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Working Memory and Falls Risk in Older Adults: An Event-Related Potential Study

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Abstract

BACKGROUND: The aging population is rapidly increasing, where currently in North America, the population of older adults (ages 60+) outnumbers the population of children. Falls are a major concern for older adults and their quality of life. Cognitive impairment has been shown to be declined in older adults at-risk for falls, but working memory has not been thoroughly investigated within this population. PURPOSE: To examine differences in Non-Fallers, Moderate Risk for Falls, and Fallers in a working memory task using electroencephalography (EEG). METHODS: Older adults (n=44, female=27) aged 60 – 80 years (m=68.8, SD=4.7) completed two separate sessions on two separate days. The first session incorporated general demographic questionnaires and Tinetti's Mobility Test. Participants were classified as Non-Fallers, Moderate Risk for Falls, or Fallers based on their Tinetti's Mobility Test results and their falls history. The second session had participants complete the n-back, a working memory test, while behavioural and EEG results were recorded. RESULTS: We found that in the 2-Back test, behaviorally those who were at risk performed the worst (slower reaction time and decreased accuracy) in comparison to the Non-Fallers and Fallers. However, from the EEG results, Fallers were more cognitively impaired, with earlier latencies for the N2 and P3 components in comparison to the other groups, while the Moderate Risk for Falls group were significantly impaired in peak latencies in the N2 only in comparison to the Non-Faller group. CONCLUSIONS: Individuals at risk and fallers differ in their impairment in working memory in comparison to non-fallers. Working memory and falls risk should be further investigated as a proactive approach to the falls phenomena.

Keywords: Working memory, Falls Risk, EEG, ERP, older adults.

Co-Authorship

Dr. Lindsay S. Nagamatsu provided feedback, considerations, and comments for this project, as well as revisions and suggestions for the completion of this thesis.

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List of Abbreviations, Symbols and Nomenclature

ABC = Activities-Specific Balance Confidence Scale

EEG = Electroencephalography

ERP = Event Related Potential

FCI = Functional Comorbidity Index

FROP-Com = Falls Risk for Older People - Community Setting

GDS = Geriatric Depression Scale

IADL = Instrumental Activities of Daily Living

MMSE = Mini-Mental State Examination

MoCA = Montreal Cognitive Assessment

PASE = Physical Activities Scale for the Elderly

SPPB = Short Physical Performance Battery

TiMT = Tinetti's Mobility Test

WM = Working Memory

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Preface

This thesis is submitted in fulfillment for my Masters of Science Degree in Kinesiology in the Faculty of Health Sciences, at Western University. The thesis is titled "Working Memory and Falls Risk in Older Adults: An Event Related Potential Study". Data collection was completed between September 6th, 2016 to April 31st, 2018 in the Exercise, Mobility, and Brain Health Laboratory in Arthur and Sonia Labatt Health Sciences Building at Western University.

The number of older adults will outnumber younger adults by 2050, and falls risk is a major concern for the older population. This is due to the negative consequences associated with falls, such as fractures, and a decrease in a quality of life. A major association with falls risk in older adults is cognitive impairment due to the aging brain. This project aims to distinguish the differences between Non-Fallers, Moderate Risk for Falls, and Fallers in terms of working memory. The primary outcomes of this study are to use working memory as a specific biomarker to help distinguish older adults that are at risk for falls proactively, and further understand the relationship between cognition, mobility, and the brain. The implications of this study are to distinguish the differences in working memory between Non-Fallers, Moderate Risk for Falls, and Fallers, and to provide evidence that working memory can be a biomarker for falls risk.

Chapter 1

1 Introduction

The number one cause for hospitalization of older adults from injuries in Canada is falls, and approximately 20% to 30% of Canadian seniors fall at least once a year (Stinchcombe, et al., 2014). Falls in older adults becomes both a burden on the individual and the health care system due to frequency and length of treatment (Alexander, et al., 1992; Tinetti, et al., 1986). With the growing population of older adults (baby boomer era), the number of hospitalizations will increase. Thus, it is paramount to understand and identify the factors that are associated with falls.

In the falls literature, it has already been shown that physical factors are associated with falls. For example, Taylor and colleagues (2012) prospectively looked at spatiotemporal gait in cognitively impaired older adults. They assessed the gait of all participants and found that individuals who reported multiple falls (≥ 2 falls) had gait issues, such as slower gait speed, shorter steps, and longer double support times in comparison to the non-fallers. This provides evidence that variant gait may be associated with falls prospectively. Another factor that has been researched is postural impairment. Melzer and colleagues (2004) looked at control of balance as a falls risk factor in community-dwelling older adults that had fallen at least twice in the past six months. Using six different standing balance positions on a force platform, they found evidence to suggest that the control of one's balance in a narrow base stance may be a major factor in identifying falls risk in older adults. Furthermore, Tinetti, et al. (1995) looked at the frequency and risk factors of falls in older adults. Through a one-year evaluation looking at over 1000 community dwelling older adults with prospective falls calendars and balance measures, they found that balance and gait impairment was a readily identifiable factor that could be used to distinguish the older fallers at risk for suffering a serious fall injury.

Recently, the falls literature has shown that impaired cognitive functions are associated with falls in older adults. In one study, Holtzer and colleagues (2007) looked at healthy older adults in regard to falls and cognitive function. Using a battery of cognitive tests that looked at verbal IQ, speed/executive attention, and memory, the authors found that there was an association between recurrent falls and poor verbal IQ scores, and speed/executive attention scores. In another study, Liu-Ambrose et al. (2008) completed a cross sectional study looking at community dwelling older adults with a history of falls and their working memory with perceived postural limits. To test for working memory, the verbal digits forward and backward test was used to classify participants into a "good working memory" group or a "poor working memory" group. Then the two groups were compared on the results of their perceived reach test. Between the two groups, the poor working memory group performed significantly poorer (less accurate in the estimation of their perceived postural limits) in the perceived reach test in comparison to the good working memory group. This study suggests that impaired cognition may increase falls risk, as individuals may not be able to properly plan their motor activities for daily living. Furthermore, Mirelman and colleagues (2012) conducted a study looking at single and dual task walking ability to assess gait and executive function in older adults in relation to falls risk. They assessed executive function, attention, single gait, and dual task gait over the course of 5 years in 256 healthy community-living older adults. The results suggested that dual task gait, executive function, and attention are all associated with future falls, demonstrating that future falls in older adults can be predicted by executive function and attention years prior.

Furthermore, previous studies have found that within the broad domain of cognition, there is an association between impaired executive function and falls. Executive function refers to the ability to process and complete complex tasks such as selecting relevant information, mentally processing the coordination of a set, and inhibiting a response (Miller & Wallis, 2009). In a two-year prospective study conducted by Herman and colleagues (2010), falls were three times more likely to occur per year for individuals with lower executive functioning scores compared to individuals with higher executive functioning scores. Specifically, the executive functions that were associated with falls risk were processing speed, response inhibition, and attention (Herman, et al., 2010). Multiple other studies have also supported the relationship between executive function and falls such as Anstey et al. (2009) examining response inhibition in Fallers, Sosnoff et al. (2013) examining frequency of falls and processing speed, and Nagamatsu et al. (2009; 2013) uncovering evidence of impaired attention in Fallers. While there is a clearly established relationship between executive function and falls, one specific aspect of executive function that has not been explored in great detail in the context of falls is working memory.

Working memory refers to a component of short-term memory that is equipped with the ability to retain relevant information for processing (Baddeley, 1992). Why might working memory be relevant for falls? First, there is a neuroanatomical link between working memory and falls. Both working memory and falls have pathways that disseminate into the cerebellum (Thach, et al., 1992; Marvel, et al., 2010), frontal lobe (Prabhakaran, et al., 2000; Muakkassa, et al., 1979), and prefrontal cortex (Diamond, 2000). These neuroanatomical structures are used for both motor control (Diamond, 2000), such as mobility (Tiedemann, et al., 2008), and executive functioning (Springer, et al., 2006). Diamond (2000) overviews neuroimaging studies that provide evidence for interrelations of the cerebellum and prefrontal cortex with functions such as motor function and cognitive development. With the cerebellum, it is a highly complex structure of the brain, and may contain more neurons than all the nervous system combined (Andersen, et al., 1992). Within the cerebellum, there are parallel fibre pathways that is received by the cerebellar modules, which are used to formulate and strengthen the cerebellar modules for both motor learning and cognitive functioning (Bloedel, 1992; Glickstein, 1990). Therefore, this suggests that impairment in one domain (mobility or working memory) might co-occur with impairment in the other.

Second, we know that decreases in working memory performance and increased risk of falls co-occur with aging and are even more pronounced in those with neurodegenerative disease. Studies have found a relationship between neurodegenerative diseases such as Alzheimer’s disease and Mild Cognitive Impairment (MCI) with both working memory and mobility. Belleville, and colleagues (2007) looked more closely at the facets that make up working memory on a continuum between MCI and Alzheimer’s disease. This study found a negative correlation between cognitive deficits and attentional control task, suggesting that with progressive deterioration in the continuum, attentional control tasks are more impaired. Furthermore, in a longitudinal study conducted by Baddeley and colleagues (1991) looking at the facets of working memory (divided attention, manipulation capacities, and inhibition) in Alzheimer patients, the authors discovered that at both 6-month and 12-month time points, there was a significant progressive decline in performance, specifically seen in inhibition, which was not simply due to task difficulty. Moreover, various studies uncovered evidence that suggests that MCI and/or Alzheimer's disease are linked to aspects of mobility such as gait variability, balance assessments, and falls occurrence. Delbaere et al. (2012) looked at 419 community-dwelling older adults in a prospective cohort study. To determine MCI, four cognitive domains were assessed and participants were classified as normal cognitive functioning or MCI. Prospectively, the authors found that MCI could be considered a risk factor for multiple falls or injurious falls. In a different study, Alexander, et al. (1995) recorded and compared the balance abilities, gait speed, and obstacle approaches between healthy older adults and older adults with Alzheimer's disease. Using a force plate and camera, movement times and forces of each physical activity (normal walking speed, body motion, and force output) were recorded. They found that there was a difference in normal walking speed and body motion in overcoming an obstacle, where the older adults with Alzheimer's disease had a slower walking speed and had more difficulty in approaching and overcoming an obstacle in comparison to the healthy older adults. More evidence to contribute to the relationship between Alzheimer's disease and mobility (falls risk) can be seen in a prospective study conducted by Horikawa and colleagues (2005). This study found that older adults with mild to moderate Alzheimer's disease that had associated periventricular white matter lesions and drug usage were at greater risk of falling. Therefore, from the evidence in the literature, mobility and working memory may be linked.

Third, in addition to sharing neuroanatomical regions and co-occurring in clinical populations, working memory impairments may also directly impact mobility. Specifically, working memory is critical for postural control. Postural control is defined as the ability to relay sensory information to signal the motor pathways to produce enough muscle strength to maintain controlled upright posture (Horak, 1987). Postural control is essential for mobility because it encompasses both coordination of movements to maintain ones center of balance (postural equilibrium) and alignment adaptations of the head, trunk, and surface based on somatosensory information (Horak, 2006).

Importantly, research has found that postural control is attention demanding (Redfern, et al., 2001) and requires updating of relevant information (Sui, et al., 2007) – precisely the same processes involved in working memory. Previous studies have shown that there is an association between postural control and working memory. In 2009, Doumas and his colleagues found that when asked to maintain dynamic postural control while performing a working memory task, older adults prioritized posture significantly more than younger adults. This evidence suggests that with aging, not only is there a decline in cognitive function, but postural control becomes prioritized. Additionally, Liu-Ambrose and colleagues (2008) found that Fallers with poor working memory were significantly less accurate when determining their perceived postural limits in comparison to Fallers with good working memory. The evidence from these studies suggest that there is an association between general balance mobility control, which is important in preventing falls, and working memory, which is required to assist in postural control.

Importantly, examining the relationship between working memory and falls is worth exploring because working memory can be improved through interventions. Borello and colleagues (2010) looked at the transferability and maintenance of verbal, visuospatial working memory gains, and inhibition with processing speed in older adults from a working memory intervention. This study encompassed a variety of transferable tests such as The Dot Matrix Task, Digit Span (Forward and Backward), Culture Fair Test, Scale 3, Stroop Colour Task, and the Pattern Comparison Test for the intervention group. The results from their study showed that the transfer working memory intervention group obtained better results in comparison to the individuals who were not trained and these cognitive gains were maintained at the 8-month follow-up period. In addition, Richmond and colleagues (2011) also researched the effect of working memory training and transfer in older adults that were transferable in younger adults. Within this study, using transfer working memory tasks (California Verbal Learning Test, Test of Everyday Attention, Reading Span, and complex verbal and spatial working memory conditions, they found that older adults in a working memory-training group reported improvements in everyday attention and activities. This is vitally important because if working memory is associated with falls, there is a possibility that implementing such interventions may improve mobility and reduce falls risk in older adults.

Therefore, we conducted a cross-sectional study to examine the relationship between working memory and falls in older adults. In our study, we assessed working memory using the n-back test. The cognitive requirements of the n-back consist of attention control to collect relevant information, memory retention for processing needs, and response inhibition to accurate decision-making (Baddeley, 1992; Kane, et al., 2007). During performance of the n-back, we recorded behavioral performance and event-related potentials (ERPs). ERPs are post-synaptic potential voltage fluctuations that are time-locked to a specific stimulus or task (Picton, et al., 2000). Using ERPs to assess cognition is great because it is minimally invasive, and more importantly, the temporal resolution is excellent (precise timing) (Luck, 2005).

To specifically assess the cognitive processing of working memory, we focused on two ERP components: the N2 and the P3. These components are associated with cognitive processing, specifically working memory with decision-making (Achtziger, et al., 2012; Sauseng, et al., 2005). The N2 component is negative potential wave that peaks between 200 to 350 ms after the onset of a stimulus and represents the inhibition phase and aspects of working memory maintenance (Luck, 2005; Vogel & Machizawa, 2004). The ability to inhibit the incorrect response and process is important in evaluating the stimulus which occurs in the P3. The P3 is a positive potential that peaks between 250 – 500 ms and is generally known as the most cognitive processing wave (how the individual evaluates the stimuli) encompasses decision-making – a requirement for working memory (Luck, 2005). We examined the amplitudes and latencies of these components in order to inform us about the amount of cognitive resources to correctly complete the task and cognitive processing speed. Larger amplitudes would indicate more cognitive resources are required for the task, while an earlier latency would indicate faster processing speed (Luck, 2005).

To address our research question, we compared working memory between three distinct groups of older adults: Non-Fallers, Moderate Risk for Falls, and Fallers. Three classification groups were used because studies have primarily focused on defining the differences between Fallers and Non-Fallers. While it is important to examine the differences between the Fallers and Non-Fallers, it is a reactive approach to the issue. On the other side, a proactive field of research to address this problem would be assessing falls risk. Falls risk, defined as the probability of falling (Demura, et al., 2011), is a relatively novel field, and has not been properly identified in research in terms of where at risk individuals would fit between the literature of Fallers and Non-Fallers. Based on previous studies conducted by St. George et al. (2007) and Lord et al. (2001), when performing a choice-stepping task in correspondence with a working memory task, older adults who were at high risk for falls showed difficulty in the task which was reflected in their performance (higher error rates). We hypothesized that the Fallers will have the poorest performance overall in the working memory test in comparison to the Moderate Risk for Falls group and the Non-Fallers, and that the cognitive processing of response inhibition and context updating will be significantly impaired in the Fallers.

Chapter 2

2 Methods

2.1 Subjects

Participants were recruited via senior programs and community centres in London, Ontario, Canada. Participants were recruited if they met the following criteria: 1) 60 – 80 years of age, 2) completed high school, 3) currently live in their own home, 4) comfortable writing and reading English, 5) able to walk independently, 6) have no neurodegenerative disease or cognitive impairment. Participants were excluded if they had any of the following: 1) diagnosed psychiatric condition, 2) sustained a concussion in the last 12 months, 3) had a history of stroke(s), 4) indicated any musculoskeletal or joint disease, 5) experiences vertigo, 6) has any visual, auditory, or somatosensory impairment, 7) is left-hand dominant, and/or 8) scored below 25/30 on the Montreal Cognitive Assessment (MoCA). The research ethics board at Western University approved this study and all participants provided written informed consent.

2.2 Descriptive Measures

General demographic information (age, sex, education, and marital status) was obtained via questionnaire. Daily function was assessed via the Instrumental Activities of Daily Living (IADL) questionnaire (Lawton & Brody, 1970). The Functional Comorbidity Index (FCI) (Groll et al., 2005) was used to collect the number and type of comorbidities of each participant. The MoCA (Nasreddine et al., 2005) and Mini Mental State Examination (MMSE) (Folstein et al., 1975) were used to assess global cognition. To screen for undiagnosed depression, the Geriatric Depression Scale (GDS) was used where a score equal to or greater than 10 indicates depression (Sheikh & Yesavage, 1986). Physical activity levels were obtained through the Physical Activity Scale for the Elderly (PASE) questionnaire (Washburn et al., 1993). This data was collected during session one, day one the participants came into the lab.

2.3 Group Classification: Non-Fallers, Moderate Risk for Falls, or Fallers

We classified participants into their respective groups based on: 1) falls history, and 2) physiological falls risk. To assess falls history, we used the Falls Risk for Older People – Community setting (FROP-COM) (Russel et al., 2008) where participants self-reported their falls history in the past twelve months. A fall was defined as "unintentionally coming to the ground or some lower level other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or an epileptic seizure" (Kellogg & Work, 1987).

We assessed physiological falls risk using Tinetti's Mobility Test (TiMT) (Lin, et al., 2004). The TiMT assesses balance and gait consisting of sitting balance, arising from an armless chair, attempts to arise, immediate standing balance (first five seconds), standing balance, three nudges at the sternum, eyes closed balance, turning 360 degrees, sitting down in an armless chair, the initiation of gait, step length and height, step symmetry, step continuity, walking path, trunk movement, and walking stance. The test is scored out of 28, with 16 points allocated to balance and 12 points allocated to gait. Scores less than 19 indicate that individuals are at a high risk for falls, scores between 19-24 indicate that they are at medium risk for falls, and scores ≥25 indicate they are at low risk for falls. This test has shown to exhibit high test re-test reliability and predictive validity (Kegelmeyer et al., 2007; Lin et al., 2004). One examiner administered this test to all participants to ensure experimenter reliability of the test.

Participants were classified as Non-Fallers if they did not fall within the last twelve months and had scored ≥25 on the TiMT. Participants were classified as Fallers if they reported one or more falls in the past twelve months. Lastly, participants were classified as Moderate Risk for Falls if they did not fall in the past twelve months but had moderate or high physiological falls risk score (<25). No participants were classified into more than one group classification. This data was collected during session one, day one the participants came into the lab.

2.4 Working Memory Task

Participants were seated in a chair in front of a 25-inch computer monitor. The distance between the chair and monitor was 34 inches, and the height from the floor to the bottom of the monitor was fixed at 43 inches. To examine working memory, participants completed three different versions (0, 1, 2) of the n-back test (Gazzaniga et al., 2009). Each n-back test assessed a higher level of working memory as it progressed from: 0-back (selective memory), to 1-back (working memory), and then lastly to 2-back (higher order working memory). All participants completed the three tests in this specific order.

Figure 1 displays the stimulus presentation for each n-back test. The test was designed with numbers one to eight presented one at a time in a randomly generated sequence in the center of the screen above a fixation cross. Participants were required to press a right trigger button of a gamepad with their right index finger each time a “target” appeared, and a left trigger button of a gamepad with their left index finger each time a “non-target” appeared. For the 0-back test, the target was the number “5” and non-targets were any other number. For the 1-back test, participants had to compare the number they saw immediately before to the currently presented number, with targets being the same number being repeated and non-targets being non-repeated numbers. Lastly, for the 2-back participants had to compare the number they were currently seeing to the number they saw two numbers back. If the numbers were the same, it would be classified as a target. If they were not the same, it would be classified as a non-target. Participants were instructed to respond to the stimuli as quickly and as accurately as possible.

Each digit appeared on the screen for 500 ms, and the delay between stimulus presentations was randomized between 700 to 1200 ms to reduce anticipation. A maximum of 2000 ms was allotted for a response, and if a response was not generated within that time-frame, the next stimuli would appear which would result as a ‘No Response’ for that specific stimuli. During each n-back, behavioural responses (reaction times and accuracy) and continuous electroencephalograms (EEG) were recorded. Each version of the n-back test contained eight blocks, with breaks (determined by the participants) in between each block. Each block was approximately one minute and fifty seconds long, with a maximum of five minutes for the breaks. This data was collected during session two, day two (a maximum of one week apart from the first session) the participants came into the lab.

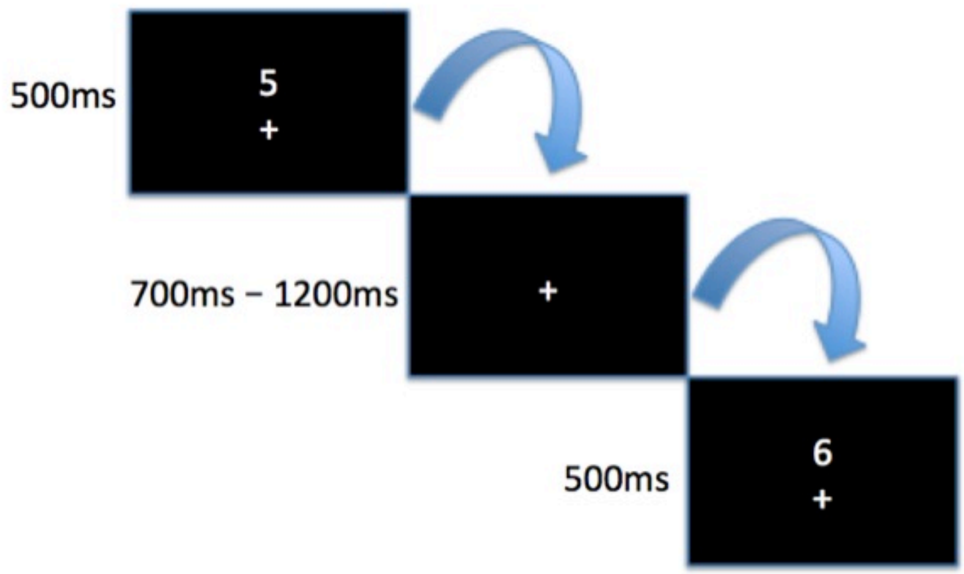

Figure 1. Stimulus presentation and timing for the n-back test.

2.5 Electrophysiological Recording and Analysis

Throughout each n-back test, continuous EEGs were recorded from 64 active scalp electrodes (Brain Vision ActiCHamp) using Brain Vision PyCorder (http://www.brainvision.com/pycorder.html). The electrodes were mounted on a fitted cap with a standard 10-20 layout. All EEG activity was recorded relative (GND) to a scalp electrode located over the anterior frontal cortex (AFz). Vertical and horizontal electrooculograms (VEOGs and HEOGs) were recorded from electrodes placed below and on the outer canthi of both eyes to monitor eye movements. All electrode impedances were kept below 20 kΩ. EEG signals were filtered at 0.01 Hz Low Cutoff and 100 Hz High Cutoff and digitized at a rate of 500 Hz. The data was imported into EEGLAB (v13.5.4b) and was re-referenced to the average between the two mastoid electrode sites. Next, ERPLAB (v5.0.0.0) was used to preprocess the raw EEG data. The raw EEG data was filtered using a 0.1 Hz high pass and a 30 Hz low pass filter. This filter process is used to allow for a specific range of higher and lower frequency to pass the filter. Specific event lists and bins were created to appropriately classify the task and the responses for the event related potentials. Continuous EEG data was segmented into epochs from -200 ms to 800 ms. To remove any outliers from the EEG dataset, artifact detection was performed on the epoched data using moving window peak-to-peak thresholds at VEOG, and HEOG channel sites (moving windows full width = 200 ms, window step = 100 ms). FP1 and FP2 channel sites were used in addition for artifact detection in order to better classify eye movements. Furthermore, manual detection was utilized after the first two artifact detection steps for quality assurance. After, epochs assigned to each bin and were averaged together for each participant.

The grand averages were created across all viable participants to compare the three groups: Non-Fallers, Moderate Risk for Falls, and Fallers. The mean amplitudes (mean voltage within a specific time frame) and peak latencies (the time at where the peak point occurs) of the ERP components of interest (N2 and P3) at electrode site Fz (Onton, et al., 2005; Sauseng, et al., 2005) were extracted using ERP Measurement Tool and imported into SPSS (v24 for Mac) for statistical analysis. This data was collected during session two, day two the participants came into the lab.

2.6 **Statistical Analyses**

Based on our hypotheses regarding the relationship between falls, falls risk, and higher order working memory, our analyses focused on the 2-back test specifically. Reaction times and ERPs were analyzed for correct trials only. For our descriptive, behavioural, and electrophysiological data, we used one-way ANOVAs to determine whether any differences exist for our main variables of interest between groups (Non-Fallers, Moderate Risk for Falls, Fallers). Significant findings were followed up using Tamhane T2 post-hoc test to account for differences in sample size between groups.

Lastly, we assessed the relationship between the behavioral and electrophysiological results by calculating Pearson's bivariate correlations between performance (reaction time and accuracy) and amplitudes and latencies of our ERP components of interest. Significance was set to $p \leq 0.05$ for all statistical analyses.

Chapter 3

3 Results

Sixty-two participants were recruited for the study. Of the 62 participants, 10 participants were excluded due to their MoCA score (≤25) and eight participants dropped out of the study (five participants could not participate within the time-frame and did not complete any sessions and three participants did not want to continue participating after completing session one). Therefore, 44 healthy community-dwelling older adults (M = 68.8, S.D. = 4.7) were eligible and completed both sessions of this study.

3.1 Descriptive and Mobility Measures

All descriptive data are presented in Table 1. Between the groups, no significant differences were seen in age, sex, education, functional comorbidities, global cognition, and daily functioning (all p's > 0.05). However, there was a significant difference in physical activity level $F(2,44) = 5.670$, $p=0.007$, number of falls in the past twelve months $F(2,44) = 85.45$, $p<0.001$, and Tinetti's Mobility Test scores $F(2,44) = 34.248$, $p<0.001$ between groups. However, there was no significant difference between Non-Fallers and Moderate Risk for Falls, Non-Fallers and Fallers, or Moderate Risk for Falls and Fallers in terms of physical activity levels in the post-hoc analysis. On the other hand, for the number of falls in the past twelve months, there was a significant difference between the Non-Fallers and Moderate Risk for Falls in comparisons to the Fallers ($p<0.001$, $p<0.001$), but no significant difference between the Non-Fallers and Moderate Risk for Falls ($p=1.00$). Similarly with the TiMT scores, the Non-Fallers and Fallers had lower physiological falls risk scores in comparison to the Moderate Risk for Falls ($p<0.001$), but no significant difference between the Non-Fallers and Fallers ($p=0.692$).

Table 1. Descriptive Measures

Variable	Non-Fallers (n=27)	Moderate Risk for Falls (n=6)	Fallers (n=11)	All Subjects (n=44)
Age (years)	69.3 ± 4.5	70.5 ± 5.2	66.4 ± 4.2	68.8 ± 4.7
Females, No. (%)	14 (51.6)	4 (66.6)	9 (81.8)	27 (61.4)
Education, No. (%)				
• High School graduate, diploma or equivalent	3 (11.1)	0 (0.0)	0 (0.0)	3 (6.8)
• Some college, no degree	5 (18.5)	1 (16.7)	4 (36.4)	10 (22.7)
• Trade/technical/ vocational training	3 (11.1)	2 (33.3)	1 (9.1)	6 (13.6)
• Bachelor's Degree	8 (29.6)	2 (33.3)	5 (45.4)	15 (34.1)
• Graduate Degree	8 (29.6)	1 (16.7)	1 (9.1)	10 (22.7)
FCI[a]	1.1 ± 1.1	1.5 ± 0.8	0.4 ± 0.7	1.0 ± 1.0
MMSE[b]	28.0 ± 1.3	27.0 ± 1.1	28.2 ± 1.3	27.9 ± 1.3
MoCA[c]	27.3 ± 1.5	26.3 ± 1.9	27.5 ± 2.2	27.2 ± 1.8
FROP-COM[d]	5.0 ± 2.5	3.8 ± 3.1	6.4 ± 2.5	5.3 ± 2.7
GDS[e]	0.9 ± 1.4	0.8 ± 0.8	0.7 ± 0.7	0.9 ± 1.1
PASE[f]	181.7 ± 56.7**	144.0 ± 77.6**	261.9 ± 117.3**	196.6 ± 86.4
IADLs[g]	7.8 ± 0.6	7.5 ± 1.2	8.0 ± 0.0	7.8 ± 0.7
Falls History (past 12 months)	0.0 ± 0.0‡‡	0.0 ± 0.0‡‡	1.6 ± 0.7¤¤••	0.8 ± 0.4
TiMT[h]	27.1 ± 1.0¤¤‡‡	23.2 ± 1.0••‡‡	26.6 ± 1.3•¤	26.3 ± 1.7

[a] Functional Comorbidity Index
[b] Mini Mental State Examination
[c] Montreal Cognitive Assessment
[d] Falls Risk for Older People – Community Setting
[e] Geriatric Depression Scale
[f] Physical Activity Scale for the Elderly
[g] Instrumental Activities of Daily Living
[h] Tinetti's Mobility Test
• $p < 0.05$ difference from Non-Faller
•• $p < 0.01$ difference from Non-Faller
¤ $p < 0.01$ difference from Moderate Risk for Falls
¤¤ $p < 0.01$ difference from Moderate Risk for Falls
‡ $p < 0.01$ difference from Faller
‡‡ $p < 0.01$ difference from Faller
* $p < 0.05$ mean difference in the omnibus ANOVA
** $p < 0.01$ mean difference in the omnibus ANOVA

3.2 Behavioral performance on the n-back

Behavioural results for the 2-back test are presented in Table 2[1]. We only included behavioral results for participants with viable ERP data. Overall, twelve participants from the Non-Faller group[2] and one participant from the Moderate Risk for Falls group[3] were removed from this analysis.

Overall, Non-Fallers responded to targets faster than the Moderate Risk for Falls group and Fallers. This was confirmed by the significant mean difference in reaction times from the omnibus ANOVA for targets between groups $F(2,28) = 4.237$, $p = 0.025$. Furthermore, the Non-Fallers generally made fewer errors when they performed 2-back compared to both the Moderate Risk for Falls and Fallers. The difference was revealed in the percentage of correct responses between groups $F(2,28) = 4.775$, $p=0.017$. However, no significant differences were seen between any two specific groups in their responses. This was seen in the post-hoc analysis for reaction time and accuracy between Non-Fallers and Moderate Risk for Falls (p=0.082, p=0.208), Non-Fallers and Fallers (p=0.995, p=0.087), and Moderate Risk for Falls and Fallers (p=0.105, p=0.983).

Table 2. The behavioral results from the 2-Back Test.

2-Back Behavioral Data	Non-Fallers (n = 14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
Target Reaction Time (ms)	820.3 ± 174.4*	1053.5 ± 164.0*	833.5 ± 136.7*
Correct (%)	90.6 ± 3.6*	81.1 ± 8.9*	82.8 ± 10.0*

* p < 0.05 mean difference in the omnibus ANOVA
** p < 0.01 mean difference in the omnibus ANOVA

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[1] Data from the 0-back and 1-back tests are presented in Appendix F. There were no significant between group differences for performance on these tests.

[2] Nine individual's EEG recordings had too much (>80% artifact rejection rate) noise (e.g. blinks) to obtain clean ERP plots and three participants did not complete the 2-back test due to tiredness and/or did not feel they could complete the task after performing a practice session.

[3] Due to noisy EEG recordings (>80% artifact rejection rate).

3.3 Electrophysiology

The average mean amplitudes and peak latencies for each group are presented in Table 4 and the group ERP waveforms are presented in Figure 2. Fourteen participants (thirteen Non-Fallers, and one Moderate Risk for Falls) were excluded from the electrophysiological analysis due to noise within their recorded data (e.g., high artifact rejection rates) or withdrawal from the task.

3.3.1 N2 ERP Component

The N2 component was used to assess the response inhibition to targets for the working memory task. For the mean amplitude, no significant differences were seen between groups for the targets ($p=0.747$). However, we found significant differences in peak latency, $F(2,28) = 124.634$, $p<0.001$.

Our posthoc analysis revealed that Fallers had the earliest peak latency in comparison to both the Moderate Risk for Falls group $p=0.027$ and the Non-Fallers $p<0.001$. Furthermore, the Moderate Risk for Falls group had a significantly earlier latency peak than the Non-Fallers ($p=0.001$).

3.3.2 P3 ERP Component

The P3 component was used to assess cognitive processing with context updating for targets. For the mean amplitude, no significant differences were seen between the groups for targets in the 2-back test ($p=0.809$). On the other hand, analysis of the peak latencies yielded significant differences in P3 component for the targets. This was revealed in the differences in specific peak times for the P3 peak, $F(2,28) = 170.734$, $p<0.001$.

Further analysis for the P3 peak latency component showed that the Fallers again had significantly earlier peak latencies in comparison to the Moderate Risk for Falls group ($p<0.001$) and the Non-Fallers ($p<0.001$,). However, no significant differences were seen in the P3 peak latencies between the Moderate Risk for Falls and Non-Fallers, $p=0.126$.

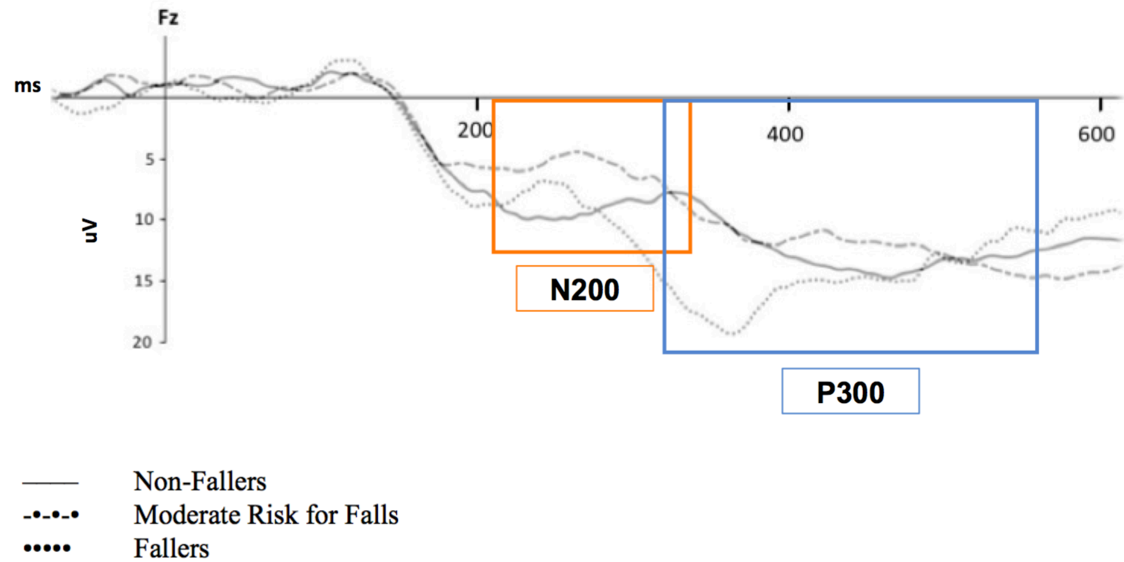

Figure 2. The ERP waves for the correct targets for the 2-back test between all classifications.

Table 3. The electrophysiological results for targets at the Fz electrode site for the 2-Back Test.

	Non-Fallers (n=14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
N2 Peak Latency (ms)	324.7 ± 12.8‡‡	271.2 ± 13.8‡	245.6 ± 12.2••¤
N2 Mean Amplitude (μV)	8.6 ± 6.5	4.9 ± 4.3	7.5 ± 8.3
P3 Peak Latency (ms)	464.6 ± 15.3¤¤‡‡	389.2 ± 14.7••	370.5 ± 8.7••
P3 Mean Amplitude (μV)	15.8 ± 12.9	11.8 ± 5.5	18.4 ± 22.0

• p < 0.05 difference from Non-Faller
•• p < 0.01 difference from Non-Faller
¤ p < 0.01 difference from Moderate Risk for Falls
¤¤ p < 0.01 difference from Moderate Risk for Falls
‡ p < 0.01 difference from Faller
‡‡ p < 0.01 difference from Faller
* p < 0.05 mean difference in the omnibus ANOVA
** p < 0.01 mean difference in the omnibus ANOVA

3.4 Relationship Between Electrophysiology and Behavioral Performance

We found significant relationships between reaction times and mean amplitudes of the N2 and P3 ERP components, where the faster an individual responded to the target correctly, the larger the N2 and P3 mean amplitudes were r^2= -0.426, p = 0.019 for the N2 component, and r^2= -0.364, p = 0.048 for the P3 component. As well, there was a significant relationship between accuracy and N2 peak latency, where the later the peak latency occurred, the higher the accuracy rate, $r^2 = 0.513$, $p = 0.004$. However, there was no significant relationship between the reaction time and peak latencies, and accuracy and mean amplitudes for the N2 or P3 component, p's > 0.05.

Chapter 4

4 Discussion and Conclusion

4.1 Discussion

The purpose of our study was to determine if working memory differed between falls risk classification of Non-Fallers, Moderate Risk for Falls, and Fallers. In terms of the descriptive measures between the three classifications, there was no differences seen in age, sex, or education, however the PASE Scores and Tinetti's Mobility Test scores were significantly different between groups. It was expected that there would be differences in the TiMT scores between the Moderate Risk group to the Fallers, and Non-Fallers, as the test was used as a classifier for the Moderate Risk group. Within this population, the participants were high-functioning older adults that exercised on a regular basis. However, the physical activity levels differences were not expected, where the Fallers had a higher activity level in comparison to the other two groups. This may be the case because individuals who are more active may have more opportunities to fall. Further research should investigate and consider this occurrence.

From the cognitive task, results from our study revealed a significant difference in behavioral performance on the 2-Back test for both accuracy and reaction time, where the Moderate Risk for Falls group performed the worst, while the Non-Faller performed the best. This result aligned with the findings from previous studies (Schoene, et al., 2013; Buracchio, et al., 2011) that Fallers perform worse than Non-Fallers in cognitive tasks due to cognitive deficits. Schoene and colleagues in 2013 looked at using the Stroop Stepping Test (a test that encompasses both stepping and response inhibition to simulate real life behaviour) to discriminate fallers and non-fallers. The test involved the older adult participants to step in the direction of the word on the screen, rather than the arrow. Individuals who reported a fall in the past year had longer trial period times and made more errors, indicating that fallers were less cognitively focused to inhibit a response in comparison to the non-fallers. In another study, Buracchio and colleagues (2011) investigated if executive function scores could predict falls risk in healthy older adults with no mobility impairments. The study had older adults (aged 65 and older) undergo baseline and one-year follow up testing that encompassed neuropsychological testing, and a health history questionnaire. The authors also requested that the participants record their falls online on a weekly basis. In the follow-up period, those who reported a fall within 13 months had lower executive scores than the non-fallers, indicating that fallers may have less intact cognitive functioning in comparison to non-fallers.

However, it was somewhat surprising that the Moderate Risk for Falls group performed the worst overall. While this result does not support our hypothesis, the importance and implication of this finding suggests that when performing working memory tasks, individuals who are at Moderate Risk for Falls may be unable to react as quickly or as appropriately as their counterparts. This may suggest that the risks of injury and/or other negative consequences for those who are at Moderate Risk for Falls can be relatively similar to Fallers.

In the electrophysiological results, while mean amplitude did not differ, peak latencies were significantly different between our three groups. Our results showed that Fallers had the earliest peak latency in comparison to both other groups. Based on the assumptions of ERP components, the results of the peak latencies were interpreted in correspondence to the reaction time (Luck, 2005). In particular, earlier peak latencies tend to reflect better cognitive functioning (Zanto, et al., 2010) – however, this is only true for younger adults. The earlier the occurrence of the peak latency in young adults reflects a quicker cognitive processing of the stimulus with proper inhibition. However, the opposite is true for older adults. The earlier the occurrence of peak latencies for the components reflect poorer cognitive functioning because older adults require more time to properly assess the stimulus and the earlier the peak latency occurs may reflect the inability to properly inhibit the incorrect response (Pinal, et al., 2015; Zanto, et al., 2010). This phenomenon fits with our results, as we saw in our correlational analysis that a delay in the N2 peak latency was significantly associated with more accurate responses. This may be the case because older adults require more time to process the stimuli, and if they respond too quickly, they cannot control their inhibitory response correctly (Lucci, et al., 2013), as well as having less intact recollection due to cognitive decline (Pinal, et al., 2015; Duarte, et al., 2006). This phenomenon was shown by Lucci and colleagues (2013) when they were researching the effect of age inhibition processing on healthy younger, middle aged, and older adults. They used a Go/No-go task while recording ERPs, and they found that the N2 component in older adults was not seen in the same the time frame as the middle age or young adults. Specifically, the older adults had a later peak latency in comparison to middle age and young adults when comparing their responses to correct trials only. This study indicated that the N2 component is involved with action suppression and age may progressively impair this inhibition.

A slight departure from our hypothesis occurred when we combined our electrophysiological results and our behavioral results. The results showed that the Moderate Risk for Falls group behaviorally performed the worst in comparison to other groups, while electrophysiologically, it appeared that the Fallers were more cognitively impaired in comparison to the other groups. How can we reconcile these equivocal results? An explanation that may address why both the Moderate Risk for Falls and Fallers show a decline in working memory performance is because the reason for decline in behavioral response and cognitive function are different. To begin, when looking at behavioral response, we are referring to reaction time, which accounts for not only cognitive processing, but also response time (the initiation to end of movement), which is physiologically based. Previous studies have suggested that individuals with physiological risks will tend to be slower in initiating movement (Lord et al., 2001; St. George et al., 2007).

This may explain why individuals who are at Moderate Risk for Falls have the slowest overall reaction time because response time is a motor response, and the Moderate Risk for Falls group are classified according to their physiological risk. On the other side, when referring to cognitive function or processing, we are referring to accuracy. Accuracy differences between groups may be explained through the delayed latencies threshold. Pinal and colleagues (2015) found evidence to suggests that for older adults, a delayed peak latency is correlated to increased accuracy because older adults require more time to process the information, and our correlational results also suggest this. The electrophysiology results showed that the Fallers had the earliest peak latencies, while the Moderate Risk for Falls had peak latencies close to the Fallers, and the Non-Fallers had the most delayed peak latencies overall. There may be a threshold time for peak latencies in regard to accuracy, where if the peak of a component occurs after a specific time point, the more likely the correct response will be performed. This may be seen specifically within the P3 component as there was no significant difference in the P3 peak latency between the Fallers and Moderate Risk for Falls groups, and their accuracy results are relatively close, while there were less errors made in the Non-Fallers, and a significant P3 peak latency difference was seen Non-Fallers between the other two groups. However, we note that these explanations are merely speculative. The underlying mechanism behind this result cannot be answered through our current study so future research into this is required.

There are a few limitations that need to be addressed in the methodology of this study. The first limitation is the classification of participants into our three separate groups. The distinct problem with the classification is using a self-report questionnaire to assess previous fall history. While a fall definition was used, self-report measures are biased because they rely on retrospective memory, especially in this particular population (Sallis et al., 2000). The Gold Standard to assess falls history would be to implement prospective falls calendars (Hannan et al., 2010), but based on the timeline of the study, these were not available to us. Therefore, it is possible that our groups were not accurately formed which would impact the group averages. However, if there is overlap, this likely means that we have a conservative estimate of the true difference between these populations.

Secondly, the n-back test is not considered a "real world" task. The n-back test that was used in this study only used numbers that was not accompanied via semantics visual spatial aspects. This type of working memory cannot translate into the real world, as the transferability of working memory tasks may require more complexity. Previous studies have investigated the transferability and the maintenance of working memory training into the real world. Rather than using the n-back test, other tests such as the Categorization Working Memory Span (Borella et al., 2010), or other types of adaptive spatial and verbal working memory tasks (Brehmer et al. 2012) may have been better suited to assess 'real world' working memory. It is unclear how and if any type of n-back task would translate to the real world and environment. However, we note that using the n-back allows us to simply investigate general working memory continuously with high internal validity (required for EEG recordings), and keep in line with literature, as many studies have used the n-back test as the working memory when recording EEG (Baldwin, et al., 2012; Brouwer, et al., 2012; Ross, et al., 2000). This allows us to control for potential confounds and compare the groups in a consistent environment.

Lastly, the EEG data presented cannot be used to indicate which specific brain structures are involved. This is a limitation because brain structures can be used to infer different types of cognitive and physical functions as suggested from previous studies, and because we would want to know if there are any compensatory brain regions that may be activated in this task. The inability to indicate specific brain structures is a limitation of the EEG technique, known as the inverse problem. We cannot infer which brain regions are being activated or used within the task because there are various sets dipoles that occur in multiple parts of the brain, and no one set of dipole can be used as the reliable source for the voltage distribution. Therefore, it is impossible to infer the observed distribution to a specific configuration. However, EEG does allow the cognitive processing to be inferred.

For future studies, a few suggested considerations are noted. Specifically for falls risk classification, a more thorough criterion should be implemented to properly classify those whom would be classified as Moderate Risk for Falls, as Fallers and Moderate Risk for Falls groups are not the same. The second consideration is to contemplate different stimuli type of n-back tests, such as environmental objects (i.e., fire hydrant, fence) words and/or shapes to evaluate working memory. The evaluation of these different stimuli could add to the falls risk literature by evaluating memory of placements of objects in a particular area and size estimation memory. As well, evaluating working memory in older adults using other neuroimaging techniques (fMRI, NIRS, etc.) are recommended to understand the mechanisms related to this decline. Then lastly, research on falls risk should be further investigated to better comprehend and differentiate between individuals who have physiological falls risk indicators and fallers to proactively identify the factors that are associated with falls risk, and the progress to falls.

4.2 Conclusion

In conclusion, this study suggests that there are different impairments in higher order working memory in different falls risk groups, where behaviorally individuals who are at Moderate Risk for Falls are the slowest, but in terms of cognitive processing, Fallers are the worst by comparison. The important focal point from this study is that falls risk in older adults is complex. There are cognitive and physiological differences between Non-Fallers, Fallers, and individuals who are at physiological risk (Moderate Risk for Falls), and we cannot group individuals at physiological risk (Moderate Risk for Falls) with Non-Fallers, or Fallers. It is highly recommended that future research in the field of older adults and falls investigate further into the differences between these three groups.

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Appendices

Appendix A: Descriptive and Cognitive Function Measures

Table 1

The Functional Comorbidity Index [[9]]

Instructions: Check off either yes or no in the following list if any conditions do or do not apply to you.

Comorbidity	YES	NO
Arthritis (rheumatoid and osteoarthritis)		
Osteoporosis		
Asthma		
Chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), or emphysema		
Angina		
Congestive heart failure (or heart disease)		
Heart attack (myocardial infarction)		
Neurological disease (e.g., multiple sclerosis or Parkinson's disease)		
Stroke or transient ischemic attack (TIA)		
Peripheral vascular disease		
Diabetes types I and II		
Upper gastrointestinal disease (e.g., ulcer, hernia, reflux)		
Depression		
Anxiety or panic disorders		
Visual impairment (e.g., cataracts, glaucoma, macular degeneration)		
Hearing impairment (i.e., very hard of hearing, even with hearing aids)		
Degenerative disc disease (e.g., back disease, spinal stenosis or severe chronic back pain)		
Obesity and/or body mass index (BMI) > 30		

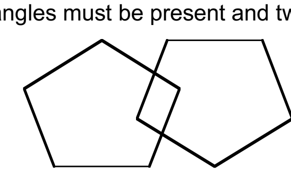
Fan *et al.*

Fan *et al.* *BMC Anesthesiology* 2012 **12**:21 doi:10.1186/1471-2253-12-21

OPEN DATA

Mini-Mental State Examination (MMSE)

Instructions: Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now (building, floor)? Province? Country? Town/city?
3		Listen to the following: "apple," "table," "penny." Repeat all 3. (1 point for each correct answer.)
# of Trials	( )	(Repeat the objects until the patient learns all 3. Make a maximum of 6 trials. Record the number of trials.)
5		"Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes." Find on MMSE pg. 2)
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

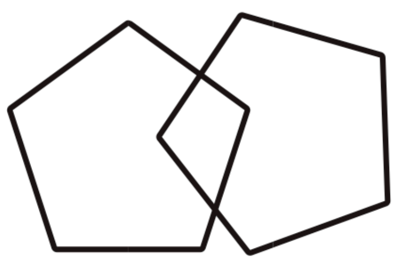
Mini-Mental State Examination (MMSE)

READING:

Close your eyes.

WRITING:

COPYING:

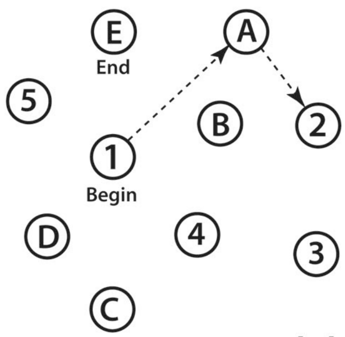


NAME :
Education : Date of birth :
Sex : DATE :

MONTREAL COGNITIVE ASSESSMENT (MOCA)

Version 7.1 Original Version

VISUOSPATIAL / EXECUTIVE



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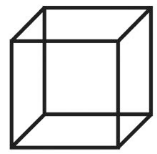


Copy cube

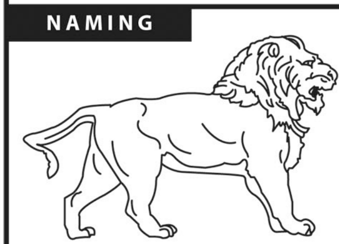
[ ]

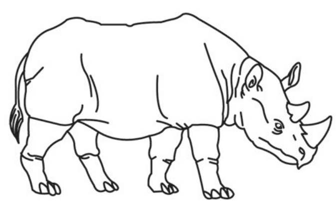
Draw CLOCK (Ten past eleven)
(3 points)

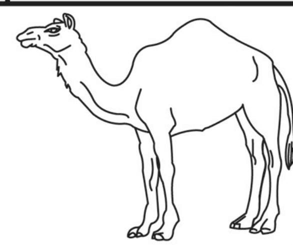
[ ] Contour [ ] Numbers [ ] Hands

POINTS ___/5

NAMING


[ ]


[ ]


[ ]

___/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful.
Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words) ___/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler ___/2

DELAYED RECALL

		FACE	VELVET	CHURCH	DAISY	RED	
	Has to recall words **WITH NO CUE**	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only
Optional	Category cue						
	Multiple choice cue						

___/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

 www.mocatest.org Normal ≥ 26 / 30

TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________________

Instrumental Activities of Daily Living (IADL)

Instructions: Circle the scoring point for the statement that most closely corresponds to the patient's current functional ability for each task. The examiner should complete the scale based on information about the patient from the patient him-/herself, informants (such as the patient's family member or other caregiver), and recent records.

A. Ability to use telephone	Score
1. Operates telephone on own initiative; looks up and dials numbers, etc.	1
2. Dials a few well-known numbers	1
3. Answers telephone but does not dial	1
4. Does not use telephone at all	0

B. Shopping	
1. Takes care of all shopping needs independently	1
2. Shops independently for small purchases	0
3. Needs to be accompanied on any shopping trip	0
4. Completely unable to shop	0

C. Food preparation	
1. Plans, prepares, and serves adequate meals independently	1
2. Prepares adequate meals if supplied with ingredients	0
3. Heats and serves prepared meals, or prepares meals but does not maintain adequate diet	0
4. Needs to have meals prepared and served	0

D. Housekeeping	
1. Maintains house alone or with occasional assistance (e.g., "heavy work domestic help")	1
2. Performs light daily tasks such as dishwashing, bed making	1
3. Performs light daily tasks but cannot maintain acceptable level of cleanliness	1
4. Needs help with all home maintenance tasks	1
5. Does not participate in any housekeeping tasks	0

E. Laundry	Score
1. Does personal laundry completely	1
2. Launders small items; rinses stockings, etc.	1
3. All laundry must be done by others	0

F. Mode of transportation	
1. Travels independently on public transportation or drives own car	1
2. Arranges own travel via taxi, but does not otherwise use public transportation	1
3. Travels on public transportation when assisted or accompanied by another	1
4. Travel limited to taxi or automobile with assistance of another	0
5. Does not travel at all	0

G. Responsibility for own medications	
1. Is responsible for taking medication in correct dosages at correct time	1
2. Takes responsibility if medication is prepared in advance in separate dosages	0
3. Is not capable of dispensing own medication	0

H. Ability to handle finances	
1. Manages financial matters independently (budgets, writes checks, pays rent and bills, goes to bank), collects and keeps track of income	1
2. Manages day-to-day purchases, but needs help with banking, major purchases, etc.	1
3. Incapable of handling money	0

(Lawton & Brody, 1969)

Scoring: The patient receives a score of 1 for each item labeled A – H if his or her competence is rated at some minimal level or higher. Add the total points circled for A – H. The total score may range from 0 – 8. A lower score indicates a higher level of dependence.

Sources:

- Cromwell DA, Eagar K, Poulos RG. The performance of instrumental activities of daily living scale in screening for cognitive impairment in elderly community residents. *J Clin Epidemiol*. 2003;56(2):131-137.
- Lawton MP. The functional assessment of elderly people. *J Am Geriatr Soc*. 1971;19(6):465-481.
- Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist*. 1969;9(3):179-186.
- Polisher Research Institute. Instrumental Activities of Daily Living Scale (IADL). Available at: http://www.abramsoncenter.org/PRI/documents/IADL.pdf. Accessed February 15, 2005.

LEISURE TIME ACTIVITY

1. Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV or doing handcrafts?

[0.] NEVER ↓ GO TO Q.#2	[1.] SELDOM (1-2 DAYS) ↓	[2.] SOMETIMES (3-4 DAYS) ↓	[3.] OFTEN (5-7 DAYS) ↓

1a. What were these activities?

____

1b. On average, how many hours per day did you engage in these sitting activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

2. Over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example, for fun or exercise, walking to work, walking the dog, etc.?

[0.] NEVER ↓ GO TO Q.#3	[1.] SELDOM (1-2 DAYS) ↓	[2.] SOMETIMES (3-4 DAYS) ↓	[3.] OFTEN (5-7 DAYS) ↓

2a. On average, how many hours per day did you spend walking?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

3. Over the past 7 days, how often did you engage in light sport or recreational activities such as bowling, golf with a cart, shuffleboard, fishing from a boat or pier or other similar activities?

[0.] NEVER	[1.] SELDOM	[2.] SOMETIMES	[3.] OFTEN
↓	(1-2 DAYS)	(3-4 DAYS)	(5-7 DAYS)
GO TO Q.#4	↓	↓	↓

3a. What were these activities?
____

3b. On average, how many hours per day did you engage in these light sport or recreational activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

4. Over the past 7 days, how often did you engage in moderate sport and recreational activities such as doubles tennis, ballroom dancing, hunting, ice skating, golf without a cart, softball or other similar activities?

[0.] NEVER	[1.] SELDOM	[2.] SOMETIMES	[3.] OFTEN
↓	(1-2 DAYS)	(3-4 DAYS)	(5-7 DAYS)
GO TO Q.#5	↓	↓	↓

4a. What were these activities?
____

4b. On average, how many hours per day did you engage in these moderate sport and recreational activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

5. Over the past 7 days, how often did you engage in strenuous sport and recreational activities such as jogging, swimming, cycling, singles tennis, aerobic dance, skiing (downhill or cross-country) or other similar activities?

[0.] NEVER ↓ GO TO Q.#6 | [1.] SELDOM (1-2 DAYS) ↓ | [2.] SOMETIMES (3-4 DAYS) ↓ | [3.] OFTEN (5-7 DAYS) ↓

5a. What were these activities?

____

5b. On average, how many hours per day did you engage in these strenuous sport and recreational activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

6. Over the past 7 days, how often did you do any exercises specifically to increase muscle strength and endurance, such as lifting weights or pushups, etc.?

[0.] NEVER ↓ GO TO Q.#7 | [1.] SELDOM (1-2 DAYS) ↓ | [2.] SOMETIMES (3-4 DAYS) ↓ | [3.] OFTEN (5-7 DAYS) ↓

6a. What were these activities?

____

6b. On average, how many hours per day did you engage in exercises to increase muscle strength and endurance?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

HOUSEHOLD ACTIVITY

7. During the past 7 days, have you done any light housework, such as dusting or washing dishes?

   [1.] NO [2.] YES

8. During the past 7 days, have you done any heavy housework or chores, such as vacuuming, scrubbing floors, washing windows, or carrying wood?

   [1.] NO [2.] YES

9. During the past 7 days, did you engage in any of the following activities?

   Please answer YES or NO for each item.

		NO	YES
a.	Home repairs like painting, wallpapering, electrical work, etc.	1	2
b.	Lawn work or yard care, including snow or leaf removal, wood chopping, etc.	1	2
c.	Outdoor gardening	1	2
d.	Caring for an other person, such as children, dependent spouse, or an other adult	1	2

WORK-RELATED ACTIVITY

10. During the past 7 days, did you work for pay or as a volunteer?

[1.] NO [2.] YES

10a. How many hours per week did you work for pay and/or as a volunteer?

________________ HOURS

10b. Which of the following categories best describes the amount of physical activity required on your job and/or volunteer work?

[1] Mainly sitting with slight arm movements. [**Examples:** office worker, watchmaker, seated assembly line worker, bus driver, etc.]

[2] Sitting or standing with some walking. [**Examples:** cashier, general office worker, light tool and machinery worker.]

[3] Walking, with some handling of materials generally weighing less than 50 pounds. [**Examples:** mailman, waiter/waitress, construction worker, heavy tool and machinery worker.]

[4] Walking and heavy manual work often requiring handling of materials weighing over 50 pounds. [**Examples:** lumberjack, stone mason, farm or general laborer.]

The Activities-specific Balance Confidence (ABC) Scale*

Instructions to Participants: For each of the following activities, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100% If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports.

0%	10	20	30	40	50	60	70	80	90	100%
No Confidence										Completely Confident

How confident are you that you will not lose your balance or become unsteady when you…

1. …walk around the house? _____%
2. …walk up or down stairs? _____%
3. …bend over and pick up a slipper from the front of a closet floor? _____%
4. …reach for a small can off a shelf at eye level? _____%
5. …stand on your tip toes and reach for something above your head? _____%
6. …stand on a chair and reach for something? _____%
7. …sweep the floor? _____%
8. …walk outside the house to a car parked in the driveway? _____%
9. …get into or out of a car? _____%
10. …walk across a parking lot to the mall? _____%
11. …walk up or down a ramp? _____%
12. …walk in a crowded mall where people rapidly walk past you? _____%
13. …are bumped into by people as you walk through the mall? _____%
14. …step onto or off of an escalator while you are holding onto a railing? _____%
15. …step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? _____%
16. …walk outside on icy sidewalks? _____%

*Powell LE & Myers AM. The Activities-specific Balance Confidence (ABC) Scale. Journal of Gerontology Med Sci 1995; 50(1):M28-34.

Total ABC Score: __________

Scoring: _____________ **/ 16 =** __________% of self confidence
Total ABC Score

Geriatric Depression Scale: Short Form

Choose the best answer for how you have felt over the past week:

1. Are you basically satisfied with your life? YES / **NO**

2. Have you dropped many of your activities and interests? **YES** / NO

3. Do you feel that your life is empty? **YES** / NO

4. Do you often get bored? **YES** / NO

5. Are you in good spirits most of the time? YES / **NO**

6. Are you afraid that something bad is going to happen to you? **YES** / NO

7. Do you feel happy most of the time? YES / **NO**

8. Do you often feel helpless? **YES** / NO

9. Do you prefer to stay at home, rather than going out and doing new things? **YES** / NO

10. Do you feel you have more problems with memory than most? **YES** / NO

11. Do you think it is wonderful to be alive now? YES / **NO**

12. Do you feel pretty worthless the way you are now? **YES** / NO

13. Do you feel full of energy? YES / **NO**

14. Do you feel that your situation is hopeless? **YES** / NO

15. Do you think that most people are better off than you are? **YES** / NO

Answers in **bold** indicate depression. Score 1 point for each bolded answer.

A score > 5 points is suggestive of depression.
A score ≥ 10 points is almost always indicative of depression.
A score > 5 points should warrant a follow-up comprehensive assessment.

Source: http://www.stanford.edu/~yesavage/GDS.html
This scale is in the public domain.

The Hartford Institute for Geriatric Nursing would like to acknowledge the original author of this Try This, Lenore Kurlowicz, PhD, RN, CS, FAAN, who made significant contributions to the field of geropsychiatric nursing and passed away in 2007.

NARI

Falls Risk for Older People – Community setting (FROP-Com)

Marital Status:
Single / Married (defacto) / Widowed / Divorced (separated) / Unknown (circle)

Usual living arrangements: ____

Recent health / community services use:

1. Community Aged Care Packages/Services	Y/N	2. Community Rehabilitation..................	Y/N
3. Doctors Appointment...	Y/N	4. Doctor Home Visit	Y/N
5. Home Help..	Y/N	6. Home Modifications	Y/N
7. Home Rehabilitation	Y/N	8. Linkages Package..........................	Y/N
9. Meals on Wheels...	Y/N	10. OT Home visit...............................	Y/N
11. Outpatient Appointment.......................................	Y/N	12. Other..	Y/N
13. Post Acute Care	Y/N	14. Personal Care	Y/N
15. Respite Care..	Y/N	16. District Nursing Services	Y/N
17. Physiotherapist Appointment...............................	Y/N	18. Dietician	Y/N
19. Podiatrist..	Y/N	20. Personal Alarm	Y/N
21. Day Centre	Y/N	22. Falls and Balance clinic	Y/N

• Is English the individuals preferred language? If not, what is? ……………………………..	o Yes o No
• Does the individual have functional English?	o Yes o No

History of falls *(0-3points)*		**SCORE**
1. Number of falls in the past 12 months? ……………………………..	o No falls (0) o 1 fall (1) o 2 falls (2) o 3 or more (3)	[ ]
2. Was an injury sustained in any of the fall/s in the past 12 months? *(rate most severe injury due to a fall in the past 12 months)*	o No (0) o Minor injury, did not require medical attention (1) o Minor injury, did require medical attention (2) o Severe injury (fracture, etc) (3)	[ ]
3. Describe the circumstances of the most recent fall in the past 12 months. **Time of fall**: AM / PM *(please circle)* **Location of fall**: inside home / outside home / community **Direction of fall**: left / right / forward / backward / down / can't remember / other **Cause of fall**: trip / slip / loss of balance / knees gave way / fainted / feeling dizzy or giddy / alcohol or meds / fell out of bed / unknown **Injuries:**		
	Sub total for this page	[ ]

Medications *(0-3 points)*		
4. List all medications currently taken.	+ + + + + + + +	+ + + + + + + +
5. Number of prescription medications.	o No medication (0) o 1 –2 medications (1) o 3 medications (2) o 4 or more medications (3)	[ ]
6. Does the individual take any of the following type of medication? o sedative o antidepressant o anti-epileptics o central acting analgesic o digoxin o diuretics o type 1a antiarrythmic o vestibular suppressant	o None apply (0) o 1–2 apply (1) o 3 apply (2) o 4 or more apply (3)	[ ]
Medical conditions *(0-3 points)*		
7. Does the individual have a chronic medical condition/s affecting their balance & mobility? o Arthritis o Respiratory condition o Parkinson's Disease o Diabetes o Dementia oPeripheral neuropathy o Cardiac condition oStroke o Other neurological conditions o Lower Limb Amputation. oOsteoporosis o Vestibular Disorder o Other dizziness o Back pain olower limb joint replacement	o None apply (0) o 1-2 apply (1) o 3-4 apply (2) o 5 or more apply (3) Osteoporosis: o Unknown o does not have	[ ]
Sensory loss		
8. Does the client have an uncorrected sensory deficit/s that limits their functional ability?	Vision Somato Sensory o no (0) o no (0) o yes (1) o yes (1)	[ ]
Feet & footwear		
9. Does the client have foot problems, e.g. corns, bunions, swelling etc.	o no (0) o yes (1) (specify):	[ ]
10. Does the client have inappropriate, poorly fitting or worn footwear?	o no (0) o yes (1) (specify):	[ ]
Cognitive status*: (score 0-3 points).*		
11. AMTS score o Age o Time to the nearest hour o Current season o Current year o Current location (where are we?) o Recognition of two persons (Dr, nurse) o Current date o Years of first World War o Name of current prime minister o Count backwards from 20 by ones	Number of correct responses: o 9-10 (0 point) o 7-8 (1 point) o 5-6 (2 points) o 4 or less (3 points) Score: ……………/ 10	[ ]
Continence:		
12. Is the individual continent?	o Yes (0) o No (1)	[ ]
13. Does the individual regularly have to go to the toilet in the night (3 or more times)?	o No (0) o Yes (1) (if uses a bottle, rate as 0)	[ ]
	Sub total for this page	[ ]

Nutritional status *(score 0-3 points)*		
14. Has the individual's food intake declined in the past three months due to a loss of appetite, digestive problems, chewing or swallowing difficulties?	o No (0) o Small change, but intake remains good (1) o Moderate loss of appetite (2) o Severe loss of appetite / poor oral intake (3)	[ ]
15. Weight loss during the last 3-12 months.	o Nil (0) o Minimal (<1 kg) or unsure (1) o Moderate (1-3kg) (2) o Marked (>3kg) (3)	[ ]
16. Number of alcoholic drinks consumed in the past week	o Nil (0) o 1-3 (1) o 4-10 (2) o 11+ (3)	[ ]
Environment *(score 0-3 points)*		
17. Did the home environment appear safe? *(NOTE: only rate if undertaking a home visit assessment, leave blank otherwise)*	o Yes (0) o Minimal environmental hazards (1) o Moderate environmental hazards requiring modification (2) o Extremely unsafe environment (3)	[ ]
Functional Behaviour *(score 0 –3 points)*		
18. Observed behaviours in Activities of Daily Living and Mobility indicate	o Consistently aware of current abilities /seeks appropriate assistance as required (0) o Generally aware of current abilities /occasional risk-taking behaviour (1) o Under-estimates abilities / inappropriately fearful of activity (2) o Over-estimates abilities/frequent risk-taking behaviour (3)	[ ]
Function *(score 0-3 points)*		
19. Prior to this fall, how much assistance was the individual requiring for personal care activities of daily living (eg dressing, grooming, toileting)? *(NOTE: If no fall in last 12 months, rate current function)*	o none (completely independent) (0) o supervision (1) o some assistance required(2) o completely dependent (3)	[ ]
20. Has this changed since the most recent fall? *(leave blank if no falls in 12 months)*	o No (0) o Yes (1) (specify):	[ ]
21. *Prior to this fall, how much assistance was the individual requiring for instrumental activities of daily living (eg shopping, housework, laundry)? (NOTE: If no fall in last 12 months, rate current function)*	o none (completely independent) (0) o supervision (1) o some assistance required(2) o completely dependent (3)	[ ]
22. Has this changed since the most recent fall? *(leave blank if no falls in 12 months)*	o No (0) o Yes (1) (specify):	[ ]
	Sub total for this page	[ ]

Balance *(score 0-3 points)*		
23. Does the individual, upon observation of walking and turning, appear unsteady or at risk of losing their balance? *(NOTE: Rate with usual walking aid. Tick one only, if level fluctuates, tick the most unsteady rating)*	o No unsteadiness observed (0) o Yes, minimally unsteady on walking or turning (1) o Yes, moderately unsteady on walking or turning (needs supervision) (2) o Yes, consistently and severely unsteady on walking or turning (needs constant hands on assistance (3)	[ ]
Gait / Physical Activity *(score 0-3 points)*		
24. Can the individual walk safely around their own home?	o Independent, no gait aid needed (0) o Independent with a gait aid (1) o Safe with supervision / physical assistance o (2) o Unsafe (3)	[ ]
25. Can the individual walk safely in the community?	o Independent, no gait aid needed (0) o Independent with a gait aid (1) o Safe with supervision / physical assistance (2) o Unsafe (3)	[ ]
26. If a walking aid is used, list the aid and when it is used.	Aid……………………….. o indoors o outdoors	
27. How physically active is the individual?	o Very active (exercises 3 times per week) (0) o Moderately active (exercises less than twice per week) (1) o Not very active (rarely leaves the house) (2) o Inactive (rarely leaves one room of the house) (3)	[ ]
28. Has this changed since the most recent fall?	o No (0) o Yes (1) (specify):	[ ]
	Sub total for this page	[ ]
	Sub total for page 1	[ ]
	Sub total for page 2	[ ]
	Sub total for page 3	[ ]
	Total Risk Score	[ ]

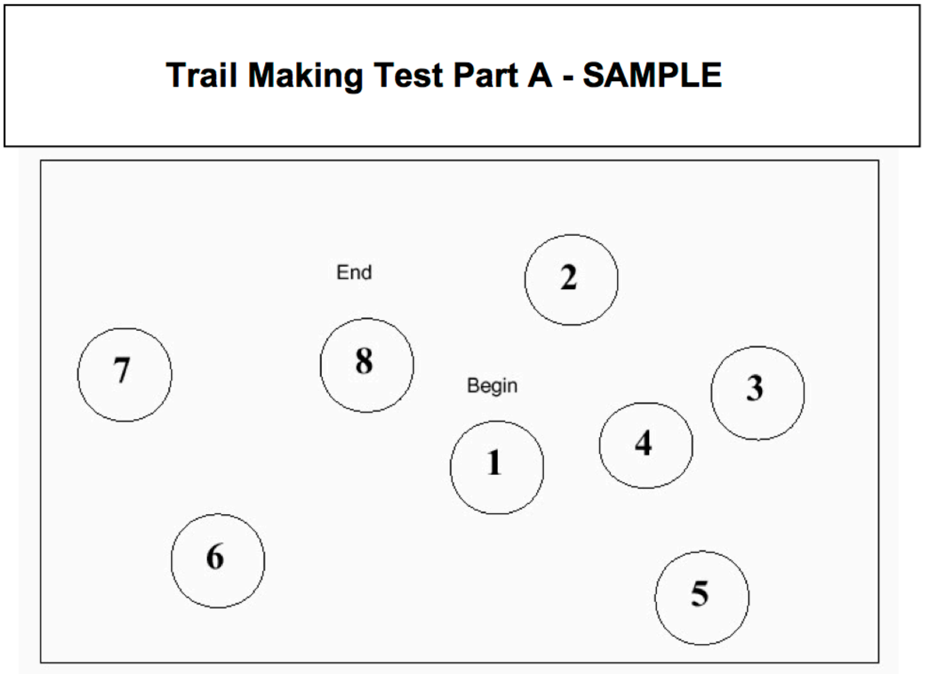
Grading of falls risk:

o Mild to moderate falls risk	0 – 20	Implement actions for identified individual risk factors, & recommend health promotion behaviour to minimise future ongoing risk (eg – increased physical activity, good nutrition)
o High falls risk	21 - 60	Implement actions for identified individual risk factors, and implement additional actions for high falls risk

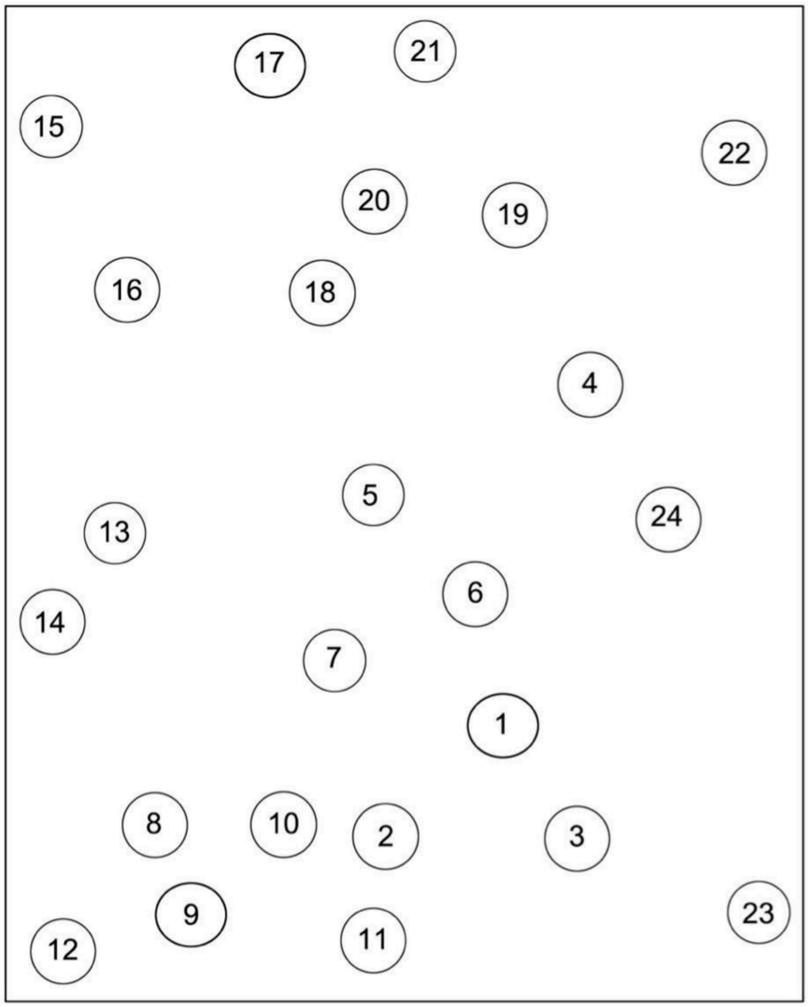
(maximum =60)

In 2009 the Department of Health funded Northern Health, in conjunction with the National Ageing Research Institute, to review the Department of Health's falls prevention resources website. The materials used as the basis of this generic resource were developed by the National Ageing Research Institute under a Service Agreement with the Department of Human Services, now the Department of Health. This and other falls prevention resources are available from the department's Aged Care website at: http;//www.health.vic.gov.au/agedcare/maintaining/falls/index.htm.

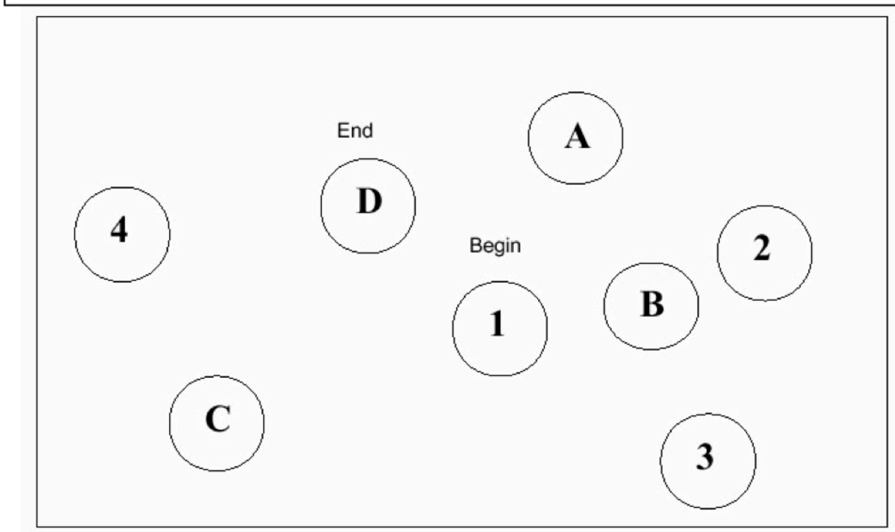
Appendix B: Executive Function Questionnaires



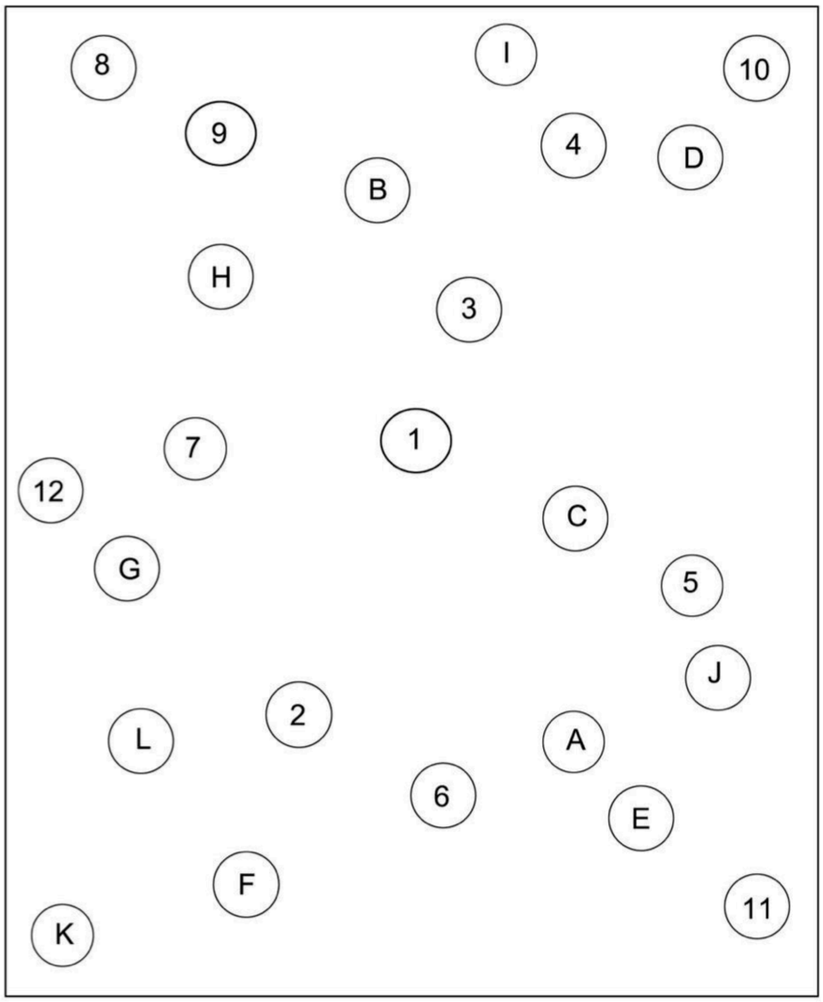
Trail Making Test Part A



Trail Making Test Part B - SAMPLE



Trail Making Test Part B



The Stroop Effect: Test #1

Instructions:

____

____

RED	GREEN	RED	BLUE	GREEN
BLUE	BLUE	RED	RED	BLUE
GREEN	RED	GREEN	BLUE	BLUE
RED	BLUE	GREEN	RED	GREEN
BLUE	RED	GREEN	GREEN	BLUE
RED	RED	GREEN	BLUE	RED
BLUE	GREEN	BLUE	RED	GREEN
RED	GREEN	RED	BLUE	GREEN
BLUE	BLUE	RED	RED	RED
GREEN	BLUE	GREEN	BLUE	GREEN
BLUE	GREEN	RED	GREEN	GREEN
RED	BLUE	BLUE	BLUE	GREEN
GREEN	BLUE	RED	RED	RED
BLUE	RED	BLUE	GREEN	GREEN
RED	BLUE	BLUE	GREEN	BLUE
RED	GREEN	BLUE	GREEN	RED

The Stroop Effect: Test #2

Instructions:
____
____

XXX	XXXXX	XXXX	XXXX	XXX
XXX	XXXXX	XXX	XXXXX	XXXX
XXXXX	XXX	XXXX	XXX	XXXX
XXXXX	XXX	XXXX	XXXXX	XXX
XXXX	XXXXX	XXX	XXX	XXXX
XXXXX	XXXXX	XXX	XXXX	XXXXX
XXX	XXXX	XXX	XXXXX	XXX
XXXX	XXXX	XXXXX	XXX	XXXXX
XXX	XXX	XXX	XXXX	XXXXX
XXXX	XXXX	XXXXX	XXXXX	XXX
XXXX	XXX	XXXX	XXXX	XXX
XXXXX	XXXX	XXXXX	XXX	XXXX
XXXXX	XXX	XXX	XXXX	XXXXX
XXXXX	XXXX	XXXXX	XXX	XXXX
XXX	XXX	XXXXX	XXX	XXXX
XXXXX	XXX	XXXX	XXXX	XXXXX

The Stroop Effect: Test #3 -- SAMPLE

Instructions:
____
____

RED BLUE GREEN RED GREEN

The Stroop Effect: Test #3

Instructions: ____
____

RED	GREEN	RED	BLUE	GREEN
BLUE	BLUE	RED	RED	BLUE
GREEN	RED	GREEN	BLUE	BLUE
RED	BLUE	GREEN	RED	GREEN
BLUE	RED	GREEN	GREEN	BLUE
RED	RED	GREEN	BLUE	RED
BLUE	GREEN	BLUE	RED	GREEN
RED	GREEN	RED	BLUE	GREEN
BLUE	BLUE	RED	RED	RED
GREEN	BLUE	GREEN	BLUE	GREEN
BLUE	GREEN	RED	GREEN	GREEN
RED	BLUE	BLUE	BLUE	GREEN
GREEN	BLUE	RED	RED	RED
BLUE	RED	BLUE	GREEN	GREEN
RED	BLUE	BLUE	GREEN	BLUE
RED	GREEN	BLUE	GREEN	RED

Appendix C: Tinetti's Mobility Test

Health

Tinetti Performance Oriented Mobility Assessment

POMA is a task- oriented test that measures an older adult's gait and balance abilities by an ordinal scale of 0 (most impairment) to 2 (independence). The assessments takes **10 - 15 minutes to complete.**

(See: Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. JAGS 1986; 34: 119-126. Scoring description: PT Bulletin Feb. 10, 1993)

Name: **Date:**

Location: **Administrator:**

Balance Assessment

Instructions: Subject is seated in a hard, armless chair. The following maneuvers are tested.

	Task	Description of Balance	Possible	Score
1	Sitting Balance	Leans or slides in chair	0	
		Steady, safe	1	
2	Arises	Unable without help	0	
		Able, uses arms to help	1	
		Able without using arms	2	
3	Attempts to arise	Unable without help	0	
		Able, requires > 1 attempt	1	
		Able to rise, 1 attempt	2	
4	Immediate standing balance (first 5 seconds)	Unsteady (swaggers, moves feet, trunk sway)	0	
		Steady but uses walker or other support	1	
		Steady without walker or other support	2	
5	Standing Balance	Unsteady	0	
		Steady but wide stance (medial heels > 4 inches apart) and uses cane or other support	1	
		Narrow stance without support	2	
6	Nudged (subject at max position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)	Begins to fall	0	
		Staggers, grabs, catches self	1	
		Steady	2	
7	Eyes closed (at maximum position #6)	Unsteady	0	
		Steady	1	
8	Turning 360 degrees	Discontinuous steps	0	
		Continuous steps	1	
		Unsteady (grabs, swaggers)	0	
		Steady	1	
9	Sitting Down	Unsafe (misjudged distance, falls into chair)	0	
		Uses arms or not a smooth motion	1	
		Safe, smooth motion	2	

0 = highest level of impairment
2 = independent

Total Balance Score (out of 16) =

Health

Tinetti Performance Oriented Mobility Assessment

POMA is a task- oriented test that measures an older adult's gait and balance abilities by an ordinal scale of 0 (most impairment) to 2 (independence). The assessments takes **10 - 15 minutes to complete.**

(See: Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. JAGS 1986; 34: 119-126. Scoring description: PT Bulletin Feb. 10, 1993)

Name: **Date:**

Location: **Administrator:**

Balance Assessment

Instructions: Subject is seated in a hard, armless chair. The following maneuvers are tested.

	Task	Description of Balance	Possible	Score
1	Sitting Balance	Leans or slides in chair	0	
		Steady, safe	1	
2	Arises	Unable without help	0	
		Able, uses arms to help	1	
		Able without using arms	2	
3	Attempts to arise	Unable without help	0	
		Able, requires > 1 attempt	1	
		Able to rise, 1 attempt	2	
4	Immediate standing balance (first 5 seconds)	Unsteady (swaggers, moves feet, trunk sway)	0	
		Steady but uses walker or other support	1	
		Steady without walker or other support	2	
5	Standing Balance	Unsteady	0	
		Steady but wide stance (medial heels > 4 inches apart) and uses cane or other support	1	
		Narrow stance without support	2	
6	Nudged (subject at max position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)	Begins to fall	0	
		Staggers, grabs, catches self	1	
		Steady	2	
7	Eyes closed (at maximum position #6)	Unsteady	0	
		Steady	1	
8	Turning 360 degrees	Discontinuous steps	0	
		Continuous steps	1	
		Unsteady (grabs, swaggers)	0	
		Steady	1	
9	Sitting Down	Unsafe (misjudged distance, falls into chair)	0	
		Uses arms or not a smooth motion	1	
		Safe, smooth motion	2	

0 = highest level of impairment
2 = independent

Total Balance Score (out of 16) =

Appendix D: Letter of Information and Consent

Appendix E: Ethics Form

Appendix F: Supplementary Tables.

Table 4. The unreported executive function results.

Variable	Non-Fallers (n=27)	Moderate Risk for Falls (n=6)	Fallers (n=11)	All Subjects (n=44)
Stroop (C-B)	42.5 ± 13.3	53.3 ± 14.5	36.6 ± 13.6	42.5 ± 14.1
Trail Making Test (B-A)	28.0 ± 12.9	43.8 ± 20.8	32.2 ± 18.2	31.2 ± 16.0
RAVLT (Delay)[1]	7.9 ± 2.9	7.5 ± 4.4	9.4 ± 2.9	8.3 ± 3.2

[1] Rey's Auditory Verbal Learning Test

Table 5. The behavioral results from the 0-Back Test.

0-Back Behavioural Data	Low Risk (LR) (n=14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
All Target Types Reaction Time (ms)	521.3 ± 72.1	554.8 ± 111.5	546.9 ± 63.6
Target Reaction Time (ms)	538.7 ± 69.7	557.6 ± 77.6	560.5 ± 58.5
Non-Target Reaction Time (ms)	518.8 ± 80.0	553.9 ± 125.3	542.2 ± 66.5
Correct %	99.0 ± 1.2	99.2 ± 0.5	99.7 ± 0.3
Error %	1.0 ± 1.2	0.8 ± 0.5	0.3 ± 0.3

Table 6. The behavioral results from the 1-Back Test.

1-Back Behavioural Data	Low Risk (LR) (n=14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
All Target Types Reaction Time (ms)	627.5 ± 100.8	672.2 ± 145.4	680.0 ± 120.4
Target Reaction Time (ms)	638.0 ± 107.6	646.3 ± 96.1	642.3 ± 99.4
Non-Target Reaction Time (ms)	622.1 ± 103.5	680.9 ± 164.2	691.9 ± 130.1
Correct %	98.2 ± 1.0	95.6 ± 2.87	97.9 ± 2.6
Error %	1.8 ± 1.0	4.4 ± 2.9	2.2 ± 2.6

Table 7. The unreported behavioral results from the 2-Back Test.

2-Back Behavioral Data	Non-Fallers (n = 14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
All Target Types Reaction Time (ms)	877.9 ± 139.6¤	1147.1 ± 150.3•	1016.8 ± 150.3
Non-Target Reaction Time (ms)	890.5 ± 137.8¤	1170.7 ± 151.7•	1058.6 ± 200.0

• $p < 0.05$ difference from Non-Faller
•• $p < 0.01$ difference from Non-Faller
¤ $p < 0.01$ difference from Moderate Risk for Falls
¤¤ $p < 0.01$ difference from Moderate Risk for Falls
‡ $p < 0.01$ difference from Faller
‡‡ $p < 0.01$ difference from Faller
* $p < 0.05$ mean difference in the omnibus ANOVA
** $p < 0.01$ mean difference in the omnibus ANOVA

Table 8. The electrophysiological results for the non-targets in the 2-Back Test at the Fz electrode site.

	Non-Fallers (n=14)	Moderate Risk for Falls (n=5)	Fallers (n=11)
N2 Peak Latency (ms)	300.6 ± 16.5‡‡¤¤	276.0 ± 11.7•‡	259.3 ± 15.3••
N2 Mean Amplitudes (µV)	8.0 ± 5.4	5.1 ± 4.8	5.7 ± 8.3
P3 Peak Latency (ms)	465.6 ± 12.8‡‡¤¤	495.2 ± 14.5•‡	416.9 ± 14.6••¤¤
P3 Mean Amplitudes (µV)	15.2 ± 10.7	17.1 ± 10.0	16.7 ± 17.6

• $p < 0.05$ difference from Non-Faller
•• $p < 0.01$ difference from Non-Faller
¤ $p < 0.01$ difference from Moderate Risk for Falls
¤¤ $p < 0.01$ difference from Moderate Risk for Falls
‡ $p < 0.01$ difference from Faller
‡‡ $p < 0.01$ difference from Faller
* $p < 0.05$ mean difference in the omnibus ANOVA
** $p < 0.01$ mean difference in the omnibus ANOVA

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	Exercise is Medicine The University of Western Ontario 2017-2018
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