Evaluating the Attention Network Test and its Ability to Detect Cognitive Decline

Stephanie Campbell

Lakehead University

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Supervisor: Dr. Michel Bédard

Internal Examiner: Dr. Michael Stones

External Examiner: Dr. Carlos Zerpa

Abstract

The current study involved an evaluation of the Attention Network Test (ANT) as a neurocognitive tool for assessing fitness to drive in the senior population. The ANT measures three distinct functions of attention: alerting, orienting and executive control. This test has been successfully utilized in a variety of clinical and research settings. Few studies have applied the ANT to driving research and none have examined the psychometric properties of the ANT over multiple time points. The participants in this study were senior drivers from the Candrive study. Overall, the ANT was found to have strong psychometric properties. Specifically, the ANT has good test-retest reliability demonstrated high convergent and divergent validity with other commonly used measures (i.e., MoCA, MMSE, Trails A and B, MVPT-3 and SIMARD-MD). In our sample, only Trails A, the SIMARD-MD and alerting scores showed significant change over time. Although the ANT was not *more* sensitive to cognitive decline as predicted, the cognitive changes were not redundant with other neurocognitive assessment tools. This high functioning sample of seniors coupled with only three annual measurement points may have limited our ability to detect drastic cognitive decline. Nonetheless, the current study provided valuable insight into the utility of a test of attentional processes, the Attention Network Test.

For the majority of Canadians, driving is a part of everyday life. Investigating the factors surrounding safe driving practices will continue to be a major public health concern. The types of driver safety concerns vary as people age. For example, initiatives to reduce texting and driving target younger populations, while screening for cognitive fitness to drive is most appropriate for older drivers. This latter concern is growing in importance as the number of older drivers continues to increase. In 2009, 3.25 million Canadian seniors aged 65 and older had their drivers licence (Statistics Canada, 2009). This number equates to 75% of Canadian seniors currently driving. As the baby boomers age and life expectancy increases, the number of older drivers will continue to rise. In fact, this population represents the fastest growing segment of Canadian drivers. By 2040, the number of older drivers is expected to double (CAOT, 2009). Hence, research needs to address the best methods for screening and assessing fitness to drive. These research initiatives will help ensure that every preventative measure is taken to protect the health of our seniors and population as a whole.

Unfortunately, as people age, they are more likely to be fatally injured in a car crash (Bédard et al, 2002). Car crashes are the leading cause of preventable death for seniors aged 65-75 (CAOT, 2009). This observation can be partially explained by the increased risk of death due to frailty and weakened ability to recover from serious injuries (Dickerson, Meuel, & Ridenour, 2014; O'Neill, Bruce, Kirby, & Lawlor, 2000). Another important contributor is the increased risk of car crashes due to physical and cognitive changes associated with aging. Age related health conditions such as stroke, Parkinson's, Alzheimer's, and even chronic conditions such as diabetes can reduce individuals' ability to drive safely (Korner-Bitensky, Menon, Von Zweck, & Van Benthem, 2010). Investigating how age-related changes are linked to unsafe driving behaviours has been a recent topic of interest in the driving literature (Barrash et al., 2010;

Bédard, Weaver, Darzins, & Porter, 2008; O'Neill et al., 2000). Knowledge of these associations can allow for the development of specific tools to screen for and assess potential risks to driver safety.

It is important to note that age alone should not be used as a discriminating factor in determining fitness to drive. Decisions related to driving need to be determined by assessing one's functional ability, which highlights the importance of tools that are *comprehensive* and *valid* in risk assessment (Barrash et al., 2010; Dickerson et al., 2014). In the senior population, driving has been linked to health, well-being, community participation and personal autonomy (Canadian Association of Occupational Therapists, 2009; Zur & Vrkljan, 2014). The cost of making incorrect classifications can be detrimental to older individuals' quality of life. In order to maximize the accuracy in classifying seniors as fit or unit to drive, all screening and assessment tools must be critically evaluated.

Screening and Assessing for Fitness to Drive

As can be seen in society, many older drivers can maintain safe driving behaviors or are able to independently identify when they should stop driving. However, for many individuals there is a grey area in which the ability to operate a motor vehicle safely is questionable due to physiological or cognitive changes. Cognitive impairment is common among the elderly with one in seven people over the age of 71 suffering from some degree of impairment (Plassman et al., 2007). Not only does this directly affect the ability to drive safely, but impairment also threatens the ability of seniors to make reliable judgments regarding their own driving competence (Dickerson et al., 2014).

An important consideration, especially with older drivers, is the *degree* of cognitive impairment. Fitten and colleagues (1995) argue that the degree of impairment is a better indicator of crash risk than any specific diagnosis. Investigating how varying degrees of cognitive impairment relate to safe and unsafe driving behaviour is a main objective for driving researchers. Understanding these associations and establishing valid cut points for neurocognitive assessment tools is the foundation for screening and assessing fitness to drive.

In reference to driving, screening can be defined as a quick examination of one's driving specific skills with the intention of separating those who are likely safe drivers, from those who require further assessment (Korner-Bitensky et al., 2010). A driving evaluation, on the other hand, is a more comprehensive process than screening and involves more extensive consideration of all physical and cognitive skills relevant to driving. This process may also involve further exploration of any problem areas identified through screening (Korner-Bitensky et al., 2010).

In Canada, the licensing of medically at-risk drivers falls under provincial legislation, resulting in varied policies and procedures across the provinces (Zur & Vrkljan, 2014). Currently in Ontario, occupational therapists (OTs) are responsible for performing comprehensive driving evaluations (CDEs) which are quite extensive and involve both in-office and on-road assessments. According to recent statistics, only 18 out of 5,841 registered occupational therapists declared their main practice area to be driver evaluation and training (Canadian Association of Occupational Therapists, 2011). Even more alarming was that in a survey evaluating the current OT training programs in Canada, chairs admitted that "all of the programs, including those in Quebec, felt graduates did not have the skills, knowledge and ability to perform the in-depth procedures involved with conducting a CDE" (Zur & Vrkljan, 2014, p.19).

For OTs to perform CDEs to the highest standard, researchers need to inform practice and training programs of the most appropriate tools for assessing fitness to drive. A major responsibility of researchers involves the development and validation of specific tools or tests that can be used to measure cognition and predict driving outcomes. Once these tools have been empirically validated and can inform best practice, this information can be assimilated into OT training programs.

Cognition and Driving

Driving is a complex task; one that requires integration of physical movement, perceptual information, and cognitive processes (Kwok, Gelinas, Benoit, & Chilingaryan, 2015; Mazer et al., 2004). The cognitive changes that occur as people age can be detrimental to one's ability to safely operate a motor vehicle. The relationship between cognitive impairment and crash risk has been well-established through previous research (Carr & Ott, 2010; Ferreira, Simões, & Marôco, 2012).

Reaction time on both simple and complex tasks increases steadily with age (Beck, 2008). This age-related decrease in speed of processing has been linked to performance on a variety of tasks (Salthouse, 2005). Therefore, processing speed can be best conceptualized as a core general ability that influences the decline of more specific cognitive abilities (Li et al., 2004). These declines in cognitive processing are inevitable as people age. However, these natural changes have been linked to driving behaviours in ways that make older drivers more susceptible to crash risk. For example, Sommer at al. (2008) found that reaction time and overall speed of processing were associated with performance on a standardized driving test. Similarly, reaction time was associated with hazard detection, or the "the ability of individuals to anticipate potentially dangerous situations on the road ahead" (Horswill et al., 2008, p.212). Findings such as these highlight the importance of accurately assessing cognitive functioning in comprehensive driving evaluations.

In addition to the generalized factors such as speed of processing, there are more specific processes such as attention that have been linked to driving ability. In fact, Sommer et al. (2008) measured a large number of cognitive and personality variables and found attention to be one of the best predictors of individual driving performance.

Attention and Driving

Even in the earliest cognitive investigations, researchers were able to demonstrate that people actually fail to see objects that are right in front of them due to a lack of attention. This term has been appropriately labelled inattentional blindness (Mack & Rock, 1998; Reisberg, 2010). Taken from these findings, Mack and Rock (1998) have made the strong argument that "no *conscious* perception can occur without attention" (p.14). From this perspective, attention is the foundation for all information that is consciously perceived and used to guide behaviour.

There is a need to emphasize the importance of attention in the act of safe driving. More recently, the widespread usage of cell phones while driving has initiated a surge of research indicating that decreased attention to the road (due to cell phone use) can produce a significant increase the likelihood of crashing or committing other unsafe acts (Lamble, Kauranen, Laakso, & Summala, 1999; Strayer, Drews, & Johnston, 2003; Strayer & Drews, 2007). Researchers found that drivers who were texting and driving were 23 times more likely to be involved in a crash, or near crash than drivers who were not texting (Virginia Tech Transportation Institute, 2010). This alarming statistic has inspired national ad campaigns and triggered the implementation of distracted driving laws across North America.

Texting and driving relates to the principle of divided attention. There are limited cognitive resources available to perform any mental task. Therefore, when an individual is attempting to perform multiple tasks at the same time, there is competition for resources (i.e., attention) that must be divided between the two tasks. If the cognitive "demand" exceeds the "supply", performance on one or both tasks will be negatively affected. Divided attention therefore refers to your ability to perform multiple tasks simultaneously (Reisberg, 2010). The complexity of the task and the available cognitive resources determine the limits of divided attention.

Selective attention, on the other hand, refers to the ability of one to actively attend to one source of information and ignore another (Reisberg, 2010). A classic experiment testing this concept involves playing two verbal messages at the same time, one into each ear. Initially, neither message can be understood but if an individual chooses to listen only to the message in the left ear and tune out the message on the right, the verbal message can be heard clearly (Cherry, 1953). These results demonstrate the power of selective attention. Selective attention has been found to correlate significantly with driving performance in a standardized driving test (Sommer et al., 2008). Since the earliest investigations, researchers have suggested that selective attention is the type of attention most relevant to the act of driving; performing this complex task safely requires constant multi-tasking and selection between competing sources of information (Sussman, Bishop, Madnick, & Walter, 1982).

In order to drive safely, one must be able to attend to important information, filter out irrelevant information, manage competing demands on attention and also sustain attention for as long as required by the length of the drive. Therefore, attention is central to the integration of visual information, resulting in appropriate behavioural responses such as slowing for a red light, or moving over to avoid a cyclist.

Researchers investigating how attention is affected by the aging process have found some clear patterns of deterioration. For example, as people age they are less able to perform complex tasks simultaneously, and switch back and forth between mental operations. These observations are linked to a decrease in the amount of information that can be actively attended to at one time (Kray, Li, & Lindenberger, 2002; Radvansky, Zacks, & Hasher, 2005). The cognitive slowing of older individuals, as indicated by increased reaction times on an attention task, were related to more self-reported attention lapses while driving compared to younger drivers (López-Ramón, Castro, Roca, Ledesma, & Lupiañez, 2011).

The ability to ignore irrelevant information, also called inhibition, has been shown to decrease as people age making them more distractible (Berk, 2008). For example, on a continuous performance task, participants are shown a series of letters and are asked to hit the spacebar only after a particular sequence of letters is displayed (e.g., only when the letter B is presented immediately after the letter U). As individuals age, they are more likely to make errors of commission (i.e., pressing the space bar after incorrect letter sequences). Older individuals are also more likely to make errors of omission (i.e., failing to press the spacebar after a U-B sequence) when extraneous noise is introduced. (Mani, Bedwell & Miller, 2005). This finding has clear implications for driving, suggesting that older drivers may be more susceptible to the effects of distraction. Inhibitory difficulties may make older drivers more susceptible to distraction by passengers, construction, or the environment which can increase the risk of accidents or driving infractions.

In order to reliably measure individual differences in attention, there needs to be an established theory of attention that can guide the development of specific tools. One widely accepted theory is that of the human attention network.

Human Attention Network (HAN) Model

This model of attention was developed by Posner and colleagues (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Fan, McCandliss, Sommer, Raz, & Posner, 2002; Macleod et al., 2010; Posner, 1990). This group of researchers mapped out three independent neural networks in the brain that correspond to different functions of attention. Through imaging studies, it has been shown that each network has its own function and corresponding anatomical locations in the brain (Corbetta, Kincade, Ollinger, McAvoy & Shulman, 2000; Fan, Wu, Fossella & Posner, 2001; Fan et al., 2005; Neuhaus et al., 2007; Reuda, Rothbart, McCandliss, Saccomanno & Posner, 2005). In response to this research, the HAN model was developed and has allowed psychologists and neurologists to identify three distinct functions of attention: alerting, orienting and executive control.

Alerting is the ability to be aware of incoming stimuli and devote attentional resources to processing this information. Alerting can be thought of as a readiness to respond. Orienting is the ability to shift attention spatially and select the relevant sensory information. Lastly, executive control reflects the ability to deal with competing or conflicting demands on attention (Fan et al., 2002; Macleod et al., 2010; Weaver, Bédard, & McAuliffe, 2013). The HAN model has received strong empirical support, is highly reliable, and has demonstrated functional independence of the three individual attention processes (Fan et al., 2002). Table 1 summarizes the findings of neuroimaging research that has identified separate brain structures and neurotransmitters that correspond with each function of attention (Weaver et al., 2009).

Table 1 Physical Structure and Neurotransmitters associated with Attention Networks

Function	Brain Structures	Primary Neurotransmitter
Alerting	Locus coruleus Right frontal cortex Parietal cortex	Norepinephrine
Orienting	Superior parietal lobe Temporal-parietal junction Frontal eye fields Superior colliculus	Acetylcholine
Executive Control	Anterior cingulate cortex Lateral ventral cortex Prefrontal cortex Basal ganglia	Dopamine

Note: Adapted from Weaver et al. (2009)

Using the HAN model, clinicians and researchers have advanced knowledge about how attentional systems develop in the brain and how attention deficits relate to neurological or genetic disorders (Macleod et al., 2010).

The Attention Network Test (ANT)

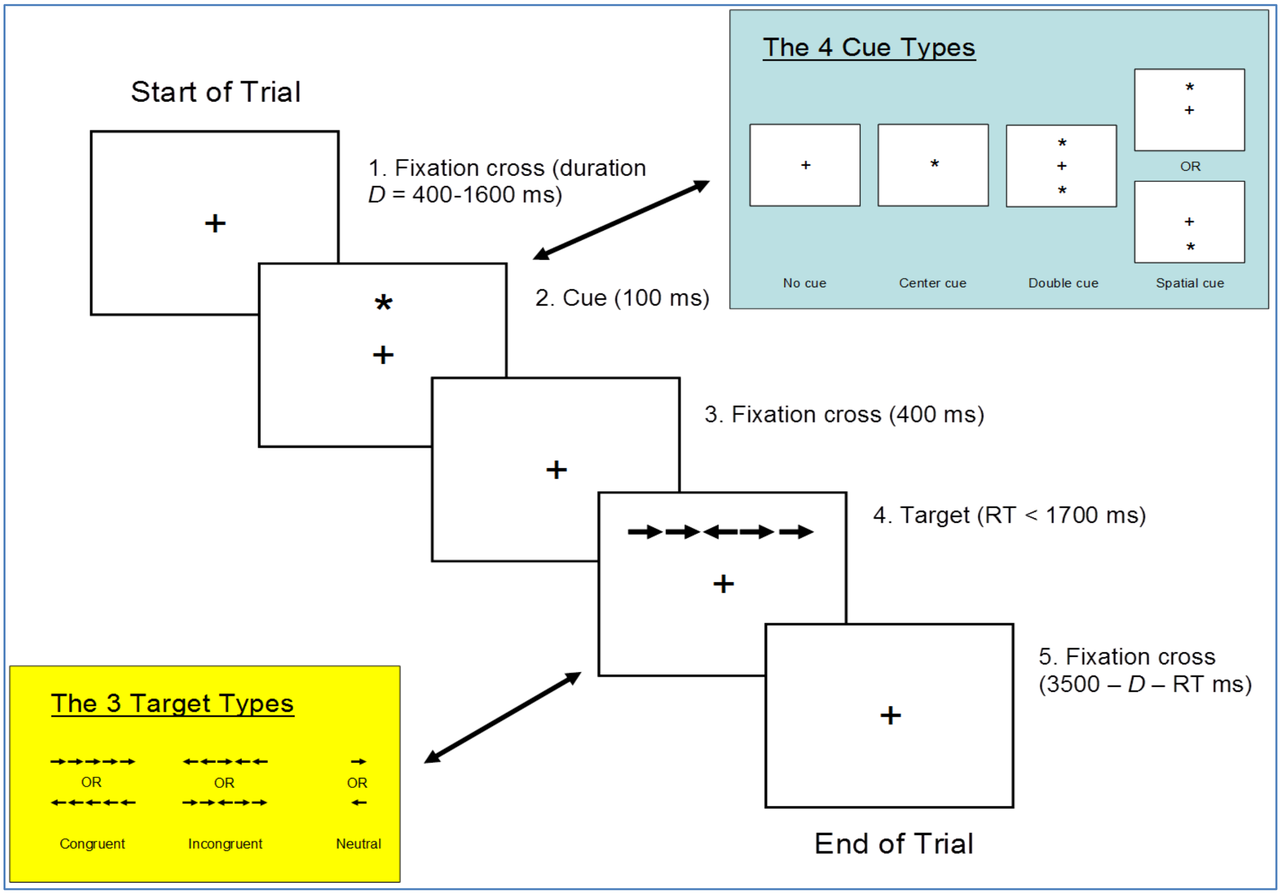
In order to reliably assess and separate the three distinct functions of attention from the HAN model, researchers utilize the Attention Network Test (ANT). This test was developed by combining elements of Posner's (1980) spatial cuing task and Eriksen's (1974) flanker task**.**

In the ANT, each trial begins with a fixation cross displayed in the middle of screen for variable intervals, ranging from 400-1600 ms. Next, one of four possible cues is presented on the screen for 100 ms, followed again by the fixation cross for 400 ms. The next screen involves presentation of the target arrow from one of three possible conditions. This screen remains for 1700 ms or until the participant makes a response indicating the direction of the target arrow (left/right). Finally, the fixation cross is presented again between trials (Jennings, Dagenbach, Engle, & Funke, 2007).

The types of cues that are presented can be informative to the participants. The three types of temporally informative cues are: centre cue, double cue, or spatial cue. The centre cue appears directly in the middle of the screen and alerts participants that the target will soon appear but does not provide any information as to where. This cue condition is used to calculate orienting scores because the central cue causes participants to orient attention to *one* specific location. The double cue involves two asterisks in the middle of the screen, one directly above and below the middle fixation point. Similar to the centre cue, this condition alerts participants that the target will be presented but does not guide participants' attention to an informative location. The main difference between centre cue and double cue is that the double cue causes participants to split their attention between both locations in which the target may appear (i.e. upper and lower areas of the screen). Therefore, it is double cue that is used in calculating alerting scores to separate the benefits of alerting and orienting attention. Lastly, spatial cues are the most informative because these cues alert participants but also direct them to the correct location of the target (i.e., where on the screen it will be presented). Some trials are not cued and therefore are uninformative temporally. In total there are four different conditions for cue presentation.

Target presentation involves three different conditions: congruent (flanker arrows in the same direction as the target), incongruent (flanker arrows in the opposite direction of the target) or neutral (no flanker arrows). The various combinations of conditions (cue type and target type) allow for the functions of attention to be empirically tested separately (Jennings et al., 2007; Macleod et al., 2010; Weaver et al., 2013; Weaver, Bédard, McAuliffe, & Parkkari, 2009). Figure 1 visually depicts the various trial conditions of the ANT.

Figure 1



By comparing response times for the conditions relevant to each function of attention, scores can be obtained for alerting, orienting and executive functioning. For alerting, scores on the double cue condition are subtracted from the no cue condition. Alerting scores demonstrate the benefits of increasing participants' vigilance by making them more sensitive to incoming visual stimuli (i.e., the target). Orienting scores can be calculated using the difference in response times for centre cue and spatial cue trials. These scores represent the benefit of orienting participants spatially to the position where they should focus attention to prepare for target presentation. Lastly, executive control can be defined by the difference between congruent and incongruent trials averaged across cuing conditions. Executive functioning scores demonstrate how participants' performance can be compromised by the conflicting information of the incongruent arrows (Macleod et al., 2010; Weaver et al., 2013, 2009).

Since its introduction, the ANT has established utility for a wide variety of clinical and research purposes. The ANT has been used to assess attentional deficits for a range of psychological and genetic disorders to determine which specific attention networks have been affected by a particular disorder. For example, the ANT has been used in research pertaining to ADHD, borderline personality disorder, depression, dyslexia and schizophrenia (Adolfsdottir et al., 2008; Bish, Ferrante, McDonald-McGinn & Simon., 2005; Macleod et al., 2010; Murphy & Alexopoulos, 2006; Rogosch & Cicchetti, 2005; Wang et al., 2005).

Functions of Attention and Aging

Research into the influence of aging on the three attention networks is limited. Furthermore, the findings are mixed regarding the impact of aging on each attentional network (Gamboz, Zamarian, & Cavallero, 2010; Jennings et al., 2007; López-Ramón et al., 2011; Mahoney, Verghese, Goldin, Lipton, & Holtzer, 2010; Zhou, Fan, Lee, Wang, & Wang, 2011).

For alerting, one group of researchers found similar alerting effects for older and younger participants (Mahoney et al., 2010) . In both groups, alerting enhanced performance for congruent trials but not for incongruent trials. However, two independent groups of researchers found that alerting scores decreased in older participants, both before and after correcting for the generalized slowing that occurs with age (Gamboz et al., 2010; Jennings et al., 2007). On the other hand, Fernandez-Duque and Black (2006) found an increased alerting effect with age, suggesting that older adults benefit more from the alert due to their decreased ability to sustain attention. Methodological differences have been used to explain these inconsistencies. Specifically, the duration of cue presentation and cue type have been shown to interact with the age of participants, producing mixed findings (Jennings et al., 2007; Mahoney, Verghese, Dumas, Wang, & Holtzer, 2012; Zhou et al., 2011).

Researchers appear to agree that orienting is the function of attention that is least affected by aging. For all studies that were reviewed, the evidence suggests that young and old participants benefit equally from cues that orient them to the location in which a target will be presented (Gamboz et al., 2010; Jennings et al., 2007; Mahoney et al., 2010; Zhou et al., 2011).

Executive control is a higher order cognitive process which can be expected to be most compromised through aging. Jennings et al. (2007) first reported age differences; older adults were more negatively affected than younger adults for trials where the flanker arrows were incongruent with the target stimulus. However, when controlling for the age-related speed of processing deficits, the interaction between age and flanker disappeared. Two other groups of researchers also found reliable differences in executive control demonstrating that performance on incongruent trials was significantly worse for older participants. These findings can largely be attributed to the generalized slowing of responding and decreased cognitive capacity of the prefrontal cortex that occur with age (Mahoney et al., 2010; Zhou et al., 2011).

The Current Study

The current study sought to evaluate the psychometric properties of the ANT to both replicate previous findings and help settle any conflicting accounts in the literature. As MacLeod et al. (2010) suggested, one of the best ways to strengthen the confidence in results using ANT data is to obtain repeated measurements over time. In the literature, there are no existing studies that investigate the ANT over multiple measurement points. Therefore, the current study has made a unique contribution to the study of attention by validating the ANT as a useful tool for cognitive assessment.

Despite the fact that the ANT has been used extensively in both applied clinical and research settings for nearly a decade, some criticism in the literature does exist. Macleod et al.'s (2010) evaluation of psychometric properties highlighted the low reliability of ANT scores, particularly for the functions of alerting and orienting. For reaction time, the following split-half reliability estimates were found: for alerting (.20), orienting (.32) and executive control (.65). MacLeod et al. (2010) make an interesting point that perhaps alerting and orienting can be conceptualized as "state-like" whereas executive control is more "trait-like". This theory is consistent with the observed variation in patterns of reliability and studies of heritability. Executive control has been linked to genetic influences, whereas alerting and orienting have not (Fan, Wu, Fossella, & Posner, 2001; Posner, Rothbart, & Sheese, 2007). Therefore, executive control should be more consistent and produce more reliable scores over time, which is exactly what research has shown. Also in line with this theory, alerting scores have been found to fluctuate based on environmental cues such as time of day (Knight & Mather, 2013). This suggests alerting is a more variable, state-dependent function of attention.

Based on previous research, it was predicted that the test-retest reliability of the ANT scores will be in the moderate range (r = .5 to .7; *Hypothesis 1a*). High test-retest reliability was not anticipated considering participants are seniors whose cognitive capacities are changing over time at different rates. Lower test-retest reliabilities were hypothesized for alerting and orienting scores than for executive control scores (*Hypothesis 1b)*. This prediction was based on existing research that suggests executive control is more trait-like, whereas alerting and orienting are more state-like leading to greater variability in scores.

In order to assess the construct validity of the ANT, this study considered evidence of convergent and divergent validity. Correlations were calculated between ANT scores and scores for other cognitive assessment tools commonly used in driving research such as the: Mini-Mental State Exam (MMSE), Montreal Cognitive Assessment (MoCA), Trails A & B, Motor-free Visual Perception Test-3 (MVPT), and the Screen for the Identification of cognitively impaired Medically At-Risk Drivers- Modification of the DemTect (SIMARD-MD). It was predicted that ANT scores would correlate moderately ($r = |.20|$) with generalized cognitive assessment tools such as the MoCA, MMSE, and the SIMARD-MD (*Hypothesis 2a).* Correlations with generalized measures were considered as evidence for divergent validity because conceptually, the MMSE, MoCA and SIMARD-MD are tapping into a broad range of cognitive processes. Therefore, very strong associations are not anticipated between generalized tests of cognitive functioning and the ANT which measures a specific cognitive process, attention. Stronger correlations (i.e., $r = .30$-$.50$) were predicted between the ANT and Trail-Making Tests (TMT), and the ANT and MVPT (*Hypothesis 2b).* This hypothesis was based on the fact that the ANT, TMT and MVPT require related cognitive processes and focused attention for successful completion.

Researchers have argued that the attentional networks may not be as independent as Fan et al. (2002) claim (Macleod et al., 2010). Although each network has different anatomical locations in the brain and associated neurotransmitters, MacLeod et al. (2010) found that the networks do not operate independently of one another. These researchers utilized ANT data from 15 unique data sets and found significant inter-network correlations for both reaction times and error rates. The raw inter-network correlations that were found to be significant ranged from .06 to .33. After being corrected for attenuation, the correlations ranged from .13 to .72. However, these researchers note that with overlapping neural networks, complete independence is unlikely (Macleod et al., 2010). The current study evaluated the independence of the three functions in order to address this discrepancy in the literature. It was predicted that there will be little to no correlation (r = 0 to .2) between the scores for the three independent functions of attention (*Hypothesis 3).*

The literature contains conflicting accounts of how each function of attention is affected by the aging process. In the current study, rates of change for each function were calculated and compared using slopes of the regression lines. Based on previous findings and fundamental differences between the three distinct functions, it was predicted that executive function scores would be most affected by the aging process, followed by alerting, with orienting scores showing the smallest change over time (*Hypothesis 4).*

Lastly, this study assessed how sensitive the ANT is to cognitive decline, or change that occurs over time in senior drivers. Because the participants are older individuals being tested annually over a three-year period, the tests were expected to detect naturally occurring cognitive deterioration. If the ANT detected a rate of cognitive change comparable to other tools, this would provide evidence for the ANT's validity. If, however, the ANT was able to detect more cognitive deterioration than other tools, (i.e. having a steeper slope than the MoCA, MMSE, Trails, MVPT and SIMARD), then the ANT may have something unique to offer in terms of assessing cognition in older adults. It was predicted that the ANT would be sensitive enough to detect cognitive change that is occurring over time in a sample of older drivers (*Hypothesis 5).* In addition, the ANT was predicted to measure unique cognitive change that was not redundant with other assessment tools (*Hypothesis 6).* As suggested by Sommer et al. (2008), attention is one of the best cognitive predictors of driving performance. Therefore, capturing deterioration in attentional processes may have important implications for predicting fitness to drive. The ANT is a test that can be utilized to explicitly measure attention and maximize the accuracy of these important predictions.

Method

Participants

The current study used data collected as part of an ongoing longitudinal study called Candrive (Canadian Driving Research Initiative for Vehicular safety in the Elderly). Older drivers (minimum age 70) were assessed annually in one of the seven testing centres across Canada (Thunder Bay, Ottawa, Toronto, Montreal, Hamilton, Winnipeg and Victoria) from 2009-2016. Every year, participants provided researchers with a variety of information such as: demographics, health status, activities of daily living, driving habits, comfort levels and changes to driving behaviour. In addition to this information, participants completed a variety of physical and cognitive assessments. The portions of the annual assessment that are relevant to the current study are discussed below.

Measures

Montreal Cognitive Assessment (MoCA)

The MoCA is a generalized cognitive assessment tool that can be administered quickly and provides insight into a person's overall functioning. Administration of this measure takes only ten minutes. It is comprised of a variety of subtests including: visuospatial, naming, memory, attention, language, abstraction, delayed recall and orientation. The MoCA is scored out of a maximum 30 points, with higher scores reflecting higher functioning. This measure has strong psychometric properties with excellent test-retest reliability ($r = .92$, $p < .001$) and internal consistency (Cronbach's alpha = .83) (Nasreddine et al., 2005). The MoCA has high specificity and sensitivity in detecting mild cognitive impairment (Nasreddine et al., 2005; Smith, Gildeh,

& Holmes, 2007). An example of the MoCA score sheet used in Candrive assessments can be found in Appendix A.

Mini-Mental State Exam (MMSE)

The MMSE is another short measure used to provide an overall assessment of cognitive functioning. In this assessment, participants are asked basic orientation information such as the date/season/location. In addition, participants complete a number of tasks requiring basic skills such as reading, writing, spelling, drawing, memory and object identification. Completion of this assessment takes approximately 10 minutes. The MMSE is scored out of a maximum 30 points with higher scores reflecting higher functioning (Folstein, Folstein & McHugh, 1975). The MMSE has high test-retest reliability ($r = .90$, $p < .001$) and good internal consistency (Cronbach's alpha > .80) (Pangman, Sloan & Guse, 2000). An example of the MMSE score sheet used in Candrive assessments can be found in Appendix B.

Trail Making Tests A and B (TMT A/B)

Trail making tests are one of the most popular neuropsychological tests and are often a part of more comprehensive assessments (Tombaugh, 2004). The TMT originated as part of the Army Individual Test Battery (1944) and was later included in the Halstead-Reitan Battery (Reitan & Wolfson, 1985). Although this particular test is quite simple, it can provide professionals with an extensive amount of information such as visual ability, processing speed, attention deficits, and executive control (Tombaugh, 2004). The first portion, TMT-A requires the individual to connect a series of numbered dots that are randomly distributed on a sheet of paper. The participant must connect the dots in the correct order and their score represents the number of seconds required to do so. The second portion, TMT-B is similar but alternates between numbers and letters (i.e., the individual must connect in the order of 1, A, 2, B, 3, C, etc.). Clearly, this task is more mentally complex and again the score is the number of seconds required to complete the task correctly. Each version of the test takes less than five minutes to complete. Both Trails A and B were found to have adequate reliability and excellent validity in a recent investigation (Vrkljan, McGrath & Letts, 2010). Lower scores reflect a higher degree of cognitive function. Appendix C contains copies of TMT-A and TMT-B.

Motor-Free Visual Perception Test, 3rd edition (MVPT-3)

Visual perception has been defined as the ability to interpret, understand and define incoming visual information (Brown et al., 2012). The MVPT-3 is a short and easy to administer test of visual perception that can be used on people ages 4 - 84+ and requires no motor involvement to indicate responses. The authors assert that this tool is both reliable and valid (Colarusso & Hammill, 2003). This test takes 20-30 minutes to administer and requires the participant to view a target drawing and make specific visual and perceptual judgments based on the task. Participants are instructed to select the correct answer from four figures that are provided. This test encompasses five core visual perceptual skills: spatial relationships, visual discrimination, figure ground, visual closure and visual memory (Brown et al., 2012). The MVPT results have been associated with on road driving performance for older individuals and has demonstrated convergent validity with other measures (Brown et al., 2005; Oswanski et al., 2007). For the purposes of Candrive, only the visual closure subtest was administered which consisted of twelve items. Scores were recorded as the number of correct responses which higher scores reflecting higher cognitive functioning. Appendix D includes an example of one test item from the MVPT-3 visual closure subtest.

SIMARD-MD/DemTect

Originally developed in Germany, the DemTect has been successfully utilized to diagnose conditions such as mild cognitive impairment (MCI) and dementia (Kalbe et al., 2004). The DemTect contains five subtests and results in scores ranging from 0-18 with an extra point allotted for a lack of postsecondary education. The SIMARD-MD is a shorter version of the test that only retains three of the original five subtests included in the DemTect (Dobbs & Schopflocher, 2010). The three subtests assess number trans-coding, semantic verbal fluency, and delayed recall. The SIMARD-MD only takes 7 minutes to administer. Scores for the SIMARD-MD are determined using a scoring algorithm and range from 0-130, with higher scores indicating a higher degree of cognitive functioning (Bédard et al., 2013). A copy of the Demtect used in the Candrive annual assessment to calculate SIMARD-MD scores can be found in Appendix E.

ANT

The Attention Network Test (ANT) is a computerized response time (RT) task that measures the three primary functions of attention: alerting, orienting, and executive function (Fan et al., 2002). The ANT also provides a measure of overall reaction time. Several versions of the ANT have been programmed. In this study, we used the CRSD-ANT, and we present the overall median reaction time in order to minimize the influence of extreme outliers (Weaver et al., 2013). This test takes approximately 20 minutes so complete with lower scores (reaction times) indicating greater attentional capacities and cognitive functioning.

Procedure

For the current investigation, existing longitudinal data from the Candrive study was analyzed in order to address the research questions. The Candrive project finished this year with a total of seven years of data collection. However, the ANT was not added as a part of the annual assessment process until the third year in 2011 and was only administered in four sites (Ottawa, Thunder Bay, Toronto, and Victoria). Therefore, the data for this study involved only subset of the Candrive data. The three-year period during which participants completed all neurocognitive assessments, *including* the ANT will be considered for analysis.

Statistical Analyses

All data analysis was completed using IBM SPSS statistical software, version 23. In order to address the specific hypotheses in this investigation, bivariate correlational analyses were utilized in addition to multilevel models. Specifically, correlational approaches were used for the reliability estimates, construct validity analyses and the test of independence for function scores (*Hypotheses 1, 2, and 3).* In order to address the analyses of change, a series of multilevel models were constructed. Multilevel analysis represents best practice with longitudinal data because this dataset involves repeated measures of the same people over different times points. This methodology does not assume independence of cases. Therefore, multilevel analysis allows to control for nesting of data that occurs between participants and time. This methodology was employed to address the hypotheses related to rates of change and ANT sensitivity. (*Hypotheses 4, 5 and 6).*

The first step involved a number of unconditional growth models to determine if each assessment tool was detecting statistically significant change over time. The second set of models were calculated to determine if changes in the ANT (over time) were associated with changes in scores for the other assessment tools. For these models, each tool alternated as the dependent variable with the fixed effects being time (year), the intercept (DV's initial value), ANT baseline score and the interaction terms for ANT median reaction time and ANT baseline scores. The variance of random intercepts was included as a random effect.

The final set of analyses involved comparing the rates of cognitive decline detected using the various assessment tools. It was determined that the best way to compare the rates of change was to compare slopes. Before the slopes could be appropriately compared, the raw scores had to be converted into standardized scores. This step was critical because many of the tests involved different units of measurement (e.g., incremental points, milliseconds, differences scores). The Z-score conversions were calculated using means and standard deviations from the current sample of participants due to a lack of age-adjusted norms for most measures. In addition to converting all raw scores to Z-scores, some of the Z scores had to be re-coded in the opposite direction. This transformation resulted in a set of standardized scores which were all coded so that lower scores represented lower cognitive functioning. It was only with these new scores that valid slope comparisons could be made and easily interpreted.

Lastly, a series of multilevel models were constructed which allowed for the slopes to be calculated (in standardized Z-score units) and individual comparisons to be made between slopes for the ANT and each other measure. In addition, the slopes were compared for alerting, orienting and executive control to determine if the function scores were changing at significantly different rates.

Results

Participants

The final sample included 480 participants ranging in age from 72 to 92 (M = 77.78, SD = 4.40). The majority of participants were male (60.2%). The highest education level achieved ranged from grade school to post graduate education. The majority of participants had some post-secondary education in the form of a degree or diploma (38.1%) with high school education being the second highest level of attainment (23.3%). Descriptive statistics for all key variables can be found in Table 1.

Table 1

Descriptive Statistics for Key Study Variables

Variable	Year 3 *M* (*SD*)	Year 4 *M (SD)*	Year 5 *M (SD)*
MMSE	28.43 (1.34)	28.35 (1.43)	28.24 (1.41)
MoCA	26.02 (2.70)	26.14 (2.53)	25.89 (2.64)
Trails A	38.00 (10.97)	39.00 (12.66)	39.95 (11.49)
Trails B	93.70 (37.65)	93.09 (39.15)	95.48 (41.16)
MVPT	11.12 (1.67)	11.17 (1.66)	11.21 (1.71)
SIMARD-MD	74.48 (21.18)	73.12 (21.42)	70.35 (21.34)
ANT (median RT)	786.34 (79.21)	786.95 (83.07)	793.02 (85.79)
Alerting	11.55 (40.52)	16.75 (38.54)	19.01 (40.91)
Orienting	41.06 (49.55)	44.17 (47.84)	39.83 (43.64)
Executive Control	79.90 (38.55)	79.41(36.19)	83.26 (41.64)

Reliability and Validity of the ANT

To determine the reliability of the ANT scores and each independent function, test-retest reliability was calculated using bivariate correlations between each year of data. The ANT median reaction time scores were found to be reliable over time with correlations ranging from r = .67-.81, $p < .001$.

In order to evaluate the construct validity of the ANT, a correlation matrix was calculated to assess for convergent and divergent validity. Scores from the ANT were correlated with scores from other established neurocognitive assessment tools (i.e., the MMSE, MoCA, Trails A, Trails B, MVPT, and the SIMARD). At all three time points, the ANT correlated highest with Trails A and B with correlations ranging from $r = .17$ to $.35$, $p < .001$. This supports the hypothesis that the ANT would correlate highest with measures involving similar cognitive processing, particularly those that involve focused attention such as Trails A and B. The ANT did not demonstrate a consistent relationship with MVPT scores as predicted, $r = -.11$ to $-.16$, $p <.05$. The broad, generalized neurocognitive assessment tools (i.e., the MMSE, MoCA and SIMARD) consistently had the weakest correlations with the ANT, ranging from $r = -.01$ to $-.23$, $p < .05$. These results provide evidence for convergent and divergent validity of the ANT. The correlations between tests for each year of data are reported in Tables 2-4.

Table 2

Correlations among Neurocognitive Tests (Year 3 Data)

Variables	MMSE	MoCA	Trails A	Trails B	MVPT	SIMARD	ANT
MMSE	1	.34**	-.18**	-.23**	.19**	.37**	-.18**
MoCA		1	-.23**	-.36**	.19**	.35**	-.11*
Trails A			1	.45**	-.10*	-.24**	.17**
Trails B				1	-.24**	-.26**	.29**
MVPT					1	.16**	-.12*
SIMARD-MD						1	-.07
ANT (median RT)							1

Notes. $N = 396$ (Year 3), * $p < .05$, ** $p < .001$

Table 3

Correlations among Neurocognitive Tests (Year 4 Data)

Variables	MMSE	MoCA	Trails A	Trails B	MVPT	SIMARD	ANT
MMSE	1	.42**	-.20**	-.25**	.13*	.41**	-.09
MoCA		1	-.28**	-.38**	.24**	.41**	-.20*
Trails A			1	.39**	-.18**	-.24**	.35**
Trails B				1	-.16**	-.27**	.26**
MVPT					1	.23**	- .15**
SIMARD-MD						1	-.20**
ANT (median RT)							1

Notes. $N = 385$, * $p < .05$, ** $p < .001$

Table 4

Correlations among Neurocognitive Tests (Year 5 Data)

Variables	MMSE	MoCA	Trails A	Trails B	MVPT	SIMARD	ANT
MMSE	1	.43**	-.18**	-.24**	.25**	.35**	-.11*
MoCA		1	-.27**	-.43**	.32**	.39**	-.18**
Trails A			1	.50**	-.18**	-.26**	.20**
Trails B				1	-.26**	-.37**	.33**
MVPT					1	.14**	- .15*
SIMARD-MD						1	-.11*
ANT (median RT)							1

Notes. $N = 340$, * $p < .05$, ** $p < .001$

Analyses for the Three Functions of Attention

Alerting scores were found to be the least reliable with correlations between time points ranging from r = .17 to .29, p < .001. Orienting scores were slightly more reliable over time, r = .34 to .41, p < .001. Lastly, executive control scores were the most reliable with correlations ranging from r = .42 to .55, p <.001.

To test for the independence of the three functions of attention, a correlation matrix was calculated between the three sets of scores (i.e., alerting, orienting and executive control). Table 5 presents all correlations between functions for each time point.

Table 5

Test of Independence between Functions of Attention

Function Score	Year 3	Year 4	Year 5
Alerting and Orienting	-.01	-.02	-.06
Alerting and Executive Control	.05	.01	.07
Orienting and Executive Control	-.16**	-.17**	-.14**

Notes. ** p < .001

Analyses of Change

The first step of the analyses of change involved calculating unconditional growth models for each variable of interest. For each variable, the first model included only two intercepts, one for the initial value and one for the rate of change per unit of time (one year). The intercept for rate of change reflects the amount of change in the initial value per year. For example, the MMSE had an initial value of 28.39 (95% CI, 28.27-28.51) and the intercept for rate of change was -.05 (95% CI = -.13 - .02). Therefore, for every year, the MMSE score went down .05 points on average, from the initial value. The rate of change was not significant, p = .16. For all variables of interest, only Trails A, the SIMARD-MD, and alerting scores demonstrated significant change over time. All unconditional growth models are reported in Table 6.

Table 6

Unconditional Growth Models for Key Study Variables

	B	*SE*	*df*	*t*	*p*	95% Confidence Interval Lower	Upper
Initial Values							
MMSE	28.39	0.06	434.30	452.13	<.01	28.27	28.51
MoCA	26.04	0.12	461.55	211.45	<.01	25.80	26.28
Trails A	38.33	0.54	435.69	70.87	<.01	37.27	39.39
Trails B	93.63	1.71	452.25	54.71	<.01	90.27	97.00
MVPT	11.15	0.08	476.26	146.65	<.01	11.00	11.30
SIMARD- MD	74.06	0.99	467.71	74.80	<.01	72.12	76.01
ANT (median)	787.17	3.77	460.16	208.73	<.01	779.76	794.58
Alerting	11.47	1.84	438.68	6.23	<.01	7.85	15.09
Orienting	41.56	2.25	444.76	15.46	<.01	37.14	45.99
Exec. Control	79.14	1.72	440.92	45.91	<.01	75.75	82.53
Rate of Change							
MMSE	-0.05	0.04	404.42	-1.40	.16	-0.13	0.02
MoCA	-0.02	0.06	341.70	-0.24	.81	-0.14	0.11
Trails A	0.72	0.31	410.93	2.34	.02	0.12	1.33
Trails B	0.60	0.90	763.61	0.66	.51	-1.17	2.37
MVPT	0.03	0.04	768.94	0.59	.56	-0.07	0.11
SIMARD- MD	-1.44	0.54	399.47	-2.64	.01	-2.51	-0.37
ANT (median)	1.26	1.71	421.23	0.73	.46	-2.11	4.62
Alerting	4.22	1.35	386.34	3.14	.01	1.58	6.87
Orienting	0.09	1.39	374.18	0.07	.95	-2.64	2.82
Exec. Control	1.53	1.07	402.75	1.43	.15	-0.57	3.63

For the second set of analyses, a series of multilevel models were constructed to determine if changes in ANT scores over time were associated with changes in scores for the various other neurocognitive assessment tools. For each of these multilevel models, the explanatory variables entered were the ANT median reaction time, baseline ANT median reaction time, and the interaction terms for each of ANT variables with time. In each model, the neurocognitive assessment tools alternated as the dependent variable. The variance of random intercepts was included as a random effect. Neither gender nor the variance of random slopes was significantly related to model fit. Age was not included in the models as a covariate because over-controlling for this variable may mask the effect of age-related cognitive changes being assessed in this study.

Changes in the ANT scores over time were not significantly associated with changes in scores for the MMSE (B = .00, p = .62), MVPT (B = - .001, p = .07) or the SIMARD-MD (B = -.01, p = .26). Significant associations were identified between changes in ANT scores over time and changes in scores for the MoCA (B = -.002, p = .01), Trails A (B = .008, p = .04) and Trails B (B = .03, p = .01).

To compare rates of cognitive change detected using the different tools, a series of tests were run through mixed models to contrast slopes. For each assessment tool, a slope was calculated to reflect how much scores change over time. As mentioned in the method section, raw scores had to be converted to Z-scores to allow for interpretable comparisons with standardized units. Transformations were introduced to ensure all variables were coded similarly, such that lower scores reflect lower cognitive functioning. Table 7 includes the slopes for each assessment tool in these transformed and standardized units.

Table 7

Slopes for each Neurocognitive Assessment Tool Investigated (reflecting rate of change)

Slope (in *Z*-score units)	**B**	***SE***	***df***	***t***	***P***	**95% Confidence Interval Lower**	**Upper**
MMSE	-0.07	0.04	764.72	-1.81	.07	-0.14	0.01
MoCA	-0.02	0.04	764.60	-0.58	.56	-0.09	0.05
Trails A	-0.09	0.04	723.17	-2.38	.02	-0.16	-0.01
Trails B	-0.02	0.04	763.99	-0.58	.56	-0.10	0.05
MVPT	-0.02	0.04	769.44	0.69	.49	-0.05	0.10
SIMARD-MD	-0.10	0.04	746.35	-2.62	.01	-0.11	-0.04
ANT	-0.04	0.04	771.40	-0.99	.32	-0.11	0.04
Alerting	0.09	0.04	770.72	2.55	.01	0.02	0.16
Orienting	-0.01	0.03	772.60	-0.43	.67	-0.08	0.05
Executive Control	-0.04	0.04	792.73	-1.08	.28	-0.11	0.03

Note: All raw scores were converted to standardized Z-scores. Scores were transformed such that lower scores reflect lower cognitive functioning for all variables to allow for easily interpretable comparisons.

A series of tests were run to compare differences in rates of change (i.e., slopes) between the ANT and other tests considered in this investigation. The rate of change detected by the ANT did not differ significantly from the rate of change for any other tests. Table 4 includes the results of all slope comparisons.

Similarly, the slopes for each function of attention were compared to determine if the separate functions change at different rates over time. In order to be consistent in reporting, the standardized Z-score slopes are as follows: alerting (B = .09, $p = .01$), orienting (B = -.01, $p = .67$) and executive control (B = -.04, $p = .28$). Alerting scores showed more change over time than orienting scores and the difference in slopes was significant, (B = -.11, $p = .03$). Similarly, alerting scores showed a greater rate of change than executive control and the test for difference in slopes was significant, (B = -.13, p = .01). Lastly, orienting and executive control scores did not differ significantly in the rate of change (B = -.02, p = .58). The details of the statistical tests for slope comparisons can be found in Table 8.

Table 8

Tests Comparing Differences in Slopes for the Tests and Function Scores

Slope Comparison	**B**	***SE***	***df***	***T***	***P***	**95% Confidence Interval**	
						Lower	**Upper**
ANT vs. MMSE	0.03	0.05	770.25	0.61	.54	-0.06	0.12
ANT vs. MoCA	-0.02	0.05	770.17	-0.34	.74	-0.11	0.08
ANT vs. Trails A	0.05	0.05	718.86	1.08	.28	-0.04	0.15
ANT vs. Trails B	-0.01	0.04	699.88	-0.32	.74	-0.10	0.07
ANT vs. MVPT	-0.06	0.05	767.10	-1.28	.20	-0.16	0.03
ANT vs. SIMARD	0.06	0.05	753.61	1.18	.24	-0.04	0.16
Alerting vs. Orienting	-0.11	0.05	772.24	-2.13	.03	-0.20	-0.01
Alerting vs. Executive Control	-0.13	0.05	797.71	-2.51	.01	-0.24	-0.03
Orienting vs. Executive Control	-0.03	0.05	817.13	-0.56	.58	-0.12	0.06

Note: All raw scores were converted to standardized Z-scores

Discussion

The purpose of this investigation was to evaluate the psychometric properties of the ANT over multiple time points using a large sample from a senior population. The second goal in this investigation was to determine if the ANT was more sensitive to cognitive change than neurocognitive tools being used most frequently in assessing fitness to drive. Overall, the ANT was found to be both reliable and valid. Although the ANT was not necessarily found to be *more* *sensitive,* this test does appear to be detecting *unique* cognitive change that may not be adequately captured by the tools commonly used in assessing fitness to drive.

Overall, the ANT scores were quite reliable over time. The moderate correlations reflect the reality that participants were seniors whose cognitive capacities may change over time at different rates. Since the test-retest interval was one year, perfect correlations were not anticipated. However, taking these age-related changes into consideration, the ANT does produce reliable and consistent estimates of individuals' attentional processes.

In evaluating the construct validity of the ANT, we found that this test had the strongest correlations with measures involving related cognitive processes and focused attention (i.e., Trails A and B). The analyses of change for the ANT mirrored the relationships observed in the correlational analyses. Over time, changes in the ANT were significantly associated with changes in the TMT. These parallel findings can strengthen the validity of our conclusions by demonstrating that not only are the annual sets of scores for the ANT and TMT highly associated, but they also show similar patterns of deterioration over time. In line with our predictions, the weakest correlations were observed between the ANT and tests that are more generalized, involving a greater breadth of cognitive processes (i.e., MMSE and SIMARD).

In addition, MVPT did not correlate with the ANT as strongly as predicted. The hypothesized correlation was based on the premise that both tests utilize narrow and specific cognitive processes, as opposed to tests that utilize a wide range of cognitive processes. The weak correlation observed may be explained by the fact that although these two measures are similar in their narrow focus, they are admittedly different in the specific skills required for successful completion. Although the MVPT does require focused attention to make accurate judgements, this measure relies more heavily on visuospatial processing than the ANT which may account for the weak correlation observed.

In addition to validating the ANT as an independent and valuable assessment tool, this study included specific hypotheses relating to the three distinct functions of attention that can be measured separately using this test. The first analysis determined that of the three distinct functions, executive control scores were the most stable over time, supporting the notion proposed by McLeod et al. (2010) that executive control is more trait-like than the other two functions. Scores for executive control remained fairly stable suggesting the ability to attend to conflicting demands on attention may be linked to genetic influences as suggested by previous research (Fan et al., 2001; Posner et al., 2007).

Alerting and orienting scores were less reliable supporting the hypothesis that these functions are more state-dependent. Research suggests individuals' ability to attend to information and orient themselves spatially to the relevant information is influenced by environmental circumstances (Knight & Mather, 2013). It makes intuitive sense that these two functions of attention would be more variable because they are not restricted by genetic determinants. By contrast, executive control involves appropriately responding to competing demands on attention. This function requires higher level processing which is more susceptible to the limits placed on intellect through genetics. Not to say that executive functioning cannot also be influenced by external states; however, this function tends to be more stable due its high heritability. Although research into the reliability of function scores is sparse at best, the findings of the current study are consistent with previous research (Fan, Wu, Fossella, & Posner, 2001; Knight & Mather, 2013; McLeod et al., 2010; Posner, Rothbart, & Sheese, 2007). It should be noted that function scores are calculated by identifying relevant trials, and subtracting two sets of raw scores (in milliseconds). The reported correlations are therefore the product of difference scores and should be interpreted as such. Overall, the results from the reliability analyses support the hypotheses.

The three functions of attention have been labelled as independent of one another by Fan et al. (2002). Other researchers such as McLeod (2010) have disagreed with this assertion and provided evidence of inter-network correlations to prove their argument. The results of this study found very weak correlations between function scores ranging from $r = -.01$, *ns* to $r = -.16$, $p < .001$. Although the highest correlations are not strong in magnitude, the large sample size provided enough power for the correlations to reach statistical significance.

The magnitude of the correlations suggests the function scores are fairly independent of one another as originally stated by Fan et al. (2002). Research has successfully demonstrated that the three functions of attention each relate to different neurotransmitters and anatomical locations in the brain. Therefore, in the strictest sense they are *functionally* independent in that they each correspond to a different attentional process and brain region. However, given that they are still part of an interconnected neural network that is fundamentally linked to a single concept (i.e. attention), complete independence is not logical. If the three function scores were all correlated at zero, this finding would threaten the integrity of the human attention network model. Although the correlations between orienting and executive control scores were weak in magnitude, the small correlations do suggest some shared variance between the functions of attention.

Further examination of the correlation matrix indicates that orienting and executive control are the most highly correlated at every time point, which suggests that these two functions share the most variance. This can be best understood by reflecting back on exactly what each function represents. The ability to quickly orient attention to a correct location and the ability to not be influenced by conflicting information both require a higher cognitive demand than simply being alert to process incoming stimuli. It follows then that orienting and executive control would demonstrate stronger associations, which is exactly what this study found.

The rates of change for each function of attention were investigated in this study in an attempt to settle conflicting accounts in the literature. Interestingly, it appears that as people age, their alerting scores get significantly better over time. These findings are in line with the argument put forth Fernandez-Duque and Black (2006) suggesting that older adults benefit more from the alert due to their decreased ability to sustain attention. Our study was able to demonstrate that as people age, the benefits of alerting participants that the target would soon be presented increased with age. It appears that alerting can compensate for the age-related changes in sustaining attention.

In the current investigation, orienting and executive control scores did get worse over time, although the rates of change were not significant. The magnitude of the slopes reveals that alerting scores changed the most over time, followed by executive control and lastly, orienting scores showed very little change over time.

Similarly, exploring the rates of change between different assessment tools revealed a number of relevant findings. First of all, the only measures that detected statistically significant change were Trails A, the SIMARD-MD and alerting function scores within the ANT. On the surface, this suggests that Trails A, the SIMARD, and the alerting function of attention may be the most sensitive to slight changes in cognitive processing that occur as people age. Interestingly, performance on Trails B did not get significantly worse over time despite the fact that Trails B involves higher cognitive demand than Trails A. However, the unconditional growth models do show that cognitive changes are occurring in the anticipated directions for each individual measure. Limitations discussed later may have reduced the likelihood that such changes would reach the level of significance. However, the current study was able to detect patterns of cognitive decline even in a relatively healthy senior population.

Although the ANT scores did not demonstrate *statistically significant* change over time, there was some evidence of cognitive decline. Changes in the ANT over time were associated with changes in Trails A and B as predicted. These associations provide further evidence for the notion that the ANT and the trail making tests are tapping into similar cognitive processes involving focused attention. There is some validity in these associations however. The ANT must be assessing unique cognitive change or the correlations and intercepts would reflect a perfect relationship. In other words, the moderate relationships between ANT scores and TMT suggest that the ANT is appropriately measuring attention but in such a way that is not redundant with other cognitive tests.

The series of slope comparisons reveal interesting information about the rate of change detected by the various measures included in this investigation. First of all, looking at the standardized slopes, it appears that the MMSE, Trails A and the SIMARD are detecting cognitive decline the most efficiently. These conclusions are supported by the previously discussed findings that Trails A and the SIMARD were also the only two measures to detect *statistically significant* change over time.

Consideration of the slopes suggests that the ANT is more sensitive to cognitive decline than the MoCA, Trails B and the MVPT. Although some measures do require highly related cognitive processes for successful completion, they are not identical. Therefore, it is difficult to directly compare the magnitudes of standardized slopes. In other words, we cannot conclude that the Trails A is twice as sensitive as the ANT simply because the standardized slope of Trails A is double that of the ANT. Standardization was necessary in order to make interpretable judgments but we have to be cautious in directly comparing the magnitude of slopes as illustrated above.

As with all research designs, our current study is not without limitations. A major limitation in this investigation was the fact that all data was obtained through the ongoing Candrive assessments. The dataset by nature represents high functioning seniors. The seniors who continue to drive, and thus remain in the study, are likely not suffering from a high degree of cognitive impairment. Those who experience adverse changes in health or who are identified as suffering from impairment such as dementia will likely drop out of the Candrive study. Therefore, this study is affected by the methodological issue known as survivor bias, where only the strongest participants survive, or remain in the participant pool for the entire duration of the study. It is suspected that this form of range restriction introduced the greatest threat to our ability to detect significant declines in cognitive functioning. Analyzing this healthy subset of participants allowed researchers to identify only slight and subtle declines in cognition. Had we been able to follow and assess the senior participants who were affected by neurodegenerative conditions throughout the course of Candrive, the patterns of cognitive decline would have likely been far more pronounced. Further research in this area should strive to utilize this approach for longitudinal investigations to ensure that other common and significant age-related cognitive changes are adequately captured and observed by researchers.

Related to the above limitation, a longer period of study is always ideal. For the purposes of this investigation, only three time points were utilized which reflects a span of two years. Although Candrive did run for seven years, the ANT was not introduced until year three. On one hand, this time period was long enough to detect some significant changes and relationships.

However, it was not able to demonstrate that the ANT is capable of detecting significant cognitive decline in a senior population. Taken together, the short span of time combined with the survival bias discussed above limited our ability to make strong arguments for the differences in sensitivity between measures.

In order to ease interpretation when comparing slopes, all scores were converted to standardized Z-scores. Due to the variability in units of measurement between tests, this step was critical for making valid comparisons between rates of change. However, most of the tests involved in this study do not have age-based norms available for Z-score conversions. This highlighted a need for future research to develop age-adjusted norms for many cognitive assessment measures. Not only does this facilitate standardization across tests so different units of measurement can be compared, but it also ensures that seniors are being evaluated against appropriate norms. For example, Tombaugh (2004) has published age-adjusted norms for both Trails A and B. To illustrate the age-related differences, someone aged 25 in the 90^{th} percentile would have a score of 33 seconds on Trails B. An individual aged 70 in the 90^{th} percentile would have a score of 64 seconds on Trails B. This one example highlights the drastic ways in which age-adjusted norms can influence the validity of conclusions drawn by utilizing appropriate reference groups.

In the current study, the utility of the ANT was assessed as it applies to fitness to drive. However, there are a wide variety of settings in which a test of attention may be appropriate. The most obvious extension is other positions which require validation of safe driving ability such as bus drivers, taxi drivers or truck drivers. In situations where cognitive impairment is unlikely, for example younger job applicants, a quick test of attention may be a valuable addition to the current procedures of requesting drivers abstracts. There are other professional environments that may benefit from evaluating prospective employees' ability to quickly orient attention and manage competing demands on attention. To name a few, air traffic controllers, machine operators, engineers and health care professionals all require high attentional capacity to do the job effectively. In many of these cases, mistakes can result in loss of life so any test that can identify threats to one's ability to perform the job safely should be considered.

Keeping with the driving application, future research should study the ways in which ANT scores relate to unsafe driving behaviours such as car crashes or driving infractions. The first step should involve evaluating the predictive validity of the ANT. By demonstrating an individual's ANT score can be used to predict driving behaviours with reasonable accuracy, the likelihood of this measure being utilized in driver evaluations will be substantially increased. Once predictive validity for the ANT has been established through research, a logical extension would be to develop specific ranges of scores that correspond to risk levels for unsafe driving behaviours (i.e. low risk, moderate risk or high risk).

A final suggestion for future research includes developing a test of attention that can be administered through a driving simulator. Currently, participants in the simulator are required to drive pre-programmed routes on a computer screen, fully equipped with a steering wheel and gas and brake pedals. By incorporating a test of attention into the driving simulation, the external validity will be increased. Administering the attention test while participants are engaged in a driving simulation will increase the likelihood that these findings will generalize to how their attention affects real-life driving behaviour.

As mentioned in the introduction, decisions relating to fitness to drive have important implications for seniors' independence and well-being. This research project focused on the validation of one individual measure in order to determine if it is a valid tool for assessing cognition. In addition, the ANT was evaluated to determine if this test could detect changes in attention that relate to the ability to drive safely. Although this study was able draw some interesting conclusions, it needs to be emphasized that no single test should *ever* be utilized to make decisions regarding fitness to drive. The assessments are comprehensive for good reason. There are many factors to consider when evaluating an individual's ability to operate a vehicle safely. Cognitive variables are extremely important, but physical variables are a critical portion of comprehensive driving assessments as well. The results of this study suggest that the ANT may be a valuable addition to the comprehensive cognitive assessments for determining fitness to drive.

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Appendix A

5794302189

Montreal Cognitive Assessment (MoCA)
(Appendix A)

SITE # - PT ID   dd / mm / 2 0 yyyy

Candrive

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

	POINTS
LANGUAGE	
Sentence Repetition: "I am going to read you a sentence. Repeat it after me, exactly as I say it." *[pause]*: ☐ *"I only know that John is the one to help today."* "Now I am going to read you another sentence. Repeat it after me, exactly as I say it." *[pause]* ☐ *"The cat always hid under the couch when dogs were in the room ."*	☐ /2
Verbal fluency: "Tell me as many words as you can think of that begin with a certain letter of the alphabet that I will tell you in a moment. You can say any kind of word you want, except for proper nouns, numbers, or words that begin with the same sound but have a different ending (for example, love, lover, loving). I will tell you to stop after one minute. Are you ready? *[Pause]* Now, tell me as many words as you can think of that begin with the letter F." *[time for 60 sec]* # of words: ☐☐ ☐ 1 point if 11 words or more	☐ /1
ABSTRACTION "Tell me how an orange and a banana are alike." *If the subject answers in a concrete manner, then say only one additional time*: "Tell me another way in which those items are alike." *If the subject does not give the appropriate response (fruit), say:* "Yes, and they are also both fruit." ☐ "Now, tell me how a train and a bicycle are alike." ☐ "Now tell me how a ruler and a watch are alike."	☐ /2
DELAYED RECALL "I read some words to you earlier, which I asked you to remember. Tell me as many of those words as you can remember." FACE: category cue: part of the body/multiple choice: nose, face, hand; VELVET: category cue: type of fabric/multiple choice: denim, cotton, velvet; CHURCH: category cue: type of building /multiple choice: church, school, hospital; DAISY: category cue: type of flower/multiple choice: rose, daisy, tulip; RED: category cue: a colour/multiple choice: red, blue, green	

	Recall words WITH NO CUE	☐ Face	☐ Velvet	☐ Church	☐ Daisy	☐ Red	Points for UNCUED recall only
	Category cue	○ Face	○ Velvet	○ Church	○ Daisy	○ Red	
Optional	Multiple choice cue	○ Face	○ Velvet	○ Church	○ Daisy	○ Red	☐ /5

ORIENTATION "Tell me the date today." *If the subject does not give a complete answer, then prompt accordingly by saying:* "Tell me the [year, month, exact date, and day of the week]." *Then say*: "Now, tell me the name of this place, and which city it is in." ☐ /6

Year	Month	Date	Day	Place	City
○ correct ○ incorrect	○ correct ○ incorrect	○ correct ○ incorrect	○ correct ○ incorrect	○ correct ○ incorrect	○ correct ○ incorrect

TOTAL add 1 point if <=12 yr education ☐ ☐☐ /30

Appendix B

0401453715

Mini Mental State Exam(MMSE)

(Appendix B)

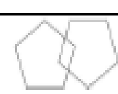
Randomization Order: ☐

☐☐ - ☐☐☐☐ SITE # PT ID

Date: ☐☐ / ☐☐ / 2 0 ☐☐ dd mm yyyy

Candrive

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

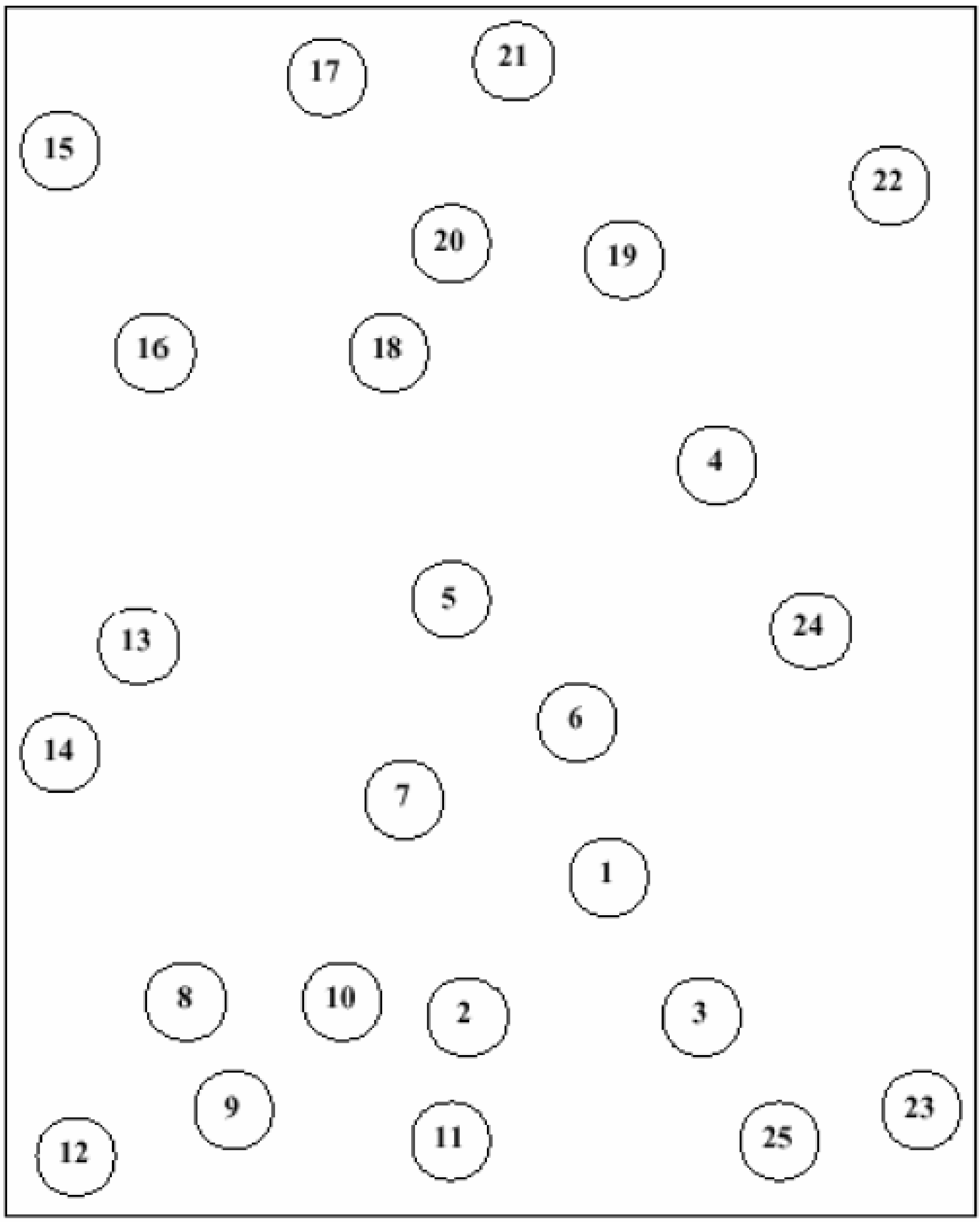
	Maximum Score	Score
What is the ... ☐ Year? ☐ Season? ☐ Month? ☐ Day? ☐ Date?	5	☐
Where are we now? ☐ Province ☐ Country ☐ Town/City ☐ Building ☐ Floor	5	☐
Listen carefully, I am going to say 3 words. You say them back after I stop. Ready? Here they are: "Pony" "Quarter" "Orange" Now repeat those words back to me. ☐ Pony ☐ Quarter ☐ Orange Now keep those words in mind. I'm going to ask you to say them again in a few minutes.	3	☐
Spell WORLD forward, then backward __ D=1 __ L=1 __ R=1 __ O=1 __ W=1	5	☐
What were those three words I asked you to remember? ☐ Pony ☐ Quarter ☐ Orange	3	☐
What is this? ☐ [Point to a pencil or pen] What is this? ☐ [Point to a watch]	2	☐
Now I am going to ask you to repeat what I say. Ready? "NO IFS, ANDS, OR BUTS." Now you say that. ☐ No ifs, ands, or buts.	1	☐
Listen carefully, because I'm going to ask you to do something. Take this paper in your right hand [pause], fold it in half [pause], and put it on the floor. ☐ Take in right hand ☐ Fold in half ☐ Put on floor (or table)	3	☐
Please read this and do what it says. Close your eyes	1	☐
Please write a sentence (if no response, say write about weather) Write a sentence	1	☐
Please copy this design. 	1	☐
	Total Score:	☐☐ /30

Adapted from Folstein MF, Folstein SE, and McHugh Pr. "MINI-MENTAL STATE." a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975; 12:196-8 and Cockrell JR, and Folstein MF. Mini-mental State Examination (MMSE) Psychopharm Bull 1988:24 (4):669-92

Appendix C

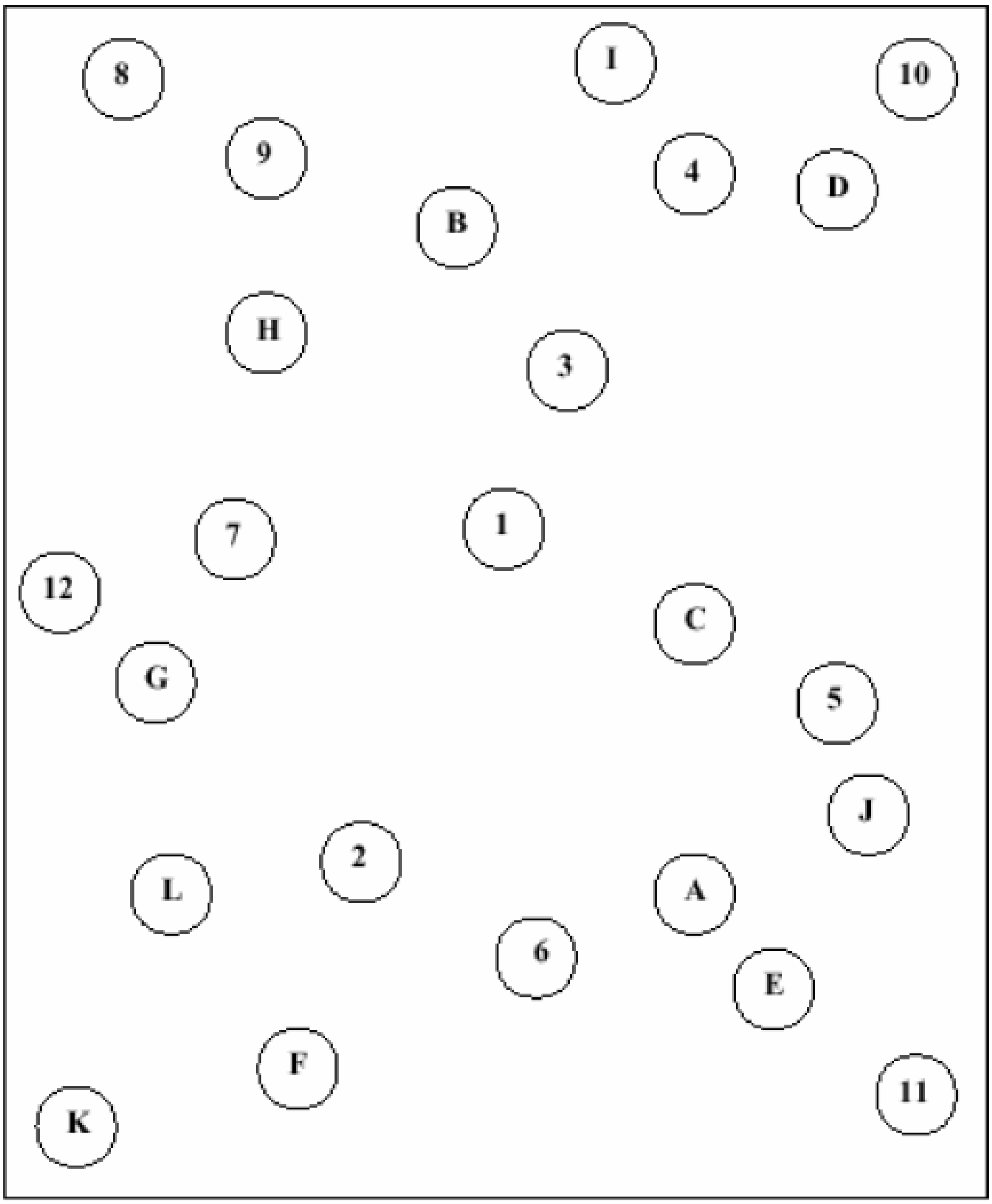
Trail Making Test Part A

Patient's Name: ______________________________ Date: ____________________



Trail Making Test Part B

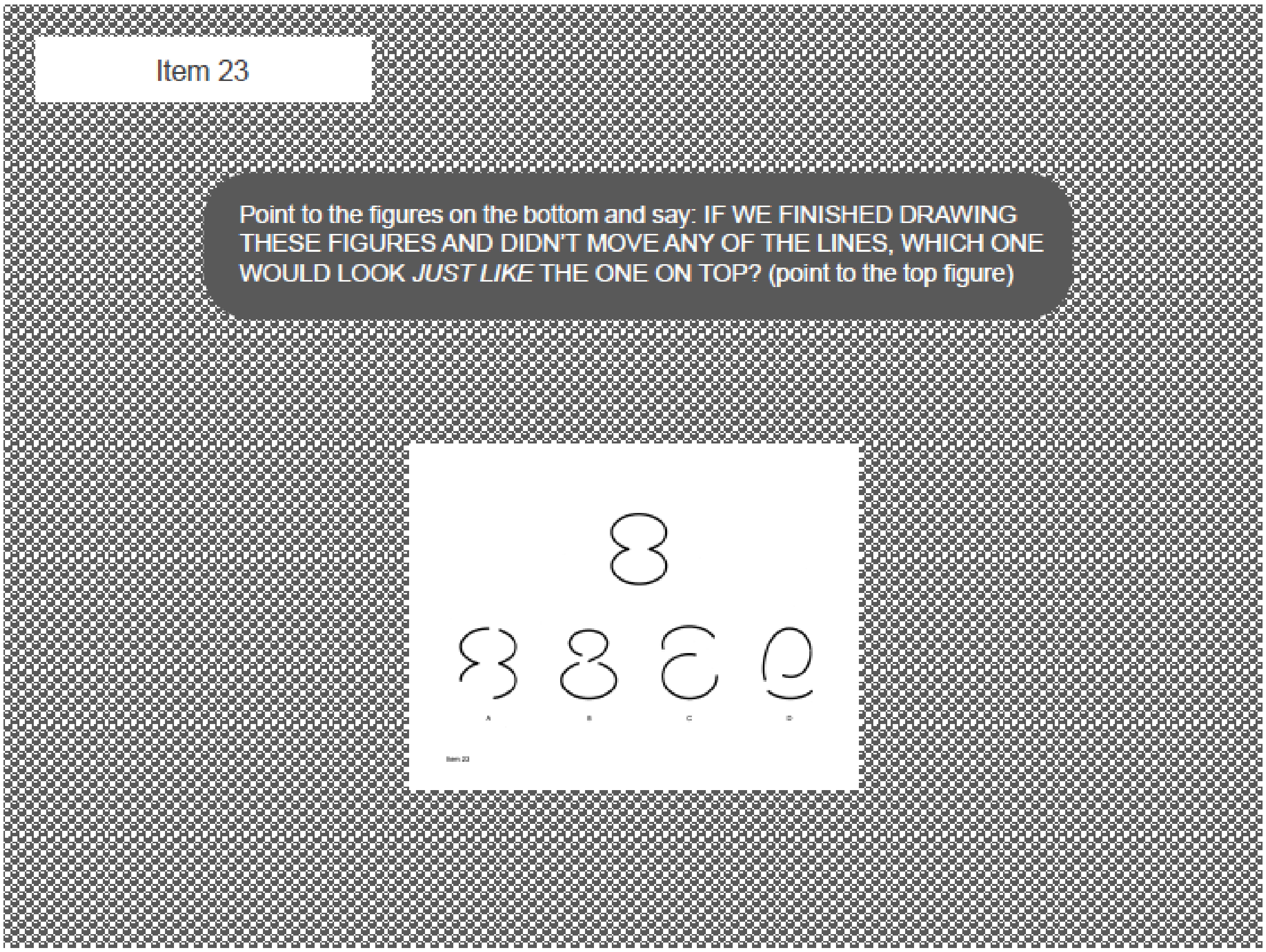
Patient's Name: ______________________ Date: ______________



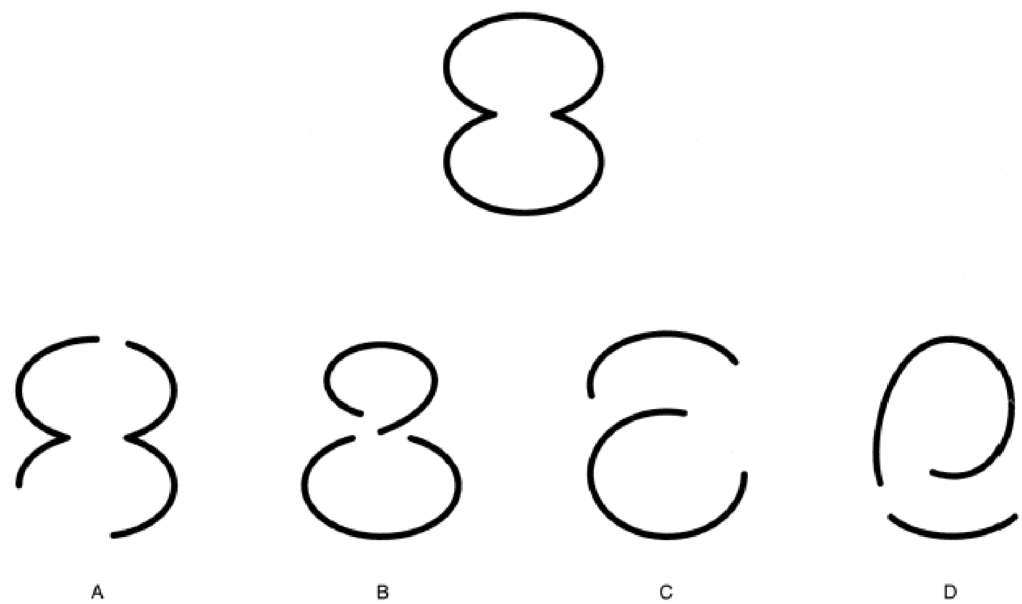
Appendix D

Sample item from MVPT-3: Visual Closure Subtest

Instructions for administrator:



Item shown to participant:



Item 23

Appendix E

DemTect Administration Form

☐

Site: 01 **Study ID:** ______ **Visit:** ______ **Date**: ________________

Cognitive Test #3

Word List

I will now slowly read you a list of 10 words. When I have finished, please repeat as any of these words as possible. The order doesn't matter.

1. Apple	Ink	Nail	Bird	Book	Ticket	Tree	Chair	House	Ship
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Thank you. Now I will read you the same words again. Please repeat as many of these words as possible when I have finished.

2. Apple	Ink	Nail	Bird	Book	Ticket	Tree	Chair	House	Ship
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Correctly remembered words (max. 20) ☐

Number Conversion

As you can see from this example, we can also write the number "5" as the word "five", and the word "three" as the number "3". Part of this task is like writing out a cheque. Please write the numbers in words and the words as numbers.

Example: 5 – five three – 3

209 ☐ 4054 ☐

Six hundred and eighty one ☐ Two thousand and twenty seven ☐

Correct conversions (max. 4) ☐

Supermarket Task

Please name as many things as possible that you can buy in a supermarket. You have one minute to do this.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Total named objects (max. 30) ☐

Series of Numbers in Reverse

I will now give you a series of numbers which you should then repeat in their reverse order. For example if I say "four-five", you would say "five-four" **(Cont'd on next page)**

1st Attempt	**2nd Attempt**		
7-2	8-6 †	☐	2
4-7-9	3-1-5	☐	3
5-4-9-6	1-9-7-4	☐ †	4
2-7-5-3-6	1-3-5-4-8	☐ †	5
8-1-3-5-4-2	4-1-2-7-9-5†	☐	6

Longest series of numbers correctly given in reverse (max. 6) ☐

Repeat of the Word List

At the beginning of this test, I read you 10 words. Can you remember these words?

1. Apple	Ink	Nail	Bird	Book	Ticket	Tree	Chair	House	Ship
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Correctly remembered words (max. 10) ☐

Words named but not on the list:

If total # of years in education is 11 or less add one extra point ☐

Total Score: ☐

Ethnic Background

People in Canada come from many racial or cultural groups. You may belong to more than one group on the following list. Are you...

- ☐ White/ Causasian
- ☐ African American/ Black
- ☐ Chinese
- ☐ Southeast Asian (Vietnamese, Cambodian, Malaysian, Laotian, etc…)
- ☐ Filipino
- ☐ Latin American
- ☐ West Asian (Iranian, Afghan, etc…)
- ☐ South Asian (East Indian, Pakistani, Sri Lankan, etc…)
- ☐ Korean
- ☐ Japanese
- ☐ Aboriginal
- ☐ Other __________________

Education

How many years of schooling did you complete, including elementary/public school, high school, college, CEGEP, trade school and university?
(numeric value) ☐

Site: _____ Study ID: ______ Visit: ______ Date: ________________

Number Conversion

Example: 5 – five three – 3

209 = ____

4054 = ____

Six hundred and eighty one = ____

Two thousand and twenty seven = ______________________________________