VALIDATION OF INHIBITION TASKS FOR A COMPREHENSIVE ASSESSMENT OF VISUAL ATTENTION

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ABSTRACT

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ASSESSMENT OF VISUAL ATTENTION

by Davis A. Conley Jr.

The goal of this study was to assess the utility of a task designed to measure response inhibition within a comprehensive assessment of visual attention. The Conners' Continuous Performance Task (CPT) was added to an existing attention battery in order to provide it with a better measure of response inhibition. 120 Participants were divided into three groups (young, middle age, and old) in order to assess age group differences within the individual task analyses. To assess the Conners' CPT in relation to the other tasks, two Principal Component Analyses (PCA) were performed, one with the Conners' CPT and one without. They were then compared in order to assess any differences within the resulting component solutions. The two component solutions were almost identical, with the exception of an additional component of response inhibition existing within the PCA containing the Conners' CPT. In addition, age group differences were also assessed by using the component scores from the PCA. The component score analysis produced results similar to the task analyses, in that they suggest that older participants make few errors but have significantly longer reaction times than younger participants. Overall, the PCA revealed that the Conners' CPT did add a meaningful component of response inhibition to the existing attention battery, and age group differences appeared to be consistent with what is commonly found within the literature.

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CHAPTER I

INTRODUCTION

A decline in cognitive processing with age can influence a wide range of activities that require attention and memory, as well as the brain's ability to filter out irrelevant information (i.e. inhibition). Because of this decline, any comprehensive assessment of visual attention should be sensitive to several dimensions of attention, especially those that tap into inhibition. It is also important to consider the effects of aging on different areas of cognition. This decline in cognitive functioning influences many things, particularly how an individual attends to their environment. Everyday tasks such as driving are of particular interest because of the attentional demands associated with operating a motor vehicle, such as the ability to divide one's attention and efficiently scan the environment. Therefore it is important to create a comprehensive assessment of visual attention that is applicable to multiple fields of research, particularly driving safety.

Aging can have several debilitative effects on the human body, both physical and mental. Mobility declines, vision deteriorates, and several cognitive processes begin to experience slowing. Attentional performance in particular can vary greatly from person to person due to a vast array of individual differences, and one of the greatest sources of attentional variation between individuals is age. Aside from general cognitive decline, aging is also related to a range of cognitive disorders, such as Alzheimer's disease and other types of dementia. These disorders are known to affect a person's memory, concentration, and ability to successfully divide attention. Several studies in cognition have used the comparison of young and old participants to determine whether such effects are more likely due to individual differences or the effects of aging. The present study seeks to compare young, middle age, and older individuals on several dimensions of attention, including inhibition.

The inhibition of irrelevant perceptual information can be considered one of the most important functions of the human brain. Without inhibition our brains would be overwhelmed by the millions of bits of information that they sense at any given second. We inhibit information in two primary ways, one being non-conscious and relatively automatic, and the other being far more controlled and goal driven (Grande et al., 2006). As an individual increases in age the process of inhibition becomes less effective, which in turn affects a wide array of everyday tasks (Hasher & Zacks, 1988). When a task is particularly demanding in attention, any decrease in inhibitory functioning can result in serious problems. Therefore a comprehensive assessment of visual attention is not complete without an effective measure of inhibition.

Due to the decline of their physical, perceptual, and cognitive abilities some older adults have a more difficult time carrying out complex tasks. Therefore, it is important to develop a comprehensive assessment of attention that is predictive of an individual’s ability to perform tasks that require high levels of focus and attention, such as driving a car. First I will discuss the primary functions of attention, including their descriptions and the various methods by which they are measured. That section will then lead into a discussion on the relationship between attention and aging. Following that section will be a detailed breakdown of the inhibitory processes of attention, including a discussion on the effects of aging on inhibition. Finally, the introduction will end with a discussion of what the current study will attempt to accomplish.

Attention

Functions of Attention

The extent to which we understand the intimate nature of attention is fairly limited, but what we do posses is an understanding of the functional separation of attention (Woodrow, 1914). Essentially, attention is not a single function within itself, but a collection of separate functions operating together. The literature primarily defines four different functions of attention as switching, selective, divided and sustained (McDowd & Shaw, 2000; Parasuraman and Nestor, 1991). Aside from those, another function that has recently been explored is that of visual scanning (Neisser, 1963). Performance within each of these functions can be measured through a variety of different tasks, although few tasks are designed to be exclusive to a single function of attention. It is common for a single task to effectively tap into multiple functions of attention. The present study will include a variety of tasks in hopes to effectively measure performance within each of the functions stated above.

Switching. Switching attention entails the disengagement/reengagement of an individual's focus of attention between multiple sources of information within their environment. This can occur with the use of multiple spatial locations, tasks, or component processes (McDowd & Shaw, 2000). Although it is primarily used as a visual scanning task, part B of the trail making task is also used to measure switching attention. Trail making tasks often take form as a display populated with numbers and/or letters, requiring the participant to select them in order (Reitan, 1958). Trails B requires participants to select both numbers *and* letters in order, switching back and forth between the two (i.e., 1-A-2-B-3-C).

Selective. Selective attention refers to an individual's ability to focus on relevant information within their environment while ignoring irrelevant information. Tasks that are used to measure selective attention are generally designed to create situations in which there are multiple sources of information available for processing, but only a subset are relevant to the primary objective. The Stroop task (Stroop, 1935) and the conflict network variable of the Attention Network Task (ANT; Fan et al., 2002) are good examples of this process. The Stroop task emphasizes the difficulty that most individuals have focusing on one characteristic of a stimulus while trying to ignore others that are often times more powerful. The task is commonly presented in the form of both text and colors, where individuals are required to identify the color of the text, rather then simply reading it. This often proves to be difficult, because the mental processes behind reading are far more automated, and therefore harder to inhibit than those used in identifying colors. Similarly, the conflict network variable of the ANT requires the participant to identify the direction of the center arrow in a string of five arrows. In order to make a correct response the participant must ignore the direction of the flanking arrows, which can be either congruent or incongruent with the center arrow. Other tasks operate on a similar concept, but without presenting multiple sources of information at once. Instead, such tasks will commonly present target and distracter stimuli separately, but in succession. Good examples of this are go/no-go tasks, such as a continuous performance task (CPT). Go/no-go tasks require the participant to respond only to the target stimulus when it is presented, and to withhold any response when a distracter is present.

Divided. Divided attention requires that the individual attend to two or more sources of information at the same time. This can include performing two different tasks, monitoring two sources of information, or a combination of both. Often times two tasks will fall within a single perceptual modality, be it visual or auditory. When this happens the limited attentional resources are divided between the two tasks, effectively decreasing performance in both. For example, reading a book and driving a car are two rather manageable tasks when performed individually. However, performing both tasks simultaneously can easily result in any number of disastrous consequences.

Sustained. Sustained attention refers to an individual's ability to attend to a particular task over a prolonged period of time. Any task designed with a long performance period can incur a decrement in performance, be it through boredom or fatigue. Continuous performance tasks (CPT), as their name implies, are designed for this very purpose. A standard CPT will often require an individual to maintain focus for anywhere between 10-30 minutes. This will often involve responding to a set proportion of targets within a long series of detractors (i.e., F's among all the letters of the alphabet).

Scanning. Visual scanning refers to an individual's ability to actively search their environment for a particular target among distracting stimuli. Where selective attention primarily involves the identification and suppression of stimuli based on their features, scanning attention refers more to the movement of an individual's focus of attention. This particular function can be assessed with a number of different tasks such as visual search and trail making. Visual search tasks often require participants to determine if a target stimulus is present within a display of distracters (i.e., an F among E's and T's; Neisser, 1963). Trail making requires participants to scan a display littered with letters and/ or numbers, the object of which is to create paths between the stimuli by selecting them in order (Reitan).

Attention and Aging

Many psychologists agree that the most consistent and observable effects of aging on attention can be found within dual-task processing (Craik, 1977; Kramer & Larish, 1996). A good example of the effects of age on divided attention is that of Wickens, Braune, and Stokes (1987), who evaluated the speed and capacity of the human information processing system in individuals ranging from ages 20 to 65. In one experiment they used a tracking task in conjunction with a memory-scanning task, in which participants were given a unique set of digits and were asked to identify whether or not the following probe digit (0-9) appeared in that set. This provided them with a measure of the degree of attentional resource competition between the two tasks. What they found was that an increase in age was coupled with a decrease in processing speed, but at the same time there were no differences in time-sharing abilities between the young and old groups. Essentially, older subjects could perform certain dual task operations as well as younger subjects, only it took them longer to do so. This speed/ accuracy trade-off between performance and reaction time is also observable in several other functions of attention, such as switching.

In terms of aging, switching attention is often studied in the context of visual-spatial locations, as well as switching between different tasks. Salthouse, Fristoe, McGuthry, and Hambrick (1998) examined switching attention between separate tasks in a sample of adults 18-80 years-of-age. They designed their experiment using three sets of tasks, each of which was further divided into two component tasks. Participants were required to either maintain performance on one component task, or to switch between the two. The first task set involved presenting two digits side-by-side, requiring the participants to identify and respond to either the digit on the left or the digit on the right. The second task set required the participants to either identify whether a single digit was even or odd, or to identify whether it was greater or less than 5. The third task set required either the addition or subtraction of two presented digits. The signal that was used to instruct participants to switch between component tasks appeared as a rectangle surrounding the presented digit(s). This signal was presented simultaneously with the stimuli at unpredictable intervals. Upon analyzing response times, the results clearly indicated that switching attention for each task set was slower among older adults when compared to young adults. A similar decrease in reaction times between young and old adults is also found when examining the switching of attention between spatial locations (Greenwood & Parasuraman, 1994; Folk & Hoyer, 1992).

Studies that involve switching attention between multiple spatial locations often employ the use of central and/or peripheral cues to indicate the possible location of the target stimulus. Peripheral cues tend to elicit an involuntary shift of attention, whereas central cues elicit more of a voluntary shift. Greenwood and Parasuraman (1994) found that up until about age 75, involuntary shifts of attention elicited by either valid or invalid peripheral cues do not differ as a function of age, whereas central cues that elicit a voluntary shift of attention do produce age-related effects. However, beyond the age of 75 both voluntary and involuntary shifts of attention show age-related effects. The older group showed a benefit from valid cues equal to that of the young group, but the cost of invalid cues was much higher. This suggests that older individuals have a harder time disengaging and reallocating their attention between spatial locations. In addition to this, there are some conditions in which older adults have a harder time maintaining attention over a prolonged period of time.

Within the literature regarding sustained attention, few investigations have reported finding age-related effects in vigilance task performance. Of the few to do so, Mouloua and Parasuraman (1995) were able to identify two conditions in which age-related effects on vigilance were observable. They manipulated event rate (low, high) and target location certainty (low, moderate, high) in a 30-minute vigilance task. What they discovered was that task performance deteriorated across time at a faster rate for older adults than for young adults when event rate was high and target location certainly was low. These results suggest that sustained attention does change in relation to age, at least under increased demands on visual attention. Such demands can also result in a decreased ability to attend to relevant information while ignoring that which is irrelevant.

Among the many means in which selective attention is measured, McCarley, Mounts, and Kramer (2004) investigated the age-related differences in how environmental stimuli interfere with an individual's ability to locate a target stimulus. In their two experiments the participants performed a selective attention task in which they were to determine whether or not two stimuli were the same shape by responding manually via key press. The first experiment explored the possibility of age-related differences in the magnitude and spatial extent of localized attentional interference. This difference is related to a person's ability to visually select an item in their field of view while suppressing any irrelevant environmental stimuli. The second experiment was performed to account for any possible sensory explanations for the results. What the authors found was that older adults had longer reaction times (RTs) for the tasks than younger adults, and that the RTs for both young and old adults increased with a greater spatial separation of the stimuli. The mean error rate for older adults was much higher than that of younger adults, as well as the fact that the error rates of the older adults increased more with increases in the spatial separation between stimuli. Essentially, older adults have a reduced ability to attend to multiple sources of information that have a low spatial proximity. The literature also suggests that older individuals have a decreased ability to selectively attend to individual characteristics of a single stimulus, a finding commonly associated with the Stroop task of interference.

Many studies have typically reported that older adults have a greater susceptibility to Stroop interference than young adults, which suggests that declines in selective attention are directly related to age (Houx, Jolles, & Vreeling, 1993; Klein, Ponds, Houx, & Jolles, 1997). However, others such as Salthouse and Meinz (1995) state that the Stroop task is not a pure measure of selective attention, arguing that age-related effects found using the task are more a result of a general slowing of information processing. In a more recent study Bugg, DeLosh, Davalos, and Davis (2007) examined the contribution of general slowing and task-specific deficits to age-related changes in Stroop interference. In a sample of over 900 participants aged 20 to 89 years they found that age differences in Stroop interference were only partially attributed to general slowing, whereas the rest were attributed to age-related changes in task-specific processes, such as inhibition.

Inhibition

Inhibition and Attention

Inhibition takes on many forms and plays a key role in many cognitive processes such as emotion, memory, and attention. Attention in particular requires the processing and filtering of a vast amount of environmental information, and naturally only a very small portion of that information is actually attended to. Inhibition plays the important role of filtering out the relatively large amount of information that is irrelevant to our immediate goals. Though a large portion of this process is automatic, there are several instances in which humans are required to consciously activate their inhibitory mechanisms. Grande et al. (2006) emphasizes this point by stating that inhibition within attention can be evoked either exogenously (automatic) or endogenously (controlled).

Exogenous Inhibition. Exogenously evoked inhibition refers to the attentional process by which irrelevant stimuli are ignored and filtered out automatically. This process is essential because of the relatively large amount of information we perceive from our environment, most of which is irrelevant to our immediate goals. This is considered to be an adaptive mechanism which is crucial to how humans attend to their surroundings. However, many researchers argue that inhibition can also have a negative effect on attention. A common paradigm that is used to illustrate this point is inhibition of return.

Posner and Cohen (1984) were the first to illustrate the concept of inhibition of return (IOR). They discovered that a very brief lag time of 100-300 ms between a cue and target stimulus results in a reduced RT to the second stimuli. However, if the lag time is increased to over 500 ms it will cause a significant increase in RT. The authors attributed this phenomenon to a possible build up of visuospatial inhibition. Essentially, a prolonged lag time between cue and target evokes an inhibitory mechanism that causes the individual to attend to other, previously unattended objects in the scene. This attentional straying from the cued location is what is said to cause the increase in response latency. IOR is also said to be associated with the occurrence in which an individual's response time to a target is increased if it is presented in a position spatially identical to the target that precedes it. A common task that is often used to illustrate this occurrence is the feature based visual search task.

Feature-based visual search tasks vary in design, but they are generally defined as those in which an individual is required to locate a specific target stimulus within a display that includes a number of distracters. Accuracy and RTs for visual search tasks depend on a number of variables such as display size, target/distracter similarity, and target orientation. As previously mentioned, RTs for visual search tasks can also be affected by certain inhibitory mechanisms.

Expanding on Posner and Cohen's IOR paradigm, Klein (1988) supported their findings using a visual search task. He found that RTs were generally increased when the target stimulus appeared in a previously attended location. Essentially the spatial location in which an object is attended to, whether it be a previous target or a distracter, is mentally tagged and inhibited from immediate re-attention. Many researchers state that this mechanism is primarily adaptive, in that it prevents us from searching the same place twice. However, others argue that it can act as a limitation. Modern visual search tasks overcome this effect through the use of a fixed cue preceding each trial. This cue causes the subject's attention to be focused at the same spatial location for each trial of the task. This procedure can be considered a manipulation of the subject's non-conscious inhibitory mechanisms, but as previously mentioned inhibition can also be manipulated at a conscious level.

Endogenous Inhibition. Certain inhibitory mechanisms have also been found to be evoked in a deliberate, goal-driven manner. One mechanism in particular that is often used to illustrate this property is response inhibition. Essentially, response inhibition is the suppression of actions that are inappropriate in a given context and that interfere with goal-driven behavior (Logan, 1994). Response inhibition can be measured by a variety of different tasks, though the most common and effective are those of the stop-signal or go/no-go designs.

In a typical stop-signal design participants are required to perform a task in which they are required to respond to a long chain of stimuli. Within the task they are occasionally presented with a "stop" stimulus that requires them to withhold any physical response (Logan, 1994). Performance on such a task is often illustrated by the race model of inhibition. This model represents a figurative race between the excitatory and inhibitory response processes of the brain (Logan & Cowan, 1984). Upon perceiving a given stimulus, both processes are activated individually and proceed to compete with each other. If the inhibitory process finishes before the excitatory, the response is successfully inhibited; otherwise, a response is made. If an individual's inhibitory process loses too often, especially in the presence of stop-signals, it can often be attributed to a general decline in cognition due to aging or the presence of a neurological disorder. The outcome of this race can also be affected by varying parameters within the given task, such as the time between stimuli, the extent to which the stop signal resembles the primary stimulus, and the proportion of stop-signals to target stimuli.

Similar to the choice response tasks often used in a stop-signal design, the CPT is a measure often used in the assessment of attention. Originally designed by Rosvold et al. (1956), the CPT is a test of sustained attention that often requires the individual to respond to a certain letter (e.g., F) among a long series of similar letters. Although it is an effective measure of sustained attention and impulsivity, it is *not* an adequate measure of response inhibition. Although low levels of inhibition are required to refrain from responding to non-target stimuli, the relatively high proportion of non-target stimuli allows the process of inhibition to become somewhat automatic. However, if the proportion of targets is increased and the proportion of distracters decreased, response times to target stimuli will become faster and the probability of successful inhibition of distracters will become lower (Ramautar, Kok, & Ridderkhof, 2004). In turn, this increase in responses allows for a more refined and measurable component of inhibition. An altered form of the standard CPT that is often used in this fashion is the Conners' continuous performance task (Conners, 2000). Like the standard CPT, the Conners' CPT requires the individual to respond to certain letters within a prolonged series. However, instead of responding to only one letter among many, the individual is required to respond to *all* but one letter. This increased proportion of target stimuli effectively decreases the amount of automated inhibition found in the normal CPT, thus creating an ideal measure for response inhibition. Among the task's many possible applications, the one of most interest to this study is the effect of aging on certain areas of cognition, particularly attention.

Inhibition and Aging

Within the field of cognitive aging, it is commonly believed that several cognitive processes that function within the frontal cortex of the brain are the first to decline with age (Raz, 2000). A primary function which operates within the frontal cortex is executive control, which serves to control and manage several cognitive processes. It is said to be responsible for areas such as abstract thinking, rule acquisition, and initiation/inhibition of actions. Therefore processes such as selective inhibition that require high levels of executive functioning are the first to show noticeable declines.

In an attempt to measure the effects of aging on inhibition with different levels of executive functioning, Andres et al. (2008) designed two experiments employing different methods of inhibitory control. The first experiment was designed to measure the Stroop effect of inhibition in young adults aged 18-25 years and older adults over the age of 60 years. The results seemed to show that the older group exhibited higher levels of interference than that of the young group. This seems to indicate that older individuals have a harder time suppressing irrelevant features of certain stimuli. In their second experiment they used a stop-signal task with a high proportion of targets, similar to the Conners' CPT mentioned earlier. Much like the Stroop effect in Experiment 1, in Experiment 2 they found a consistent decline in response inhibition among the older participants, which would seem to indicate that older individuals have a more difficult time withholding responses to non-target stimuli. However, in both experiments they found an absence of negative priming, which is an inhibitory effect characterized by the failure of responses to target stimuli that closely resemble previously presented distracters. The absence of this effect is primarily due to the high proportion of targets, which in turn leads to a high level of automatic excitation. Since increased automation results in a decreased need for executive functioning, this pattern would suggest that inhibitory mechanisms with relatively low levels of executive control are largely unaffected by age.

In their earlier investigations, Hasher and Zacks (1988) suggested that age-related changes in inhibitory functioning may be responsible for a variety of cognitive deficits. They proposed that as inhibition begins to decline, the amount of irrelevant information that would normally be filtered out of working memory increases, causing a cluttering effect. Essentially, a build up of irrelevant information within working memory can reduce or prevent the processing of information more relevant to our immediate goals. This in turn causes several cognitive processes to slow down in order to maintain effective performance.

In a more recent study Darowski, Helder, Zacks, Hasher, and Hambrick (2008) examined the mediating role of inhibition in the relationship between age and higher order cognition. To measure inhibition they used a reading with distraction task with two levels of interference (low or high). Participants were required to read eight narrative passages, half in the distraction condition and the other half in the baseline (low distraction) condition. Within the distraction condition, words and phrases related to the topic appeared every 3-4 words. The baseline condition substitutes these words for a series of Xs, in order to maintain passage length. The idea is that actual words require more processing than a simple series of Xs, which are easily identified and ignored. Higher order cognition was assessed by measuring working memory span and matrix reasoning. Working memory was tested using three separate computerized tasks designed to measure the participants' sentence, operation, and rotation spans. Matrix reasoning was measured using the Raven's advanced progressive matrices task, where participants were required to fill in the missing cells of several 3 by 3 matrices in order to complete a specific pattern within each. The results of the study indicated that the reading task, especially with a high level of distraction, was a significant predictor of working memory and matrix reasoning. And as expected, older adults seemed to require more time to complete the reading task, in conjunction with showing decreased levels of working memory and matrix reasoning. This supports Hasher and Zacks' initial theory that inhibition mediates working memory, which in turn plays a pivotal role in several cognitive processes.

Pilot Study

A study conducted by Tuttle (2008) acted as a pilot study for developing a comprehensive driving assessment test battery that could be used for any age group. It was designed to be sensitive to the areas of concern in the aging driver, as well as other demographics associated with attention dysfunction. The study was conducted using an altered computerized attention test battery based on the Assessment Software for Attention Profiles (ASAP; Washburn & Putney, 2007). The main goal of the Tuttle study was to use a Principal Component Analysis (PCA) to assess the consistency of the component structure of attention functions in young and old adults. In other words, the idea was to test whether a single component solution could be used for both the young and old adults or if separate solutions were needed.

Six separate components emerged from the combined groups PCA (speed, accuracy, sustained, visual search, inhibition/selection, & executive/divided), each of which explained at least 5% of the variance within the test battery. Variable loadings for the combined age groups can be found with the rotated component matrix in Table 1 below. However, when the age groups were separated the variables loaded differently onto the components, causing the structure for the young group to change. The component structures for the two age groups remained fairly similar, with only one noticeable exception. Variable loadings for the young group showed a separation in the inhibition/selective component, resulting in two new components that were independent of each other. This may be due to the old group showing less evidence of inhibition and therefore using their selective attention abilities to complete the given tasks. Another possible explanation is that the task battery simply did not include an adequate measure for inhibition. It is the goal of the present study to explore the second explanation by introducing a definitive measure of response inhibition into the existing attention battery.

Table 1. Rotated PCA Component Matrix for Younger and Older Participants Combined from Tuttle (2008)

	Component					
	1	2	3	4	5	6
ANT Alerting	.088	.047	.052	.145	.063	**-.703**
ANT Executive Control	-.287	.039	.090	-.052	-.072	**.761**
ANT Orienting	.077	.035	-.045	**-.486**	-.016	.145
Anti-cue Accuracy Center Cue	-.009	**.846**	-.032	-.164	.114	-.089
Anti-cue Accuracy No Cue	.051	**.845**	.048	-.213	.139	-.095
Anti-cue RT Center Cue	**.855**	-.117	.007	-.081	.090	-.044
Anti-cue RT No Cue	**.793**	.112	.162	.050	.051	.096
CPT RT Block 1	.004	.035	**.924**	.088	-.005	-.068
CPT RT Block 2	.108	-.047	**.846**	.051	-.033	.067
CPT RT Block 3	.026	.023	**.779**	-.099	-.108	.035
RT-2 Accuracy	-.055	**.913**	-.046	.097	.015	.069
RT-2 RT	**.888**	-.149	.087	.053	.171	.022
Pro-cue Accuracy Center Cue	-.034	**.892**	.031	.280	-.041	.045
Pro-cue Accuracy No Cue	-.091	**.877**	.015	.309	-.078	.065
Pro-cue Accuracy Peripheral Cue	.028	**.917**	.006	.113	-.032	-.005
Pro-cue RT Center Cue	**.736**	-.398	.030	-.370	.132	.060
Pro-cue RT No Cue	**.845**	-.145	-.027	-.344	.157	.007
Pro-cue RT Peripheral Cue	**.921**	-.061	.049	-.232	.083	-.006
Stroop Accuracy Congruent	.168	.077	-.128	.320	.394	.374
Stroop Accuracy Incongruent	-.045	.026	-.095	.440	**.787**	.111
Stroop RT Congruent	**.831**	.029	.055	-.042	-253	.184
Stroop RT Incongruent	**.658**	.110	.029	-.037	-.572	.129
Tracking Accuracy	**-.759**	-.052	.018	-.054	-.006	.135
Tracking RMSE	**.709**	.155	.072	.043	-.280	.025
Tracking RT	.366	-.030	.074	-.230	.111	**.736**
Trail Making Test Part A Total Time	**.817**	-.039	-.077	-.029	-.161	-.185
Trail Making Test Part B Total Time	**.752**	.062	-.051	-.019	-.206	-.089
Visual Search Accuracy Feature Task	-.002	.135	-.109	**.522**	.250	-.077
Visual Search Accuracy Pop-out Task	-.004	.066	.176	**.662**	-.014	-.069
Visual Search Slope Feature Task	.204	-.091	.102	-.396	.106	.008
Visual Search Slope Pop-out Task	.111	-.096	.044	.229	**-.745**	.111

BOLD indicates high component loadings for each measure.

Present Study

Previous studies have shown that the assessment of attention is a key component in cognitive research, particularly in studies involving aging. Aging has essentially become synonymous with a general decline in performance across several cognitive processes, especially those related to attention. A possible explanation for this is the idea that as we age, different areas of the brain are essentially repurposed in order to maintain efficiency within several of our cognitive processes (Raz, 2000). The question that has often been raised is whether or not this "repurposing" of the brain results in any significant changes within the functionality of attention. If changes do occur, this would imply that the means by which we measure attention in young adults would not be appropriate for individuals of advanced age. Tuttle (2008) determined for the most part that this is not the case, showing that the component structures of attention for young and old adults are fairly similar. However, some unexplained differences still remained. It was the goal of this study to account for those differences, in an effort to create a fully comprehensive assessment of visual attention.

The present study was used to improve and extend the results found in the pilot study in the following ways. Primarily, the Conners' CPT was added to the existing attention battery in order provide a defined measure of response inhibition. This is achieved through the proportion of target stimuli used in the Conners' CPT, in contrast to what is used in the standard CPT. The Conners' CPT uses an 80% proportion of stimuli that require a response, compared to the 20% proportion used in the standard CPT. This shift in target proportions effectively decreased the amount of automated inhibitory processing, which in turn provided a far more conscious and goal driven measure of inhibition.

The purpose of this study was to determine whether or not adding the Conners' CPT provided the assessment with a meaningful measure of response inhibition. To achieve this, two separate PCAs were performed; one containing the Conners' CPT and one without it. The resulting comparison between the two provided the means to measure the impact of the Conners' CPT on the existing attention battery. PCAs were used because of their ability to isolate perceptual-motor processing speed as a separate component, thereby allowing the remaining components to be statistically independent from each other. Ideally, finding an additional component with high loadings on the Conners' CPT within the PCA that included it would suggest that the measure is distinct and meaningful, and therefore should remain within the assessment for future investigations. Component scores from the PCA containing the Conners' CPT were also assessed in order to generate meaningful comparisons between the age groups that are more representative of the overall functions of attention, rather than just the individual tasks found within the preliminary analysis.

Hypotheses

H1: Inclusion of the Conners' CPT into the existing attention battery will result in the formation of an additional component for response inhibition within the respective PCA.

H2: There will be age group differences within the component score analysis, independent from the effects of perceptual-motor processing speed, that are more specific to the functions of attention identified from the other components.

CHAPTER II

METHOD

Participants

Participants were recruited from the general student body at Central Michigan University and the local community of Mount Pleasant, MI. Three age groups of participants were created to establish norms and assess the reliability and validity of the current attention battery. Each age group contained an approximately 40 participants, for a total of 120 participants overall. The young group consisted primarily of CMU students ages 18-30 years, who were solicited via use of the Department of Psychology Subject Pool. The middle age group consisted of individuals ranging from ages 31 to 59 years-old, who were recruited through advertisements placed in the local newspaper as well flyers placed in the university out patient clinic (Appendix B). The older age group consisted of elderly persons aged 60 years-old and above, who were recruited in a similar fashion as the middle age group, in addition to an advertisement in the local Commission on Aging newsletter. Students enrolled within psychology courses were compensated with course credit through the subject pool, and the community members were compensated monetarily at $15.00 per hour.

Demographics

Demographic measures were taken for each participant including age, gender, handedness, race, and education information (Table 2). There were a total of 40 participants in the young age group, 39 in the middle age group, and 37 in the old age group. Four participants were excluded from the entire analyses due to missing data.

Table 2. Participant Demographics

		Young		Middle		Old	
Category	Measure	*f*	%	*f*	%	*f*	%
Age	Mean	21		46		70	
	Minimum	18		30		60	
	Maximum	28		58		90	
Gender	Males	16	40	14	35.9	13	35.1
	Females	24	60	25	64.1	24	64.9
Handedness	Left	3	7.5	11	28.2	3	8.1
	Right	37	92.5	29	74.4	34	91.9
Ethnicity	Caucasian	33	82.5	35	82.1	35	94.6
	Asian/Pacific Islander	3	7.5	0	0	0	0
	African American	1	2.5	2	5.1	0	0
	American Indian	1	2.5	1	2.6	1	2.7
	Hispanic	1	2.5	1	2.6	0	0
	Other	1	2.5	1	2.6	1	2.7
Education	College	33	82.5	24	61.5	26	70.3
	High School	6	15	15	38.5	11	29.7
	< High School	0	0	1	2.6	0	0

Health Measures

The health measures included questions concerning the participant's health rating, health problems, and health satisfaction (see Table 2). Each participant was asked to rate their health with the majority of the young group (62.4%, n =40), the middle group (45%, n=40), and the old group (40.5 %, n=37) rating their health as good. A 5 (health rating: poor, fair, okay, good, excellent) x 3 (age group: young, middle, old) Chi-square analysis was done to determine if there were any age group associations to health rating and none were found, $\chi^2(8) = 7.18$, p=.518. Health was also rated in terms of how much health problems limit daily activity, where 75% of the young group (n =40) reported having no limitations from health problems, 55% of the middle group (n =40) and 45.9% of the old group (n =37) reported having a lot of limitations from health problems. (A 3 (health problem limitations: none, little, some, a lot) x 3 (age group: young, middle, old) Chi-square analysis was done to determine if there were any age group associations to health problems and there were none, $\chi^2(6) = 8.06$, p=.234.

As for overall health satisfaction, 67.5% (n =40) of the young group reported being satisfied with their health, 42.5% (n =40) of the middle group reported being satisfied with their health, and 59.5% (n =37) of the old group reported feeling satisfied. A 4 (health satisfaction: not, a little, satisfied, very) x 3 (age group: young, middle, old) Chi-square analysis was done to determine if there were any age group associations to health satisfaction and there were, $\chi^2(6) = 13.39$, p=.037. Older participants were more likely to be satisfied with their health than middle and younger participants.

Table 3. Health Measures Percentages and Frequencies by Age Group

Health Measure	Rating	Young n = 40 *f*	%	Middle n = 39 *f*	%	Old n = 37 *f*	%
Health Rating	Poor	0	0	1	2.6	0	0
	Fair	2	5	4	10.3	6	16.2
	Okay	6	15	8	20.5	7	18.9
	Good	25	62.5	17	43.6	15	40.5
	Excellent	7	17.5	9	23.1	9	34.3
Health Problems	None	30	75	1	2.6	1	2.7
	Little	8	30	6	15.4	6	16.2
	Some	2	5	10	25.6	13	35.1
	A lot	0	0	22	56.4	17	45.9
Health Satisfaction	Not	1	2.5	7	18	0	0
	A little	2	15	8	20.5	7	18.9
	Satisfied	27	67.5	17	43.6	22	59.5
	Very	6	15	7	20.5	8	21.6

Materials

Neuropsychological Tests

Besides the general assessment of attention, neuropsychological assessments are important because they can inform researchers of how well an individual will perform on tasks involving visual attention. Because attention is a part of cognition as a whole, basic neuropsychological tests can be useful for identifying serious cognitive impairments. It is important to screen for such impairments because of the possibility that they will impede on an individual's ability to understand and follow directions necessary for completing complex tasks.

As an initial measure to assess cognitive status, participants were given the Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975). The MMSE contains 11 categories of assessment: Orientation to Time, Orientation to Place, Registration, Attention and Calculation, Recall, Naming, Repetition, Comprehension, Reading, Writing, and Drawing. The official cutoff score for the MMSE is 23, with scores of 23 or lower indicating the presence of cognitive impairment. Test-retest reliability for the MMSE ranges from .8 to .95, with sensitivity percentages at 87% and a positive predictive value percentage at 79% (Mental Measures Yearbook, January 22, 2007). A copy of the test can be found in Appendix C at the end of this document.

Participants were also assessed using the digit span test from the Wechsler Adult Intelligence Scale (Wechsler, 1997). The digit span is a simple test to measure working memory and attention. The test is separated into two individual tasks; digits forwards and digits backwards. For the digits forwards task the participant is read a series of numbers and is required to repeat them back to the examiner. The forwards task contains 8 separate difficulties, beginning at 2 digits and working up to 9, each containing two trials. The digits backwards task is similar, but the participants are required to repeat the numbers backwards instead. The backwards task also only contains 7 difficulties, rather then 8. For both tasks scoring is the same; 1 point is awarded for every correctly completed trial, with a maximum score of 16 for the forwards task and 14 for the backwards. A copy of the test can be found in Appendix D.

Participants also performed a computerized version of the Wisconsin Card Sort Test (WCST) to assess executive control (Heaton, 1981). The WCST consists of four stimulus cards and two sets of 64 response cards that depict four shapes (circle, crosses, triangles, and stars), in four colors (red, yellow, blue, and green), and with four numbers of shapes (one, two, three, and four). Participants used feedback to match cards to current categories based on shape, color, or number, depending on the current rule. The range of interscorer reliability for the WCST is between .88 and .93 and the range of intrascorer coefficients is between .91 and .96 (Mental Measures Yearbook, January 22, 2007).

Vision Assessment

Vision assessment is often used in attention research to screen for any sensory deficits an individual may have that can result in poor performance on tasks involving visual attention. Poor vision is a serious experimental confound in attention research, therefore individuals must be carefully screened in order to safely concluded that any drop in performance is due to a decline in attention, and not a visual impairment. Measures for visual assessment include visual acuity, color vision, depth perception, and peripheral vision. These measures are useful for ruling out any degenerative eye diseases such as cataracts or glaucoma, as well as determining general eye health. To assess vision, the present study will employ the use of a Titmus I-500 vision tester, similar to those used at the Department of Motor Vehicles.

Attention Assessment

Participants completed a computerized attention battery to assess the five functions of attention: scanning, selective, switching, divided, and sustained. The task battery was presented on a 16-in CRT monitor, positioned approximately 24 inches from the face. Participants provided responses primarily with a mouse and keyboard, as well a common joystick used on the dual-task. All tasks were presented in white text on a black background, with the exception of the dual-task which was presented in black text on white background.

Scanning attention was assessed with visual search tasks, trail making, and components from the attention network task (ANT). Selective attention was assessed by the Stroop task. Switching attention was assessed using a two-choice reaction time task (RT-2), and part B of the trail making test. Divided attention was assessed with a dual-task of single-axis compensatory tracking and the RT-2. Sustained attention was measured by a standard 10-minute CPT. Finally, response inhibition was assessed by the newly added Conners' CPT. Detailed task descriptions can be found in Table 2.

Table 4. Task Descriptions

Task	Description
Feature Visual Search (Neisser, 1963)	Task that involves searching for an F among E's and T's in arrays of 10, 40, or 70 letters.
Pop-out Visual Search	Task that involves searching for an O among \'s and /'s in arrays of 10, 40, or 70 characters.
Distracter Visual Search	Task that involves searching for an F among E's and T's while ignoring a distracter stimulus (O) located within the array.
Trail Making Test Part A (Reitan, 1958)	Task that involves scanning for numbers and clicking on each number in order (1-2-3, etc.).
Trail Making Test Part B	Task that involves scanning for numbers and letters and selecting them in order (1 A, 2 B, 3 C, etc.).
Attention Network Task (ANT) (Fan et al., 2002)	Task that involves clicking the mouse button corresponding to the direction of the middle arrow in a string of five arrows (i.e.←←→←←). Task also operates on cue recognition, where a possible cue (*) may appear above or below the fixation point, indicating where the proceeding string of arrows will appear.
Continuous Performance Task	15-min long task that involves responding to the letter F among other letters of the alphabet. Hit rate for the task is approximately 20%.
Conners' CPT (Conners, 2000)	15-min long task that involves *withholding* responses to the letter F among other letters in the alphabet. Hit rate for the task is approximately 80%.
RT-2 Choice Response Task	Task that involves responding to E's and F's with appropriate mouse button presses (left for F, right for E).
Stroop Task (Stroop, 1935)	This task involves responding blue and red color-words with appropriate button presses (Left for blue, right for red).
Dual-Task Tracking and RT-2	This task involves a horizontal compensatory tracking task combined with a reaction time task. It involves the use of a joystick to keep a cursor centered on a crosshair presented on the screen, performed in conjunction with the RT-2 task.

Procedure

Each participant was seen individually for one data collecting session. Participants were greeted and given an informed consent form to review and sign, and a copy of the form was given to them (Appendix A). To begin, the researcher assessed the cognitive status of the participant by administering the MMSE and digit span test. Following cognitive assessment, the researcher assessed the participant's visual acuity, depth perception, and peripheral vision using the Titmus I-500 vision tester. After the vision test, the participant proceeded with the computerized attention battery, which includes the WCST. All computerized tasks, with the exception of the dual-task, were presented in a random order for each participant. The dual-task occurred last for each participant. Upon completion of the attention battery, participants were debriefed, thanked, and compensated for their time. The length of the entire procedure was approximately 80 min., including time for consent and debriefing.

Data Analysis

Data were analyzed by examining the error rates and RTs of the tasks in the computerized attention battery along with the data from the WCST, MMSE, and vision assessments. There were three main steps to the overall analyses. The first step consisted of analyzing RTs and error rates from each attention task, in order to validate that each was working properly. Age group differences were assessed within each task. For the second step, two separate Principal Component Analyses (PCA) were performed, one containing the Conners' CPT and one without it. The resulting comparison between the two would indicate whether or not the Conners' CPT was able to create a distinct and meaningful component for response inhibition. The third step of the analysis was to use the individual component scores from the second PCA within a series of ANOVAs, in order to generate meaningful comparisons between the age groups.

As an exploratory analysis individual age group PCAs were also performed with and without the Conners' CPT. However, the sample sizes were far too small to draw any meaningful conclusions from the results. Despite their limited value, each of these analyses can still be found in Appendix E. Similarly, a correlation matrix of all of the variables included within the final PCA can be found in Appendix G.

CHAPTER III

RESULTS

Vision Measures

Useful Field of View

The Useful Field of View (UFOV) refers to the visual area over which information can be extracted at a brief glance without head or eye movements. For this measure, three different tests were used: processing speed, divided attention, and selective attention. Once the results for each of the three tests were acquired, they were combined to give one score. This score was then used to determine the participants' category level, or risk assessment (see Table 4). There were 4 missing data points in the UFOV. In the UFOV measure, 95% (*n*=38) of participants in the young age group received a category level of very low, and 5% (*n*=2) received low. In the UFOV measure, 80% (*n*=32) of participants in the middle age group received a category level of very low, 10% (*n*=4) received low, 7.5% (*n*=3) received low to moderate, and 2.5% (n=1) received very high. There was a wide range in the old age group on the UFOV measure; 45.5% (*n*=15) received a category level of very low, 6.1% (*n* =2) received low, 12.1% (*n* =4) received low to moderate, 6.1% (*n* =2) received moderate to high, and 6.1% (*n* =2) received a high category level. A 5 (UFOV category: very low, low, low to moderate, moderate to high, high) x 3 (age group: young, middle, old) Chi-square analysis was done to determine if there were any age group associations to UFOV category. The analysis showed that associations were present, $\chi^2(12) = 31.75$, $p = .002$. The young group had more individuals in the very low category than both the middle and old age groups.

Visual Acuity

The Titmus i500 was used to measure far and near acuity with both eyes, color vision, and peripheral vision. There was data missing from four young participants and two older participants. Acceptable visual acuity criteria were taken from the Department of Motor Vehicles for Michigan; anything below 20/40 vision was acceptable. All of the young age group had acceptable visual acuity. Only 2.5% (*n*=1) were unacceptable in the middle age group, and 6.1% (*n*=2) were unacceptable in the old age group. Therefore, the groups were similar with regard to having met the State of Michigan vision standards. For near acuity in both eyes, 29% (*n* =8) had 20/20 vision in the young age group, while only 10% (*n*=4) had 20/20 vision in the old middle age group, and 3% (*n*=1) had 20/20 vision in the old age group. Four (10%) of the young group failed the color vision test. Five (12.5%) of the middle group failed the color vision test. Two (6.1%) of the old group failed the color vision test. Two (5%) of the young group missed left peripheral indication at 70°. Three (7.5%) of the middle group missed left peripheral indication at 70°, and one (2.5%) missed right peripheral indication at 85°. Eight (24%) of the old group missed left peripheral indication at 70°, and five (15%) missed right peripheral indication at 85°.

Table 5. Percentages and Frequencies of Visual Measures by Age Group.

		Young n = 40		Middle n = 40		Old n = 37	
Measure	Category	%	*f*	%	*f*	%	*f*
UFOV Category Level	Very Low	95	38	80	32	45.5	15
	Low	5	2	10	4	27.3	9
	Low to Moderate	0	0	7.5	3	12.1	4
	Moderate to High	0	0	0	0	6.1	2
	High	0	0	0	0	6.1	2
	Very High	0	0	2.5	1	0	0
Color Vision	Fail	12.5	5	12.5	5	6.1	2
Visual Acuity for Both Eyes that met 20/40 Criteria	Far	97	35	98	39	94	29
	Near	83	30	58	23	35	11
	Night	86	31	85	34	55	17
Peripheral Vision Left (degrees of visual angle from center)	85°	97	35	98	39	94	29
	70°	94	34	95	38	87	27
	55°	100	36	100	40	100	31
Peripheral Vision Right (degrees of visual angle from center)	85°	92	33	100	40	90	28
	70°	100	36	98	39	87	27
	55°	100	36	100	40	100	31
Sign Acuity	70°	100	36	100	40	100	31
	40°	100	36	100	40	100	31

Neuropsychological Measures

Mini Mental State Exam

The MMSE was used to assess mental status and as a screening measure for dementia. The young age group (n=40) had a mean score of 29.38 (SD=.46), with a minimum score of 27 and a maximum score of 30. Six (15%) of the young group were below the age group norm. The middle age group (n=40) had a mean score of 28.90 (SD=.55), with a minimum score of 25 and a maximum score of 30. Six (15%) of the middle age group were below the age group norm. The old age group (n=37) had a mean score of 28.46 (SD=1.28), with a minimum score of 25 and a maximum score of 30. Seven participants (18.9%) within the old age group scored below the age group norm. An ANOVA was performed to compare the group means and age group differences were found, $F(2,114)=6.30$, $p=.003$. The young age group had higher scores than the old age group on the MMSE. Although significant, the mean difference is small and clinically not different. The older adult volunteers were generally high functioning.

Digit Span Forward

The young age group (n=38) had a mean score of 10.68 (SD=2.47), with a minimum score of 5 and a maximum score of 16. The middle age group (n=40) had a mean score of 10.85 (SD=2.68), with a minimum score of 6 and a maximum score of 16. The old age group (n=36) had a mean score of 10.94 (SD=2.31), with a minimum score of 6 and a maximum score of 17. An ANOVA was performed to compare the group means and no age group differences were found, $F(2,113)=.10$, $p=.90$.

Digit Span Backward

For digit span backwards, the young age group (n=38) had a mean score of 7.34 (SD=2.60), with a minimum score of 3 and a maximum score of 14. The middle age group (n=40) had a mean score of 7.23 (SD=2.32), with a minimum score of 3 and a maximum score of 12. The old age group (n=36) had a mean score of 7.19 (SD=2.19), with a minimum score of 4 and a maximum score of 12. An ANOVA was performed to compare the group means and no age group differences were found, $F(2,113)=.04$, $p=.96$.

Wisconsin Card Sort Task

The WCST was used to assess executive control, as well as working memory and several components of visual attention. To compare age groups in performance on the WCST, a one-way ANOVA was performed for each individual measure within the task. Three subjects were removed due to missing data. Table 6 shows the means and standard deviations for each measure on the WCST by age group. There were significant age group differences in the amount of non-perseverative errors $F(2,110)=3.08$, $p=.05$, partial $\eta^2=.05$, the percentage of non-perseverative errors, $F(2,110)=3.27$, $p=.04$, partial $\eta^2=.06$, and the number of categories completed, $F(2,110)=6.21$, $p=.003$, partial $\eta^2=.1$. Post-hoc analysis using the Tukey HSD test showed that the young group was significantly different from the old group at the $p<.05$ level for each of the three measures. Due to the nature of the task, these results would suggest that older individuals have a less efficient degree of executive control.

In summary, the old age group scored lower on the MMSE than the young and middle age groups, although none of the scores were below the cut of score of 23. No age group differences were found in either of the digit span tasks. Some group differences were found within the WCST, but only in a select few of its measures. The minimal differences within the neuropsychological tasks could be explained in part by the fact that the majority of elderly participants that volunteered for this study were high functioning individuals.

Table 6. Descriptive Statistics of Wisconsin Card Sort Test Measures

	Young		Middle		Old	
Measure	M	SD	M	SD	M	SD
Errors	18.26	11.44	23.1	12.56	26.03	16.8
Percent Errors	18.5	7.35	22.26	8.84	23.42	12.49
Perseverative Responses	9.68	6.93	11.82	7.15	12.89	9.19
Percent Perseverative Responses	9.84	5.08	11.41	5.20	12.03	6.62
Perseverative Errors	9.18	6.42	10.9	6.30	12.36	8.51
Percent Perseverative Errors	9.37	4.55	10.64	4.36	11.56	6.11
Non-perseverative Errors*	9.11	6.14	12.21	7.83	13.64	9.89
Percent Non-perseverative Errors*	9.18	4.18	11.74	5.49	12.39	7.23
Conceptual Level Responses	76.5	11.34	72.21	12.24	70.36	15.00
Categories Completed**	5.84	0.55	5.64	0.96	5.00	1.51
Trials to Complete First Category	13.55	5.69	17.21	12.1	15.61	9.94
Failure to Maintain Set	1.03	1.28	0.95	1.15	1.42	1.76
Learning to Learn Score	-2.45	4.12	-2.33	4.37	-2.73	5.32

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

Reaction Time Task-2

Two one-way ANOVAs were performed to compare RTs and error rates between age groups. Table 7 displays the means and standard deviations for RT and error rates by age group. There was a significant age group difference in RTs, $F(2,113)=16.88$, $p<.001$, partial $\eta^2=.23$. Post hoc comparisons using the Tukey HSD test indicated that all age group RTs were significantly different at the $p<.05$ level. There were no significant age group differences in error rates.

Table 7. RT-2 Task RT (in ms) and Error Rates by Age Group Means and (SD)

Measure	Young	Middle	Old	M
RT	510. 61	578.12	644.79	576.1
	(93.24)	(104.04)	(106.56)	
Error Rate	.032	. 03	.024	.029
	(.031)	(.041)	(.037)	

In summary, the old group had significantly longer RTs than both the young and middle aged group, but there were no group differences in error rates. Slower RTs for the old group are to be expected, as it is commonly seen in the literature. The lack of difference in error rates suggests that both groups had an easy time understanding the task and were able to perform it successfully.

Trail Making Test Parts A and B

Total RT (time to finish) was used in the analyses for Trail Making Parts A and B. There were no accuracy measures in these tasks because the correct answers were necessary to proceed with the task. A one-way ANOVA was performed for each trail making task to compare age groups on total RT. Table 8 shows the means and standard deviations for each trail by age group. There was an overall significant age group difference in Trails A, $F(2,113)=3.26$, $p=.042$, partial $\eta^2=.06$. However, post hoc comparisons using Tukey HSD showed that there were no individual group differences. For Trails B there was also a significant age group difference, $F(2,113)=9.17$, $p<.001$, partial $\eta^2=.14$. Post hoc comparisons indicated that the mean score for the young group was significantly lower than both the middle and old age groups at the .05 alpha level.

Table 8. Trail Making Test Parts A and B Total Time to Finish in ln(ms) and (SD) by Age Group

Trail Task	Young	Middle	Old	M
Part A	11.4 (.37)	11.62 (.58)	11.64 (.39)	11.55
Part B	12.16 (.30)	12.38 (.41)	12.49 (.35)	12.34

In summary, the young age group took significantly less time to do Trails B than the middle and old age groups. However, there were no age group differences in Trails A. This would suggest that older individuals are just as good at visual scanning, but have a lower degree of executive functioning.

Stroop

A 3 (age group: young, middle, old) x 3 (trial type: congruent, incongruent, neutral) mixed-design ANOVA was performed for both RTs and error rates to determine if there was a difference between age groups on the three types of trials in the task. Table 9 shows the means and standard deviations for RTs, as well as the mean error rates for each trial type by age group.

For RTs, there was a significant main effect of trial type, $F(2,113) = 75.02$, $p<.001$, partial $\eta^2=.4$, HF epsilon=.669. Post hoc simple contrasts showed that RTs were significantly longer in the incongruent trials compared to the neutral trials, $F(1,114)=71.33$, $p<.001$, partial $\eta^2=.39$. There was also a significant main effect between age groups, $F(2,114) = 18.3$, $p<.001$, partial $\eta^2=.25$. Post hoc comparisons using the Tukey HSD test indicated that all age group RTs were significantly different at the $p<.05$ level. There was also a significant interaction of trial type by age group, $F(4,111)=13.13$, $p<.001$, partial $\eta^2=.19$, HF epsilon=.669, which indicated that older individuals have slower RTs in respect to incongruent trials then they do congruent or neutral trials.

For error rates, there was a significant main effect of trial type, $F(2,113)=10.77$, $p<.001$, partial $\eta^2=.09$, HF epsilon=.763. Post hoc simple contrasts showed that there were significantly more errors in the incongruent trials than the congruent trials, $F(1,114)=13.5$, $p<.001$, partial $\eta^2=.11$, as well as the neutral trials, $F(1,114)=10.97$, $p=.001$, partial $\eta^2=.09$. There was no significant main effect between age groups, nor was there a significant interaction of trial type by age group.

Table 9. Stroop RT (in ms) and Error Rates Trial Type by Age Group Means and (SD)

Measure	Condition	Young	Middle	Old	M
RT	Congruent	521.64	617.63	716.01	618.43
		(109.57)	(140.4)	(212.59)	
	Incongruent	593.96	709.89	963.6	755.82
		(201.27)	(178.92)	(387.91)	
	Neutral	517.8	634.35	715.11	622.4
		(100.2)	(165.33)	(171.19)	
	M	544.47	653.96	798.24	
Error Rate	Congruent	.017	.012	.015	.015
		(.036)	(.028)	(.033)	
	Incongruent	.039	.028	.06	.042
		(.046)	(.052)	(.127)	
	Neutral	.024	.02	.013	.019
		(.044)	(.032)	(.035)	
	M	.027	.02	.029	

In summary, the interaction between age and congruency in the RT analysis indicates that older individuals generally have slower RTs, especially when faced with incongruent stimuli. Increased errors in the incongruent trials also suggest that most individuals have a harder time selectively inhibiting irrelevant stimuli, particularly so with older individuals.

Continuous Performance Task

A 3 (age group: young, old, middle) x 3 (block) mixed-design ANOVA was done to compare the age groups on performance across three 5 min blocks for RT and error rates separately. Trials were divided into three blocks to assess for a vigilance decrement. Only trials that required a response were used in the RT and error analyses. Table 10 displays the means and standard deviations for each block mean RT and error rates by age group.

For RTs, there was a significant main effect for block, $F(2,113) = 6.25$, $p=.002$, partial $\eta^2=.05$, HF epsilon=.993. Post hoc simple contrasts showed that RTs for block 1 were significantly lower then those of block 2, $F(1,114)=12.57$, $p=.001$, partial $\eta^2=.1$, as well as block 3, $F(1,114)=7.5$, $p=.007$, partial $\eta^2=.06$. There was no difference between blocks 2 and 3. There was a significant main effect between age groups, $F(2,113)=3.2$, $p=.04$, partial $\eta^2=.05$. Post hoc comparisons using the Tukey HSD test indicated that the RTs for the young group were significantly different then the old group at the $p<.05$ level. The interaction between block and age group was not significant, $F(4,111)=.106$, $p=.98$, partial $\eta^2=.002$, HF epsilon=.993.

For error rates, there was a significant main effect for block, $F(2,113) = 4.98$, $p=.009$, partial $\eta^2=.04$, HF epsilon=.953. Post hoc simple contrasts showed that errors for block 1 were significantly higher then those of block 2, $F(1,114)=10.35$, $p=.002$, partial $\eta^2=.1$, and that block 2 errors were significantly lower then those of block 3, $F(1,114)=5.09$, $p=.026$, partial $\eta^2=.04$. There was no significant difference between block 1 and block 3. There was also no significant main effect between age groups, $F(2,113)=.126$, $p=.88$, partial $\eta^2=.002$, and the interaction between block and age group only approached significance, $F(4,111)=2.4$, $p=.054$, partial $\eta^2=.002$, HF epsilon=.953.

Table 10. CPT RT (in ms) and Error Rate by Age Group Means and (SD)

Measure	Block	Young	Middle	Old	M
Go RT	1	475.58	493.95	512.88	493.65
		(54.35)	(57.91)	(65.76)	
	2	491.8	507.46	524.22	507.41
		(60.63)	(59.65)	(74.43)	
	3	490.11	508.21	521.99	506.36
		(60.13)	(64.23)	(81.29)	
	M	485.83	503.21	519.7	
Error Rate	1	.011	.006	.006	.008
		(.018)	(.014)	(.012)	
	2	.002	.004	.004	.003
		(.005)	(.009)	(.009)	
	3	.004	.005	.008	.006
		(.009)	(.013)	(.017)	
	M	.006	.005	.006	

In summary, there were faster RTs in Block 1 than Block 2, but no difference between Blocks 2 and 3. Overall the old group had slower RTs than the young and middle aged groups, which is an expected age group difference. Error rates dropped significantly from Block 1 to Block 2, which is evident of learning. The error rates then increased from blocks 2 to 3, which is more indicative of a vigilance decrement. This is to be expected in long tasks that utilize low stimulus rates.

Conners' Continuous Performance Task

A 3 (age group: young, old, middle) x 3 (block) mixed-design ANOVA was done to compare the age groups on performance across three 5 min blocks for RT and error rates separately. Trials were divided into three blocks to assess for a vigilance decrement. Only trials that required a response were used in the RT analyses. For error rates, the trials that did require a response were analyzed separately from those that did not. There were three missing data points for the Conners' CPT task. Table 11 displays the means and standard deviations for each block mean RT and error rates by age group.

For RTs, the main effect for block was not significant, $F(2,110) = 2.44$, $p=.097$, partial $\eta^2=.02$, HF epsilon=.875. However, a significant main effect between age groups was found, $F(2,110)=18.84$, $p<.001$, partial $\eta^2=.26$. Post hoc comparisons using the Tukey HSD test indicated that all age group RTs were significantly different from each other at the $p<.05$ level. The interaction between block and age group was not significant, $F(4,108)=1.82$, $p=.136$, partial $\eta^2=.03$, HF epsilon=.875.

For the target-present error rates, the main effect for block was not significant, $F(2,110) = .04$, $p=.96$, partial $\eta^2<.000$, HF epsilon=.95. There was, however, a significant main effect between age groups, $F(2,110)=3.55$, $p=.032$, partial $\eta^2=.06$. Post hoc comparisons using the Tukey HSD test indicated that the young group was significantly different from the old group at the $p<.05$ level. The interaction between block and age group was not significant, $F(4,108)=.615$, $p=.65$, partial $\eta^2=.011$, HF epsilon=.95.

For the inhibitory error rates, the main effect for block was not significant, $F(2,110) = .17$, $p=.844$, partial $\eta^2=.002$, HF epsilon=1.0. There was, however, a significant main effect between age groups, $F(2,110)=3.25$, $p=.04$, partial $\eta^2=.06$. Post hoc comparisons using the Tukey

HSD test indicated that none of the age group error rates were significantly different from one another at the $p<.05$ level; However, the young group had a noticeably higher error rates than the middle and old groups. The interaction between block and age group was also not significant, $F(4,108)=.615$, $p=.65$, partial $\eta^2=.011$, HF epsilon=1.0.

Table 11. Conners' RT (in ms) and Go/No Go Error Rates by Age Group Means and (SD)

Measure	Block	Young	Middle	Old	M
Go RT	1	441.96 (52.35)	491.66 (67.55)	538.31 (69.59)	490.22
	2	458.22 (50.89)	486.78 (73.11)	532.37 (67.44)	492.11
	3	465.19 (50.24)	496.78 (69.75)	537.61 (63.78)	499.53
	M	455.12	491.74	536.1	
Go Error Rates	1	.004 (.12)	.01 (.17)	.03 (.07)	.01
	2	.01 (.02)	.01 (.04)	.01 (.03)	.01
	3	.01 (.02)	.01 (.02)	.02 (.03)	.01
	M	.01	.01	.01	
No Go Error Rates	1	.16 (.12)	.11 (.12)	.11 (.12)	.13
	2	.16 (.11)	.11 (.09)	.12 (.14)	.13
	3	.17 (.14)	.14 (.14)	.10 (.13)	.14
	M	.16	.12	.11	

In summary, there were no significant differences between blocks in either the RT or error rate analyses. The young group had significantly lower RTs than both the middle and old age groups, which is an expected age group difference. However, the old group had noticeably (although not significantly) less errors in the inhibitory trials than the young group, thus revealing the speed/accuracy trade off that is common in older participants. The high errors in the young group could be explained by a similar yet opposite speed/accuracy trade off in which the younger participants respond faster, despite the risk of making more errors by responding to non-target stimuli.

Visual Search

There were three separate tasks within visual search (feature, pop-out, & distracter). A 3 (age group: young, old, middle) x 3 (set size: 10, 40, 70) mixed-design ANOVA was performed for each task to compare age group error rates across array size. Table 12 shows the means and standard deviations for the error rates for each task across array size by age group. Two subjects were removed due to missing data.

For the feature task there was a significant main effect of array size, $F(2,111)=120.35$, $p<.001$, partial $\eta^2=.52$, HF epsilon=1.0. Post hoc simple contrasts showed that error rates for the 10 character array size were significantly lower then those of the 40 character size, $F(1,112)=129.29$, $p<.001$, partial $\eta^2=.54$, as well as the 70 character size, $F(1,113)=206.7$, $p<.001$, partial $\eta^2=.65$. Error rates for the 40 character size were also significantly lower then the 70 character size, $F(1,112)=19.04$, $p<.001$, partial $\eta^2=.15$. There was no significant main effect between age groups, $F(2,111)=.035$, $p=.966$, partial $\eta^2=.001$, nor was there a significant interaction between age and array size, $F(4,109)=.649$, $p=.628$, partial $\eta^2=.012$, HF epsilon=1.0.

For the pop-out task there was no significant main effect of array size, $F(2,111)=.659$, $p=.518$, partial $\eta^2=.006$, HF epsilon=1.0. There was also no significant main effect between age groups, $F(2,111)=.48$, $p=.62$, partial $\eta^2=.009$, nor was there a significant interaction between age and array size, $F(4,109)=.698$, $p=.594$, partial $\eta^2=.012$, HF epsilon=1.0.

For the distracter task there was a significant main effect of array size, $F(2,111)=101.1$, $p<.001$, partial $\eta^2=.48$, HF epsilon=1.0. Post hoc simple contrasts showed that error rates for the 10 character array size were significantly lower then those of the 40 character size, $F(1,112)=99.11$, $p<.001$, partial $\eta^2=.47$, as well as the 70 character size, $F(1,112)=170.63$, $p<.001$, partial $\eta^2=.61$. Error rates for the 40 character size were also significantly lower then the 70 character size, $F(1,112)=20.79$, $p<.001$, partial $\eta^2=.16$. There was no significant main effect between age groups, $F(2,111)=.02$, $p=.98$, partial $\eta^2<.001$, nor was there a significant interaction between age and array size, $F(4,109)=1.26$, $p=.3$, partial $\eta^2=.022$, HF epsilon=1.0.

For RTs, the data for each participant was converted into slopes and intercepts across array size for each of the three visual search tasks to reduce the number of variables. The slope represents the rate of change in RTs across array size, and the intercept indicates the time for all other processes such as perception and response. A one-way ANOVA was performed for both slope and intercept separately to compare age group means within each task. Table 13 shows the means and standard deviations of the slopes and intercepts by task for each age group. One subject was removed from the RT analysis due to missing data.

For the feature task, there was a significant age group main effect for slope, $F(2,112)=3.62$, $p=.03$, partial $\eta^2=.06$, but not intercept, $F(2,112)=1.95$, $p=.15$, partial $\eta^2=.03$. Post-hoc comparisons using Tukey HSD show that the young group had significantly lower slopes then the old group at the $p=.05$ level. For the pop-out task, there was a significant age group main effect for slope, $F(2,112)=5.04$, $p=.008$, partial $\eta^2=.08$, as well as intercept, $F(2,112)=13.35$, $p<.001$, partial $\eta^2=.19$. Post-hoc comparisons show that the young group had significantly lower slopes then the middle group at the $p=.05$ level. As for intercepts, the young group had significantly lower scores then the middle group, as well as the old group. For the distracter task, there was a significant age group main effect for slope, $F(2,112)=5.13$, $p=.007$, partial $\eta^2=.08$, but not intercept, $F(2,112)=1.89$, $p=.16$, partial $\eta^2=.03$. Post-hoc comparisons show that the young group had significantly lower slopes then the old group at the $p=.05$ level.

Table 12. Visual Search Task Error Rates by Set Size by Age Group Means and (SD)

Task	Array Size	Young	Middle	Old	M
Feature	10	.04 (.07)	.07 (.15)	.05 (.07)	.05
	40	.25 (.16)	.23 (.18)	.25 (.18)	.24
	70	.34 (.17)	.31 (.20)	.32 (.23)	.32
	M	.21	.20	.21	
Pop-out	10	.03 (.05)	.02 (.04)	.03 (.05)	.02
	40	.02 (.04)	.01 (.03)	.02 (.06)	.02
	70	.02 (.04)	.02 (.05)	.03 (.07)	.03
	M	.02	.02	.03	
Distracter	10	.03 (.05)	.03 (.07)	.03 (.05)	.03
	40	.17 (.14)	.22 (.18)	.19 (.20)	.19
	70	.28 (.18)	.25 (.18)	.27 (.23)	.27
	M	.16	.17	.16	

Table 13. Visual Search RT Slope and Intercept by Age Group Means and (SD)

	Age Group	Feature	Pop-out	Distracter
Slope	Young	49.37	.696	51.57
		(29.21)	(1.4)	(36.75)
	Middle	61.69	1.65	63.9
		(31.03)	(1.01)	(49.82)
	Old	75.06	1.14	85.36
		(59.43)	(1.51)	(52.55)
	M	61.71	1.15	66.52
Intercept	Young	898.48	556.31	616.59
		(499.26)	(88.66)	(586.78)
	Middle	849.78	625.61	733.88
		(772.35)	(119.73)	(704.84)
	Old	1180.18	681.1	910.64
		(1012.76)	(109.09)	(724.93)
	M	973.02	619.36	749.96

In summary, there were no age group differences in the amount of errors committed in each of the three tasks. However, there were age group differences in the RT slopes for each of the three tasks. This indicates that the old group had more difficulty efficiently scanning arrays within increasingly larger set sizes.

Attention Networking Task

A 3 (age group: young, middle, old) x 4 (cue type: center, double, spatial, none) x 3 (flanker congruency: congruent, incongruent, neutral) ANOVA was performed for RT and error rates to determine if there was a difference between age groups on the types of trials differing in flanker and cue. Five subjects were removed from the RT analysis due to missing data. Table 14 shows the means and standard deviations for RTs in each trial type by age group.

For RT, there was a significant main effect of cue, $F(3,107)=46.25$, $p<.001$, partial $\eta^2=.3$, HF epsilon=.962, with spatial cue trials having faster RTs than center cue trials, $F(1,109)=82.61$, $p<.001$, partial $\eta^2=.43$, double cue trials, $F(1,109)=83.45$, $p<.001$, partial $\eta^2=.44$, and no cue trials, $F(1,109)=74.32$, $p<.001$,partial $\eta^2=.41$. There was a significant main effect of congruency, $F(2,108)=254.21$, $p<.001$, partial $\eta^2=.7$, HF epsilon=.718, with the incongruent flanker having slower RTs than the congruent flanker, $F(1,109)=293.76$, $p<.001$, partial $\eta^2=.73$, and the neutral flanker, $F(1,109)=281.98$, $p<.001$, partial $\eta^2=.72$. There was a significant main effect of age group, $F(2,108)=19.94$, $p<.001$, partial $\eta^2=.27$. Post hoc tests using Tukey HSD show that all group differences are significant at the $p=.05$ level. There was a significant cue by congruency interaction, $F(6,104)=2.58$, $p=.02$, partial $\eta^2=.23$, HF epsilon=.957, as well as a significant 3-way interaction between age, cue and congruency, $F(12,98)=2.07$, $p=.019$, partial $\eta^2=.037$ (see Figures 1, 2, and 3).

Table 15 shows the means and standard deviations for the error rates across trial type by age group. For error rates, there was a significant main effect of cue type, $F(3,112)=3.97$, $p=.008$, partial $\eta^2=.03$, HF epsilon=1.0, with the center cues having more errors than the double cues, $F(1,114)=8.94$, $p=.003$, partial $\eta^2=.07$, as well as the spatial cues, $F(1,114)=7.11$, $p=.009$, partial $\eta^2=.06$. The main effect of congruency was also found to be significant, $F(2,113)=28.86$,

p<.001, partial η^2=.2, HF epsilon=.527, with the incongruent flanker having more errors than the congruent flanker, F(1,114)=29.49, p<.001, partial η^2=.2, and the neutral flanker, F(1,114)=28.87, p<.001, partial η^2=.2. There was no main effect of age, F(2,113)=2.15, p=.12, partial η^2=.04, nor was there was a significant cue by congruency interaction, F(6,109)=.91, p=.49, partial η^2=.008, HF epsilon=.865.

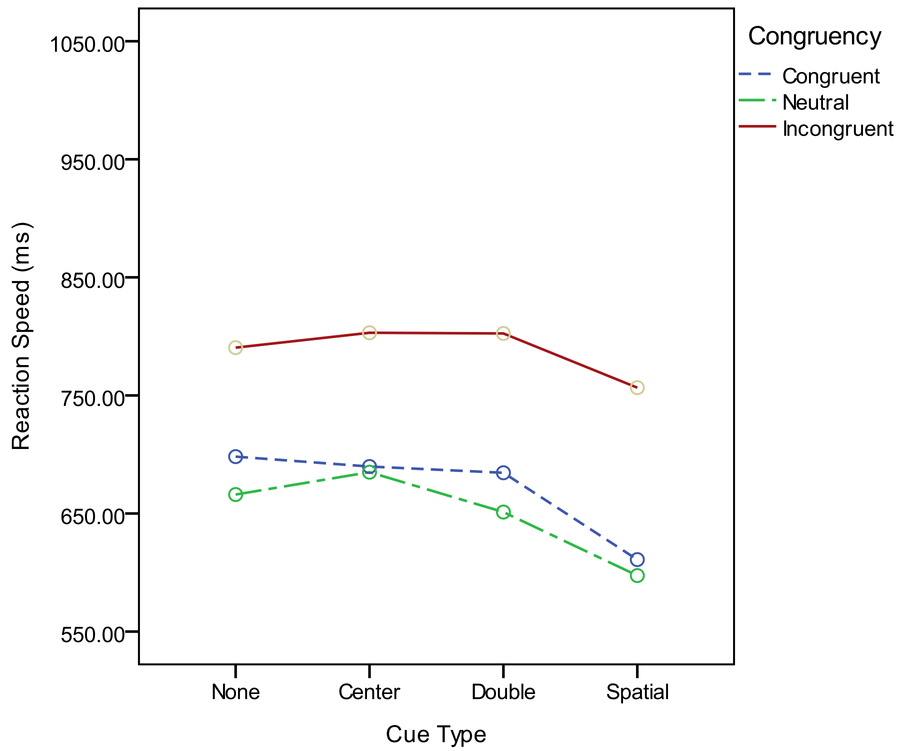


Figure 1. ANT Cue Type by Congruency for Young Age Group

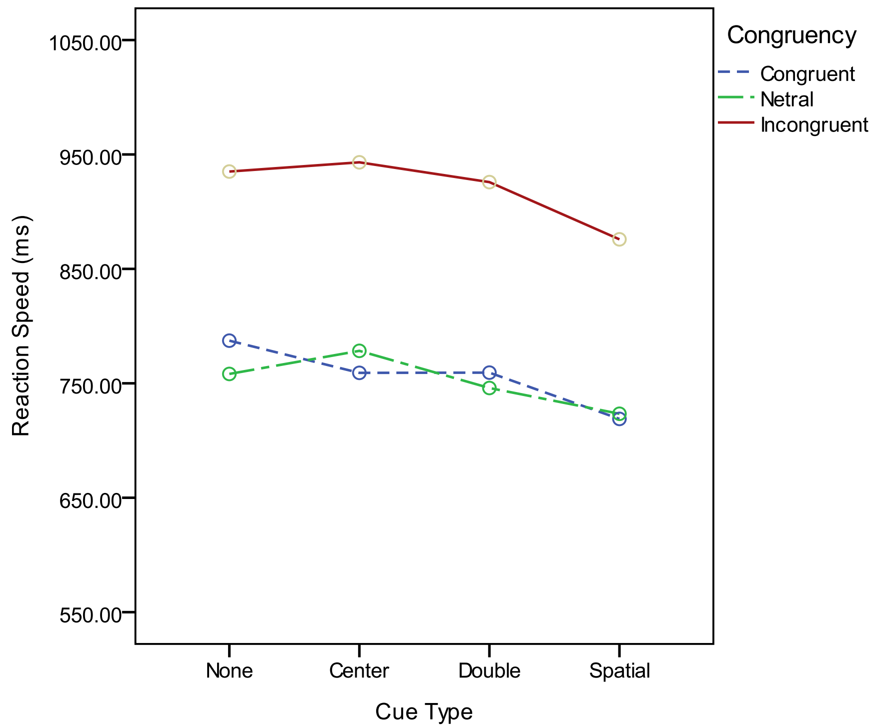


Figure 2. ANT Cue Type by Congruency for Middle Age Group

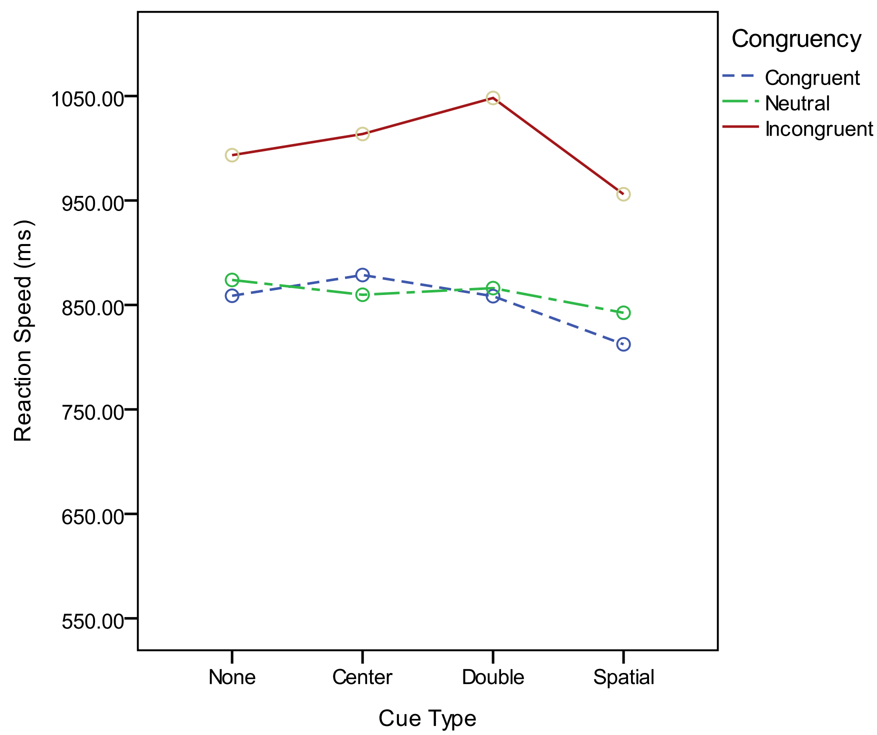


Figure 3. ANT Cue Type by Congruency for Old Age Group

Table 14. ANT RTs (in ms) by Trial Type by Age Group Means and (SD)

Age Group	Cue Type	Flanker type			M
		Congruent	Incongruent	Neutral	
Young	Center	689.79 (87.43)	803.07 (128.3)	684.99 (94.91)	725.95
	Double	684.5 (104.75)	802.49 (148.45)	651.22 (93.09)	712.74
	Spatial	610.95 (106.99)	756.57 (156.27)	597.43 (90.44)	654.98
	No Cue	689.17 (103.58)	790.49 (129.06)	666.05 (109.86)	715.24
	M	668.6	788.16	649.92	
Middle	Center	759.14 (153.65)	943.13 (235.23)	778.37 (155.73)	826.88
	Double	759.33 (165.65)	802.49 (148.45)	651.22 (93.09)	737.68
	Spatial	718.9 (179.82)	756.57 (156.27)	723.37 (169.05)	732.95
	No Cue	787.27 (158.96)	935.06 (245.57)	758.18 (152.33)	826.84
	M	756.16	859.31	727.79	
Old	Center	878.65 (162.75)	1013.63 (156.55)	859.75 (137.35)	917.34
	Double	858.38 (127.83)	1048.15 (168.6)	866.1 (128.63)	924.21
	Spatial	812.32 (111.78)	955.97 (165.46)	842.5 (152.31)	870.26
	No Cue	858.79 (121.57)	993.38 (167.17)	873.94 (132.26)	908.7
	M	852.04	1002.78	860.57	

Table 15. ANT error rates by Trial Type by Age Group Means and (SD)

		Flanker type			
Age Group	Cue Type	Congruent	Incongruent	Neutral	M
Young	Center	.009 (.03)	.10 (.21)	.003 (.19)	.04
	Double	.006 (.03)	.08 (.23)	.01 (.04)	.03
	Spatial	0 (0)	.10 (.23)	.009 (.03)	.04
	No Cue	.009 (.03)	.11 (.24)	.006 (.03)	.04
	M	.006	.10	.007	
Middle	Center	.02 (.09)	.13 (.20)	.04 (.08)	.17
	Double	.02 (.07)	.11 (.19)	.03 (.07)	.05
	Spatial	.02 (.07)	.11 (.20)	.02 (.07)	.05
	No Cue	.02 (.06)	.13 (.21)	.02 (.06)	.06
	M	.02	.12	.03	
Old	Center	.04 (.11)	.20 (.30)	.04 (.10)	.09
	Double	.04 (.09)	.16 (.29)	.01 (.04)	.07
	Spatial	.03 (.06)	.17 (.30)	.02 (.06)	.07
	No Cue	.04 (.07)	.16 (.29)	.06 (.13)	.09
	M	.04	.17	.03	

The ANT task measures three components of the attention network: alerting efficiency, orienting efficiency, and executive control. Alerting is computed by subtracting the mean RT of the double cue trials from the mean RT of the no cue trials. Orienting is computed by subtracting the mean RT of the spatial cue trials from the mean RT of the center cue trials. Executive control is computed by subtracting the mean RT of the congruent trials from the mean RT of the incongruent trials. Higher scores mean better alerting (i.e., greater benefit of cueing), and better orienting (i.e., greater benefit of peripheral cueing). For executive control, lower scores mean less of a conflict cost. Table 16 shows the means and standard deviations of the three attention networking components by age group. There were no significant age group main effects for alerting, $F(2,111)=1.17$, $p=.31$, or orienting, $F(2,111)=1.72$, $p=.18$. However, the age group main effect was significant for the executive control component, $F(2,111)=3.33$, $p=.04$. Post hoc analysis using Tukey HSD revealed that the young group had significantly lower conflict scores than the middle age group at the $p=.05$ level. This suggests that older individuals have a harder time correctly identifying targets in the presence of incongruent falnkers.

Table 16. ANT Component scores by Age Group Means and (SD)

Component	Young	Middle	Old	M
Alerting	9.78 (54.08)	14.77 (59.56)	-5.13 (59.87)	6.91
Orienting	70.89 (70.65)	63.21 (72.25)	41.41 (68.87)	59.21
Executive Control	116.85 (89.09)	167.89 (99.8)	159.26 (92.26)	147.33

In summary, there were significant age group differences in RTs, but not in error rates. This simply indicates that in order to maintain good performance, older individuals have a tendency to take more time in their responses. As for the network variables, only executive control was found to be significantly different between groups. This suggests that older individuals are just as effective at disengaging/reengaging the focus of their attention between multiple sources of information, but have a harder time correctly identifying targets in the presence of incongruent flanking stimuli.

Divided Attention

The divided attention function was assessed with a single-axis compensatory tracking task in conjunction with a 2-choice RT task. Participants were to respond to both E's and F's while maintaining a randomly moving cursor in the center crosshair with a joystick. There were eight missing data points for the divided attention task. Table 17 shows the means and standard deviations for RTs, error rates, and RMS error by age group. RMS error refers to the accuracy of maintaining the cursor in the center of the line. Age groups were compared by performing a one-way ANOVA for each variable. There were significant age group differences in RMS error, $F(2,105)=11.2$, $p<.001$, $\eta^2=.18$. Post-hoc analysis using Tukey HSD indicated that at the p=.05 level, the young group had lower RMS error then the both the middle and old age groups. There were also significant age group differences in RTs, $F(2,105)=4.34$, $p=.015$, $\eta^2=.08$. Post-hoc analysis shows that the young group had significantly faster RTs than the old age group at the p=.05 level. There were no age group differences in error rates, $F(2,105)=1.46$, $p=.237$, $\eta^2=.08$.

Table 17. Dual Task Measures by Age Group Means and (SD)

Measure	Young	Middle	Old
RMS Error	.30 (.12)	.41 (.17)	.46 (.13)
Error Rate	.05 (.14)	.06 (.11)	.10 (.15)
RT	640.10 (62.56)	697.05 (129.63)	716.87 (131.09)

In summary, the groups differed in RMS error and in RTs, but non in regular error rates. This would suggest that older individuals took more time responding in an effort to make fewer errors. The old age group also performed worse on the tracking portion of the task then the young age group, which would indicate that they also have a harder time performing two tasks within the same perceptual modality.

Principal Component Analyses

A PCA was performed for all three age groups combined to find an overall component structure. Once a component structure was established another similar analysis was then performed including variables from the Conners' CPT. Results from the two analyses were then compared in order to evaluate the effects of adding the Conners' CPT to the existing attention battery. Component scores from this analysis were then compared between each age group using a series of one-way ANOVAs.

Without Conners' CPT

A PCA was performed using Varimax rotation with 15 variables from the various attention tasks. Casewise exclusion was done yielding a total sample of 105 participants across the three age groups. A number of exploratory analyses were done to determine the optimum number of variables and components to use that would explain the variance in the most logical way, while attempting to maximize the subject-to-variable ratio. In the preliminary analyses several variables were removed that were found to contribute minimal variance to the component structure; for example, the error rates from several of the tasks. Visual search intercept data was also excluded, as well as the entire pop-out task, which offered little variance. Visual search RTs were reduced using bivariate regression to create an overall slope-across-array-size variable for each task. The Stroop task was also reduced down to a single variable that represented the difference between the incongruent and neutral trials. The congruent trials were not used because they were found to be redundant with the neutral trials. The final analysis resulted in the inclusion of 15 out of 34 possible variables.

The number of components to be extracted was determined by examining the overall interpretability of the factor solution. It was decided that 6 components provided the best component structure for the remaining 15 variables, where each component accounted for at least 5% of the total variance, before rotation. Table 18 contains the rotated component matrix from the PCA analysis with Varimax rotation. Component 1, a perceptual-motor processing speed component, had high loadings on the RTs for the RT-2 task, CPT, and dual task. Component 2, a switching component, had high loadings on parts A and B of the Trail Making task. Component 3 had high loadings on Stroop incongruency loss, the conflict network variable of the ANT, and dual task RMS error, suggesting that this is a component for selective attention/executive functioning. Component 4 appeared to be a visual search component, containing high loadings on the RT slopes of the visual search feature and distracter tasks. Component 5, a sustained attention component, had high loadings on the ANT alerting and orienting network variables.

Component 6 was a divided attention component, which contained high loadings on dual-task error and the orienting variable of the ANT.

Table 18. Rotated PCA Component Matrix Without the Conners' CPT for Young, Middle, and Old Age Groups Combined (n=105)

	Component					
	1	2	3	4	5	6
CPT Block 2 RT	**.917**	.005	.011	.074	.156	-.030
CPT Block 3 RT	**.866**	.039	.146	.004	.106	.039
CPT Block 1 RT	**.837**	.047	.147	.193	.218	.084
RT-2 RT	**.656**	.121	.140	.230	-.326	.055
Dual Task RT	**.591**	.378	.269	-.025	-.317	-.026
Trails B Time to Complete	.125	**.952**	.123	.076	.013	-.009
Trails A Time to Complete	.010	**.949**	-.013	.059	.067	.053
ANT Conflict	.140	.219	**.812**	.080	.120	-.033
Stroop Incongruency Loss	.138	-.108	**.712**	.219	-.157	.039
Dual Task RMS Error	.291	.462	**.477**	.009	-.240	-.150
Visual Search Distracter Slope	.148	.131	.086	**.834**	-.039	.029
Visual Search Feature Slope	.099	-.012	.166	**.814**	-.100	-.116
ANT Alerting	.086	.102	-.037	-.092	**.824**	-.074
ANT Orienting	.169	-.171	-.045	-.083	**.502**	**.475**
Dual Task Error	.011	.069	-.010	-.045	-.067	**.915**
Eigen Value	3.28	2.30	1.58	1.54	1.34	1.12
% of Variance Explained	21.86	15.35	10.56	10.23	8.92	7.48

Bold = High Loading

With Conners' CPT

In an attempt to analyze its impact on the overall component structure, variables from the Conners' CPT were added to the previous PCA. Since the purpose of the task was to add a more defined component of controlled inhibition to the overall structure, only the error rates from the no-go trials were used. RTs and target present error rates from the task were excluded because they did not provide any meaningful variance. Thus the new analysis resulted in the inclusion of 18 out of the now 43 possible variables.

Seven components provided a better component structure for the remaining variables, where each component still accounted for at least 5% of the total variance, before vota. Table 20 contains the amount of variance explained by the 7 components extracted through the PCA, before and after varimax rotation. Table 19 contains the rotated component matrix from the PCA analysis with varimax rotation. The component loadings remained similar to the previous combined groups PCA, with the exception of the additional component. All three variables from the Conners' CPT loaded highly onto Component 3, creating an new component for response inhibition. The remaining 6 components did not change from the previous analysis.

Table 19. Rotated PCA Component Matrix Including the Conners' CPT for Young, Middle, and Old Age Groups Combined (n=105)

	Components						
	1	2	3	4	5	6	7
CPT Block 2 RT	**.920**	.017	-.062	-.023	.073	.131	-.054
CPT Block 3 RT	**.863**	.039	-.110	.122	.007	.094	.034
CPT Block 1 RT	**.846**	.052	-.102	.092	.204	.194	.060
RT 2 RT	**.629**	.107	-.027	.261	.168	-.269	.038
Dual Task RT	**.570**	.369	-.118	.310	-.035	-.302	.026
Trails A Time to Complete	.017	**.954**	-.003	-.010	.054	.063	.062
Trails B Time to Complete	.132	**.954**	.033	.138	.072	.011	-.011
Conners Block 2 no-go Error	-.137	.002	**.747**	-.046	-.036	-.021	-.161
Conners Block 3 no-go Error	-.119	.014	**.706**	.207	-.177	.155	.085
Conners Block 1 no-go Error	-.023	.005	**.692**	-.251	.121	-.097	.186
ANT Conflict	.130	.178	-.157	**.819**	.117	.146	.025
Stroop Incongruency Loss	.201	-.106	.113	**.556**	.307	-.226	.040
Dual RMS Error	.291	.447	-.011	**.496**	.021	-.234	-.180
Visual Search Distracter Slope	.144	.143	-.140	.039	**.834**	-.049	.042
Visual Search Feature Slope	.094	-.011	.044	.209	**.787**	-.076	-.128
ANT Alerting	.069	.080	-.047	.015	-.096	**.854**	-.053
ANT Orienting	.246	-.162	.270	-.149	-.061	**.461**	.348
Dual Task Error	.012	.045	.021	.025	-.061	-.012	**.925**
Eigen Value	3.32	2.27	1.71	1.61	1.57	1.34	1.11
% of Varience Explained	18.42	12.62	9.52	8.93	8.73	7.46	6.19

Bold = High Loading

Age Group Component Scores Comparison

Individual component scores from the PCA containing the Conners' CPT were used in a series of one-way ANOVAs in order to provide a meaningful comparison of the age groups outside of the task analysis. Table 20 contains the means and SDs for the component scores by age group. There were significant age group differences in Component 1 (speed) $F(2,102)=3.69$, $p=.028$, partial $\eta^2=.07$, Component 4 (selective) $F(2,102)= 3.32$, $p=.04$, partial $\eta^2=.06$, Component 5 (visual search) $F(2,102)= 3.34$, $p=.04$, partial $\eta^2=.06$, and Component 6 (sustained) $F(2,102)=5.75$, $p=.004$, partial $\eta^2=.10$. Post hoc analysis using Tukey HSD revealed that in each of the cases above the young group had significantly lower component scores than the old age group at the p<.05 level. In component 6 the middle age group also had significantly lower component scores than the old age group at the p<.05 level. Low component scores coincide with low RTs/error rates, which indicate better performance within the tasks that load highly onto those components.

Table 20. Component Score Means and (SD) by Age Group

	Age Group								
Component	Young		Middle		Old		*F*	*p*	η^2
1 (Speed)	-.33	(.85)	.04	(.94)	.32	(1.1)	3.69	.03	.07
2 (Switching)	-.31	(.58)	.23	(1.4)	.06	(.66)	2.89	.06	.05
3 (Inhibition)	.16	(.92)	-.12	(.96)	-.03	(1.1)	.703	.50	.01
4 (Selective)	-.31	(.89)	.02	(.93)	.31	(1.1)	3.32	.04	.06
5 (Visual Search)	-.26	(.76)	-.06	(.92)	.35	(1.2)	3.34	.04	.06
6 (Sustained)	.23	(.88)	.19	(.97)	-.48	(1.0)	5.75	.004	.10
7 (Divided)	.11	(.36)	-.17	(1.6)	.09	(.43)	.903	.41	.02

CHAPTER IV

DISCUSSION

The present study was conducted in an effort to create an exhaustive attention battery to be used in a comprehensive driving assessment for evaluating older drivers and possibly individuals with neurological disorders. The focus of the study was to include a new task in the battery that would accurately represent a component for response inhibition. Although tasks such as the Stroop and ANT do contain elements of controlled inhibition, they are not suited for measuring response inhibition. Tasks like the Stroop require the individual to suppress distracting stimuli in order to make a correct response, whereas tasks that measure response inhibition require the individual to suppress their response entirely when presented with a non-target stimulus. The Conners' CPT is a go/no-go task that has proven to be an ideal measure for response inhibition. Its relatively low proportion of non-target stimuli effectively decreases the amount of automated inhibition that is common within a standard CPT. This lack of automation makes the act of inhibiting a response more defined and measurable.

The purpose of the present study was to determine if adding the Conners' CPT to the existing attention battery provided a new, meaningful component for response inhibition. The original attention battery contained several tasks that measured the various functions of attention (scanning, switching, selective, sustained, and divided), but none that focused primarily on response inhibition. It was my hypothesis that performing a PCA containing the Conners' CPT would result in the inclusion of an additional component to accommodate response inhibition. The results confirmed my hypothesis, in that the PCA that included the Conners' CPT contained 6 components (speed, switching, executive, visual search, sustained, and divided) that were very close to the PCA that did not include the Conners' CPT. In addition, the PCA that included the

Conners' CPT also contained an additional component which can be identified as response inhibition. These results would suggest that the Conners' CPT does have a meaningful place within the current attention battery.

The following discussion will begin with a brief overview of the results from the preliminary analysis, with a focus on age group differences. Being the principal focus of this study, the Conners' CPT will be examined in more detail. Following that will be a discussion on the comparison of the PCAs with and without the Conners' CPT, as well as a discussion of the results for the component score ANOVAs. Lastly, the discussion will conclude with a look at the limitations of the present study, and how it may be modified for future investigations.

Attention and Aging

Age group differences were found within the RTs of each task of the attention battery, but not within the error rates. This would suggest that in general, older individuals take more time to complete cognitive tasks, primarily in an effort to minimize the number of errors they make. A common trend in the results of the present study was an increase in RT and number of errors across age groups. However, differences in error rates were not significant for any of the tasks. Much of the literature concerning age related differences in attention makes note of a common speed/accuracy trade off found for the performance of older participants. Smith and Brewer (1995) compared young and old adults on mechanisms of trial-by-trial control of accuracy and choice reaction times. They found that the older adults were more careful, had fewer very fast responses, and experienced more slowing following an error then the young adults. This pattern is replicated in the results of the present study, where the older participants performed just as well as their younger counterparts on each of the tasks, but took longer to do so. The tasks that are of particular interest to this study are those that include elements of inhibition.

One of the primary tasks in the attention battery for measuring selective attention and controlled inhibition is the Stroop task. The Stroop task involves focusing on one characteristic of a stimulus (the color) while trying to ignore another that is more powerful (the word). In the Stroop task, there were group differences for the incongruent trials with the old group having significantly slower RTs than both the young and middle age groups. This would suggest that the older participants have a less efficient ability to inhibit irrelevant information when compared to the younger age groups. In a similar study, McDowd and Oseas-Kreger (1991) found inhibition functions to be less efficient in older adults in a colored letter reading task. These results support the idea that selective inhibition does decline with age, but the results of the present study concerning the Conners' CPT convey a slightly different trend in regards to response inhibition.

Conners' Continuous Performance Task

Although the primary focus of the present study was to analyze the utility of the Conners' CPT by looking at how it affected the PCA, the preliminary analysis yielded some interesting result. Studies like that of Andres et al. (2008) often report finding a consistent decline in response inhibition among the older participants when using stop-signal tasks such as the Conners' CPT. Similarly, the older participants in the present study experienced a speed/accuracy trade-off within the Conners' CPT, in which they took more time to recognize the stimulus in an effort to avoid responding when they are required not to. The results of the present study showed that the older participants had longer RTs than the young and middle aged participants, but maintained the same low number of errors within the target-present trials. The target-absent trials, however, show a very different trend, where the young group commits more errors than both the middle and old age groups. Essentially, the younger participants were more engaged in having faster RTs within the target-present trials, despite the risk of committing more errors by responding to non-target stimuli. This pattern suggests that younger individuals have a more difficult time inhibiting their responses to non-target stimuli, possibly due to their increased levels of impulsivity (Dickman, 1985). This phenomenon appears to be less of an issue for the older participants because they have a tendency to take more time in identifying the stimulus before responding.

Principal Component Analyses

The purpose of the PCAs was to determine if adding the Conners' CPT to the existing attention battery would create a separate, meaningful component for response inhibition. This was achieved by comparing the component structures of the PCA without the Conners' CPT to that which includes it. The PCA without the Conners' CPT contained 6 components; perceptual-motor processing speed, switching attention, executive functioning, visual search, selective attention, and divided attention. The PCA which contained the Conners' CPT had an almost identical component structure, with the exception of a seventh additional component containing all three variables from the Conners' CPT. These results confirm my first hypothesis that the Conners' CPT would create a separate component within the PCA. However, unlike the majority of the other variables in the analysis, the variables from the Conners' CPT were based on error rates. This creates the possibility that the respective component is the result of method variance. Future investigations using a larger sample size and more a diverse set of variables are needed to confirm the nature of the variance within this component.

Component scores from the PCA containing the Conners' CPT were also used in a series of ANOVAs to analyze age group differences within the resulting component structure. Similar to the results of the individual task analysis, significant age group differences were only found in the components with high loadings on variables that measure reaction time. This confirms my second hypothesis that the component score analysis would produce age group differences that reflect patterns found within the age group comparisons of the individual task analyses. These results are also consistent with the literature, in that it is common to see older individuals performing attention tasks with slower RTs than their younger counterparts. Older participants often take more time in their responses in an effort to commit fewer errors (Smith and Brewer). This is also reflected in the results, because the components that have high loadings on variables that measure errors are those that have the lowest significant differences between age groups.

Another important point to make is that the first component, psycho-motor processing speed, is not a function of attention. However, elements of psycho-motor processing speed do exist in every task within the assessment, and therefore has the potential to contaminate the results of the PCA by linking every variable together through a common form of variance. In order to compensate for this, Varimax rotation was used in the PCA analysis in order to keep the components from correlating with each other, maintaining a level of orthogonality. This resulted in the creation of a single component for psycho-motor processing speed, therein allowing the remaining components to be statistically independent. As part of the exploratory analysis, the combined groups PCAs were also performed with an oblique rotation. Results were similar, but not as interpretable as a rotation the preserves the total statistical independence of the components. Tables 29 and 30 (Appendix F) represent the PCAs that were performed using an oblique rotation.

Limitations

There were a number of limitations in this study related to the participants and the tasks within the attention battery. PCAs for the individual age groups failed to yield any stable component solutions and therefore were not interpretable, primarily because the subject-to-variable ratios did not reach acceptable levels. In order to achieve results that are more interpretable, the sample size would need to be considerably larger in order to compensate for the relatively large number of variables. This poses a problem, however, because the majority of participants in this study were community members who need to be compensated monetarily. Because of the length of the study, this can become rather costly. As a solution, the study needs to be altered to be shorter and more efficient, and/or be less dependent on the use of community members.

Another limitation concerning the participants of the study is that the old age group is not entirely representative of the elderly population. Because of the voluntary nature of the study, most of the elderly community members that participated possessed relatively high degrees of cognitive functioning. For a truly comprehensive look at the effects of age on attention, the sample of elderly participants would need to consist of a balance between low, moderate, and high functioning individuals. This poses yet another problem, because elderly individuals of limited cognitive functioning are rarely in a position to volunteer themselves for scientific studies. A possible solution would be to actively visit community senior centers in an effort to solicit a greater number of volunteers with mid-to-lower levels of cognitive functioning.

Aside from the participants, other limitations include unexplained results in a few of the attention tasks, particularly the CPT. Even though the task appeared to work properly within the preliminary analysis, it failed to load onto a separate sustained attention component of the PCA, as it had in the previous studies (e.g. Tuttle, 2008). There are a number of reasons for this to occur, the most likely of which is the structure of the task itself. Originally, that task was designed to be performed over a 30 minute period (Rosvold et al., 1956). However, in order for the present study to achieve an acceptable overall time frame, the task had to be shortened to roughly half of the original length. This change effectively decreased the probability that the participants would be exposed to boredom or fatigue, which in turn limited the measurability of any vigilance decrement created by the task.

Future Studies

There are several key changes that can be made to make future investigations of this study more effective. The first and most important change to make is an increase in the sample size. As mentioned before, the sample for the present study was comprised primarily of community members who had to be compensated monetarily. The present study was limited in this regard, but future studies may warrant an increase in funding to create a larger sample. Another change that needs to be made is the method used to solicit elderly individuals to participate in the study. The present study only utilized the use of ads placed in the newspaper and local newsletters. New efforts may include visiting local senior centers to place flyers and actively recruit elderly participants. The third and final change that needs to be made is within the normal CPT, which is the primary measure of sustained attention within the present study. Because of an overall lack of a measureable vigilance decrement within a majority of the participants, the task may need to be lengthened for future investigations. However, an alternative solution is to lower the stimulus presentation rate. Lower presentation rates have shown in many cases to decrease accuracy and increase response latency, thus increasing the measurability of any decrement in vigilance (Jenkins, 1958).

Conclusion

The results of the present study indicate that adding the Conners' CPT to the existing attention battery does provide it with a meaningful measure of response inhibition. The two combined group PCAs were almost identical, with the exception of the additional seventh component for response inhibition within the PCA containing the Conners' CPT. The preliminary task analyses also yielded results that are fairly consistent with the literature concerning the effects of age on attention. The older participants had the slowest RTs in every task, but maintained relatively low error rates similar to the young and middle age groups. In closing, the current attention battery is fairly comprehensive and effective, which makes it ideal for the use in studies containing tasks that are particularly demanding in visual attention.

APPENDICES

APPENDIX A

SUBJECT CONSENT FORM

CMU
CENTRAL MICHIGAN UNIVERSITY

Title of Project: ASSESSING ATTENTION FUNCTIONS IN DRIVING
Investigator: Stephanie Tuttle Phone: 989-774-5954
Department: Psychology Email: tuttl1s@cmich.edu

You are eligible to participate in this research if you are over the age of 18 and in good health. The following information is provided to help you make an informed decision whether or not to participate. If you have any questions, please do not hesitate to ask.

Purpose. The purpose of the current study is to create a driving assessment test battery by identifying the functional change of attention abilities across time and how these abilities are affected by driving history, behavior and knowledge, mental state, executive function, visual acuity, useful field of view size, and simulated driving performance.

Procedure. I understand that if I decide to participate in this research project the procedures will be as follows: First, I will be asked to complete demographic and driving behavior questionnaires. I will be asked to complete visual acuity, and useful field of view assessments. I will be asked to complete a mental status and executive function test. I will be asked to complete an attention battery to assess my attention abilities. Finally, I will be asked to complete a driving task in the driving simulator.

Audio/Visual. I understand that my driving behavior will be recorded including my face and my feet. I understand that the audio and visual information will be kept confidential and secure on a password protected computer. I understand that only the investigators in this study will have access to this information.

Subject's Initials _________

Timetable. I understand that this study has 2 sessions will take about 120 minutes to complete (including time for a break). I understand I will be allowed to take a break if needed. I also understand that it will take approximately one semester for the study to be completed.

Risks. I understand that there are minimal risks involved in participating in the research project. I understand that I may experience motion discomfort symptoms such as dizziness in the driving simulator. I understand that if I am under the age of 21, that alcohol use responses will be recorded and kept in the records of the study. I understand that there is a legal risk of admitting to alcohol use as an underage individual.

Benefits. I understand that the benefits from this research project will be a better understanding of how attention abilities change over time and affect driving performance. I also understand that my participation will contribute to the development of a comprehensive driving assessment.

Confidentiality. I understand that any information obtained during this study that could identify me will be kept strictly confidential and will not be released in an individually identifiable form without prior consent unless required by law. The information may be published in scientific journals or presented at scientific meetings, but my identity will be kept strictly confidential.

Compensation. I understand that as a CMU student I will receive 2 credits per hour for my participation. I understand that as a community member, who is not currently a CMU student, I will receive $15.00 per hour for my participation. I understand that this study has two sessions and after I have completed first session and return for the second session, I will receive a bonus of $10 if I am a community member participants and one credit hour if I am a CMU student for coming to do the second session.

In case of emergency. I understand that if I experience discomfort or adverse reactions during the experiment I can have the investigator call CMU Public Safety. I can also call the investigator if I have questions or concerns after the experiment.

Subject’s Initials _________

Right to refuse or withdraw. I understand that participation is entirely voluntary and that I can withdraw my consent at any time. My compensation will be prorated to the next half-hour.

Questions. I understand that the investigator will answer any questions about the research, either now or later. If I have any questions later I can contact Dr. Richard Backs (989-774-6497), Department of Psychology, Central Michigan University, Mt. Pleasant, MI 48859.

You are free to refuse to participate in this research project or to withdraw your consent and discontinue participation in the project at any time without penalty or loss of benefits to which you are otherwise entitled. Your participation will not affect your relationship with the institution(s) involved in this research project.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to the Institutional Review Board by calling 989-774-6777, or addressing a letter to the Institutional Review Board, 251 Foust Hall Central Michigan University, Mt. Pleasant, MI 48859.

My signature below indicates that all my questions have been answered. I agree to participate in the project as described above.

______________________________ __________________

Signature of Subject Date Signed

A copy of this form has been given to me. _________ Subject’s Initials

For the Research Investigator—I have discussed with this subject the procedure(s) described above and the risks involved; I believe he/she understands the contents of the consent document and is competent to give legally effective and informed consent.

______________________________ __________________

Signature of Responsible Investigator Date Signed

APPENDIX B

COMINUTY MEMBER RECRUITMENT FLYER

CMU
CENTRAL MICHIGAN UNIVERSITY

Driving Evaluation Education Research
DEER CENTER
CENTRAL MICHIGAN UNIVERSITY

CARLS CENTER for CLINICAL CARE and EDUCATION

The Department of Psychology at Central Michigan University is seeking adults for a study on attention and simulated driving.

To participate, you must have a valid Michigan driver's license and have your own transportation.

The experiment requires two one and a half hour sessions, and you will be paid $15.00 per hour for your participation.

To volunteer or obtain more information, call Dr. Richard W. Backs at (989) 774-3234 or send an email to backs1rw@cmich.edu.

02/25/09

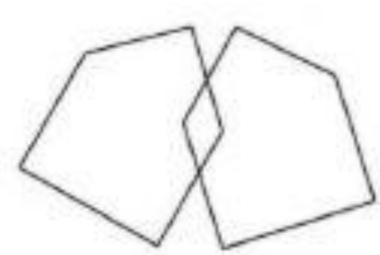
CMU, an AA/EO institution, strongly and actively strives to increase diversity within its community.

APPENDIX C

MINI-MENTAL STATUS EXAM

Task	Max Score	Score	Instructions
Orientation: What is the (year) (season) (date) (day) (month)?	5	______	Ask for the date. Then proceed to ask other parts of the question. One point for each correct segment of the question.
Where are we?: (state) (country) (town) (hospital) (floor)	5	______	Ask for the facility then proceed to parts of the question. One point for each correct segment of the question.
Registration: Name three objects (bed, apple, shoe). Ask the patient to repeat them.	3	______	Name each object slowly. Ask participant to repeat. Score by the number of objects recalled.
Attention and Calculation: Count backwards by 7s. Start with 100. Stop after 5 Calculations.	5	______	Score the total number correct. (93, 86, 79, 72, 65)
Alternate question: Spell the word "world" backwards.	5	______	Score the number of letters in correct order. (dlrow=5, dlorw=3)
Recall: Ask for the three objects used in question 2 to be repeated.	3	______	Score one point for each correct answer. (bed, apple, shoe)
Language: 1. Name objects: (watch, pencil)	2	______	Hold up object. Ask patient to name it. Score one point for each correct answer.
2. Repetition: Repeat the following: "No ifs, ands or buts."	1	______	Allow one trial only. Score one point for correct answer.

Task	Max Score	Score	Instructions
3. Follow a 3-stage command: "Take the paper in your right hand, fold it in half, and put it on the floor."	3	______	Use a blank sheet of paper. Score one point for each part correctly.
4. Reading: Read and obey the following: "Close your eyes"	1	______	Instruction should be printed on a page. Allow patient to read it. Score by correct response.
5. Writing: Write a sentence.	3	______	Provide paper and pencil. Allow patient to write any sentence. It must contain a noun, verb, and be sensible.
6. Copying: Copy this design.	5	______	All 10 angles must be present. Figures must intersect. Tremor and rotation are ignored.



Total Score:_________ Education Level:_________ Norm:_________

APPENDIX D

DIGIT SPAN TEST

Digit Span
Discontinue Rule for Digits Forward and Backward: Score of 0 on both trials of any item for both Digits Forward and Backward, administer both trials of each item even if Trial 1 is passed. Administer Digits Backward even if examinee scores 0 Digits Forward.
Scoring Rule for Each Trial: 0 or 1 pt. for each response. Item score = Trial 1 + Trial 2

Digits Forward	**Score**		**Digits Backwards**	**Score**	
Correct Response	**Trail**	**Item**	**Correct Response**	**Trail**	**Item**
1. 1-7	_____		1. 2-4	_____	
6-3	_____	_____	5-7	_____	_____
2. 5-8-2	_____		2. 6-2-9	_____	
6-9-4	_____	_____	4-1-5	_____	_____
3. 6-4-3-9	_____		3. 3-2-7-9	_____	
7-2-8-6	_____	_____	4-9-6-8	_____	_____
4. 4-2-7-3-1	_____		4. 1-5-2-8-6	_____	
7-5-8-3-6	_____	_____	6-1-8-4-3	_____	_____
5. 6-1-9-4-7-3	_____		5. 5-3-9-4-1-8	_____	
3-9-2-4-8-7	_____	_____	7-2-4-8-1-6	_____	_____
6. 5-9-1-7-4-2-8	_____		6. 8-1-2-9-3-6-5	_____	
4-1-7-9-3-8-6	_____	_____	4-7-3-9-1-2-8	_____	_____
7. 5-8-1-9-2-6-4-7	_____		7. 9-4-3-7-6-2-5-8	_____	
3-8-2-9-5-1-7-4	_____	_____	7-2-8-1-9-6-5-3	_____	_____
8. 2-7-5-8-6-2-5-8-4	_____				
7-1-3-9-4-2-5-6-8	_____	_____			
		Total: _____			Total: _____

Digits Forward Total Score + Digit Backwards Total Score = Final Score: _____

Scaled Score: _____

APPENDIX E

EXPLORATORY PRINCIPAL COMPONENT ANALYSES

Rotated PCA Component Matrix Without the Conners' CPT for Young, Middle, and Old Age Groups Combined (Forced 5 Factors)

	Component				
	1	2	3	4	5
CPT Block 2 RT	**.905**	.013	.070	-.135	-.010
CPT Block 3 RT	**.880**	.069	.020	-.027	.045
CPT Block 1 RT	**.859**	.075	.214	-.128	.093
RT-2 RT	**.614**	.145	.218	.342	.058
Dual Task RT	**.577**	.421	-.015	.375	-.034
Trails B Time to Complete	.105	**.959**	.076	-.030	.003
Trails A Time to Complete	-.029	**.932**	.042	-.136	.075
Dual Task RMS Error	.336	**.538**	.059	.388	-.179
ANT Conflict	.315	.353	.213	.244	-.097
Visual Search Distracter Slope	.127	.137	**.828**	.045	.037
Visual Search Feature Slope	.096	.010	**.821**	.140	-.119
ANT Alerting	.171	.098	-.051	**-.755**	-.060
Stroop Incongruency Loss	.269	.011	.323	**.469**	-.023
Dual Task Error	.000	.063	-.050	.097	**.912**
ANT Orienting	.224	-.176	-.058	-.425	**.480**
Eigen Value	3.44	2.48	1.63	1.52	1.14
% of Variance Explained	22.96	16.5	10.85	10.16	7.62

Bold = High Loading

Rotated PCA Component Matrix Including the Conners' CPT for Young, Middle, and Old Age Groups Combined (Forced 6 Factors)

	Component					
	1	2	3	4	5	6
CPT Block 1 RT	**.765**	-.444	.139	.028	.111	.037
CPT block 3 RT	**.738**	-.440	.157	-.030	-.101	.026
Dual Task RT	**.728**	.120	.050	-.025	-.302	-.127
CPT block 2 RT	**.723**	**-.509**	.167	.004	-.003	.092
RT-2 RT	**.690**	-.095	-.067	.194	-.176	-.103
Dual Task RMS Error	**.607**	.393	-.002	.032	-.274	.131
ANT Conflict	**.539**	.208	-.086	-.010	-.127	.194
Trails B Time to Complete	**.530**	**.662**	.416	-.169	.139	-.010
Trails A Time to Complete	.384	**.655**	.454	-.245	.234	-.092
Conners Block 3 no-go Error	-.209	.112	**.482**	.468	-.173	.203
ANT Orienting	-.035	-.460	**.479**	.134	.183	-.042
ANT Alerting	.018	-.252	.429	-.333	.347	.423
Conners Block 1 no-go Error	-.215	.038	.358	**.598**	.092	-.115
Conners Block 2 no-go Error	-.282	.161	.321	**.542**	-.085	.272
Stroop Incongruency Loss	.405	.062	-.259	.427	-.151	.021
Visual Search Distracter Slope	.446	.119	-.344	.249	**.597**	-.112
Visual Search Feature Slope	.367	.122	-.402	.429	.432	.108
Dual Task Error	.009	-.105	.338	.085	.027	**-.763**
Eigen Value	3.55	2.44	1.71	1.58	1.53	1.16
% of Varience Explained	19.71	13.58	9.49	8.78	8.51	6.44

Bold = High Loading

Rotated PCA Component Matrix without Conners' CPT for the Young Age Group (N=35)

	Component				
	1	2	3	4	5
CPT Block 2 RT	**.890**	.062	.020	.003	-.215
CPT Block 1 RT	**.873**	-.047	.060	.138	.058
RT-2 RT	**.761**	.057	.237	-.203	.143
CPT Block 3 RT	**.723**	.218	-.121	.174	-.062
Dual Task RT	.435	.193	.282	-.265	.432
Trails A Time to Complete	.034	**.977**	-.019	.020	.008
Trails B Time to Complete	.134	**.932**	.210	.041	.024
ANT Orienting	.217	-.081	**-.819**	-.122	.117
Visual Search Feature Slope	.436	.163	**.663**	.001	.092
Visual Search Distracter Slope	.398	-.019	**.512**	.136	.291
ANT Conflict	-.176	.033	.331	**.751**	.097
ANT Alerting	.140	-.142	-.237	**.733**	-.117
Stroop Incongruency Loss	.166	.332	.245	**.638**	.045
Dual Task Error	-.236	-.132	-.145	.036	**.867**
Dual Task RMS Error	.182	.284	.348	.013	**.499**
Eigen Value	3.43	2.18	1.94	1.71	1.39
% of Variance Explained	22.86	14.54	12.92	11.37	9.29

Bold = High Loading

Rotated PCA Component Matrix without Conners' CPT for the Middle Age Group (N=38)

	Component				
	1	2	3	4	5
CPT Block 3 RT	**.816**	.418	-.007	-.037	.027
Dual Task RT	**.790**	-.156	.030	-.261	-.099
CPT block 2 RT	**.771**	.486	.085	-.016	-.236
CPT Block 1 RT	**.765**	.441	-.090	.158	-.086
ANT Conflict	**.670**	-.066	.273	-.137	.447
Dual Task RMS Error	**.560**	-.393	.317	-.354	.211
RT-2 RT	**.495**	.152	-.107	-.306	-.035
Trails A Time to Complete	.437	**-.784**	-.152	.264	-.094
Trails B Time to Complete	.548	**-.778**	-.056	.170	-.065
Stroop Incongruency Loss	-.168	.309	**.722**	.031	-.079
Dual Task Error	.121	.024	**-.611**	.011	.444
ANT Alerting	.244	.200	**-.488**	.030	-.451
ANT Orienting	.169	.329	-.444	.441	.357
Visual Search Feature Slope	.208	.161	.480	**.575**	.283
Visual Search Distracter Slope	.310	-.194	.206	**.529**	-.309
Eigen Value	3.52	2.47	1.71	1.54	1.46
% of Variance Explained	23.46	16.45	11.38	10.3	9.7

Bold = High Loading

Rotated PCA Component Matrix without Conners' CPT for the Old Age Group (N=32)

	Component				
	1	2	3	4	5
CPT Block 3 RT	**.962**	-.025	-.002	.061	.055
CPT Block 2 RT	**.901**	-.016	-.132	.068	.290
CPT Block 1 RT	**.755**	-.003	.037	.266	.421
RT-2 RT	**.650**	.094	.165	.129	-.156
Dual Task RT	**.633**	.077	.139	.260	**-.500**
Trails B Time to Complete	.081	**.919**	-.171	.196	.034
Trails A Time to Complete	-.012	**.913**	-.176	.142	-.011
Visual Search Distracter Slope	.035	-.237	**.791**	.188	.090
Visual Search Feature Slope	-.050	-.075	**.790**	.209	-.138
Dual Task Error	-.229	.143	**-.682**	.443	.054
Stroop Incongruency Loss	.109	.003	.164	**.750**	.047
ANT Conflict	.211	.174	.276	**.711**	-.051
Dual Task RMS Error	.226	.204	-.262	**.575**	-.072
ANT Orienting	.173	-.082	.004	.072	**.810**
ANT Alerting	.000	**.483**	-.081	-.145	**.637**
Eigen Value	3.33	2.09	2.02	1.92	1.64
% of Variance Explained	22.21	13.93	13.46	12.81	10.94

Rotated PCA Component Matrix Including Conners' CPT for the Young Age Group (N=35)

	Components						
	1	2	3	4	5	6	7
CPT Block 1 RT	**.875**	-.031	.022	.029	.160	.010	-.063
CPT Block 2 RT	**.855**	.048	-.099	.188	.043	-.202	.222
RT-2 RT	**.798**	.017	.050	.036	-.287	-.044	-.193
CPT Block 3 RT	**.690**	.240	-.070	.130	.245	-.132	-.112
Visual Search Feature Slope	**.537**	.162	.430	-.129	-.239	.226	.314
Dual Task RT	**.502**	.197	.047	-.092	-.340	.351	-.102
Visual Search Distracter Slope	**.491**	.027	.364	-.189	-.008	.439	.284
Trails A Time to Complete	.028	**.987**	.022	.029	-.028	-.020	.024
Trails B Time to Complete	.168	**.932**	.196	-.023	-.082	.004	.063
ANT Conflict	-.127	.010	**.746**	.142	.380	.026	-.160
ANT Orienting	.068	-.054	**-.738**	.329	.206	.085	-.052
Stroop Incongruency Loss	.156	.269	**.614**	.387	.178	-.046	.063
Dual Task RMS Error	.235	.198	.399	.239	-.398	.233	-.328
Conners Block 2 no-go Error	.119	.096	.031	**.854**	-.090	.111	-.014
Conners Block 3 no-go Error	-.007	-.236	-.057	**.710**	.234	-.329	.336
ANT Alerting	.102	-.046	.118	.034	**.869**	.038	.050
Dual Task Error	-.219	-.066	-.087	.035	.039	**.891**	-.153
Conners Block 1 no-go Error	-.069	.086	-.016	.139	.061	-.112	**.862**
Eigen Value	3.6	2.16	2.04	1.71	1.55	1.42	1.32
% of Varience Explained	19.99	12.01	11.33	9.48	8.61	7.89	7.33

Bold = High Loading

Rotated PCA Component Matrix Including Conners' CPT for the Middle Age Group (N=38)

	Component					
	1	2	3	4	5	6
CPT Block 2 RT	**.937**	-.006	.124	-.044	-.075	.033
CPT Block 1 RT	**.881**	.077	.052	-.034	.181	.135
CPT Block 3 RT	**.856**	.004	.272	-.126	.131	.108
Dual Task RT	**.554**	.415	**.507**	.140	-.070	-.155
Trails A Time to Complete	-.051	**.925**	.142	-.086	.151	-.040
Trails B Time to Complete	.016	**.917**	.287	-.069	.086	-.030
Visual Search Distracter Slope	.256	**.553**	-.228	.191	-.184	.277
Dual Task RMS Error	.129	.342	**.706**	-.179	-.207	.015
ANT Conflict	.317	.138	**.670**	-.307	.048	.311
RT-2 RT	.384	-.050	**.532**	.356	.155	-.150
Conners Block 1 no-go Error	.154	.135	-.161	**.807**	-.063	.098
Conners Block 3 no-go Error	-.306	-.060	.394	**.650**	.358	.033
Conners Block 2 no-go Error	-.246	-.176	-.111	**.591**	.093	-.146
ANT Orienting	.213	-.105	-.135	.116	**.708**	.292
Stroop Incongruency Loss	.074	-.280	-.084	.205	**-.653**	.381
Dual Task Error	.067	.047	.007	.123	**.624**	-.104
Visual Search Feature Slope	.136	.042	.024	-.089	-.018	**.846**
ANT Alerting	.406	.026	-.243	-.223	.294	-.422
CPTblock2RT	3.44	2.47	2.01	1.89	1.74	1.42
CPTblock1RT	19.13	13.7	11.18	10.51	9.65	7.89

Bold = High Loading

Rotated PCA Component Matrix Including Conners' CPT for the Old Age Group (N=32)

	Components						
	1	2	3	4	5	6	7
CPT Block 3 RT	**.947**	-.044	-.054	-.041	.088	-.074	-.117
CPT Block 2 RT	**.930**	-.098	-.123	-.070	.048	.033	.152
CPT Block 1 RT	**.817**	-.114	.068	-.017	.233	.106	.284
RT-2 RT	**.623**	.141	.213	-.290	.036	.009	-.143
Conners Block 3 no-go Error	-.189	**.802**	.207	.126	-.093	-.130	-.069
Trails B Time to Complete	.123	**.766**	-.207	-.008	.174	.359	.183
Trails A Time to Complete	-.013	**.763**	-.308	-.059	.238	.226	.170
Visual Search Feature Slope	-.024	.076	**.895**	.015	.090	-.071	-.151
Visual Search Distracter Slope	.042	-.311	**.797**	-.184	.203	-.071	.112
Conners Block 1 no-go Error	-.278	.061	-.117	**.861**	-.019	.029	-.032
ANT Orienting	.325	-.110	-.052	**.602**	.178	-.178	**.540**
Conners Block 2 no-go Error	-.268	.167	.090	**.588**	-.193	**.538**	-.157
Stroop Incongruency Loss	.113	.068	.070	.152	**.843**	-.023	-.084
ANT Conflict	.177	.091	.189	-.222	**.789**	.157	-.042
Dual Task Error	-.155	.010	-.366	-.124	.089	**.785**	.167
Dual Task RMS Error	.352	.252	.114	.154	.104	**.695**	-.153
ANT Alerting	.104	.365	-.081	-.119	-.125	-.009	**.803**
Dual Task RT	**.517**	.211	.016	-.238	.332	-.154	**-.569**
Eigen Value	3.6	2.26	1.9	1.78	1.76	1.7	1.59
% of Varience Explained	19.98	12.54	10.57	9.86	9.77	9.42	8.81

Bold = High Loading

Combined Groups PCA Without Conners' CPT using Promax Oblique Rotation

	Component				
	1	2	3	4	5
CPT Block 2 RT	**.883**	.145	.186	.018	.001
CPT Block 1 RT	**.871**	.206	.323	.040	.086
CPT Block 3 RT	**.870**	.202	.143	.113	.039
RT-2 RT	**.680**	.292	.330	.469	-.018
Dual Task RT	**.655**	**.547**	.111	**.529**	-.123
Trails B Time to Complete	.262	**.955**	.127	.203	-.086
Trails A Time to Complete	.116	**.890**	.064	.062	.005
Dual Task RMS Error	.447	**.636**	.160	**.561**	-.282
ANT Conflict	.409	.444	.289	.396	-.175
Visual Search Distracter Slope	.266	.221	**.843**	.216	-.038
Visual Search Feature Slope	.219	.109	**.837**	.292	-.192
ANT Alerting	.114	.032	-.077	**-.669**	.038
Stroop Incongruency Loss	.346	.134	.391	**.538**	-.110
Dual Task Error	.031	.028	-.060	-.017	**.882**
ANT Orienting	.160	-.212	-.075	-.476	**.550**
CPTblock2RT	3.91	2.92	1.99	2.13	1.27
CPTblock1RT	28.7	13.89	11.47	7.15	6.89

Bold = High Loading

Combined Groups PCA Including Conners' CPT Using Promax Oblique Rotation

	Component					
	1	2	3	4	5	6
CPT Block 2 RT	**.863**	.136	-.118	.168	-.010	-.053
CPT Block 1 RT	**.860**	.196	-.141	.291	.012	-.028
CPT Block 3 RT	**.858**	.194	-.152	.100	.084	-.061
RT-2 RT	**.692**	.294	-.074	.246	.455	-.153
Dual Task RT	**.664**	**.544**	-.168	.035	**.517**	-.215
Trails B Time to Complete	.275	**.953**	-.009	.078	.221	-.165
Trails A Time to Complete	.126	**.887**	-.037	.043	.080	-.026
Dual Task RMS Error	.468	**.635**	-.048	.062	**.571**	-.469
ANT Conflict	.440	.448	-.123	.143	.400	-.441
Conners Block 2 no-go Error	-.211	-.072	**.737**	-.043	-.052	-.006
Conners Block 3 no-go Error	-.107	.000	**.736**	-.178	-.086	.080
Conners Block 1 no-go Error	-.141	-.113	**.679**	.123	-.100	.367
Visual Search Distracter Slope	.267	.215	-.169	**.843**	.213	-.068
Visual Search Feature Slope	.233	.111	.021	**.798**	.302	-.258
ANT Alerting	.101	.037	-.005	-.106	**-.659**	-.005
Stroop Incongruency Loss	.376	.125	.115	.347	**.527**	-.265
ANT Orienting	.164	-.221	.301	-.039	**-.501**	.448
Dual Task Error	.048	.022	.076	-.053	-.059	**.760**
Eigen Value	4.03	2.92	1.79	1.75	2.25	1.58
% of Variance Explained	24.53	11.65	10.03	8.68	5.98	5.64

Bold = High Loading

APENDEX F

VARIABLE CORRELATION MATRIX

	RT-2 RT	Stroop	Trails A	Trails B	Visual Feature
RT-2 RT	1.00	--	--	--	--
Stroop Incongruency Loss	.304	1.00	--	--	--
Trails A Time to Complete	.082	-.001	1.00	--	--
Trails B Time to Complete	.237	.096	**.927**	1.00	--
Visual Search Feature Slope	.255	.241	.029	.079	1.00
Visual Search Distracter Slope	.313	.224	.128	.186	**.473**
ANT Alerting	-.064	-.162	.062	.061	-.153
ANT Orienting	-.057	-.050	-.065	-.110	-.141
ANT Conflict	.192	.323	.185	.298	.218
Dual Task RT	**.500**	.224	.304	**.411**	.138
Dual Task Error	.064	-.047	.054	.014	-.096
Dual Task RMS Error	**.399**	.250	.310	**.489**	.185
CPT Block 1 RT	**.468**	.271	.103	.195	.236
CPT Block 2 RT	**.502**	.165	.050	.143	.125
CPT Block 3 RT	**.461**	.152	.081	.169	.131
Conners' Block 1 no-go Errors	-.158	.077	-.004	-.021	-.023
Conners' Block 2 no-go Errors	-.143	-.052	-.049	-.006	-.030
Conners' Block 3 no-go Errors	.012	-.055	.022	.023	-.011

Bold = Significant Correlations

	Visual Distracter	ANT Alerting	ANT Orienting	ANT Conflict	Dual RT
RT-2 RT	--	--	--	--	--
Stroop Incongruency Loss	--	--	--	--	--
Trails A Time to Complete	--	--	--	--	--
Trails B Time to Complete	--	--	--	--	--
Visual Search Feature Slope	--	--	--	--	--
Visual Search Distracter Slope	1.00	--	--	--	--
ANT Alerting	-.083	1.00	--	--	--
ANT Orienting	-.074	.181	1.00	--	--
ANT Conflict	.216	.033	-.067	1.00	--
Dual Task RT	.205	-.121	-.078	.369	1.00
Dual Task Error	-.023	.026	.158	-.001	.006
Dual Task RMS Error	.180	-.072	-.180	**.419**	**.458**
CPT Block 1 RT	.253	.192	.178	.252	**.422**
CPT Block 2 RT	.192	.159	.177	.166	**.438**
CPT Block 3 RT	.147	.078	.171	.330	**.487**
Conners' Block 1 no-go Errors	-.033	-.055	.142	-.204	-.103
Conners' Block 2 no-go Errors	-.103	-.061	.097	-.148	-.227
Conners' Block 3 no-go Errors	-.211	.089	.136	-.025	-.061

Bold = Significant Correlations

	Dual Error	Dual RMSE	CPT Block 1	CPT Block 2	CPT Block 3
RT-2 RT	--	--	--	--	--
Stroop Incongruency Loss	--	--	--	--	--
Trails A Time to Complete	--	--	--	--	--
Trails B Time to Complete	--	--	--	--	--
Visual Search Feature Slope	--	--	--	--	--
Visual Search Distracter Slope	--	--	--	--	--
ANT Alerting	--	--	--	--	--
ANT Orienting	--	--	--	--	--
ANT Conflict	--	--	--	--	--
Dual Task RT	--	--	--	--	--
Dual Task Error	1.00	--	--	--	--
Dual Task RMS Error	-.044	1.00	--	--	--
CPT Block 1 RT	.090	.272	1.00	--	--
CPT Block 2 RT	-.013	.239	**.810**	1.00	--
CPT Block 3 RT	.047	.250	**.727**	**.778**	1.00
Conners' Block 1 no-go Errors	.102	-.126	-.105	-.069	-.108
Conners' Block 2 no-go Errors	.004	.026	-.176	-.165	-.192
Conners' Block 3 no-go Errors	.092	-.110	-178	-.139	-.136

Bold = Significant Correlations

	Conner's Block 1	Conner's Block 2	Conner's Block 3
RT-2 RT	--	--	--
Stroop Incongruency Loss	--	--	--
Trails A Time to Complete	--	--	--
Trails B Time to Complete	--	--	--
Visual Search Feature Slope	--	--	--
Visual Search Distracter Slope	--	--	--
ANT Alerting	--	--	--
ANT Orienting	--	--	--
ANT Conflict	--	--	--
Dual Task RT	--	--	--
Dual Task Error	--	--	--
Dual Task RMS Error	--	--	--
CPT Block 1 RT	--	--	--
CPT Block 2 RT	--	--	--
CPT Block 3 RT	--	--	--
Conners' Block 1 no-go Errors	1.00	--	--
Conners' Block 2 no-go Errors	.303	1.00	--
Conners' Block 3 no-go Errors	.293	.337	1.00

Bold = Significant Correlations

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