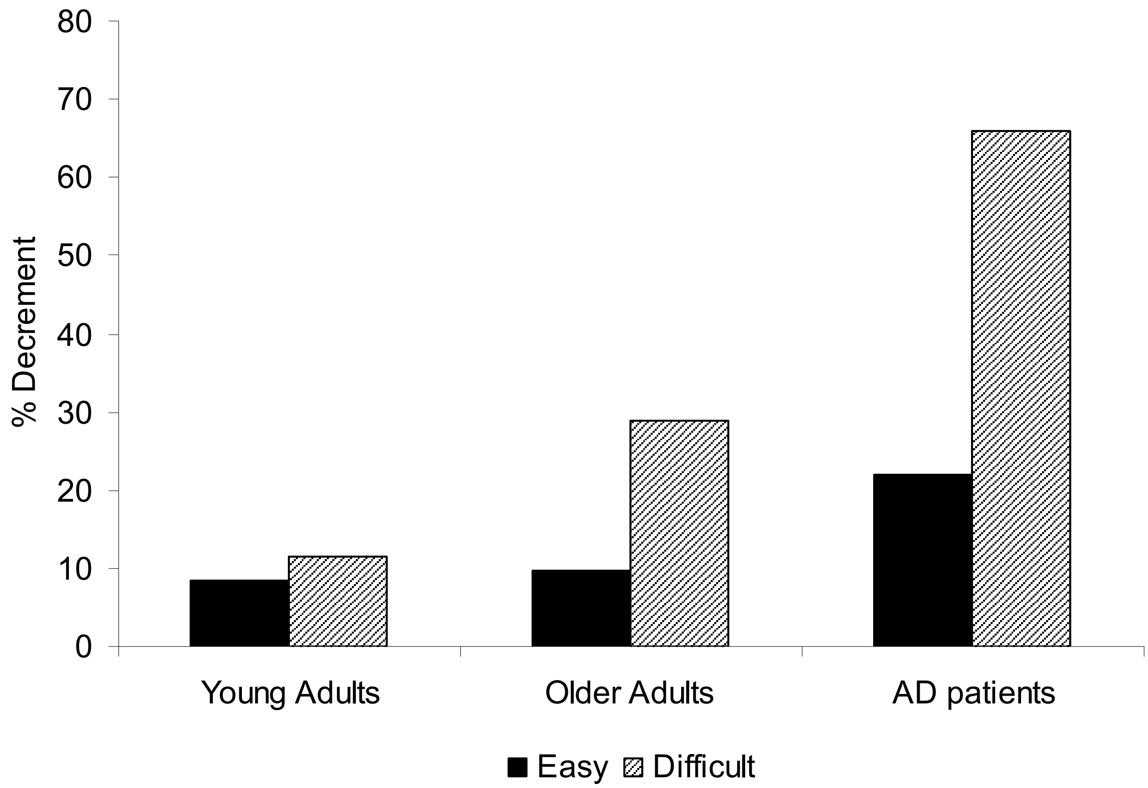
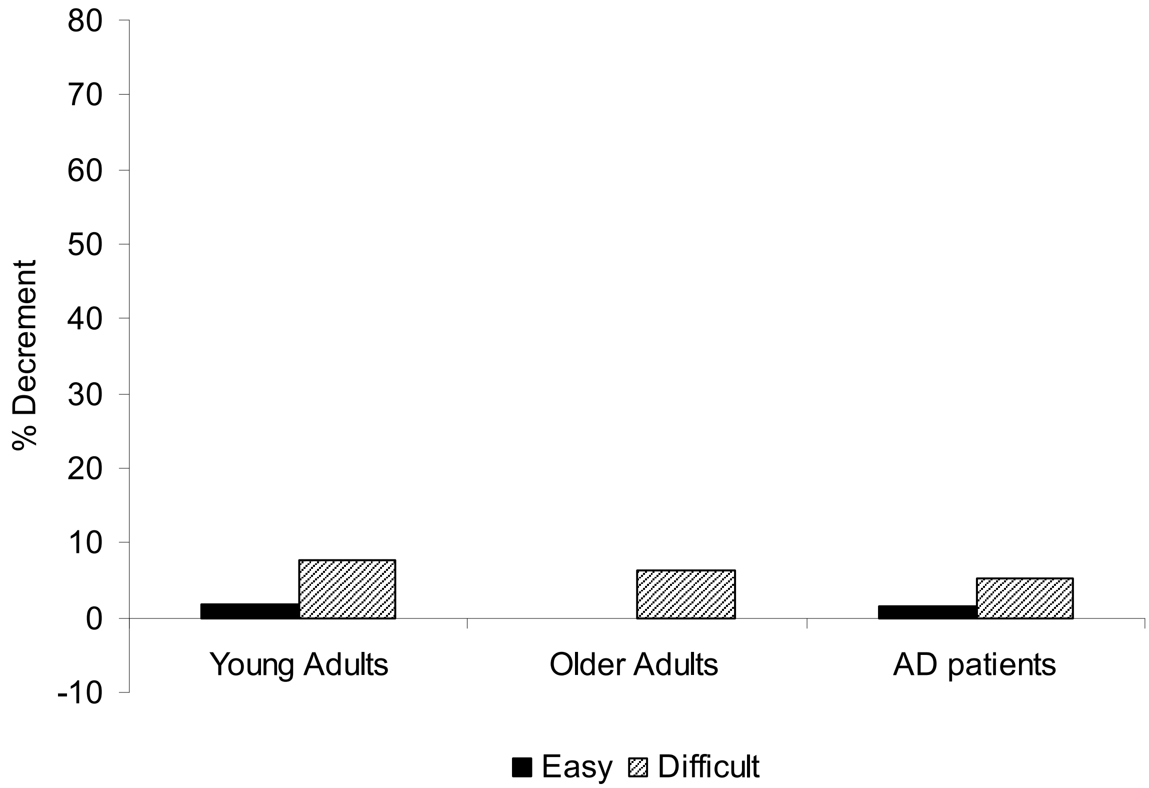


Figure 7. Mean percentage decrement in number reciting score, relative to single-task number reciting, as a function of group and level of dual-task difficulty.



Study 3: Accuracy of Attentional Measures in Discriminating Alzheimer's Disease from Normal Aging

Alzheimer's disease (AD) is currently considered to be an irreversible neurodegenerative condition characterized by progressive impairments in memory and at least one other cognitive domain (APA, 2000). AD is the most commonly diagnosed form of dementia, accounting for approximately 60% of all dementia diagnoses. Canadian prevalence data shows that approximately 5% of all adults over age 65 have AD (Canadian Study of Health and Aging Working Group, 1994). Although AD has been traditionally characterized as a memory disorder (Cummings & Benson, 1992), an increasing body of research has demonstrated that attentional processes, which have been linked to the cholinergic system (Lawrence & Sahakian, 1995), are also impaired early in the disease (Baddeley, Baddeley, Bucks, & Wilcock, 2001; Baddeley; Levinoff, Li, Murtha, & Chertkow, 2004; Crossley, Hiscock, & Beckie Foreman, 2004; Fernandez-Duque & Black, 2008; Nestor, Parasuraman, Haxby, & Grady, 1991; Parasuramen & Greenwood, 1998; Perry & Hodges, 1999)

In their review of attention and executive processes in AD, Perry and Hodges (1999) noted differential effects of AD on different facets of attention. For example, research has consistently found impaired selective attention and divided attention in AD but relatively preserved sustained attention abilities in the early stages of the disease. Perry and Hodges suggested that these differential effects support the proposal that attention should be considered as a fractionated system. Baddeley et al. (2001) tested the proposed fractionation of attention by comparing young adults, older adults, and AD patients on tests of focused attention, selective attention, and divided attention. They found a different pattern of results across the three domains of attention and argued that this supported the proposed fractionation of attention.

However, more recently Corney and Crossley (Study 2) conducted a similar study and found a consistent pattern of results across all domains of attention. Most notably, significant interactions between age and task difficulty, and AD and task difficulty were found. When tasks were sufficiently difficult, older adults performed more poorly than young adults and early stage AD patients performed more poorly than healthy older adult controls across all attentional domains, including divided attention. The finding of a significant age difference on difficult divided attention tasks contrasted the results reported by Baddeley et al. which showed no age effects on divided attention.

Alzheimer's disease typically progresses insidiously for several years before clinical symptoms become apparent (Elias et al.., 2000). Although it is currently considered an incurable disease, recent research has shown that pharmacological treatments may be helpful to slow disease progression. For example, acetylcholinesterase inhibitors may temporarily improve or at least stabilize cognitive and global functioning in some individuals with mild to moderate AD (Farlow & Cummings, 2007; Ritchie, Ames, Clayton, & Lai., 2004; Tariot et al., 2000), and recent Canadian clinical practice guidelines have recommended pharmacological treatments even in the severe stages of the disease (Herrmann, Gauthier, & Lysy, 2007). Most research supports the notion that benefits of pharmacological interventions are maximized if treatment is initiated early in the course of the disease (Cummings, Doody, & Clark, 2007; Farlow and Cummings, 2007); consequently, early detection of AD is extremely important. At present, the techniques used for diagnosing AD are imprecise, especially in the earliest stages of the disease. Therefore, the development of new measures to provide additional information about a patient's cognitive functioning may improve the accuracy of early AD diagnoses.

In light of the increasing evidence of attentional impairments in the early stages of AD, recent research efforts have focused on investigating the utility of attentional measures in predicting AD and discriminating between early AD and normal aging. Rapp and Reischies (2005) conducted a longitudinal study of 187 initially normal participants and found that performance on tests of attention and executive function discriminated between those who would develop AD and those who remained cognitively healthy after four years. Gorus, De Raedt, Lambert, Lemper, and Mets (2006) investigated the ability of selective and alternating attention measures to discriminate between early stage AD patients and healthy older adult controls. They found that their combined measures had a sensitivity of 73% and specificity of 91% for an overall hit ratio of 82%.

In the present study, we investigated the ability of four previously developed attentional measures to discriminate between early stage AD patients and cognitively healthy older adults. The sensitivity and specificity of each attentional test were assessed. Sensitivity is the proportion of people with a positive test result who have the target disorder, whereas specificity is the proportion of people with a negative test result who do not have the target disorder. We also investigated the discriminative ability of combined performance on the four attentional measures. As Baddeley et al. (2001) suggest, the use of multiple measures with a single sample allows for the opportunity to compare sensitivity across measures, which may in turn provide direction regarding development for clinical use.

Method

Participants

The present study included nineteen individuals (7 male, 12 female) diagnosed with early-stage Alzheimer's disease (AD) and a comparison group of 30 normal older adults (15 males, 15 females). Following approval of this study by the University of Saskatchewan

Research Ethics Board (Behavioral), individuals with early-stage AD were recruited from the Rural and Remote Memory Clinic, an interdisciplinary clinic where patients undergo a neuropsychological assessment for suspected dementia as well as investigations in neurology, geriatric medicine, neuroradiology, and physical therapy. Participants who received a consensus diagnosis of probable early stage AD after these comprehensive assessments were invited to take part in this study. Those who participated had an average age of 73.6 years (*SD* = 7.2, range = 63-86 years). During clinical assessments, cognitive screening tests yielded an average score of 24.6 (*SD* = 1.7) on the Mini Mental State Examination (MMSE; Folstein at al., 1975), which has an upper limit of 30 points, and 78.4 (*SD* = 7.4) on the Modified the Mini Mental State Examination (3MS; Teng & Chui, Teng & Chui, 1987), which has an upper limit of 100 points. Please refer to Study 2 for a description of other neuropsychological tests administered during the clinical assessment.

Thirty healthy older adults were recruited into the comparison group by sending invitations to participate to members of the Saskatoon Council on Aging, a non-profit organization with programs and services for seniors in Saskatoon, SK. Average age of the healthy older adult sample was 76.3 years (*SD* = 6.9, range = 62-88 years). In addition to the experimental attentional tasks described below, older adult controls completed a battery of neuropsychological tests identical to the one completed by AD participants during their Memory Clinic assessments (specific tests are described in Study 2). Normal older adults had average scores of 28.6 (*SD* = 1.9) on the MMSE and 96.5 (*SD* = 3.3) on the 3MS. Scores for normal older adults and AD patients on other neuropsychological tests are summarized in Table 1.

Procedures

Prior to participating individuals were informed that participation in this study involved completing a variety of attentional measures designed to investigate changes in attention associated with normal aging and AD. Data for the present study were collected as part of a more comprehensive study investigating changes in attention associated with normal aging and AD (Corney & Crossley, Study 2). In that study, participants completed four attentional tasks at two levels of difficulty. Consistent with Crossley, Hiscock, and Foreman (2004), it was found that differences in performance between AD patients and normal older adults were relatively small for the easy tasks but were significantly more pronounced when difficulty levels were high. For the purpose of the present study, we were interested in the ability of the difficult attentional tasks to discriminate between AD patients and normal adults, and only data from the difficult versions of the tasks were included in the analyses. For a complete description of the full procedures for the easy and difficult attentional tasks, please refer to Corney and Crossley (Study 2). A brief description of the procedures used for the difficult versions of the attentional tasks is provided below.

Difficult Version of Selective Attention

Participants were presented with a series of 8.5 x 11 sheets of paper on which were printed 150 underlined letters (10 lines of 15 letters each). Each page contained a total of 20 Zs distributed in quasi-random order (0 - 3 Zs per row). All other letters had visual features similar to those of Zs (i.e., comprised of straight lines and angles, such as K, L, W, N, etc). After a demonstration by the examiner and a practice trial, participants completed two experimental trials which were each preceded by the following instructions: “Work across the rows this way (indicate left to right) crossing out all the Zs in this group of letters. Work as quickly and carefully as you can and tell me when you are finished. Ready? Go!" Each trial was timed, and total time to completion was recorded and averaged across the two trials.

Difficult Version of Focused attention

Focused attention was assessed with a computerized choice reaction time task. Apparatus consisted of a laptop computer programmed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) to administer blocks of 20 focused attention trials. The computer was connected to a symmetrical, two button computer mouse which was mounted to a plastic board with brackets to inhibit movement of the mouse during the trials. For each trial, a shape (i.e., a circle or a square) appeared on the computer screen and participants were instructed to press one of two mouse keys depending on which shape appeared.

Each block of 20 trials consisted of 10 trials with circles presented and 10 with squares. These were presented in random order, with time between trials varying in length from 1.33 s to 4.00 s. Reaction time (i.e., time from presentation of the shape to button press) was recorded for each trial and averaged over the two blocks of 20 trials.

Difficult Version of Divided Attention I

Participants performed a box joining task and a month reciting task, first individually and then in combination. Participants completed two single task trials for each component task as well as two dual-task trials.

For single-task box joining, procedures involved a modification of procedures first described by Baddeley, Della Sala, Papagno, and Spinnler (1997). For each box-joining trial, participants were presented with an 8.5 x 11 inch sheet of paper on which were printed eighty 1 cm^2 boxes joined by lines and arranged along a winding path. Participants were instructed to draw a line joining the boxes as quickly as possible, ensuring that their lines touched the insides of the boxes. Prior to the initial single-task box-joining trial, an un-timed practice trial was administered to ensure that participants understood the task. For each of the two single-task box-joining trials, participants were told that they had 20 s to connect the boxes as quickly and accurately as possible, and that if they joined all 80 boxes, they should start again at the beginning and continue joining boxes until the experimenter indicated that the trial was over. Total number of boxes correctly joined (i.e., completely touched boxes in the correct sequence) was recorded and averaged across the two single task trials.

For the month reciting task, participants were asked to recite the months of the year backward, as quickly and clearly as possible (i.e., "December, November, October,…, etc"). After all 12 months were recited, participants were to start again at "December" and to continue until told by the experimenter to stop. Prior to the initial month reciting trial, an un-timed practice trial of 18 months was administered to ensure understanding of the task. Participants then completed two single-task trials, which were preceded with instructions to recite as many months backward as possible during the 20-s trial.

Dual-task trials consisted of box joining in combination with backwards month reciting. Participants were instructed to perform both tasks simultaneously and it was emphasized that both tasks were equally important. After an untimed practice trial was administered to ensure that the task was understood, participants completed two 20-s experimental dual-task trials. For each trial, total number of boxes joined was recorded and scores were averaged over the two dual task trials. To account for the age differences that were expected and confirmed on single task performance, interference in dual-task conditions was expressed as a percent decrement score, calculated using the following equation:

Decrement score = (single task score – dual task score) / single task score x 100%

. This allowed for an assessment of the proportional change in an individual's performance on the box joining task during dual-task conditions relative to his/her performance during the single-task conditions.

Difficult Version of Divided Attention II

The second dual-task procedure involved an alternate key finger tapping task and a number reciting task, with participants performing both tasks individually and in combination. More specifically, for single-task finger tapping, participants were instructed to use their index finger to tap the two buttons of a symmetrical computer mouse as quickly as possible, alternating between the two buttons. The mouse was secured to a board using plastic brackets to inhibit movement during the trials and was connected to a laptop computer. E-Prime software was used to generate the15-s finger tapping trials and to count the total number of taps in each trial.

For single-task number reciting, participants were asked to start with the number 70 and to count aloud backwards by twos as quickly as possible during 15-s trials. After a practice trial, participants completed two experimental single-task trials and the numbers recited were recorded by the experimenter.

Dual-task trials consisted of alternate key finger tapping in combination with counting backwards from 70 by two's. Participants were instructed to perform both tasks simultaneously and it was emphasized that both tasks were equally important. After an untimed practice trial, administered to ensure that the task was understood, participants completed two 15-s dual-task trials. For each trial, performance was measured in terms of number of taps during each 15-s dual-task trial and scores were averaged over the two trials. Percent decrement scores were calculated to express the proportional change in performance on alternate key tapping in the dual-task condition relative to performance in the single-task condition.

Results

For each of the four attentional measures under consideration, Receiver Operating Characteristic (ROC) plots were constructed and examined to determine the sensitivity and specificity of each at a range of cutoff points. Sensitivity refers to the proportion of AD patients correctly classified as having the disease while specificity refers to the proportion of healthy older adult controls correctly classified as not having AD. ROC plots show the sensitivity by 100 minus specificity over all possible cutoff points, and they vary between (0,0), or 0% sensitivity and 100% specificity, and (100,100), or 100% sensitivity and 0% specificity. The area under the curves (AUCs) of these ROC plots gives an indication of the overall accuracy of the screening tool. The area represents the probability that a randomly chosen AD patient will perform more poorly than a cognitively healthy older adult on the task under consideration (Hanley & McNeil, 1982). Therefore, numbers closest to one represent the best accuracy.

The ROC curves for the four attentional tasks are displayed in Figure 1, while optimal cutoff points to maximize sensitivity and specificity for each task are shown in Tables 2 to 5. Examination of the curves shows that average time to completion on the selective attention task was the least accurate of the four measures in discriminating AD patient from normal older adults, with an AUC 0.696 (*SE* = .0078). Average reaction time as assessed by the focused attention task had an AUC of 0.747 (*SE* = .078). Percent decrement score on the box joining task (from Divided Attention I) had an AUC of 0.807 (*SE* = .061). The dual task finger tapping decrement score from the Divided Attention II task was the most accurate predictor of group membership, with an AUC of 0.933 (*SE* =0.036). Optimal cutoff points are for the finger tapping percent decrement score are displayed in Table 5. With a cutoff percent decrement score of

50.3%, sensitivity was 100% and specificity was 80%. A slight increase in the percent decrement score cutoff to 55.2% increased specificity to 87% at the cost of reduced sensitivity (90%).

In addition to investigating each attentional task individually, we also examined the ability of the four attentional measures, in combination, to discriminate AD patients from normal older adults. A direct discriminant function analysis was performed using the four attentional tasks as predictors of AD presence/absence. Prior to the analysis, data screening showed skewed and kurtotic data for the focused attention task. A square root transformation was performed and was successful in normalizing the data.

When the four predictor variables were entered together, one discriminant function was calculated and was statistically significantly associated with group membership, $\chi 2$ (4) = 45.58, $p < .001$. Relative importance of the predictor variables was assessed via examination of standardized canonical discriminant function coefficients, which are summarized in Table 6. Results showed that the two dual-task decrement scores were most important, followed by the selective attention task and finally by the focused attention task. Examination of the classification rates revealed 19 of 19 AD cases and 25 of 30 non-AD cases were correctly classified, for a total correct classification rate of 89.8%

Discussion

This study investigated the ability of four attention measures to discriminate early-stage AD patients from healthy older adult control participants. Two measures were used to assess divided attention while one measure was used for each of selective and focused attention. In a previous study, each of these tasks was administered at two levels of difficulty (see study 2) and it was demonstrated that AD patients consistently performed more poorly than controls on all the difficult task versions. The present study provides a preliminary investigation of the clinical utility of these difficult attention tasks by examining their ability to discriminate between early stage AD and normal aging. The attentional tasks were considered individually and in combination.

Results showed that when the individual tasks were compared, there was considerable variability in the discriminative abilities of the four tasks. When using cutoff points to establish sensitivity at a high level for three of the four tasks (selective attention, focused attention task, box joining in combination with month reciting) there were too many false positives to recommend these tasks individually as efficient screening tools for AD. In contrast, for the divided attention task involving finger tapping in combination with number reciting, optimal cutoff points yielded both high sensitivity and specificity. One interpretation is that this task was set at an optimal level of difficulty to be sensitive to AD but unaffected by normal aging, while the other tasks were either too easy to be sensitive or too difficult for the control group to be specific.

When performance on all four attentional measures was combined and analyzed via discriminant function analysis, resulting classification statistics showed that all AD patients and 25 of 30 control participants were correctly classified. Of note is that two of the five control participants incorrectly classified as having AD were among the oldest control participants to take part, at ages 88 and 86. A possible interpretation for this finding is that attentional functions may be affected in advanced old age and measures of attention may therefore not be suitable to detect AD in the oldest age groups. Future research comparing young older adults with the oldest old may help to clarify the effects of advanced age on attention. Alternatively, it is possible that poor attentional performance among control participants may represent AD or another form of dementia in the preclinical phase although longitudinal data would be required to confirm this.

Although we were able to compare the discriminability of the four attentional measures using a single sample of participants, the sample size in the AD group (i.e., 19) was relatively small and replication of these results using a larger sample size would be useful to confirm the generalizability of the results. Older adult control participants had significantly more years of education than AD patients. Although groups would ideally have equivalent levels of education, data from a previous study showing no association between years of education and attentional performance (Corney & Crossley, Study 2) strengthened our confidence that results were not simply due to educational differences.

Results of the study show that attentional measures can discriminate between AD patients and healthy controls, but it is unclear if these results are specific to AD or rather reflect a more general decline in attention across most or all forms of dementia. Future research investigating the impact of other forms of dementia on attention would be beneficial. For example, the attentional profiles in frontotemporal dementia, vascular dementia, and Lewy body dementia are not well understood and would benefit from additional research.

Gaining a further understanding about attentional changes in early stage AD may have implications for the development and implementation of interventions. From a pharmacological perspective, recent research has examined the effectiveness of medications in improving attention task performance, and it has been demonstrated that galantamine improves attention performance in AD patients (Gorus, Lambert, De Raedt, & Mets, 2007; Galvin et al., 2008). However, as discussed by Perry et al. (2000), continuing to build knowledge about how attention is affected in AD will be helpful for determining how to assess the efficacy of medications.

In terms of future directions, it would be of interest to further explore the impact of non-pharmacological interventions such as cognitive rehabilitation and lifestyle changes on attention.

Although a recent meta-analysis found that effects of rehabilitation on general cognition in AD patients were inconsistent and small (Clare, Woods, Moniz Cook, Orrell, & Spector, 2004), the specific effects of rehabilitation on attentional functions have not been thoroughly studied (Yu, Kolanowski, Strumpf, & Eslinger, 2006) and would benefit from further investigation. One lifestyle factor that appears to have significant implications for attention is exercise; several studies examining the effects of aerobic exercise have shown that it can exert a beneficial influence on executive and attentional processes in both healthy older adults (Colcombe & Kramer, 2003; Hawkins, Capaldi, & Kramer,1992) and AD patients (Palleschi et al., 1996; Rolland et al., 2000; Yu et al., 2006). Future research investigating the effects of various forms of exercise on different aspects of attention would provide a valuable contribution to the literature in this area.

In summary, the present study builds upon previous research that has demonstrated attentional changes in early stage AD. This study showed that attentional measures discriminate between early stage AD patients and healthy older adult controls, with one task of divided attention having particularly impressive sensitivity and specificity. These results and future research examining attention in AD from a clinical perspective may have implications for early identification and treatment of AD.

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Figure 1. ROC plots for the four attentional tasks when screening for Alzheimer's disease.

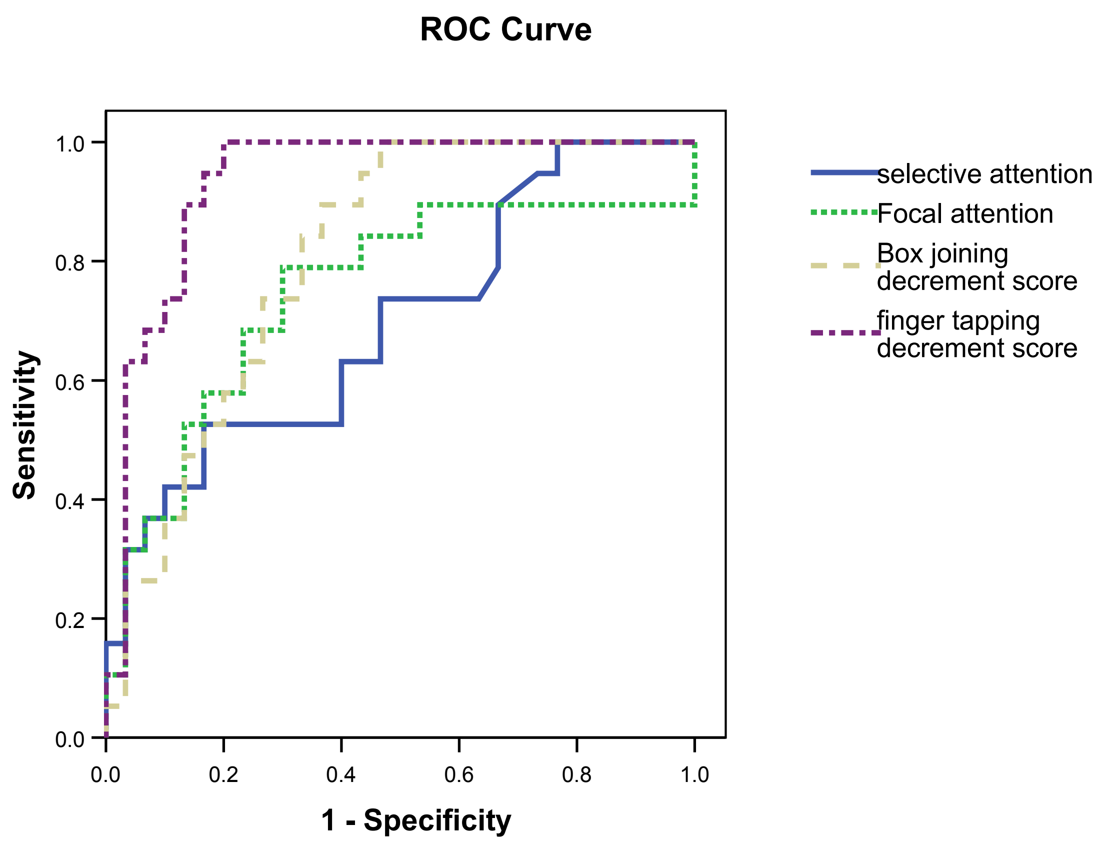

Table 1

Sample of Cutoff Points with Sensitivity and Specificity of the Selective Attention Task (Average Time to Completion in Seconds) for Detecting Alzheimer's Disease

Cutoff	Sens (%)	Spec (%)	Cutoff	Sens (%)	Spec (%)
33.15	100	23	41.25	63	60
34.25	95	27	44.45	53	80
35.00	90	33	46.55	42	90
38.50	74	50	57.25	16	100

Table 2

Sample of Cutoff Points with Sensitivity and Specificity of the Focused attention Task (Average Reaction Time in ms) for Detecting Alzheimer's Disease

Cutoff	Sens (%)	Spec (%)	Cutoff	Sens (%)	Spec (%)
487	100	0	730	68	77
636	90	47	788	58	83
660	84	67	890	37	93
709	79	70	1119	11	100

Table 3

Sample of Cutoff Points with Sensitivity and Specificity of Divided Attention Task 1 (Box Joining Decrement Score) for Detecting Alzheimer's Disease

Cutoff	Sens (%)	Spec (%)	Cutoff	Sens (%)	Spec (%)
45.8	100	53	60.6	74	73
54.0	95	57	65.3	53	80
55.8	90	63	71.5	32	90
56.6	84	67	87.6	5	100

Table 4

Sample of Cutoff Points with Sensitivity and Specificity of Divided Attention Task 2 (Finger Tapping Decrement Score) for Detecting Alzheimer's Disease

Cutoff	Sens (%)	Spec (%)	Cutoff	Sens (%)	Spec (%)
50.3	100	80	63.9	68	93
52.7	95	83	64.9	63	93
55.2	90	87	73.7	16	97
602	74	90	87.6	11	100

Table 5

Standardized Canonical Discriminant Function Coefficients

Variable	Standardized Coefficient
Selective Attention (Time to Completion)	0.366
Focused attention (Average reaction Time)	0.275
Divided Attention I (Box Joining Decrement Score)	0.517
Divided Attention II (Finger Tapping Decrement Score	0.701

General Discussion

This dissertation investigated attention in normal aging and Alzheimer's disease from both a theoretical and a clinical perspective. From a theoretical perspective, studies were designed to test the current model of working memory that conceptualizes attention as a fractionated system, consisting of several separate but inter-related subsystems (Baddeley, Baddeley, Bucks, & Wilcock, 2001). Under this model, sub-systems can be differentially affected by factors such as normal aging, Alzheimer's disease, and task difficulty (Baddeley, Bressi, Della Sala, Logie & Spinnler 1991; Perry & Hodges, 1999). This contrasts with unitary attentional hypotheses, under which attention is conceptualized as a single, unitary resource, and which proposes that older adults will be disproportionately affected by increased task difficulty compared to young adults. In keeping with the unitary attentional resource model, compared to cognitively healthy older adults, patients with AD would be expected to show disproportionate decreases in performance during difficult task conditions.

As part of a larger study investigating the proposed fractionation of attention, Baddeley, Baddeley, Bucks, and Wilcock (2001) found no differences between young and older adults on a dual-task procedure and concluded that there are no age-related changes in divided attention. This conclusion contradicts a large body of previous research that has found age effects on dual task performance. The primary goal of Study 1 was to clarify the effects of normal aging on divided attention. We identified methodological differences between the dual-task paradigm described by Baddeley et al. and the paradigms used by other dual-task researchers. Importantly, the paradigm used by Baddeley et al. did not allow for manipulation of dual-task difficulty. Studies have demonstrated that older adults will be susceptible to dual-task interference only if the component tasks are sufficiently difficult (Crossley & Hiscock, 1992; McDowd & Craik, 1988).

In Study 1, young, middle-aged, and older adults were compared on a new dual-task paradigm that was designed using stimuli similar to that used by Baddely et al. (2001), but designed specifically to allow for manipulation of task difficulty. In contrast to Baddeley et al's findings of age equivalent performance on divided attention, the findings of Study 1 demonstrated similar performance across age groups when tasks were simple, but robust age differences when component tasks were sufficiently difficult. These findings are consistent with a large body of previous research that has shown that dual-task performance is affected in normal aging. This study contributes to the literature by demonstrating that methodological considerations, and specifically the difficulty of component tasks, can play a crucial role in determining if age differences are detected. In addition, the finding of an interaction between age and task difficulty, when viewed alongside the similar pattern of results for selective and focal attention, directly challenges the evidence of age-equivalent divided attention performance that has been provided by Baddeley et al. (2001) in support of the proposed fractionation of attention.

The proposed fractionation of attention was further challenged by the findings of Study 2, in which young adults, older adults, and AD patients were compared on tasks focal attention, selective attention, and divided attention. Using similar procedures, Baddeley et al. (2001) found a contrasting pattern of results across the attentional subtypes and argued that this finding supported the idea that attention should be conceptualized as being comprised of several distinct subtypes. In particular, as described earlier, their finding of age-equivalent performance on divided attention contradicted a large body of research that has demonstrated clear age effects on dual-task performance. In light of this discrepancy, two different dual tasks were used in Study 2 to assess divided attention. As discussed by Perry and Hodges (1999), using multiple paradigms with the same study participants allows for comparison across paradigms and allows for firmer conclusions that do not depend on the assumption of subject and procedure equivalency across studies.

In contrast to the findings of Baddeley et al. (2001), results of Study 2 showed equivalent interactions between group and task difficulty across all groups for all attentional tasks, including both tasks of divided attention. As with Study 1, this finding demonstrated that age differences in divided attention performance are mediated by task difficulty. From a theoretical perspective, these findings contradicted the evidence provided by Baddeley et al. (2001) to support the fractionation of attention. The unitary attentional hypothesis offers a more parsimonious explanation for the finding of consistent results across attentional domains.

From a clinical perspective, the objectives of this dissertation were to increase understanding about attention in both normal and pathological aging and to determine if knowledge about attentional changes in early AD can contribute to identification of the disease in its early stages. Findings of Study 2 add to the growing body of literature that has shown that deficits in attentional functions do occur in the early stages of AD (Perry & Hodges, 1999; Baddeley et al., 2001; Crossley, Hiscock, & Beckie-Foreman, 2004). Study 3 incorporated information gained from Study 2 about the effects of AD on attentional processes and tested whether attentional measures can discriminate early-stage AD from normal aging. Only a small number of previous studies have investigated attention in AD from this perspective, but some studies have shown that at least some attentional tasks can discriminate early AD from normal aging (Gorus, De Raedt, Lambert, Lemper, & Mets, 2006). Looking specifically at divided attention, research has demonstrated that dual task performance is more accurate than traditional neuropsychological measures at discriminating older adults with cognitive impairment from normal controls (Holtzer, Burright, & Donovick, 2004). In Study 3, results showed that a range of attention tasks can be used to discriminate between AD patients and healthy older adults, with divided attention being the most sensitive attentional domain to accurately detect early AD. One limitation of this study is that we did not include participants with conditions such as depression and mild cognitive impairment. Recent investigations have concluded that dual-task performance is compromised in these conditions (Lonie, Tierney, Herrmann, Donaghey, Carroll, Lee, et al., 2008) which may limit the clinical utility of dual-task procedures. In an ongoing investigation by our research group, the dual task paradigm described in Study 2 (finger tapping in combination with counting backwards by two's) is being administered to patients at the Rural and Remote Memory Clinic as part of the standardized neuropsychological test battery. It is our hope that this research will be helpful in delineating the specific effects on divided attention of a range of clinical disorders affecting older adults.

Another important contribution of this program of research is that it demonstrated that attention is affected in the relatively early stages of AD. Although it is clear that attention becomes impaired by the moderate stages of AD, Perry, Watson, and Hodges (2000) found that patients in the very early stages performed normally on tasks of divided attention. In contrast to these findings, the AD sample used in Studies 2 and 3 consisted of a relatively homogeneous, very mildly impaired sample, with low variability in scores on cognitive screening tests (3MS and MMSE). Nevertheless, although mean scores for these tests fell above cutoff for dementia, results of a comprehensive interprofessional assessment resulted in a diagnosis of early stage AD for all study participants.

One of the major limitations of the studies described in this dissertation, as well as other studies of attention in AD, is that use of different methodologies to assess attention makes comparisons across studies difficult to interpret. It should also be noted that the AD patient sample included in Studies 2 and 3 (n = 19) was relatively small. Although power was sufficient to detect the hypothesized differences in all cases, future studies should attempt to include larger samples in order to strengthen confidence regarding the generalizability of the results.

In terms of future directions, additional research investigating the neuronal mechanisms mediating attention may contribute to a more specific understanding about the neural organization and how brain changes in aging and AD relate to observable changes in attention. . For example, the development of increasingly advanced brain imaging techniques may allow researchers to identify specific brain areas activated during performance of a range of attentional tasks. To date, there have already been several studies using these types of methodologies. For example, evidence suggests that AD-associated changes in attention are related to damage to the basal forebrain cholinergic system (Lawrence & Sahakian, 1995), and functional magnetic resonance imaging (fMRI) studies have shown involvement from the dorsolateral and ventrolateral prefrontal, cingulate, parietal, and premotor cortical areas during dual-task performance (see Sarter & Turchi, 2002; Dreher & Grafman, 2003 for reviews).

There are a wide range of potential practical and clinical implications to understanding attention in aging and AD that would benefit from further research. From a clinical perspective, it is becoming increasingly clear that changes in attention are an early feature of AD and tests of attention may therefore be useful for diagnosing and monitoring the disease. There are a very limited number of studies to date that have focused directly on assessing the ability of attentional measures to contribute to the early identification of AD and further investigation would be of interest. Although Study 3 showed that attentional tasks can accurately discriminate between healthy aging and AD, further research is needed to develop practical tests that are efficient and clinically useful. The relationship between newly developed, experimental attentional measures and existing neuropsychological measures also needs further exploration. In one of the few studies to date in this area, Holtzer, Stern, and Rakitin (2005) found that performance on existing neuropsychological tests of attention and executive function significantly predicted dual-task performance in young and older adults. This suggests that further research is necessary to determine if new attentional measures significantly contribute to diagnosis or if existing neuropsychological tests are sufficient. Whether forms of dementia other than AD have a significant effect on attentional functions remains a topic for further research.

Understanding effects of aging and AD on attention may also lead to research that could suggest interventions to improve attentional performance. For example, recent research has shown that pharmacological interventions may lead to an improvement in attention functions in AD patients (Gorus, Lambert, De Raedt, & Mets, 2007; Galvin, Cornblatt, Newhouse, Ancoli-Israwel, Wesnes, Williamson, et al., 2008). However, as discussed by Perry et al. (2000), continuing to build knowledge about how attention is affected in AD will be helpful in determining how to assess the efficacy of medications. In terms of a non-pharmacological intervention that may have significant positive effects on attention, research has shown that physical exercise leads to improvement in attentional performance (e.g., Dustman, Ruhling, Russel, Shearer, Bonekat, Shigeoka, et al., 1984; Hawkins, Kramer, & Capaldi, 1992). Several recent studies also have investigated the effects of exercise on general cognitive functioning in dementia (Palleschi et al., 1996; Rolland et al., 2000; Yu et al., 2006), and future research investigating specific effects on various aspects of attention would be of interest.

From a practical perspective, further research building on current understanding of attention may have important implications for various functional abilities, both in normal aging and in AD. One pertinent example of an activity that draws on a variety of attentional abilities is driving. Although it has long been suspected that "driver inattention" is a common cause of accidents, especially in older adults (Shinar, 1978 as cited in Duchek, Hunt, Ball, Buckles, & Morris, 1997), it is only more recently that researchers have investigated the specific roles of various attentional subtypes in driving. Initial studies have shown that measures of visual attention are associated with driving performance in healthy older adults (Ball, 1997) but other aspects have not yet been thoroughly investigated. There have also been relatively few studies investigating the relationship between attention and driving in AD, although a small number of studies provide early evidence that aspects of attention are related to driving skills in the early stages of the disease (Hunt, Carr, Ducheck, Grant, Buckles, & Morris, 1997) Additional research may assist in the development of new methods to help determine driving fitness among both healthy older adults and AD patients. For example, learning about the specific cognitive skills and processes that influence driving performance in healthy aging and AD may lead to the development of methods for identifying individuals at risk for unsafe driving.

The results of the three studies that constitute this dissertation shed additional light on changes in attention that occur as a result of both normal aging and AD. Aging, and to an even greater extent AD, are associated with declines in attentional abilities. This research has important theoretical implications with regard to understanding the nature of attentional processes, and clinical implications that may include improvement in the early identification and management of AD.

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Appendix A: Instructions for Study 1 Dual-Task

DUAL TASK INSTRUCTIONS

1. Box-joining
Present Box-joining sheet
I would like you to connect as many boxes as you can on this page. I would like you to start here *(show)*, **and draw a line joining the boxes. You must try not to miss out any of the boxes and you should work as quickly and accurately as you can. Make sure your line touches the insides of the boxes. When you reach the end, continue your line and go around a second time.**
Practice trial-let participant go through all boxes and start at the beginning, then stop.

Good. Now lets try it again. This time I will give you 20 seconds. Please remember to join the boxes as quickly and as accurately as you can, and remember to make sure your line touches the insides of the boxes. If you reach the end before I tell you to stop then please go around a second time. Start now.

2. Months Forward
Now I would like you to say as months as quickly and as clearly as you can. Like January, February, March, April and so on. Try not to miss any months out, and when you reach the end, start again at January and continue with another series of months. Have a go.
Practice trial-stop after 18 months are correctly recited.

Let's try again. Please remember to say the months as quickly and as clearly as you can. When you reach the end, continue with another series of months. Keep going until I say "stop." You have 20 seconds. Start now.

3. Months Backward
Now I would like you to say as many months as you can but this time in reversed order. Like December, November, October, September, and so on. Again, say as many months backward as quickly and clearly as you can and try not to leave any out. When you reach the end, continue with another series of months. Have a go.
Practice trial-stop after 18 months are correctly recited.
Let's try again. Please remember to say the months backward as quickly and as clearly as you can. When you reach the end, continue with another series of months. Keep going until I say "stop." You have 20 seconds. Start now.

4. Combined Box-joining and Months Forward
Present Box-joining sheet
Now I would like you to do two things at once. First you will join some more boxes in exactly the same way as you have been doing. You will start here. At the same time I would like you to say as many months forward, starting with January, as you can, just like we did before. Again, I would like you to do both tasks, connecting the boxes and saying the months, as quickly and as accurately as you can. Both tasks are equally important. Do you have any questions about what you have to do? Go ahead.
Practice trial-let participant go through all boxes and start at the beginning, then stop.

Lets try again. Please remember to connect the boxes and say the months forward as quickly and as accurately as you can. Again, both tasks are equally important. You have 20 seconds start now.

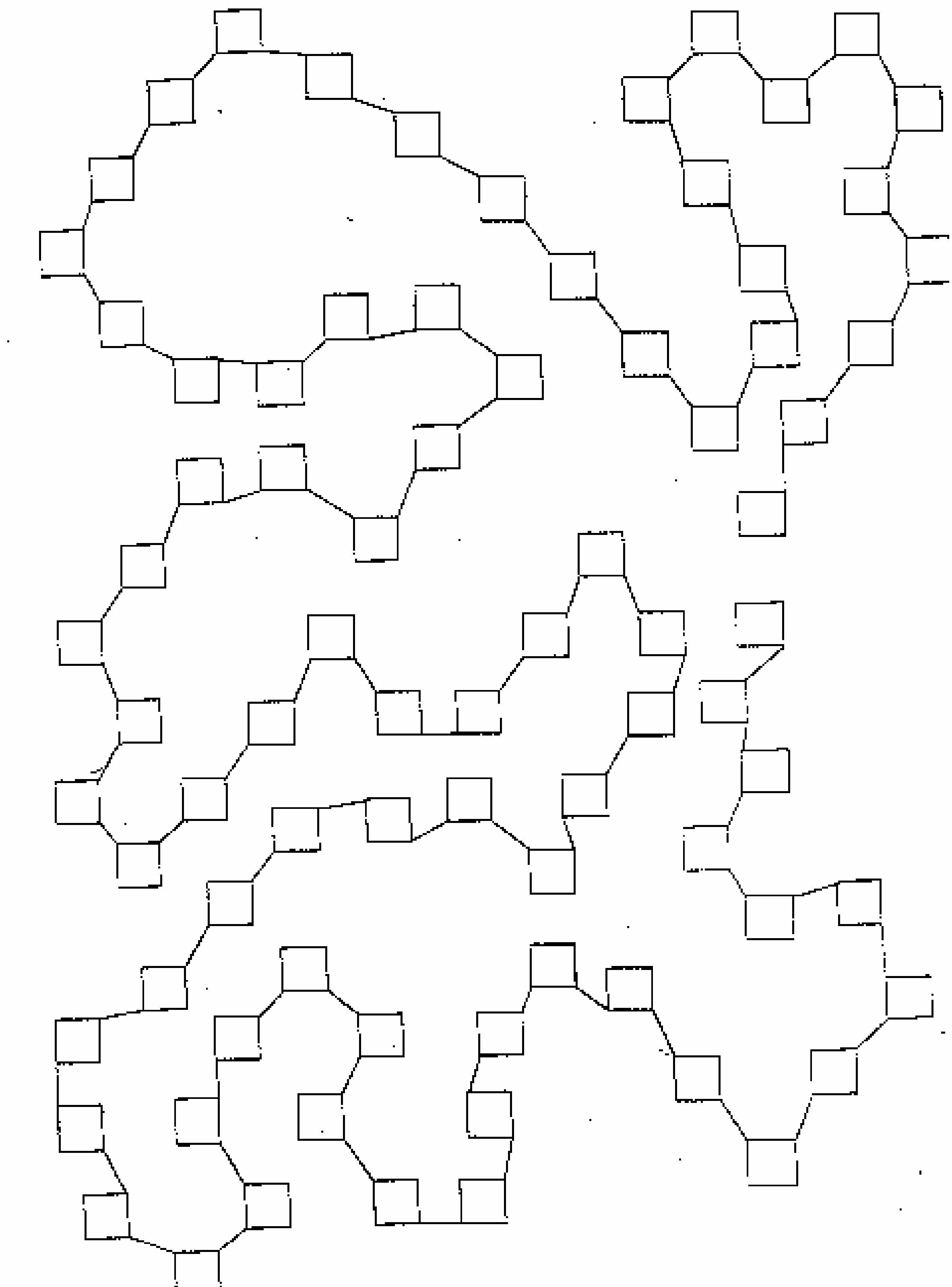
5. Combined Box-joining and Months Backward
Present Box-joining sheet
Now we are going to combine two tasks again. I would like you to join some more boxes in exactly the same way as you have been doing. You will start here. But this time, I would like you to say as many months backward as you can, starting with December, just like you did before. . Again, I would like you to do both tasks, connecting the boxes and saying the months backward, as quickly and as accurately as you can. Both tasks are equally important. Do you have any questions about what you have to do? Go ahead.
Practice trial-let participant go through all boxes and start at the beginning, then stop.

   Lets try again. Please remember to connect the boxes and say the months backward as quickly and as accurately as you can. Again, both tasks are equally important. You have 20 seconds start now.

6. Box-joining 2
Now we are going to do one task at a time again. Like before, join the boxes as quickly and as accurately as you can and remember to make sure your line touches the insides of the boxes. If you reach the end before I tell you to stop then please go around a second time. You have 20 seconds. Go.

7. Months Forward 2
Now, I would like you to say as many months forward as quickly and accurately as you can. Keep going until I say "stop." You have 20 seconds. Start now.

8. Months Backward 2
Now, I would like you to say as many months backward as quickly and accurately as you can. Keep going until I say "stop." You have 20 seconds. Start now.



Appendix B: Consent form (Studies 2 & 3)

UNIVERSITY OF SASKATCHEWAN

Department of Psychology

CONSENT FORM

You are invited to participate in a study entitled ***Attention in Individuals With and Without Memory Difficulties****. Please read this form carefully, and feel free to ask any questions you might have.*

Researcher(s): Patrick Corney, B.A.
Margaret Crossley, Ph.D., Supervisor
Aging Research and Memory Clinic
Department of Psychology, University of Saskatchewan
Phone: 966-5925

Purpose and Procedure: The purpose of this study is to investigate how well individuals of different ages, and those with and without memory difficulties, are able to pay attention and concentrate during various tasks. You will be asked to complete tasks that involve attention, concentration, and doing two things at once. You will also be asked to complete additional tasks which assess language and memory skills, and to complete a questionnaire asking about your health and lifestyle. Any questions you may have about the study will be answered by the researcher whenever possible.

Participation in this study will require approximately two hours of your time and will include a rest period.

Potential Risks: There are no known risks associated with this research.

Potential Benefits: Your participation in this study may help us improve our understanding of how attentional functions are organized. In addition, our findings may help us to develop new methods to identify people who have memory and attention difficulties.

Storage of Data: The data collected during this study will be securely stored for at least 5 years under the supervision of Dr. Margaret Crossley.

Confidentiality: All information you provide will be kept completely confidential. Your name will not be associated with your information. Instead, you will be assigned a participant number which will be used to identify your information. This consent form, and other forms on which your name appears will be stored in a separate location from information with your participant number on it.

The information collected in this study will be published in a dissertation and may be summarized in journal articles and/or professional conference presentations. At all times, only group data will be reported; individual participants will not be identified.

Right to Withdraw: Participation in this study is voluntary, and your decision to participate will not impact on any clinical services that would otherwise be available to you (e.g., assessment, treatments, etc.) You may withdraw from the study for any reason, at any time, without penalty of any sort. When completing the questionnaire, you may leave out any questions that you do not want to answer. If you withdraw from the study at any time, any data that you have contributed will be destroyed.

Questions: If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researchers at the number provided above if you have questions at a later time. This study has been approved on ethical grounds by the University of Saskatchewan Behavioural Sciences Research Ethics Board on (insert date). Any questions regarding your rights as a participant may be addressed to that committee through the Office of Research Services (966-2084). Out of town participants may call collect. If you indicate that you would like to find out about the results of this study, we will send you a summary of our findings once the study has been completed.

Consent to Participate: *I have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw this consent at any time. A copy of this consent form has been given to me for my records.*

___________________________________ ____________________
(Signature of Participant) (Date)

____
(Signature of Researcher)

Appendix C: Selective Attention Task

Participant #______________

SELECTIVE ATTENTION (ORDER 1)
INSTRUCTIONS FOR EXAMINERS

Say, **In this next task, I would like you to cross out all of the Zs in rows of letters. This first one is for practice. Use your pencil to cross out all of the Zs. Like this** (demonstrate 1st row**).**

Now you try.

Allow participant to practice until all of the Zs are crossed out and s/he clearly understands the task. Correct any mistakes. Once the task is clearly understood, say

Good job. **Now we are going to try some more. In these next ones, I am going to time you, so please try to work as quickly as possible. But also work carefully and try not to make any mistakes.**

Open to trial 1. **Cross out all the Zs in these rows of letters. Work as quickly and as carefully as you can, and tell me when you are finished.**

Ready? Go!

Repeat instructions for trials 2-4. Instructions for trials 2-4 may be shortened if the participant clearly understands the task.

If participant appears to be distracted or off task, say **Remember, cross out all the Zs.**

Results

Simple Trials	**Time (in seconds)**	**Errors of Omission**	**Errors of Commission**	**Difficult Trials**	**Time (in seconds)**	**Errors of Omission**	**Errors of Commission**
Trial 1				**Trial 2**			
Trial 4				**Trial 3**			
Simple Mean				**Difficult Mean**			

Participant #:______________

SELECTIVE ATTENTION
(Order 1)

Cross out Every Z

B R S Z P D O C Z R U Z B Z

V Y N Z M T K Z L Y X M K

Cross out Every Z

R P D Z O U B D P R Z Q D

K Y N Z X T K Z N Y X M V

D P S R B Z O C D P Z U P Z

N X V Z Y N K Z T V L Z M

O D B S P U Z Q O S U P C D

T M W Z T L M Y K V L X N

1. Cross out every Z

B C O G Z Q D R S U P D Z O S

G D P R O Z D P Z C Q S U B C

Q O Z R B D U S P D B D O R Q

U C B G O R S B D P Q Z U R Z

C Z R U R C Q G Z S U B Z O U

Z U C S B R Q Z B P R O Q S B

U O D Z R S Q Z D G C U P Z O

D Q U C P Z B C O P Z Z S B G

P O Q U S G R Q B C S Q P O C

O Z Q C D B S P B R U S Z R B

2. Cross out every Z

M T W Z N K V Y L Z T K X M V

Y V M W N K X T L T V Y X T N

V N K X Z L V T M W K Y M Z X

K V T Z K T L Z M W Z T L W Y

T W Z M K X N W Z T L V Y N K

X T L K Z N Y V X N V Y W L V

W Y N L K M Z V Z K X L M V Z

L Z M Y T V W Z K N Z V N Y W

Z K L Z T X N V W K Z Y M L X

L N K M X V N T Z Y L K W Y M

3. Cross out every Z

V N K X Z L V T M W K Y M Z X

L N K M X V N T Z Y L K W Y M

W Y N L K M Z V Z K X L M V Z

L Z M Y T V W Z K N Z V N Y W

Z K L Z T X N V W K Z Y M L X

X T L K Z N Y V X N V Y W L V

T W Z M K X N W Z T L V Y N K

M T W Z N K V Y L Z T K X M V

Y V M W N K X T L T V Y X T N

K V T Z K T L Z M W Z T L W Y

4. Cross out every Z

G D P R O Z D P Z C Q S U B C

D Q U C P Z B C O P Z Z S B G

U O D Z R S Q Z D G C U P Z O

C Z R U R C Q G Z S U B Z O U

P O Q U S G R Q B C S Q P O C

Q O Z R B D U S P D B D O R Q

O Z Q C D B S P B R U S Z R B

B C O G Z Q D R S U P D Z O S

Z U C S B R Q Z B P R O Q S B

U C B G O R S B D P Q Z U R Z

Appendix D: Focal Attention Task

Focal Attention Instructions (Order 1)

In this next task, you'll see some shapes appear on this computer screen and I want you to press a button as quickly as you can after you see the shapes.

EASY CONDITION

For the first few times, you'll only see circles. When you see a circle appear, press this button *(Point to the circle button)* **as quickly as you can. The circle will disappear and you should wait for the next one, and again press the button as quickly as you can. Keep doing this until more instructions appear on the screen.**

The first few are for practice. Ready? Go.

Experimental Trials

1. **Each time you see a circle on the screen, press the circle button as quickly as you can. The circle will disappear and you should get ready for the next one.**

After trial, take a break if needed.

2. **Each time you see a circle on the screen, press the circle button as quickly as you can. The circle will disappear and you should get ready for the next one.**

DIFFICULT CONDITION

Now, we'll do the same thing, but now you'll see circles sometimes and squares sometimes. When you see a circle, press this button *(Point to the circle button)* **as quickly as you can. When you see a square, press this button** *(Point to the square button)* **as quickly as you can. When you press a button, the shape will disappear and you should wait for the next one, and again press the button as quickly as you can. Keep doing this until more instructions appear on the screen.**

The first few are for practice again. Ready? Go!

Experimental Trials

3. **Each time you see a circle, press the circle button as quickly as possible. Each time you see a square, press the square button as quickly as possible. The shape will disappear and you should get ready for the next one.**

After trial, take a break if needed.

4. **Each time you see a circle, press the circle button as quickly as possible. Each time you see a square, press the square button as quickly as possible. The shape will disappear and you should get ready for the next one.**

Appendix E: Divided Attention Task 1

<u>Instructions for dual-task #1: Box Joining and Month Reciting (order 1)</u>

In this next activity, we are going to join some boxes using a pencil and paper, and recite the months of the year.

<u>Single-Tasks</u>

- ***Box Joining***

PRACTICE
I'd like you to start here and draw a line joining these boxes, as quickly as you can, like this *(demonstrate).* **Now you try. Make sure your line goes through each of the boxes. If you get all the way to the end, keep your line going through the start and go around again. Remember to do it as quickly as you can and keep going until I tell you to stop** *(allow a practice trial of at least 20 seconds). If the task is clearly understood, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

EXPERIMENTAL TRIAL
Good work…lets try it again, and this time I'll record the number of boxes you join, so try to do it as fast as you can, until I tell you to stop…Ready? Go! *Time for 20 seconds. At the end of 20 seconds, say* **Stop!**

- ***Months Backward***

PRACTICE
Now I'd like you to recite the months of the year backwards as quickly as you can. Start with December, and go backward, like November, October, and so on. If you make it all the way to January, go back to December and start over again. Keep going until I tell you to stop. Ready? Go! *(Allow a practice trial of at least 20 seconds). If the task is clearly understood, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

EXPERIMENTAL TRIAL
Good job…lets recite the months backward again, but this time I'm going to record the number of months you recite, so say them as fast as you can. Ready? Go! *Time for 20 seconds. At the end of 20 seconds, say* **Stop!** *Record the number of months recited.*

- ***Months Forward***

PRACTICE
Now I'd like you to recite the months of the year for me in the forward direction as quickly as you can. Like January, February, March, and so on. When you get to December, go back to January and start over again. Keep going until I tell you to stop. Ready? Go! *(allow*

a practice trial of at least 20 seconds). If the task is clearly understood, say **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

EXPERIMENTAL TRIAL
Good job…lets recite the months forward again, but this time I'm going to record the number of months you recite, so say them as fast as you can. Ready? Go!

Dual Task Trials

- ***Box Joining and Months Backward***

PRACTICE
Now I'd like you to do some more box joining and month reciting, but at the same time. First, I'd like you to recite the months *backward* while also joining boxes. Like this (demonstrate, December, November, October…)**. You should do both tasks as fast as you can, and remember that both tasks are equally important. Ready? Go!** *(Allow a practice trial of at least 20 seconds). If the task is clearly understood, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

EXPERIMENTAL TRIALS

1. **That was for practice. Now we'll do it again. Remember, recite the months *backward* while you are joining the boxes. You should do both tasks as quickly and accurately as you can and remember that both tasks are equally important. Start here.** *Indicate starting point on box joining form.* **Ready? Go!** *Time for 20 seconds. At the end of 20 seconds say* **Stop,** *and record the number of months recited.*

2. **Good work. Now we'll do it one more time. Remember, recite the months *backward* while you are joining the boxes. You should do both tasks as quickly and accurately as you can and remember that both tasks are equally important. Start here.** *Indicate starting point on box joining form.* **Ready? Go!** *Time for 20 seconds. At the end of 20 seconds say* **Stop,** *and record the number of months recited.*

- ***Box Joining and Months Forward***

PRACTICE
Now I'd like you to do some more box joining and month reciting, but at the same time. First, I'd like you to recite the months *forward* while also joining boxes Like this (demonstrate, January, February, March…)**. You should do both tasks as fast as you can, and remember that both tasks are equally important. Ready? Go!** *(Allow a practice trial of at least 20 seconds). If the task is clearly understood, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

EXPERIMENTAL TRIALS

3. **That was for practice. Now we'll do it again. Remember, recite the months *forward* while you are joining the boxes. You should do both tasks as quickly and accurately as you can and remember that both tasks are equally important. Start here.** *Indicate starting point on box joining form.* **Ready? Go!** *Time for 20 seconds. At the end of 20 seconds say* **Stop,** *and record the number of months recited.*

4. **Good work. Now we'll do it one more time. Remember, recite the months *forward* while you are joining the boxes. You should do both tasks as quickly and accurately as you can and remember that both tasks are equally important. Start here.** *Indicate starting point on box joining form.* **Ready? Go!** *Time for 20 seconds. At the end of 20 seconds say* **Stop,** *and record the number of months recited.*

<u>**Single-Tasks**</u>

- ***Box Joining***

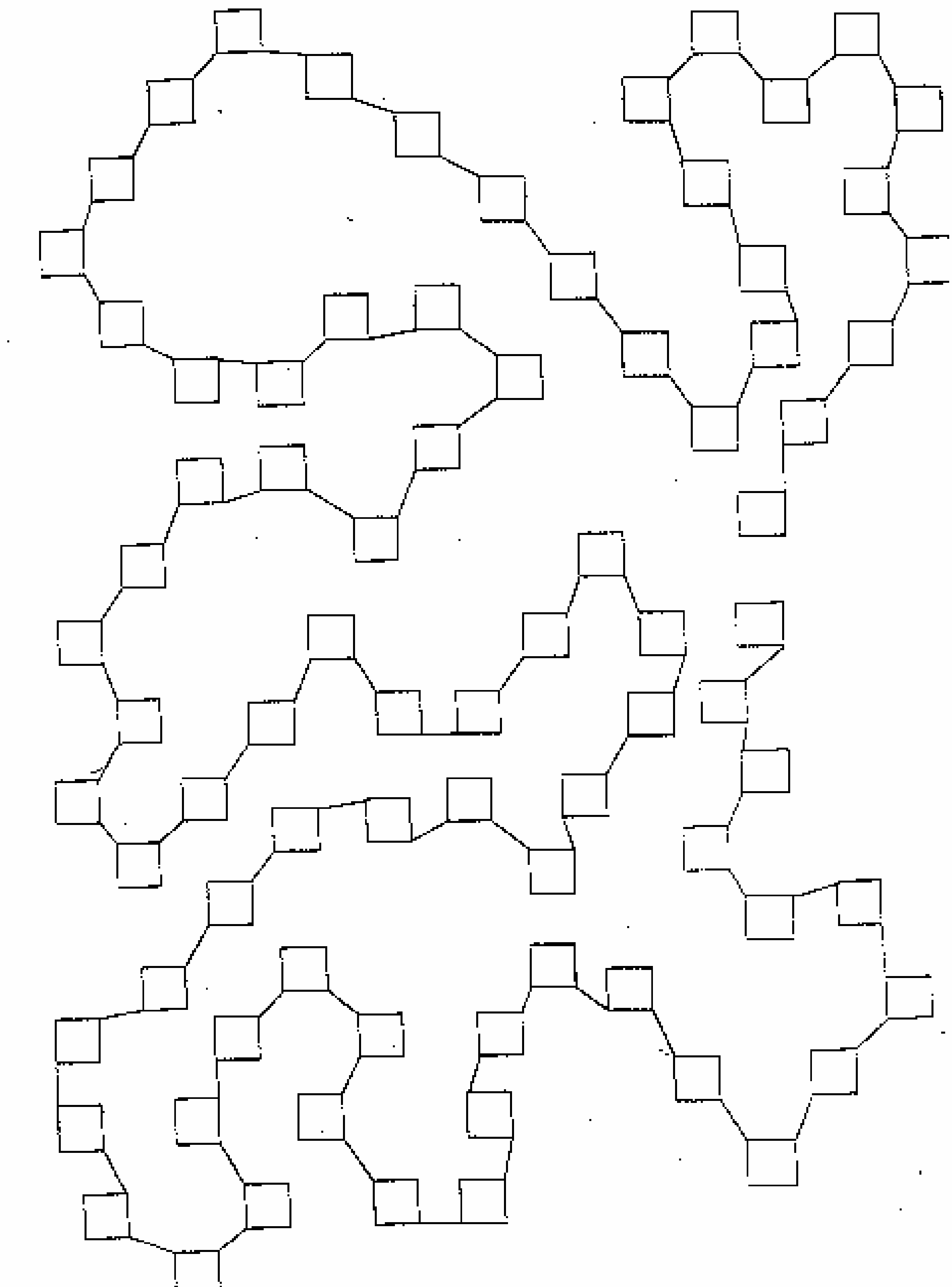
Now we are going to do each of the tasks individually one more time each. First, start here *(Indicate starting point on box joining form)* **and join these boxes as quickly as you can until I say stop. Ready? Go.** *Time for 20 seconds. At the end of 20 seconds say* **Stop.**

- ***Months Forward***

Now I'd like you to recite the months forward, one more time as quickly as you can. Ready? Go. *Time for 20 seconds. At the end of 20 seconds say* **Stop.** *and record the number of months recited.*

- ***Months Backward***

Now I'd like you to recite the months backward, one more time as quickly as you can. Ready? Go. *Time for 20 seconds. At the end of 20 seconds say* **Stop.** *and record the number of months recited.*



Participant: ____________

Box Joining and Month Reciting
Order 1 Recording Form

Single Tasks I

- **Box Joining:**

  1. Number of Boxes Joined: _____________
  2. Number of Boxes Missed: _____________
  3. Total Score (1-2): ______________

- **Months Backward**

Dec Nov Oct Sept Aug July June May Apr Mar Feb Jan

Tally of cycles	Errors	Last Month Read: ____________

- **Months Forward**

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Tally of cycles	Errors	Last Month Read: ____________

Dual Task Trials

1. **Months Backward**

Dec Nov Oct Sept Aug July June May Apr Mar Feb Jan

Tally of cycles Errors Last Month Read: ____________

Boxes Joined: _____________ # Boxes Missed: ______________

2. **Months Backward**

Dec Nov Oct Sept Aug July June May Apr Mar Feb Jan

Tally of cycles Errors Last Month Read: ____________

Boxes Joined: _____________ # Boxes Missed: ______________

3. **Months Forward**

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Tally of cycles Errors Last Month Read: ____________

Boxes Joined: _____________ # Boxes Missed: ______________

4. **Months Forward**

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Tally of cycles Errors Last Month Read: ____________

Boxes Joined: _____________ # Boxes Missed: ______________

Single Tasks 2

- **Box Joining:**

  Number of Boxes Joined: ______________

  Number of Boxes Missed: ______________

- **Months Forward**

Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

Tally of cycles	Errors	Last Month Read: ____________

- **Months Backward**

Dec Nov Oct Sept Aug July June May Apr Mar Feb Jan

Tally of cycles	Errors	Last Month Read: ____________

Appendix E: Divided Attention Task 2

Instructions for dual-task # 2: Finger tapping and number reciting (order 2)

In this next activity, we are going to do some finger tapping and some counting.

Single-Task Trials

- ***Finger Tapping***

I'd like you to tap these two buttons, back and forth, as quickly as possible, like this (*demonstrate)*. **Now you try. Place your hand flat on the table and try not to move any fingers except for your index finger. This first time is for practice. Start with this side** *(indicate side to participant's left)*, **and remember to do it as quickly as you can and keep going until I tell you to stop** (*allow a practice trial of 15 seconds*). *If the participant clearly understands the task, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

Finger tapping # 1

Good work….lets try it again, but this time the computer is going to count how many taps you make, so try to do it as fast as you can, until I tell you to stop…Ready? Go!

(Press Spacebar to Begin)

Time for 15 seconds. At the end of 15 seconds say **Stop!** *and record the number reached.*

- ***Counting backwards by 2's from 70***

Now I'd like you do some more counting. I would like you to count backwards by 2's. Starting with the number 70, please cound backwards by 2's like this: 70, 68, 66, 64, and so on. This first time is for practice. Ready?...Go! (*allow a practice trial of 15 seconds*). *If the participant clearly understands the task, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

Good work….lets try it again, but this time I'm going to record how many numbers you get, so count aloud *as fast* as you can. Remember to count quickly, but clearly, starting with the number 70 and counting backwards by 2's. Ready? Go!

Time for 15 seconds. At the end of 15 seconds say **Stop!** *and record the number reached.*

- ***Counting by 1s***

Now I'd like you to do some counting for me. Starting with the number 1, please count aloud by ones for me, as fast as you can. Like 1, 2, 3, and so on….This first time is for practice. Ready?...Go! (*allow a practice trial of15seconds*). *If the participant clearly understands the task, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

Good work….lets try it again, but this time I'm going to record how many numbers you get, so aloud *as fast* as you can. Start with the number 4. Ready? Go!

Time for 15 seconds. At the end of 15 seconds say **Stop!** *and record the number reached.*

<u>Dual Task Trials</u>

Now we are going to do some more counting and tapping, but this time we'll do them at the same time.

- ***Tapping and Counting backwards from 70 by 2's***

Now I'd like you to count backwards from 70 by 2s as fast as you can while tapping as fast as you can. Like this *(demonstrate 70, 68, 66, while tapping).* **Now you give it a try and remember that both tasks are equally important. This first time is for practice. Starting with the number 70, count backwards by 2s as fast as you can, like 70, 68, 66, while also tapping as fast as you can. Again, start with the number 70. Go ahead.** (*allow a practice trial of at least 15 seconds*). *If the participant clearly understands the task, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

Finger tapping #2

1. **Once again please count backwards from 70 by 2s as fast as you can, while also tapping as fast as you can, until I say stop. Remember, both tasks are equally important. Start with the number 70 and count backwards by twos while you're tapping. Ready? Go!** *Time for 15 seconds at the end of 15 seconds say* **Stop***, and record the number of taps and the number reached.*

(Press Spacebar to Begin)

Finger tapping #3

2. **Once again please count backwards from 70 by 2s as fast as you can, while also tapping as fast as you can, until I say stop. Remember, both tasks are equally important. Start with the number 70 and count backwards by twos while you're tapping. Ready? Go!** *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number of taps and the number reached.*

(Press Spacebar to Begin)

<u>Dual Task Trials</u>

- ***Tapping and Counting by 1s***

Now, I'd like you to count by ones as fast as you can while also tapping as fast as you can. Like this *(demonstrate 1, 2, 3 etc).* **Now you give it a try, and remember that both tasks are equally important. This first time is for practice. Starting with the number 1, count by ones as fast as you can, like 1, 2, 3, while also tapping as fast as you can. Again, start with the number 1. Go ahead.** (*allow a practice trial of at least 15 seconds*). *If the participant clearly understands the task, say* **Stop!** *If not, correct any mistakes and continue practice until the task is clearly understood.*

Finger Tapping #4

3. **That was for practice. Now we'll tap and count by 1s again. Remember to do both tasks** *as* **quickly and as accurately as you can, and remember that both tasks are equally important. Start with the number 1 and count by ones while you're tapping. Ready? Go!** *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number of taps and the number reached.*

(Press Spacebar to Begin)

Finger Tapping #5

4. **Once again, please count by 1s as fast as you can while also tapping as fast as you can, until I say stop. Remember to do both tasks as quickly and as accurately as you can, and remember that both tasks are equally important. Start with the number 1 and count by ones while you're tapping. Ready? Go!** *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number of taps and the number reached.*

(Press Spacebar to Begin)

<u>Single-task trials</u>

- ***Finger Tapping***

Finger Tapping #6

Now we are going to do each of the tasks individually one more time. First, tap these two buttons as fast as you can like (*demonstrate)* **until I say Stop. Ready? Go!** *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number of taps.*

(Press Spacebar to Begin)

- ***Counting by 1s***

Now I'd like you to count by ones. Start with the number 1 and count as fast as you can by ones until I say stop. Ready? Go! *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number reached*

- ***Counting backwards from 70 by 2s***

Now I'd like you to count backwards from 70 by 2s. Start at 70 and count backwards as fast as you can by ones until I say stop. Ready? Go! *Time for 15 seconds. At the end of 15 seconds say* **Stop***, and record the number reached*

Dual Task 2: Finger Tapping and Counting
Order 2 Recording Form

<u>Single Task Trials 1</u>

- ***Finger Tapping* – Number of taps** ____________

  Latency to 1st Tap ____________

- ***Counting backwards from 70 by 2's***

Practice
70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20
18 16 14 12 10 8 6 4 2 0

Trial
70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20
18 16 14 12 10 8 6 4 2 0

Numbers Recited: __________ **Errors:**___________

- ***Counting by 1s***

Practice
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
98 99 100

Trial
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
98 99 100

Numbers Recited: __________ **Errors:**___________

Dual Task Trials

- ***Tapping and Counting Backwards from 70 by 2s***

Practice
70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

Trial 1

- Counting

70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

Numbers Recited: __________ Errors:__________

- Finger Tapping

Number of taps____________

Latency to 1st Tap____________

Trial 2

- Counting

70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

Numbers Recited: __________ Errors:__________

- Finger Tapping

Number of taps____________

Latency to 1st Tap____________

- ***Tapping and Counting by 1s***

<u>Practice</u>
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

<u>Trial 1</u>

- Counting

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Numbers Recited: __________ Errors:___________

- Finger Tapping

Number of taps____________

Latency to 1st Tap____________

<u>Trial 2</u>

- Counting

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Numbers Recited: __________ Errors:___________

- Finger Tapping

Number of taps____________

Latency to 1st Tap____________

<u>Single Task Trials 1</u>

- ***Finger Tapping* – Number of taps** ____________

  Latency to 1st Tap ____________

- ***Counting by 1s***

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

- ***Counting backwards from 70 by 2's***

70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

Numbers Recited: __________ **Errors:**___________