Exploring Diurnal Effects on Attention and Working Memory with Young and Older Adults Using the Dalhousie Computerized Attention Battery (DalCAB)

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Abstract

Exploring Diurnal Effects on Attention and Working Memory with Young and Older Adults
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The current study was conducted to assess the feasibility of a remote administration of the DalCAB, confirm a preference for eveningness in young adults and morningness in older adults, and see if age-related shifting diurnal rhythm preferences affect attention performance. Of the 62 participants who consented to participate, 26 young adults (18-35 years) and 29 older adults (55-79 years) completed the DalCAB once in the morning (8 AM) and once in the evening (4 PM) and took the Morningness-Eveningness Questionnaire (MEQ) to assess diurnal preference. With a 90% completion rate and highly acceptable System Usability Scale scores we conclude that remote administration of the DalCAB is feasible. We found a significant relationship between age and MEQ type with an increased preference for morningness with age. Current data suggest that both older and younger adults were able to perform similarly on the DalCAB at any time during the normal workday.

Introduction

Starting in 2020 the global COVID-19 pandemic has had a significant impact on not only the way we deliver health care in Canada and across the world, but on how we conduct research as well. Safety precautions necessary to limit the spread of the virus have forced us to embrace the telehealth technology and practices currently available, and as always, more research is necessary to ensure that we are delivering the best care possible. Scientists and community members alike are not exempt from taking every precaution to protect themselves and others from COVID-19, and so valid and reliable remote administration of research must be developed as well. The current study focuses on validating an emerging tool for assessing cognitive health using remote administration, by focusing on the impact of time of assessment as a factor during cognitive testing, specifically of attention function.

Attention.

Petersen and Posner (2012) identify three specific networks that govern attention function as alerting/vigilance, orienting/selection and executive control. *Vigilance* is the active state of preparedness that allows the brain to detect and respond to stimuli, being warned that a stimulus is coming and then attending to it like setting out to watch a meteor shower and alerting to each shooting star you can see. *Orienting* is the directing of attention to a specific stimulus. Orienting involves knowing what stimulus to look for and searching to find it, like knowing that Venus will be visible in the night sky and searching for it with your telescope. *Executive control* involves the ability to initiate, switch between, and adjust tasks while performing them, as well as make decisions and detect errors. Trying to locate and identify visible constellations in the sky while simultaneously trying to count the number of shooting stars that pass by would require executive control to switch between and accurately preform both tasks (Posner & Petersen, 1990; Petersen & Posner, 2012). Complex and diffuse neural pathways throughout the brain make up the independent attention networks that give us the ability to attend to any stimulus. If these neural areas are damaged or disturbed by trauma such as a stroke or other neurological condition, any number of important processes can be interrupted, potentially disrupting the functioning of one or more networks (Fernandez-Duque & Posner, 2001).

Many physical health conditions are accompanied by cognitive health problems that often go unnoticed due to the pressing nature of the many other symptoms afflicting the patient. Adults over 65 years of age are one of the fastest growing demographics in Canada, whose healthcare needs continue to increase, but our health care system is already struggling to keep up. One of the most common age-related health problems in Canada is stroke, with 62,000 strokes occurring each year (Heart and Stroke, 2018), which could see an increase as we learn more about how COVID-19 puts people at a higher risk of experiencing a stroke (Cui et al., 2022). Cognitive changes that commonly occur with stroke and other vascular diseases are known as vascular cognitive impairment (Gorelick et al., 2011). Vascular cognitive impairment can include the focal effects of a stroke depending upon the location, as well as underlying problems with attention and working memory related to the progressive vascular pathology (Dichgans & Leys 2017). Attention problems after stroke are common and associated with poor recovery outcomes (Klinke, et al., 2015). Attention deficits still measurable months after the initial stroke in particular are associated with poor perceived quality of life by the patient (Cumming,et al., 2014; Pearce et al., 2016). Vascular diseases are just one condition common to older adults that can result in attention deficits, making attention an important focus of patient recovery. The ability to detect problems with attention as early and efficiently as possible could aide in prognosis and rehabilitation planning for many older adults relying on our overburdened healthcare system.

Typical neuropsychological measures of attention are multifactorial (Benton 1994; Lezak & Hannay, 2012), and few are based on cognitive neuroscience concepts of attention networks, making it difficult to provide targeted therapy based on the assessment results. There are exceptions, such as the Test of Everyday Attention, a battery of eight subtests designed to mimic a fictional road trip across the US (Robertson et al., 1996). The Dalhousie Computerized Attention Battery (DalCAB), an attention assessment tool developed by Eskes and colleagues (Jones et al., 2015; Jones et al., 2016; Sardiwalla et al., 2018), contains theory-based measures of these attention networks spread across 8 simple computerized tasks. Using the familiar designs of playing cards each task on the DalCAB focus on different attention functions (see Table 1) like searching for a target among distractions or making a quick visual discrimination decision, and reaction time and error rates are recorded for each. The DalCAB has been validated as a test of attention, however the majority of published work has been done on desktop devices in a laboratory or hospital setting, mostly with young adults (Jones et al., 2015; Jones et al., 2016), although it has also been recently applied to older adults (Sardiwalla et al., 2018).

Diurnal Rhythms of Performance.

An individual’s task performance may vary depending on the time of day due to their diurnal rhythm, making time of testing worth considering as a variable that may influence the results of a cognitive assessment like the DalCAB. A diurnal rhythm is the sleep-wake cycle typically followed by humans, where we are awake and active during the day when the sun is up and sleep at night when it is dark. Diurnal rhythms reflect our circadian rhythm that may vary from person to person. The time of day that a person takes a cognitive test can impact their performance based on their diurnal rhythm (Folkard & Monk, 1980; Valdez, 2019). There is evidence that the ideal time of day for peak cognitive performance can have a genetic component from person to person (Goel et al., 2013) and change as you age (Yoon et al., 1998). The idea that performance is optimized when a person is tested at their peak arousal period is known as the “synchrony effect” (May & Hasher, 1998) and their preferred time of day is known as their “chronotype” (Valdez, 2019).

Chronotype has been operationalized by the Morningness-Eveningness Questionnaire (MEQ; Horne & Östberg, 1976) a self-report measure of time of peak performance that divided people into ‘morningness’ (subjective peak cognitive performance and preference for the mornings), ‘eveningness’ (subjective peak cognitive performance and preference for the evenings) and ‘neutral-types’ (no clear preference). In the 1998 book *Cognition, Aging, and Self-Reports*, Yoon, et al., reported that in a large body of literature using the MEQ (Horne & Östberg, 1976) researchers found that there is a significant shift to ‘morningness’ after 55 years of age (Yoon, et al., 1998). A meta-analysis done in 2019 by Randler and Engelke also found that, although young men were more likely to be evening types than young women, after around age 45 (the average onset of menopause for women) men and women become more similar in their preferences and both trend more toward morningness.

Self-report chronotype data does not just stop at personal preference for one time of day over another. MEQ data have also been linked to physiological changes in the body throughout the day. In a study by Duffy et al., (1999) 68 young men (18 – 30) and 40 older men and women (64 – 81) showed a pattern of preferring morningness in later years by self reporting on the MEQ. Most of the young men fell into the neutral type, but 10 identified as morning types and 13 were evening types. Not enough of the older adults identified as evening types to be compared to their morning type same-age counterparts. Duffy and colleagues asked participants to consistently get 8 hours of sleep at their preferred bedtime and wakeup times, and after three weeks of consistent sleep participants were brought into the lab and allowed three more days of baseline preferred sleep-wake cycle (allowing for 8 hours of sleep each night). Morning type and evening type young men were compared on body temperature, plasma melatonin, and natural wake times in a constant routine that eliminated time cues from light, activity, and eating. Researchers found that the participants' patterns of body temperature and melatonin were similar (while seated and given hourly snacks over a 26 – 45-hour period) but lined up with the individual's preferred wake times such that morning types had a higher body temperature earlier in the day, and evening types' body temperature peak came later.

If people with different chronotypes are more physiologically active at their preferred time of day, it stands to reason that they may also be more cognitively active at their preferred time of day. This also raises the question of whether cognitive changes accompany chronotype preferences observed as a person ages. To understand if there were cognitive differences to go along with people's diurnal preferences and age Hasher et al., (2002) used the MEQ to identify preferences in younger and older adults, and then explored whether there were significant differences in their performance on a test of memory depending upon time of day of testing. Younger (18 – 32 years) and older (58 – 78 years) adults were selected to participate in the study based on their age and MEQ scores such that all the young adults were "eveningness" types and all the older adults were "morningness" types. The participants were split into two groups, each containing a 50% older/younger adult split. One group was tested starting at 8:00 a.m. while the other half of the participants' test period began at 4:30 p.m. Participants were presented with a list of nouns, then did a brief filler task (counting backwards by threes for 10 seconds), before being asked to recall all the words that they could remember from that list. This was done for four lists, the last of which contained nouns that were categorically different than the previous three without warning (e.g., lists one, two and three contained animal and weather nouns while list four was fruits and metals). The number of words recalled, and number of intrusions were recorded. Overall older adults recalled fewer words than their younger counterparts, and as expected morning type older adults remember more in the morning compared to morning type older adults in the afternoon and vice versa for the evening type younger adults. Older adults also had more intrusions from previous lists than younger adults, and more intrusions during the afternoon testing time compared to the morning. Younger adults did have more intrusions in the morning compared to the evening, but it was not statistically significant for the younger group. This suggests that differences in memory performance due to aging is exaggerated when participants were tested at a time of day that was not optimal for them.

Similar research has highlighted that being tested at one’s preferred time of day had an impact on performance for older adults when it came to a visuospatial working memory task. In 2009, Rowe et al., split evening type young adults and morning type older adults into two groups and had them do a Corsi Block visuospatial working memory span task either in the morning (8 or 9 am) or the afternoon (4 or 5 pm). The span task was presented in ascending order (the memory spans began short and increased in length with every span) and descending order (starting with the longest memory span and decreasing with every span). Overall young adults had higher scores on the span tasks than older adults, young adults had higher scores when tested in the evening, and older adults did better when tested in the morning. Young adults consistently performed better on the ascending span task format; however older adults performed better on the descending span task format, but only during their peak testing time in the morning. In the afternoon, older adults performed similarly on both the ascending and descending task formats. The authors suggest that older adults performing better on the descending span task format is due to a lack of interference from previous longer spans which they could now forget (whereas younger adults just benefited from more practice as spans grew longer in the ascending format). This benefit was lost however when older adults were no longer being tested at their peak time of day, suggesting that the effect of being tested at their off-peak time of day negates the benefits of the reduction in interference, and that the older adults were only able to gain this benefit when attentional control was at its peak. (Rowe et al., 2009).

Although some memory performance may be improved by being tested at one's preferred time of day, not all types of memory tasks show the same results. One study by May et al. (2005) found that being tested at one's peak time of day improved performance on an explicit memory task but had the inverse effect for implicit memory. Evening type young adults and morning type older adults were split into two even groups and tested either in the morning (8 am) or in the late afternoon (5 p.m.). Participants were shown five letter words in pairs, one of which was a target word that they were instructed to attend to and rate the pleasantness of, and one was a distractor that they could ignore. After a 10-minute delay of nonverbal decoy tasks they were given a word stem completion task (e.g. complete MON__ or LAT__) where unbeknownst to the participants some of the stems could be completed using the target words from the first task (implicit memory). Participants were then given another stem task where they were instructed to complete the stems with words from the first part of the study if they could (explicit memory). For the implicit memory task, both younger and older adults performed better at their off-peak time of day, while for explicit memory performance was better at their peak time of day. These results suggest that when someone is making an intentional effort to process and retrieve information, they will be more successful at their peak rather than off-peak time of day, but automatic, unconscious responses (such as those that are the result of priming) are more likely to be produced at when someone is not at their peak.

There is also some evidence to suggest that morning types and evening types show some differences is their ability to cope with having to perform at their not-preferred time of day. A study by Nowack and Van Der Meer in 2018 showed that morning types might be more resilient when it comes to synchrony effects compared to evening types. For this experiment researchers split adults (mean age 26.4 years) into two groups based on their chronotype (trending towards morning preference or trending towards evening preference) and had half of each group do a semantic analogy task either in the morning (between 8 and 11 am) or the afternoon/evening (between 2 and 6 pm). Participants were presented with two pairs of words for chronologically associated actions (e.g., “to cook – to eat = to saddle – to ride”) and were required to decide if the two pairs followed the same chronological pattern or not. This was thought to be a challenge of both fluid and crystal intelligence. They also measured participants pupil dilation before and during this task as a measure of psychophysiological arousal. They found that all morning types had a more dilated pupil at baseline (before testing began) that was unrelated to time of day, which they suggested was an indicator of greater alertness and wakefulness compared to evening types. They also found that while chronotype had no impact on reaction time when participants were tested at their preferred time of day, morning types had faster reaction time and no change in pupil dilation compared to evening types when tested at their off-peak time of day. The authors note that the morning type’s ability to perform well on a task of both fluid and crystallized intelligence at their non-optimal time of day may be an argument for pushing typical major social activities such as school, university, and work to be later in the day. This would ensure that everyone is able to perform at a similar level (Nowack & Van Der Meer, 2018).

Another study done by Evansova and colleges in 2020 exploring the effects of chronotype and time of day on a series of cognitive assessments found that although many were unaffected by time of testing when done at a person's off-peak time of day, for some morning types may be performing better than their peers when tested at a time that isn't ideal for them, and their window of physiological alertness (based on measures of body temperature) may be wider than their evening type counterparts. Young adults between the ages of 20 and 40 were selected based on if they were either definitely a morning type (MEQ 70 – 86), definitely an evening type (MEQ 16 – 30), or a neutral type (MEQ 42 – 58). Participants stayed at the lab for an entire weekend to ensure uniform wake-up times for participants and activity levels and body temperature were monitored in each participant throughout the weekend to corroborate their self reported chronotype and monitor their wakefulness. Each participant was tested once in the morning (8 am) and once in the evening (8 pm) on different days over one weekend. Participants were administered a reduced version of the Wechsler Intelligence Scale during their preferred testing time and the RAVLT (short term memory and learning), Trail Making Test (effectivity and processing speed), Digit Span (Short term verbal memory and working memory), Letter-Number Sequencing Test (working memory), Stroop Test (psychomotor speed and inhibitory control), CPT (attention and vigilance), and the Corsi Blocks task (spatial memory) during their non-preferred testing time. Results showed that all groups were similar in IQ and that performance on two of their measures were impacted by chronotype or time of day. Specifically, RAVLT scores were better in the evening regardless of the participant's chronotype, and morning types did better on the Stroop Test (Evansova et al, 2020), further suggesting that morning types may have an advantage over their evening type peers when they are tested at their nonoptimal time of day.

Studies that did not exclusively focus on those who identified as morning types also suggest that older adults are more significantly affected by synchrony effects across a variety of tasks relative to younger adults, showing slower reaction times and greater error rates when tested at a time that was not optimal for their preferred chronotype (Hogan et al., 200; Hasher & May, 2017). A 2017 paper by May & Hasher cites that 60% of young adults and 25% of older adults fall into the neutral-type range. As much of the cognitive diurnal rhythm research has been done on specifically morning type older adults and evening type young adults, it could be that some of the observed differences in their performance were due to neurological changes brought on by normal aging rather than differences in chronotype. A neuroimaging study by Anderson et al. had morning type older adults and younger adults with mean MEQ in the neutral range complete different attention tasks at different times of day and recorded fMRI during one of the tasks, a picture and word based 1-back task. The 1-back results showed that older adults had similar cognitive performance to that of young adults (who were tested with the same paradigm in the afternoon) when tested in the morning and that both groups were using the same neural networks of attention as shown in the fMRI data to do the task. Participants also completed a flanker task (unscanned), and young adults in the afternoon were the least impacted by the Congruency Effect, followed by the morning older and finally the afternoon older group. The young adults showed the smallest Congruency Effect, followed by the morning older adults, and the afternoon older adult’s Congruency Effect scores were the highest, though only the young adults and the afternoon older adults had a statistically significant difference. This suggested that age differences in attention regulation and inhibitory control are most pronounced when older adults are tested later in the day but are still using the same neural networks to complete the task (Anderson et al., 2014).

Based on this body of research, we know that self report MEQ type is linked not only to physiological changes in arousal throughout the day (Duffy et al., 1999) but also to cognitive arousal. Not all cognitive tasks are equally affected by diurnal preference however (May et al., 2005, Evansova et al, 2020) and deficits in performance due to aging can be exaggerated when participants are tested at a time of day that is not optimal for them (Hasher et al., 2002; Rowe, et al., 2009). Some chronotypes may also be more adaptable to performing at their non-optimal time of day as morning types, regardless of age, may be more resilient in this regard then evening and neutral types (Hogan et al., 2009; Hasher & May, 2017; Nowack & Van Der Meer, 2018; Evansova et al, 2020).

Remote Administration.

Health care providers have had to rapidly adapt to remote delivery of health care over the course of the COVID-19 pandemic. Cognitive testing, which is typically done in person with a psychologist in a clinic or hospital with computerized or paper-and-pencil cognitive assessments, is becoming increasingly inaccessible. The growing need for community health care delivery caused by pandemic lockdowns, resource availability being limited to urban centres, and reduced length of hospital stays after illness or injury make is difficult to find time and space for traditional testing methods. Using remote cognitive testing, patients could complete assessments in their homes on their own device without having to be physically present in a hospital at all and with minimal or no supervision. Remote testing would serve to ease some of the burden on our healthcare system as well as save time and travel costs for patients who are already coping with age related changes to their physical health, cognition, or neurological issues. Remote, online cognitive testing would also provide service to any rural community with internet access where before there may have been very limited or no options for care in their area. Considering early and continuing difficulties in mental healthcare related to the pandemic, especially for older adults, researchers have put out calls for improvements in telehealth assessments and availability (Danilewitz et al., 2020; Doorman et al., 2020; Nicol et al., 2020).

The decade prior to the 2020 COVID-19 outbreak saw slow but steady progress in the development of telehealth assessment techniques, with some tests of cognition showing indistinguishable results between in person and remote administration via video call or telephone call (Settle et al., 2015; Stillerova et al., 2016; Bunker et al., 2017; Barcellos et al., 2018) as well as success with assessments specifically developed for remote administration (Breitling et al., 2010). Most of this work prior to 2020 had been done using tests that are administered orally using the telephone or video call on a computer (Marra et al., 2020), which presents problems for any assessments requiring a visual component only available in print format (Hantke & Gould, 2020). Having a test require the administrator to go through the entire test with the patient also fails to free up time for the clinician or technician required to administer the assessment and is subject to human error when recording the patient’s responses. More recently, emerging evidence suggests remote unsupervised testing is feasible using mobile apps (Nicosia et al. 2022; Thompson et al, 2022; Berron et al 2022). Remote, computerized testing using online desktop or mobile apps would not only be more accessible in many cases, but also more efficient in terms of scoring assisted by the software, avoiding errors introduced by human administrators, and free up time for clinicians while the assessment is being done.

Since the pandemic began there has been an increase in patients, particularly urban living adults aged 18 – 65 experiencing chronic physical and mental health conditions, choosing telehealth as their delivery method for health care when possible, in Canada and the United States (Chu et al., 2021; Ng et al., 2022). Although telehealth practices that involve video conferencing with health care providers have proved to be better than just a phone call (Lai et al., 2020), this does not free up any extra time for the care providers in the long run. One study done by Hooyman and colleagues (2021) found that administering an unsupervised motor assessment with older adults remotely in their own home had comparable results to data collected in a laboratory setting, suggesting that more hands-off remote assessments have the potential to be as effective as assessments done with direct supervision by an administrator. There are still some extra complications that come with having participants and patients complete cognitive tests outside of the lab without direct supervision from a researcher or health care professional. Environmental distractions, differences in computer hardware and software, and compliance with test instructions are just some of the complications that are more difficult to solve with remote administration of cognitive testing. Further study of online tests will give us an idea of how much these differences matter to the final test scores and better prepare us for the issues that could potentially arise when these methods are being used in a clinical setting rather than just for research.

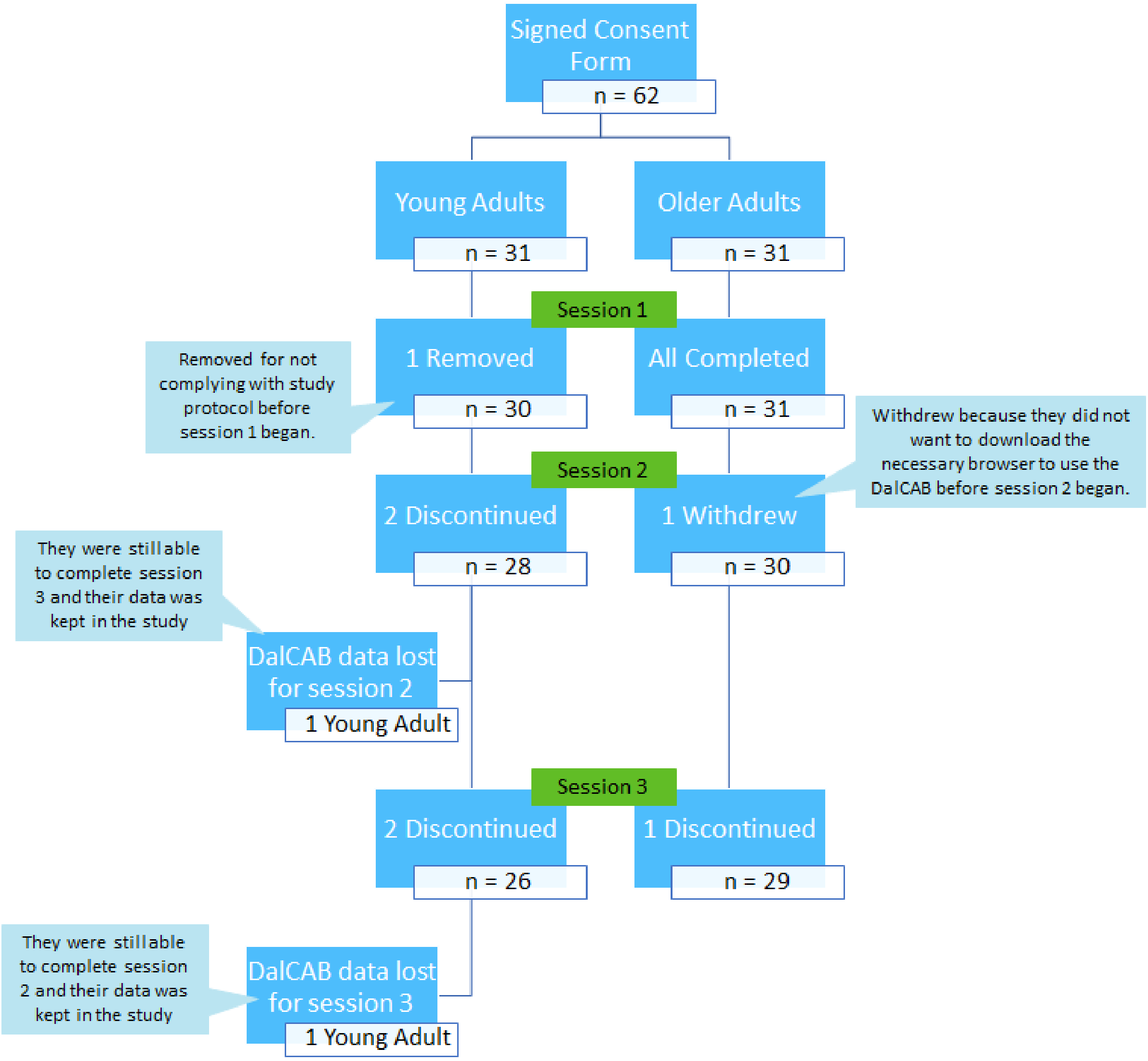
Current Study.

The purpose of the current study was to see if diurnal rhythm changes influence attention performance as we age as well, and to assess the feasibility of a completely remote, at-home administration of the DalCAB. we tested three hypotheses. The first was that an at-home administration of the DalCAB would be feasible as measured by how many participants that complete the consent process fully finished the DalCAB, and for those who did, how easy they found the software/website to use as reported on the System Usability Scale. The second hypothesis was that older adults would show a preference for morningness, and younger adults would show a preference for eveningness, using the MEQ as a measure of preference. The third hypothesis was that, due to their predicted differences in diurnal preference, older and younger adults' cognitive performance would show different diurnal patterns on the DalCAB. Specifically, we anticipated that older adults would show faster reaction time and lower rates of error on attention tasks on the DalCAB when it was done at 8am compared to 4pm, and that younger adults would show faster reaction time and lower rates of error on the DalCAB tasks done at 4pm when compared to 8am.

Methods

Participants. A total of 62 participants (31 young adults, 31 older adults) signed a consent form to participate in the study (see Figure 1). Those who completed all study measures were 26 young adults (18-35 years old) and 29 older adults (55-79 years old). Participants were recruited from the community using online advertisements, social media, an existing older adult database held by Dr. Eskes, and word of mouth recruitment through Mount Saint Vincent University's and Dalhousie University's undergraduate student research credit program. All participants were screened for self-reported normal or corrected to normal vision, hearing, and normal dominant upper limb function. Participants were excluded if they did not own a computer on which to complete the study, reported a diagnosis of a psychiatric or neurological disorder or had surgery with general anesthesia in the past six months. Exceptions were made for participants who reported no formal diagnosis of a mental health condition such as depression or anxiety but reported having prescriptions for the typical medications used to treat such conditions in both age groups (three older adults, seven young adults).

Figure 1



Note. Flow Chart of Participant Attrition. One young adult was removed after signing consent but before session 1 began for not following study protocol. One older adult withdrew after session 1 because they did not wish to download the necessary browser to use the DalCAB. All other participants discontinued without explanation.

Materials and Apparatus. This research was conducted completely remotely; all interactions with participants were completed via e-mail, phone, or Microsoft Teams (audio only). The Modified Telephone Interview for Cognitive Status (mTICS), a 14-item assessment with questions on orientation, attention and language that is scored on a scale from 0 to 50 (Duff et al.,

2009) was used as a general cognitive screening for severe dementia and was administered verbally over the phone. Administration of self report questionnaires was done via REDCap, a secure website for survey data collection, hosted through Nova Scotia Health. The Positive and Negative Affect Schedule (PANAS), a 20-item list of adjectives, 10 positive (e.g. Enthusiastic) and 10 negative (e.g. Irritable) (Watson et al., 1988), was included to screen for emotional affect differences between groups as this study was completed during a global pandemic. The Short Computer Anxiety Scale (Lester et al., 2005) was included as part of a sub-study and was not analyzed for this thesis. The Horne & Östberg (1976) Morningness-Eveningness Questionnaire (MEQ) was used to assess each participant's preferred time of day and the System Usability Scale (Bangor et al., 2008) was used as a measure of feasibility for using the DalCAB online. Participants completed the study on a desktop or laptop device with a screen, keyboard, mouse/trackpad, and speakers. No tablets or phones were used to complete the study and participants were required to use either the Google Chrome or Firefox web browsers. Participants independently completed the short form DalCAB twice online.

MEQ. For this study the Self Assessment version of the Morningness-Eveningness questionnaire (Terman & Terman, 2005) was used so that participants could answer the survey themselves on REDCap. The MEQ is a 19-item survey designed to quantify the respondent's preference (or lack thereof) for being active earlier or later in the day. It contains questions like "Approximately what time would you get up if you were free to plan your day?" and "You want to be at your peak performance for a test that you know is going to be mentally exhausting […] which one of the four testing times would you choose?". Each question has 4 or 5 available responses with an accompanying score of 0 – 5 based on the response. The MEQ is scored by adding up the total score of the 19 questions and quantifying it on a scale from Definitely Evening Type (16 – 30), Moderately Evening Type (31 – 41), Neither/Neutral Type (42 – 58), Moderately Morning Type (59 – 69), and Definitely Morning Type (70 –86). The MEQ is widely considered to be a reliable and valid tool for measuring chronotype preference (Milia et al., 2013).

SUS. The System Usability Scale is a 10-item scale designed to assess the effectiveness and user satisfaction of a digital system or software and is considered a reliable measurement tool for the usability of digital systems (Brooke, 1995; Brooke, 2013). It contains statements such as “I found the [DalCAB] unnecessarily complex.” And “I felt very confident using the [DalCAB.]” which were rated on a five-point scale from “Strongly Disagree” to “Strongly Agree” which are worth 1 to 5 points respectively. The SUS was scored using Brooke’s method (1995). The 0-100 scale has adjectives ranging from “Worst Imaginable” to “Best Imaginable” applied to it to give meaningful labels to the system’s usability score (Bangor et al., 2009).

DalCAB. The DalCAB contains eight tasks: Simple Reaction Time (SRT), Go-No-Go (GNG), 2-Choice Reaction Time (CRT), Dual Task, Flanker Task, Visual Search, Item Working Memory, and Location Working Memory (See Table 1) (Jones et al., 2016) that are presented in the same order for every participant (as done in previous research with the DalCAB; Jones et al., 2015; Jones et al., 2016) and take approximately 30 minutes to complete all together. Before each task a set of text instructions on how to do the task are displayed and for each task participants were instructed to “Try to press [the button] as quickly as possible without making any mistakes.”. Participants were given a short practice with feedback to learn the mechanics of the task before they began (Jones et al., 2016). Trial by trial reaction time (RT) and error rate data were recorded on the secure server at Dalhousie University. Data for all eight DalCAB tasks were collected and six were analyzed as part of this thesis. There is evidence that the DalCAB is a valid and reliable measure of attentional ability (Jones et al., 2015; Jones et al., 2016).

Procedure. Participants completed informed consent over the phone with a researcher before study participation began. Participants who consented to be involved with the study completed a demographic and health history questionnaire with a researcher, including computer software/hardware questions, before completing any study materials to confirm their eligibility to take part in the study. While on the phone with the researcher, participants were administered the mTICS and scheduled their online independent DalCAB sessions. During these sessions a researcher was also online so that the participant could contact them if there were any technical difficulties.

DalCAB sessions were scheduled to follow a similar procedure to Hasher, Chung, May, & Foong (2002), one in the morning starting between 8 and 9 AM and one in the evening starting between 4 and 5 PM, each approximately one week apart. The order of time of their first session (morning vs evening) was counterbalanced so that practice effects on the DalCAB could be differentiated from time-of-day effects. Roughly twenty-four hours before the scheduled sessions the participantt was sent an e-mail with a REDCap link to complete questionnaires (The PANAS and the Short Computer Anxiety Scale for the first session, and the MEQ and the System Usability Scale for the second session) as well as a link to the website where they completed the DalCAB. After the second DalCAB session, they were given a debriefing page to read and offered an opportunity to schedule a chat with a researcher to ask any questions they might have about the study.

Data Analysis. The first hypothesis was that at-home administration of the DalCAB would be feasible as measured by how many participants that completed the consent process were able and willing to finish the DalCAB and other study materials, and for those who did, how easy they found the software/website to use as reported on the SUS. To test this, we compared the number of participants who consented to participate in the study but later discontinued to the number of participants who consented to participate and completed all study materials and compared the overall SUS score between the age groups with an independent samples t-test.

For our second hypothesis we anticipated that older adults would show a preference for morningness, and younger adults would show a preference for eveningness, using the MEQ as a measure of preference. Total MEQ scores were calculated for each individual in both age groups and the mean MEQ scores for both groups were compared with a chi-square independent samples t-test.

The third hypothesis was that, due to their predicted differences in diurnal preference, the cognitive performance in older and younger adults would show different diurnal patterns on the DalCAB. Specifically, we anticipated that older adults would show better performance on attention tasks on the DalCAB when it was done at 8am compared to 4pm, and that younger adults would show better performance on the DalCAB tasks done at 4pm when compared to 8am. Six out of eight tasks on the DalCAB (described in Table 1) that were similar to and expanded on test used in previous research were chosen to be analyzed for the DalCAB specific hypothesis. These tasks were Simple Reaction Time (SRT), Two Choice Reaction Time (CRT), Flanker Task, Go-No-Go, Dual Task, and Location Working Memory. Correct Mean RT in milliseconds and error measures (% errors) were collected for these six DalCAB tasks and their variables. Reaction times less than 100 ms were coded as anticipatory and thus excluded from analysis. Reaction times greater than the maximum reaction time (varied by task) were coded as misses and excluded from reaction time analysis.

DalCAB variables were analyzed across the two sessions using a series of mixed factor Analysis of Variance (ANOVAs), with a between-subjects factor of age (younger adults and older adults) and session order (morning session first or evening session first) as well as within-subjects' factors of time of day of testing (AM or PM). Data that had an error rate equal to or greater than 0.8 (80% or greater trials were responded to incorrectly) were excluded as outliers. Significant results were followed up by multiple pairwise comparisons using Tukey HSD to correct for multiple tests. Please see Appendix 1 – 7 for a full list statistical results.

Table 1

DalCAB Tasks, Attention Networks and Variables

Task and Description	Attention Functions	Task Variables
Simple Reaction Time (SRT): Respond to each stimulus, with varied response-stimulus intervals.	Vigilance (Processing and response speed)	Overall Reaction Time (RT, averaged over all correct trials); Preparation Effect (RT at 500ms RSI minus RT at 1500ms RSI); Overall Error Rate (ER, proportion of incorrect responses)
Choice Reaction Time (CRT): Indicate the colour of each stimulus (2 choice responses, 50% each choice).	Vigilance, Executive Control	Overall RT; RT of Switch trials, RT of NonSwitch trials; Switch Effect (Mean RT of response switch trials minus mean RT of non-switch trials); Overall ER and ER for Switch trials and non-switch trials
Go-No-Go: Respond to a single target colour with high (80%) or low (20%) frequency of targets.	Inhibition Executive Control	Overall RT; Overall ER; Misses on 20% Go Block (non responses); False Alarms on 80% Go Block (responding to non-target card)
Dual Task: Complete CRT while silently counting the number of each colour of stimuli presented. Count probe for one colour at the end of each set.	Switching Executive Control	Overall RT; Switch Effect; Overall ER; Dual Task Cost (Mean CRT with counting minus mean CRT with no counting)
Flanker: Indicate shape of a central target flanked above and below by same (or different) shaped distractors. 50% distractors the same shape as the flanker shape.	Selective attention and filtering Executive Control	Overall RT; Overall ER; Congruency Effect (RT on incongruent trials minus RT on congruent trials)
Location Memory: Indicate whether a probe location was present or absent in preceding study sets of 2-6 spatial locations (50% present).	Working memory Executive Control	Overall RT; Overall ER

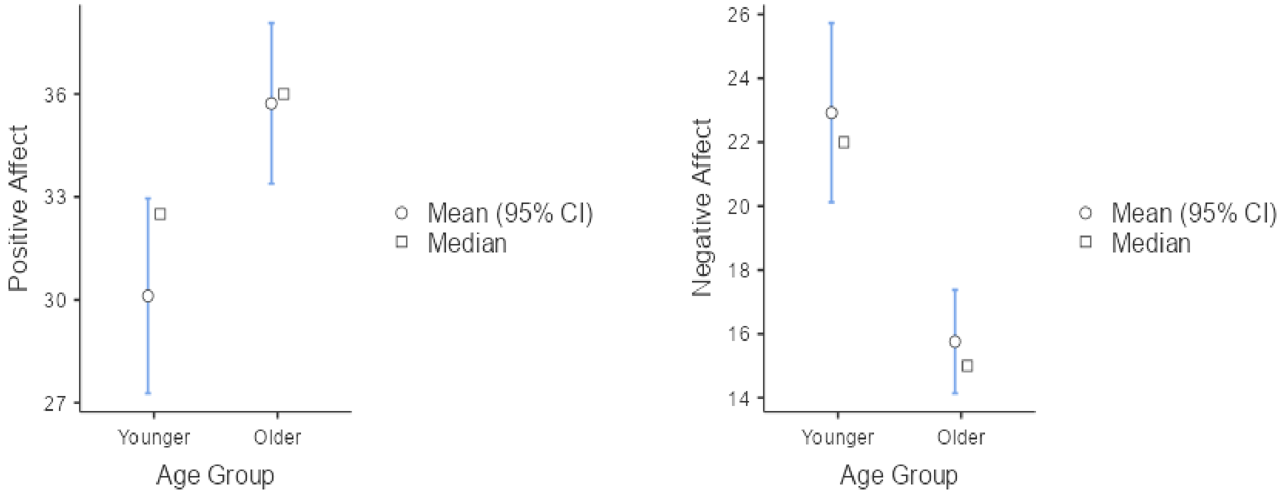
Table adapted from Jones et al. 2016.

Results

Demographics and Surveys. Only significant results ($p < 0.05$) are reported for differences in survey results, but all results can be found in the appendices below. Participants who did not complete the study were not included in demographic and survey results. There was no significant difference in years of education or mTICS total scores between younger and older adults. Both positive affect and negative affect scores on the PANAS were different between younger and older adults such that younger adult's positive affect was lower than older adults ($t(53) = -3.01$, $p = 0.002$), and younger adults negative affect was higher than older adults ($t(53) = 4.45$, $p < 0.001$), (see Table 2 and Figure 1).

Figure 2

Mean Positive and Negative Affect in Older and Younger Adults



Note. Mean and median Positive and Negative Affect scores in Older and Younger Adults. Error bars = 95% Confidence Interval. Both positive affect and negative affect scores on the PANAS were different between younger and older adults such that younger adult's positive affect was lower than older adults and younger adults negative affect was higher than older adults

Table 2

Demographic Data

Demographic Means	**Young Adults (n = 26)**	**Older Adults (n = 29)**
Mean (SD) Age in years	24.8 (4.7)	66.8 (6.2)
Gender	15 female (58%)	20 female (67%)
Mean (SD) years of Education	15.7 (1.7)	16.3 (2.2)
Mean (SD) mTICS	40.8 (3.3)	40.3 (3.6)
Mean (SD) PANAS positive	30.1 (7.4)	35.7 (6.4)
Mean (SD) PANAS negative	22.9 (7.3)	15.8 (4.6)

The first hypothesis for this study was that at-home administration of the DalCAB would be feasible. Feasibility was measured by how many participants that went through the consent process fully finished the DalCAB, and for those who did, how easy they found the software/website to use as reported on the System Usability Scale done after their second time doing the DalCAB. Of the 62 participants who signed a consent form, six withdrew from or discontinued the study before completing all study materials, and one was removed for the study for not complying with study protocol. Of those that discontinued the study, one older adult did so because they did not want to download the necessary web browser in order to do the DalCAB online, and five others (one older adult and four younger adults) stopped responding to research correspondence without giving any explanation. Of the six participants that withdrew or discontinued of their own accord three completed only session 1 (one older adult and two younger adults) and three completed sessions 1 and 2 but not session 3 (one older adult and two younger adults). Data for participants who were removed, withdrew, or discontinued the study were not used in data analysis bringing the total of each group to 26 young adults and 29 older adults (see Figure 1). Younger and older adults did not significantly differ on their mean SUS scores, giving the DalCAB a mean score of 75.7 (SD = 15.2) and 73.4 (SD = 12) respectively. Both means are in the range to consider the DalCAB's usability highly acceptable (Brooke, 2013).

For the second hypothesis, we anticipated that older adults would show a preference for morningness, and younger adults will show a preference for eveningness. When averaged together, the mean MEQ scores for both younger and older adults fall into the Neither/Neutral type (see Table 3) with the older adults having a significantly greater mean MEQ score than younger adults (t(53) = -4.55, p < 0.001). When broken down by group almost half of older adults scored in the neutral range on the MEQ, and over half the younger adults were neutral types as well (see Table 3). A chi-square test of independence was performed to examine the relation between age and MEQ type. The relation between these variables was significant, X^2(1, N = 55) = 14.7, p = 0.001, meaning proportion of each MEQ type is not the same for older and younger adults.

Table 3

Frequency of Morningness-Eveningness Questionnaire (MEQ) Types and Average by Age Group

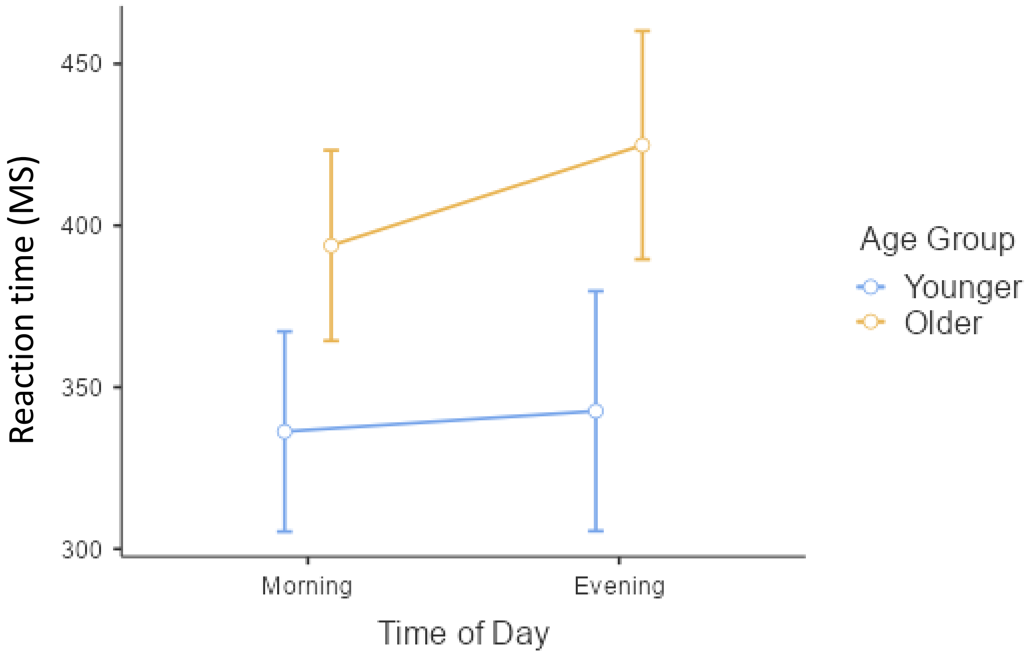
	Age Group	
MEQ Group Number	**Young Adults**	**Older Adults**
Morning Type (%)	1 (3.8%)	14 (48.2%)
Evening Type (%)	9 (34.6%)	3 (10.3%)
Neutral Type (%)	16 (61.5%)	12 (41.4%)
Mean (SD) MEQ	45.1 (7.9)	56.1 (9.8)

For the third hypothesis, we anticipated that DalCAB performance would show a diurnal pattern on the DalCAB, with different patterns in older and younger adults. Specifically, we anticipated that older adults would show better performance on attention tasks (e.g., as evidenced by faster reaction time and lower error rates) on the DalCAB when it is done at 8am compared to 4pm, and that younger adults will show better performance on attention tasks on the DalCAB done at 4pm when compared to 8am. For each task variable (listed in Table 1), a repeated measures ANOVA was performed on RTs and error rates to compare the effects of age group, time of day, session order and any relevant variable for those tasks (noted below for each task). Only significant results ($p < 0.05$) are expanded below unless there was a trend of particular interest, but all ANOVA tables can be found in the appendices.

Simple Reaction Time. A 2 x 2 x 2 (Time of Day x Age Group x Session Order) mixed ANOVA on overall reaction time revealed a main effect for age group ($F(1,51) = 13.114$, $p < 0.001$), with older adults exhibiting slower overall reaction times ($M = 411$ ms, $SD = 79.2$) compared to younger adults ($M = 339$ ms, $SD = 60.1$; See Figure 2). A separate 2 x 2 x 2 mixed ANOVA with error rate at the dependent variable found no statistically significant effects for error.

Figure 3

Time of Day by Age Group for SRT Reaction Time



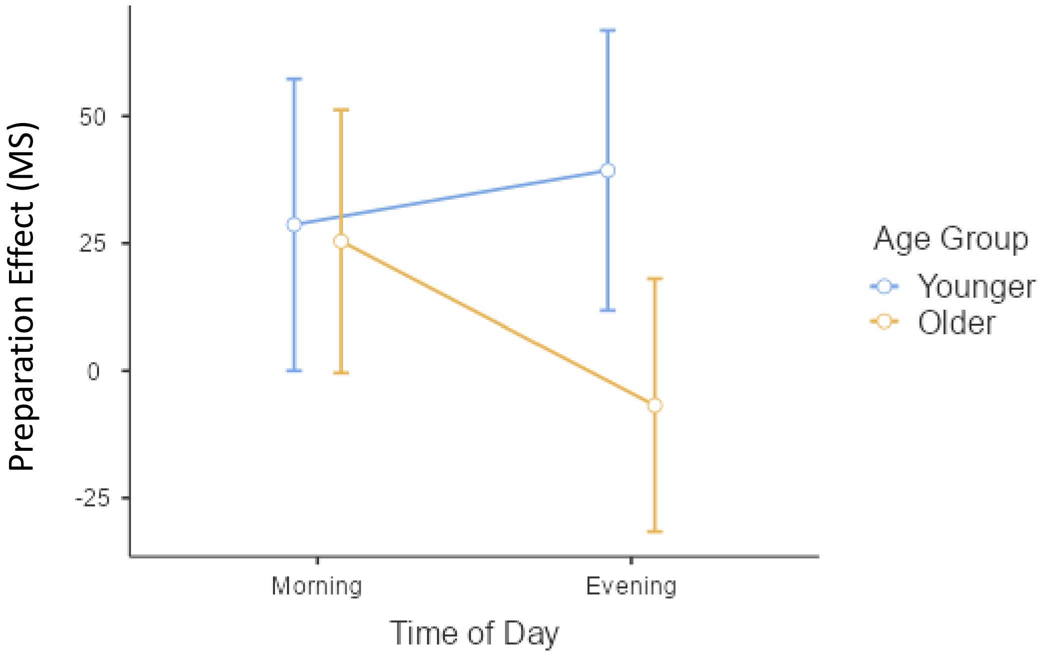
Note. Time of Day by Age Group for Simple Reaction Time (SRT). Estimated Marginal Means for Time of Day by Age Group for Simple Reaction Time Reaction Time are shown. Error bars = 95% Confidence Interval. The significant main effect of age group can be seen in the slower RTs in the older group at both times of day. While the interaction with time of day is not significant, it was included in the graph for information, given the hypotheses.

A third 2 x 2 x 2 mixed ANOVA was run with Preparation Effect as the dependent variable. This ANOVA resulted in a main effect of age group (F(1,51) = 8.829, p = 0.005) with older adults showing a smaller preparation effect (M= 11.4 ms, SD = 37.7) compared to younger adults (M= 39.8, SD = 30.7). There also was an interaction between age group, time of day, and session order for the preparation effect (F(1,51) = 5.387, p = 0.024). This interaction was explored with 2-way ANOVAs for each session order separately. When morning was the first session, there was a main effect of age group (F(1,24) = 7.41, p = 0.012) with older adults showing a smaller preparation effect (M= 13.9 ms, SD = 26.5) compared to younger adults (M=

45.6, SD = 32.4). When the evening session was first, there was a trend toward an interaction between time of day and age group (F(1,27) = 3.636, p = 0.067) (see Figure 3) and further exploration of this near interaction with Tukey posthoc comparisons showed a trend toward older and younger adults preparation effect being different in the evening only (t(1,27) = 2.552, p = 0.074), with young adults evening preparation effect being larger (M= 39.3, SD = 21.9) than older adults (M= -6.79, SD = 61.9).

Figure 4

Time of Day by Age Group for SRT Preparation Effect when Evening was the First Session

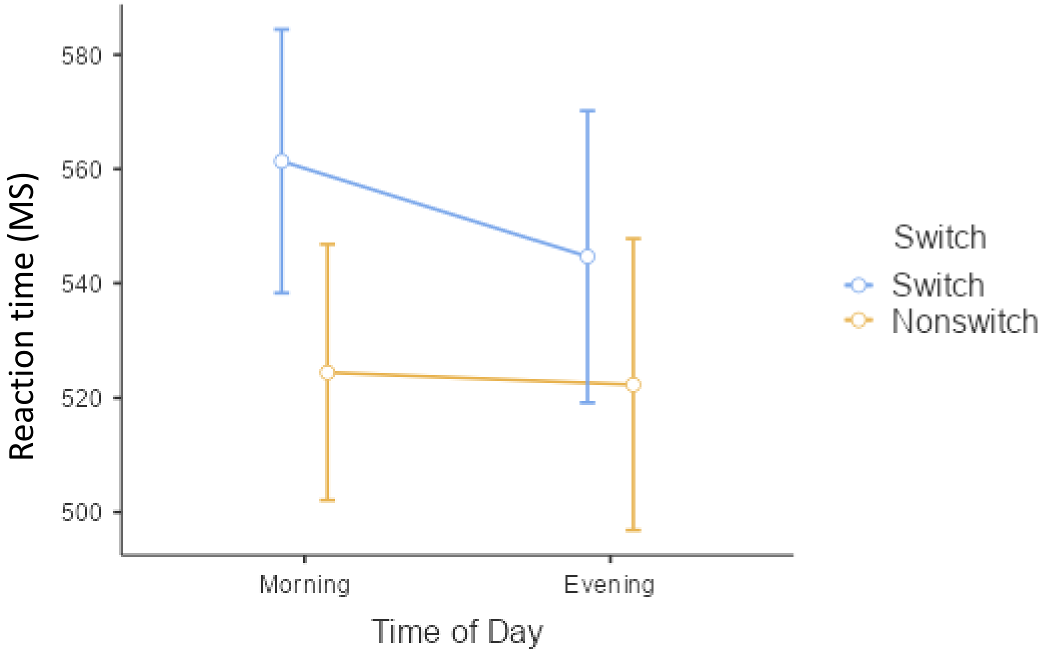


Note. Time of Day by Age Group for SRT Preparation Effect when Evening was the First Session. Estimated Marginal Means for Time of Day by Age Group for Simple Reaction Time preparation effect for participants whose evening session was their first DalCAB session are shown. Error bars = 95% Confidence Interval. A trend toward an interaction between time of day and age group can be seen in the smaller preparation effect in the evening for older adults. While the interaction is not significant, it was included in the graph for information, given the hypotheses.

Two Choice Reaction Time. ANOVAs for CRT included the task variable of switch (response switch vs no-switch trials) for a 2 x 2 x 2 x 2 (Time of Day x Age Group x Session Order x Switch) mixed ANOVA on overall reaction time. There was a main effect of age group for overall reaction time (F(1,51) = 18.295, p < 0.001), with older adults exhibiting slower reaction times (M = 589 ms, SD = 87.6) compared to younger adults (M = 493 ms, SD = 73.2). In addition, there was a main effect for the switch variable RTs (F(1,51) = 45.03, p < 0.001), with participants responding to nonswitch trials faster (M = 528 ms, SD = 93.8) than switch trials (M = 557 ms, SD = 95.5). The significant differences between switch and nonswitch trials was qualified by an interaction between switch and time of day (F(1,51) = 5.343, p = 0.025). Further exploration of this interaction with the Tukey posthoc comparisons did not identify the source of the interaction, but simply confirmed the difference between switch and non-switch trials at each time of day (AM comparison = t(51) = 6.442, p < 0.001); PM comparison = t(51) = 4.384, p < 0.001). The time of day effect for either trial type was not significant.

Figure 5

Time of Day by Switch/Nonswitch for CRT Reaction Time



Note. Time of Day by Switch/Nonswitch for CRT Reaction Time. Estimated Marginal Means for time of day by switch/nonswitch for Two Choice Reaction Time reaction time. Error bars = 95% Confidence Interval. There was a significant interaction between switch and time of day but further exploration of this interaction with the Tukey posthoc comparisons did not identify the source of the interaction.

There was also an interaction between time of day and session order (F(1,51) = 5.555, p = 0.022) for the ANOVA on overall reaction time. This interaction was explored with 2-way ANOVAs for each session order separately. When morning was the first session, there was a main effect of switch (F(1,26) = 20.19, p < 0.001) with participants responding to nonswitch trials faster (M = 524 ms, SD = 75.7) than switch trials (M = 551 ms, SD = 76.9). There was also a trend toward a main effect of time of day (F(1,26) = 4.22, p = 0.050) with reaction time being faster in the evening (M = 524 ms, SD = 84.7) than in the morning (M = 555 ms, SD = 84.2) and a trend toward an interaction between time of day and switch (F(1,26) = 4.00, p = 0.056). When evening was the first session there was a main effect of switch (F(1,27) = 27.42, p < 0.001) with participants responding to nonswitch trials faster (M = 531 ms, SD = 110) than switch trials (M = 563 ms, SD = 112).

Another 2 x 2 x 2 x 2 mixed ANOVA was run with overall error rate as the dependent variable. There was a main effect for age group for error F(1,51) = 10.46, p = 0.002) with older adults having a lower error rate (M = 0.016) compared to younger adults (M = 0.033), and an interaction between switch and age group (F(1,51) = 6.539, p = 0.014). Further exploration of this interaction with the Tukey posthoc comparisons showed that nonswitch trials for young adults were different from nonswitch trials for older adults t(51) = 3.89, p = 0.002) such that young adults had a higher mean error rate on nonswitch trials (M= 0.040, SD = 0.039) when compared to older adults (M= 0.011, SD = 0.012).

A separate 2 x 2 x 2 mixed ANOVA was also run with the Switch Effect in relation to reaction time (see Table 1) as the dependent variable. There was a main effect of time of day for the Switch Effect F(1,51) = 5.342, p = 0.025) with a larger Switch Effect in the morning (M = 37.1 ms) compared to the evening (M = 22.3 ms). A parallel mixed ANOVA with error rate showed there was also a main effect of age group for Switch Effect error F(1,51) = 6.538, p = 0.014) with older adults Switch Effect error rate being higher (M = 0.008, SD = 0.024) than younger adults (M = - 0.014, 0.038).

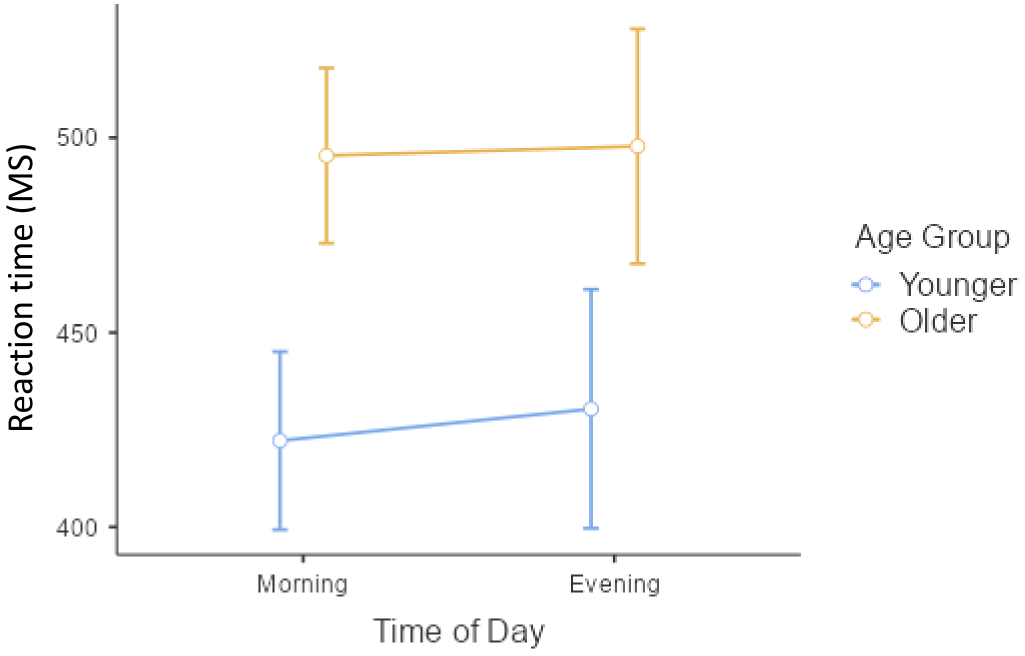
Go-No-Go. Two participants were excluded from the analysis of this task for responding to 80% or more trials incorrectly. The two conditions (20% and 80% go trials) were analyzed separately. In terms of the 20% go condition, a 2 x 2 x 2 (Time of Day x Age Group x Session Order) mixed

ANOVA was run with reaction time as the dependent variable. There was a main effect of age group for overall reaction time (F(1, 49) = 17.021, P < 0.001) with older adults showing slower reaction times (M = 497 ms, SD = 68.5) compared to younger adults (M = 427 ms, SD = 51.4, Figure 5).

A separate 2 x 2 x 2 mixed ANOVA was run for the 20% condition with error rate as the dependent variable. There were no significant effects for overall error. A third 2 x 2 x 2 ANOVA was run for misses in the 20% go condition, and there were no main effects for misses on 20% go trials.

Figure 6

Time of Day by Age Group for Go-No-Go Reaction Time for 20% Go



Note. Time of Day by Age Group for Go-No-Go Reaction Time for 20% Go. Estimated Marginal Means for Time of Day by Age Group for Go-No-Go Reaction Time for 20% Go. Error bars = 95% Confidence Interval. There was a main effect of age group for overall reaction time with older adults showing slower reaction times compared to younger adults. While the interaction with time of day is not significant, it was included in the graph for illustration, given the hypotheses.

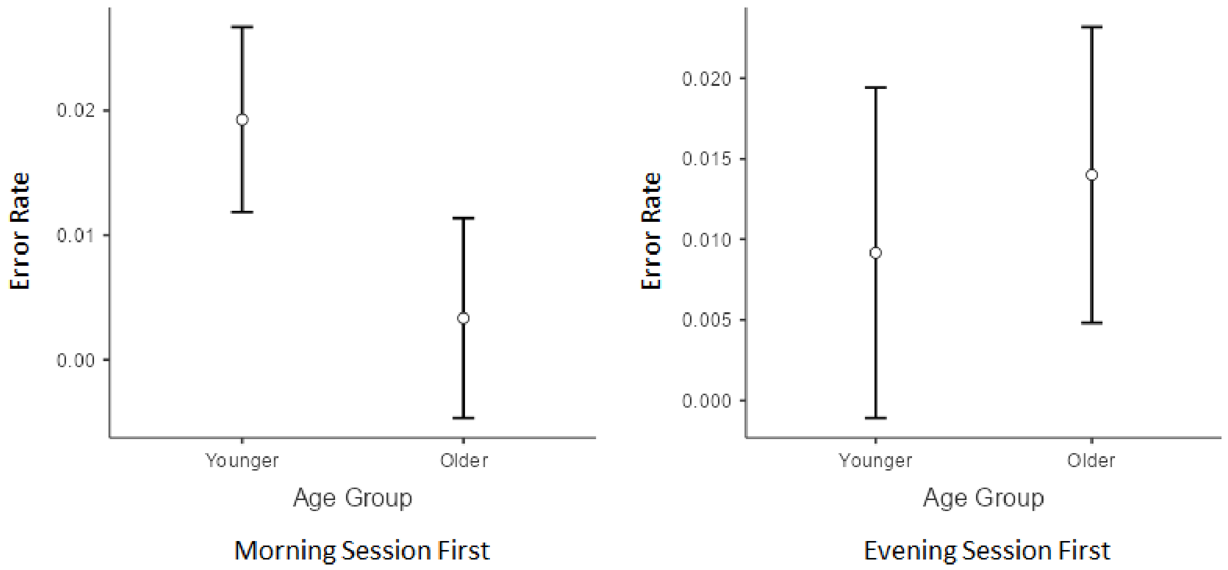
In terms of the 80% go condition, a 2 x 2 x 2 mixed ANOVA was run with reaction time as the dependent variable. There was also a main effect of age group for overall reaction time (F(1, 49) = 12.445, $p < 0.001$) with the same pattern as the 20% condition (Older adult M = 468 ms, SD = 74.6, younger adult M = 403 ms, SD = 55.6).

A separate 2 x 2 x 2 mixed ANOVA was run for the 80% go condition with overall error rate as the dependent variable. There were no significant main effects for overall error rate for 80% go trials, however there was an interaction between age group and session order for error rate on 80% go trials (F(1, 49) = 5.881, p = 0.019). This interaction was explored with 2-way ANOVAs for each session order separately. When morning was the first session, there was a main effect of age group (F(1,24) = 7.41, p = 0.012) with older adults showing a lower error rate (M= 0.003, SD = 0.012) compared to younger adults (M= 0.027, SD = 0.033). When the evening session was first, there were no significant effects for overall error on 80% go trials (see figure 6).

A third 2 x 2 x 2 ANOVA was run for false alarms in the 80% go condition, and there were no main effects for false alarms on 80% go trials.

Figure 7

Age Group Separated by Session Order for Go-No-Go Error Rate for 80% Go



Note. Age Group Separated by Session Order for Go-No-Go Error Rate for 80% Go Marginal Means for age group separated by session order where the left graph is session order 1 (first session was a morning session) and the right graph is session order 2 (first session was an evening session). Error bars = 95% Confidence Interval. When morning was the first session, there was a main effect of age group with older adults showing a lower error rate compared to younger adults, but when the evening session was first, there were no significant effects for overall error on 80% go trials.

Flanker Task. ANOVAs for the Flanker Task included the task variable of congruency (congruent vs incongruent trials, see Table 1). Firstly, we ran a 2 x 2 x 2 x 2 (Time of Day x Age Group x Session Order x Congruency) mixed ANOVA on overall reaction time. There was a main effect of age group for reaction time (F(1,51) = 40.688, p <0.001) with older adults exhibiting slower reaction times (M = 841 ms, SD = 86.7) compared to younger adults (M = 658 ms, SD = 88.2), as well as a main effect for congruency (F(1,51) = 235.113, p < 0.001) with reaction time for congruent trials being faster (M = 706, SD = 119) than incongruent trials (M = 771, SD = 115). There was also an interaction between time of day and session order (F(1,51) =

18.810, p <0.001). This interaction was explored with 2-way ANOVAs for each session order separately. When morning was the first session, there was a main effect of time of day (F(1,27) = 19.752, p < 0.001) with participants having faster reaction time in the evening (M = 703 ms, SD = 107) compared to the morning (M = 741 ms, SD = 108). There was also a main effect of congruency (F(1,27) = 148.716, p < 0.001) with reaction time being faster for congruent trials (M = 686 ms, SD = 106) than incongruent (M = 758 ms, SD = 107). When evening was the first session there was a trend toward a main effect of time of day (F(1,27) = 4.23, p = 0.051) with participants having faster reaction time in the morning (M = 745 ms, SD = 126) compared to the evening (M = 768 ms, SD = 135). There was also a main effect of congruency (F(1,27) = 92.177, p < 0.001) with the same pattern as session order 1 (congruent M = 729 ms, SD = 131, incongruent M = 784 ms, SD = 125).

Another 2 x 2 x 2 x 2 mixed ANOVA was run with overall error rate as the dependent variable and there was a main effect for congruency (F(1,51) = 235.113, p < 0.001) with error rate for congruent trials being lower (M = 0.017, SD = 0.035) than on incongruent trials (M = 0.036, SD = 0.036).

A final 2 x 2 x 2 ANOVA was run with the Congruency Effect as the dependent variable. There were there were no statistically significant effects for any variable for the Congruency Effect (incongruent – congruent trial reaction time) on reaction time or errors.

Dual Task. Performance on choice reaction time was also examined while doing an additional task (counting black and red cards) with a similar ANOVA as done for CRT. ANOVAs for dual task included the task variable of switch (response switch vs no-switch trials). Firstly, we ran a 2 x 2 x 2 x 2 (Time of Day x Age Group x Session Order x Switch) mixed ANOVA on overall reaction time. There was a main effect of age group for reaction time (F(1,51) = 7.556, p =

0.008), with older adults exhibiting slower reaction times (M = 720 ms, SD = 137) compared to younger adults (M = 622 ms, SD = 118), and a main effect for switch (F(1,51) = 224.689, $p < 0.001$), with participants responding to nonswitch trials (M = 612 ms, SD = 128) faster than switch trials (M = 735 ms, SD = 150). There was also an interaction between time of day and session order (F(1,51) = 20,885, $p < 0.005$), and this interaction was explored with 2-way ANOVAs for each session order separately. When morning was the first session, there was a main effect of time of day (F(1,26) = 12.238, p = 0.002) with slower reaction times in the morning (M= 681 ms, SD = 136) compared to the evening (M= 637, SD = 121). There was also a main effect for switch (F(1,26) = 70.594, $p < 0.001$). When the evening session was first, there was a main effect of time of day (F(1,27) = 8.393, p = 0.007) with slower reaction times in the evening (M= 706 ms, SD = 156) compared to the morning (M= 669, SD = 146). There was also a main effect for switch (F(1,26) = 201.922, $p < 0.001$).

Another 2 x 2 x 2 x 2 mixed ANOVA was run with overall error rate as the dependent variable. There was a main effect of switch for error (F(1,51) = 17.061, $p < 0.001$), with participants having a lower error rate on nonswitch trials (M = 0.028, SD = 0.037) than on switch trials (M = 0.047, SD = 0.055).

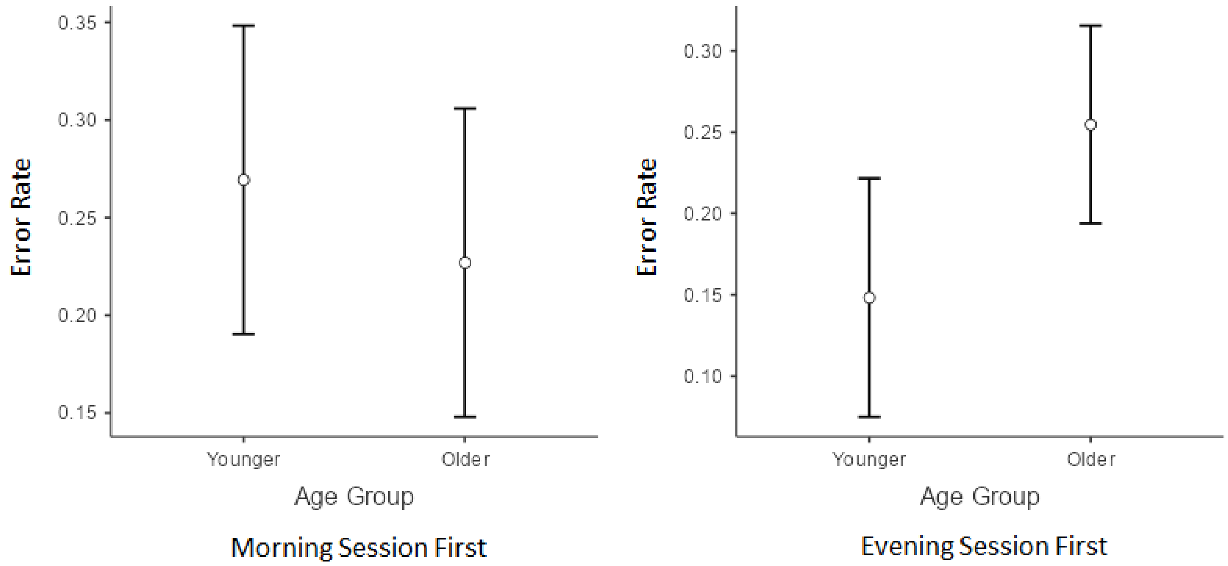
A final 2 x 2 x 2 ANOVA was run with dual task cost as the dependent variable. There were no statistically significant effects for the dual task cost on reaction time.

Location Working Memory. Morning session data for one participant and evening session data for another participant were not collected for this task due to software crashes and thus were excluded from analysis. A 2 x 2 x 2 (Time of Day x Age Group x Session Order) mixed ANOVA on overall reaction time revealed a main effect of age group (F(1, 49) = 40.957, $p < 0.001$) with older adults showing slower reaction times (M = 1543 ms, SD = 228) compared to younger adults

(M = 1142 ms, SD = 216). There was a main effect of time of day for reaction time (F(1,49) = 18.638, p <0.001) with slower reaction times in the evening (M = 1421 ms, SD = 370) compared to the morning (M = 1282 ms, SD = 282). There was also an interaction between time of day and session order (F(1, 49) = 10.162, p = 0.002). This interaction was explored with 1-way ANOVAs for each session order separately. When morning was the first session, there was no main effect for time of day. However, when the evening session was first, there was a main effect of time of day (F(1,26) = 33.0, p < 0.001) with slower reaction times in the evening (M= 1549 ms, SD = 335) compared to the morning (M= 1287, SD = 301).

Figure 8

Time of Day Separated by Session Order for Location Memory Reaction Time



Morning Session First

Evening Session First

Note. Time of Day Separated by Session Order for Location Memory Reaction Time Marginal Means for time of day separated by session order where the left graph is session order 1 (first session was a morning session) and the right graph is session order 2 (first session was an evening session). Error bars = 95% Confidence Interval.

Another 2 x 2 x 2 mixed ANOVA was run for error rate. There was a main effect for time of day on errors (F(1.49) = 8.145, p = 0.006) with lower error rates in the morning (M = 0.191, SD = 0.130) compared to the evening. (M = 0.268, SD = 0.188). Lastly, there was an interaction between age group and session order (F(1,49) = 4.378, p = 0.042), which was explored with 1-way ANOVAs for each session order separately. When morning was the first session, there was no main effect for age group. However, when the evening session was first, there was a main effect of age group (F(1,26) = 5.29, p = 0.030) with older adults having a higher error rate (M= 0.255, SD = 0.123) compared to younger adults (M= 0.148, SD = 0.111).

Discussion

The goal of this research was to assess the feasibility of a completely remote, at-home administration of the DalCAB and to investigate whether diurnal rhythm changes influence our attention performance as we age. To accomplish this, we tested three hypotheses. The first was that an at-home administration of the DalCAB was feasible as measured by how many participants that completed the consent process fully finished the DalCAB, and for those who did, how easy they found the software/website to use as reported on the System Usability Scale. About 9% of participants who signed a consent form either withdrew from the study, discontinued without explanation or were removed for not complying with study protocol, meaning that there was a roughly 90% completion rate for this protocol. The single participant who gave a reason for discontinuing the study did so because they did not want to download the web browser required to do the DalCAB. While both younger and older participants experienced technical difficulties in some cases that required assistance from a researcher throughout the study, none reported these issues as a reason for discontinuing, and minimal data were lost due to technical issues. Younger and older adults also gave the DalCAB similar SUS scores, and both group means are in the range to consider the DalCAB's usability highly acceptable (Brooke, 2013). Based on the 90% completion rate, the highly acceptable SUS scores, and the willingness of participants to continue the study in the face of technical issues, we conclude that a remote, home administration of the DalCAB is feasible for research purposes with healthy adults. These results are in line with several other studies (Breitling et al., 2010; Nicosia et al., 2022; Thompson et al, 2022; Berron et al 2022) suggesting that remote computerized attention testing in general could be a great alternative when conducting research under conditions where meeting in person is inconvenient or just not an option. These are encouraging findings as well for future research on using these same methods with clinical populations in research and if that is successful as well, in healthcare.

The second hypothesis was that older adults would show a preference for morningness, and younger adults would show a preference for eveningness, using the MEQ as a measure of preference. Unlike previous research on diurnal rhythm and age differences in cognition (Hasher, et al., 2002; May et al., 2005; Rowe et al., 2009; Anderson et al. 2014) we did not preselect participants using their chronotype preferences such that all older adults were morning types, and all young adults were evening types, and instead invited all volunteers who met the inclusion criteria to be a part of the study. The mean MEQ scores for both younger and older adults fall into the Neither/Neutral type, although the older adults had a significantly greater mean MEQ score than younger adults, suggesting that more older adults lean toward being morning types than younger adults. Almost half of the older adults scored in the neutral range on the MEQ, and over half the younger adults were neutral types as well. Other studies have also found large proportions of young adults fall into the neutral type rage when sampling by age rather than screening for MEQ type (Adan & Natale, 2002). While more extreme MEQ scores are not uncommon, the typical aging population overall may not be that different from their younger peers. Although we cannot conclude given the present data that older adults have a specific preference for being morning types and young adults have a specific preference for being evening types, we can conclude that there is a significant relationship between age and MEQ preference.

The third hypothesis was that cognitive performance would show diurnal patterns on the DalCAB that differed in older and younger adults. Specifically, we anticipated that older adults would show better performance on attention tasks on the DalCAB when it was done at 8am compared to 4pm, and that younger adults would show faster reaction time and lower rates of error on the DalCAB tasks done at 4pm when compared to 8am. There were no significant interactions between age group and time of day that did not also include session order. For the Simple Reaction Time preparation effect there was an interaction between age group, time of day and session order that ultimately only amounted to a trend toward young adults being more prepared only in the evening. There was also an interaction between time of day and session order for 2 Choice Reaction time that showed a trend toward a practice effect such that when participants' morning session was first, their evening session reaction time was faster, though interestingly there was no trend for the inverse. There was also a main effect of time of day for the Switch Effect, with a larger Switch Effect in the morning compared to the evening, though this did not interact with age. An interaction between time of day and session order for the Flanker task indicated a practice effect as well where if the morning session was first, evening session reaction time was better and vice versa, and the Dual Task saw the same pattern. There was also an interaction between time of day and session order for Location Memory, but the practice effect was one sided in that if the evening session was first then participants had faster reaction time in the morning, but the parallel was not true if the morning session was first, which may coincide with previous evidence that morning types are more resilient when being tested at their non optimal time of day (Nowack & Van Der Meer, 2018; Evansova el al., 2020).

When looking at overall reaction time for each task there was a main effect of age group such that younger adults RT was faster than that of older adults, but this effect did not carry over to variables dependant on subtraction scores (like the Switch and Congruency Effects). CRT was the only task that showed main effect of age group for error rates, and older adults actually had a lower error rate than younger adults, suggesting that there was a speed accuracy trade off for this task, though this effect did not seem to carry over to when they were being required to multitask in Dual Task. There was also an interaction between switch and age for error on the CRT with young adults making more errors than older adults on nonswitch trials, reinforcing the speed accuracy trade off especially on trials that required less cognitive effort. There were some interactions between session order and age group, such as for the Go-No-Go task where older adults had a lower error rate than younger adults if their morning session was their first session. There was a mirrored result for the session order and age group interaction for location memory, where if older adults had their evening session first, they made more errors than young adults. This may be pointing toward an impact of diurnal rhythm for older adults that is conflated with practice effects on the DalCAB.

Many tasks saw results that would be expected given the nature of the task (Jones et al., 2016), such as a main effect of switch on RT for the CRT with nonswitch trials (where the correct response to the target is the same as the one before, such that there is no need to switch the response) being responded to faster than switch trials (where the correct response to the target is different than the one before it, requiring the participant to switch their response to answer correctly). Dual Task results showed a similar pattern with a main effect for switch RT and error rate such that participants responded faster and made fewer errors on nonswitch trials. For the Flanker task, results also showed that participants responded to congruent trials faster than incongruent trials and made fewer errors on congruent compared to incongruent trials.

There were also several instances where our results suggest that younger adults slightly outperform older adults regardless of time of day. As mentioned above, younger adults had faster overall reaction time for every task analyzed for this thesis. On the SRT, older adults showed a smaller preparation effect (see Table 1) suggesting that younger adults benefited more from extra time between trials to prepare for the next target On the CRT older adults had a higher error rate for the Switch Effect, indicating that they had a larger increase in errors on switch compared to nonswitch trials than did young adults. Interestingly, on the CRT task there was a main effect of time of day for the Switch Effect with a larger Switch Effect in the morning compared to the evening, meaning there was a bigger discrepancy in RT to switch trials compared to nonswitch trials in the morning. In contrast, there was a main effect for time of day on both RT and error rates for Location memory with faster RT and lower error rates in the morning, perhaps suggesting that spatial working memory was more affected by fatigue of the day than it was by age or even session order.

It is also worth noting here that the PANAS results showed that younger adults' positive affect was lower than older adults, and younger adults negative affect was higher than older adults. This could be an indicator that the young adult group, many of whom were students, could have been under significantly more stress than the older adults, many of whom were retired, and this could have had a negative impact on their performance.

Limitations. One limitation of this study was that when recruiting from smaller universities on the east coast of Canada there is not a large enough pool of research volunteers willing to participate in a three-part, three-hour commitment study for little (bonus points in their university courses) or no compensation to collect a large dataset in under a year. Because of the smaller pool of available participants and restricted timeframe required for keeping the study within the scope of a master's thesis we could not select participants based on their MEQ scores as has been done in previous research. More participants in this study identified as neutral types than morning types or evening types combined. Ideally, we would have had enough participants to be able to separate and compare neutral types to the more extreme types on their DalCAB performance. With more recruitment reach, time, and funds, enough participants could be added to the sample to add MEQ type into the analysis as its own variable, giving us the ability to compare the different chronotypes to each other.

It is also possible that some of the unusual diurnal patterns in the results of the study were complicated or obscured by practice effects. There were no significant interactions between age group and time of day that did not also include session order, but when analysis was separated out by session some of the practice effects were one sided such as in the case of the Location Memory task where if the evening session was first then participants had faster reaction time in the morning, but the parallel was not true if the morning session was first. With a large enough sample, a follow up study could be done using a between subjects design to avoid any possible interferences from practice effects.

Another limitation is that the DalCAB is also only available remotely via desktop (or laptop) devices and requires use of the Google Chrome web browser to function. With the rising popularity of mobile devices, having a remote version of the DalCAB that participants could complete on their tablet or even cell phone may make participation more accessible to volunteers. Other studies have already seen some success with mobile app based cognitive assessment on both smart phone and tablets (Nicosia et al. 2022; Thompson et al, 2022; Berron et al 2022), so it may be worthwhile exploring this option for the DalCAB.

Future Directions. Based on the conclusion for the first hypothesis, a logical next step for testing the feasibility of using the DalCAB as a remote test of attention would be to use it in clinical research setting with patient populations. Some studies using this approach are already underway to explore post operative cognitive decline in older adults using an in-person version of the DalCAB (Sardiwalla et al., 2018) and a remote version (Schmidt et al., 2020) and expanding to more patient populations would highlight where the DalCAB could be most helpful when used remotely.

Continued, targeted recruitment for this study could be done to bolster the number of participants that fall into each MEQ group until sufficient numbers were reached to compare morning type older adults, evening type young adult and a neutral type of group for each. If given the opportunity to partner with researchers in provinces outside of Nova Scotia, research volunteers could be recruited from anywhere in Canada to participate.

Conclusion. These findings suggest that remote administration is a feasible way to administer the DalCAB to both healthy younger and older adults, and that time of day may not be a cause for concern when planning a DalCAB session. Given our results for the Location Memory task, which is reported by participants to be one of the more difficult tasks on the DalCAB, and previous findings by Nowack & Van Der Meer (2018) Evansova el al. (2020), it may be reasonable to suggest doing the DalCAB in the afternoon, when possible, to take advantage of the resiliency of morning types to ensure a uniform sample in future research.

Although it would be nice to be able to take participant’s chronotype preference into account when planning attention tests under ideal circumstances for their comfort, the current study suggests that both older and younger adults should be able to do their best at any time during the normal workday. Our findings also highlight that, while many young adults do fall into the eveningness chronotype, and even more older adults fall into the morningness chronotype, the largest group by far are still neutral types. Based on our second and third hypotheses, this study suggests that personal chronotype preference and time of day may not be a great cause for concern when planning a DalCAB session for younger or older adults. It may also be the case that a large enough proportion of both the young and older adult population falls into the neutral type range that being given a test of attention and working memory during normal working hours is ideal for most people. This may also generalize more broadly to other tests of attention, computerized or traditional.

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Appendix 1 Demographics and Surveys

Demographics

Independent Samples T-Test Years of Education

Independent Samples T-Test

		Statistic	df	p
education_years	Student's t	-1.30	53.0	0.200

Independent Samples T-Test modified Telephone Interview for Cognitive Status Total

Independent Samples T-Test

		Statistic	df	p
mtics_total	Student's t	0.567	53.0	0.573

Independent Samples T-Test The Positive and Negative Affect Schedule (Positive)

Independent Samples T-Test

		Statistic	df	p
PA	Student's t	-3.01	53.0	0.002

Note. H_a $\mu_0 < \mu_1$

Independent Samples T-Test The Positive and Negative Affect Schedule (Negative)

Independent Samples T-Test

		Statistic	df	p
NA	Student's t	4.45	53.0	< .001

Note. H_a $\mu_0 > \mu_1$

Independent Samples T-Test System Usability Scale

Independent Samples T-Test

		Statistic	df	p
SUS Total	Student's t	0.605	53.0	0.548

Independent Samples T-Test Morningness-Eveningness Questionnaire Score

Independent Samples T-Test

		Statistic	df	p
MEQ Score	Student's t	-4.55	53.0	< .001

Note. H_a $\mu_0 < \mu_1$

Contingency Tables for MEQ

Contingency Tables

		MEQ Type			
Age Categorical		**Morning**	**Neutral**	**Evening**	**Total**
Older Adult	Observed	14	12	3	29
	Expected	7.91	14.8	6.33	29.0
Young Adult	Observed	1	16	9	26
	Expected	7.09	13.2	5.67	26.0
Total	Observed	15	28	12	55
	Expected	15.00	28.0	12.00	55.0

χ^2 Tests

	Value	**df**	**p**
χ^2	14.7	2	< .001
N	55		

Appendix 2 Simple Reaction Time

Simple Reaction Time.

Repeated Measures ANOVA for Simple Reaction Time

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	9532	1	9532	1.9457	0.169
Time of Day ✻ Age Group	4168	1	4168	0.8508	0.361
Time of Day ✻ Session Order	597	1	597	0.1219	0.728
Time of Day ✻ Age Group ✻ Session Order	196	1	196	0.0400	0.842
Residual	249845	51	4899		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	133193	1	133193	13.114	< .001
Session Order	7094	1	7094	0.699	0.407
Age Group ✻ Session Order	5786	1	5786	0.570	0.454
Residual	517981	51	10156		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Simple Reaction Time Error

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	0.00131	1	0.00131	0.31078	0.580
Time of Day ✻ Age Group	7.40e-6	1	7.40e-6	0.00175	0.967
Time of Day ✻ Session Order	7.40e-6	1	7.40e-6	0.00175	0.967
Time of Day ✻ Age Group ✻ Session Order	9.46e-4	1	9.46e-4	0.22439	0.638
Residual	0.21505	51	0.00422		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.0100	1	0.01005	1.21	0.277
Session Order	0.0161	1	0.01613	1.94	0.170
Age Group ✻ Session Order	0.0145	1	0.01448	1.74	0.193
Residual	0.4243	51	0.00832		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Simple Reaction Time Preparation Effect

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1780	1	1780	1.237	0.271
Time of Day ✻ Age Group	569	1	569	0.396	0.532
Time of Day ✻ Session Order	198	1	198	0.137	0.712
Time of Day ✻ Age Group ✻ Session Order	7753	1	7753	5.387	0.024
Residual	73403	51	1439		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	21608	1	21608	8.829	0.005
Session Order	1788	1	1788	0.731	0.397
Age Group ✻ Session Order	327	1	327	0.134	0.716
Residual	124812	51	2447		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Simple Reaction Time Preparation Effect Session Order 1

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	377	1	377	0.369	0.549
Time of Day ✻ Age Group	1963	1	1963	1.924	0.178
Residual	24492	24	1021		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	12988	1	12988	7.41	0.012
Residual	42064	24	1753		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Simple Reaction Time Preparation Effect Session Order 2

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1664	1	1664	0.919	0.346
Time of Day ✻ Age Group	6586	1	6586	3.636	0.067
Residual	48911	27	1812		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	8738	1	8738	2.85	0.103
Residual	82749	27	3065		

Note. Type 3 Sums of Squares

Post Hoc Tests

Post Hoc Comparisons - Time of Day ✻ Age Group

Comparison								
Time of Day	Age Group	Time of Day	Age Group	Mean Difference	SE	df	t	p_{tukey}
Morning	0	Morning	1	3.25	18.8	27.0	0.173	0.998
		Evening	0	-10.66	16.7	27.0	-0.638	0.919
		Evening	1	35.45	18.5	27.0	1.919	0.244
	1	Evening	0	-13.91	18.4	27.0	-0.756	0.873
		Evening	1	32.20	15.0	27.0	2.140	0.166
Evening	0	Evening	1	46.11	18.1	27.0	2.552	0.074

Note. Age Group 1 = older adults, 0 = younger adults.

Appendix 3 Two Choice Reaction Time

Two Choice Reaction Time

Repeated Measures ANOVA for Two Choice Reaction Time (CRT)

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	4817.502	1	4817.502	1.18341	0.282
Time of Day ✻ Age Group	240.051	1	240.051	0.05897	0.809
Time of Day ✻ Session Order	22614.172	1	22614.172	5.55514	0.022
Time of Day ✻ Age Group ✻ Session Order	1018.421	1	1018.421	0.25017	0.619
Residual	207613.666	51	4070.856		
Switch	47741.206	1	47741.206	45.02991	< .001
Switch ✻ Age Group	6.253	1	6.253	0.00590	0.939
Switch ✻ Session Order	359.352	1	359.352	0.33894	0.563
Switch ✻ Age Group ✻ Session Order	0.241	1	0.241	2.27e-4	0.988
Residual	54070.767	51	1060.211		
Time of Day ✻ Switch	2880.974	1	2880.974	5.34256	0.025
Time of Day ✻ Switch ✻ Age Group	261.306	1	261.306	0.48457	0.490
Time of Day ✻ Switch ✻ Session Order	118.528	1	118.528	0.21980	0.641
Time of Day ✻ Switch ✻ Age Group ✻ Session Order	15.726	1	15.726	0.02916	0.865
Residual	27501.752	51	539.250		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	472299.8	1	472299.8	18.29546	< .001
Session Order	39.8	1	39.8	0.00154	0.969
Age Group ✻ Session Order	83056.4	1	83056.4	3.21735	0.079
Residual	1.32e+6	51	25815.1		

Note. Type 3 Sums of Squares

Post Hoc Tests for CRT

Post Hoc Comparisons - Time of Day ✻ Switch

Comparison								
Time of Day	**Switch**	**Time of Day**	**Switch**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
Morning	Switch	Morning	Nonswitch	36.91	5.73	51.0	6.442	< .001
		Evening	Switch	16.69	9.10	51.0	1.834	0.270
		Evening	Nonswitch	39.04	9.11	51.0	4.284	< .001
	Nonswitch	Evening	Switch	-20.22	10.28	51.0	-1.967	0.214
		Evening	Nonswitch	2.13	9.31	51.0	0.229	0.996
Evening	Switch	Evening	Nonswitch	22.35	5.10	51.0	4.384	< .001

Repeated Measures ANOVA for Two Choice Reaction Time Session Order 1

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	23849	1	23849	4.22	0.050
Residual	147024	26	5655		
Switch	19745	1	19745	20.19	< .001

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	25422	26	978		
Time of Day ✻ Switch	2040	1	2040	4.00	0.056
Residual	13267	26	510		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	580498	26	22327		

Note. Type 3 Sums of Squares

Post Hoc Tests for CRT Session Order 1

Post Hoc Comparisons - Time of Day ✻ Switch

Comparison								
Time of Day	**Switch**	**Time of Day**	**Switch**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
Morning	Switch	Morning	Nonswitch	35.74	6.85	26.0	5.215	< .001
		Evening	Switch	38.41	15.67	26.0	2.451	0.092
		Evening	Nonswitch	56.76	14.73	26.0	3.853	0.004
	Nonswitch	Evening	Switch	2.68	16.56	26.0	0.162	0.998
		Evening	Nonswitch	21.03	14.53	26.0	1.447	0.483
Evening	Switch	Evening	Nonswitch	18.35	7.95	26.0	2.307	0.122

Repeated Measures ANOVA for Two Choice Reaction Time Session Order 2

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	3964	1	3964	1.73	0.199
Residual	61856	27	2291		
Switch	29098	1	29098	27.42	< .001
Residual	28656	27	1061		
Time of Day ✻ Switch	1073	1	1073	2.00	0.169
Residual	14513	27	538		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	1.29e+6	27	47958		

Note. Type 3 Sums of Squares

Post Hoc Tests for CRT Session Order 2

Post Hoc Comparisons - Time of Day ✻ Switch

Comparison								
Time of Day	**Switch**	**Time of Day**	**Switch**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
Morning	Switch	Morning	Nonswitch	38.43	8.79	27.0	4.371	< .001
		Evening	Switch	-5.71	8.76	27.0	-0.651	0.914
		Evening	Nonswitch	20.34	10.24	27.0	1.986	0.218
	Nonswitch	Evening	Switch	-44.13	11.60	27.0	-3.804	0.004
		Evening	Nonswitch	-18.09	11.19	27.0	-1.617	0.387
Evening	Switch	Evening	Nonswitch	26.05	6.07	27.0	4.288	0.001

Repeated Measures ANOVA for Two Choice Reaction Time Error

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	7.76e-5	1	7.76e-5	0.08272	0.775
Time of Day ✻ Age Group	1.26e-4	1	1.26e-4	0.13457	0.715
Time of Day ✻ Session Order	0.00104	1	0.00104	1.11130	0.297
Time of Day ✻ Age Group ✻ Session Order	8.72e-6	1	8.72e-6	0.00930	0.924
Residual	0.04781	51	9.38e-4		
Switch	5.26e-4	1	5.26e-4	0.52188	0.473
Switch ✻ Age Group	0.00659	1	0.00659	6.53859	0.014
Switch ✻ Session Order	3.68e-5	1	3.68e-5	0.03651	0.849
Switch ✻ Age Group ✻ Session Order	1.08e-7	1	1.08e-7	1.07e-4	0.992
Residual	0.05143	51	0.00101		
Time of Day ✻ Switch	7.01e-5	1	7.01e-5	0.11251	0.739
Time of Day ✻ Switch ✻ Age Group	7.95e-6	1	7.95e-6	0.01277	0.910
Time of Day ✻ Switch ✻ Session Order	4.26e-4	1	4.26e-4	0.68426	0.412
Time of Day ✻ Switch ✻ Age Group ✻ Session Order	6.33e-6	1	6.33e-6	0.01016	0.920
Residual	0.03175	51	6.23e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.01812	1	0.01812	10.46	0.002
Session Order	0.00331	1	0.00331	1.91	0.173
Age Group ✻ Session Order	0.00623	1	0.00623	3.59	0.064
Residual	0.08839	51	0.00173		

Note. Type 3 Sums of Squares

Post Hoc Tests for CRT Error

Post Hoc Comparisons - Switch ✻ Age Group

Comparison								
Switch	Age Group	Switch	Age Group	Mean Difference	SE	df	t	p_{tukey}
Switch	0	Switch	1	0.00724	0.00664	51.0	1.09	0.697
		Nonswitch	0	-0.01412	0.00625	51.0	-2.26	0.121
		Nonswitch	1	0.01514	0.00708	51.0	2.14	0.154
	1	Nonswitch	0	-0.02136	0.00712	51.0	-3.00	0.021
		Nonswitch	1	0.00790	0.00593	51.0	1.33	0.547
Nonswitch	0	Nonswitch	1	0.02926	0.00753	51.0	3.89	0.002

Note. Age Group 1 = older adults, 0 = younger adults.

Repeated Measures ANOVA for Two Choice Reaction Time Switch Effect (RT)

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	5761.9	1	5761.9	5.3426	0.025
Time of Day ✻ Age Group	522.6	1	522.6	0.4846	0.490
Time of Day ✻ Session Order	237.1	1	237.1	0.2198	0.641
Time of Day ✻ Age Group ✻ Session Order	31.5	1	31.5	0.0292	0.865
Residual	55003.5	51	1078.5		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	12.506	1	12.506	0.00590	0.939
Session Order	718.703	1	718.703	0.33894	0.563
Age Group ✻ Session Order	0.481	1	0.481	2.27e-4	0.988
Residual	108141.534	51	2120.422		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Two Choice Reaction Time Switch Effect Error

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1.40e-4	1	1.40e-4	0.1125	0.739
Time of Day ✻ Age Group	1.59e-5	1	1.59e-5	0.0128	0.910
Time of Day ✻ Session Order	8.52e-4	1	8.52e-4	0.6843	0.412
Time of Day ✻ Age Group ✻ Session Order	1.27e-5	1	1.27e-5	0.0102	0.920
Residual	0.0635	51	0.00125		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.0132	1	0.01319	6.5386	0.014
Session Order	7.36e-5	1	7.36e-5	0.0365	0.849
Age Group ✻ Session Order	2.15e-7	1	2.15e-7	1.07e-4	0.992
Residual	0.1029	51	0.00202		

Note. Type 3 Sums of Squares

Appendix 4 Go-No-Go

Go-No-Go

Repeated Measures ANOVA for Go-No-Go Reaction Time for 20% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	729.33	1	729.33	0.417	0.521
Time of Day ✻ Age Group	216.61	1	216.61	0.124	0.726
Time of Day ✻ Session Order	1.62	1	1.62	9.26e-4	0.976
Time of Day ✻ Age Group ✻ Session Order	3650.02	1	3650.02	2.089	0.155
Residual	85622.76	49	1747.40		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	129788.8	1	129788.8	17.02060	< .001
Session Order	41.9	1	41.9	0.00549	0.941
Age Group ✻ Session Order	2009.0	1	2009.0	0.26346	0.610
Residual	373644.2	49	7625.4		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go Error for 20% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	4.96e-4	1	4.96e-4	3.42628	0.070
Time of Day ✻ Age Group	8.37e-7	1	8.37e-7	0.00579	0.940
Time of Day ✻ Session Order	1.88e-4	1	1.88e-4	1.30197	0.259
Time of Day ✻ Age Group ✻ Session Order	5.81e-5	1	5.81e-5	0.40184	0.529
Residual	0.00709	49	1.45e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	3.95e-5	1	3.95e-5	0.167	0.685
Session Order	3.64e-4	1	3.64e-4	1.541	0.220
Age Group ✻ Session Order	2.02e-4	1	2.02e-4	0.854	0.360
Residual	0.0116	49	2.37e-4		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go Misses for 20% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	3.35e-6	1	3.35e-6	0.280	0.599
Time of Day ✻ Age Group	3.35e-6	1	3.35e-6	0.280	0.599
Time of Day ✻ Session Order	3.35e-6	1	3.35e-6	0.280	0.599
Time of Day ✻ Age Group ✻ Session Order	3.35e-6	1	3.35e-6	0.280	0.599
Residual	5.86e-4	49	1.20e-5		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	2.50e-5	1	2.50e-5	1.05	0.312
Session Order	2.50e-5	1	2.50e-5	1.05	0.312
Age Group ✻ Session Order	7.50e-5	1	7.50e-5	3.14	0.083
Residual	0.00117	49	2.39e-5		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go Reaction Time for 80% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	489.6	1	489.6	0.3048	0.583
Time of Day ✻ Age Group	39.0	1	39.0	0.0243	0.877
Time of Day ✻ Session Order	34.1	1	34.1	0.0212	0.885
Time of Day ✻ Age Group ✻ Session Order	481.7	1	481.7	0.2999	0.586
Residual	78702.1	49	1606.2		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	110633	1	110633	12.445	< .001
Session Order	1855	1	1855	0.209	0.650
Age Group ✻ Session Order	6577	1	6577	0.740	0.394
Residual	435597	49	8890		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go Error for 80% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	3.88e-4	1	3.88e-4	1.216	0.276
Time of Day ✻ Age Group	2.65e-4	1	2.65e-4	0.831	0.366
Time of Day ✻ Session Order	4.23e-4	1	4.23e-4	1.324	0.256
Time of Day ✻ Age Group ✻ Session Order	5.75e-4	1	5.75e-4	1.800	0.186
Residual	0.0156	49	3.19e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	8.11e-4	1	8.11e-4	1.68297	0.201
Session Order	1.97e-6	1	1.97e-6	0.00408	0.949
Age Group ✻ Session Order	0.00284	1	0.00284	5.88128	0.019
Residual	0.02362	49	4.82e-4		

Note. Type 3 Sums of Squares

Post Hoc Tests for Go-No-Go 80% Error

Post Hoc Comparisons - Age Group ✻ Session Order

Comparison								
Age Group	**Session Order**	**Age Group**	**Session Order**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
0	1	0	2	0.01012	0.00611	49.0	1.657	0.357
		1	1	0.01595	0.00611	49.0	2.612	0.056
		1	2	0.00529	0.00577	49.0	0.916	0.796
	2	1	1	0.00583	0.00634	49.0	0.920	0.794
		1	2	-0.00483	0.00601	49.0	-0.804	0.852
1	1	1	2	-0.01067	0.00601	49.0	-1.774	0.298

Note. Age Group 1 = older adults, 0 = younger adults.

Repeated Measures ANOVA for Go-No-Go Error for 80% Go Session Order 1

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	7.98e-4	1	7.98e-4	1.83	0.189
Time of Day ✻ Age Group	7.98e-4	1	7.98e-4	1.83	0.189
Residual	0.0105	24	4.36e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.00329	1	0.00329	9.05	0.006
Residual	0.00872	24	3.63e-4		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go Error for 80% Go Session Order 2

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	3.70e-7	1	3.70e-7	0.00179	0.967
Time of Day ✻ Age Group	3.00e-5	1	3.00e-5	0.14507	0.707
Residual	0.00517	25	2.07e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	3.11e-4	1	3.11e-4	0.523	0.476
Residual	0.0149	25	5.96e-4		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Go-No-Go False Alarms for 80% Go

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	5.18e-5	1	5.18e-5	0.443	0.509
Time of Day ✻ Age Group	1.52e-4	1	1.52e-4	1.299	0.260
Time of Day ✻ Session Order	2.26e-5	1	2.26e-5	0.194	0.662
Time of Day ✻ Age Group ✻ Session Order	5.18e-5	1	5.18e-5	0.443	0.509
Residual	0.00572	49	1.17e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	4.51e-4	1	4.51e-4	3.577	0.065
Session Order	1.93e-5	1	1.93e-5	0.153	0.697
Age Group ✻ Session Order	3.17e-4	1	3.17e-4	2.518	0.119
Residual	0.00617	49	1.26e-4		

Note. Type 3 Sums of Squares

Appendix 5 Flanker

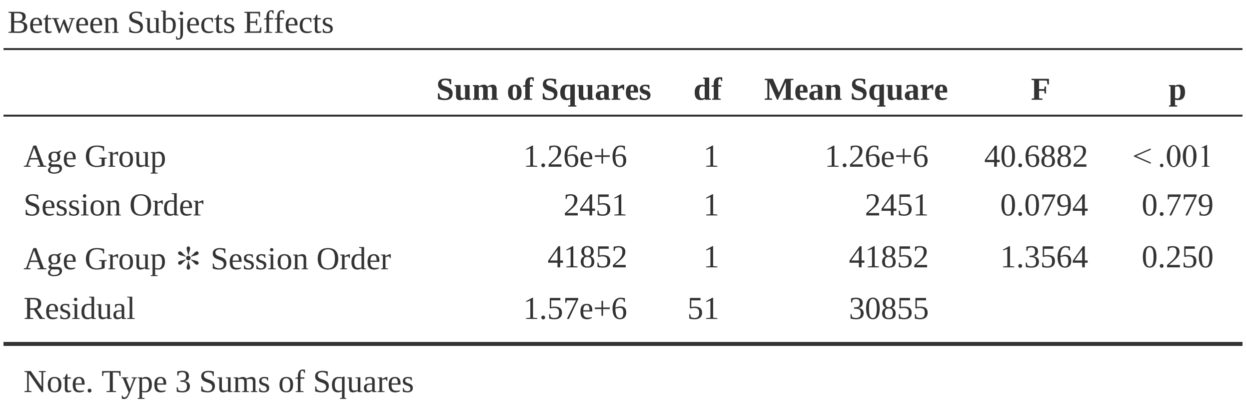
Flanker.

Repeated Measures ANOVA for Flanker Reaction Time

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	2546.8534	1	2546.8534	0.88741	0.351
Time of Day ✻ Age Group	1475.3578	1	1475.3578	0.51406	0.477
Time of Day ✻ Session Order	53983.6267	1	53983.6267	18.80969	< .001
Time of Day ✻ Age Group ✻ Session Order	212.3895	1	212.3895	0.07400	0.787
Residual	146369.5089	51	2869.9904		
Congruency	217898.1598	1	217898.1598	235.11271	< .001
Congruency ✻ Age Group	823.9137	1	823.9137	0.88901	0.350
Congruency ✻ Session Order	2855.1350	1	2855.1350	3.08070	0.085
Congruency ✻ Age Group ✻ Session Order	5.8745	1	5.8745	0.00634	0.937
Residual	47265.8667	51	926.7817		
Time of Day ✻ Congruency	872.6347	1	872.6347	1.05825	0.308
Time of Day ✻ Congruency ✻ Age Group	0.0850	1	0.0850	1.03e-4	0.992
Time of Day ✻ Congruency ✻ Session Order	60.0046	1	60.0046	0.07277	0.788
Time of Day ✻ Congruency ✻ Age Group ✻ Session Order	262.2388	1	262.2388	0.31802	0.575
Residual	42054.6880	51	824.6017		

Note. Type 3 Sums of Squares



Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	1.26e+6	1	1.26e+6	40.6882	< .001
Session Order	2451	1	2451	0.0794	0.779
Age Group ✻ Session Order	41852	1	41852	1.3564	0.250
Residual	1.57e+6	51	30855		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Flanker Error

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1.05e-4	1	1.05e-4	0.08508	0.772
Time of Day ✻ Age Group	8.37e-6	1	8.37e-6	0.00677	0.935
Time of Day ✻ Session Order	0.00106	1	0.00106	0.86005	0.358
Time of Day ✻ Age Group ✻ Session Order	0.00413	1	0.00413	3.33860	0.074
Residual	0.06304	51	0.00124		
Congruency	0.02130	1	0.02130	19.50365	< .001
Congruency ✻ Age Group	0.00145	1	0.00145	1.32953	0.254
Congruency ✻ Session Order	5.30e-4	1	5.30e-4	0.48526	0.489
Congruency ✻ Age Group ✻ Session Order	0.00434	1	0.00434	3.97794	0.051
Residual	0.05570	51	0.00109		
Time of Day ✻ Congruency	9.29e-4	1	9.29e-4	0.98328	0.326
Time of Day ✻ Congruency ✻ Age Group	1.36e-4	1	1.36e-4	0.14411	0.706
Time of Day ✻ Congruency ✻ Session Order	0.00213	1	0.00213	2.25571	0.139
Time of Day ✻ Congruency ✻ Age Group ✻ Session Order	6.75e-4	1	6.75e-4	0.71440	0.402
Residual	0.04819	51	9.45e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.00701	1	0.00701	1.83472	0.182
Session Order	5.69e-6	1	5.69e-6	0.00149	0.969

Between Subjects Effects

	Sum of Squares	**df**	**Mean Square**	**F**	**p**
Age Group ✻ Session Order	0.00398	1	0.00398	1.04243	0.312
Residual	0.19493	51	0.00382		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Flanker Congruency Effect

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1745.269	1	1745.269	1.0582	0.308
Time of Day ✻ Age Group	0.170	1	0.170	1.03e-4	0.992
Time of Day ✻ Session Order	120.009	1	120.009	0.0728	0.788
Time of Day ✻ Age Group ✻ Session Order	524.478	1	524.478	0.3180	0.575
Residual	84109.376	51	1649.203		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	1647.8	1	1647.8	0.88901	0.350
Session Order	5710.3	1	5710.3	3.08070	0.085
Age Group ✻ Session Order	11.7	1	11.7	0.00634	0.937
Residual	94531.7	51	1853.6		

Note. Type 3 Sums of Squares

Appendix 6 Dual Task

Dual Task.

Repeated Measures ANOVA for Dual Task Overall Reaction Time for CRT

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	327.84	1	327.84	0.07510	0.785
Time of Day ✻ Age Group	3722.04	1	3722.04	0.85259	0.360
Time of Day ✻ Session Order	91174.21	1	91174.21	20.88493	< .001
Time of Day ✻ Age Group ✻ Session Order	1478.00	1	1478.00	0.33856	0.563
Residual	222643.09	51	4365.55		
Switch	801935.47	1	801935.47	224.68907	< .001
Switch ✻ Age Group	9.90	1	9.90	0.00277	0.958
Switch ✻ Session Order	6319.78	1	6319.78	1.77070	0.189
Switch ✻ Age Group ✻ Session Order	7819.95	1	7819.95	2.19102	0.145
Residual	182023.58	51	3569.09		
Time of Day ✻ Switch	336.69	1	336.69	0.22507	0.637
Time of Day ✻ Switch ✻ Age Group	2260.83	1	2260.83	1.51135	0.225
Time of Day ✻ Switch ✻ Session Order	300.91	1	300.91	0.20116	0.656
Time of Day ✻ Switch ✻ Age Group ✻ Session Order	304.12	1	304.12	0.20330	0.654
Residual	76291.00	51	1495.90		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	**df**	**Mean Square**	**F**	**p**
Age Group	494294	1	494294	7.556	0.008
Session Order	15913	1	15913	0.243	0.624
Age Group ✻ Session Order	127073	1	127073	1.943	0.169
Residual	3.34e+6	51	65416		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Dual Task Overall Reaction Time for CRT Session Order 1

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	50588.04	1	50588.04	12.23754	0.002
Residual	107479.87	26	4133.84		
Switch	333318.63	1	333318.63	70.59418	< .001
Residual	122762.02	26	4721.62		
Time of Day ✻ Switch	5.77	1	5.77	0.00362	0.952
Residual	41403.43	26	1592.44		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	1.62e+6	26	62257		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Dual Task Overall Reaction Time for CRT Session Order 2

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	37430	1	37430	8.393	0.007
Residual	120404	27	4459		
Switch	501717	1	501717	201.922	< .001
Residual	67087	27	2485		
Time of Day ✻ Switch	507	1	507	0.366	0.550
Residual	37439	27	1387		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	2.34e+6	27	86786		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Dual Task Overall Error for CRT

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	9.65e-4	1	9.65e-4	0.36403	0.549
Time of Day ✻ Age Group	7.75e-4	1	7.75e-4	0.29253	0.591
Time of Day ✻ Session Order	3.71e-6	1	3.71e-6	0.00140	0.970
Time of Day ✻ Age Group ✻ Session Order	0.00256	1	0.00256	0.96567	0.330
Residual	0.13518	51	0.00265		
Switch	0.01946	1	0.01946	17.06050	< .001
Switch ✻ Age Group	0.00173	1	0.00173	1.51871	0.223
Switch ✻ Session Order	4.18e-4	1	4.18e-4	0.36639	0.548
Switch ✻ Age Group ✻ Session Order	0.00225	1	0.00225	1.97165	0.166
Residual	0.05816	51	0.00114		
Time of Day ✻ Switch	4.26e-5	1	4.26e-5	0.04895	0.826
Time of Day ✻ Switch ✻ Age Group	4.03e-4	1	4.03e-4	0.46357	0.499
Time of Day ✻ Switch ✻ Session Order	2.03e-4	1	2.03e-4	0.23308	0.631
Time of Day ✻ Switch ✻ Age Group ✻ Session Order	2.47e-4	1	2.47e-4	0.28464	0.596
Residual	0.04434	51	8.69e-4		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	**df**	**Mean Square**	**F**	**p**
Age Group	3.66e-4	1	3.66e-4	0.0500	0.824
Session Order	0.00304	1	0.00304	0.4149	0.522
Age Group ✻ Session Order	0.02690	1	0.02690	3.6765	0.061
Residual	0.37318	51	0.00732		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Dual Task Cost Reaction Time

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	1818	1	1818	0.492	0.486
Time of Day ✻ Age Group	1278	1	1278	0.346	0.559
Time of Day ✻ Session Order	11360	1	11360	3.073	0.086
Time of Day ✻ Age Group ✻ Session Order	1230	1	1230	0.333	0.567
Residual	188555	51	3697		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	721.247	1	721.247	0.0615	0.805
Session Order	8832.606	1	8832.606	0.7536	0.389
Age Group ✻ Session Order	0.294	1	0.294	2.51e-5	0.996
Residual	597768.347	51	11720.948		

Note. Type 3 Sums of Squares

Appendix 7 Location Memory

Location Memory.

Repeated Measures ANOVA for Location Memory Reaction Time

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	487785	1	487785	18.638	< .001
Time of Day ✻ Age Group	25061	1	25061	0.958	0.333
Time of Day ✻ Session Order	265944	1	265944	10.162	0.002
Time of Day ✻ Age Group ✻ Session Order	10195	1	10195	0.390	0.535
Residual	1.28e+6	49	26171		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	4.00e+6	1	4.00e+6	40.957	< .001
Session Order	214396	1	214396	2.193	0.145
Age Group ✻ Session Order	31922	1	31922	0.326	0.570
Residual	4.79e+6	49	97784		

Note. Type 3 Sums of Squares

Post Hoc Tests

Post Hoc Comparisons - Time of Day

Comparison							
Time of Day		**Time of Day**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
Morning	-	Evening	-137	31.7	49.0	-4.32	< .001

Post Hoc Comparisons - Age Group

Comparison							
Age Group		**Age Group**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
0	-	1	-392	61.3	49.0	-6.40	< .001

Note. 1 = older adults, 0 = younger adults.

Post Hoc Comparisons - Time of Day ✻ Session Order

Comparison								
Time of Day	**Session Order**	**Time of Day**	**Session Order**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
Morning	1	Morning	2	10.3	60.9	49.0	0.170	0.998
		Evening	1	-35.8	44.9	49.0	-0.798	0.855
		Evening	2	-227.6	69.0	49.0	-3.299	0.009
	2	Evening	1	-46.1	69.0	49.0	-0.668	0.908
		Evening	2	-237.9	44.8	49.0	-5.311	< .001
Evening	1	Evening	2	-191.8	76.3	49.0	-2.515	0.070

Repeated Measures ANOVA for Location Memory Reaction Time Session Order 1

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	16669	1	16669	0.625	0.437
Residual	667256	25	26690		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	4.27e+6	25	170782		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Location Memory Reaction Time Session Order 2

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	825942	1	825942	33.0	< .001
Residual	650425	26	25016		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Residual	4.56e+6	26	175377		

Note. Type 3 Sums of Squares

Repeated Measures ANOVA for Location Memory Error

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Time of Day	0.15065	1	0.15065	8.1449	0.006
Time of Day ✻ Age Group	0.01568	1	0.01568	0.8477	0.362
Time of Day ✻ Session Order	0.00883	1	0.00883	0.4773	0.493
Time of Day ✻ Age Group ✻ Session Order	2.02e-4	1	2.02e-4	0.0109	0.917
Residual	0.90634	49	0.01850		

Note. Type 3 Sums of Squares

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
Age Group	0.0267	1	0.0267	0.812	0.372
Session Order	0.0566	1	0.0566	1.719	0.196
Age Group ✻ Session Order	0.1440	1	0.1440	4.378	0.042
Residual	1.6122	49	0.0329		

Note. Type 3 Sums of Squares

ANOVA for Location Memory Error Session Order 1

ANOVA - Mean Overall Error Rate

	Sum of Squares	df	Mean Square	F	p
Age Group	0.0117	1	0.0117	0.612	0.442
Residuals	0.4570	24	0.0190		