A Cross-Sectional Examination of Aging, Alcohol Use, and Cognitive Health in The Canadian Longitudinal Study of Aging (CLSA) Baseline Data

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Abstract

Age, sex, and alcohol use have been identified as factors that influence cognition. The present study aimed to replicate and extend these findings by examining the effects of age, sex, alcohol use, and their interactions on cognition in a large sample of older Canadian adults (*N*=30,097, aged 45-85). Cross-sectional data from the Canadian Longitudinal Study of Aging (collected during the first wave of data collection between 2011 and 2015) included a cognitive test battery, allowing for domain-specific analyses. The results supported the following hypotheses: (1) younger adults have higher cognitive test scores than older adults, (2) women score higher than men on tasks assessing memory and verbal fluency, and (3) alcohol use is associated with higher cognitive test scores with a very small effect size. Small interactions occurred between age, sex, and levels of alcohol use. Study limitations and small effect sizes, combined with previous evidence of neurotoxic and other adverse effects of alcohol, suggest that the finding of a cognitive benefit of alcohol use should be interpreted with caution. The large sample, breadth of measures and covariates, age and sex analyses, and consistency of the findings across analyses suggest that further longitudinal and experimental research is warranted.

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Healthy aging is associated with a decline in some cognitive abilities over time, leading to decreased performance on tasks that assess domains such as memory, verbal fluency, and executive functioning (e.g., Singh-Manoux et al., 2012; Zelinski & Burnight, 1997). When cognitive performance in one or more domains has declined to a degree that results in functional impairment, an individual may meet the criteria for mild cognitive impairment (MCI) or dementia (Winblad et al., 2004). According to the Canadian Study of Health and Aging (CSHA), approximately 30% of Canadians over the age of 65 may be classified as being cognitively impaired to some degree without meeting the diagnostic criteria for dementia (Ebly, Hogan, & Parhad, 1995). These individuals have an increased risk of experiencing functional impairments (e.g., planning and problem solving) which can negatively affect their quality of life by interfering with daily activities such as household chores or scheduling social activities (Aretouli & Brandt, 2009). Optimal aging involves minimizing declines in cognitive functioning. Therefore, understanding the biological, environmental, and lifestyle contributions to age-related cognitive decline is essential for informing and guiding health behaviour recommendations to promote healthy cognitive aging for Canadians. Numerous studies have identified alcohol use as a lifestyle factor that impacts cognition, but results have been mixed regarding whether the influence of alcohol is beneficial or detrimental and which cognitive domains are primarily affected (e.g., Galanis et al., 2000; Ganguli et al., 2005; Kalmijn et al., 2002; Liappas et al., 2007; Montgomery et al., 2012; Solfrizzi et al., 2007; Stampfer et al., 2005). The present study examines associations between alcohol use and cognition in 30,000 older Canadians.

Aging and the Brain

Due to a gradual and progressive reduction in synaptic density, grey matter volume in the brain decreases with age (Terry & Katzman, 2001). This volume reduction is most prominent in the prefrontal cortex and in the hippocampus (Raz et al., 2004; Salat et al., 2004). The prefrontal cortex is closely associated with cognitive functions such as reasoning, planning, mental manipulation, and problem solving (Kane & Engle, 2000), while the hippocampus is known for its involvement in spatial and episodic memory (Burgess, Maguire, & O'Keefe, 2002). Synaptic loss in these brain regions is especially prevalent in individuals who have been diagnosed with dementia, and the extent of synaptic reduction correlates with cognitive impairment levels as assessed by the Mini Mental State Examination (MMSE; DeKosky & Scheff, 1990).

Some research has proposed that symptoms of cognitive impairment develop at a point where individuals experience a loss in connectivity that equates to 40% lower synaptic connectivity than is found in healthy adults (Terry et al., 1991). This theory implies that synaptic density at birth and the development of new neural networks in early development will influence age-related cognitive decline in later life, and may account for the fact that cognitive skills in childhood are highly predictive of cognitive abilities in later life (e.g., Deary et al., 2000; Gow et al., 2011). Continued development of neural networks may persist into adulthood and older age. A large meta-analysis spanning 135 studies and 128,000 older adult participants found that commonly used proxy measurements for brain development during adulthood (including education, occupation, and participation in mentally stimulating activities) were positively associated with cognitive test performance (Opdebeeck et al., 2016). Higher education level in particular has been associated with lower levels of cognitive decline in older adult participants (Angel et al., 2010; Le Carret et al., 2010). A number of mechanisms have been suggested by

which mental stimulation throughout adulthood may counter the effect of more adverse age-related brain changes. Cognitive efficiency may be increased via neuron growth, increased neural plasticity, the maintenance of neurons and neural connections in the face of age-related cell death, or by the development of beneficial cognitive strategies (Vasile, 2013).

Reductions in prefrontal white matter, the myelinated axon tracts that are responsible for efficient information transmission between brain regions, are even greater than changes in prefrontal grey matter among older adults (Salat et al., 1999). These findings suggest a potential reduction in efficient information processing within the frontal lobe for this population. White matter loss has also been observed in the corpus callosum and hippocampus of healthy adults over the age of 70, suggesting potential disruption of the information flow across hemispheres and between the prefrontal cortex and hippocampus (Maier-Ruge et al., 1992; Rogalski et al., 2012). More recent research has demonstrated that reduced white matter volume in the corpus callosum is correlated with impaired performance on a task-switching exercise in older adults compared to younger adults (Madden et al., 2012). Task-switching is a complex cognitive skill that requires accurately shifting attention to provide an appropriate response to a stimulus (Monsell, 2003). Thus, white matter deterioration has implications for complex attention.

In addition to structural brain changes, aging is also associated with changes in patterns of neuronal activation. Diffusion tensor imaging and functional magnetic resonance imaging (fMRI) studies have revealed that older adults experience increased prefrontal cortex activity in regions contralateral to those that are most active in younger adults during a word matching task. This decreased lateralization is potentially an adaptive mechanism to compensate for reduced overall frontal cortex activation (Davis et al., 2012). The scaffolding theory of aging and cognition suggests that increased bilateral activation during cognitive task performance is the

result of forming new neural circuits to maintain cognitive function with reduced prefrontal cortex activation associated with advancing age (Park & Reuter-Lorenz, 2009).

Approximately 50-60% of individual variability in cognitive performance has been attributed to genetics (Davies et al., 2011; McClearn et al., 1997**)**. However, some modifiable health factors (e.g., obesity, stress, hypertension) are known to reduce hippocampal volume, and interventions such as physical exercise and mental stimulation have demonstrated potential to increase both hippocampal size and white matter integrity in the brains of older adults (Fotuhi et al., 2012; Gow et al., 2012). These results raise the possibility that environmental and lifestyle factors may influence cognitive outcome for aging adults. The "cognitive reserve" hypothesis suggests that early life experiences which increase cognitive ability, such as proper nutrition, exercise, or mental stimulation, lead to structural brain changes that increase an individual's ability to maintain cognitive function in the face of age-related neurostructural or neurophysiological changes (Whalley et al., 2004). This hypothesis supports the finding that risk factors for Alzheimer's disease include low educational or occupational attainment (Stern et al., 1994). The well-known "use it or lose it" hypothesis suggests a positive relationship between overall cognitive function and current level of engagement in mentally stimulating activities, regardless of early life experiences (Salthouse, 2006). In contrast, the cognitive reserve hypothesis implies that lifetime engagement in mentally stimulating activities is protective of age-related cognitive decline by way of building up the reserve over a longer period of time.

The following sections will discuss the specific cognitive changes that are associated with healthy aging and examine the impact of alcohol use on cognitive performance in older adults. In reviewing the literature, focus was maintained on articles published within the past 20 years and

those which directly address the topic of age-related cognitive decline. Emphasis was placed on meta-analyses, longitudinal studies, and large-scale or well-cited experimental studies.

Cognitive Changes associated with Healthy Aging

Studies on the Scottish Lothian Birth Cohorts of 1921 (N=89,498) and 1936 (N=70,805) have suggested that general mental ability remains stable from late-childhood into old age (Deary et al., 2000; Gow et al., 2011). However, de-normalized scores on the Wechsler Adult Intelligence Scale III (WAIS-III) display a negative relationship between overall test performance and age (Ryan et al., 2000) as well as increased heterogeneity in test scores for older adults (Anstey & Low, 2004; Ardila, 2007). Although test performance is considered to remain stable whereby individuals retain their relative standing when compared to others within a certain group over time, these results also demonstrate that healthy aging is associated with a gradual overall decline in cognitive function that begins as early as age 20, with a steeper drop in abilities occurring after the age of 50 (Desjardins & Warnke, 2012).

The specific rate and pattern of change over time with aging varies among the cognitive domains that are typically assessed in research. These cognitive domains can be broadly divided into measures of crystallized and fluid intelligence (Cattell, 1963). Crystallized intelligence refers to a set of cognitive skills which rely on prior learning, knowledge, and experience. This type of intelligence is most frequently measured using tests of vocabulary, general knowledge, and comprehension. Research has demonstrated that performance on tests of crystallized intelligence remains stable or even improves with age (Ryan et al., 2000; Verhaeghen, 2003). In contrast, fluid intelligence is defined as a set of cognitive tasks on which performance does not rely on prior knowledge. Examples of cognitive skills that rely on fluid intelligence include mental flexibility, processing speed, mental manipulation, abstract reasoning, and the ability to

solve new problems. Cognitive tests that assess these skills typically involve comparisons of symbols or images, spatial reasoning, memory recall, or the mental ordering of a letter or number series. Scores on each of these tests demonstrate a distinct downward trend with increasing age (Hoyer et al., 2004; Kaufman, Reynolds, & McLean, 1989; Ryan et al., 2000). While crystallized intelligence may continue to increase during early-to-mid adulthood before reaching a plateau that persists into old age, fluid intelligence both levels off and begins its decline at a much younger age (Desjardins & Warnke, 2012; McArdle et al., 2000; Salthouse, 2010). Although the majority of studies reporting on trends in fluid and crystallized intelligence across the lifespan have relied on cross-sectional designs (e.g., Horn & Cattell, 1967; Ryan et al., 2000; Verhaeghen & Salthouse, 1997) further evidence can also be drawn from longitudinal studies (e.g., Lindenberger & Reischies, 2010; Schaie, 1994; Zahodne et al., 2011).

Vocabulary versus Verbal Fluency

The concepts of crystallized and fluid intelligence can be further divided into more concrete cognitive abilities. Crystallized intelligence includes domains such as vocabulary knowledge, verbal fluency, and general knowledge (Cattell, 1964; Harada et al., 2013). While most types of crystalized intelligence appear to remain stable or increase with age, verbal fluency is an exception (e.g., Singer et al., 2003; Singh-Manoux et al., 2012).

A number of large research studies have demonstrated that vocabulary knowledge remains stable or even increases with age. Ryan et al. (2000) administered the WAIS-III to 2450 participants ranging in age from 16-89, and reported that Vocabulary subtest scores peak between age 45-54 and remain consistent until beginning a very slight decline after age 80. Comparable stable patterns of test performance were observed for the Similarities subtest, which relies heavily on verbal knowledge and comprehension, as well as the Information and

Comprehension subtests, which assess general knowledge (Ryan et al., 2000). Likewise, the Whitehall II cohort study administered tests of memory, reasoning, vocabulary, and phonemic and semantic fluency to over 10,000 participants over the span of 10 years and observed a significant decline in all cognitive scores except for vocabulary (Singh-Manoux et al., 2012). A comparable pattern of cognitive change was observed in the 6-year longitudinal Berlin Aging Study (Singer et al., 2003). A meta-analysis reviewing 324 independent pairings of younger and older adults demonstrated an average effect size of 0.80 SD favoring older adults on vocabulary test scores, including the WAIS and WAIS-R Vocabulary subtests, the Mill-Hill Vocabulary scale, the Nelson-Denny Reading Test, the Shipley Scale, and vocabulary tests taken from the Educational Testing Services Kit (Verhaeghen, 2003). In contrast to the majority of reported results, a cross-sectional cohort analysis from the Seattle Longitudinal Study of Adult Intelligence (N=5000) has suggested that verbal ability scores (described below) do decline with age. However, the onset of decline for verbal ability seen in this study was still several decades later than the onset of decline for measures of fluid intelligence (Schaie, 1994). This discrepancy may be accounted for by differences in the tests used to assess verbal ability across studies. The Seattle Longitudinal Study is unique in its use of the Primary Mental Ability (PMA) Verbal Meaning test, a four-choice synonym test that is highly speeded and shows a strong correlation with processing speed (Schaie et al., 1989). Processing speed depends on the speed of cognitive processes and the speed of motor responses, both of which begin to slow after age 30 and may therefore affect scores on speeded tests that aim to measure a different cognitive domain (Harada et al., 2013). Cohort-level analysis of other large-scale longitudinal studies has demonstrated a significant and consistent age-related decline in task performance for all tasks that rely on processing speed, including the WAIS Symbol Search and Block Design subscales (Ryan et al.,

2000), Digit-Letter task, and Identical Pictures task (Singer et al., 2003) as well as simple reaction time, which increases by approximately 0.5ms per year beginning at age 20 (Fozard et al., 1994).

Unlike the relative stability observed for vocabulary test scores across the lifespan, verbal fluency test scores demonstrate significant age-related changes. The Whitehall II study and the Berlin Aging Study both administered tests of phonemic fluency (i.e., generating as many words as possible beginning with a particular letter or sound within one minute) and semantic fluency (i.e., naming as many items within a given category as possible within one minute) and reported consistent declining patterns of test scores for all age groups over time for both tasks (Singer et al., 2003; Singh-Manoux et al., 2012). The Seattle Longitudinal Study assessed verbal fluency using the PMA Word Fluency task, which allows participants five minutes to name as many words as possible within a category. Performance on this task also demonstrates consistent decline with advancing age, despite the increased time limit when compared to more commonly administered tests (Schaie, 1994). Some researchers have reported that, among healthy adults, age is a strong predictor of semantic fluency performance but not phonemic fluency (e.g., Troyer, 2000).

Patients with Alzheimer's Disease (AD) demonstrate impaired performance on both phonemic and semantic verbal fluency tasks (Henry et al., 2004). However, semantic fluency shows the best discrimination between patients with AD and healthy controls, with a sensitivity of 100% and specificity of 92.5% (Monsch et al., 1992). Performance differences between AD patients and healthy controls include both the number of words generated within the time limit as well as the use of clustering and switching. Clustering and switching is a performance technique whereby participants recall as many items as possible within a single category (e.g., domestic

animals) before switching to a new category (e.g., zoo animals; Gomez & White, 2006). Individuals with MCI display intermediate performance between control subjects and patients with AD on tasks of semantic verbal fluency, but tests of phonemic fluency do not differentiate between MCI and controls (Murphy et al., 2006). The number of items generated in a semantic verbal fluency task requiring participants to name as many animals as possible within one minute has shown strong correlation with scores on both the MMSE and the Clinical Dementia Rating Scale (CDR) and may therefore be useful in screening for dementia (Lopes et al., 2009).

While vocabulary and verbal fluency are both considered to be aspects of crystallized intelligence, they undergo different patterns of age-related change. Further research is needed to understand how age-related declines in semantic and phonemic fluency differ in terms of how they correlate with changes in other domains that directly impact adaptive functioning (e.g., memory, attention, or decision making). Careful differentiation of these two seemingly similar tasks may reveal underlying mechanisms of age-related cognitive decline and impairment.

Memory

Memory decline is a frequent concern among older adults, and may be the result of reduced efficiency at either the encoding or retrieval stages of information storage. Slowed information processing in older adults may affect working memory (i.e., the ability to temporarily store and manipulate information in the mind) by allowing sufficient time for new memory traces to deteriorate before they can be fully encoded, weakening the links between pieces of information being stored in long-term memory (Luszcz & Bryan, 1999; Salthouse, 1996). In two large-scale studies of verbal memory (N = 1250 and N = 2656), older adults performed significantly worse than younger adults on the immediate-recall trial for the Logical Memory subscale of the Wechsler Memory Scale (WMS) and the REY Auditory Verbal

Learning Test (RAVLT). These differences between the two age groups did not increase for the delayed-recall trials, suggesting that the decline is more significant at the encoding stage rather than the retrieval stage (Davis et al., 2013; Haaland et al., 2003). A 16-year follow-up in the Seattle Longitudinal Study has produced similar results at the individual level, suggesting that observed differences in immediate and delayed word recall are better explained by age than by cohort differences (Zelinski & Burnight, 1997). At the recall stage, age appears to affect the total number of words recalled in a list-learning task as well as subjective organization of the words produced, which reflects executive functioning (Davis et al., 2003; Davis et al., 2013). Davis et al. (2003) also reported that the rate of word-learning in the RAVLT is similar across all ages. Both older and younger adults learn words at approximately the same rate over five identical list recall trials completed in close succession, but older adults perform more poorly on a delayed recall trial of the same word list completed at a later time, implying that older adults are more severely impaired in the recall stage than the encoding stage of memory. This may be due to age-related declines in executive function, a cognitive meta-activity that allows for the integration of other cognitive processes. Impairments in executive function may influence retrieval strategies such as subjective organization of learned material (Luszcz & Bryan, 1999). Executive function also facilitates cognitive inhibition, or the ability to ignore irrelevant information or suppress incorrect responses to stimuli. Research has shown that older adults are less capable of ignoring distracting information on a reading memory task (Darowski et al., 2008) which supports the notion that weakened aspects of executive function directly impact memory. Tests of verbal learning and memory (e.g., RAVLT) have demonstrated potential use in the detection of MCI and early-stage AD because word-recall scores correlate highly with more functional scales such

as the MMSE and Blessed's Dementia Rating (Estevez-Gonzalez et al., 2003; Schoenberg et al., 2006).

Prospective memory is the ability to remember to perform an intended action in the future. This skill can be broken down into "time-based" and "event-based" subcategories. Event-based prospective memory occurs when an external stimulus prompts the appropriate intended action, and time-based prospective memory requires the action to occur at a particular time or after a specified amount of time has elapsed (McDaniel et al., 1999). This type of memory is essential for independent functioning in older adults because it directly applies to tasks such as remembering to take medication or turn off an oven. A meta-analytic review suggests that younger adults outperform older adults on both time and event-based prospective memory tasks (Henry et al., 2004). This age-related decline in performance is correlated with simultaneous declines in tasks that measure executive function (e.g., cognitive inhibition, Schnitzspahn et al., 2013) and on neuropsychological tests associated with frontal lobe functioning (McDaniel et al., 1999) in healthy adults. Individuals with both MCI and dementia demonstrate difficulty with remembering to perform future actions compared to healthy controls (Huppert et al., 2001; Thompson et al., 2010) and this particular impairment has a strong impact on the lives of the family caregivers of dementia patients (Smith et al., 2010).

As one of the primary symptoms of dementia and a major determinant of independent functioning, age-related memory impairment significantly impacts quality of life and places a strain on the Canadian healthcare system when individuals require institutionalization or full-time care. Thus, it is useful to conduct further research into modifiable factors (e.g., patterns of alcohol use) that may protect against memory impairment and other domains of age-related cognitive decline.

Lifestyle Factors and Cognitive Change

The results of the 2016 Canadian Census revealed that, for the first time, Canadian seniors outnumber children under the age of 14 (Statistics Canada, 2016). The health of older Canadians has always been an important area of research. However, given that Canadians over the age of 65 make up such a significant portion of the national population, research on behavioural and lifestyle factors that may facilitate the maintenance of cognitive ability in old age is becoming increasingly relevant and important for the health and well-being of our country.

The theory of cognitive reserve suggests that experiences in childhood through to early adult life are crucial to the development of cognitive flexibility and efficiency. These skills are associated with increased neuron development and may protect against cognitive decline in old age by buffering individuals against the functional consequences of age-related neuron death (Tucker & Stern, 2011; Whalley et al., 2004). Cognitive reserve is often approximated in research studies using measures of intelligence, educational attainment, and occupational complexity. These proxies for cognitive reserve are associated with better performance on tasks of semantic fluency (e.g., the Controlled Oral Word Association Test), attention (e.g., the WAIS digit span subtest), and increased use of memory strategies in daily life (e.g., rehearsal, visual imagery) among older adults (Frankenmolen et al., 2018; Roldan-Tapia et al., 2012). These results suggest a potential role for early life environment and mid-life experience in shaping the trajectory of age-related cognitive decline. In contrast, the cognitive-enrichment hypothesis emphasizes the importance of present environment and adult experience in maintaining cognitive abilities with advancing age. This enrichment framework proposes that levels of adult cognitive performance remain malleable in old age, despite being constrained by biological limitations such as synaptic loss and neuron death (Hertzog, 2009). Neuroscience research has demonstrated

that experiences such as short-term training (e.g., studying) may induce structural changes in the brain (Draganski et al., 2006) and that environmental factors such as psychological stress may have a negative impact on brain function in adults (Cacioppo et al., 2006). This type of neural plasticity persists into old age (Kempermann, 2008; Park & Reuter-Lorenz, 2009) and supports the cognitive enrichment hypothesis.

Sex, Estrogens, and Cognition

Some differences have been identified in the ways that aging men and women are cognitively impacted by a variety of lifestyle variables including nutrition, tobacco use, physical activity, and alcohol use (e.g., Barha et al., 2017; Kalmijn et al., 2002; Lee et al., 2001; Mukmakel et al., 2003; Sabia et al., 2014). In general, the cognitive effects of aging are more apparent in men than in women, particularly with respect to changes in reaction time (Der & Dreary, 2006). Results of the Baltimore Longitudinal Study of Aging report that, while men out-performed women in terms of visuospatial ability at baseline, they also showed a steeper rate of decline in perceptual speed and visuospatial ability at a 9-year follow-up. At baseline, women outperformed men in all other cognitive domains. This suggests that women are more resilient to age-related cognitive decline than men (McCarrey et al., 2016).

Another long-term study demonstrated that greater lifetime exposure to estrogen (e.g., later onset of menopause) may slow the rate of cognitive decline among women (McLay et al., 2003). Accordingly, there has been a great deal of research into the ways in which sex-steroid hormones may account for cognitive differences between men and women.

Male aging is associated with a small and gradual decline in testosterone levels (Barron & Pike, 2013). In contrast, women undergo a more rapid hormonal transition following menopause. Menopause involves a drop in hormone levels and the permanent loss of

menstruation. Onset of symptoms occurs at a median age of 45-47 and lasts an average of 4 years before menstruation ceases permanently (Burger et al., 2002). The perimenopausal stage is associated with a gradual decline in estrogen production, but estrogen and progesterone levels drop steeply following the final menstrual cycle (Al-Azzawi & Palacios, 2009). Changes in circulating hormone levels lead to a variety of menopausal symptoms including hot flashes, sweating, depression, and cognitive changes including subjective complaints about cognitive decline (Hogervorst, 2000; Makara-Studzinska et al., 2014).

A large-scale Finnish study demonstrated that low levels of plasma BDNF are related to impaired performance on the MMSE and verbal memory tasks for healthy older women, but BNDF was not related to cognitive performance for men (Komulainen et al., 2008). BDNF levels are known to be influenced by sex-steroid hormones. Specifically, BDNF is upregulated by estradiol and down-regulated by testosterone (Scharfman et al., 2003; Skucas et al., 2013). Animal studies have consistently shown that estrogen administration enhances recognition and spatial memory in ovariectomized female rodents. These cognitive enhancements are associated with increased spine density in the hippocampus and altered noradrenergic and dopamine neurotransmission in the prefrontal cortex (Almey et al., 2015; Luine & Frankfurt, 2012). Estrogen also impacts the glutamatergic neurotransmission system through upregulation of NMDA receptors, and influences the GABA-ergic transmission system through changes in receptor subunit composition in the hippocampus. These changes appear to enhance long-term potentiation in the hippocampus which leads to improvements in rodent spatial memory (Barth et al., 2015; Vierk et al., 2015).

The results of animal studies led to the widespread use of hormone-replacement therapy (HRT) in the 1990s to enhance cognition in post-menopausal women through the use of estrogen

or progesterone. According to the 1994-1995 National Population Health Survey, 22% of Canadian women between the ages of 45-64 used some form of HRT for menopausal symptoms in the month of the interview (Statistics Canada, 1997). It should also be noted that increased risks of breast cancer, stroke, and thrombosis may lead to many women discontinuing hormone-based treatments (Bjorn & Backstrom, 1999).

The results of human trials investigating the impact of HRT on cognition have been heavily mixed. Current plasma levels of estradiol are linked to higher scores on tests of verbal memory, reasoning, and perceptual speed (Drake et al., 2000; LeBlanc et al., 2001). These improvements are accompanied by increased blood flow to the hippocampus (Resnick & Maki, 2001). While some studies report beneficial effects only for women who experience severe menopausal symptoms (e.g., LeBlanc et al., 2001), others have found cognitive improvements for asymptomatic women following short-term estrogen administration (e.g., Duka et al., 2000). Lifetime use of HRT has been associated with slowed cognitive decline over a period of three years (Carlson et al., 2001). However, some randomized controlled trials of HRT have failed to report any significant effect of HRT on cognition (Binder et al., 2001; Lethaby et al., 2008) and still others have suggested that HRT may actually have a detrimental impact on MMSE performance (Espeland et al., 2004). Generally, meta-analyses and systematic reviews have reported highly mixed results in terms of the strength and directionality of the relationship between HRT and cognition found by randomized controlled trials. Cognitive domains proposed to be affected by sex differences or HRT also vary considerably among studies and include episodic memory, verbal memory, executive function, perceptual speed, facial recognition, and attention (Boss et al., 2014; Daniel et al., 2000; Herlitz & Rehnman, 2008; Hogervorst et al., 2000; Hogervorst et al., 2002; Maki, 2013; Nelson et al., 2002).

A meta-analysis of observational studies has shown that HRT reduces the risk of dementia by 39-50% in postmenopausal women (Whitmer et al., 2011). These results are supported by the large-scale longitudinal Cache County Study (Zandi et al., 2002). However, the Women's Health Initiative Memory Study (WHIMS) included several randomized-double-blind controlled trials testing the effects of estrogen and progestin (a synthetic progesterone) administration on 4,532 women over the age of 65. At 4-year follow up, the hazard ratio for dementia incidence was 2.05 (95% CI 1.21-3.48) for users of combined estrogen and progestin HRT compared to women in the placebo group (Shumaker et al., 2003). In addition, women who took estrogen-only HRT had impaired MMSE scores (HR: 1.47, 95% CI 1.04-2.07) at a 5-year follow up (Espeland et al., 2004). Given the many strengths of the WHIMS, these findings raised serious questions about the risks and value of HRT for women's cognition.

Some studies have suggested that cognitive differences between men and women are unrelated to sex hormone levels. When age and estradiol levels are matched across male and female participants, sex differences in episodic memory persist (Yonker et al., 2003). Furthermore, at least one longitudinal study has shown that sex differences in episodic memory, visuospatial ability, facial and verbal recognition, and verbal fluency remain stable for 10 years for participants aged between 35-80 years old, despite individual changes in menopausal status for older women (de Frais et al., 2007). Therefore, sex differences in cognitive function may be influenced by prenatal or postnatal organizational factors or hormone exposure (not just activational ones), but also by non-hormonal factors.

While some sex and hormone-related differences have been noted in the way that lifestyle factors influence age-related cognitive change, the majority of longitudinal and experimental studies fail to take sex differences into account. Consideration of the ways in which

men and women may be differentially affected by age and lifestyle factors (e.g., alcohol) in future research will help to inform Canadian health recommendations and guidelines. More human-centered research is essential in understanding the specific cognitive domains that differ between aging men and women through the use of more extensive neuropsychological batteries, as well as investigating healthy levels of age-related decline that do not meet criteria for a dementia diagnosis. Considering the fact that women experience dementia at a higher rate than men and also experience more severe cognitive symptoms in earlier stages of disease progression (Laws et al., 2018), this type of work will add to the current body of knowledge surrounding sex differences in the cognitive changes experienced by aging adults.

Alcohol Use and Cognitive Change with Aging

Alcohol has been demonstrated to have both neurotoxic and neuroprotective effects. The overall effect of alcohol on cognition depends on the duration, intensity, and frequency of alcohol use over the lifespan (Kim et al., 2012). Acute alcohol abuse (i.e., binge drinking) results in temporary cognitive impairment in domains such as judgement, memory, and attention, even when blood-alcohol level has returned to zero (Prat et al., 2008). The experience of "blackouts" (i.e., alcohol-induced dysfunction in the encoding and retrieval stages of memory) results from physical damage to the hippocampus and from suppression of N-methyl-D-aspartate (NMDA) receptor activation, which is required for long-term encoding of information (Lee et al., 2009). Individuals who experience temporary cognitive dysfunction in the form of blackouts and hangovers are at increased risk of more permanent cognitive dysfunction in older age (Newlin & Pretorius, 1990; Read et al., 2007). Over longer periods of time, excessive alcohol consumption has been linked to structural changes in the frontal cortex as well as upregulation of NMDA receptors in the frontal cortex and the hippocampus. This upregulation leads to excessive

excitation and may produce symptoms such as alcohol-induced delirium, alcohol-induced dementia, and seizures (Abernathy et al., 2010; Brust, 2010; Panza et al., 2009; Perry et al., 2011). Recently detoxified men with a history of excessive alcohol consumption demonstrate significant impairment in short-term memory, executive function, declarative memory, and motor skills when compared to healthy controls (Sullivan et al., 2000). While long-term abstinent individuals with a history of alcohol abuse appear to maintain deficits in spatial processing, they do not vary from healthy controls on measures of attention, working memory, delayed memory, psychomotor function, or verbal ability (Fein et al., 2006). This suggests that recovery of alcohol-induced cognitive decline is possible to some extent.

While older adults with a history of heavy alcohol use show impairments in executive functioning, the age of onset of alcohol abuse does not seem to influence the extent of cognitive impairment in later life (Kist, 2014). This differs from research on adolescent populations, which suggests that younger onset of alcohol use is associated with greater reductions in executive function and working memory (Nguyen-Louie et al. 2017), likely because the frontal lobe is still developing during adolescence. Alcohol-dependent dementia patients have poorer cognitive outcomes than sober control dementia patients in the domains of verbal fluency, working memory, and other forms of memory (Liappas et al., 2007). Among adolescents and young adults, excessive alcohol use has been associated with diminished performance on tests of prospective memory (Heffernan, 2006; Heffernan, 2010), executive function (Montgomery, 2012), and visuospatial ability (Sher et al., 1997). However, some studies have suggested that pre-existing cognitive dysfunction (particularly related to executive function) may be a risk factor for the development of substance abuse across all age groups (Giancola & Moss, 1998) and so the direction of this alcohol-cognition relationship is not yet clear.

In contrast to the clear negative effects of heavy long-term alcohol use, studies reporting the effect of light-to-moderate drinking (LMD) patterns on cognition report mixed results. An inverse U-shaped dose-response pattern is often observed, whereby both non-drinkers and heavy drinkers perform poorly on cognitive tasks compared to light-to-moderate drinkers (e.g., Galanis et al., 2000). Some research suggests that the effect of LMD is more pronounced when comparing low-level alcohol users to individuals who report drinking heavily in earlier life before becoming a non-drinker (i.e, previous drinkers), rather than comparing them to lifelong abstainers (Ganguli, 2005). However, the rate of age-related cognitive decline observed for LMD drinkers over time is the same as for non-drinkers in both categories (Stampfer et al., 2005). Estimates of optimal alcohol intake for improving cognition and lowering the risk of dementia have varied considerably across studies, including ranges such as "less than one drink per month" (Antilla et al., 2004) to "one to six drinks per week" (Mukamal et al., 2003; Solfrizzi et al., 2007) to as much as "1-4 drinks per day" (Kalmijn et al., 2002). The large amount of variability both between studies and within studies about how much alcohol is beneficial for cognition suggests that further research is needed where the impact of smaller ranges of alcohol use are investigated. Systematic reviews and meta-analyses have generally concluded that small amounts of alcohol are protective for cognitive decline, but the heterogeneity in calculated relative risk ratios for drinkers (ranging from approximately 0.40 to 0.90) and in defining LMD suggest that these result should be interpreted with caution (Anstey et al., 2009; Antilla et al., 2004; Neafsey & Collins, 2011; Peters et al., 2008; Topiwala & Ebmeier, 2018). Several studies have reported that the potential cognitive benefit of LMD is modified by the apolipoprotein e4 allele (APOE-e4). This allele has also been identified as a risk factor for development of dementia and there is evidence that only non-carriers of the gene experience improved cognition

in response to any level of alcohol use (Antilla et al., 2004; Artero et al., 2008; Gu et al., 2014; Topiwala & Ebmeier, 2017).

Despite the evidence presented above, several recent studies have failed to find any protective benefit for LMD. Moussa and colleagues (2015) reported no difference in performance on tasks of working memory or attention among light drinkers (1-8 drinks per month) and moderate drinkers (7-21 drinks per week) in a sample of adults who have maintained a stable drinking pattern for at least three years. Hassing (2018) analyzed longitudinal data to investigate the relationship between mid-life alcohol consumption and cognition in older age, and determined that alcohol had a detrimental effect on episodic memory and MMSE scores even at the lowest levels of consumption. One study reported a potential beneficial effect of LMD on abstract reasoning test scores among men at age 53, but this apparent protective effect disappeared when controlling for educational attainment and cognitive ability measured at a younger age (Krahn et al., 2006). Another study found that among middle-aged men, alcohol use accounts for only 5% of variance in cognitive ability and less than 2% of variance in any individual test score (Schinka, 2002), which suggests that the relationship between alcohol use and cognition may not be clinically significant when compared to other known predictors such as education and physical health.

Researchers have reported some sex differences in alcohol and age-related cognitive decline. Specifically, cognitive decline associated with long-term drinking is more prevalent among men (Mukamal et al., 2003). For women, LMD (between 1-4 alcoholic drinks per day) is associated more strongly with increased perceptual speed and cognitive flexibility compared to men (Kalmijn et al., 2002) One study also found that cognitive ability and alcohol consumption are positively correlated in women, but for men, the relationship is an inverted U-shape (Kalmijn

et al., 2002). However, it is important to note that participants in the heaviest drinking categories for this study consisted of men only. The results are supported by findings from the Whitehall II cohort study, which revealed that, for women but not for men, non-drinkers experience faster declines in overall cognitive performance and in tests of executive function compared to LMD (Sabia et al., 2014). These studies provide some preliminary support to suggest a possible protective effect of LMD in women but not men as they age.

Correlational findings about the relationship between alcohol consumption and cognition have been mixed, potentially due to differences in the studied populations (e.g., sex of participants) and variation among covariates included in analysis. Further research is needed to understand the relationship between specific cognitive domains and drinking frequency, intensity, and the type of alcohol consumed in a Canadian population, particularly with respect to possible sex differences.

The Present Study

Previous research has demonstrated that lifestyle factors, such as alcohol use, may influence the rate and severity of cognitive decline among older adults. The present study aimed to replicate some of these findings in a large national sample of Canadian adults, and to explore potential interactions between sex, age, and alcohol use in terms of their impact on age-related cognitive differences. The inclusion and exploration of interaction terms between all of these factors is extremely rare in the current literature, despite the common assumption that cognition is impacted by a large number of individual characteristics and lifestyle choices. This study also included narrower alcohol use categories than in past studies, allowing examination of many different levels of alcohol use. Furthermore, the breadth of information provided by the CLSA

allowed us to incorporate a larger variety of cognitive test scores, alcohol use variables, and covariates than many previous studies.

Primary measures were a series of alcohol-focused questionnaires and a neuropsychological test battery administered to participants ($N = 30, 097$) within the Canadian Longitudinal Study of Aging (CLSA) during its first wave of data collection (between 2011 and 2015). The CLSA is a large-scale longitudinal study that aims to collect health-related information from 50,000 participants distributed across the country through the use of regular telephone interviews as well as an in-person assessment. Data collection began in 2011, and will continue until 2031 (Raina et al., 2008).

Four main hypotheses were tested using a cross-sectional design. The first hypothesis was that cognitive test scores will be associated with age such that younger adults achieve higher test scores than older adults across all domains (Hypothesis 1). A second research question will examine sex differences in the domains of auditory memory, prospective memory, verbal fluency, attention, choice reaction time, and executive function. Based on the results of previous studies, women are expected to outperform men on tests of verbal fluency and memory (Hypothesis 2a) and to show a smaller difference in performance than men across age groups (i.e., an age/sex interaction, Hypothesis 2b). These first two hypotheses were tested to replicate results of earlier studies that have demonstrated a relationship between age and cognition, as well as sex differences across cognitive domains.

Third, we predicted that low-levels of drinking, but not high-levels of drinking, would have a beneficial effect on cognition across the examined domains (Hypothesis 3). Finally, it was hypothesized that there would be interactions between age, sex, and alcohol use on cognitive function (Hypothesis 4). This hypothesis was exploratory and non-directional in nature.

Individually, all three of these factors have shown the potential to influence a wide range of cognitive domains. It is therefore possible that interactions between two or more of these factors account for discrepancies in previously reported results. All hypotheses were evaluated both with and without covariates (i.e., sex, age, education, income, language, and number of chronic conditions).

Method

Participants

Data for the current project were obtained from the Canadian Longitudinal Study on Aging (CLSA). CLSA participants include Canadians who were aged between 45-85 years at the time of recruitment in 2010. Participants were recruited through collaborations with Statistics Canada and provincial health registration databases (Raina et al., 2008). Initial exclusion criteria included individuals who lived in long-term care institutions, as well as individuals with cognitive impairment prior to the first wave of data collection. All participants were required to speak English and/or French with sufficient proficiency to complete telephone interviews.

The CLSA divided participants into two groups: the "Tracking" (less intensive participation) group (N = 21,241) and "Comprehensive" (more intensive participation) group. The Comprehensive Group represents the focus of the current study (N = 30,097; 50.8% women; mean age = 62.96 ± 10.25). Of these participants, 80.6% completed the questionnaires in English and the remainder completed them in French. 77.6% of participants completed a post-secondary certificate program or higher level of education. Additional demographic information is available in Table 1.

Participants in the Comprehensive Group are required to travel to one of the CLSA's designated data collection sites every three years. These sites are located in Surry, Victoria, Vancouver, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St.

Table 1

Demographic Information for the CLSA Comprehensive Group (N = 30,097)

Demographic Information	Sex (% Female)	50.8%
	Age (Mean ± SD)	62.96 ± 10.25
	Language (% English)	80.6%
	Household Income (% by group)	Less than 20k per year (5.2%); 20-50k per year (22.6%); 50-100k per year (35.2%); 100-150k per year (19.6%); over 150k per year (17.0%)
	Education (% by group)	Grade 8 or lower (1.5%); grade 9-12 (2.3%); grade 11-13 non-graduates (1.6%); high school graduate (9.4%); some post-secondary education (7.4%); non-university certificate or diploma (32.5%); Bachelor's degree (23.5%); university degree above Bachelor's degree (21.6)
	Chronic Conditions (% by number of conditions)	0 (13.6); 1 (21.1%); 2 (21.8%); 3 (17.1%); 4 (11.4%); 5 (7.0%); 6 (3.8%); 7 (2.2%); 8 (1.1%); 9+ (1.0%)
Cognitive Tests (Mean ± SD)	Immediate recall (REY I; number of words)	5.85 ± 1.91
	Delayed recall (REY II; number of words)	4.04 ± 2.16
	Prospective Memory (PMT; score from 0 to 9)	8.44 ± 1.40
	Mental Alternation (MAT; number of alternations)	26.53 ± 8.75
	Animal Naming (AFT; number of words)	21.41 ± 6.47
	Verbal Fluency (COWA; number of words)	13.07 ± 4.26
	Stroop Task (number of errors)	0.71 ± 2.06
	Reaction Time (CRT; milliseconds)	852.63 ± 258.20
Alcohol Use Variables (% by Group)	Drinks Per Week (*N* = 29,893)	Never-drinker (2.4%); 12-month abstainer (30.7%); 1 to 7 (42.9%); 8 to 21 (20.7%); 22 to 30 (2.0%); 31 to 50 (1.0%); 51+ (0.3%)
	Frequency of Alcohol Consumption (*N* = 30,083)	Never-drinker (2.4%); 12-month abstainers (11.4%); ≤ 1 per month (18.9%); 2-4 times per month (20.9%); 2-3 times per week (20.4%); 4+ times per week (26.1%)
	Binge Frequency (*N* = 27,071)	Never-drinker (2.6%); 12-month abstainers (12.7%); no binging (46.8%); ≤ 1 per month (28.2%); ≤ 1 per week (6.7%); 2 to 3 times per week (1.9%); 4+ times per week (1.1%)
	Alcohol Use History (*N* = 15,185)	Never-drinker (4.7%); 12-month abstainer (18.1%); low history (54.6%); moderate history (19.5%); high history

	(2.6%); very high history (0.5%)
Binge History (N = 19,950)	Never-drinkers (3.6%); 12-month abstainers (17.2%); no binging (63.4%); low binge history (15.2%); high binge history (0.6%)
Alcohol Type (N = 8548)	Red wine (12.4%); white wine (19.6%); beer (24.2%); spirits (12.3%)

Note. Alcohol use variables, cognitive variables, and covariate categories are explained in more detail in Appendix A. Higher group numbers for alcohol use variables reflect greater alcohol consumption.

John's. Therefore, the Comprehensive participants reside solely within these localized urban regions and must also have the physical and economic means to travel to a data collection site. Participants were compensated $30 at the completion of each visit to a data collection site to assist with travel expenses. Residents of the three Canadian territories, persons living on federal First Nations reserves, and full-time members of the Canadian Armed Forces were excluded from CLSA recruitment strategies, as were individuals living in institutions. Data used in the present study included only the Comprehensive group of participants due to its larger sample size and more valid comprehensive in-person neuropsychological data collection. To maximize generalizability of the findings, no additional exclusion criteria were applied in this study.

Measures

Alcohol Use Measure

The CLSA administered an Alcohol Use Questionnaire to all participants. This questionnaire contains five items assessing the amount and type of alcohol consumed over the past 12 months, as well as one item to estimate how this pattern compares to the period of heaviest drinking across the lifetime (Appendix B1). The questions were adapted from the Ontario Health Study (2009) and were originally taken from the Centre for Addiction and Mental Health Monitor (Ialomiteanu & Adlaf, 2011). The choice of alcohol variables used in the current study was based on the availability of data collected by the CLSA and the range of variables that

are commonly used in research to reflect the amount, frequency, and intensity of alcohol consumption, binge drinking patterns, alcohol use history, and the primary type of alcohol consumed within the past 12 months. All variables from the original CLSA dataset were modified such that higher scores on each scale reflects greater amounts of alcohol consumption (see derived variable descriptions below, or a summary in Appendix A for more detail). Spearman correlations between these alcohol use variables ranged from medium to large (.585 to .974; Appendix D).

Drinks Per Week. The *Drinks Per Week* variable represents the number of alcoholic drinks consumed during a typical week over the past 12 months. The original CLSA dataset included separate responses for the number of drinks of red wine, white wine, beer, spirits, and other alcohol consumed over (1) the average week spanning from Sunday to Thursday, and (2) the average weekend spanning from Friday to Saturday. The number of drinks of all types of alcohol consumed over weekdays and weekends were added together to produce a simplified scale reflecting the number of alcoholic beverages consumed in a typical week for each participant (M = 6.02, SD = 7.92, range = 0 to 280 drinks consumed during a typical week).

This continuous scale was then grouped into seven ordinal categories for compatibility with ANOVA, which was chosen due to the nonlinear relationships between alcohol use and cognition, as well as to allow for the inclusion of categorical groups across all alcohol use variables (i.e., never-drinkers and non-drinkers). The final scale ranges from 0 to 6 where 0 = never-drinker (i.e., has never consumed alcohol); 1 = 12-month abstainer (i.e., no alcohol consumption over the past 12 months, but has consumed alcohol previously); 2 = low alcohol use (1-7 drinks per week); 3 = low-moderate use (8-12 drinks per week); 4 = high-moderate use (22-30 drinks per week); 5 = high use (31-50 drinks per week); and 6 = very high use (50+

drinkers per week). The estimates of alcohol use that are included in these ranges are higher than the ranges used by many other studies (e.g., Galanis et al., 2000; Stampfer et al., 2005; Solfrizzi et al., 2007), which reflects the full range of reported use. Use of all of these categories serves several additional purposes. First, use of categories instead of continuous data compensates for the possibility of inflated self-reports that might result from participants estimating their alcohol consumption separately for each type of alcohol included in the questionnaire and separately for weekdays and weekends. Second, grouping this variable into categories better reflects the non-normal distribution of the data. Finally, using categories reflecting higher consumption allows for better distinction between the various levels of "moderate" and "high" alcohol users, who are often grouped together.

Alcohol Frequency. The *Frequency* variable represents the overall frequency of alcohol consumption over the past 12 months. The original CLSA item assessing Frequency was transformed into a six-point scale where higher numbers represent higher levels of drinking. The transformed scale ranges from 0 to 5 where 0 = never-drinker; 1 = 12-month abstainer; 2 = consumed alcohol up to once a month; 3 = consumed alcohol 2-4 times per month; 4 = consumed alcohol up to 2-3 times per week; and 5 = consumed alcohol 4 times per week or more.

Binge Drinking Frequency. The original CLSA dataset coded binge drinking separately for men and women such that one single-item scale assessed binge drinking frequency over the past year for men (5+ drinks on a single occasion) and another scale assessed binge drinking frequency over the past year for women (4+ drinks on a single occasion). The variable was transformed so that higher numbers on the scale represented higher frequencies of binge drinking. The final scale ranges from 0 to 6 such that 0 = never-drinker; 1 = 12-month abstainer; 2 = has consumed alcohol over the past 12 months, but has not binged; 3 = binges up to once a

month; 4 = binges up to once a week; 5 = binges 2-3 times per week; 6 = binges 4 or more times per week.

Alcohol Type. The original CLSA dataset contained questions regarding the number of drinks of each type of alcohol (i.e., red wine, white wine, beer, liquor, and "other" alcohol) consumed in a typical week over the past 12 months. Responses to these items were used to categorize some participants by drinker type. If the number of drinks of red wine consumed weekly was greater than 0, and the number of drinks of all other kinds of alcohol was equal to zero, the individual was given a value of 1 indicating that they strictly consume red wine in a typical week. Similar scales were constructed for the other types of alcohol and these were combined into a final *Alcohol Type* variable with four categories such that 1= individuals who have generally only consumed red wine within the past year; 2 = individuals who have generally only consumed white wine within the past year; 3 = individuals who have generally consumed only beer within the past year; and 4 = individuals who have generally consumed only liquor/spirits within the past year. Individuals who reported only drinking "other" types of alcohol were excluded due to an inability to specify the type of alcohol being consumed, resulting in a more valid comparison between drinker groups.

Alcohol Use History. The CLSA-administered Alcohol Use Questionnaire contained a single item where participants rated their current level of alcohol consumption as being either equal to or lower than their period of heaviest-ever alcohol consumption. Participants were coded as having a lifetime history of "low" alcohol consumption if they currently consume less than 7 drinks per week and consider this to be equal to their heaviest period of drinking. Participants were considered to have a lifetime history of "moderate" alcohol use if they currently consume between 8-21 alcoholic drinks per week and consider this to be equal to their heaviest period of

drinking. A lifetime history of "high" alcohol use indicates that participants currently consume between 22-45 alcoholic drinks per week and consider this to be lower than their period of heaviest drinking. A lifetime history of "very high" alcohol use represents participants who currently consume more than 45 drinks per week and consider this to be lower than their period of heaviest drinking. The final alcohol use history scale ranges from 0-5 where 0 = never drinkers; 1 = 12-month abstainers; 2 = history of low alcohol use; 3 = history of moderate alcohol use; 4 = history of high alcohol use; and 5 = history of very high alcohol use. Using the CLSA dataset, it was not possible to classify participants who endorsed other combinations of past and current alcohol use. The final categories were chosen based on the availability and validity of alcohol use data.

Binge History. Where data were available, the *Binge History* variable estimates a participant's lifetime of binge drinking. It incorporates information regarding both binge drinking within the past 12 months and the alcohol use history item. The scale ranges from 1 to 5 where 1 = never-drinkers; 2 = 12-month abstainers; 3 = individuals who currently consume alcohol but have not binged in the past year; 4 = individuals who currently report binge drinking up to once a month, and consider this past year to be equal to their heaviest period of drinking; 5 = individuals who currently report binge drinking 4 or more times per week, and consider this past year to be lower than their heaviest period of drinking.

Recent Alcohol Composite. A composite alcohol use score was created by calculating and averaging the z-scores for the *Drinks Per Week, Binge Drinking Frequency,* and *Alcohol Frequency* variables. This composite reflects a broader estimate of the level/amount of alcohol consumption for each participant over the past 12 months. Creating composite scores through

aggregation is known to increase the reliability and generalizability of variables (Ossenkopp & Mazmanian, 1984).

Alcohol Use History Composite. The *Alcohol Use History* composite score was created by calculating and averaging the z-scores for the *Alcohol History* and the *Binge History* variables. This composite score was created to measure alcohol history with greater reliability and generalizability (Ossenkopp & Mazmanian, 1984).

Cognitive Tests and Variables

Global Cognition. To create a composite score of cognition, test scores for Choice Reaction Time, Stroop Error scores, and the time to complete the Stroop interference trial were reversed so that higher scores reflected better test performance. Each of these tests are described in more detail below. The z-scores for all nine cognitive test scores (Rey Auditory Verbal Learning Test immediate and delayed recall scores, Prospective Memory Test, Animal Fluency Test, Controlled Oral Word Association, Mental Alternation Test, Stroop Time, Stroop Error, and Choice Reaction Time) were then calculated and a mean was taken to reflect overall cognitive performance. As noted above, composite scores should be more reliable and generalizable than the individual scores on which they are based (Ossenkopp & Mazmanian, 1984).

Rey Auditory Verbal Learning Test (RAVLT). The RAVLT is a 15-item word-learning task that assesses verbal memory (Rey, 1964). A list of words is read at a rate of one item per second, followed by an immediate recall trial where participants repeat back the words they can remember in any order. In the original version of the test, this immediate recall trial is repeated in full several times to assess learning rate. The CLSA uses a modified version of the original RAVLT that involves only two trials: one immediate-recall trial (i.e., REYI), and a

delayed-recall trial which is conducted approximately 5 minutes following the immediate-recall trial (i.e., REYIII; Tuokko et al., 2017). In the delayed trial, participants are instructed to recall as many words as they can from the previous trial without having the opportunity to hear the list a second time.

The RAVLT is a widely-used neuropsychological test (Butler et al., 1991) and psychometric data are available for both the English and French versions (Schmidt, 1996; Spreen & Strauss, 1998); test-retest reliability is typically reported to be within the range of 0.51-0.86 (Tuokko et al., 2017). Individuals experiencing mild cognitive impairment have been found to recall significantly fewer words than healthy controls (Petersen et al., 1997). Variables of interest were the number of correctly recalled items on (a) the immediate recall trial and (b) the delayed recall trial.

Prospective Memory Test (PMT). The version of the Prospective Memory Test (PMT; Loewenstein & Acevedo, 2001) that was administered in the CLSA is an event-based prospective memory task cued after a 30 minute delay. The interviewer presents the participant with an envelope containing a nickel, a quarter, 3 loonies, a five dollar bill, a ten dollar bill, and a twenty dollar bill. They instruct the participant to retrieve the envelope, to place a 5 dollar bill in front of the interviewer, and to place a ten dollar bill in front of themselves when they hear an alarm go off at a later time. In the time between the instructions and the alarm, other tasks were completed. The participant was not aware of the length of the time delay. Upon hearing the alarm sound, if no actions were taken for 60 seconds, the interviewer prompts the participant with a series of reminder questions. Scoring is based on intention to perform an action, accuracy of the response, and the need for reminders, all of which are rated on a scale of 0 to 3. Performance on the PMT has implications for adaptive functioning in older populations (e.g., taking medications,

turning off the stove, paying bills on time). While most CLSA participants achieved a perfect score on this version of the test (Simard et al., 2018), scores on other prospective memory tasks decline with age and are sensitive to detecting cognitive impairment (Henry et al., 2004; Huppert & Beardsall, 1993; Huppert et al., 2001).

Animal Fluency Test. The Animal Fluency Test is a measure of semantic verbal fluency, a type of executive function, and requires participants to name as many animals as possible in 60 seconds (Himmelfarb & Murrell, 1983; Read, 1987). This test is sensitive to detecting age-related cognitive decline, may help to discriminate healthy cognitive decline from early-stage dementia (Crossley et al., 1997), and is a predictor of Alzheimer's disease (Troyer et al., 1998). Normative data is available for both English and French populations (Tombaugh et al., 1999; Troyer, 2000). Test-retest reliability of the animal naming test is reasonable (0.56 over a period of one month, $p < 0.001$; Bird et al., 2004).

Controlled Oral Word Association (COWA). The COWA is a measure of phonemic verbal fluency, a type of executive function, that requires participants to generate as many words beginning with a given letter as possible within 60 seconds (Lezak et al., 2004). Three trials were administered using the standard three letters for this test. The COWA score used here is the mean score across all three trials. The COWA demonstrates high test-retest reliability (.74, $p < .001$) and normal cognitive function in adults aged 16 to 70 is reflected by a score of 28 words or more across all three trials after scores have been adjusted for level of education (i.e., points subtracted for higher levels of education; Ruff, Light, Parker, & Levin, 1996).

Stroop Test (Victoria Version). The Stroop test is a measure of attention and mental inhibition (an executive function; Strauss et al., 2006). The Victoria version of the test contains three parts. First, the participant is asked to name the colour of a series of dots presented on a

card. Next, they are asked to name the ink color of non-colour related words. Finally, in the interference/inhibition trial, the participant is asked to name the ink colour for a list of colour words but refrain from reading the words themselves aloud. For the present study, Stroop scores included the time (in seconds) taken to complete the inhibition trial as well as the number of errors committed on that trial. The interference/inhibition trial of the Victoria Stroop test has good test-retest reliability (0.76; Spreen & Strauss, 1998). Both increasing age and Alzheimer's Disease have been linked to poorer performance on the interference/inhibition condition of the Stroop task (Bondi et al., 2002; Cohn et al., 1984; Troyer et al., 2006). Reduced performance with age may be due to a general slowing or may be a specific impairment of mental inhibition (Verhaeghen & De Meersman, 1998).

Mental Alternation Test (MAT). The Mental Alternation Test (MAT; Teng, 1994) is based on the Trail Making Test, a measure that is sensitive to detecting progressive cognitive decline in dementia (Lezak et al., 2004). The MAT is designed to assess executive function, a construct that is associated with mental flexibility, working memory, planning, self-regulation, response inhibition, and problem solving (Kahokehr et al., 2004; Wecker et al., 2000). The MAT has been validated for use in older populations (Himmelfarb & Murrell, 1983). The first part of the test requires participants to count aloud from 1-20, and then recite the alphabet. If they are unable to perform either of these tasks then the MAT will not be administered due to a low likelihood of being able to correctly perform the task, and validity issues related to the measurement of the cognitive constructs. In the next part of the test, participants are asked to alternate between number and letter (i.e., 1-A, 2-B, etc.) as quickly as possible for thirty seconds. The number of correct alternations determines the score, which ranges from 0 to 51. The MAT is comparable to the Mini Mental State Examination (MMSE) in terms of sensitivity and specificity

for detecting cognitive impairment in older adults and in individuals with HIV-related cognitive impairment (Billick et al., 2001; Jones et al., 1993; Salib, 2002).

Choice Reaction Time (CRT). The Choice Reaction Time task (CRT; Gallacher et al., 2013) is a computer-administered test in which participants are presented with two blank boxes on a touch screen monitor, each with an arrow beneath it. A grey square will appear in one of the boxes and participants are instructed to press on the corresponding arrow as quickly as possible. Participants are instructed to sit comfortably in front of the screen and to use only one hand to select responses. After two practice trials, 52 test trials are completed. Scoring consists of the percentage of correct responses and the mean reaction time (excluding incorrect answers). Reaction times are known to increase and become more variable with age (Hultsch et al., 2002; Williams et al., 2005). Additionally, simple reaction times have been shown to differentiate healthy control adults from adults with dementia (Hultsch et al., 2000). Greater variability in reaction time is predictive of overall cognitive performance on tasks assessing vocabulary, verbal recall, working memory, and pattern detection (MacDonald et al., 2003).

Covariates

Primary covariates included age, sex, household income (HI), education, language, and physical health. In some cases, additional covariates were used in follow-up analyses. These include a measure of social engagement, physical test performance, and personality measures.

A new age variable was created so that participants were grouped by decade (i.e., 40-49, 50-59, etc.). Sex (male/female) and the language in which the interview was conducted (English/French) were dummy coded. The remaining covariates were derived from available CLSA data as explained below.

Household Income. The household income (HI) variable was created using a single item. The scale ranged from 1-5 so that 1 = less than $20,000 per year; 2 = $20,000-50,000 per year; 3 = $50,000-100,000 per year; 4 = $100,000-150,000 per year; 5 = over $150,000 per year. Annual household income is one of the most commonly used measures of socioeconomic status in social science research because it provides a simple measure of access to resources, and it changes over time to reflect fluctuations in status (Diemer et al., 2013). More complex indicators of HI (i.e., total wealth including assets and debt) are frequently left blank and are prone to being misreported if participants do not understand the question. Individuals tend to differ in whether they choose to include non-salary related sources of income (i.e., government or workplace benefits) or assets (i.e., savings, property) and debt (i.e., personal loans from friends or family) in their responses, and individuals with a large number of indirect sources of wealth may find it more difficult to recall them accurately (Diemer et al., 2013).

Education. The CLSA questionnaires contain a single item regarding the highest level of education attained. For this study, some levels of education which were deemed to be equivalent were combined to create a scale on which a higher score reflects a higher level of education. The final scale ranges from 1 to 8 so that 1 = grade 8 or lower; 2 = grade 9-10; 3 = grade 11-13 non-graduates; 4 = secondary school graduate with no post-secondary education; 5 = some post-secondary education; 6 = trade certificate or diploma from a vocational school, other post-secondary education, non-university certificate program, or diploma from a community college or university; 7 = Bachelor's degree; 8 = university degree above Bachelor's degree.

Number of Chronic Conditions. The CLSA administered a questionnaire consisting of a list of chronic health conditions which are prevalent among older adults. Participants were asked to indicate which conditions had been diagnosed by a medical service provider. The list included

high blood pressure, heart disease, angina, heart attack history, peripheral vascular disease, stroke, mini-stroke, memory problems, Alzheimer's disease, Parkinson's disease, multiple sclerosis, epilepsy, migraines, ulcers, bowel disorder, bowel and urinary incontinence, cancer, mood disorders, anxiety, osteoporosis, back problems, overactive and underactive thyroid gland, kidney disease, or "other" chronic condition. The number of chronic conditions experienced by a participant was used as a proxy for overall physical health status.

Physical Function. Participants completed a series of physical tests conducted at the data collection centers. These tests include a timed up-and-go test (Podsiadlo et al., 1991), standing balance test, a timed 4 meter walk (Cesari et al., 2008), grip strength (Frederickson et al., 2006), and a timed chair raise (Bohannan, 1995). The z-scores for each test were calculated and averaged into an overall measure of physical function. All of these tests are used in the present work and in other studies as measures for functional impairment, frailty, and physical limitation in older adults. More information is available in the CLSA Study Design and Baseline Protocol document (Raina et al., 2008).

Social Engagement. The CLSA administered a series of questionnaires assessing social network size, frequency of social participation, and recency of social interaction (see Appendix B2). To maximize reliability and generalizability of the measure, z-scores for each of these scales were calculated and averaged together to create an overall measure of social engagement.

Personality. The CLSA administered the Ten Item Personality Inventory (TIPI; Gosling et al., 2003) to measure the constructs of openness, conscientiousness, extraversion, agreeableness, and emotional stability (see Appendix B3). Each construct has two items and is each rated on a scale ranging from 1to 7 where 1 indicates the participant is low on the trait and 7 indicates the participant is high on the trait. These five personality scores were used as additional

covariates. Each of the five construct scales on the TIPI show good convergent validity with the scales on the original Big-Five Inventory (r = .65 to .87) as well as good test-retest reliability (r = .72, Gosling et al., 2003).

Procedure

The dataset utilized in the present study was obtained from the CLSA in 2018 and includes only the first wave of data collection (i.e., interviews conducted between 2011 and 2015; Raina, Wolfson, & Kirkland, 2008). Within this timeframe, participants in the Comprehensive Group completed a telephone questionnaire, a face-to-face home interview, and provided physical and medical data derived from physical examinations, biological specimen collection, and neuropsychological testing conducted at one of the approved data collection sites by CLSA employees. A summary of the derived Alcohol Use variables and Cognitive variables is available in Appendices A2-A3).

Analyses.

A set of analyses of variance (ANOVAs) and analyses of covariance (ANCOVAs) designed to investigate the relationship between age, sex, alcohol use, and cognitive test performance were conducted. This cross-sectional analysis procedure is summarized in Appendix C. Participants were excluded from analyses on a test-by-test basis only if they had not provided data for one or more of the relevant variables, including cognitive test scores, alcohol use measures, or covariates. The primary aim of this study was to investigate the relationship between alcohol use measures and cognitive test scores using a total of 8 alcohol use variables and 13 cognitive test scores. The analyses in Part 1 begins with ANOVAs and ANCOVAs assessing the main effects of age and sex on Global Cognition. In cases where this broad analysis produced a significant main effect, it was followed by a second set of analyses investigating the effects of age and sex for each specific cognitive test. Analyses in Part 2 investigate the main

effects of alcohol use variables on cognitive tests. In Part 3, potential interactions between age, sex, and alcohol use scores on cognition were assessed for all cognitive test scores. This sequential strategy was chosen to maximize the number of available data points for each analysis and increase statistical power across tests, while also completing the minimum number of analyses required. ANOVA/ANCOVA were chosen over other strategies (e.g., regression) due to the non-continuous nature, non-normal distribution, and non-linear relationships between some variables. In addition, ANCOVA allows for clear visualization and graphing of the results.

Figure 1 depicts the maximum number of potential pairings that can occur in Part 2. For each colored arrow, the following tests were performed: (1) an ANOVA (without covariates) assessing whether different levels of the given alcohol variable were associated with differences in a particular cognitive test score (i.e., main effect of the alcohol variable); (2) an ANCOVA assessing whether different levels of the alcohol variable were associated with cognitive test score differences, including the covariates of age, sex, education, HI, language, and physical health (i.e., chronic conditions); (3) an ANCOVA including age, sex, and the given alcohol variable as primary factors to determine whether any of the three factors interact to influence cognitive test score performance, using the same covariates as Part 2. As previously described, the global alcohol composite variable was analyzed first, and the more specific alcohol variables were only investigated when the global alcohol score yielded a significant effect.

Post-hoc Bonferroni comparisons with correction for multiple comparisons were used for significant results to describe the pattern and direction of the relationship between alcohol use and cognitive test performance. Further follow-up tests were performed in two scenarios. The first follow-up scenario occurred when post-hoc Bonferroni tests suggested a beneficial relationship between higher levels of alcohol use and cognitive test scores in Part 2 of the analysis. In these cases, the test was repeated with additional covariates (social interaction score, physical function, and five TIPI personality measures) to search for other potential variables that are associated with both alcohol consumption and cognitive test scores. This test was used as an

ethical precaution against erroneously reporting beneficial effects of high alcohol use which could be better explained by a non-alcohol related factor (type I error). The second scenario in which follow-up tests were implemented was after observing a significant interaction in Part 3 ($p \leq 0.01$) between Alcohol x Age, Alcohol x Sex, or Alcohol x Age x Sex. In these circumstances, separate ANCOVAs were completed for each level of age or by each level of sex, and post-hoc Bonferroni tests were used to describe the nature of the interactions. For follow-up analyses based on a breakdown using age or sex, some variables were restructured such that the two highest levels of alcohol use were combined into a single group. This was to ensure that each level of alcohol use maintained a sufficient *N* for comparison. The two highest age groups (70s and 80s) were combined during follow-up analyses for the same reason.

For all analyses, when reporting effect sizes, partial eta-squared (η_p^2) of 0.01 is considered small, 0.06 is considered moderate, and 0.14 is considered large (Kreppel, 1991; Richardson, 2011). To remain conservative in the face of many comparisons and a large sample size, an alpha level of $p < .001$ was considered significant for all analyses.

Results

Demographic information for participants and the means for primary cognitive test scores and alcohol use measures are summarized in Table 1. Correlations summarizing the relationships between covariates, alcohol use measures, and cognitive test scores are shown in Appendix D (Tables D1-D6). The overall trend shows a positive association between alcohol use and cognition. Generally, non-drinkers have lower cognitive test scores than individuals who consume alcohol at any level, and increased levels of alcohol use do not have a detrimental effect. Visual inspection of the correlations between the alcohol variables and the cognitive variables indicates that binge frequency is the alcohol variable that shows the strongest

correlation with the composite measure of cognition (Global Cognition, $r = .200$, $p < .01$) and with every individual cognitive test score except COWA in men (Appendix D6).

Part 1: Main Effects of Sex and Age on Cognition

Effects of Sex and Age on Global Cognition (Composite Score)

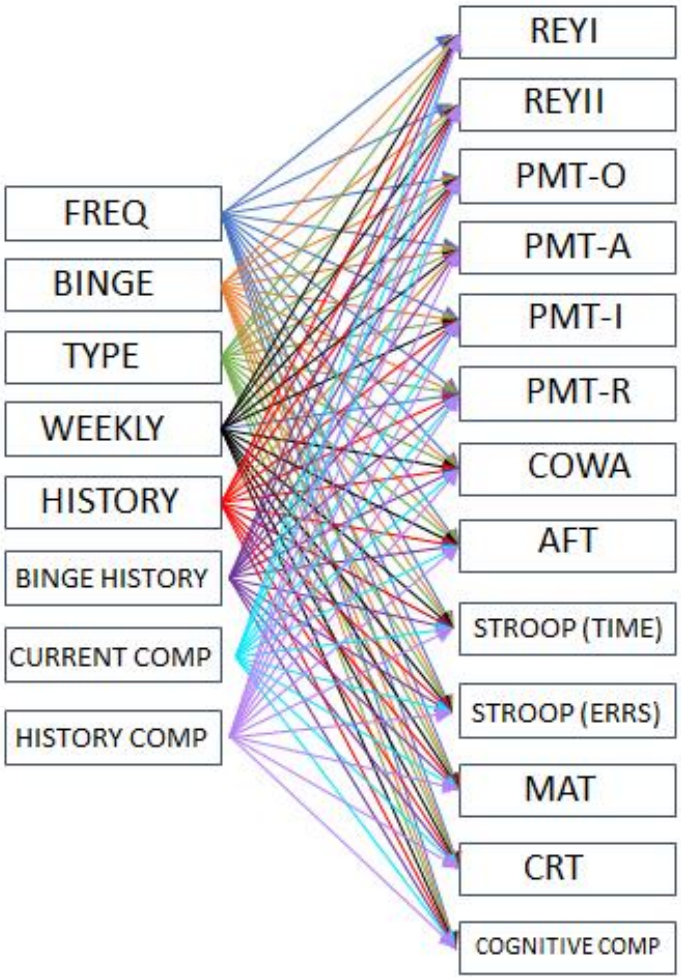
The first analyses were a series of ANOVAs and ANCOVAs designed to investigate potential main effects of sex and age on a broad cognitive measure referred to throughout the section as Global Cognition. In general, women outperformed men and younger adults outperformed older adults.

The result of the Levene's test was significant ($p < 0.001$) suggesting that the assumption of homogeneity of variance was violated in this analysis, potentially due to differences in group size. When large variances are associated with large group sizes, as in the CLSA sample, this leads to a decrease in the power of the test and an increased likelihood of falsely accepting the null hypothesis. Other aspects of this study design (i.e., large sample size and a large number of analyses) can lead to the opposite type of error, so this violation was considered to be acceptable. Analyses were continued as specified above and these violations were ignored moving forward.

When education, HI, language, and overall health (as measured by the number of chronic conditions reported) were included in the analysis as covariates, all tests were significant (Table 2; Figure 2). There was a main effect of sex. Women had higher scores than men on the Global Cognition scale ($p < .001$). This reflects better cognitive performance among women compared to men ($p < .001$) with a small effect size ($\eta_p^2 = 0.013$). There was also a main effect of age. Younger adults had higher Global Cognition scores than older adults ($p < .001$) across all age

Figure 1

ANOVA/ANCOVA Pairings between Alcohol Use Variables and Cognitive Test Scores



Note. A visual depiction of ANOVA/ANCOVA pairings between each alcohol variable (left-hand column) and each cognitive test score (right-hand column). Alcohol use variables include (from top to bottom): frequency of alcohol consumption, frequency of binge drinking, type of alcohol consumed, number of alcoholic drinks consumed per week, alcohol history, binge drinking history, current alcohol use composite score, and alcohol history composite score. Cognitive test scores include RAVLT immediate recall score (REYI) and delayed recall score (REYII), prospective memory overall score (PMT-O) as well as each of the constituent PMT scales of accuracy, intention, and reminders (PMT-A, PMT-I, PMT-R), Controlled Oral Word Association score (COWA), Animal Fluency Test (AFT) score, Stroop (both time and error scores), Mental Alternation Test (MAT), Choice Reaction Time (CRT), and a cognitive test score composite score. Each arrow represents the following group of tests: (1) one ANOVA (without covariates) and one ANCOVA (with covariates) demonstrating potential main effects of specific alcohol use factors on various cognitive test scores; (2) one ANCOVA demonstrating interactions between age, sex, and specific alcohol use factors which may influence cognitive test score; (3) follow-up tests for main effects and interactions that are significant at the $p \leq 0.001$ level.

groups and the effect size was large (η_p^2 = 0.165). While there was a potential Age x Sex interaction, the effect size was very small (η_p^2 = 0.001).

Main Effects of Sex and Age on Cognitive Test Scores

REYI (Immediate Recall) Scores.

Mean scores for all memory tasks are summarized in Appendix E (Table E1) as a function of age and sex. When covariates were included, main effects of age and sex on REYI scores were significant. The ANOVA/ANCOVA results for the effects on age and sex on REYI scores are presented in Table 3. Women recalled a higher number of words than men ($p < .001$) and younger adults recalled more words than older adults ($p < .001$). Post-hoc Bonferroni tests revealed that mean score differences were significant (all $p < 0.001$) for all age group comparisons as well as the sex group comparison. The mean score differences in REYI scores by age and sex are presented in Figure 3.

REYII (Delayed Recall) Scores.

Mean scores are presented in Appendix E1and ANOVA/ANCOVA results in Table 3. When covariates were included, the effects of both sex and age were significant. Women recalled a higher number of words than men ($p < .001$) and younger adults recalled more words than older adults ($p < .001$; see Figure 4). Post-hoc Bonferroni tests revealed that mean score differences were significant ($p < 0.001$) for all age group comparisons.

Prospective Memory Test (PMT) Scores.

Mean PMT scores are available in Appendix E (Table E1) and ANOVA/ANCOVA results are in Table 3. When covariates were included, the effect of age was significant ($p < .001$) and the effect size was moderate (η_p^2 = .052). Post-hoc Bonferroni tests indicated that mean PMT scores did not differ between participants in the 40s and 50s age groups ($p < .001$) but scores

Table 2

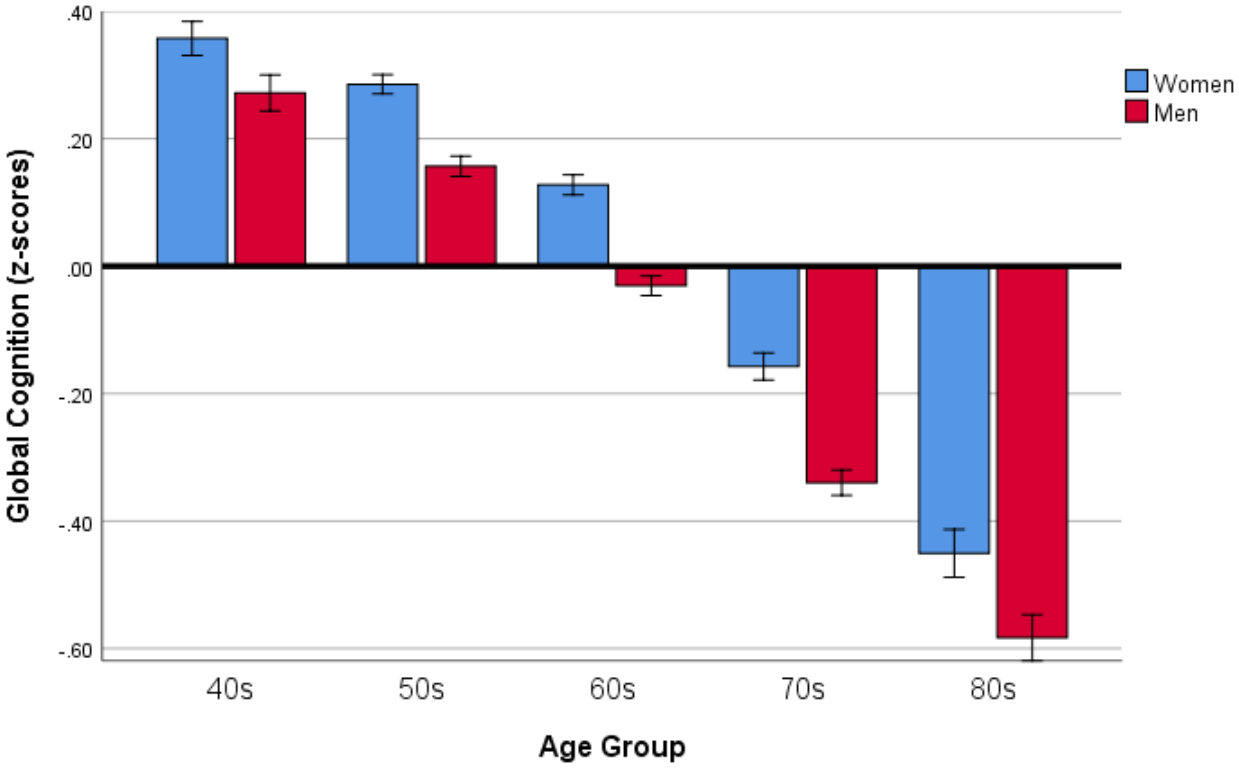
ANOVA/ANCOVA Table: Main Effects of Age and Sex on Global Cognition

	No covariates				Covariates = education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Age	2008.963	4, 26491	< .001	.233	1160.89	4, 23558	< .001	.165
Sex	93.467	1, 26491	< .001	.004	309.835	1, 23558	< .001	.013
Age x Sex	1.602	4, 26491	.171	< .001	5.047	4, 23558	< .001	.001

Note. HI = household income

Figure 2

Main Effects of Age and Sex on Global Cognition



Note: Across all age groups, women obtained higher Global Cognition scores than men. For both sexes, Global Cognition scores were highest among adults in their 40s and decreased consistently as age increased. All group differences are significant ($p < .001$). Error bars represent SE ± 2. Covariates include education, HI, language, and chronic conditions.

Table 3

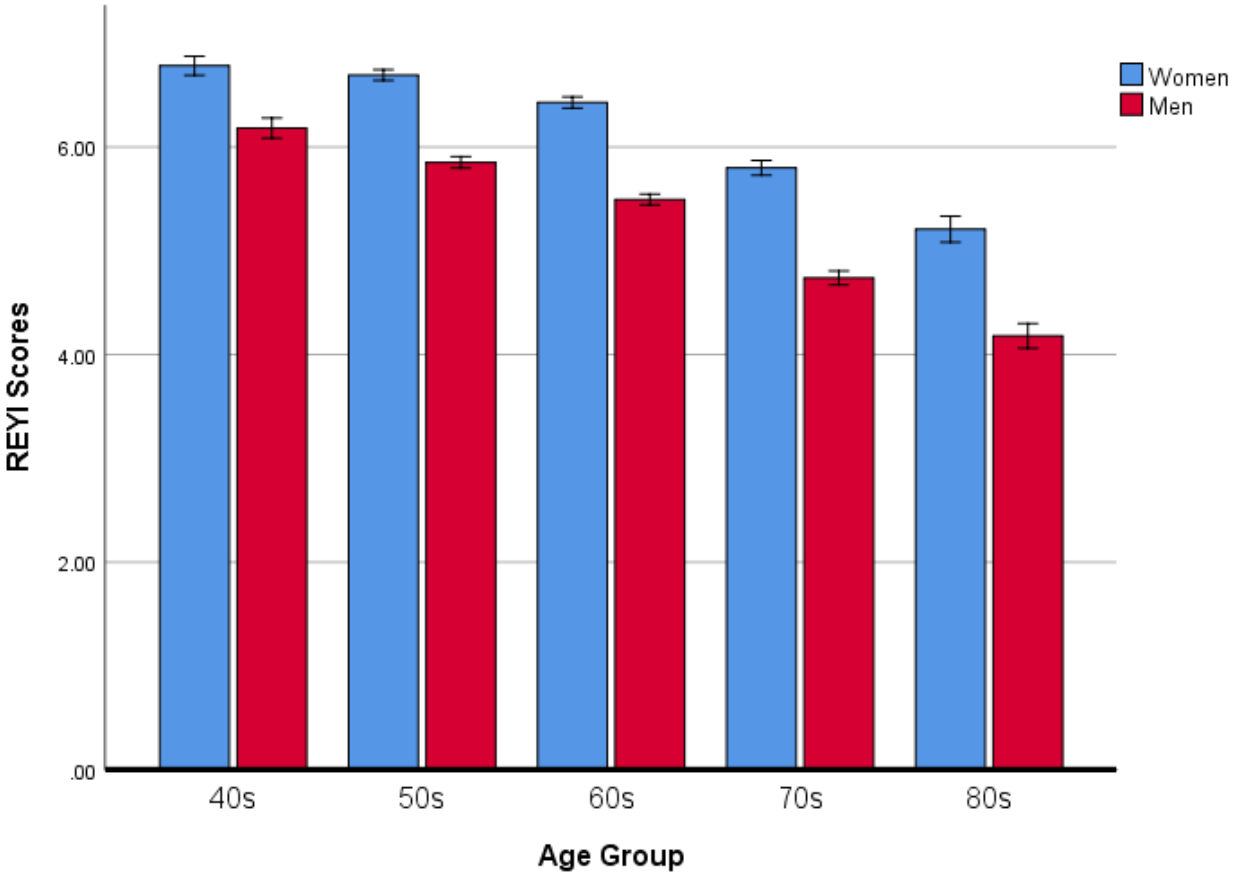
ANOVA/ANCOVA Table: Main Effects of Age and Sex on Memory Test Scores

		No covariates				Covariates = education, HI, language, chronic conditions			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REYI	Age	905.642	4, 29067	< .001	.111	472.121	4, 25700	< .001	.068
	Sex	918.985	1, 29067	< .001	.031	1145.264	1, 25700	< .001	.043
	Age x Sex	4.447	4, 29067	.001	.001	9.188	4, 25700	< .001	.001
REYII	Age	940.333	4, 29036	< .001	.115	512.826	4, 25676	< .001	.074
	Sex	1024.480	1, 29036	< .001	.034	1221.151	1, 25676	< .001	.045
	Age x Sex	2.536	4, 29036	.038	.000	4.577	4, 25676	.001	.001
PMT	Age	554.646	4, 29842	< .001	.069	358.649	4, 26323	< .001	.052
	Sex	8.397	1, 29842	.004	.000	2.871	1, 29842	.090	< .001
	Age x Sex	4.474	4, 29842	.001	.001	5.328	4, 29842	< .001	.001

Note. REYI = immediate recall scores of the Rey Auditory Verbal Learning Test (RAVLT); REYII = delayed recall scores of the RAVLT; PMT = Prospective Memory Test

Figure 3

Main Effects of Age and Sex on Immediate Recall



Note. Across all age groups, women recalled more words than men during the immediate recall trial of the Rey Auditory Verbal Learning Test (REYI; $p < .001$). For both sexes, mean REYI scores were highest among adults in their 40s and decreased consistently with each successive age group ($p < .001$). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

were significantly lower for adults in higher age groups (Figure 5). The main effect of sex on PMT scores was not statistically significant ($p = 0.090$). There was a significant Age x Sex interaction ($p = 0.001$) but the effect size was very small ($\eta_p^2 = .001$) and this interaction was not explored further.

Animal Fluency Test (AFT) Scores.

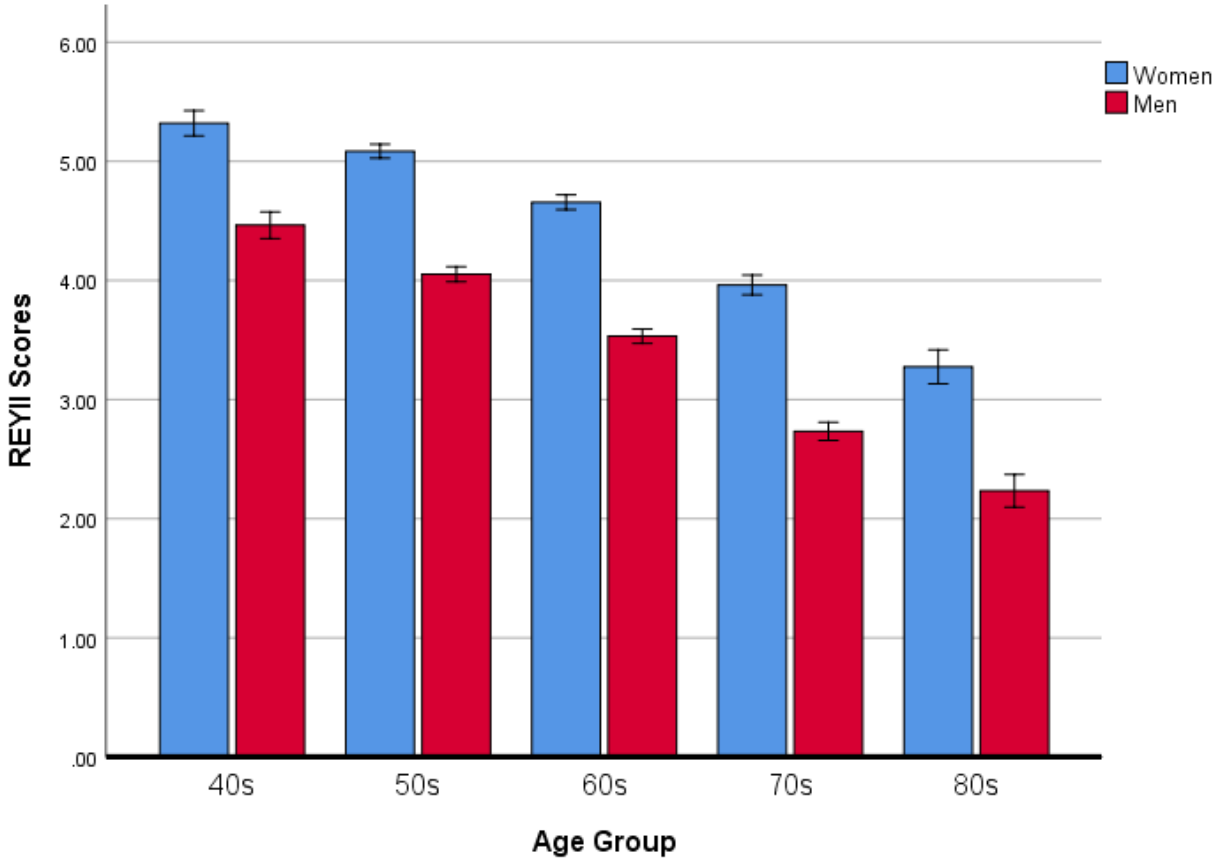
For mean AFT scores, see Appendix E (Table E2). ANOVA/ANCOVA results are found in Table 4. When covariates were included, the effect of age was significant ($p < .001$) and the effect size was medium ($\eta_p^2 = .066$). Post-hoc Bonferroni tests show that the mean AFT scores for each age group differed significantly compared to all other age groups ($p < .001$) with younger adults outperforming older adults (Figure 6). There was a significant main effect of sex on AFT scores with women scoring higher than men ($p < .001$) but the effect size was not detectable ($\eta_p^2 < .001$).

Controlled Oral Word Association (COWA) Scores.

Mean COWA scores are summarized in Appendix E (Table E2) and ANOVA/ANCOVA results are in Table 4. When covariates were included, the effect of age was significant ($p < .001$) but the effect size was very small ($\eta_p^2 = .007$). Post-hoc Bonferroni tests showed that the mean COWA scores did not differ significantly between participants in the 40s and 50s age groups, but the number of words generated decreased with each successive age group beyond the 50s ($p < .001$). There was also a main effect of sex ($p < 0.001$) with a small effect size ($\eta_p^2 = .01$). Women had higher COWA scores than men. The main effects of age and sex are reflected in Figure 7.

Figure 4

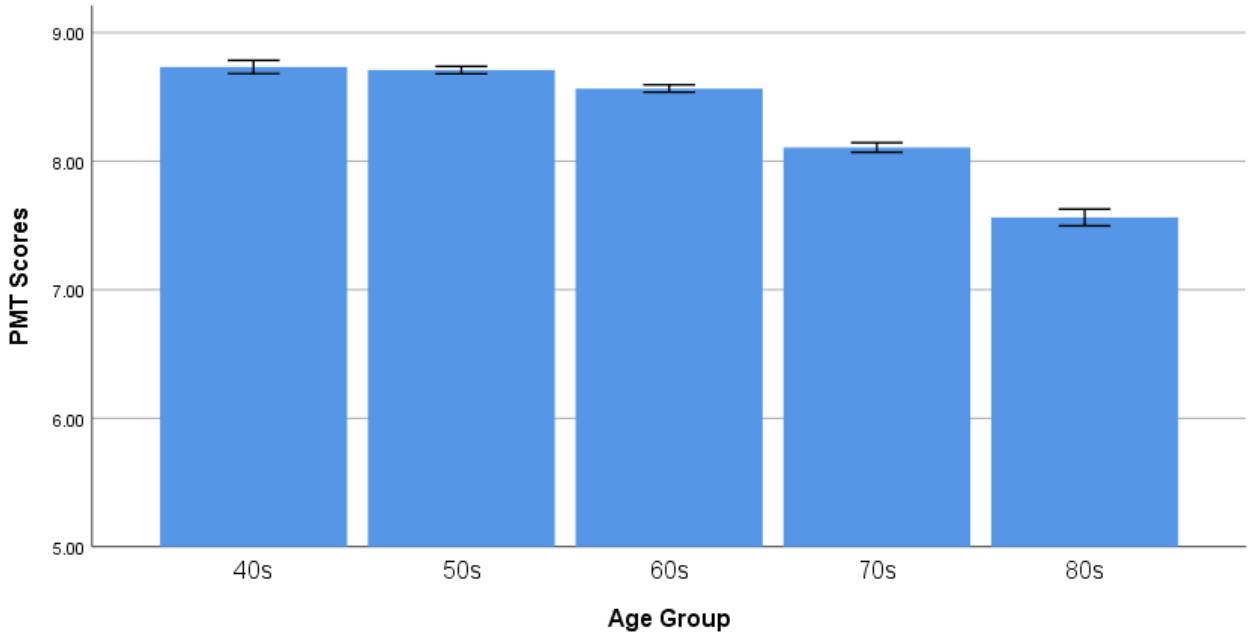
Main Effects of Age and Sex on Delayed Recall



Note. Across all age groups, women recalled more words than men during the delayed recall trial of the Rey Auditory Verbal Learning Test ($p < .001$). For both sexes, mean REYII scores were highest among adults in their 40s and decreased consistently with age ($p < .001$). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

Figure 5

Main Effect of Age on Prospective Memory



Note. Prospective memory (PMT) scores were highest among younger adults and decreased as age groups increased. Adults in their 40s and 50s did not differ from one another, but mean scores decreased significantly with each successive decade (all $p < .001$). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

Table 4

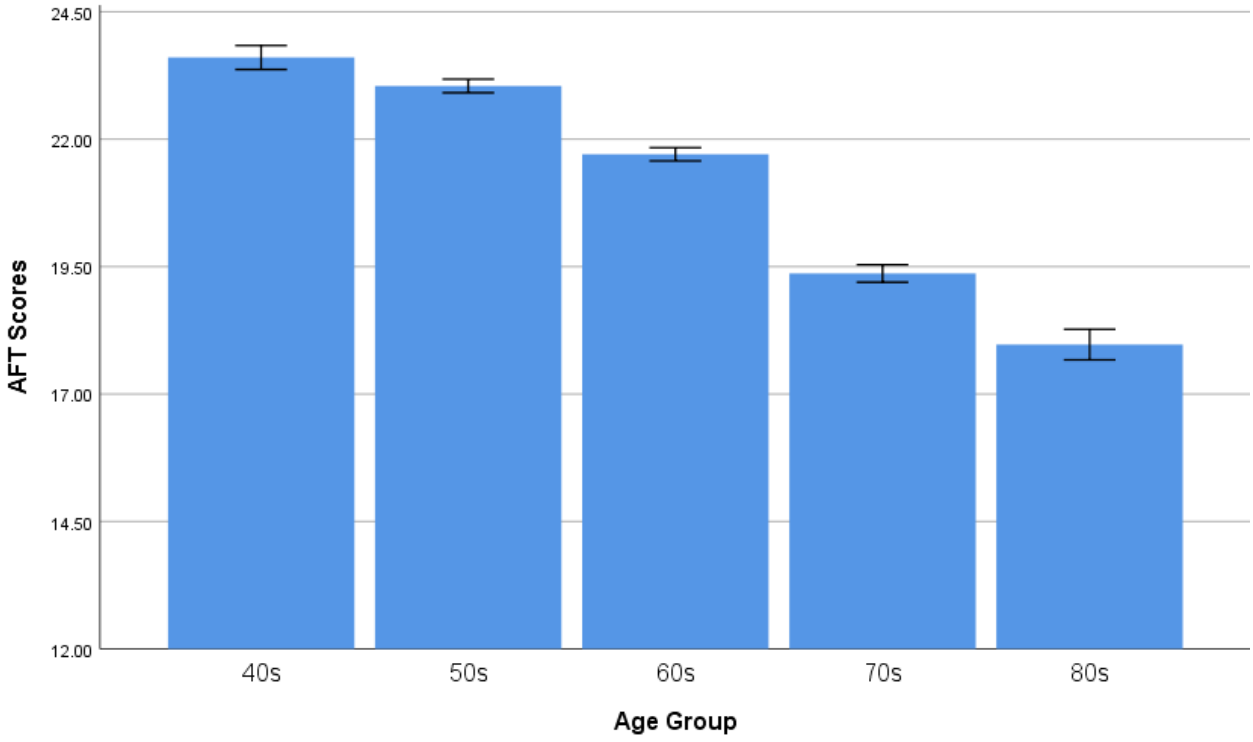
ANOVA/ANCOVA Table: Main Effects of Age and Sex on Verbal Fluency Test Scores

		No covariates				Covariates = education, HI, language, chronic conditions			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
AFT	Age	903.792	4, 29356	< .001	.110	454.782	4, 25930	< .001	.066
	Sex	43.842	1, 29356	< .001	.001	16.820	1, 25930	< .001	< .001
	Age x Sex	1.267	4, 29456	.281	.000	.808	4, 25930	.520	< .001
COWA	Age	190.821	4, 29012	< .001	.026	44.172	4, 25609	< .001	.007
	Sex	119.769	1, 29012	< .001	.004	265.945	1, 25609	< .001	.010
	Age x Sex	1.985	4, 29012	.094	.000	3.774	4, 25609	.005	.001

Note. AFT = Animal Fluency Test; COWA = Controlled Oral Word Association.

Figure 6

Main Effect of Age on Semantic Verbal Fluency



Note. Animal Fluency Test (AFT) scores were highest among younger adults and decreased as age increased ($p <$ .001). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

Stroop Scores.

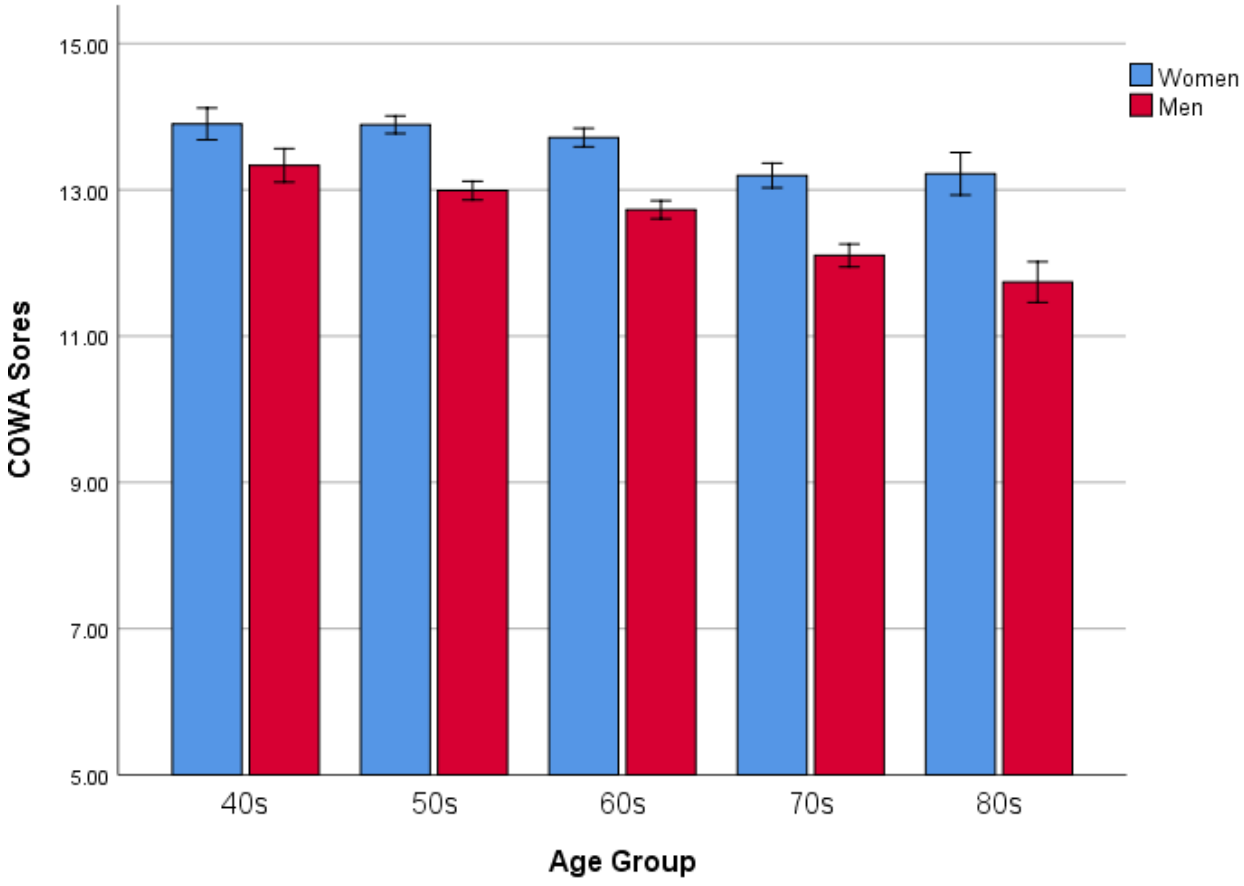
Mean scores for Stroop Time and Stroop Error are shown in Appendix E (Table E3) and ANOVA/ANCOVA results are in Table 5.

For Stroop Time scores, the effect of age was significant ($p < .001$, and the effect size was large ($\eta_p^2 = .113$) when covariates were included. Post-hoc Bonferroni tests showed that the mean scores differed significantly across all age groups, with adults in their 40s reporting the lowest (i.e., fastest) scores and adults in their 80s reporting the highest (i.e., slowest) scores. There was also a main effect of sex on Stroop Time ($p < 0.001$) with a very small effect size ($\eta_p^2 = .005$) such that women had overall faster time scores than men. The main effects of age and sex are shown in Figure 8. There was also a significant Age x Sex interaction ($p < 0.001$) but the effect size was very small ($\eta_p^2 = .001$).

For Stroop Error scores, the effect of age was significant ($p < .001$) and the effect size was small ($\eta_p^2 = .027$) when covariates were included. Post-hoc Bonferroni tests show that the mean scores did not differ between adults in their 40s and 50s, but scores increased significantly with each subsequent age group (i.e., from age 50 to 80; $p < 0.001$). There was also a main effect of sex ($p < 0.001$) with a very small effect size ($\eta_p^2 = .003$). Women made fewer errors than men. The main effects of age and sex are shown in Figure 9. There was a significant Age x Sex interaction ($p < 0.001$) such that the effects of age appear greater for men than women, but the effect size was very small ($\eta_p^2 = .002$).

Figure 7

Main Effects of Age and Sex on Phonemic Verbal Fluency



Note. Controlled Oral Word Association (COWA) scores were higher for women than men in all age groups. Mean scores were highest among younger adults and decreased with each successive age group between 50 and 80 ($p <$ .001). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

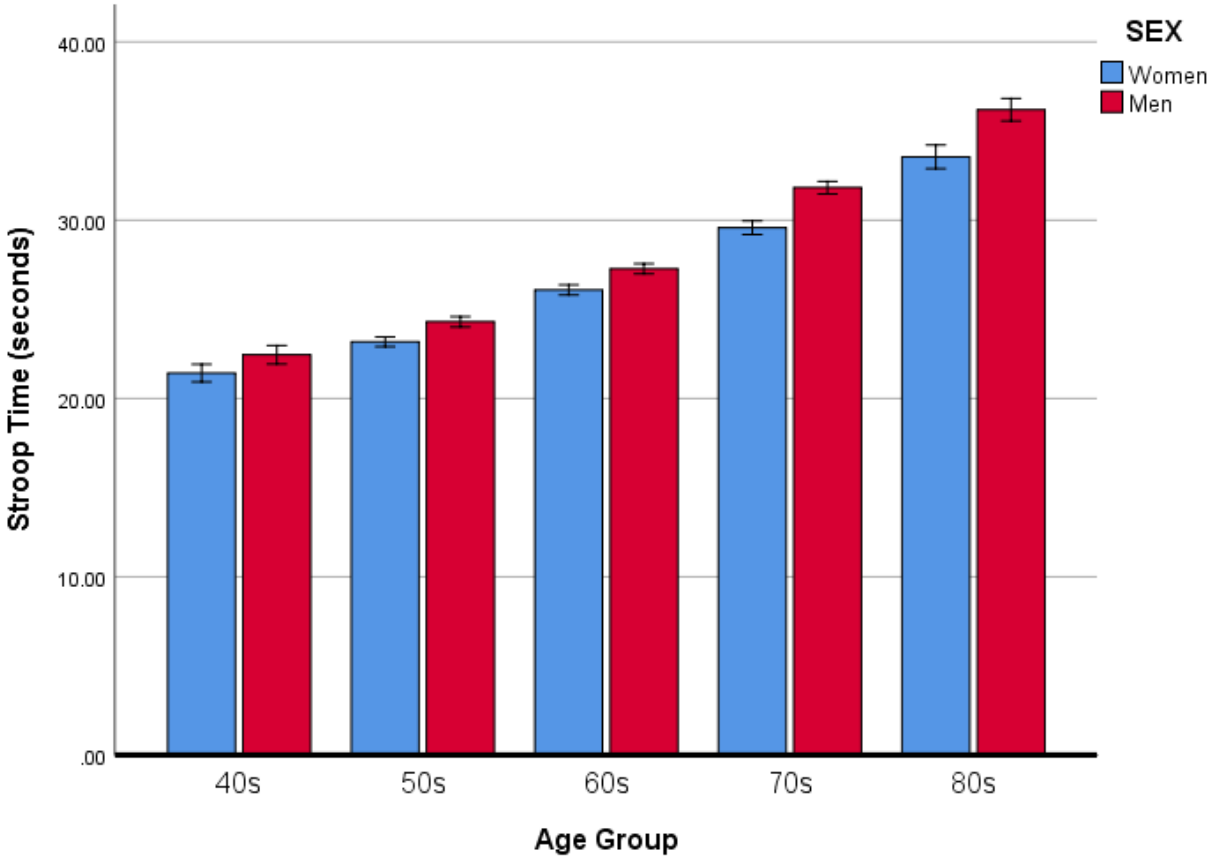
Table 5

ANOVA/ANCOVA Table: Main Effects of Age and Sex on Attention/Executive Function (Stroop test and Mental Alternation Test)

		No covariates				Covariates = education, HI, language, chronic conditions			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Stroop Time	Age	1532.828	4, 29679	< .001	.171	832.614	4, 26179	< .001	.113
	Sex	45.936	1, 29679	< .001	.002	139.099	1, 26179	< .001	.005
	Age x Sex	2.591	4, 29679	.035	< .001	5.610	4, 26179	< .001	.001
Stroop Errors	Age	360.236	4, 29544	< .001	.047	177.530	4, 26070	< .001	.027
	Sex	15.194	1, 29544	< .001	.001	66.349	1, 26070	< .001	.003
	Age x Sex	33.473	4, 29544	< .001	.001	14.079	4, 26070	< .001	.002
MAT	Age	493.642	4, 28601	< .001	.065	195.556	4, 25332	< .001	.030
	Sex	140.318	1, 28601	< .001	.005	30.112	1, 25332	< .001	.001
	Age x Sex	.804	4, 28061	.522	< .001	1.000	4, 25332	.406	< .001

Figure 8

Main Effects of Age and Sex on Stroop Time Scores



Note. Stroop Time scores were lowest among younger adults (i.e., 40s) and increased as age group increased (all $p <$ .001). Women reported significantly faster/better Stroop scores than men overall ($p <$ .001). Error bars reflect ± 2 SE. Covariates included education, HI, language, and chronic conditions.

Mental Alternation Test (MAT) Scores.

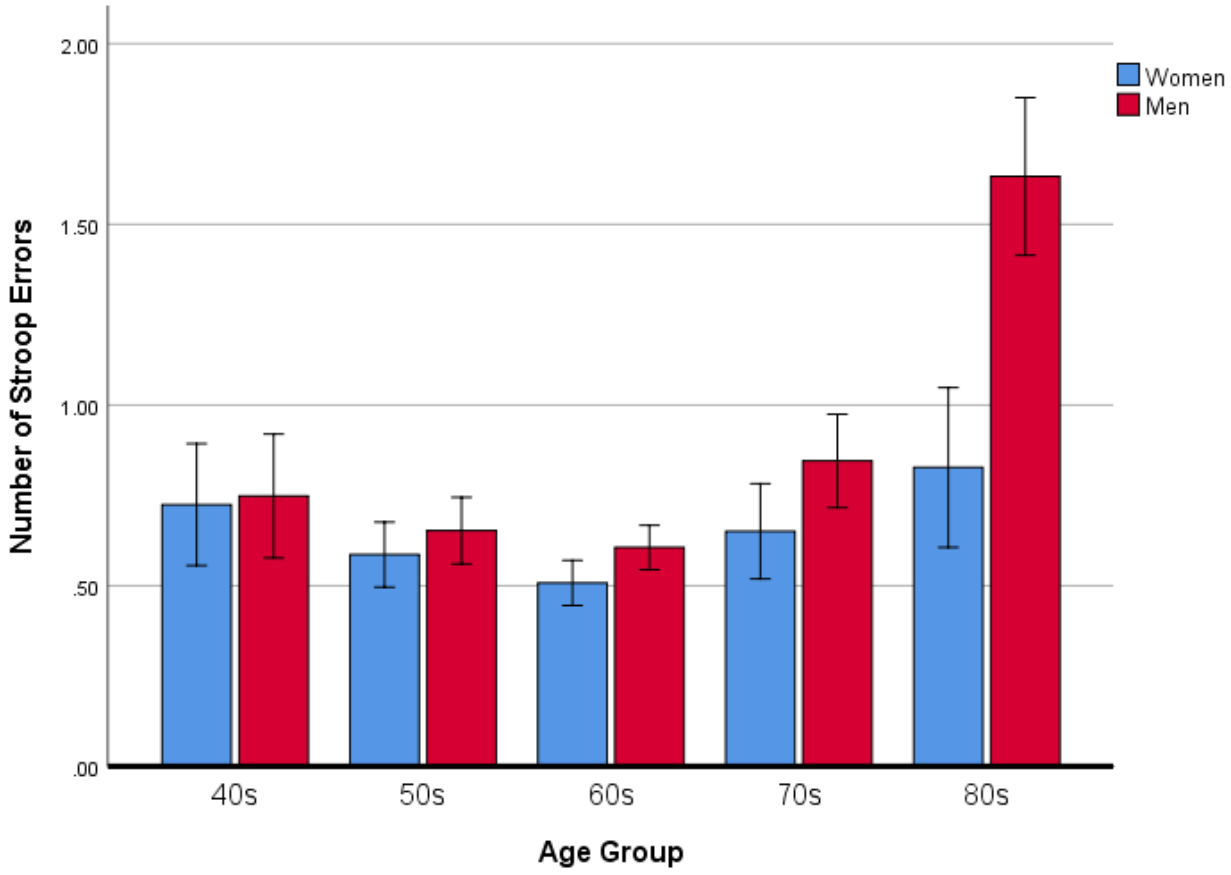
Mean scores for MAT are shown in Appendix E (Table E3) and ANOVA/ANCOVA results are in Table 5. When covariates were included, the effect of age was significant ($p < .001$) and the effect size was small ($\eta_p^2 = .03$). Post-hoc Bonferroni tests showed no differences between age groups for participants in their 40s and 50s, but lower scores were found in older age groups (i.e., adults in their 60s, 70s, and 80s). There was also a main effect of sex ($p < 0.001$) with a very small effect size ($\eta_p^2 = .001$). Men had higher MAT scores than women overall. The age and sex effects are illustrated in Figure 10.

Choice Reaction Time (CRT) Scores.

Mean CRT scores are summarized in Appendix E (Table E4) and ANOVA/ANCOVA results in Table 6. When covariates were included, the effect of age was significant ($p < .001$) and the effect size was moderate ($\eta_p^2 = .067$). Post-hoc Bonferroni tests showed that all age groups differed significantly from one another ($p < 0.001$) such that older age groups had longer reaction times (Figure 11). There was also a main effect of sex ($p < 0.001$) with a very small effect size ($\eta_p^2 = .002$). Men had faster reaction times than women overall ($p < 0.001$). Both the age and sex effects are shown in Figure 11.

Figure 9

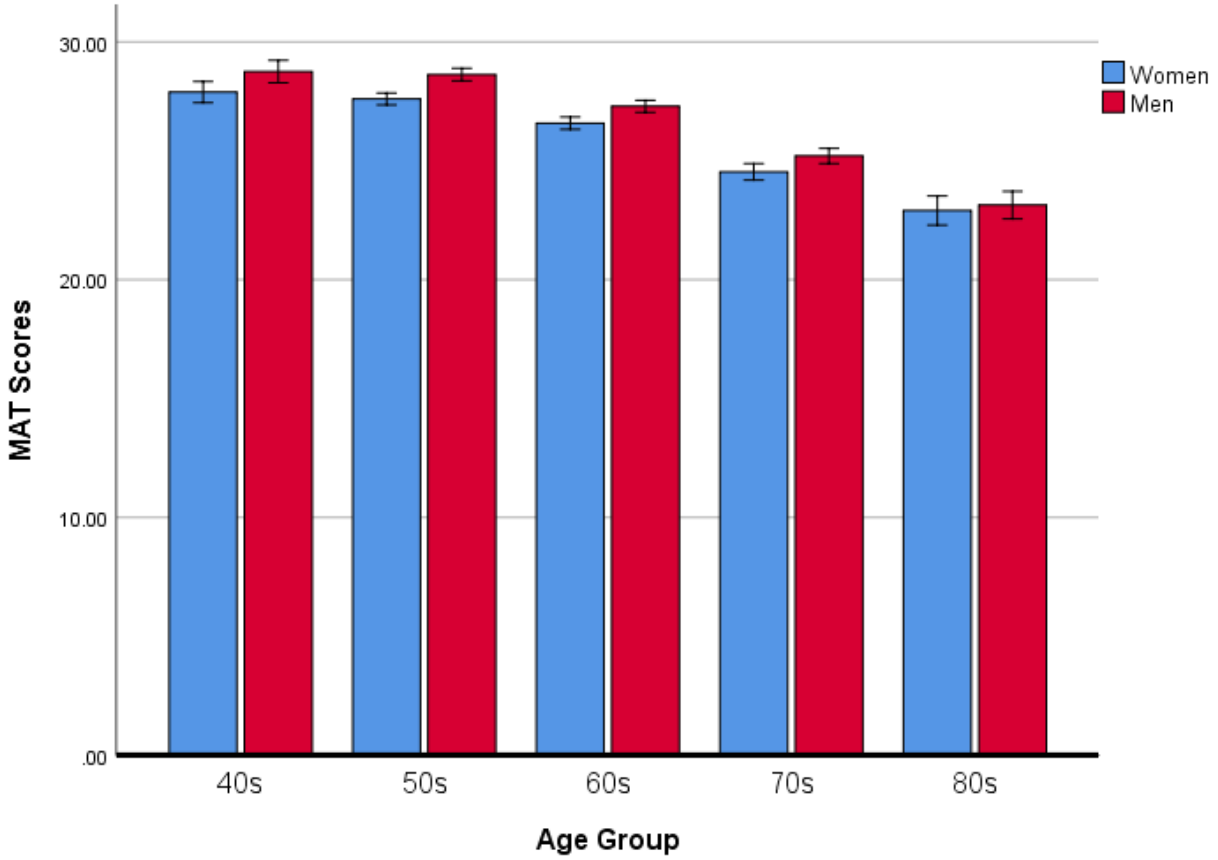
Main Effect of Age and Sex on Stroop Error Scores



Note. There were no differences in Stroop Error scores between adults in their 40s, 50s and 60s, but scores were significantly higher (i.e., worse) with each successive older age group between 60 and 80 ($p < .001$). Women had significantly lower Stroop Error scores than men overall ($p < .001$) and in the 80s decade ($p < .001$). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

Figure 10

Main Effect of Age and Sex on Mental Alternation Test Scores



Note. There were no differences in MAT scores between adults in their 40s and 50s, but scores were significantly lower in each successive older age group ($p < .001$). On average, men performed better on this test than women (i.e., completed a greater number of alternations than women; $p < .001$). Error bars reflect ± 2 SE. Covariates included education, HI, language, and chronic conditions.

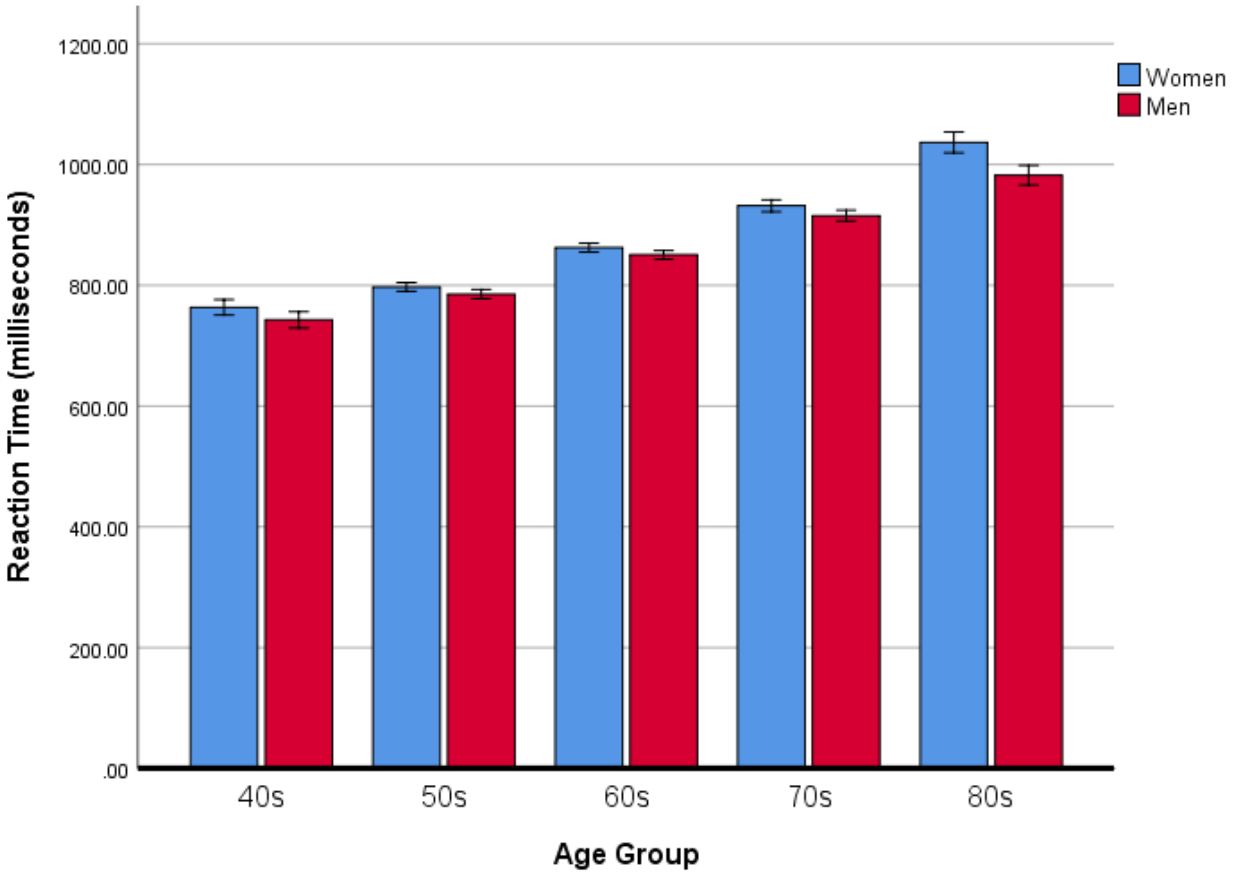
Table 6

ANOVA/ANCOVA Table: Main Effects of Age and Sex on Choice Reaction Time (CRT) Scores

	No covariates				Covariates = education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*P*	η_p^2
Age	715.691	4, 29645	< .001	.088	467.659	4, 26158	< .001	.067
Sex	66.674	1, 29645	< .001	.002	40.564	1, 26158	< .001	.002
Age x Sex	3.246	4, 29645	.011	< .001	3.059	4, 26158	.016	< .001

Figure 11

Main Effects of Age and Sex on Choice Reaction Time (CRT) Scores



Note. CRT scores increased significantly ($p < .001$) between all age groups as age increased (i.e., reaction times were fastest for adults in their 40s and decreased in speed for each successive decade of age). Men had faster reaction times than women ($p < .001$). Error bars reflect ± 2 SE. Covariates include education, HI, language, and chronic conditions.

Part 2: Effects of Alcohol Use on Cognition

Alcohol Use Composites and Global Cognition (Composite Score)

The next series of analyses were ANOVAs and ANCOVAs designed to investigate any main effects of current and past alcohol use (via composite alcohol use scores) on the Global Cognition score without considering the influence of age and sex. Means and SDs for Global Cognition scores by level of the Current Alcohol Use Composite scores are shown in Appendix F (Table F1) and ANOVA/ANCOVA results are found in Table 7. When covariates were included, the main effect of the Current Alcohol Composite was significant ($p < 0.001$) with a small effect size ($\eta_p^2 = .008$). Post-hoc Bonferroni tests show that the lowest two categories of Current Alcohol Use were associated with the lowest Global Cognition scores, while users with mid-to-high alcohol use scores had significantly higher Global Cognition scores but these scores did not differ significantly from one another (Figure 12).

The main effect of Alcohol History Composite scores on Global Cognition scores was also significant ($p < 0.001$) with a small effect size ($\eta_p^2 = .009$). Post-hoc tests show that the lowest alcohol history group had lower cognitive scores than all other groups ($p < .001$) and mid-level alcohol use history scores ($z = 0$ through $z = 2$) were associated with higher cognitive scores than the lower alcohol history groups ($z < 0$), but did not differ from higher-level alcohol use groups ($z > 2$; Figure 13).

Specific Alcohol Use Measures.

Significant main effects of both composite alcohol use measures on Global Cognition were used as justification for additional analyses which examine the relationship of their component measures with Global Cognition test scores. Where main effects of any alcohol measure indicated a significant effect on Global Cognition ($p < 0.001$), follow-up analyses were

Table 7

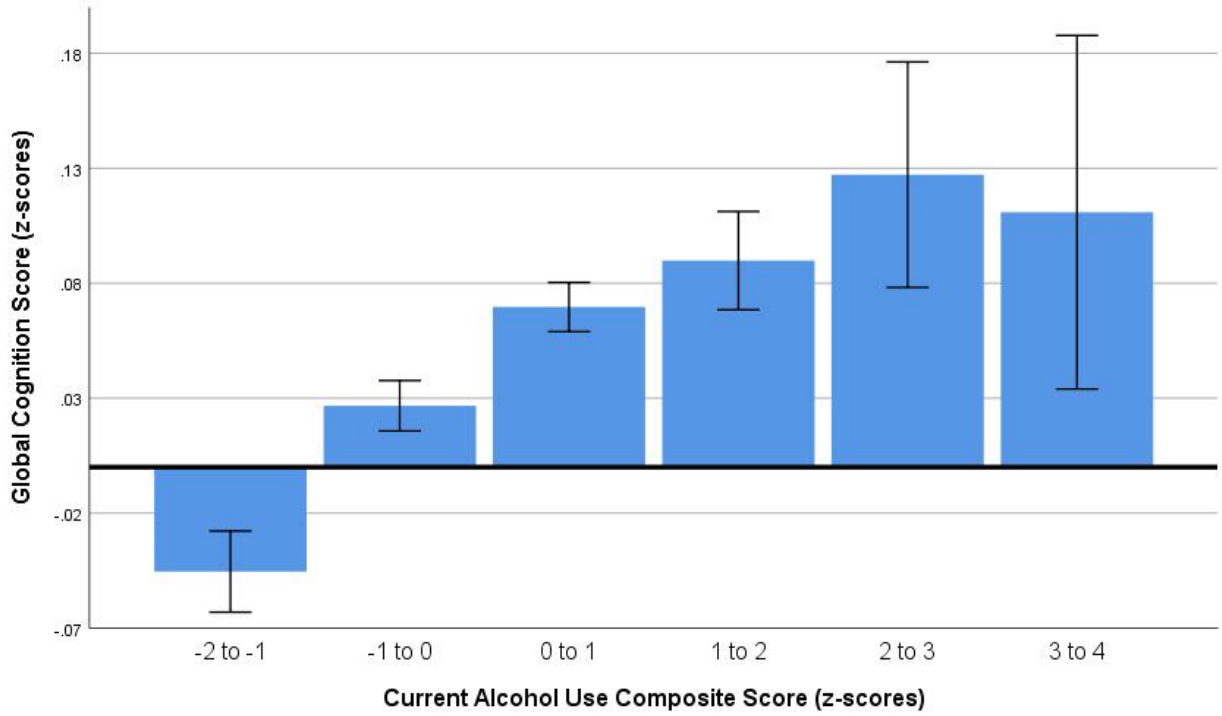
Main Effects of Alcohol Use Composite Scores on Global Cognition

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
Alcohol Use Composite Score	*F*	*Df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Current Alcohol	98.439	5, 23754	< .001	.020	32.036	5, 21129	< .001	.008
Alcohol History	45.558	6, 11360	< .001	.023	15.301	6, 9980	< .001	.009

Notes: The Current Alcohol Composite is a score created from the mean z-scores of the Drinks Per Week, Binge Frequency, and Alcohol Use Frequency variables. The Alcohol History Composite score was created using Alcohol Use History and Binge Drinking History variables.

Figure 12

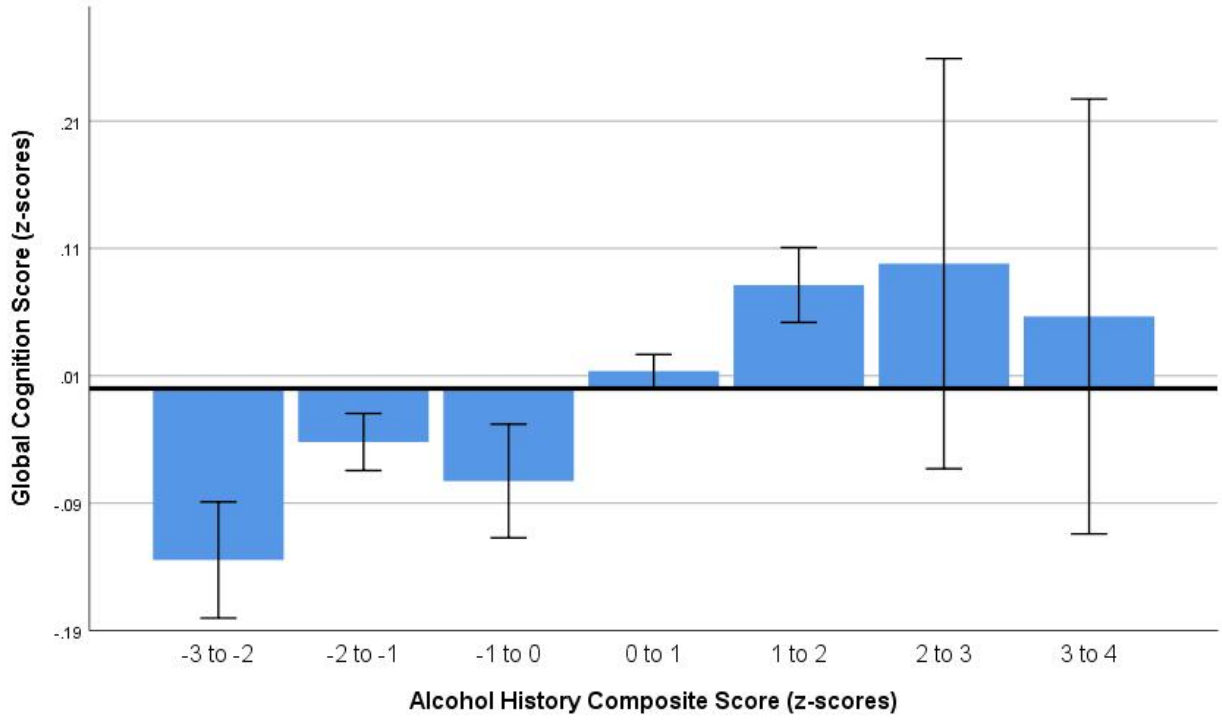
Main Effect of Current Alcohol Use Composite Scores on Global Cognition



Note. The Global Cognition score reflects the average z-scores of all 9 cognitive tests, with higher z-scores indicating better test performance. Mean Global Cognition scores for the two lowest alcohol use groups were significantly lower than all higher alcohol use groups ($p < .001$). The lowest two alcohol use groups also differed significantly from one another ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Figure 13

Main Effect of the Alcohol History Composite Score on Global Cognition



Note. The Global Cognition score reflects the average z-scores across all 9 cognitive tests, with higher z-scores indicating better test performance. Mean Global Cognition scores for the lowest three alcohol use groups were significantly lower than all higher alcohol use groups ($p < .001$). The lowest two alcohol use groups also differed significantly from one another ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

conducted between that alcohol use measure and each individual cognitive test score. Regardless of whether an alcohol use measure showed a significant main effect on an individual cognitive test score, a final set of tests were conducted to detect potential interactions between alcohol, age, and sex. This analysis procedure is reviewed in Appendix C.

Drinks Per Week.

Drinks Per Week and Global Cognition.

Mean Global Cognition scores as a function of Drinks Per Week are shown in Appendix F (Table F2) and ANOVA/ANCOVA results are found in Table 8. When covariates were included, the effect of the Drinks Per Week variable was significant ($p < .001$) with a small effect size ($\eta_p^2 = .009$). Post-hoc tests reveal that never-drinkers had lower cognitive scores than all other groups except for the very high group (all $p < 0.001$). Twelve-month abstainers had higher scores than never-drinkers ($p < 0.001$) but lower scores than all other groups except for the very high group (all $p < 0.001$). No significant differences were observed between groups who consume alcohol at any level. However, there was a non-significant trend towards higher levels of alcohol use being associated with higher Global Cognition scores up to the high level of alcohol consumption (Figure 14).

The number of drinks consumed weekly (Drinks Per Week) showed significant main effects (with very small effect sizes) on each cognitive test scores included in the CLSA dataset except for Choice Reaction Time (see Table 9). The relationship between the Drinks Per Week variable and each of these tests is explained in more detail below.

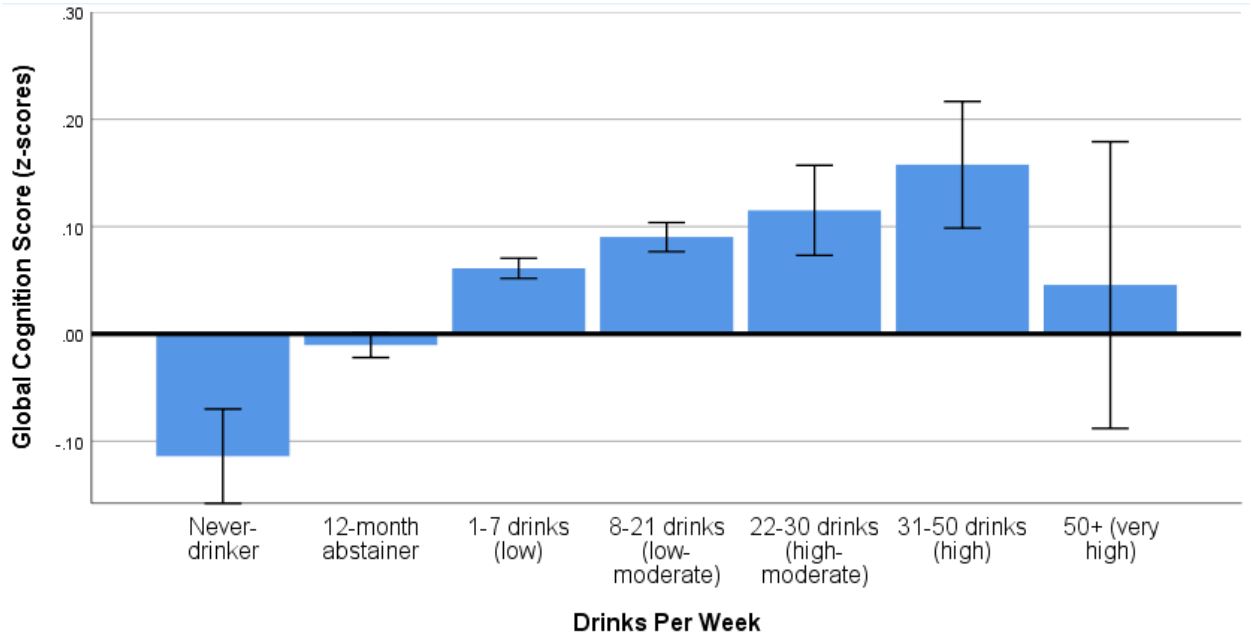
Table 8

ANOVA/ANCOVA Table: Main Effects of Specific Alcohol Use Variables on Global Cognition

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*P*	η_p^2	*F*	*df*	*p*	η_p^2
Drinks Per Week	82.280	6, 26342	< .001	.018	36.216	6, 23439	< .001	.009
Alcohol Use Frequency	125.220	5, 26487	< .001	0.023	53.526	5, 23554	< .001	.011
Binge Frequency	148.872	6, 23816	< .001	.036	24.992	5, 21174	< .001	.007
Alcohol History	46.394	5, 13363	< .001	.017	18.595	5, 11794	< .001	.008
Binge History	100.195	4, 17453	< .001	.022	24.159	4, 15332	< .001	.006
Alcohol Type	18.400	3, 7517	< .001	.007	5.954	3, 6734	< .001	.003

Figure 14

Main Effect of the Number of Drinks Consumed Weekly on Global Cognition



Note. Mean Global Cognition scores differ significantly as a function of Drinks Per Week. Non-drinkers (both never-drinkers and 12-month abstainers) had lower cognitive scores than groups who consumed alcohol at any level, except for the *very high* level of drinking (50 or more drinks per week; all $p < .001$). Never-drinkers also had lower scores than 12-month abstainers ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, education, HI, language, and number of chronic conditions.

Table 9

ANOVA/ANCOVA Table: Effect of Drinks Per Week on Each Cognitive Test Score

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	26.440	6, 28883	< .001	.005	11.215	6, 25552	< .001	.003
REY II	16.507	6, 28854	< .001	.003	7.389	6, 25531	< .001	.002
PMT	26.584	6, 29644	< .001	.005	10.793	6, 26165	< .001	.002
AFT	69.138	6, 29167	< .001	.014	17.780	6, 25779	< .001	.004
COWA	54.716	6, 28833	< .001	.011	27.388	6, 25464	< .001	.006
Stroop Time	60.567	6, 29483	< .001	.012	19.841	6, 26023	< .001	.005
Stroop Errors	29.637	6, 29349	< .001	.006	7.928	6, 25915	< .001	.002
MAT	59.182	6, 28422	< .001	.012	10.056	6, 25188	< .001	.002
CRT	15.645	6, 29453	< .001	.003	3.187	6, 26005	.004	.001

Note: Test scores include the Rey Auditory Verbal Learning Test immediate and delayed recall trials (REYI/REYII), Prospective Memory Test (PMT), Animal Fluency Task (AFT), Controlled Oral Word Association Test (COWA), Stroop Time and Error Scores, Mental Alternation Test (MAT) and Choice Reaction Time (CRT) scores.

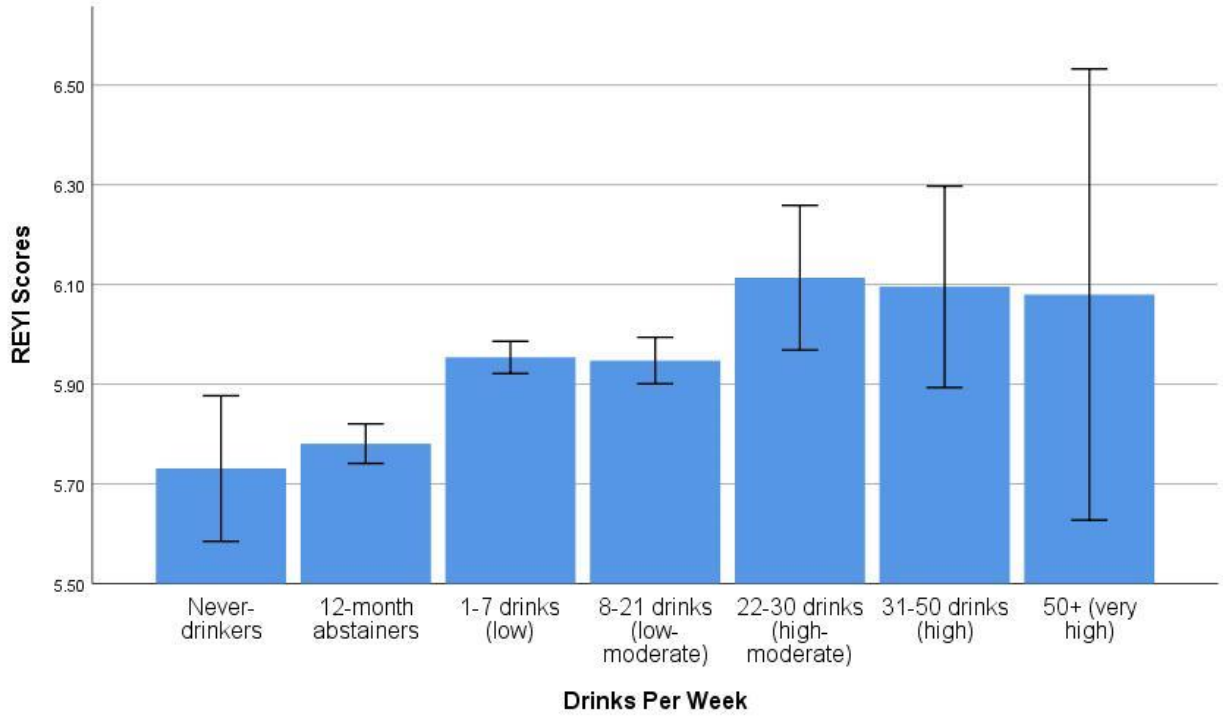
Drinks Per Week and REYI.

Mean REYI scores as a function of Drinks Per Week are shown in Appendix G (Table G1) and ANOVA/ANCOVA results are found in Table 9. There was a significant main effect ($p < .001$) with a small effect size ($\eta_p^2 = .003$). Post-hoc tests show that 12-month abstainers had lower scores than low, low-moderate, and high-moderate drinkers ($p < .001$). There were no significant differences between alcohol groups at higher consumption levels and no significant differences between never-drinkers and 12-month abstainers (Figure 15).

Because the results suggested that alcohol use may be associated with improved REYI test scores, follow-up tests were conducted with additional covariates to explore possible explanations for the findings. These included a measure of physical function derived from physical tests conducted at the data collection site, a social measure based on self-reports of social interaction and community engagement, and the personality factors of openness, conscientiousness, extraversion, agreeableness, and emotional stability as assessed by the TIPI personality test. The follow-up results showing relationships between Drinks Per Week and all cognitive tests with these additional covariates are shown in Appendix H. With these additional covariates, the relationship between Drinks Per Week and REYI scores approached (but did not reach) significance, $F(6,11136) = 2.956$, $p = .007$ ($\eta_p^2 = .002$). Of the new covariates in this ANCOVA, those which produced a significant effect ($p < .001$) on REYI scores were the social engagement ($\eta_p^2 = .002$) and physical function ($\eta_p^2 = .008$). The F-statistics and effect sizes for these covariates on all cognitive test scores *without* the influence of any alcohol use variables are reported in Appendix I (Table I1). Analyses showing the effects of alcohol use variables while controlling for the follow-up covariates for each cognitive test score are not shown for brevity.

Figure 15

Effect of Drinks Per Week on Immediate Verbal Memory Test Scores



Note. Mean scores for the Rey Auditory Verbal Learning Test immediate recall trial (REYI) differ significantly as a function of Drinks Per Week. Twelve-month abstainers did not differ from never-drinkers, but both groups had lower scores than low, low-moderate, and high-moderate drinkers (all $p < .001$). There were no significant differences in REYI scores between any of the current alcohol-using groups (i.e., low to very high number of drinks per week). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

To investigate whether the effect of Drinks Per Week on REYI scores changes as a factor of age or sex, ANOVAs/ANCOVAs were done to explore interaction terms. Based on their previous significant effect on REYI scores, the covariates of physical function and social engagement were included in this analysis. Additionally, we used a modified version of the age variable (combining adults in their 70s and 80s) and the Drinks Per Week variable (combining high and very high levels of drinkers) to retain a sufficient N for group comparisons. These additional covariates and modified variables were used in all further analyses requiring group classification by age or sex.

There was a significant interaction between Drinks Per Week (DPW) and sex ($p < .001$) with a small very effect size ($\eta_p^2 = .001$). Therefore, further ANOVAs/ANCOVAs were conducted as a factor of sex (Table 10). There were no sex differences in REYI scores for never-drinkers ($p = .018$) but sex differences were evident at every other level of alcohol use such that women had higher scores than men ($p \leq .001$; Figure 16). Neither men nor women showed any statistically significant differences ($p < .001$) in REYI scores by level of Drinks Per Week. However, women showed a non-significant trend towards higher levels of alcohol consumption associating with higher REYI scores (Figure 16).

There was also a significant DPW x Age x Sex interaction for REYI scores ($p < .001$) with a very small effect size ($\eta_p^2 = .003$). Based on these results, further ANOVAs/ANCOVAs explored the relationship between Drinks Per Week and REYI as a function of both age and sex (Table 10). The results of these ANCOVAs did not indicate a significant main effect of Drinks Per Week on REYI scores for any age/sex group. Figure 17 reflects the three-way interaction. Post-hoc tests showed that women in their 70s who are non-drinkers or low-level drinkers performed worse on the immediate recall trial than all younger women ($p < .001$), but with

Table 10

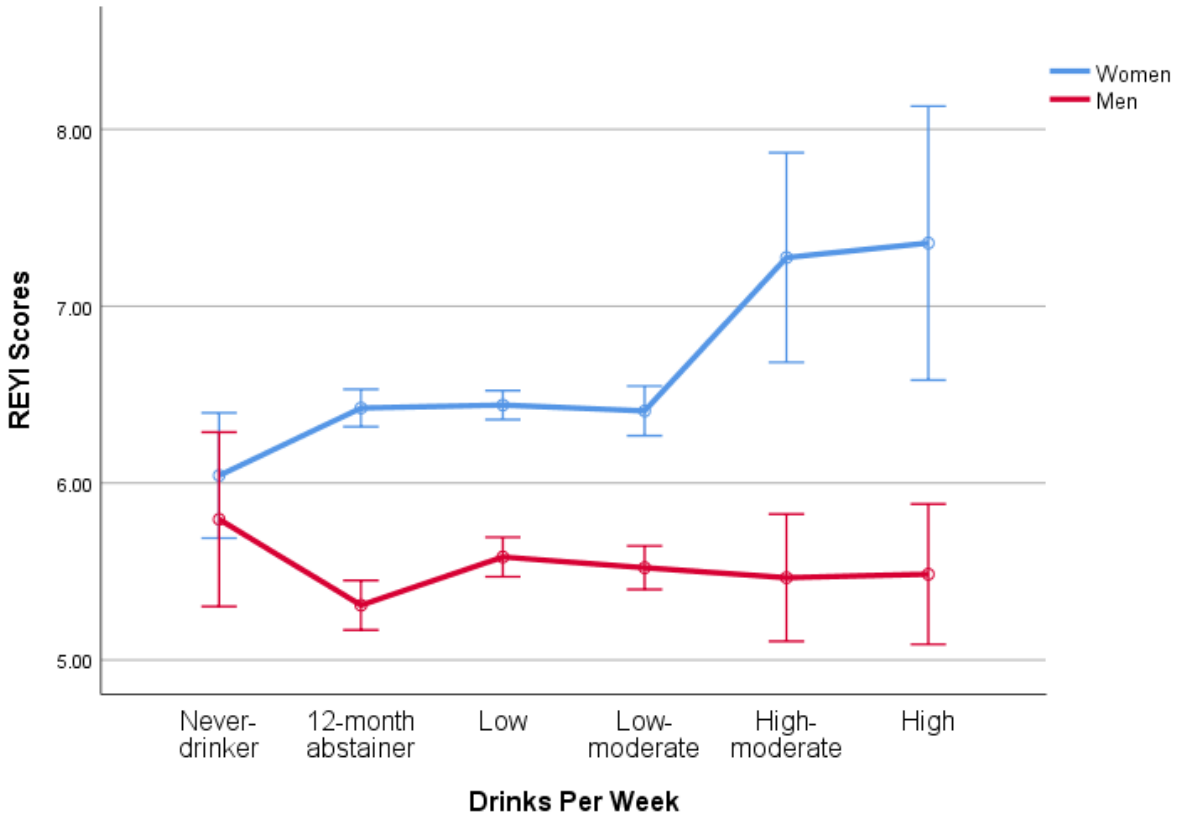
ANOVA/ANCOVA Table: REYI Scores Are Influenced by Interactions Between Age, Sex, and Drinks Per Week (DPW)

		No covariates				Covariates = education, HI, language, physical function, social composite			
	DPW	*F*	*df*	*p*	η_p^2	*F*	*df*	*P*	η_p^2
	Drinks Per Week (DPW)	31.409	5, 28842	< .001	.005	3.248	5, 12406	.006	.001
	DPW x Age	2.003	15, 28842	.012	.001	.936	15, 12406	.523	.001
	DPW x Sex	1.750	5, 28842	.119	.000	4.431	5, 12406	< .001	.002
	DPW x Age x Sex	1.920	15, 28842	.017	.001	2.865	14, 12406	< .001	.003
	DPW (by sex)	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
	Women	31.926	5, 13698	< .001	.011	1.958	5, 6238	.082	.002
	Men	22.860	5, 14184	< .001	.008	4.220	5, 6196	.001	.003
	DPW (by age and sex)	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
40s	Women	2.395	5, 1434	.036	.008	3.019	5, 308	.018	.038
	Men	2.442	5, 1313	.033	.009	.781	5, 192	.564	.020
50s	Women	6.691	5, 4743	< .001	.007	1.559	5, 2035	.157	.004
	Men	5.889	5, 4314	< .001	.007	2.153	5, 1670	.057	.006
60s	Women	6.882	5, 4584	< .001	.007	.872	5, 2308	.499	.002
	Men	8.617	5, 4560	< .001	.009	2.937	5, 2355	.012	.006
70s	Women	9.936	5, 3915	< .001	.013	2.717	5, 1560	.019	.009
	Men	11.543	5, 3979	< .001	.014	2.129	5, 1947	.059	.005

Note. Covariates for all analyses included education, HI, language, social engagement, and physical function. For the DPW by sex interaction, age was added as a covariate.

Figure 16

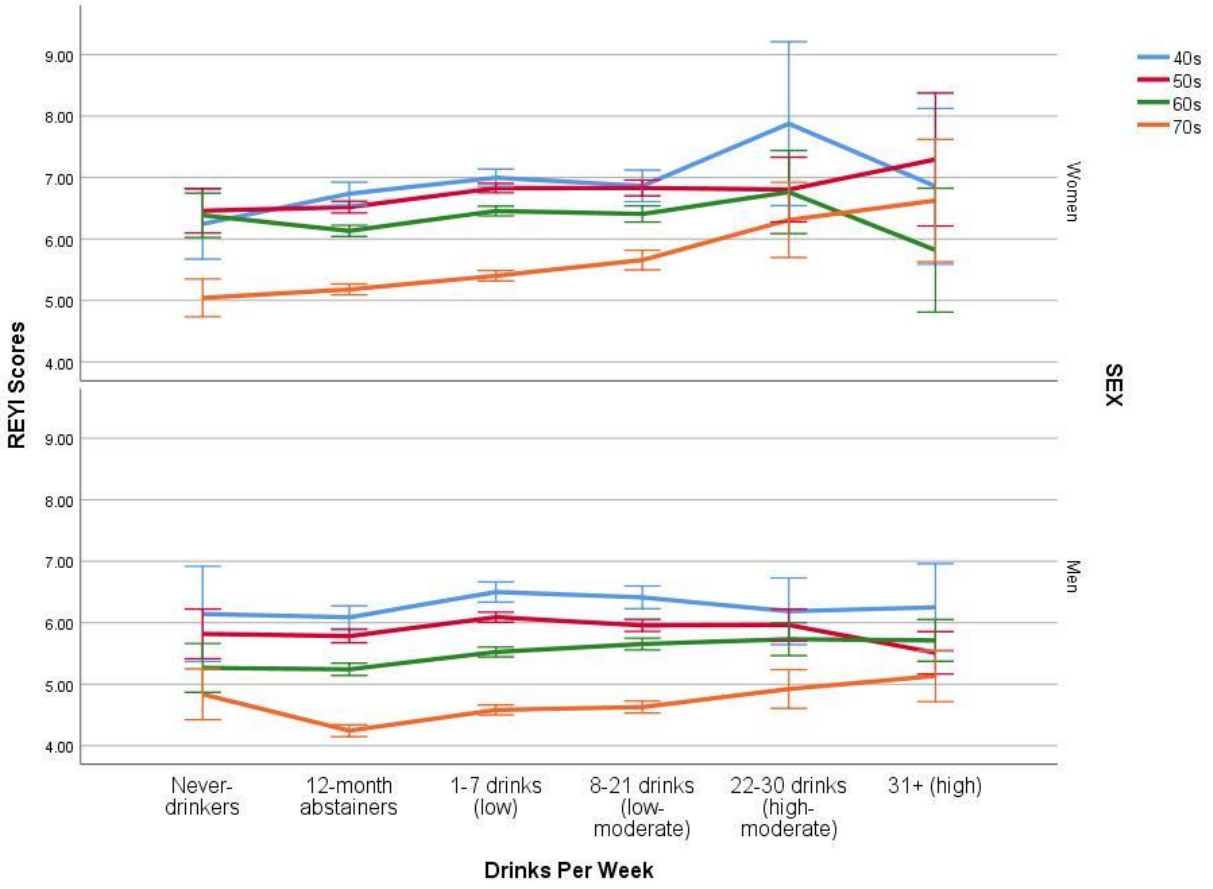
2-way Interaction between Sex and Drinks Per Week for Immediate Verbal Memory



Note. Rey Auditory Verbal Learning Test immediate recall scores (REYI) showed a significant Drinks Per week x Sex interaction. Never-drinkers showed no sex difference in REYI scores, but women outperformed men at every other level of alcohol use ($p < .001$). Women trended towards higher cognitive test scores with higher levels of alcohol use, which was not statistically significant. Covariates included education, HI, language, social engagement, and physical function. Error bars reflect ± 2 SE.

Figure 17

3-way Interaction Between Age, Sex, and Drinks Per Week for Immediate Verbal Memory



Note. The 3-way interaction seems to reflect that women in their 70s who drink low-moderate amounts of alcohol (8 to 21 drinks) or less performed worse on average than younger age groups on the test, but women in their 70s who drink higher levels of alcohol tended to perform equivalently on the REYI to the younger age groups ($p < .001$). Men in their 70s who are 12-month abstainers, low-level, or low-moderate drinkers perform worse than younger men ($p < .001$). Covariates included education, HI, language, social engagement, and physical function. Error bars reflect SE ± 2.

higher levels of alcohol consumption their performance was comparable to younger age groups. Men in their 70s performed worse than younger men among 12-month abstainers, low, and low-moderate drinkers ($p < .001$) but not at higher levels of drinking. Among low-level drinkers only, men in their 60s also performed worse than younger men.

Sex differences also varied as a function of age and Drinks Per Week. Among 12-month abstainers, low-level and low-moderate drinkers, women outperformed men at every age. Among high-moderate drinkers, women only outperformed men in the 40s age category. Among high-level drinkers, women only outperformed men within the 50s age group (Appendix K1).

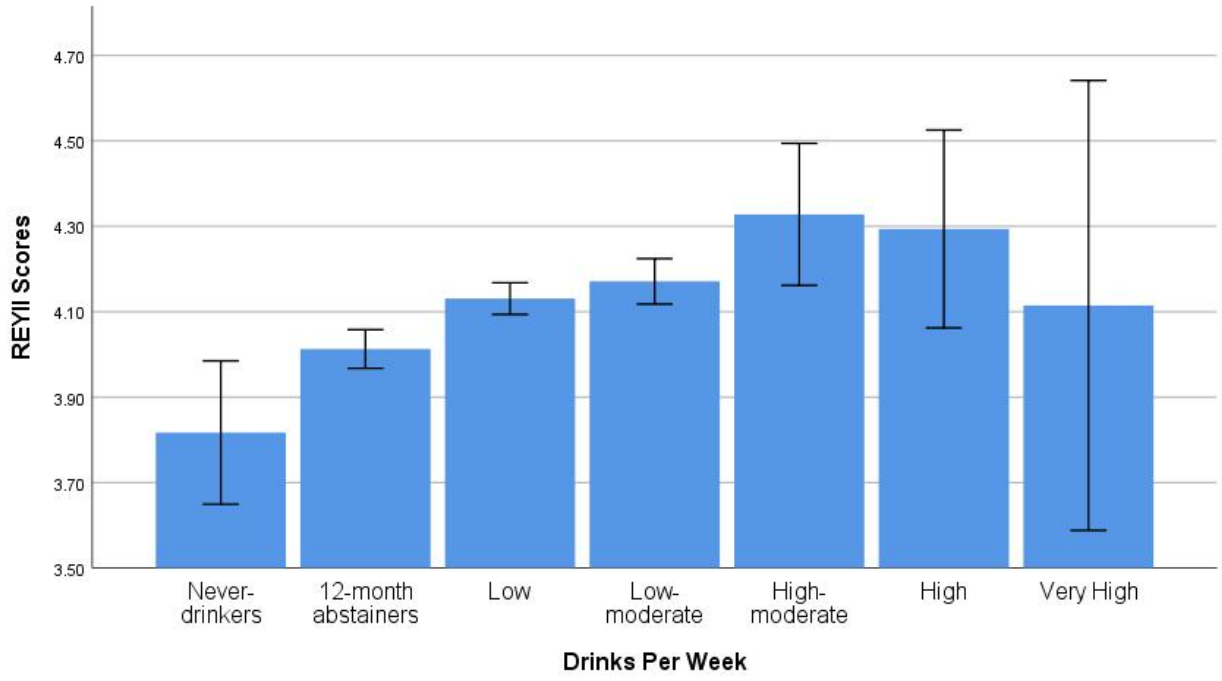
Drinks Per Week and REYII.

Mean REYI scores as a function of Drinks Per Week are shown in Appendix G (Table G1). There was a significant main effect of Drinks Per Week on REYII scores with a very small effect size ($p < .001$; $\eta_p^2 = .002$). Post-hoc tests showed that never-drinkers and 12-month abstainers had lower mean REYII scores than low, low-moderate, and high-moderate consumers of alcohol based on the Drinks Per Week variable ($p < .001$ to $p = .006$). There were no significant differences in REYII scores between alcohol groups at higher consumption levels (Figure 18).

Because alcohol use was associated with improved REYII test scores, follow-up tests were conducted with additional covariates to explore other potential explanatory factors. With the additional covariates, the main effect of Drinks Per Week on REYII scores approached significance, $F(6,1111) = 3.024$, $p = .006$ ($\eta_p^2 = .002$; Table H1). In addition, the covariate measures of physical function, social function, conscientiousness, openness, agreeableness, and emotional stability each showed main effects on REY II scores. The strongest effect size was

Figure 18

Effect of Drinks Per Week on Delayed Verbal Memory Scores



Note. Mean scores for the Rey Auditory Verbal Learning Test delayed trial (REYII) differed significantly as a function of Drinks Per Week. Never-drinkers and 12-month abstainers had lower scores than low, low-moderate, and high-moderate drinkers (p = .001 to p = .006). There were no differences between consumers of alcohol at any level (i.e., low to very high drinks per week). Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

associated with physical function (η_p^2 = .031). F-statistics for these covariates *without* alcohol use variables included are shown in Appendix I.

To investigate whether the effect of Drinks Per Week on REYII scores changed as a function of age or sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 11. A 3-way interaction between Drinks Per Week, age, and sex approached (but did not reach) significance, $F(14, 12387) = 2.118$, $p = .009$ ($\eta_p^2 = .002$).

Drinks Per Week and Prospective Memory.

Mean scores as a function of Drinks Per Week are shown in Appendix G (Table G1). There was a significant main effect of Drinks Per Week on Prospective Memory (PMT) scores ($p < .001$; $\eta_p^2 = .002$; Table 9). Post-hoc tests showed that never-drinkers had lower PMT scores than all groups except those drinking a very-high number of drinks per week ($p < .001$), and 12-month abstainers had lower PMT scores than low-moderate drinkers ($p < .001$). There were no differences in mean PMT scores between any other levels of alcohol use (see Figure 19).

Because it appears that alcohol use is associated with improved PMT test scores, follow-up tests were conducted. After controlling for the additional covariates, the main effect of Drinks Per Week on PMT scores was no longer significant, $F(6,11433) = 1.707$, $p = .115$ ($\eta_p^2 = .001$; Table H1). Several of the covariates (including social function, physical function, conscientiousness, and emotional stability) had a significant effect on PMT test scores (see Appendix I for covariate effects without the inclusion of alcohol use variables).

To investigate whether the effect of Drinks Per Week on PMT changed as a factor of age or sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 12. When the covariates were included, no relationship was found between Drinks Per Week, age, and sex. Therefore, further examination of these interactions was not pursued.

Table 11

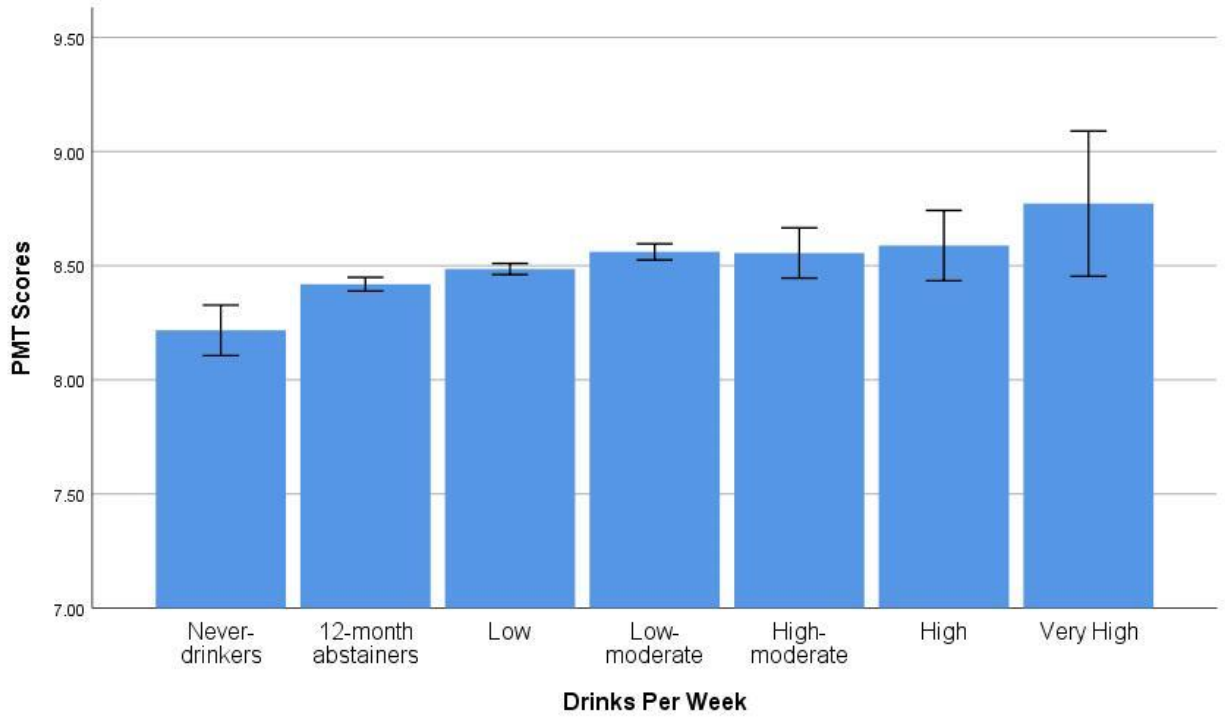
ANOVA/ANCOVA Tables: Interactions Between Age, Sex, and Drinks Per Week

		No covariates				Covariates = education, HI, language, physical function, social composite			
	DPW	*F*	*df*	*p*	η_p^2	*F*	*df*	*P*	η_p^2
	Drinks Per Week (DPW)	19.281	5, 28813	< .001	.003	2.659	5, 12387	.021	.001
	DPW x Age	2.315	15, 28813	.003	.001	1.649	15, 12387	.054	.002
	DPW x Sex	1.762	5, 28813	.117	.000	2.536	5, 12387	.144	.000
	DPW x Age x Sex	1.949	15, 28813	.015	.001	2.118	14, 12387	.009	.002
	DPW (by age and sex)	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
40s	Women	.738	5, 1437	.595	.003	2.038	5, 309	.089	.026
	Men	1.768	5, 1324	.116	.007	.655	5, 194	.017	.017
50s	Women	8.099	6, 4747	< .001	.008	2.230	5, 2039	.049	.005
	Men	5.324	5, 4311	< .001	.006	1.965	5, 1666	.081	.006
60s	Women	4.235	5, 4584	.001	.005	1.502	5, 2298	.196	.003
	Men	5.349	5, 4563	< .001	.006	3.303	5, 2362	.006	.007
70s	Women	8.352	5, 3902	< .001	.011	2.180	5, 1558	.064	.007
	Men	7.821	5, 3945	< .001	.010	1.842	5, 1926	.102	.005

Note. Covariates for all analyses include education, HI, language, social engagement, and physical function.

Figure 19

Main Effect of Drinks Per Week on Prospective Memory Test (PMT) Scores



Note. Mean PMT scores differed significantly as a factor of Drinks Per Week. Never-drinkers had lower scores than all other groups except for the very-high group ($p < .001$). There were no differences in PMT scores between consumers of alcohol at any level. Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Table 12

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Drinks Per Week on PMT, AFT, and COWA Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
PMT	Drinks Per Week (DPW)	16.166	5, 29603	< .001	.003	.708	5, 12754	.617	.000
	DPW x Age	2.863	15, 29603	< .001	.001	.943	15, 12754	.514	.001
	DPW x Sex	.946	5, 29603	.450	.000	.098	5, 12754	.992	.000
	DPW x Age x Sex	.925	15, 29603	.535	.000	.574	14, 12754	.886	.001
AFT	Drinks Per Week (DPW)	50.401	5, 29126	< .001	.009	3.792	5, 12515	.002	.002
	DPW x Age	2.270	15, 29126	.003	.001	.425	15, 12515	.973	.001
	DPW x Sex	1.609	5, 29126	.154	.000	.509	5, 12515	.770	.000
	DPW x Age x Sex	.829	15, 29126	.646	.000	.556	14, 12515	.900	.001
COWA	Drinks Per Week (DPW)	53.435	5, 28785	< .001	.009	8.171	5, 12419	< .001	.003
	DPW x Age	1.527	15, 28785	.086	.001	.587	15, 12419	.888	.001
	DPW x Sex	.456	5, 28785	.809	.000	.575	5, 12419	.719	.000
	DPW x Age x Sex	.902	15, 28785	.562	.000	.689	14, 12419	.787	.001

Note: PMT = Prospective Memory Test, AFT = Animal Fluency Test, COWA = Controlled Oral Word Association test.

Drinks Per Week and Semantic Fluency (Animal Fluency Test).

Mean scores for AFT as a function of Drinks Per Week are shown in Appendix G (Table G4). There was a significant main effect of Drinks Per Week on the AFT scores ($p < .001$; $\eta_p^2 = .004$; Table 9). Post-hoc tests showed that never-drinkers had lower AFT scores than all groups except for the Very High level drinkers ($p < .001$) and 12-month abstainers had lower scores than Low, Low-Moderate, and High-Moderate groups ($p < .001$ to $p = .008$). There were no differences between mean AFT scores for any of the alcohol consuming groups (low to very high drinks per week; Figure 20).

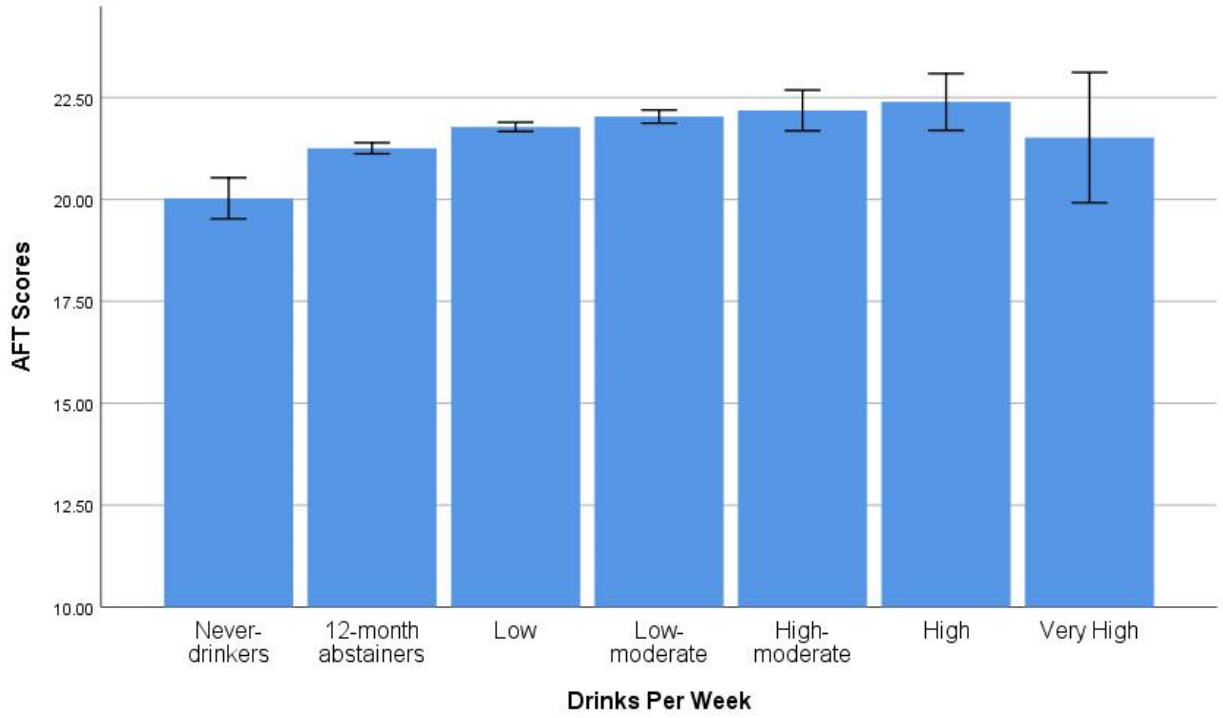
Given that alcohol use was associated with improved AFT test scores, follow-up tests were conducted with additional covariates. After controlling for these extra covariates, the main effect of Drinks Per Week on AFT scores remained significant, $F(6,11232) = 4.697$, $p < .001$ ($\eta_p^2 = .002$; Table H1). Several of the added covariates (including physical functioning, conscientiousness, openness, and emotional stability) showed a significant effect on AFT test scores (Appendix I2). The effect size was largest for physical functioning ($\eta_p^2 = .093$). To investigate whether the effect of Drinks Per Week on AFT changed as a function of age or sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 12. When covariates were included, no interactions were seen between Drinks Per Week, Age, and Sex on AFT. Therefore, further examination of these interactions was not pursued.

Drinks Per Week and Phonemic Fluency (Controlled Oral Word Association).

Mean COWA scores as a function of Drinks Per Week are shown in Appendix G (Table G1). There was a significant main effect of Drinks Per Week on COWA scores when covariates were included ($p < .001$; $\eta_p^2 = .006$; Table 9). Post-hoc Bonferroni tests show that never-drinkers

Figure 20

Main Effect of Drinks Per Week on Animal Fluency Test Scores



Note. Mean Animal Fluency Test (AFT) scores differed significantly as a function of Drinks Per Week. Never-drinkers had lower scores than all groups except for the Very High drinkers ($p < .001$); 12-month abstainers had lower scores than Low, Low-Moderate, and High-Moderate groups ($p = .001$ to $p = .008$). There were no differences in AFT scores between consumers of alcohol at any level. Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

had significantly lower test scores than participants in the low-moderate, high-moderate, and high categories ($p < .001$). Twelve-month abstainers had lower scores than individuals in all higher categories apart from the Very High group (all $p < .001$). Low-level drinkers had lower mean scores than those in the low-moderate *(*$p < .001$) and high ($p = .001$) groups. There were no significant differences among the other alcohol consumption categories (Figure 21).

Because alcohol use was associated with improved COWA test scores, follow-up tests were conducted with the additional covariates. After controlling for these extra covariates, the main effect of Drinks Per Week on COWA scores remained significant, $F(6,11144) = 14.216$, $p < .001$ ($\eta_p^2 = .008$; Table H1). While this effect was small, this effect for COWA was the largest effect of all the individual cognitive tests examined. Several of the added covariates (including social function, physical function, extraversion, and conscientiousness) also showed a significant effect on COWA test scores (Appendix I2).

To investigate whether the effects of Drinks Per Week on COWA changed as a factor of age or sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 12. When covariates were included, none of the interaction terms were significant, and further analyses were not conducted.

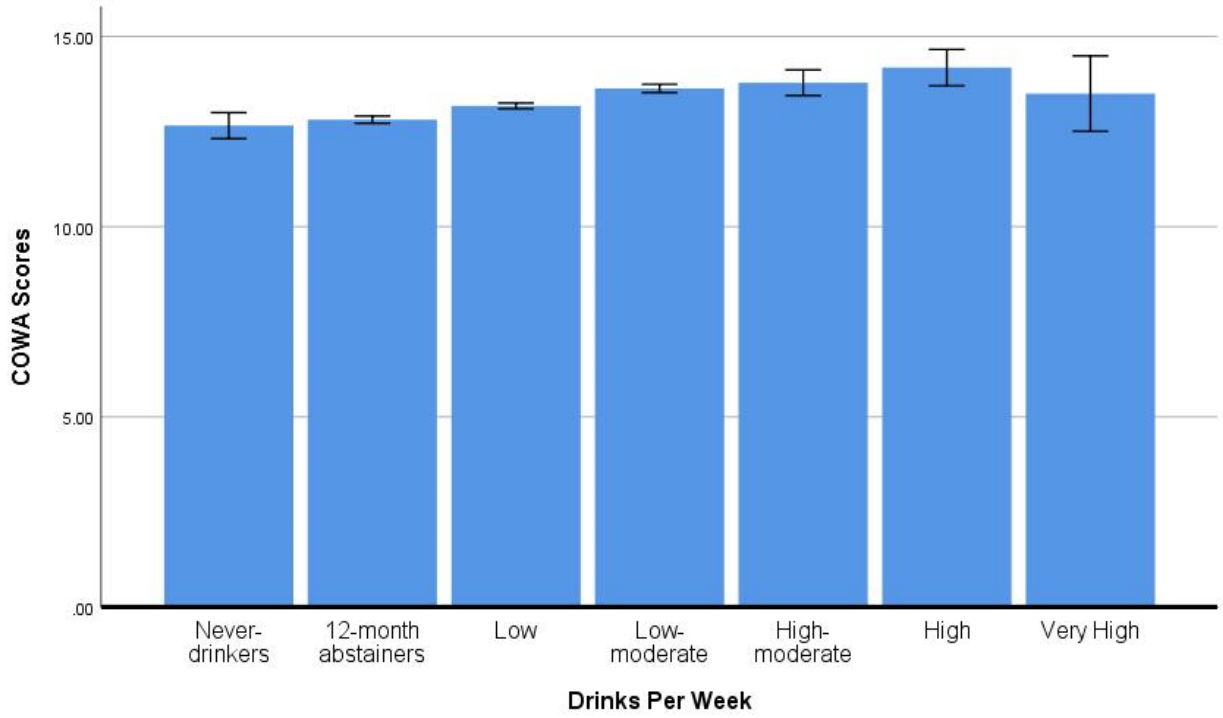
Drinks Per Week and Stroop Scores.

Mean scores for Stroop Time and Stroop Error as a function of Drinks Per Week are shown in Appendix G. There was a significant main effect of Drinks Per Week on the Stroop time scores ($p < .001$; $\eta_p^2 = .005$) and Stroop Error scores ($p < .001$; $\eta_p^2 = .002$) when covariates were included (see Table 9).

For the Stroop Time scores, post-hoc Bonferroni tests showed no significant difference between never-drinkers and 12-month abstainers. However, never-drinkers took more time to

Figure 21

Main Effect of Drinks Per Week on COWA Scores



Note. Mean Controlled Oral Word Association (COWA) scores differed significantly as a function of Drinks Per Week. 12-month abstainers had lower scores than Low, Low-Moderate, and High-Moderate groups (p = .001 to p = .008). There were no differences among consumers of alcohol at any level. Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

complete the task compared to the low, low-moderate, high-moderate groups ($p < .001$) and approached significance for high-level drinkers ($p = .003$). Twelve-month abstainers had higher (i.e., slower) time scores than low ($p < .001$), low-moderate ($p < .001$), and high-moderate groups ($p = .001$). There were no group differences between drinkers of any level of alcohol use (i.e., low to very-high; Figure 22).

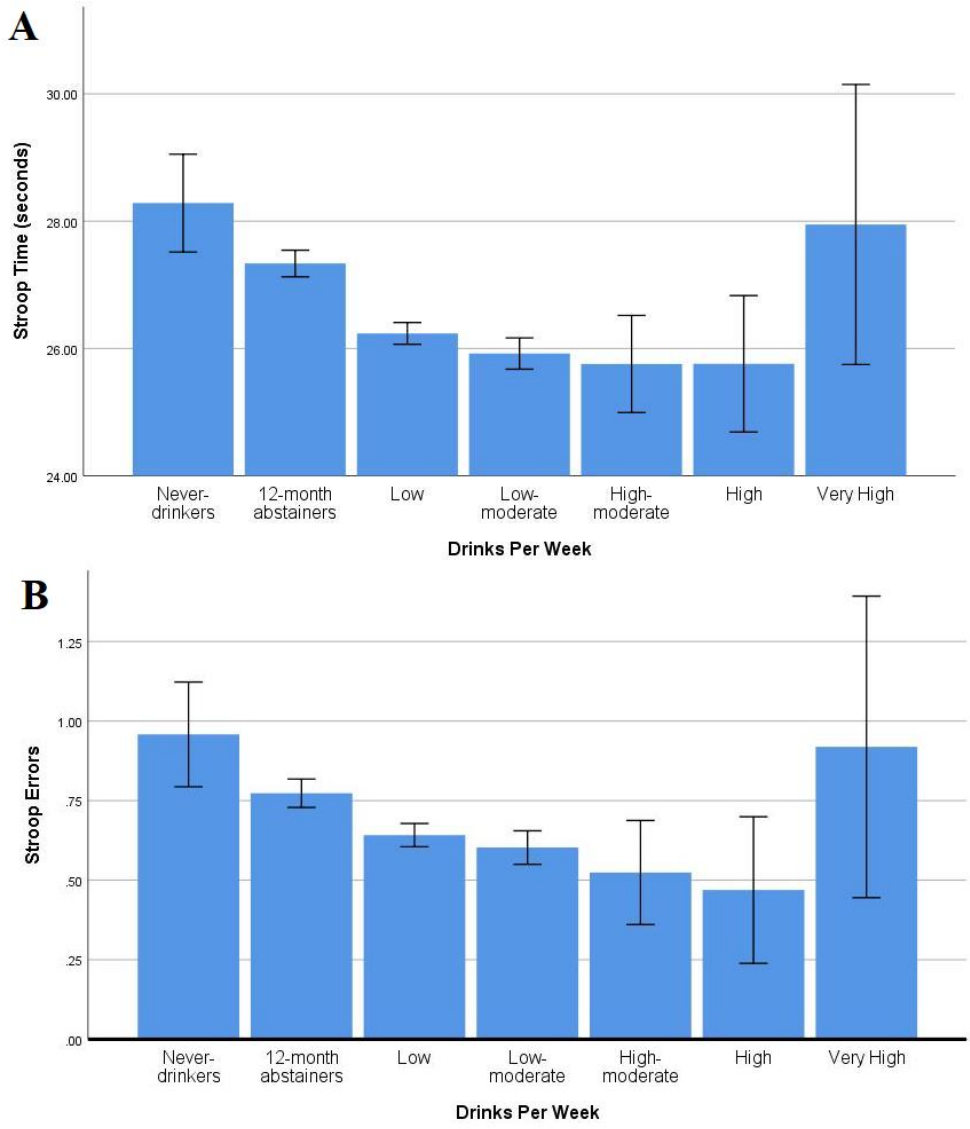
For Stroop Errors, post-hoc tests also indicated no significant difference between non-drinkers. Never-drinkers reported more errors than low-moderate ($p = .001$) drinkers, and 12-month abstainers had more errors than the low and low- moderate groups ($p < .001$). There were no significant differences between other drinker levels. Mean Stroop Error scores for each group are shown in Figure 22.

Because alcohol use was associated with improved Stroop performance, follow-up tests were conducted with additional covariates. The main effect of Drinks Per Week on Stroop Time scores remained significant, $F(6,11390) = 11.516$, $p < .001$ ($\eta_p^2 = .006$; see Table H1) but the effect on Stroop Errors was not, $F(6,11349) = 2.224$, $p = .036$ ($\eta_p^2 = .001$). All covariates were significantly associated with Stroop Time. Physical function had the largest effects on both Stroop Time and Stroop Error scores, and openness was also associated with Stroop Time (see Appendix I; Table I3)

To investigate whether the effect of Drinks Per Week on Stroop scores changed as a function of age, sex, or age X sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 13. When covariates were included, none of the interaction terms were significant, and further analyses were not conducted.

Figure 22

Main Effects of Drinks Per Week on Stroop Time and Stroop Error Scores



Note. **A.** Stroop Time scores differed significantly as a function of Drinks Per Week. Never-drinkers and 12-month abstainers had higher time scores than low, low-moderate, and high-moderate groups ($p < .001$) and never-drinkers trended towards higher/slower scores than high-level drinkers ($p = .003$). **B.** All non-drinkers reported more errors than low and low-moderate drinkers ($p = .001$ to $p = .004$) and never-drinkers also trended towards more errors than high-moderate drinkers ($p = .004$). Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Table 13

ANOVA/ANCOVA Tables: Age, Sex, and Age X Sex Interactions for Stroop Time, Stroop Error, Mental Alternation Test, and Choice Reaction Time Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Stroop Time	Drinks Per Week (DPW)	44.639	5, 29442	< .001	.008	5.546	5, 12706	< .001	.002
	DPW x Age	2.693	15, 29442	< .001	.001	1.087	15, 12706	.362	.001
	DPW x Sex	.793	15, 29442	< .001	< .001	1.222	5, 12706	.296	< .001
	DPW x Age x Sex	1.283	15, 29442	.203	.001	.974	14, 12706	.477	.001
Stroop Errors	Drinks Per Week (DPW)	19.135	5, 29308	< .001	.003	1.743	5, 12657	.121	.001
	DPW x Age	3.597	15, 29308	< .001	.002	1.152	15, 12657	.303	.001
	DPW x Sex	.639	5, 29308	.670	< .001	1.185	5, 12657	.314	< .001
	DPW x Age x Sex	.758	15, 29308	.726	< .001	.565	14, 12657	.894	.001
MAT	Drinks Per Week (DPW)	37.675	5, 28381	< .001	.007	2.728	5, 12221	.018	.001
	DPW x Age	1.368	15, 28368	.153	.001	.884	15, 12221	.582	.001
	DPW x Sex	2.466	5, 28368	.031	< .001	.734	5, 12221	.598	< .001
	DPW x Age x Sex	.859	15, 28381	.611	< .001	1.015	15, 12221	.434	.001
CRT	Drinks Per Week (DPW)	7.132	5, 29412	< .001	.001	.415	5, 12696	.838	< .001
	DPW x Age	1.043	15, 29412	.406	.001	1.174	15, 12696	.284	.001
	DPW x Sex	1.150	5, 29412	.331	< .001	.430	5, 12696	.828	< .001
	DPW x Age x Sex	.810	15, 29412	.669	< .001	.475	15, 12696	.947	.001

Drinks Per Week and the Mental Alternation Task.

Mean scores for the MAT as a function of Drinks Per Week are shown in Appendix G (Table G1). There was a significant main effect of Drinks Per Week on the MAT scores ($p <$ .001; $\eta_p^2 = .002$). Post-hoc Bonferroni comparisons revealed no significant differences between never-drinkers and 12-month abstainers. However, never-drinkers achieved fewer alternations than low, low-moderate, and high-level drinkers ($p < .001$); 12-month abstainers had lower scores than low and low-moderate drinkers (Figure 23). There were no significant differences between alcohol consumption groups at higher levels (i.e., high-moderate, high, and very high).

Because it appeared that alcohol use was associated with improved MAT test performance, follow-up tests were conducted with additional covariates. After controlling for these extra covariates, the main effect of Drinks Per Week on MAT scores was still significant, $F(6,10976) = 6.165$, $p < .001$ ($\eta_p^2 = .003$; Table H1). Physical function, social function, emotional stability, conscientiousness, extraversion, and openness also produced significant main effects on MAT scores, The effect of these covariates without the influence of alcohol variables is shown in Appendix I3.

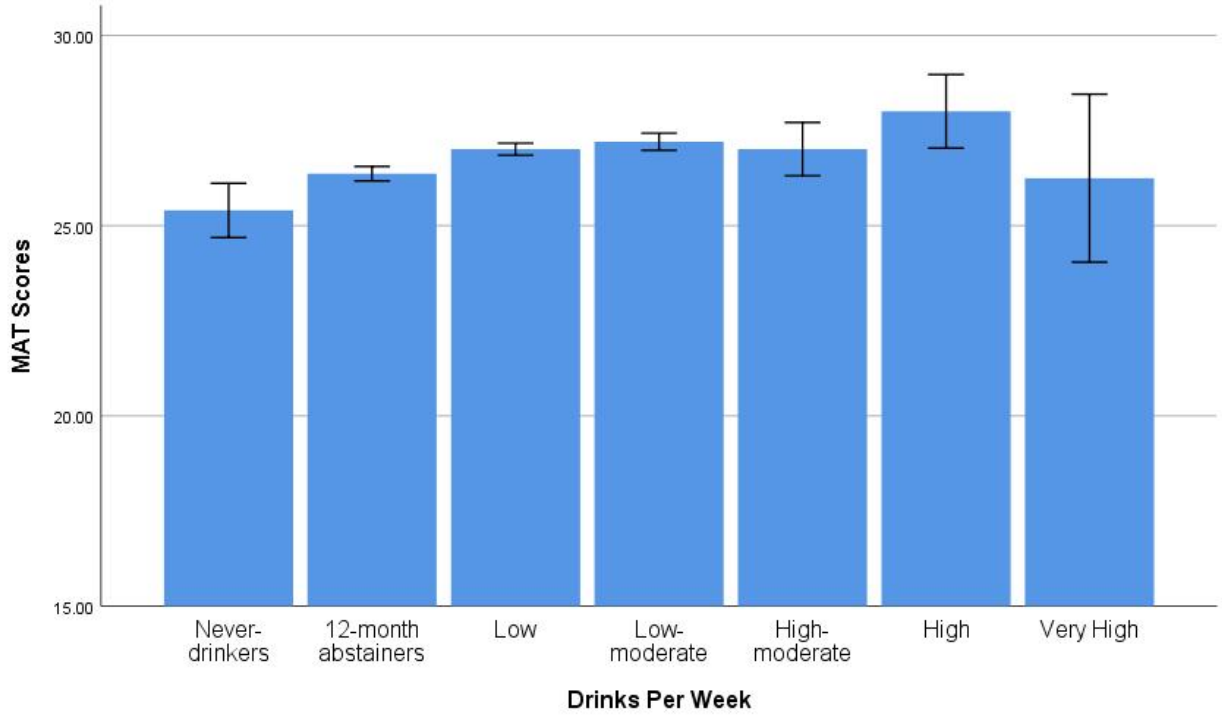
To investigate whether the effects of Drinks Per Week on MAT scores changed as a function of age, sex, or age X sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 13. When covariates were included, none of the interaction terms were significant, and further analyses were not conducted.

Drinks Per Week and Choice Reaction Time.

Mean scores for CRT as a function of Drinks Per Week are shown in Appendix G (Table G1). The main effect of Drinks Per Week on CRT scores showed a nonsignificant trend ($p =$ .004; $\eta_p^2 = .001$; Table 9). Post-hoc analyses showed that never-drinkers trended towards slower

Figure 23

Main Effect of Drinks Per Week on Mental Alternation Test Scores



Note. Mean Mental Alternation Test (MAT) scores differ significantly as a function of Drinks Per Week. Both groups of non-drinkers had lower scores than low and low-moderate drinkers ($p < .001$) and never-drinkers had lower scores than high-level drinkers ($p < .001$). Categories are defined by the following number of drinks per week: Low = 1-7; Low-moderate = 8-21; High-moderate = 22-30; High = 31-50; Very High = 51 or more. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

reaction times than low level drinkers (p = .006); no other group differences were observed (Appendix K; Figure K2).

Because higher alcohol use was associated with improved test performance, follow-up tests were conducted with additional covariates. After controlling for these extra covariates, the main effect of Drinks Per Week on CRT scores was no longer significant, $F(6,11383) = .326$, p =.924 (η_p^2 = .000; Table H1).

To investigate whether the effects of Drinks Per Week on CRT scores changed as a function of age, sex or age X sex, ANOVAs/ANCOVAs were done to explore interaction terms. The results are shown in Table 13. When covariates were included, none of the interaction terms were significant, and further analyses were not conducted.

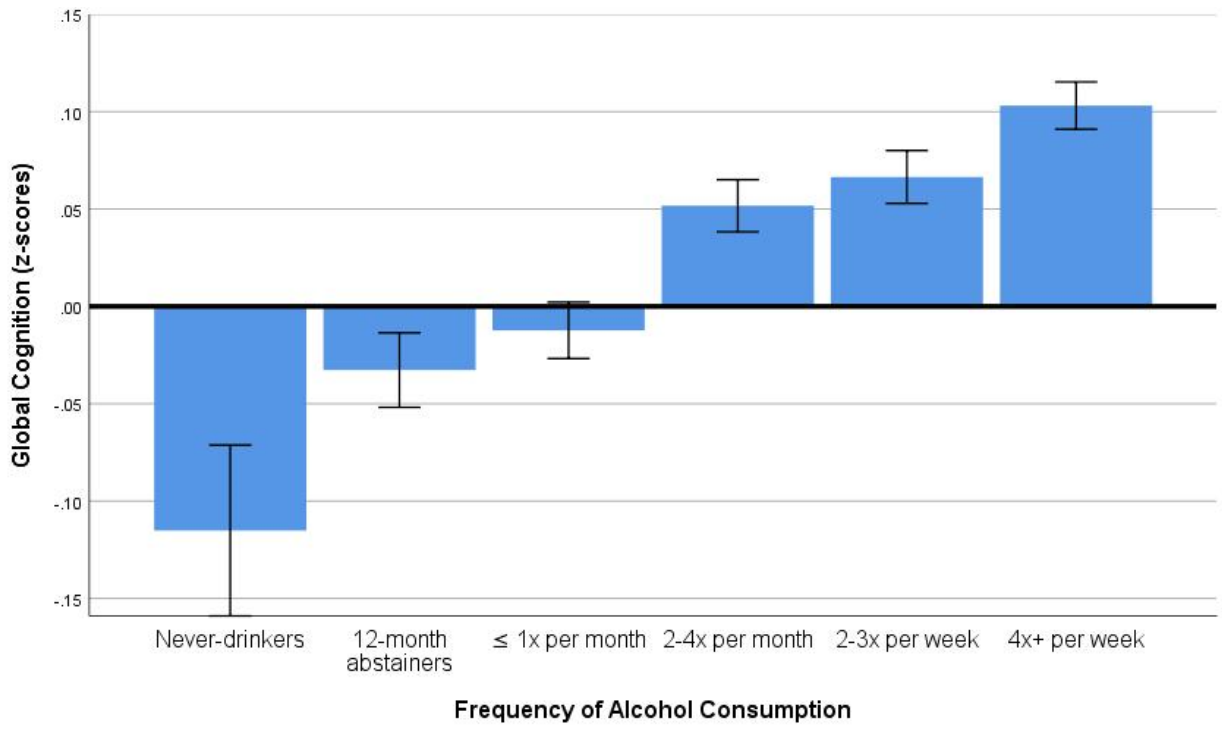
Frequency of Alcohol Use

Frequency of Alcohol Consumption and Global Cognitive scores.

Mean scores for Global Cognition based on Alcohol Use Frequency are shown in Appendix F (Table F2). When covariates were included, the effect was significant, $F(5,23554) = 53.526$, $p < 0.001$ (η_p^2 = .011; see Table 8; Figure 24). While this effect was small in size, Alcohol Use Frequency had the largest effect on Global Cognition of all the individual alcohol use variables. Post-hoc tests showed that more frequent alcohol consumption was associated with higher global cognitive scores ($p < 0.001$). The only groups that did not differ significantly ($p <$ .001) were the 12-month abstainers versus the infrequent drinkers (≤ 1 time per month), and the moderate drinkers (2-4 times per month) versus frequent drinkers (2-3 times per week; p = 1.000).

Figure 24

Main Effect of Alcohol Use Frequency on Global Cognition



Note. Mean Global Cognitive scores differed significantly by level of Alcohol Frequency, such that less frequent alcohol consumption was generally associated with lower cognitive test scores and more frequent consumption was associated with higher cognitive test scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Frequency of alcohol consumption had a significant main effect on each of the cognitive test scores included in the CLSA dataset (all $p < .001$; see Table 14). The relationship between the Alcohol Use Frequency and each of these tests is examined in more detail below.

Alcohol Use Frequency and REY I.

Mean REYI scores as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on REYI scores ($p < .001$; $\eta_p^2 = .004$; Table 14). Post-hoc tests showed that never-drinkers trended towards lower scores than individuals who consumed alcohol 4+ times per week ($p = .004$) and12-month abstainers had lower scores than those who consumed alcohol 2-4 times per month or more ($p < .001$). Infrequent drinkers (< 1 time per month) had lower immediate recall scores than individuals who consumed alcohol at all higher levels (all $p < .001$); there were no significant differences between groups who consumed alcohol 2-4 times a month and those who consumed it more frequently (see Figure 25).

Because alcohol use was associated with improved test performance, follow-up tests were conducted with additional physical, social, and personality covariates. After controlling for these extra covariates, the main effect of Frequency on REYI scores remained significant, $F(5,11184) = 5.575$, $p < .001$ ($\eta_p^2 = .002$; Table H2). As noted above, the relationship between frequency of drinking and REYI scores cannot be fully explained by social interaction, physical functioning, conscientiousness, and emotional stability scores (see Appendix I for the influence of these covariates without alcohol use variables).

To investigate whether the effects of alcohol consumption Frequency on REYI scores change based on sex, age, or age X sex, ANOVAs/ANCOVAs explored interaction terms. The

Table 14

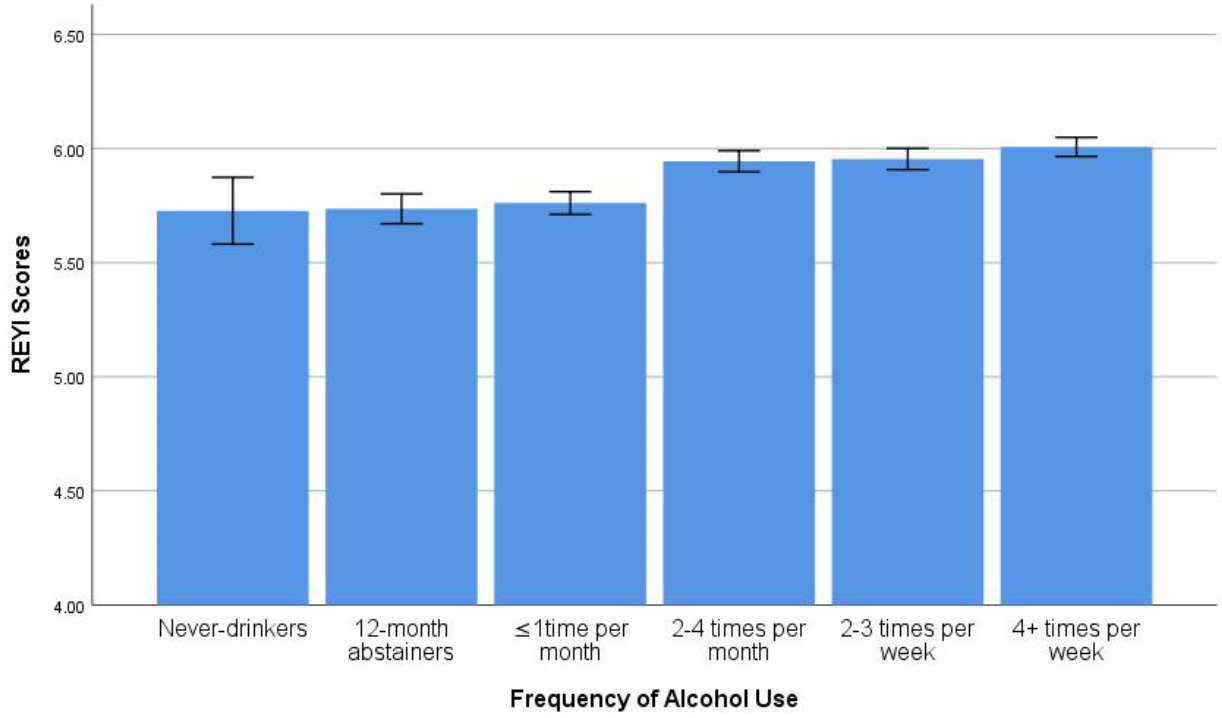
ANOVA/ANCOVA Table: Effect of Alcohol Use Frequency on all Nine of the Cognitive Test Scores

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	43.567	5, 29058	< .001	.007	18.183	5, 25693	< .001	.004
REY II	35.556	5, 29028	< .001	.006	12.610	5, 25670	< .001	.002
PMT	36.357	5, 23833	< .001	.006	14.549	5, 26315	< .001	.003
AFT	99.975	5, 29343	< .001	.017	28.832	5, 25923	< .001	.006
COWA	83.750	5, 29004	< .001	.014	38.317	5, 25602	< .001	.007
Stroop Time	93.171	5, 29670	< .001	.015	28.461	5, 26171	< .001	.005
Stroop Errors	45.681	5, 29541	< .001	.008	13.746	5, 26062	< . 001	.003
MAT	83.767	5, 28595	< .001	.014	14.129	5, 25327	< .001	.003
CRT	34.822	5, 29636	< .001	.006	5.292	5, 26150	< .001	.001

Note: Cognitive test scores include the REY Auditory Verbal Learning Test immediate and delayed recall trials (REYI/REYII), Prospective Memory Test (PMT), Animal Fluency Test (AFT), Controlled Oral Word Association test (COWA), Stroop Time and Error scores, Mental Alternation Test (MAT) and Choice Reaction Time (CRT).

Figure 25

Main Effect of Alcohol Use Frequency on Immediate Verbal Memory (REYI Scores)



Note. Mean REYI scores differed significantly by levels of alcohol use frequency. Never-drinkers trended towards lower scores than those who consumed alcohol 4+ times per week ($p = .004$). Both 12-month abstainers and infrequent drinkers (≤ 1 per month) had lower scores than those who consumed alcohol 2-4 times per month, 2-3 times per week, and 4+ times per week ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

results are shown in Table 15. There were no significant age or sex interactions between alcohol use frequency and REYI scores.

Alcohol Use Frequency and REY II.

Mean REYII scores as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on REYII scores ($p < .001$; $\eta_p^2 = .002$; Table 14). Post-hoc tests showed that never-drinkers trended towards lower REYII scores compared to individuals who consumed alcohol 2-4 times per month ($p = .004$), 2-3 times per week ($p = .002$), or 4+ times per week ($p < .001$), and 12-month abstainers had lower scores than those who typically drank alcohol 2-4 times per week or more ($p < .001$). Infrequent drinkers (up to once per month) trended towards lower scores than the group who drank 2-3 times per week ($p = .007$) or 4+ times per week ($p < .001$). There were no significant differences between groups who consumed alcohol 2-4+ times per week or more frequently (Figure 26).

Because alcohol use was associated with improved test performance, follow-up tests were conducted with additional covariates. After controlling for these extra covariates, the main effect of alcohol use Frequency on REY II scores remained significant, $F(5,11167) = 4.344$, $p < .001$ ($\eta_p^2 = .002$; Appendix H2). The effects of some covariates were significant (see Appendix I).

To investigate whether the effect of alcohol consumption Frequency on REYI scores change based on sex, age, or sex X age, ANOVAs/ANCOVAs explored the interaction terms. The results are shown in Table 15. There were no significant interactions between alcohol use frequency, age, and sex in terms of their influence on REY II scores.

Alcohol Use Frequency and Prospective Memory.

Mean scores for the PMT as a function of Alcohol Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on Prospective Memory

Table 15

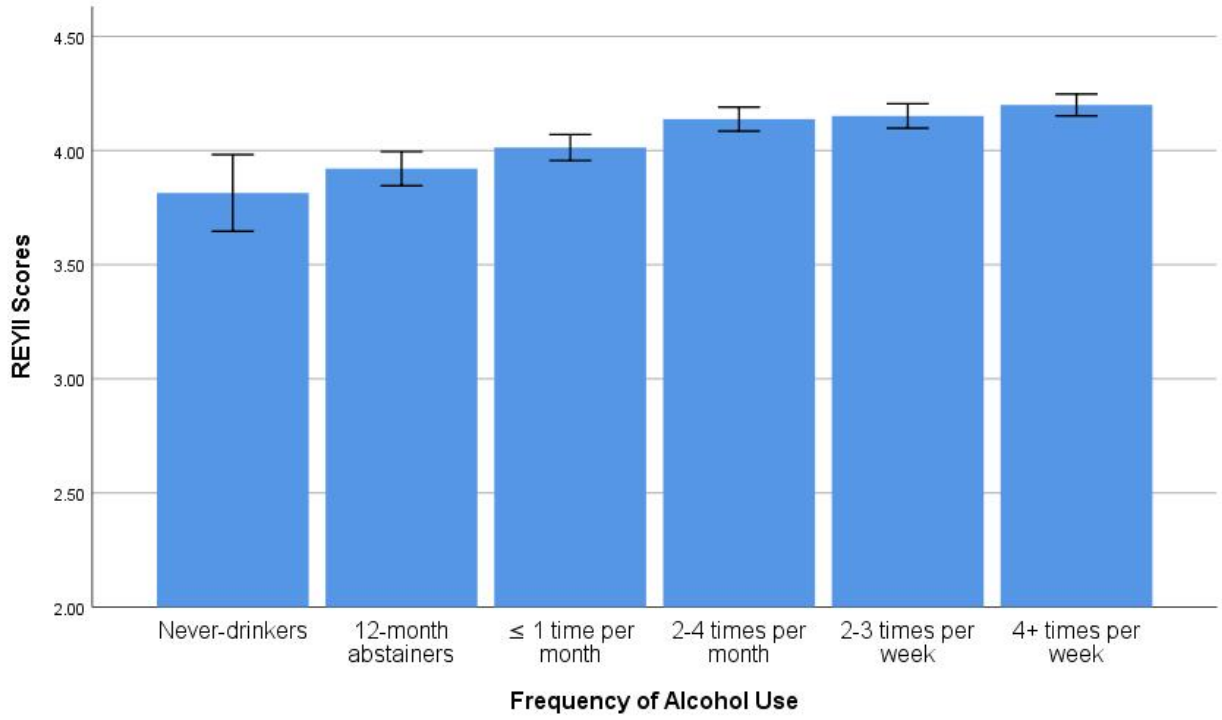
Interactions Between Age, Sex, and Alcohol Use Frequency on Memory Test Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REYI	Frequency (FRE)	43.213	5, 29016	< .001	.007	3.185	5, 12464	.007	.001
	FRE x Age	.783	15, 29016	.698	< .001	.737	15, 12464	.749	.001
	FRE x Sex	.905	5, 29016	.476	< .001	1.760	5, 12464	.117	.001
	FRE x Age x Sex	1.403	15, 29016	.136	.001	1.483	15, 12464	.102	.002
REYII	Frequency (FRE)	31.172	5, 28986	< .001	.005	3.356	5, 12446	.005	.001
	FRE x Age	1.370	15, 28986	.152	.001	1.294	15, 12446	.196	.002
	FRE x Sex	1.488	5, 28986	.190	< .001	1.997	5, 12446	.076	.001
	FRE x Age x Sex	1.058	15, 28986	.391	.001	1.508	15, 12446	.093	.002
PMT	Frequency (FRE)	16.497	5, 29791	< .001	.003	1.306	5, 12815	.258	.001
	FRE x Age	2.320	15, 29791	.003	.001	.835	15, 12815	.639	.001
	FRE x Sex	.918	5, 29791	.468	< .001	.162	5, 12815	.977	.000
	FRE x Age x Sex	.815	15. 29791	.662	< .001	.841	15, 12815	.633	.001

Note: REYI = Rey Auditory Verbal Learning Test immediate recall trial; REYII = Rey Auditory Learning Verbal Test delayed recall trial; PMT = Prospective Memory Test

Figure 26

Main Effect of Alcohol Use Frequency on Delayed Verbal Recall



Note. Mean scores for the Rey Auditory Verbal Learning Test (delayed trial; REYII) differed significantly as a function of alcohol use frequency. Non-drinkers (never-drinkers and 12-month abstainers) and infrequent drinkers (up to once per month) had recalled fewer words than groups who consumed alcohol at greater frequencies ($p < .001$ to $p = .007$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

(PMT) scores ($p < .001$; $\eta_p^2 = .003$; Table 14). Post-hoc tests indicated that never-drinkers had lower scores than groups who consumed alcohol up to once a month ($p = .001$) or more frequently (all $p < .001$) and 12-month abstainers had lower scores than those who drank 2-4 times per month ($p = .001$) and at higher levels (all $p < .001$). Infrequent drinkers (up to once per month) and those who typically drink 2-4 times per month both had lower scores than those who typically drink 4+ times per week ($p < .001$ and $p = .008$ respectively; see Figure 27).

Follow-up ANCOVAs with additional covariates (social, physical, and personality factors) were conducted. After controlling for these extra covariates, the main effect of Frequency on PMT scores was no longer significant, $F(5,11484) = 2.991$, $p = .011$ ($\eta_p^2 = .001$; Table H2). While this does not rule out the possibility that alcohol use frequency affects PMT scores, it suggests that these additional variables may help to explain, or account for, the relationship.

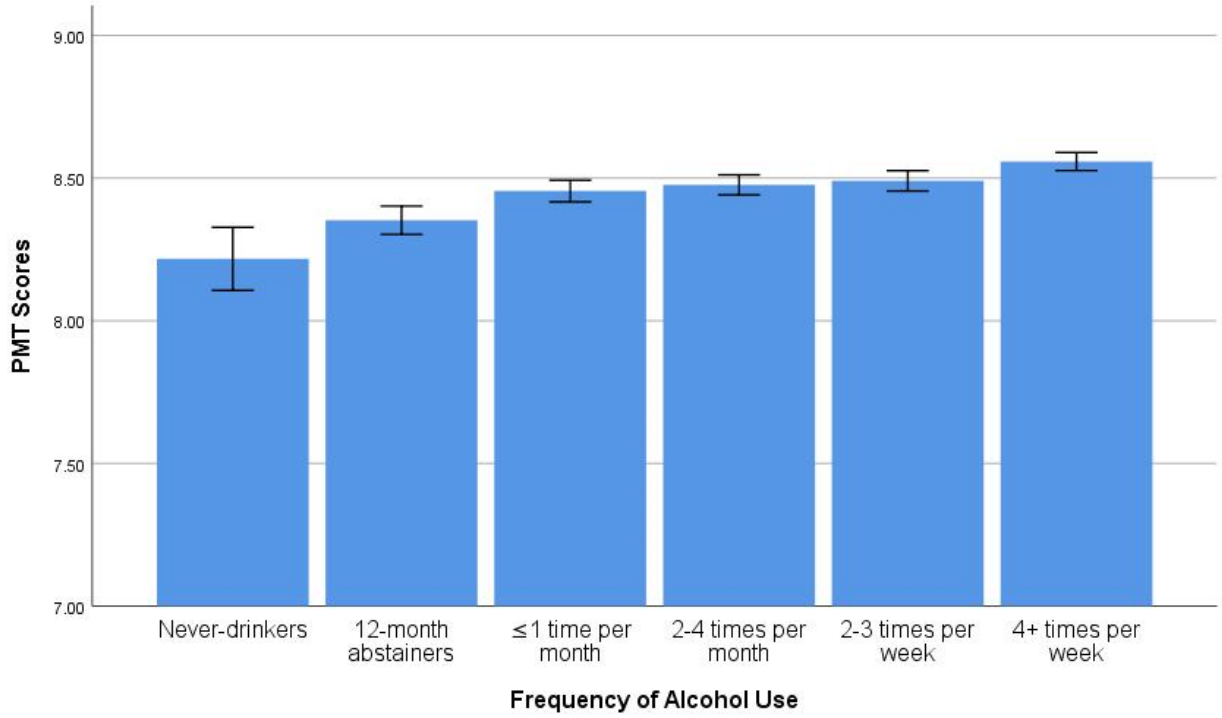
To investigate whether the effects of alcohol consumption Frequency on PMT change based on sex, age, or age X sex, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 15. There were no significant interactions between Frequency, age, and sex in terms of their influence on REYII scores and no further analyses were conducted.

Alcohol Frequency and Semantic Verbal Fluency.

Mean scores for the Animal Fluency Test (AFT) as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on Animal Fluency Test scores with the main covariates included, $F(5, 25923) = 28.923$, $p < .001$, ($\eta_p^2 = .006$; Table 14). Post-hoc tests showed that never-drinkers performed worse than 12-month abstainers ($p = .001$) and all four higher drinking frequency groups (all $p < .001$). Twelve-month abstainers and those who drink less than once per month had lower AFT scores than those

Figure 27

Main Effect of Alcohol Use Frequency on Prospective Memory Test Scores



Note. Mean PMT scores differed significantly as a function of alcohol use frequency. Never-drinkers had lower scores than groups who consume alcohol up to once a month or more (all $p < .001$). 12-month abstainers had lower scores than those who typically drink 2-4 times per month or more (both $p < .001$). Individuals who typically drink up to once a month, and those who drink 2-4 times per week, had lower scores than those who consumed alcohol at the highest frequency. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

who consumed alcohol 2-3 times a week or more (all p <.001) and those who drink 2-4 times per month had lower scores than those who drink 4+ times per week (p <.001; Figure 28).

Follow-up analyses that included additional physical, social, and personality covariates were conducted to explore possible explanations for the above findings. The main effect of alcohol use Frequency on AFT scores remained significant, $F(5, 11282) = 7.917$, $p < .001$, (η_p^2 = .003; see Appendix H2). See Appendix I for the effect sizes of these covariates on AFT without the inclusion of alcohol use variables.

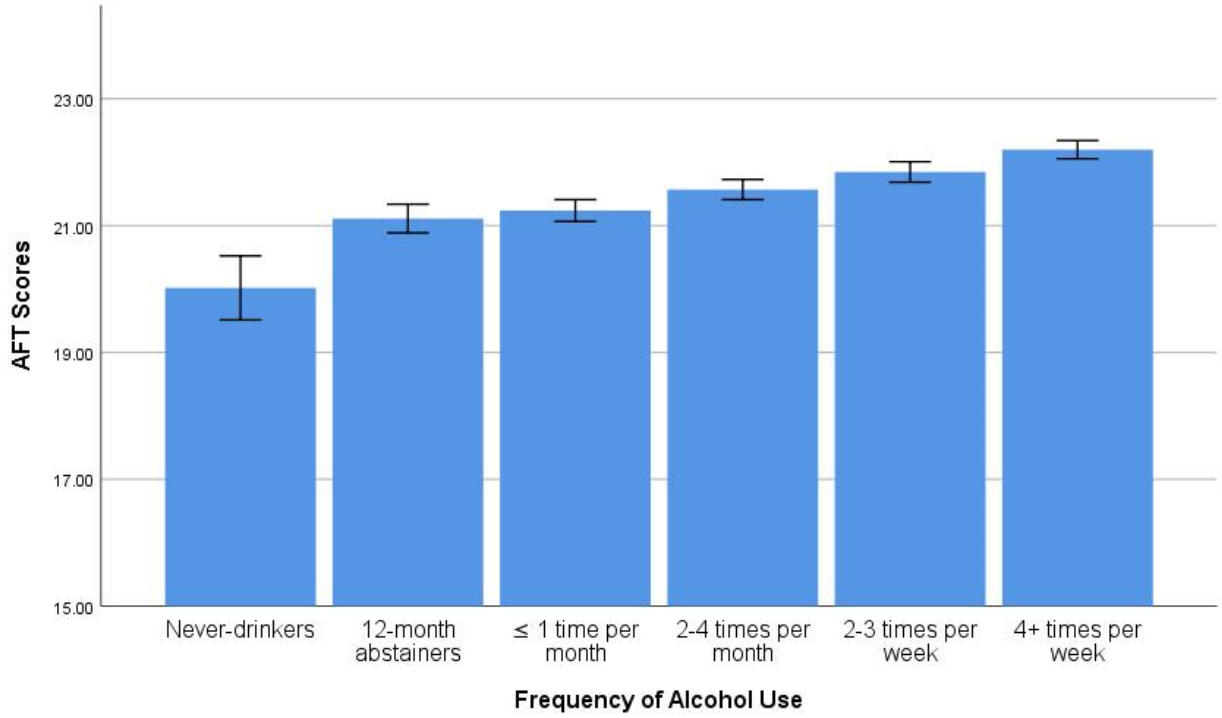
To investigate whether the effects of alcohol consumption Frequency on AFT scores change based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 16. There were no significant interactions between alcohol use frequency, age, and sex in terms of their influence on AFT test scores and no further analyses were conducted.

Alcohol Frequency and Phonemic Verbal Fluency (COWA).

Means for COWA scores as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on COWA scores with the primary covariates included, $F(5, 25602) = 38.317$, $p < .001$ (η_p^2 = .007; Table 14). Post-hoc tests indicated that never-drinkers had lower scores than individuals who consume alcohol 4+ times per week (p <.001). Twelve-month abstainers trended towards lower scores than those who drink 2-4 times per week (p =.009), 2-3 times per week (p =.001), and 4+ per week (all p <.001). Those who drink up to once per month had lower scores than all more frequently drinking groups (all p <.001). Individuals who drink 2-4 times per month or 2-3 times per week had lower scores than those consuming alcohol 4+ times per week (p <.001; see Figure 29).

Figure 28

Main Effect of Alcohol Use Frequency on Semantic Verbal Fluency



Note. Mean Animal Fluency Test (AFT) scores differed significantly by level of alcohol use frequency. AFT scores increased with higher frequencies of alcohol use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

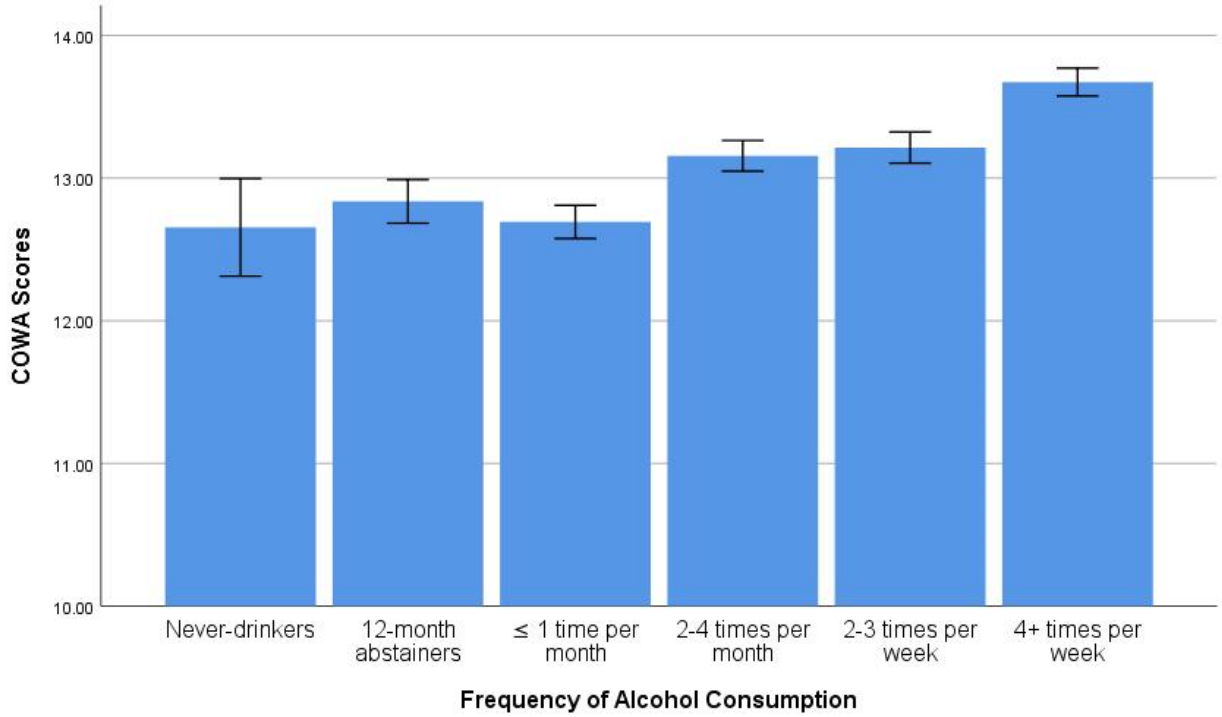
Table 16

ANOVA/ANCOVA Tables: Interactions Between Age, Sex, and Alcohol Use Frequency on Verbal Fluency Test Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
AFT	Frequency (FRE)	64.628	5, 29305	< .001	.011	5.189	5, 12575	< .001	.002
	FRE x Age	1.226	15, 29305	.243	.001	0.569	15, 12575	.900	.001
	FRE x Sex	1.147	5, 29305	.333	< .001	0.886	5, 12575	.489	< .001
	FRE x Age x Sex	0.935	15, 29305	.524	< .001	0.616	15, 12575	.864	.001
COWA	Frequency (FRE)	74.277	5, 28962	< .001	.013	6.795	5, 12475	< .001	.003
	FRE x Age	0.890	15, 28962	.575	< .001	1.585	15, 12475	.069	.002
	FRE x Sex	1.228	5, 28962	.293	< .001	1.859	5, 12475	.098	.001
	FRE x Age x Sex	0.796	15, 28962	.683	< .001	1.048	15, 12475	.402	.001

Figure 29

Main Effect of Alcohol Use Frequency on Phonemic Verbal Fluency



Note. Mean scores on the Controlled Oral Word Association test (COWA) differed significantly as a function of alcohol use frequency. Scores generally increased with higher frequencies of alcohol use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

The main effect of alcohol use frequency on COWA scores remained significant when the additional physical, social, and personality covariates were included, $F(5, 11190) = 18.807$, $p < .001$, ($\eta_p^2 = .008$; Table H2). The main effect of alcohol use frequency on COWA scores was the largest of all the effects between alcohol frequency the nine individual cognitive test scores when covariates were included.

To investigate whether the effects of alcohol consumption frequency on COWA scores changed based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 16. There were no significant interactions between alcohol use frequency, age, and sex in terms of their influence on COWA test scores and no further analyses were conducted.

Alcohol Use Frequency and Stroop Scores

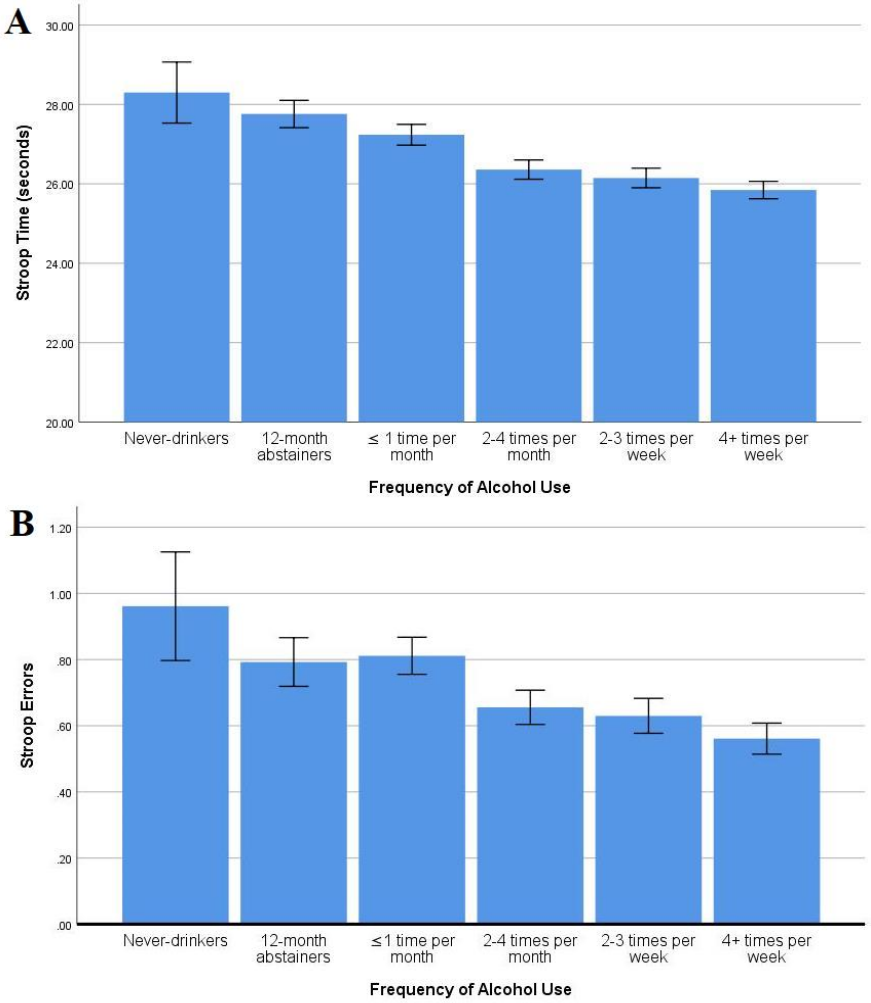
Mean Stroop scores as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on the Stroop Time scores, $F(5, 26171) = 28.461$, $p < .001$, ($\eta_p^2 = .005$), and Stroop Error scores, $F(5, 26062) = 13.746$, $p < .001$, ($\eta_p^2 = .003$), when covariates were included (see Table 14).

For the Stroop Time scores, post-hoc Bonferroni tests showed no significant difference between never-drinkers and 12-month abstainers. Never-drinkers and 12-month abstainers also took more time to complete the task compared to those who consume alcohol 2-4 times per week or more ($p <.001$). Those who consume alcohol less than once per month had slower scores than those who drink more frequently ($p < .001$). There were no differences between the higher alcohol use frequency groups (all $p > . 001$; see Figure 30).

For Stroop Error scores, post-hoc tests also indicated no significant difference between the two non-drinker groups. Never-drinkers trended towards more errors than those who drink

Figure 30

Main Effects of Alcohol Use Frequency on Stroop Time and Error Scores



Note. Mean Stroop Time (A) and Error (B) scores differed significantly as a function of alcohol use frequency. Scores generally decreased/improved with higher frequencies of alcohol use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

2-4 times per week (p = .006), 2-3 times per week (p = .002), and 4+ times per week (p < .001). Twelve-month abstainers had more errors than those who drink 2-3 times per week (p = .006) or 4+ times per week (p < .001). Infrequent drinkers (less than once per month) made more errors than individuals who consume alcohol 2-3 times per month (p = .001) or more (p < .001). There were no significant differences between groups at higher levels of alcohol use frequency (i.e., 2-4 times per month or higher; see Figure 30).

Follow-up analyses that included the additional physical, social, and personality covariates were conducted to examine possible explanations for the findings. The main effect of Frequency on Stroop time scores remained significant, $F(5, 11440) = 14.871$, $p < .001$, (η_p^2 = .006) as did the effect of Frequency on Stroop error scores, $F(5,11399) = 5.012$, $p < .001$ (η_p^2 = .002). See Appendix I (Table I3) for the effect of these covariates without the influence of alcohol use variables.

To investigate whether the effects of alcohol consumption frequency on Stroop time and error scores changed based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 17. When covariates were included, there were no significant interactions between alcohol use frequency, age, and sex in terms of their influence on either of the Stroop test scores, and no further analyses were conducted.

Alcohol Use Frequency and the Mental Alternation Test.

Mean scores for MAT as a function of Alcohol Use Frequency are shown in Appendix G (Table G2). There was a significant main effect of alcohol use frequency on MAT scores when the primary covariates were included, $F(5, 25327) = 14.129$, $p < .001$ (η_p^2 = .003; Table 14). Post-hoc tests indicated that there were no differences between never-drinkers and 12-month abstainers ($p > .001$). Never-drinkers had worse scores than those who drink 2-4 times per month

Table 17

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Alcohol Use Frequency on Executive Function Tests

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Stroop Time	Frequency (FRE)	53.104	5, 29628	< .001	.009	5.462	5, 12766	< .001	.002
	FRE x Age	2.102	15, 29628	.007	.001	.675	15, 12766	.811	.001
	FRE x Sex	.461	5, 20628	.806	.000	1.369	5, 12766	.232	.001
	FRE x Age x Sex	1.042	15, 29628	.407	.001	.564	15, 12766	.904	.001
Stroop Error	Frequency (FRE)	25.239	5, 29493	< .001	.004	2.418	5, 12717	.034	.001
	FRE x Age	4.231	15, 29493	< .001	.002	1.865	15, 12717	.022	.002
	FRE x Sex	.417	5, 29493	.837	.000	1.064	5, 12717	.378	.000
	FRE x Age x Sex	.687	15, 29493	.800	.000	.253	15, 12717	.998	.000
MAT	Frequency (FRE)	48.486	5, 28553	< .001	.008	3.118	5, 12277	.008	.001
	FRE x Age	1.282	15, 28553	.204	.001	1.458	15, 12277	.112	.002
	FRE x Sex	2.138	5, 28553	.058	.000	2.866	5, 12277	.014	.001
	FRE x Age x Sex	.783	15, 28553	.698	.000	1.176	15, 12277	.282	.001
CRT	Frequency (FRE)	10.892	5, 29594	< .001	.002	.363	5, 12755	.874	.000
	FRE x Age	.592	15, 29594	.884	.000	.873	15, 12755	.595	.001
	FRE x Sex	1.213	5, 29594	.300	.000	.822	5, 12755	.534	.000
	FRE x Age x Sex	.979	15, 29594	.475	.000	.597	15, 12755	.880	.001

($p < .001$) or higher (both $p < .001$). Twelve-month abstainers had lower scores than those who drink 4+ times per week ($p = .001$). Those who drink less frequently than once a month had lower scores than those who drink at any of the higher (i.e., more frequent) levels (all $p < .001$) and there were no differences between any of these three higher frequency groups (i.e., 2-4 times per month or more; $p > .001$). These relationships are shown in Figure 31.

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of alcohol use frequency on MAT scores remained significant, $F(5, 11024) = 7.070$, $p < .001$, ($\eta_p^2 = .003$; Table H2).

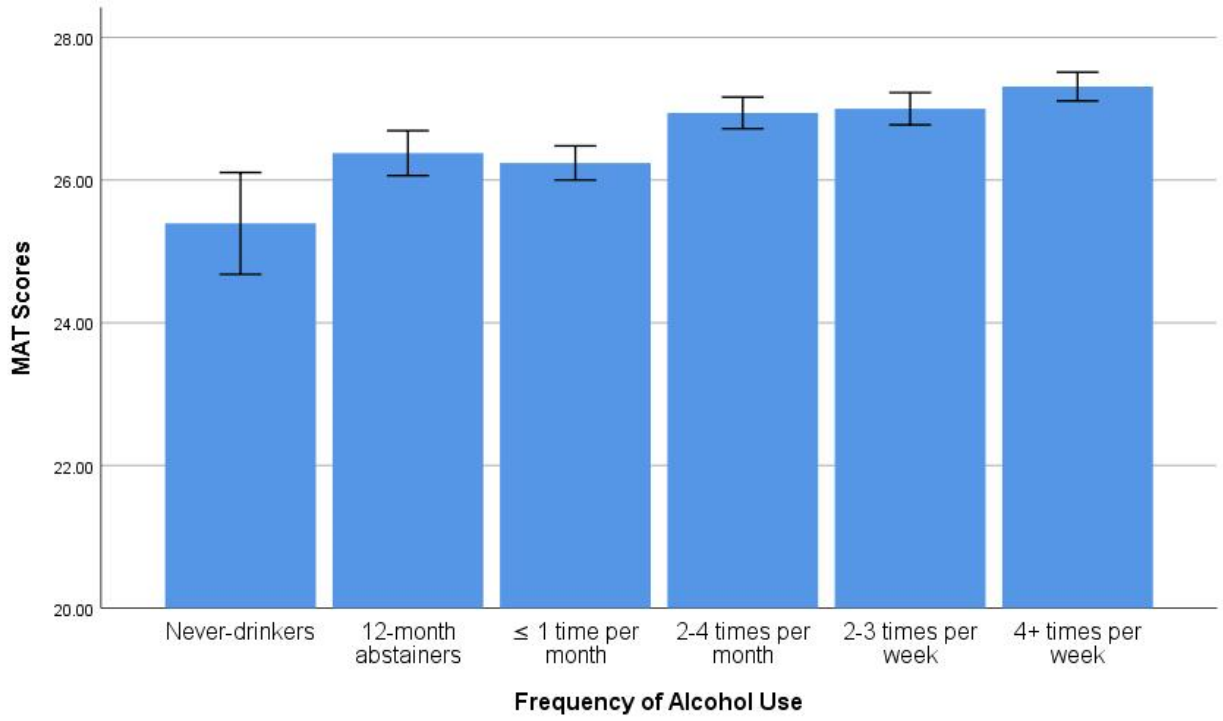
To investigate whether the effects of alcohol consumption Frequency on MAT scores changed based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 17. When covariates were included, there were no significant interactions between alcohol use frequency, age, and sex and no further analyses were conducted.

Alcohol Frequency and Choice Reaction Time.

Mean CRT scores as a function of Alcohol Use History are shown in Appendix G (Table G2). There was a significant main effect of Alcohol Frequency on CRT scores, $F(5, 26150) = 5.292$, $p < .001$, ($\eta_p^2 = .001$; Table 14). Post-hoc tests indicated that there were no differences between never-drinkers and 12-month abstainers. Never drinkers trended towards slower reaction times than those who drink 2-4 times per month ($p = .005$) or 2-3 times per week ($p = .002$). Twelve-month abstainers trended towards slower reaction times than those drinking 2-3 times per week ($p = .005$) and there were no significant differences between those groups who consume alcohol with any level of frequency (all $p > .001$; Figure 32).

Figure 31

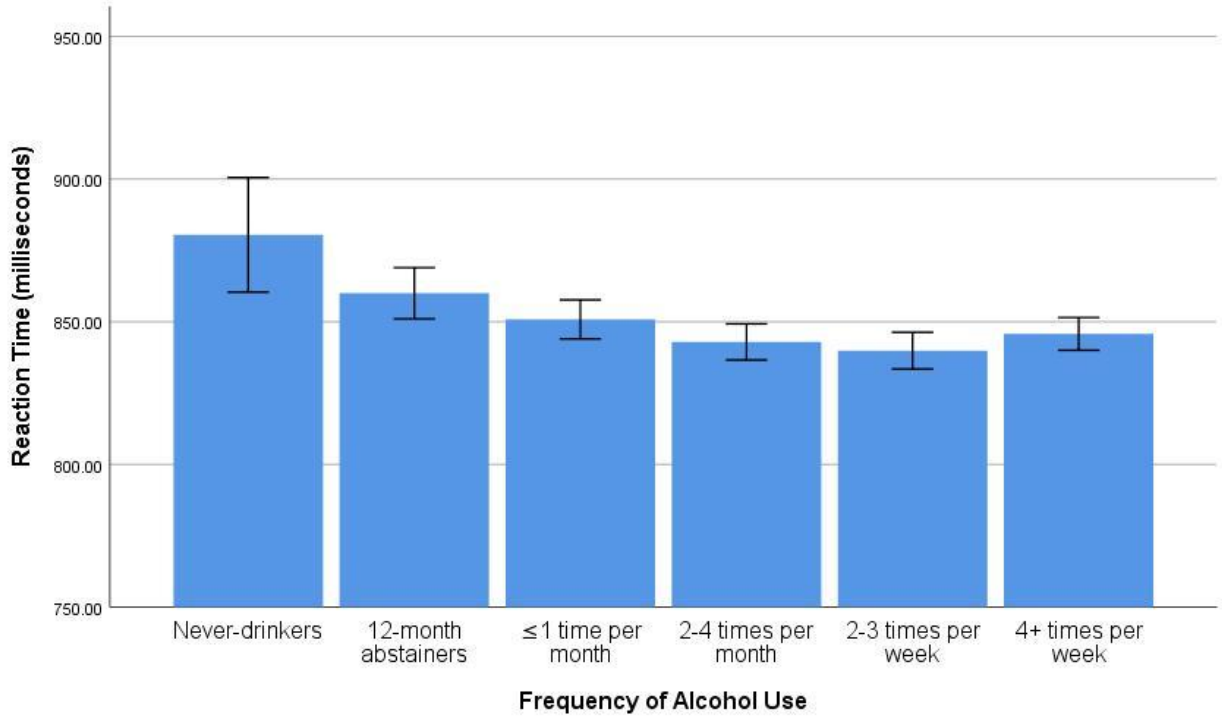
Main Effect of Alcohol Use Frequency on Mental Alternation Test Scores



Note. Mean MAT scores differed significantly as a function of alcohol use frequency. Scores increased with higher frequencies of alcohol use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure 32

Main Effect of Alcohol Use Frequency on Choice Reaction Time



Note. Mean CRT scores differed significantly by levels of alcohol use frequency such that higher levels of alcohol use were generally associated with improved performance. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Follow-up analyses that included additional physical, social, and personality covariates were conducted to explore explanations for the effect. The main effect of drinking frequency on CRT scores was no longer significant, $F(5, 11434) = .300$, $p = .913$ ($\eta_p^2 = .000$; Table H2). The large and significant positive effect of physical functioning on CRT scores might help to explain the initial beneficial relationship found between drinking frequency and CRT scores (see Appendix I4 for the influence of the covariates on CRT without inclusion of alcohol use variables).

To investigate whether the effect of alcohol consumption frequency on CRT scores changed based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 17. When covariates were included, there were no significant interactions between alcohol use frequency, age, and sex and no further analyses were conducted.

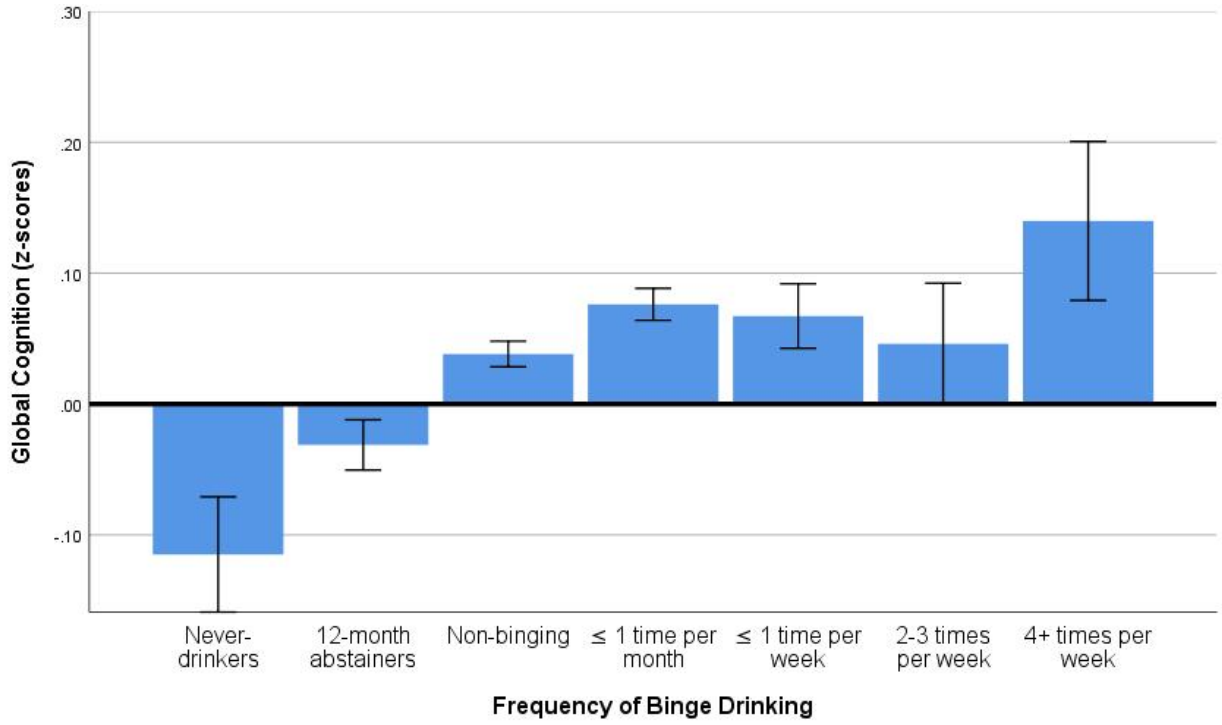
Frequency of Binge Drinking.

Frequency of Binge Drinking and Global Cognition.

Group means for Global Cognition as a function of Binge Drinking are shown in Appendix F (Table F2). When covariates were included, the effect was significant, $F(6, 21174) = 24.992$, $p < 0.001$ ($\eta_p^2 = .007$; Table 8). Post-hoc Bonferroni tests indicated that binge drinking at low rates (i.e., up to once a month) was associated with higher Global Cognitive scores compared to lower levels (i.e., non-drinkers and those who drink without binging; $p < .001$) but there were no significant differences between individuals reporting binge drinking "up to once a week" and those reporting higher frequencies (Figure 33).

Figure 33

Main Effect of Binge Drinking Frequency on Global Cognition



Note. Mean Global Cognitive scores differ significantly by levels of Binge Frequency, such that individuals who binge up to once per month had higher scores than non-drinkers and those who drink without binging ($p < .001$). Higher levels of binge drinking were not associated with any further increases in global cognition scores. However, individuals who binge drink alcohol at any frequency (including 4+ times per week) have higher scores than non-drinkers. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

The frequency of binge drinking produced a significant main effect on all individual cognitive test scores included in the CLSA dataset ($p < .001$; see Table 18). The relationship between the Binge frequency variable and each of these tests is examined in more detail below.

Binge Frequency and REYI.

Mean REYI scores as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on REYI scores ($p < .001$; $\eta_p^2 = .002$; see Table 18). Post-hoc tests showed no significant difference between never-drinkers and 12-month abstainers; never-drinkers had lower scores than those who binge drink 4+ times per week; 12-month abstainers had lower scores than those who drank but did not binge over the past 12 months ($p = .001$), those who binge less than once per month ($p < .001$), and those who binge 4 or more times per week ($p < .001$); there were no significant differences between groups who reported consuming alcohol in the past 12 months with any level of binge drinking (Figure 34).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge frequency on REY I scores was no longer significant, $F(5, 10043) = 2.456$, $p = .022$ ($\eta_p^2 = .001$; Table H3).

To investigate whether the effects of Binge frequency on REYI scores change based on sex or age group interactions, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 19. When covariates were included, there were no significant interactions between binge frequency, age, or sex.

Binge Frequency and REYII.

Mean scores for REYII as a function of Binge Frequency are shown in Appendix G. There was a significant main effect of Binge Frequency on REY II scores ($p < .001$; $\eta_p^2 = .002$; Table 18). Post-hoc tests showed no significant difference between never-drinkers and 12-month

Table 18

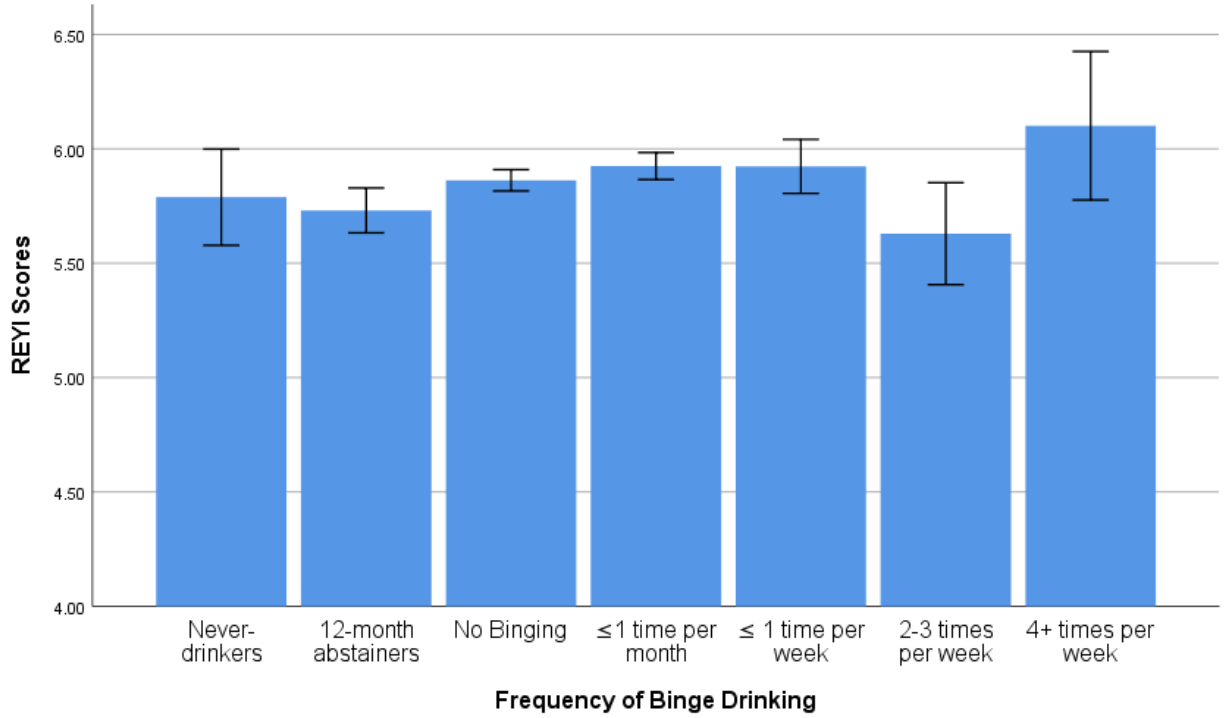
Effect of Binge Frequency on the Nine Cognitive Test Scores

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	51.896	6, 26140	< .001	.012	8.106	6, 23108	< .001	.002
REY II	49.870	6, 26119	< .001	.011	7.308	6, 23094	< .001	.002
PMT	60.563	6, 26839	< .001	.013	11.857	6, 23674	< .001	.003
AFT	99.847	6, 26396	< .001	.022	14.768	6, 23315	< .001	.004
COWA	46.908	6, 26107	< .001	.011	16.470	6, 23041	< .001	.004
Stroop Time	116.580	6, 26686	< .001	.026	13.535	6, 23538	< .001	.003
Stroop Errors	36.916	6, 26564	< .001	.008	4.308	6, 23438	< .001	.001
MAT	60.201	6, 25720	< .001	.014	4.870	6, 22744	< .001	.001
CRT	56.878	6, 26663	< .001	.013	3.898	6, 23526	.001	.001

Note: Cognitive test scores include the Rey Auditory Verbal Learning Test immediate recall (REYI) and delayed recall (REYII) trials, Prospective Memory Test (PMT), Animal Fluency Task (AFT), Controlled Oral Word Association (COWA), Stroop Time and Error scores, Mental Alternation Test (MAT) and Choice Reaction Time (CRT).

Figure 34

Main Effect of Binge Drinking Frequency on Immediate Recall Scores



Note. Mean scores for the Rey Auditory Verbal Learning Test immediate recall trial (REYI) differed significantly by levels of Binge Frequency, such that non-drinkers tended to have lower scores than those who reported binge drinking at higher frequencies ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Table 19

Interactions Between Binge Drinking, Age, and Sex on Memory Test Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
	REYI	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
	Binge Frequency	17.780	6, 26091	< .001	.004	2.691	6, 11181	.013	.001
	Binge x Age	2.399	18, 26091	< .001	.002	1.442	18, 11181	.101	.002
	Binge x Sex	.990	6, 26091	.430	< .001	2.164	6, 11181	.043	.001
	Binge x Age x Sex	2.889	18, 26091	.537	.001	1.469	18, 11181	.090	.002
	REYII	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
	Binge Frequency	19.097	6, 26070	< .001	.013	3.490	6, 11161	.002	.002
	Binge x Age	2.577	18, 26070	< .001	.002	2.239	18, 11161	.002	.004
	Binge x Sex	1.087	6, 26070	.367	< .001	2.382	6, 11161	.027	.001
	Binge x Age x Sex	1.103	18, 26070	.341	.001	1.560	18, 11161	.061	.003
Binge	40s	4.593	6, 2439	< .001	.011	1.714	6, 457	.116	.022
	50s	7.624	6, 8178	< .001	.006	2.304	6, 3315	.032	.004
	60s	1.744	6, 8304	.107	.001	1.624	6, 4223	.136	.002
	70s	6.324	6, 7177	< .001	.005	4.071	6, 3175	< .001	.008
	PMT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
	Binge Frequency	16.085	6, 26790	< .001	.006	1.557	6, 11496	.155	.001
	Binge x Age	3.305	18, 26790	< .001	.002	1.403	18, 11496	.118	.002
	Binge x Sex	1.670	6, 26790	.124	< .001	.352	6, 11496	.909	< .001
	Binge x Age x Sex	1.005	18, 26790	.450	.001	.500	18, 11496	.960	.001

Note. REYI = immediate recall trial of the Rey Auditory Verbal Learning Test; REYII = delayed recall trial of the Rey Auditory Verbal Learning Test; PMT = Prospective Memory Test

abstainers ($p > .001$). Never-drinkers trended towards lower scores than those who binge less than once per month ($p = .002$) and less than once per week ($p = .009$). Abstainers had lower scores than those who drink but do not binge, as well as those who binge less than once per month (all $p < .001$), and those who binge up to once a week ($p = .003$). There were no significant group differences among the groups of adults who report binge drinking (at any frequency) in the past 12 months (Figure 35).

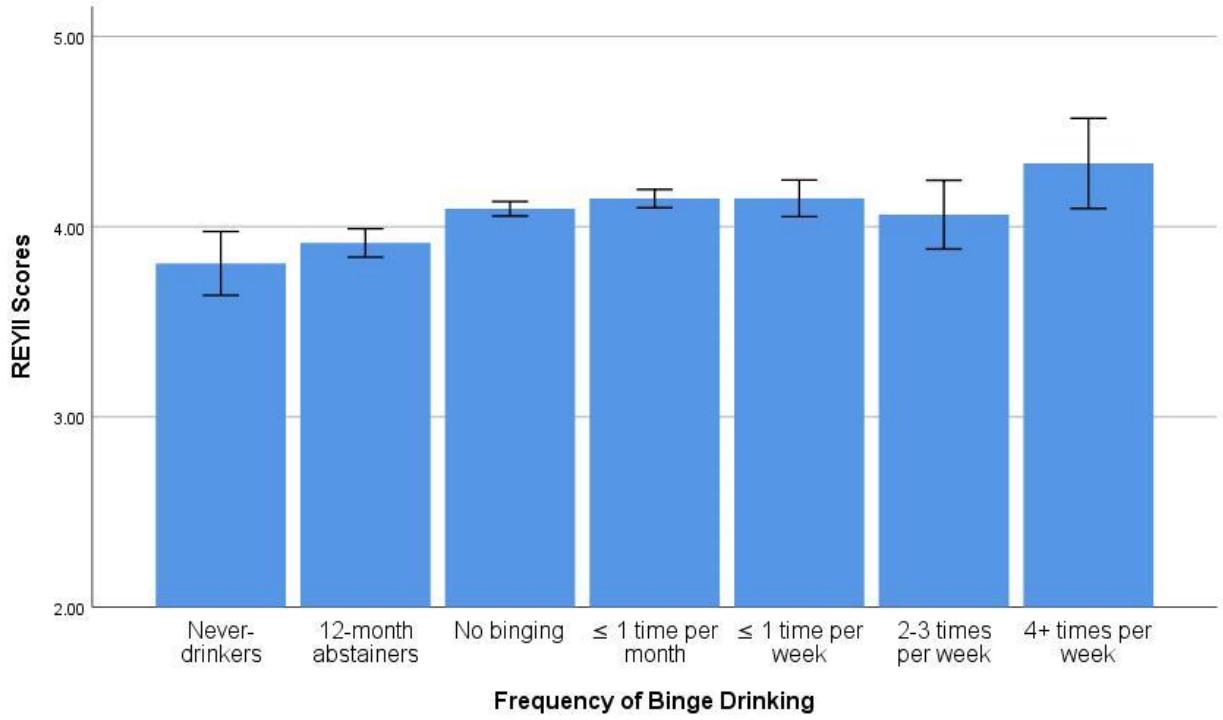
Follow-up analyses including additional physical, social, and personality covariates were conducted to further examine the result suggesting a beneficial association between binge-drinking and delayed verbal recall. With these covariates controlled, the main effect of Binge on REY II scores was no longer significant, $F(6, 10026) = 1.716$, $p = .113$ ($\eta_p^2 = .001$; see Appendix H3). The covariates with stronger (but still small effect) associations with REYII scores were physical function, social engagement, and extraversion. These variables may help to understand the main effect positive association between binge-drinking and REYII scores (see Appendix I2 for the effect of these covariates without the inclusion of alcohol variables).

Follow-up analyses including additional physical, social, and personality covariates were conducted. The main effect of Binge drinking frequency on PMT scores was no longer significant when these variables were controlled, $F(6, 10315) = 2.077$, $p = .052$ ($\eta_p^2 = .001$).

To investigate whether the effects of Binge frequency on REYII scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. When covariates were included, the interaction between the frequency of binge drinking and age trended towards significance ($p = .002$; $\eta_p^2 = .004$; see Table 19). The age X binge frequency interaction effect on REYII scores is illustrated in Appendix K3. Follow-up ANCOVAs revealed that only the 70+ age group showed a main effect of binge drinking on REYII scores ($p < .001$; $\eta_p^2 = .008$; see

Figure 35

Main Effect of Binge Drinking Frequency on Delayed Recall Scores



Note. Mean scores for the Rey Auditory Verbal Learning Test delayed trial (REYII) differ significantly by levels of Binge Frequency, such that non-drinkers have lower scores than those who binge drink at higher frequencies (all $p <$ .001). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Table 19). Post-hoc Bonferroni tests indicated that within this particular age group, 12-month abstainers trended towards lower scores than those who binge between once per month and once per week ($p = .006$). There were no significant differences in REYII scores between those who binge at higher frequencies.

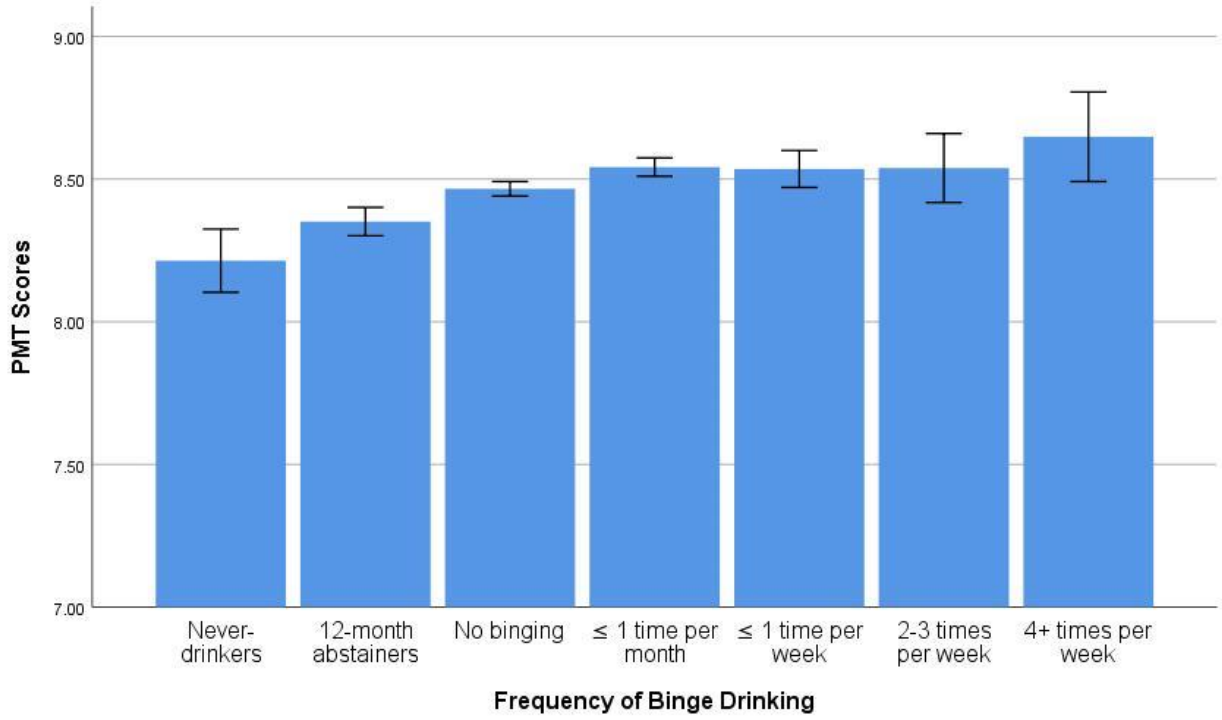
Binge Frequency and Prospective Memory.

Mean PMT scores as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on PMT scores, $F(6, 23674) = 11.857$, $p < .001$ ($\eta_p^2 = .003$; Table 18). Post-hoc tests showed no significant difference between never-drinkers and 12-month abstainers. Never-drinkers had lower scores than those who drink but do not binge and those who report binge drinking at any frequency (all $p < .001$). Twelve-month abstainers had lower scores than those who drink but do not binge ($p < .001$), those who binge up to once a week ($p < .001$), and those who binge 4+ times per week ($p = .006$). Those who drink but do not binge trended towards lower scores than those who binge less than once a month ($p = .005$). For those who engage in binge-drinking there were no differences in PMT scores among binge drinkers at any level (Figure 36). As indicated in Appendix I1 (without the inclusion of alcohol use variables), the physical function covariate had the strongest relationship with PMT scores, and thus higher physical functioning in binge-drinkers may account for the positive relationship between binge-drinking and PMT scores.

To investigate whether the effects of Binge frequency on PMT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 19. With covariates included, there were no interactions between binge drinking, age, and sex.

Figure 36

Main Effect of Binge Drinking Frequency on Prospective Memory Test Scores



Note. Mean PMT scores differed significantly by levels of Binge Frequency, such that higher frequencies of binge drinking are generally associated with higher scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Binge Frequency and Semantic Verbal Fluency (Animal Fluency Test).

Mean scores for the Animal Fluency Test as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on AFT scores, $F(6, 23315) = 14.768$, $p < .001$ ($\eta_p^2 = .004$; Table 18). Post-hoc Bonferroni tests indicated that never-drinkers had lower scores than 12-month abstainers ($p < .001$), those who drink without binging ($p < .001$), those who binge up to once per week ($p < .001$), and trended towards significance for lower test scores than those who drink 2-3 times per week ($p = .008$), and 4+ times per week ($p = .006$). Twelve-month abstainers had lower scores compared to those who drink without binging ($p = .002$) as well as those who binge up to once a week ($p < .001$). The non-binging drinking group trended towards lower scores than those who binge up to once a month ($p = .002$). There were no differences among the higher binge frequency groups (i.e., those binging less than or equal to once a week up to four or more times per week; Figure 37).

Follow-up analyses that include additional physical, social, and personality covariates were conducted. The main effect of Binge on AFT scores was no longer significant after controlling for these covariates, $F(6, 10129) = 3.313$, $p = .003$ ($\eta_p^2 = .002$; Table H3).

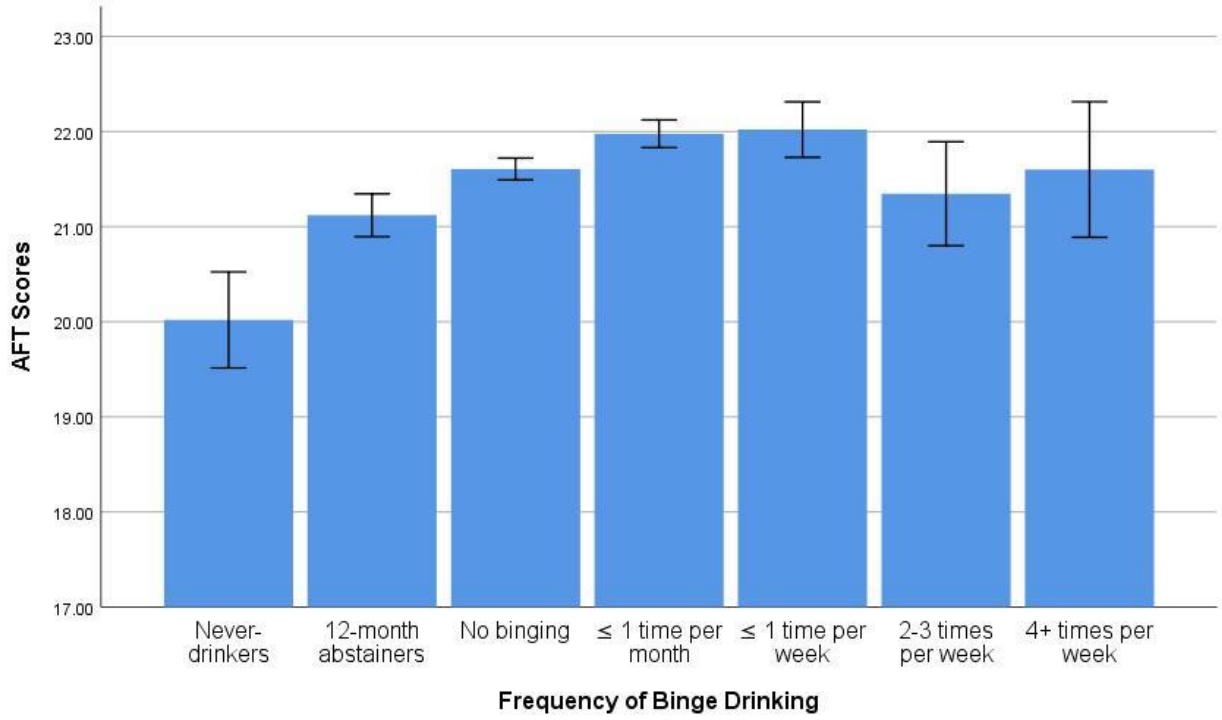
To investigate whether the effects of Binge frequency on AFT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 20. There were no significant interaction terms.

Binge Frequency and Phonemic Verbal Fluency (COWA).

Mean COWA scores as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on COWA scores, $F(6, 23041) = 16.470$, $p < .001$ ($\eta_p^2 = .004$; Table 18).

Figure 37

Main Effect of Binge Frequency on Animal Fluency Test Scores



Note. Mean AFT scores differed significantly by levels of Binge Frequency, such that non-binging groups have lower scores than those that binge at the lower frequencies. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Table 20

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Binge Frequency for Verbal Fluency Task Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
AFT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	30.149	6, 26347	< .001	.007	3.333	6, 11275	.003	.002
Binge x Age	1.764	18, 26347	.024	.001	.838	18, 11275	.656	.001
Binge x Sex	1.506	6, 26347	.172	.000	.603	6, 11275	.728	.000
Binge x Age x Sex	.673	18, 26347	.842	.000	.647	18, 11275	.865	.001
COWA	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	21.789	6, 26058	< .001	.005	2.846	6, 11196	.021	.001
Binge x Age	1.146	18, 26056	.299	.001	.891	18, 11196	.589	.001
Binge x Sex	.927	6, 26058	.474	.000	.626	6, 11196	.710	.000
Binge x Age x Sex	.799	18, 26058	.703	.001	.512	18, 11196	.955	.001

Note: AFT = Animal Naming Test; COWA = Controlled Oral Word Association

Post-hoc Bonferroni tests indicated no difference between never-drinkers, 12-month abstainers, and those who drink but have not binged in the last 12 months. However, never-drinkers had lower scores than those who binge up to once a month ($p = .001$), up to once a week ($p < .001$), 2-3 times per week ($p = .004$), and 4+ times per week ($p < .001$). Twelve-month abstainers had lower scores than those who binge up to once a month to once a week ($p < .001$), 2-3 times per week ($p = .003$), and 4+ times per week ($p < .001$). Those who drink without binging had lower scores than groups who binge once a month to once a week ($p < .001$), as well as 4+ times per week ($p < .001$). There were no differences between groups who binge drink at any level (i.e., once a month or more; Figure 38).

Follow-up analyses that included the additional physical, social, and personality covariates were conducted. The main effect of Binge Frequency on COWA scores was no longer significant, $F(6, 10057) = 3.497$, $p = .002$ ($\eta_p^2 = .002$; Table H3).

To investigate whether the effects of binge frequency on AFT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 20. There were no significant interaction effects.

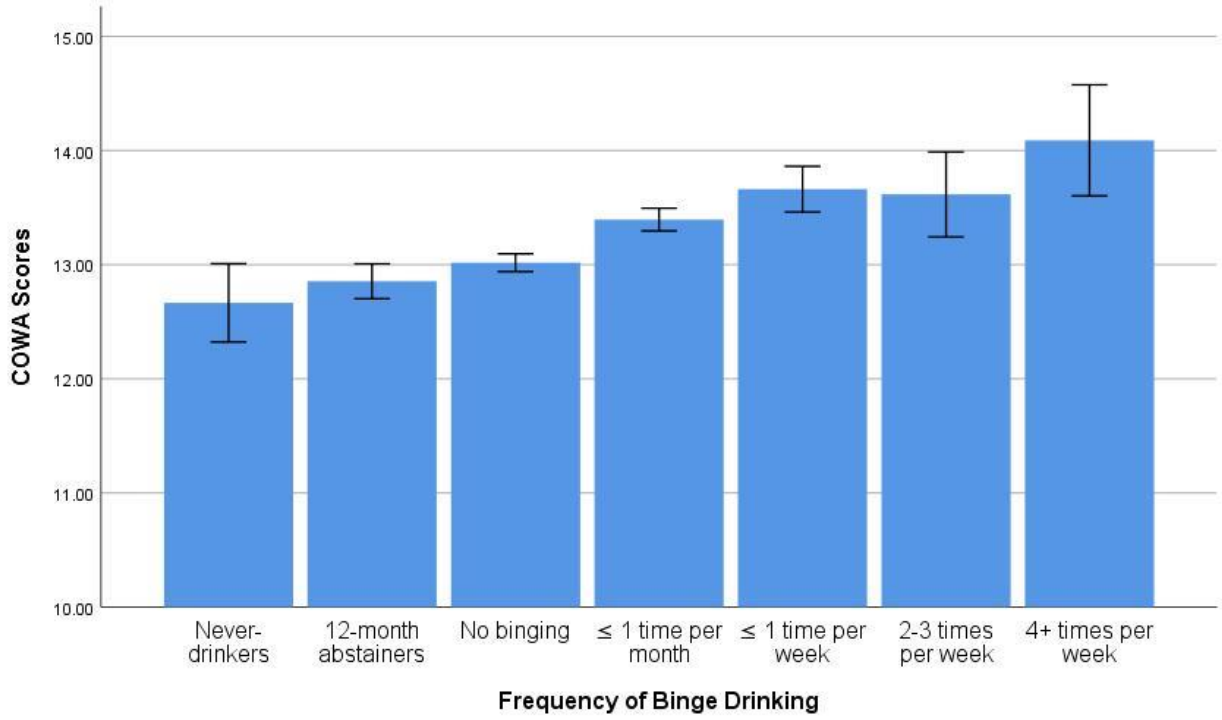
Binge Frequency and Stroop Scores

Mean Stroop time and error scores as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on the Stroop Time scores, $F(6, 23563) = 13.535$, $p < .001$ ($\eta_p^2 = .003$; Table 18), and Stroop Error scores, $F(6, 23438) = 4.308$, $p < .001$ ($\eta_p^2 = .001$) when covariates were included (Table 21).

For the Stroop Time scores, post-hoc Bonferroni tests showed no difference between either group of non-drinkers. Never-drinkers had higher/slower Stroop times than those who

Figure 38

Main Effect of Binge Drinking Frequency on COWA Scores



Note. Mean scores for the Controlled Oral Word Association Test (COWA) differ significantly by levels of Binge Frequency. Higher frequencies of binge drinking were generally associated with higher verbal fluency scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 21

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Binge Frequency for Attention/Executive Function Tasks (Stroop, MAT, and CRT)

	No covariates				Covariates = education, HI, language, physical function, social composite			
Stroop Time	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	25.139	6, 26637	< .001	.021	3.232	6, 11447	.004	.002
Binge x Age	1.825	18, 26637	.017	.001	1.074	18, 11447	.372	.002
Binge x Sex	1.000	6, 26637	.423	.000	.382	6, 11447	.891	.000
Binge x Age x Sex	1.146	18, 26637	.299	.001	.285	18, 11447	.999	.000
Stroop Error	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	9.482	6, 26515	< .001	.002	1.045	6, 11402	.393	.001
Binge x Age	1.391	18, 26515	.124	.001	1.012	18, 11402	.442	.002
Binge x Sex	.294	6, 26515	.940	.000	.966	6, 11402	.446	.001
Binge x Age x Sex	.686	18, 26515	.829	.000	.425	18, 11402	.983	.001
MAT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	15.097	6, 25671	< .001	.004	1.769	6, 11003	.101	.001
Binge x Age	.719	18, 25671	.795	.001	.999	18, 11003	.457	.002
Binge x Sex	1.184	6, 25671	.092	.000	1.472	6, 11003	.183	.001
Binge x Age x Sex	1.017	18, 25671	.436	.001	.811	18, 11003	.690	.001
CRT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge Frequency (Binge)	8.375	6, 26614	< .001	.002	.338	6, 11445	.917	.000
Binge x Age	.742	18, 26614	.770	.001	.610	18, 11445	.895	.001
Binge x Sex	.582	6, 26614	.745	.000	.549	6, 11445	.990	.000
Binge x Age x Sex	.883	18, 26614	.600	.001	.666	18, 11445	.847	.001

Note. MAT = Mental Alternation Test; CRT = Choice Reaction Time

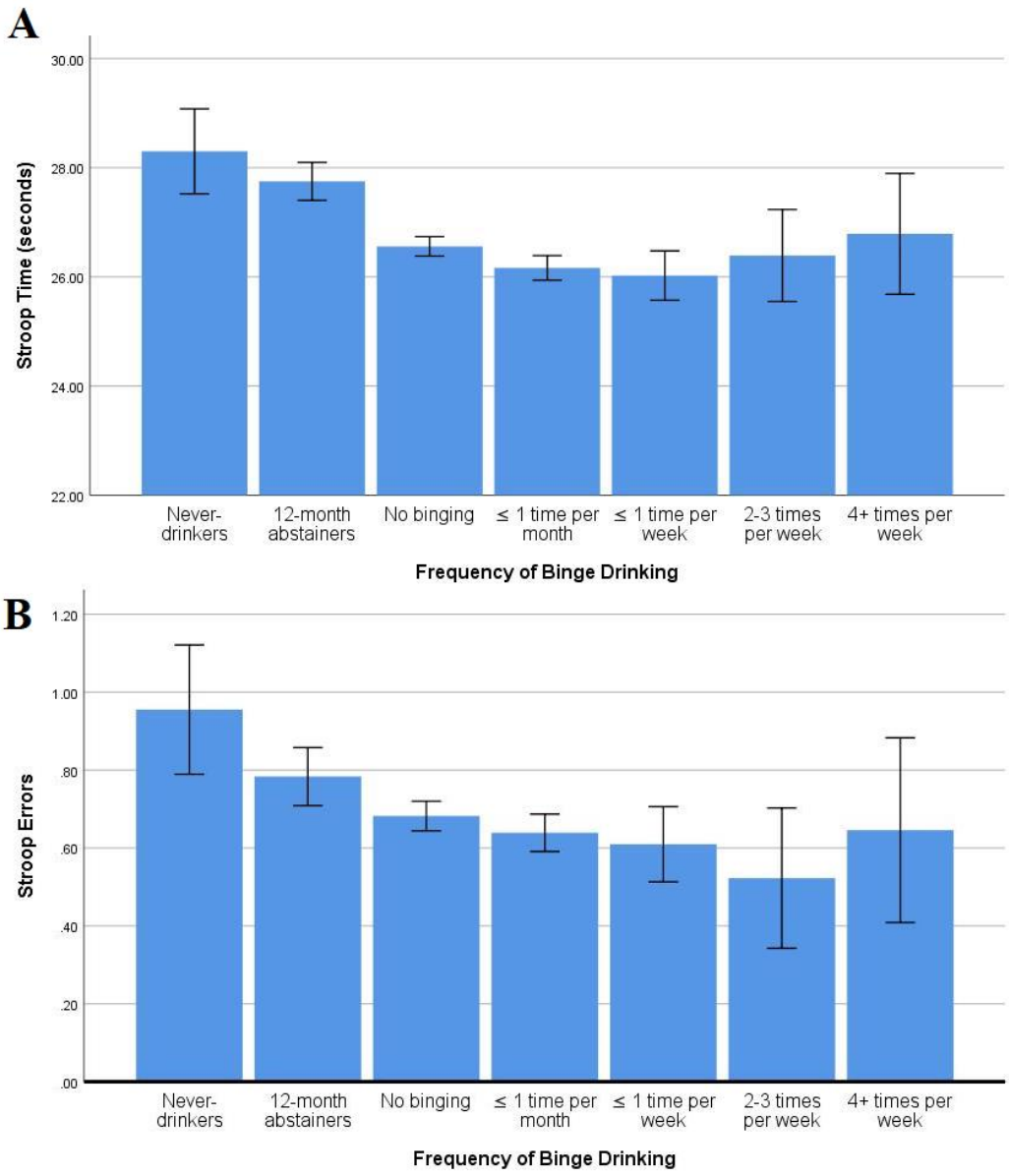
drink but do not binge, as well as those who binge up to once a month and once a week ($p <$ .001). Twelve-month abstainers had slower times than those who drink without binging and also those who binge up to once a month or once a week (both $p <$.001). There were no significant differences in performance between those who drink without binging and those who binge at any frequency (all $p >$ .001; Figure 39). For Stroop Errors, post-hoc tests also indicated no significant difference between non-drinkers. Never-drinkers trended towards more errors than those who binge up to once a month (p = .006), once a week (p = .007), and 2-3 times per week (p = .009). There were no significant differences among other groups. The relationship between binge frequency and both Stroop scores is illustrated in Figure 39 and Appendix G3.

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge drinking on Stroop Time scores remained significant, $F(6, 10271) = 4.844$, $p < .001$ ($\eta_p^2 = .003$; Appendix H3), suggesting that these covariates could not fully explain or account for the effect. The effect of binge frequency on Stroop Errors was no longer significant with the additional covariates added, $F(6,10233) = 0.910$, $p = .486$ ($\eta_p^2 =$ .001). This may be due to the association between physical function and Stroop Errors ($\eta_p^2 =$ .029; see Appendix I3 for the main effect of the physical function covariate without the influence of alcohol use).

To investigate whether the effects of Binge frequency on Stroop scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 21. There were no significant interaction effects with or without the covariates, so further analyses were not pursued.

Figure 39

Main Effects of Binge Drinking Frequency on Stroop Time and Error Scores



Note. Alcohol use without binge-drinking as well as binge drinking up to two to three times per week were associated with improved Stroop time and Stroop Error scores as compared to non-drinkers ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Binge Frequency and MAT.

The mean scores of MAT as a function of Binge Frequency are shown in Appendix G (Table G3). There was a significant main effect of Binge Frequency on MAT scores, $F(6, 22744) = 4.870$, $p < .001$ ($\eta_p^2 = .001$; Table 18). Post-hoc Bonferroni tests indicated no difference between never-drinkers and 12-month abstainers. Never-drinkers had lower MAT scores than those who drink without binging ($p < .001$), binge less than once a month ($p < .001$), and binge 4+ times per week (p = .003). There were no differences between any other groups (Figure 40).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge Frequency on MAT scores was no longer significant, $F(6, 9890) = 2.849$, $p = .009$ ($\eta_p^2 = .002$; Appendix H3). The added covariate of physical functioning had a medium effect sizes on MAT scores (see Appendix I3).

To investigate whether the effects of binge frequency on MAT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction effects. The results are shown in Table 21. There were no significant interaction effects.

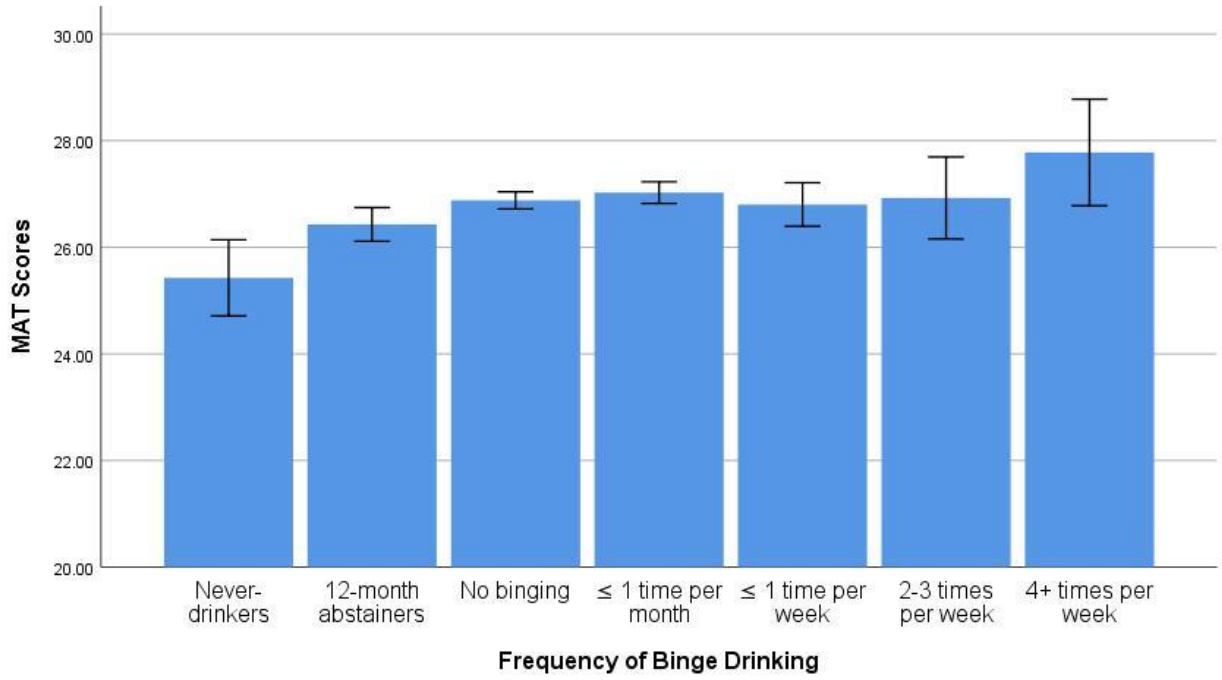
Binge Frequency and Choice Reaction Time (CRT).

There was a significant main effect of Binge Frequency on CRT scores, $F(6, 23526) = 3.898$, $p < .001$ ($\eta_p^2 = .001$; Table 18). Post-hoc Bonferroni tests indicated no differences between never- drinkers, 12-month abstainers, and those who drink without binging. Never-drinkers trended towards slower reaction time scores than those who binge up to once a month ($p = .006$). There were no differences between other groups (see the figure in Appendix K4).

In follow-up analyses with additional covariates included to explore reasons for the effect, the main effect of Binge frequency on CRT scores was no longer significant,

Figure 40

Main Effect of Binge Drinking Frequency on MAT Scores



Note. Alcohol use (including binge-drinking) was associated with improved Mental Alternation Test (MAT) scores when compared to never-drinkers ($p < .001$). There was no evidence of an adverse effect of binge-drinking on MAT scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

$F(6, 20271) = .477$, $p = .826$ ($\eta_p^2 = < .001$; Table H3). Given that physical functioning was a significant covariate, the loss of significance may be due to the medium size effect of physical function on CRT scores independent of alcohol ($\eta_p^2 = .074$; Appendix I3).

To investigate whether the effects of binge frequency on choice reaction time scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 21. There were no significant interaction effects with or without covariates.

Alcohol Use History

Alcohol History and the Global Cognitive Composite Score.

Mean scores for Global Cognition as a function of Alcohol Use History are shown in Appendix G (Table G4). When covariates were included, the main effect of alcohol history on the Global Cognitive Composite was significant, $F(5,11794) = 18.595$, $p < .001$ ($\eta_p^2 = .008$; Table 8). Post-hoc tests show that higher levels of Alcohol History were generally associated with higher Global Cognition scores ($p < 0.001$ to $p = .007$) although scores did not improve between the "moderate" and "high" history groups, and the "very high" group did not differ from any of the other groups (Figure 41).

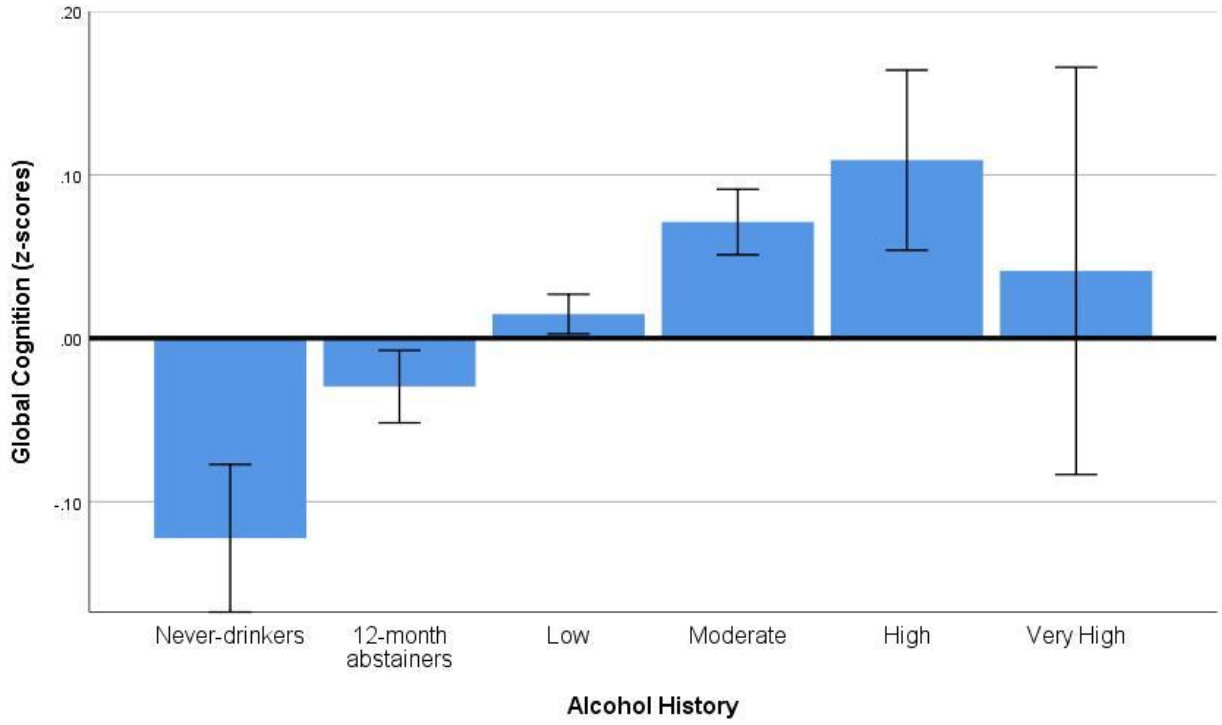
When the first set of covariates were included, Alcohol History produced a significant main effect on each of the individual cognitive test scores ($p < .001$; Table 22) with the exception of CRT scores ($p = .193$). The relationship between Alcohol History and each of these tests is examined in more detail below.

Alcohol History and REYI.

Mean scores for REYI as a function of Alcohol Use History are shown in Appendix G (Table G4). There was a significant main effect of Alcohol History on REYI scores, $F(5, 12870) = 5.555$, $p < .001$ ($\eta_p^2 = .002$; Table 22). Post-hoc tests showed no significant difference between

Figure 41

Main Effect of Alcohol Use History on Global Cognitive Composite Scores



Note. Mean Global Cognitive composite scores differ significantly by levels of Alcohol Use History, such that a higher history of alcohol consumption is associated with significantly higher cognitive test scores up to the moderate level group. Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 22

ANOVA/ANCOVA Table: Effect of Alcohol Use History on the Nine Individual Cognitive Test Scores

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	21.896	5, 14668	< .001	.007	5.555	5, 12870	< .001	.002
REY II	26.298	5, 14640	< .001	.009	7.128	5, 12852	< .001	.003
PMT	18.090	5, 15030	< .001	.006	7.707	5, 13164	< .001	.003
AFT	34.731	5, 14812	< .001	.012	10.570	5, 12981	< .001	.004
COWA	30.731	5, 14648	< .001	.010	13.422	5, 12832	< .001	.005
Stroop Time	29.127	5, 14942	< .001	.010	8.348	5, 13076	< .001	.003
Stroop Errors	15.854	5, 14882	< .001	.005	4.299	5, 13030	.001	.002
MAT	30.184	5, 14414	< .001	.010	5.708	5, 12673	< .001	.002
CRT	10.948	5, 14947	< .001	.004	1.478	5, 1303	.193	.001

never-drinkers and any other group. Twelve-month abstainers had lower test scores than those with a low history of alcohol use (p = .002) and moderate alcohol use (p <.001) but not with individuals with high or very high alcohol use history. There were no significant differences between groups who reported consuming any level of alcohol (see Figure 42).

In follow-up analyses with the additional covariates, the main effect of Alcohol History on REYI scores was no longer significant, $F(6, 20271) = 0.905$, $p = .477$ ($\eta_p^2 = .001$; Appendix H4). This may be due to associations between physical function, social function, extraversion, and openness to experience covariates and REYI scores (small effect sizes; Appendix I1).

To investigate whether the effect of Alcohol History on REYI scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 23. There were no significant interaction effects with or without covariates.

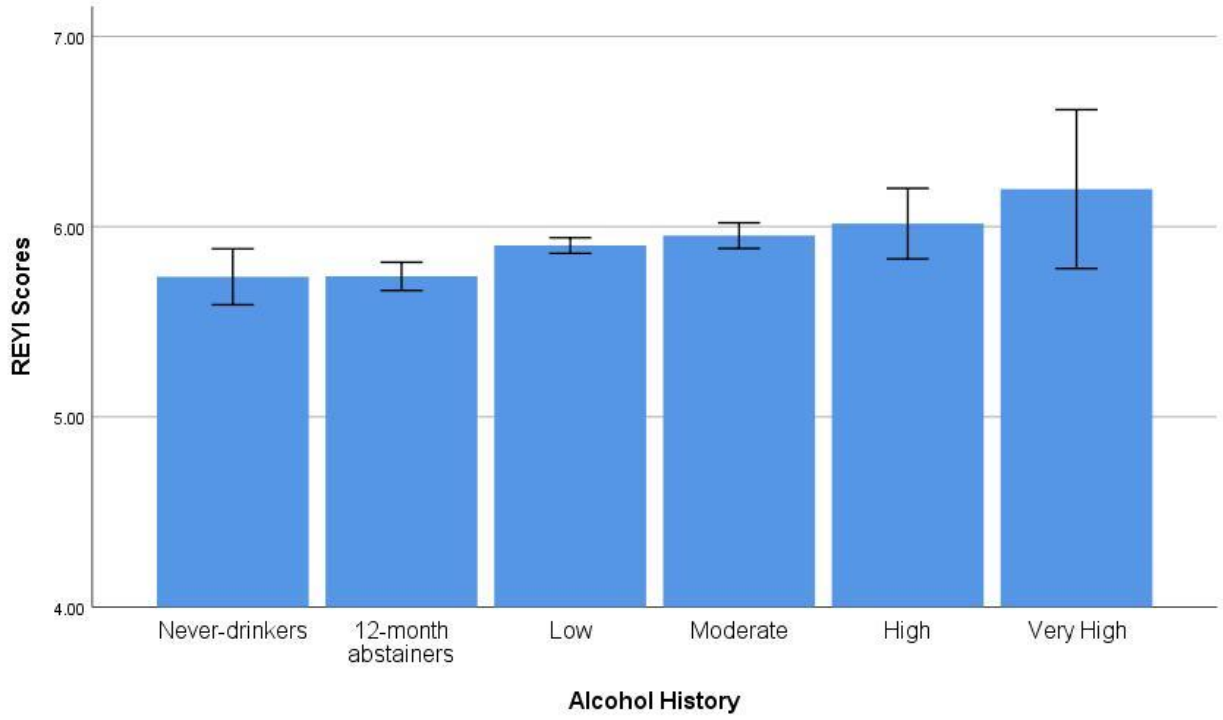
Alcohol History and REY II.

Mean scores for REYII as a function of Alcohol Use History are shown in Appendix G (Table G4). There was a significant main effect of Alcohol History on REY II scores with the primary covariates (i.e., age, sex, education, HI, language, and number of chronic conditions), $F(5, 12852) = 7.128$, $p < .001$ ($\eta_p^2 = .003$; Table 22). Post-hoc tests showed no significant difference between never-drinkers and 12-month abstainers. However, never-drinkers trended towards lower scores than those with low (p = .006) and moderate (p = .002) histories. Twelve-month abstainers had lower scores than low and moderate groups as well (both $p < .001$). There were no differences in the delayed memory scores between low, moderate, high, or very high alcohol history groups (Figure 43).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Alcohol History on REYII scores was no longer significant

Figure 42

Main Effect of Alcohol Use History on Immediate Recall Scores



Note. Scores on the immediate recall trial of the Rey Auditory Verbal Learning Test (REYI) varied as a function of Alcohol History. Twelve-month abstainers had lower scores than those in the "moderate" group. Definitions of low, moderate, high, and very high Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

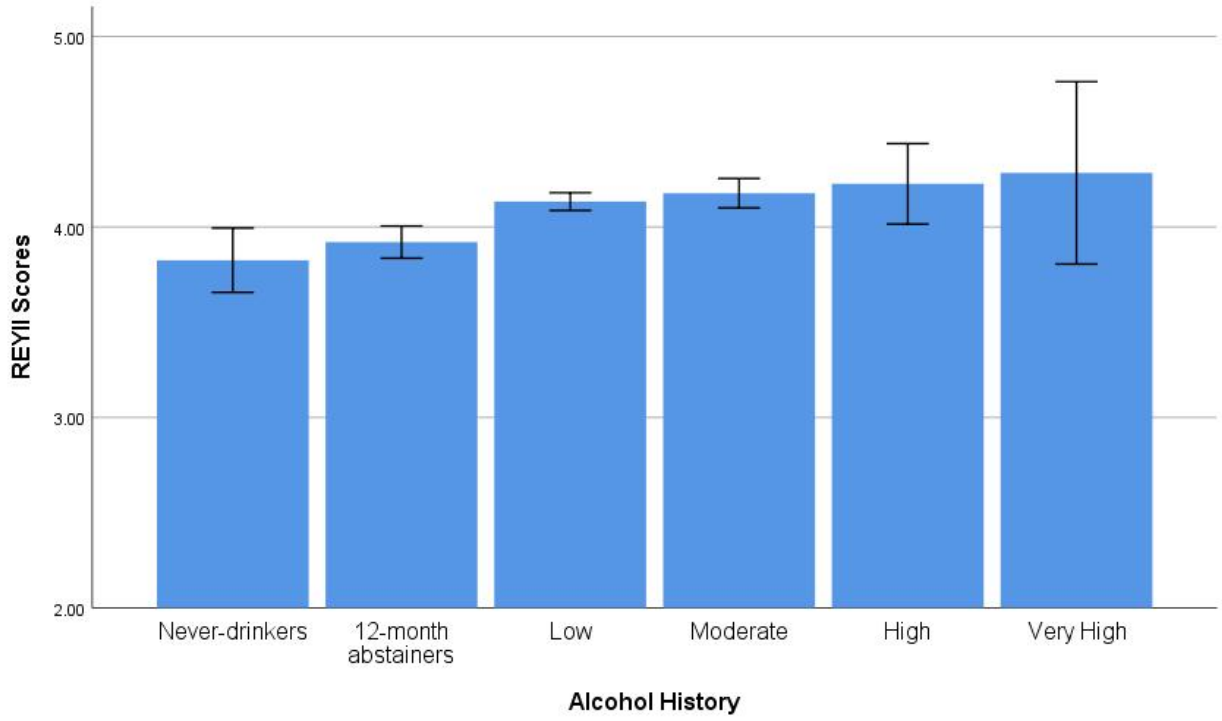
Table 23

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Alcohol Use History on Memory Test Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REYI	History (HIS)	16.700	4, 13634	< .001	.005	2.489	4, 6369	< .041	.002
	HIS x Age	1.324	12, 14643	.197	.001	.679	12, 6369	.773	.001
	HIS x Sex	.560	4, 14634	.692	< .001	2.778	4, 6369	.025	.002
	HIS x Age x Sex	1.904	12, 14634	.029	.002	2.197	12, 6369	.010	.004
REYII	History (HIS)	20.546	4, 14606	< .001	.006	4.163	4, 6362	.002	.003
	HIS x Age	2.307	12, 14606	.006	.002	1.284	12, 6362	.220	.002
	HIS x Sex	1.687	4, 14606	.150	< .001	1.900	4, 6362	.108	.001
	HIS x Age x Sex	1.369	12, 14606	.173	.001	1.134	12, 6362	.326	.002
PMT	History (HIS)	11.716	4, 14996	< .001	.003	.427	4, 6545	.789	< .001
	HIS x Age	3.183	12, 14996	< .001	.003	.864	12, 6545	.583	.002
	HIS x Sex	.746	4, 14996	.561	< .001	.228	4, 6545	.923	< .001
	HIS x Age x Sex	1.046	12, 14996	.403	.001	.683	12, 6545	.770	.001

Figure 43

Main Effect of Alcohol Use History on Delayed Recall Scores



Note. Scores on the delayed recall trial of the Rey Auditory Verbal Learning Test (REYII) varied as a function of Alcohol History. Twelve-month abstainers had lower scores than the "low" and "low moderate" levels. Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

with the added covariates, $F(5, 5718) = 1.493$, $p = .189$ ($\eta_p^2 = .001$; Table H4), likely largely due to the effect of physical functioning on REYII scores ($\eta_p^2 = .031$; see Appendix I1).

To investigate whether the effects of Alcohol History on REYII scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 23. There were no significant interaction effects in the ANCOVAs with covariates included, and no further analyses were conducted.

Alcohol Use History and Prospective Memory.

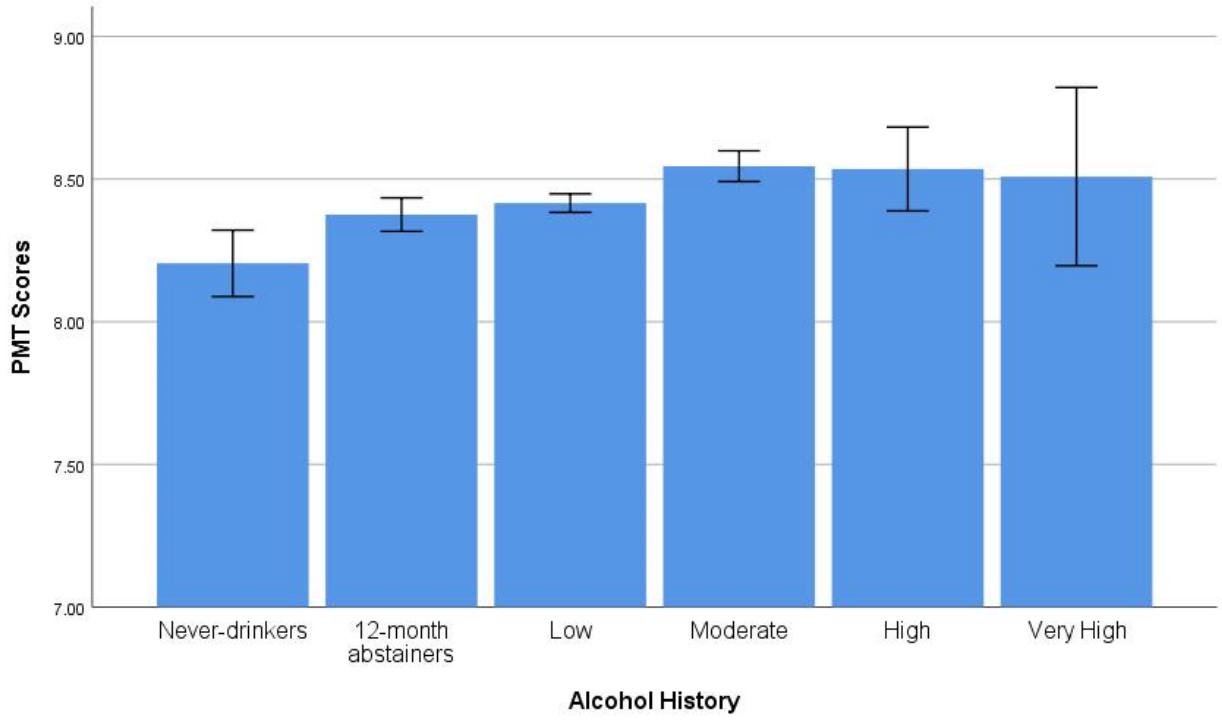
Mean scores for PMT as a function of Alcohol Use History are shown in Appendix G (Table G4). There was a significant main effect of Alcohol History on PMT scores with the primary covariates included, $F(5, 13164) = 7.707$, $p < .001$ ($\eta_p^2 = .003$; Table 22). Post-hoc tests showed no significant difference between never-drinkers and 12-month abstainers. Never-drinkers had lower scores than those with low ($p = .007$), moderate ($p < .001$), and high ($p = .006$) alcohol use histories. Twelve-month abstainers had lower scores than those with moderate alcohol use histories ($p < . 001$). Low alcohol use history was associated with lower scores than the moderate history group ($p = .001$). There were no significant differences between moderate and higher history groups (see Figure 44).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Alcohol Use History on PMT scores was no longer significant with the added covariates, $F(5, 5878) = 0.519$, $p = .762$ ($\eta_p^2 = .000$; Table H4), likely partly due to the relationship between physical functioning and REYII scores ($\eta_p^2 = .031$; shown in Appendix I1 without inclusion of alcohol use variables).

To investigate whether the effects of Alcohol History on PMT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in

Figure 44

Main Effect of Alcohol Use History on Prospective Memory Test Scores



Note. PMT scores vary as a function of Alcohol Use History. Never-drinkers, 12-month abstainers, and those with a low alcohol history have lower scores than those with a "moderate" history ($p < .001$). Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 23. While there was an age X alcohol history effect on PMT scores, it disappeared when covariates were added, and there were no other significant interaction effects. No further analyses were conducted.

Alcohol Use History and Semantic Verbal Fluency (Animal Fluency Task).

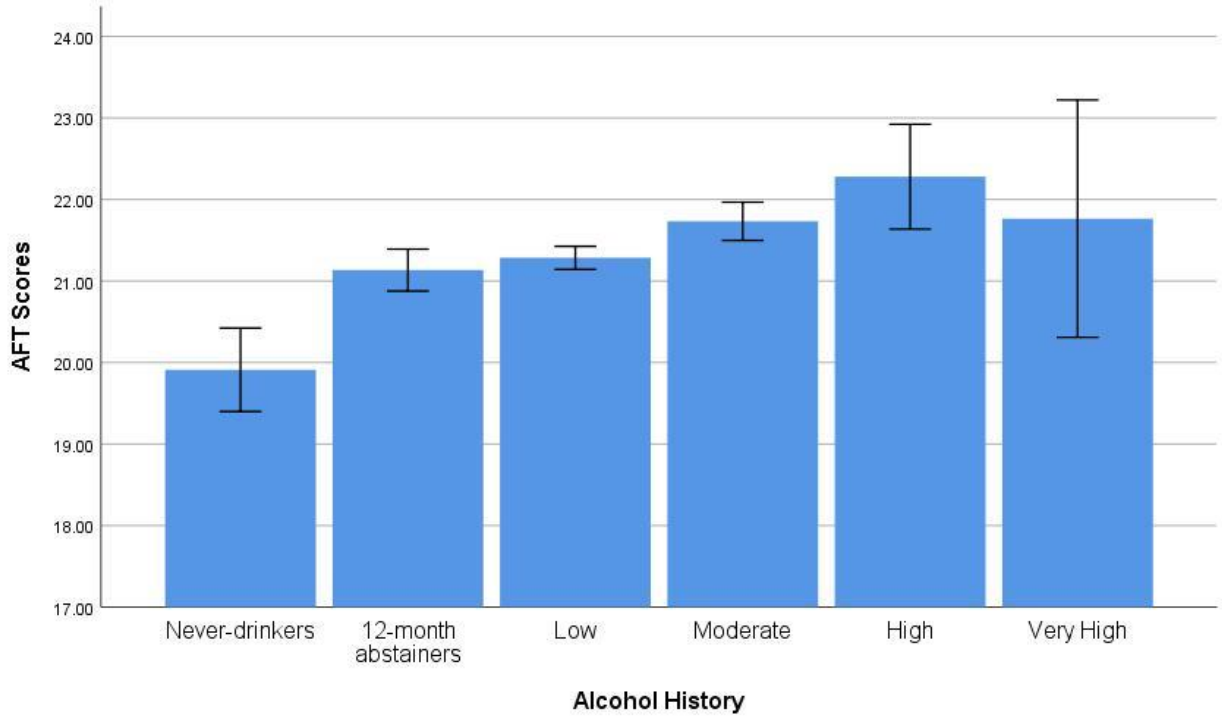
Mean scores for AFT as a function of Alcohol Use History are available in Appendix G (Table G4). There was a significant main effect of Alcohol History on AFT scores, $F(5, 12981) = 10.570$, $p < .001$, even when the covariates were included ($\eta_p^2 = .004$; Table 22). Post-hoc tests showed a significant difference between never-drinkers and 12-month abstainers, as well as between never drinkers and all levels of alcohol history except the very high group ($p < .001$). Twelve-month abstainers trended towards lower scores than those with a moderate history ($p = .010$) and there were no differences in the effect of alcohol history on AFT scores between any alcohol use history groups among those who have drank in the last 12 months (see Figure 45).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of alcohol use history on AFT scores remained significant with the added covariates, $F(5, 5780) = 4.120$, $p = .001$ ($\eta_p^2 = .004$; Table H4), suggesting that the medium effect of physical functioning on AFT scores ($\eta_p^2 = .093$) could not fully explain or account for the main effect (Appendix I2).

To investigate whether the effects of Alcohol Use History on AFT scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 24. There were no significant interaction effects either with or without covariates, and no further analyses were conducted.

Figure 45

Main Effect of Alcohol Use History on Animal Fluency Test Scores



Note. Animal Fluency Test (AFT) scores vary as a function of Alcohol History. Never-drinkers had lower scores than all other groups ($p < .001$). Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 24

Interactions Between Age, Sex, and Alcohol Use History on Verbal Fluency Test Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
AFT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	23.978	4, 14778	< .001	.006	2.953	4, 6435	.019	.002
History x Age	1.794	12, 14778	.043	.001	.474	12, 6435	.931	.001
History x Sex	1.145	4, 14778	.333	.000	.394	4, 6435	.813	.000
History x Age x Sex	1.136	12, 14778	.325	.001	.421	12, 6435	.956	.001
COWA	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	24.806	4, 14614	< .001	.007	4.227	4, 6386	.002	.003
History x Age	.857	12, 14614	.591	.001	.326	12, 6386	.985	.001
History x Sex	1.235	4, 14614	.294	.000	.922	4, 6386	.450	.001
History x Age x Sex	.622	12, 14614	.826	.001	.455	12, 6386	.941	.001

Note. Verbal fluency test scores included the Animal Naming Test (AFT) and the Controlled Oral Word Association Test (COWA).

Alcohol Use History and Phonemic Verbal Fluency (COWA).

Mean COWA scores as a function of Alcohol Use History are shown in Appendix G (Table G4). There was a significant main effect of Alcohol Use History on AFT scores with the primary covariates included, $F(5, 12832) = 13.422$, $p < .001$ ($\eta_p^2 = .005$; Table 22). Post-hoc tests showed significant differences between never-drinkers, 12-month abstainers, and those with a low level of alcohol use history (all $p < .001$). Never-drinkers also had lower scores than those with moderate or high alcohol histories ($p < .001$), 12-month abstainers had lower scores than moderate or high groups ($p < .001$), and the low level History group had lower scores than moderate or high groups (both $p < .001$). There were no differences among moderate, high, or very high levels of alcohol use history (see Figure 46).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of alcohol use History on COWA scores remained significant with the added covariates, $F(5, 5743) = 6.724$, $p < .001$ ($\eta_p^2 = .006$; Table H4). This suggested that the covariates could neither explain nor fully account for the main effect despite all seven of them having a significant association with COWA scores (see Appendix I2 for the influence of these covariates without the inclusion of alcohol use variables).

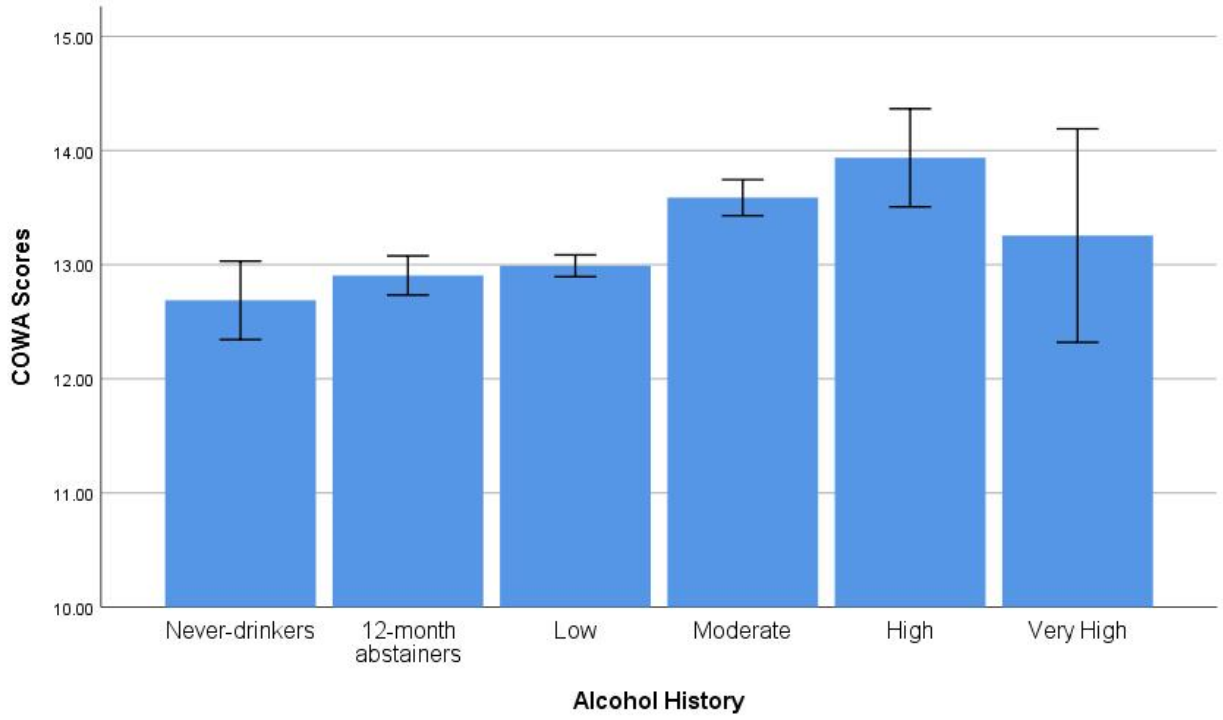
To investigate whether the effects of Alcohol History on COWA scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 24. There were no significant interaction effects either with or without covariates, and no further analyses were conducted.

Alcohol Use History and Stroop Scores

Mean Stroop time and error scores as a function of Alcohol Use History are shown in Appendix G4). There was a significant main effect of Alcohol History on the Stroop Time

Figure 46

Main Effect of Alcohol Use History on Controlled Oral Word Association (COWA) Scores



Note. Alcohol Use History had an effect on COWA scores. Non-drinkers have a lower score than those with a moderate or high alcohol use history (all $p < .001$) and those in the low history group had lower scores than the moderate and high groups (both $p < .001$). Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

scores, $F(5, 13076) = 8.348$, $p < .001$ ($\eta_p^2 = .003$; Table 22), and Stroop Error scores, $F(5, 13030) = 4.299$, $p < .001$ ($\eta_p^2 = .002$) when covariates were included. For the Stroop Time scores, post-hoc Bonferroni tests showed no difference between the two groups of non-drinkers. Never-drinkers had higher/slower Stroop times than those with low ($p = .004$), moderate ($p < .001$), and high ($p < .009$) alcohol use histories. Twelve-month abstainers had slower Stroop completion times than those with low and moderate histories ($p < .001$). There were no differences in Stroop time scores between the four current drinker groups (i.e., low, moderate, high, and very high; see Figure 47). For Stroop Errors, post-hoc tests also indicated no significant difference between never drinkers, 12-month abstainers, or those with a low alcohol use history. While never-drinkers made more errors than those with moderate ($p = .006$) or high ($p = .003$) alcohol use histories, no other groups differed (see Figure 47; Appendix G4).

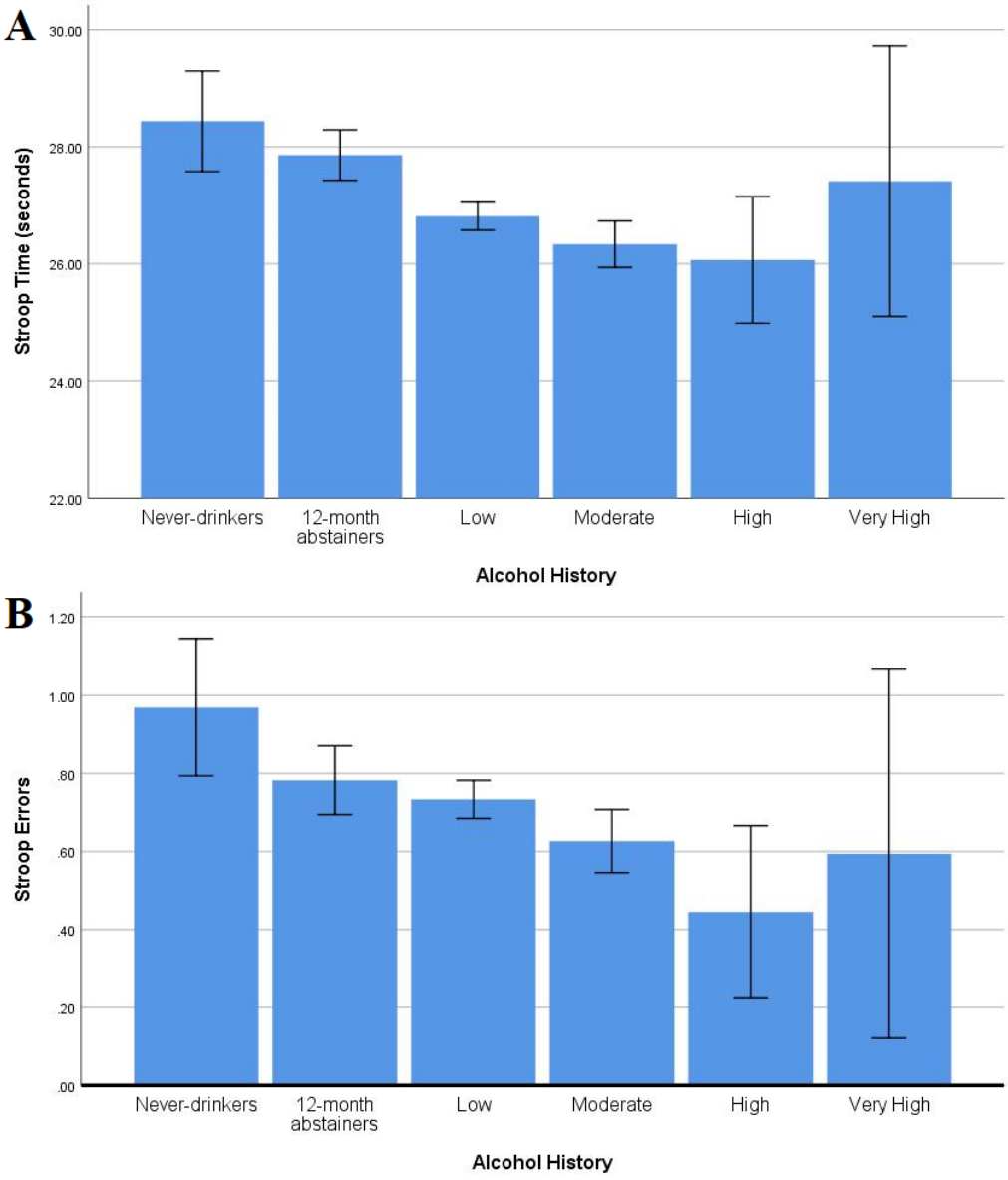
Follow-up analyses that included additional physical, social, and personality covariates were conducted to examine if these variables could help explain or account for the main effect The main effect of Alcohol Use History on Stroop time scores remained significant with the added covariates, $F(5, 5854) = 6.132$, $p < .001$ ($\eta_p^2 = .005$; Table H4) even though the covariates of agreeableness and physical function also had a main effect.

The main effect of Alcohol History on Stroop Errors was no longer significant with the added covariates, $F(5, 5839) = 1.704$, $p = .130$ ($\eta_p^2 = .001$). This suggests that physical function (small effect size effect on Stroop Errors), and both extraversion and openness to experience (both very small effect size associations with Stroop Errors) partly explain or account for the relationship between alcohol use history and errors on the Stroop test (Appendix I3).

To investigate whether the effects of Alcohol Use History on Stroop Time and Error scores differed based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The

Figure 47

Main Effect of Alcohol Use History on Stroop Time and Error Scores



Note. **A.** For Stroop Time, never-drinkers had slower (i.e., worse) scores than those with a moderate alcohol use history. Twelve-month abstainers had slower scores than those with both low and moderate histories ($p < .001$). **B.** For Stroop Errors, there are no significant differences between groups. Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use.. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

results are shown in Table 25. There were no significant interaction effects for the time scores or errors, and no further analyses were conducted.

Alcohol Use History and Mental Alternation Test Scores.

Mean scores for the MAT as a function of Alcohol Use History are shown in Appendix G (Table G4). There was a significant main effect of Alcohol History on MAT scores, $F(5, 12673) = 5.708$, $p < .001$, ($\eta_p^2 = .002$; Table 22). Post-hoc Bonferroni tests indicated no differences between never-drinkers, 12-month abstainers, and those with histories of low-level alcohol use (all $p > .001$) However, never-drinkers had lower scores than those with a moderate history ($p < .001$). The low history group trended towards lower scores than the moderate group ($p = .007$), and there were no differences between the moderate, high, and very high alcohol use history groups (see Figure 48).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Alcohol History on MAT scores was no longer significant with the added covariates, $F(5, 5630) = 3.868$ $p = .002$ ($\eta_p^2 = .003$; Table H4).

To investigate whether the effect of Alcohol History on MAT scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 25. There were no significant interaction effects and no further analyses were conducted.

Alcohol Use History and Choice Reaction Time (CRT).

Mean CRT scores as a function of Alcohol Use History are shown in Appendix G (Table G4). Alcohol use history was not associated with CRT scores when the main covariates were included, $F(5, 1303) = 1.478$, $p = .193$ ($\eta_p^2 = .001$; Table 22). Due to the lack of any main effect, follow-up analyses were not conducted (see Appendix K; Figure K5).

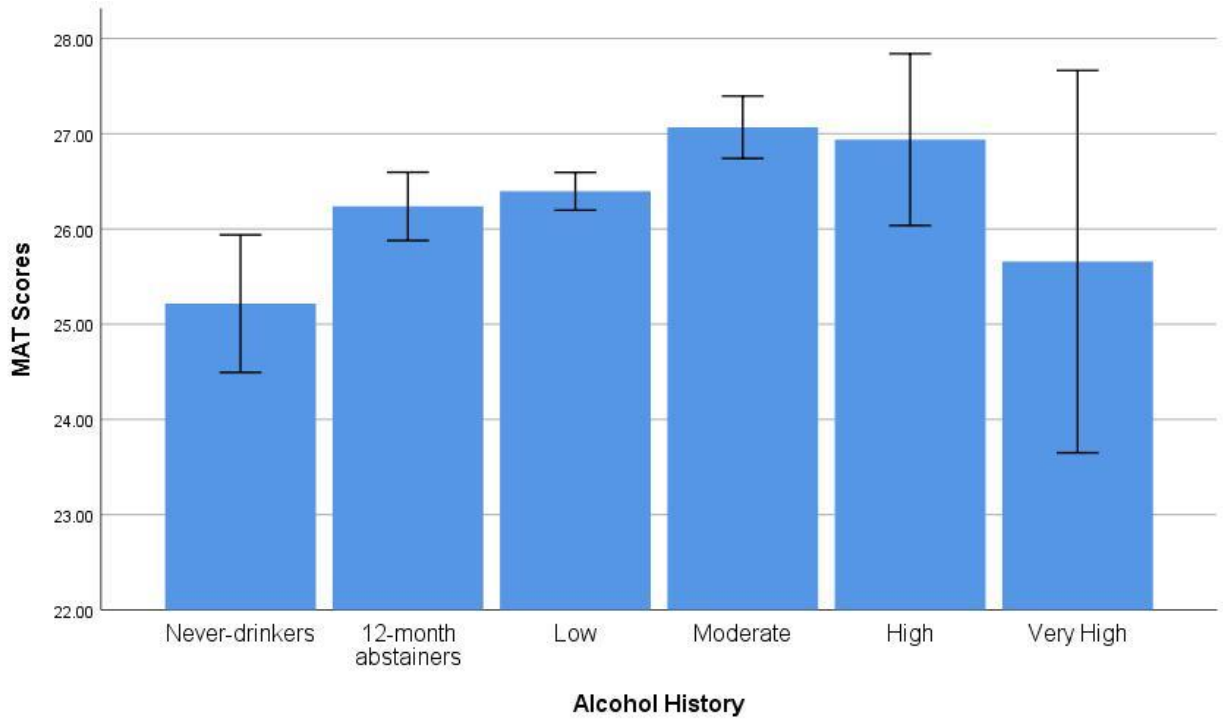
Table 25

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Alcohol Use History for Stroop, MAT, and CRT Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
Stroop Time	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	15.044	5, 14901	<.001	.005	1.779	5, 6515	.114	.001
History x Age	1.082	15, 14901	.367	.001	.342	15, 6515	.991	< .001
History x Sex	.226	5, 14901	.951	< .001	.198	5, 6515	.963	< .001
History x Age x Sex	.752	14, 14901	.723	.001	.238	14, 6515	.998	< .001
Stroop Error	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	9.302	4, 14848	< .001	.002	.652	4, 6502	.625	.000
History x Age	1.792	12, 14848	.044	.001	.433	12, 6502	.951	.001
History x Sex	.987	4, 14848	.413	< .001	1.481	4, 6502	.205	.001
History x Age x Sex	.818	12, 14848	.632	.001	.568	12, 6547	.870	.001
MAT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	18.821	4, 14380	< .001	.005	2.481	4, 6260	.042	.002
History x Age	.721	12, 14380	.732	.001	.379	12, 6260	.971	.001
History x Sex	.975	4, 14380	.420	< .001	1.030	4, 6260	.390	.001
History x Age x Sex	.671	12, 14380	.671	.781	.375	12, 6260	.973	.001
CRT	*F*	*Df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol History	5.315	4, 14913	< .001	.001	.095	4, 6527	.984	.000
History x Age	.575	12, 14913	.864	< .001	.559	12, 6527	.876	.001
History x Sex	.449	4, 14913	.773	< .001	.746	4, 6527	.560	< .001
History x Age x Sex	1.148	12, 14913	.316	.001	.543	12, 6527	.888	.001

Figure 48

Main Effect of Alcohol Use History on Mental Alternation Test (MAT) Scores



Note. MAT scores vary as a function of Alcohol Use History. Never-drinkers had lower scores than those with a moderate alcohol use history. Low = current usage of 7 drinks/week, reflecting heaviest-ever period of use; Moderate = current usage of 8-21 drinks/week, reflecting heaviest-ever period of use; High = current usage of 22-45 drinks/week, which is lower than previous heaviest-ever period of use; Very High = current usage of 45+ drinks/week which is lower than previous heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions

To investigate whether the effects of Alcohol History on CRT scores changed based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 25. There were no significant interaction effects and no further analyses were conducted.

Binge Drinking History

Binge History and Global Cognition.

Mean scores for Global Cognition as a function of Binge History are shown in Appendix F (Table F3). When covariates were included, the effect of alcohol Binge History was significant, $F(4,15332) = 24.159$, $p < 0.001$ ($\eta_p^2 = .006$; see Table 8). Post-hoc Bonferroni tests indicated that never-drinkers and 12-month abstainers had the lowest cognitive composite test scores compared to all other groups (all $p < .001$ to $p = .005$) but there were no significant differences between any groups that indicated a history of binge drinking (all $p > .001$; Figure 49). There was a significant main effect of Binge History on each of the cognitive test scores (Table 26). The relationship between Binge History and each of these tests will be examined in more detail below.

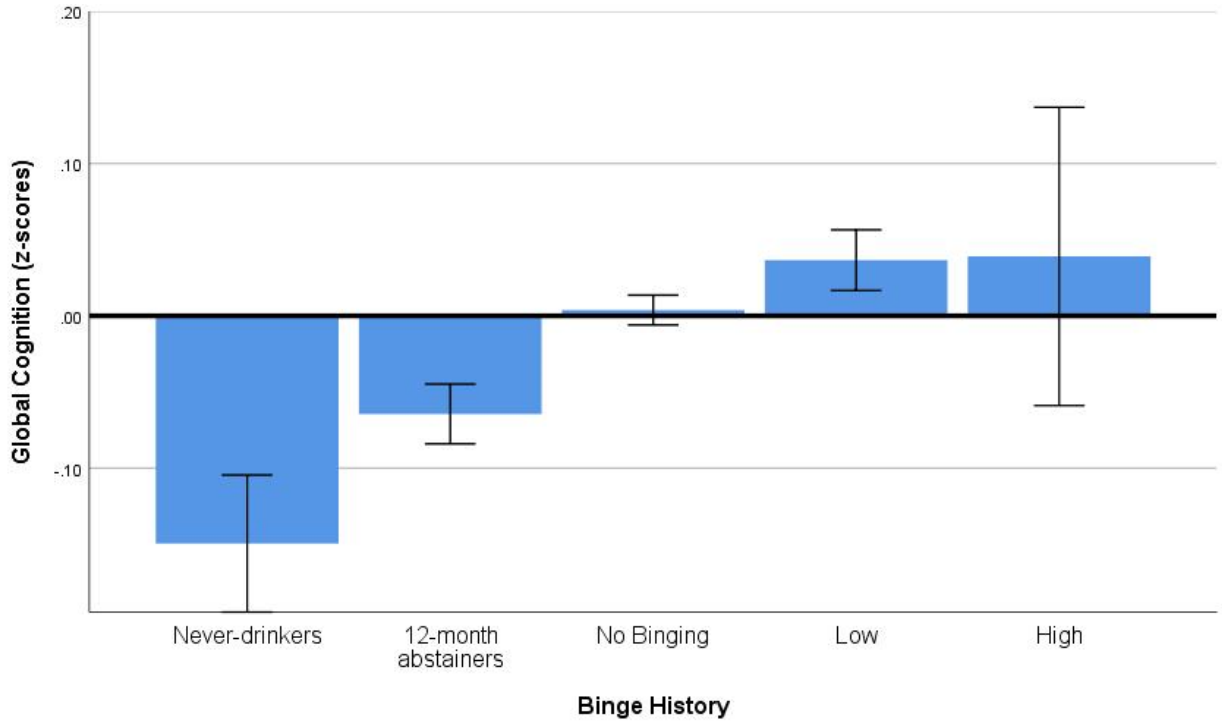
Binge History and REY I.

Mean REYI scores as a function of Binge History are shown in Appendix G5). There was a significant main effect of Binge History on REYI scores with the primary covariates included, $F(4, 16785) = 6.151$, $p < .001$ ($\eta_p^2 = .001$; Table 26). Post-hoc tests showed that 12-month abstainers had lower scores than those who drink without binging ($p < .001$) and those with a low binge-drinking history ($p = .002$); there were no other group differences (Figure 50).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge History on REYI scores was no longer significant with the added covariates, $F(4, 7284) = 0.579$ $p = .678$ ($\eta_p^2 < .001$; Table H5). This may be due

Figure 49

Main Effect of Alcohol Binge History on the Global Cognitive Composite Scores



Note. Mean Global Cognitive composite scores differed significantly by level of Binge Drinking History, such that binge drinkers (low and high history) as well as the non-bingeing drinkers all had higher cognitive test scores than the non-drinkers (all $p < .001$ to $p = .005$). No binging = individuals who currently consume alcohol without binge drinking; Low = currently binge up to once a month, and this is their heaviest-ever level of alcohol use; High = currently binge 4+ times per week and report this to be lower than their heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

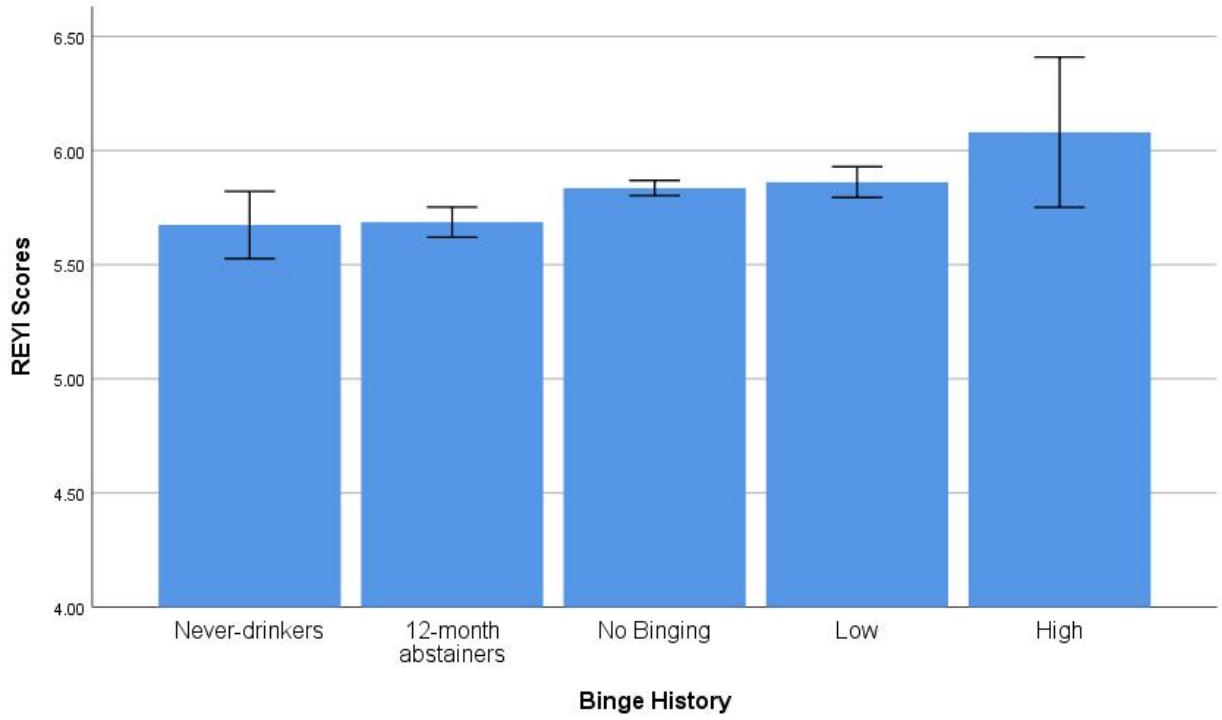
Table 26

ANOVA/ANCOVA Tables: Effect of Binge Drinking History on Each of the Nine Cognitive Test Scores

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	41.471	4, 19230	< .001	.009	6.151	4, 16785	< .001	.001
REY II	49.646	4, 19191	< .001	.010	9.186	4, 16753	< .001	.002
PMT	36.643	4, 19764	< .001	.007	11.144	4, 17211	< .001	.003
AFT	66.177	4, 19425	< .001	.013	15.119	4, 16937	< .001	.004
COWA	34.811	4, 19238	< .001	.007	7.559	4, 16765	< .001	.002
Stroop Time	72.720	4, 19630	< .001	.015	14.709	4, 17089	< .001	.003
Stroop Errors	26.191	4, 19547	< .001	.005	28.358	4, 17026	.002	.001
MAT	40.407	4, 18898	< .001	.008	5.949	4, 16520	< .001	.001
CRT	25.041	4, 19627	< .001	.005	3.804	4, 17099	< .004	.001

Figure 50

Main Effect of Binge Drinking History on Immediate Recall Scores



Note. Scores on the immediate recall trial of the Rey Auditory Verbal Learning Test (REYI) scores varied as a function of Binge History. No binging = individuals who currently consume alcohol without binge drinking; Low = currently binge up to once a month, and this is their heaviest-ever level of alcohol use; High = currently binge 4+ times per week and this is lower than their heaviest-ever period of use. Twelve-month abstainers had lower scores than those who drink alcohol without binging ($p < .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

to the small effect association of social functioning (η_p^2 = .010), and the medium effect of physical functioning (η_p^2 = .041), on REYI scores (see Appendix I1 for the effect sizes of these covariates without the influence of alcohol use variables).

To investigate whether the effect of Binge History on REYI test scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 27. There were no significant interaction effects (all $p > .001$) and no further analyses were conducted.

Binge History and REY II.

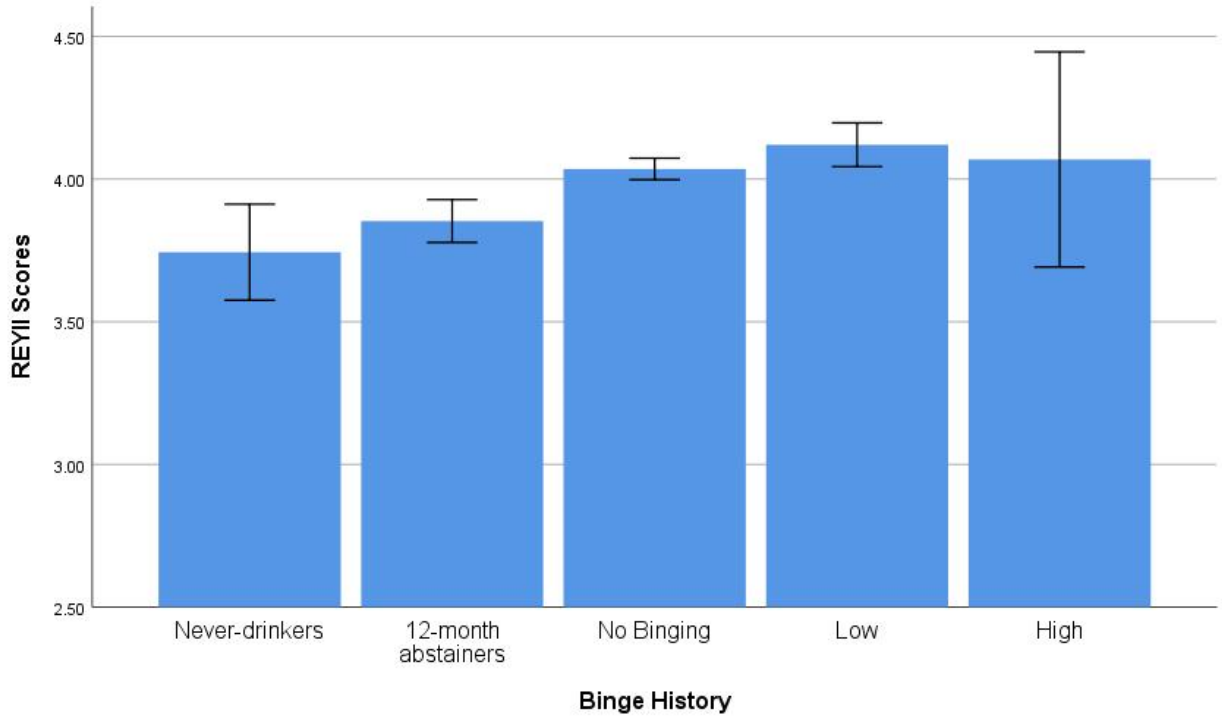
There was a significant main effect of Binge History on REY II scores, $F(4, 16753) = 9.186$, $p < .001$, (η_p^2 = .002; Table 26). Post-hoc tests showed that never-drinkers had lower scores than current non-bingers ($p = .007$) and the low history group ($p < .001$); 12-month abstainers had lower scores than individuals who drink without binging or have a low binge history ($p < .001$); there were no significant differences between other groups (Figure 51; Appendix G5).

Follow-up analyses that included the additional physical, social, and personality covariates were conducted. The main effect of Binge History on REYII scores was no longer significant with the added covariates, $F(4, 7263) = 0.200$ $p = .678$ (η_p^2 = .001; Table H5) and the physical function covariate had the largest main effect. See Appendix II for the effect of these covariates on REYII scores without the influence of alcohol variables.

To investigate whether the effect of Binge History on REYII test scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms (see Table 27). There were no significant interaction effects and no further analyses were conducted.

Figure 51

Main Effect of Binge History on Delayed Recall Scores



Note. Scores on the delayed trial of the Rey Auditory Verbal Learning Test (REYII) vary as a function of Binge History. Never-drinkers have lower scores than those with a low binge history, and 12-month abstainers have lower scores than those who drink without binging or have a low binge history (all $p < .001$). No binging = individuals who currently consume alcohol without binge drinking; Low = currently binge up to once a month, and this is their heaviest-ever level of alcohol use; High = currently binge 4+ times per week and this is lower than their heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 27

Two- and Three-Way Interactions Between Age, Sex, and Binge History for Memory Test Scores

		No covariates				Covariates = education, HI, language, physical function, social composite			
REYI		*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History		20.787	4, 19885	< .001	.004	2.506	4, 9481	.040	.003
Binge History x Age		2.451	12, 19885	.003	.001	1.350	12, 9481	.183	.002
Binge History x Sex		.585	4, 19885	.673	.000	2.830	4, 8491	.023	.001
Binge History x Age x Sex		1.346	12, 19885	.185	.001	2.329	12, 8491	.006	.003
REYII		*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History		25.856	4, 19849	< .001	.005	3.538	4, 8474	.007	.002
Binge History x Age		2.672	12, 19849	.001	.002	1.512	12, 8474	.112	.002
Binge History x Sex		1.058	4, 19849	.376	.000	3.102	4, 8474	.015	.001
Binge History x Age x Sex		1.086	12, 19849	.367	.001	1.325	12, 8474	.196	.002
PMT		*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History		14.538	4, 20428	< .001	.003	6.287	4, 16498	< .001	.002
Binge History x Age		3.527	12, 20428	< .001	.002	2.403	12, 16498	.004	.002
Binge History x Sex		1.595	4, 20428	.173	.000	1.803	4, 16498	.125	.000
Binge History x Age x Sex		.885	12, 20428	.562	.001	1.304	12, 16498	.208	.001
		F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History	40s	6.465	4, 1596	< .001	.016	.818	4, 292	.514	.011
	50s	7.900	4, 5677	< .001	.006	2.078	4, 2273	.081	.004
	60s	2.089	4, 6591	.079	.001	.689	4, 3312	.599	.001
	70s	11.551	4, 6584	< .001	.007	1.597	4, 2856	.172	.002

Binge History and PMT.

Mean PMT scores as a function of Binge History are shown in Appendix G (Table G5). There was a significant main effect of Binge History on PMT scores, $F(4, 17211) = 11.144$, $p < .001$, ($\eta_p^2 = .003$; Table 26). Post-hoc tests showed that never drinkers and 12-month abstainers had lower scores than the non-binging drinker group and low binge history group ($p < .001$). There were no differences in PMT scores between the non-binging, low, and high binging history groups (see Figure 52).

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge History on PMT scores was no longer significant with the added covariates, $F(4, 7480) = 0.231$ $p = .678$ ($\eta_p^2 = .001$; Table H5) and the physical function covariate had the largest effect size of all covariates (Appendix I1).

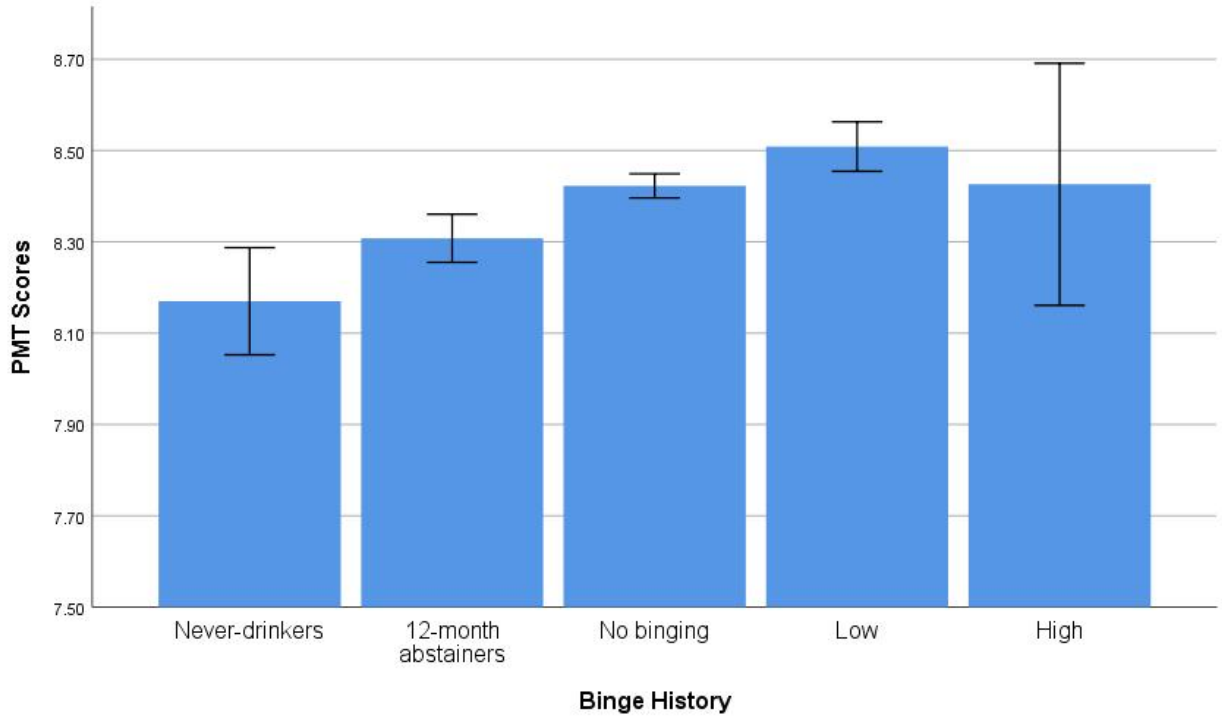
To investigate whether the effect of Binge History on PMT test scores differs based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 27. With the covariates included, the interaction between Age and Binge History approached (but did not reach) significance, $F(12, 16428) = 2.403$, $p = .004$, ($\eta_p^2 = .002$; see Appendix K6 for illustration).

Binge History and Semantic Verbal Fluency (AFT).

The mean scores for AFT as a function of Binge History are shown in Appendix G5). There was a significant main effect of Binge History on AFT scores, $F(4, 16937) = 15.119$, $p < .001$ ($\eta_p^2 = .004$; see Table 26). Post-hoc tests showed that never drinkers had lower scores than 12-month abstainers ($p = .001$), the non-binging group, and those with low binge histories ($p < .001$). Twelve-month abstainers had lower scores than those who do not binge ($p = .002$) and the

Figure 52

Main Effect of Binge History on Prospective Memory Test (PMT) Scores



Note. PMT scores vary as a function of Binge History. Never-drinkers and 12-month abstainers have lower scores than the non-binging drinker group and the low binge history group (both $p < .001$). No binging = individuals who currently consume alcohol without binge drinking; Low = currently binge up to once a month, and this is their heaviest-ever level of alcohol use; High = currently binge 4+ times per week and this is lower than their heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

low history binging group (p <.001). No differences were seen among drinkers at any level. These relationships are illustrated in Figure 53.

Follow-up analyses that included additional physical, social, and personality covariates were conducted. The main effect of Binge History on AFT scores was no longer significant with the added covariates, $F(4, 7348) = 3.966$, $p = .003$ ($\eta_p^2 = .002$; Appendix H5).

To investigate whether the effect of Binge History on AFT test scores changed based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 28. With covariates included, there were no significant interaction effects.

Binge History and Verbal Fluency (COWA).

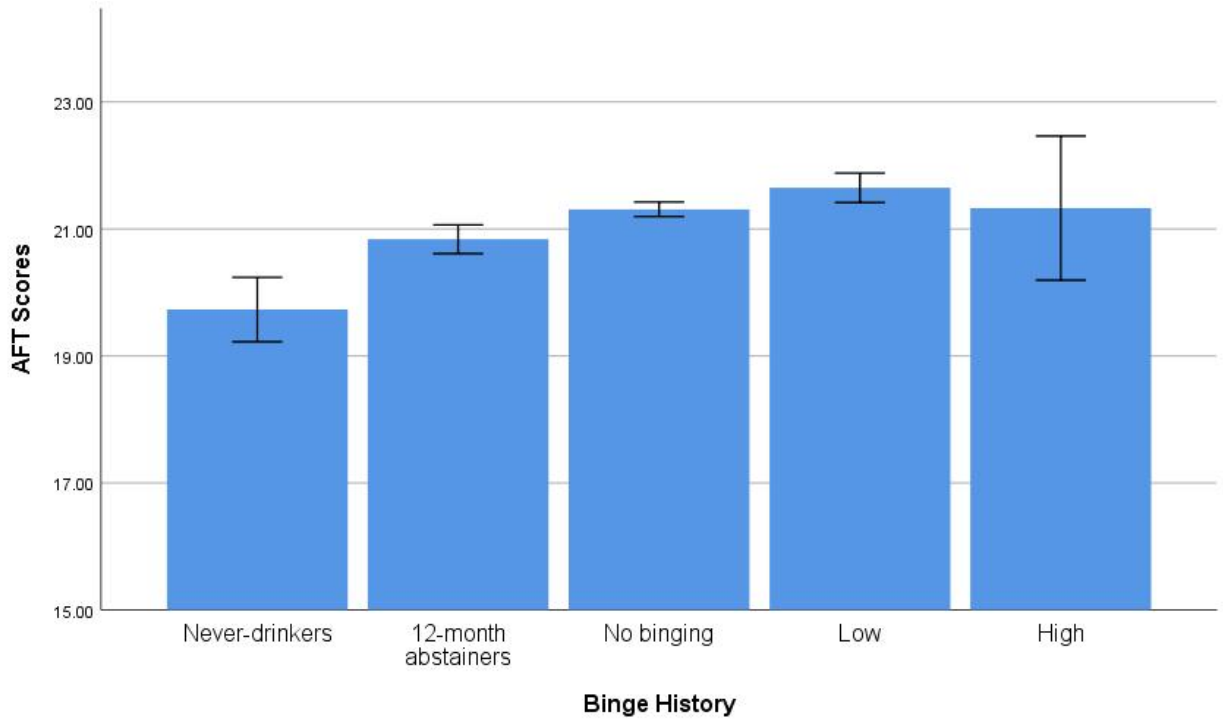
Mean COWA scores as a function of Binge History are shown in Appendix G5). There was a significant main effect of Binge History on COWA scores, $F(4, 16765) = 7.559$, $p < .001$ ($\eta_p^2 = .002$; Table 26). Post-hoc tests showed that never-drinkers and 12-month abstainers had lower scores than the low history group ($p = .002$ and $p < .001$). Those who drink without binging had lower scores than the low binge history group ($p = .001$; see all relationships in Figure 54).

Follow-up analyses that included the additional physical, social, and personality covariates were conducted. The main effect of Binge History on COWA scores was not significant with the added covariates, $F(4, 7279) = 2.226$ $p = .064$ ($\eta_p^2 = .001$; Appendix H5).

To investigate whether the effect of Binge History on AFT test scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 28. With covariates included, there were no significant interaction effects.

Figure 53

Main Effect of Binge Drinking History on Animal Fluency Test (AFT) Scores



Note. AFT scores differed as a function of Binge History. Never-drinkers had lower scores than 12-month abstainers ($p = .001$) and than the non-binging and low-history group ($p < .001$). Twelve-month abstainers also had lower scores than the low binge history group ($p < .001$). No binging = individuals who currently consume alcohol without binge drinking; Low = currently binge up to once a month, and this is their heaviest-ever level of alcohol use; High = currently binge 4+ times per week and this is lower than their heaviest-ever period of use. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

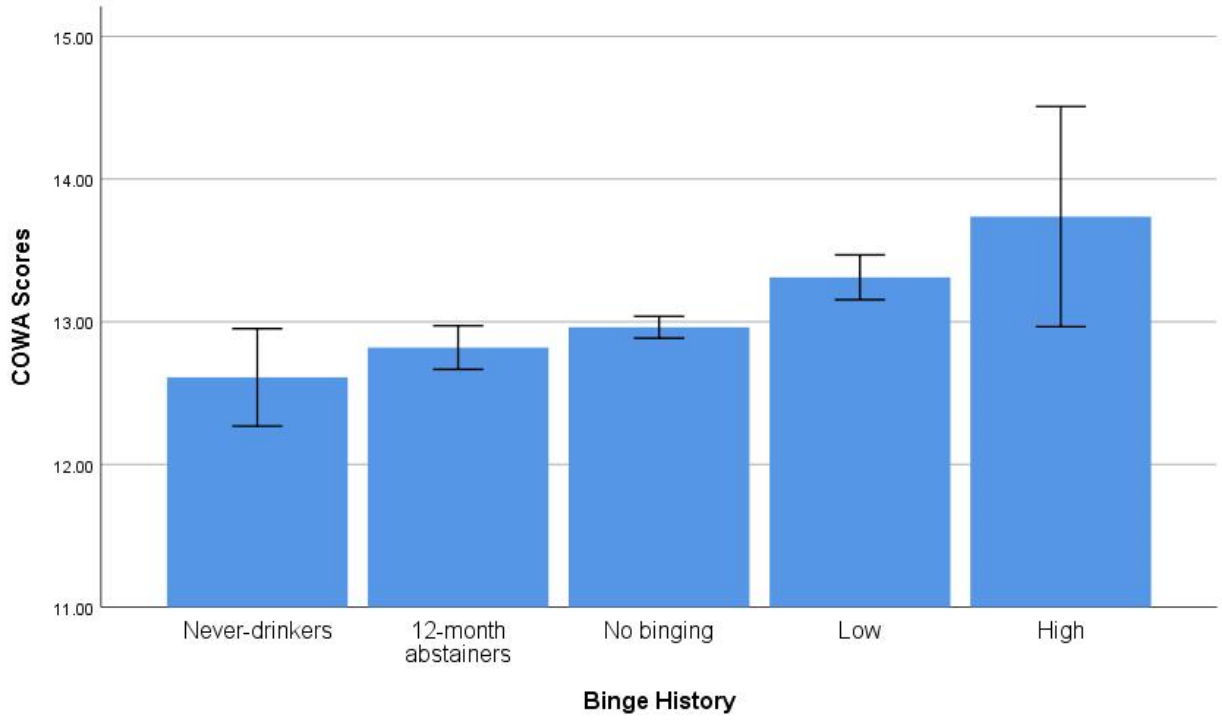
Table 28

Interactions Between Age, Sex, and Binge History for Verbal Fluency Test Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
AFT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History	34.581	4, 20088	< .001	.007	2.984	4, 8569	.018	.001
Binge History x Age	1.722	12, 20088	.056	.001	1.245	12, 8569	.245	.002
Binge History x Sex	1.723	4, 20088	.142	.000	.312	4, 8569	.870	.000
Binge History x Age x Sex	.674	12, 20088	.779	.000	.502	12, 8569	.915	.001
COWA	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History	20.256	4, 19889	< .001	.004	1.469	4, 8510	.209	.001
Binge History x Age	.786	12, 19889	.665	.000	.608	12, 8510	.837	.001
Binge History x Sex	.839	4, 19889	.500	.000	.420	4, 8510	.772	.000
Binge History x Age x Sex	.693	12, 19889	.760	.000	.512	12, 8510	.908	.001

Figure 54

Main Effect of Binge Drinking History on COWA Scores



Note. Scores on the Controlled Oral Word Association test (COWA) varied as a function of Binge History. For COWA scores, never-drinkers, 12-month abstainers, and those who drink without binging had lower scores than those in the low-history group ($p \leq .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Binge Drinking History and Stroop Scores

Mean Stroop time and error scores as a function of Binge History are shown in Appendix G5. There was a significant main effect of Binge History on the Stroop Time scores, $F(4, 17089) = 14.709$, $p < .001$ ($\eta_p^2 = .003$; Table 26) and a nonsignificant trend for the Stroop Error scores, $F(4, 17026) = 28.358$, $p = .002$ ($\eta_p^2 = .001$) when covariates were included.

For the Stroop Time scores, post-hoc Bonferroni tests showed never drinkers had worse scores than the drink-with-binging group and low binge drinkers ($p < .001$) but no differences from 12-month abstainers. Abstainers had slower times than the non-binging group and the low history group (both $p < .001$). There were no differences among those in any of the drinking groups (Figure 55; Appendix G5). For Stroop Errors, none of the post-hoc tests were significant at the $p < .001$ level but the relationship is illustrated in Figure 55.

Follow-up analyses that included physical function, social engagement, and personality covariates indicated that Stroop Time scores remains significant with additional covariates, $F(4, 7442) = 6.425$ $p < .001$ ($\eta_p^2 = .003$; Table H5) and the covariates of physical functioning and agreeableness were significant (Appendix I3). The effect of Binge History on Stroop Error scores was no longer significant with the extra covariates, $F(4, 7419) = 0.943$ $p = .438$ ($\eta_p^2 = .001$).

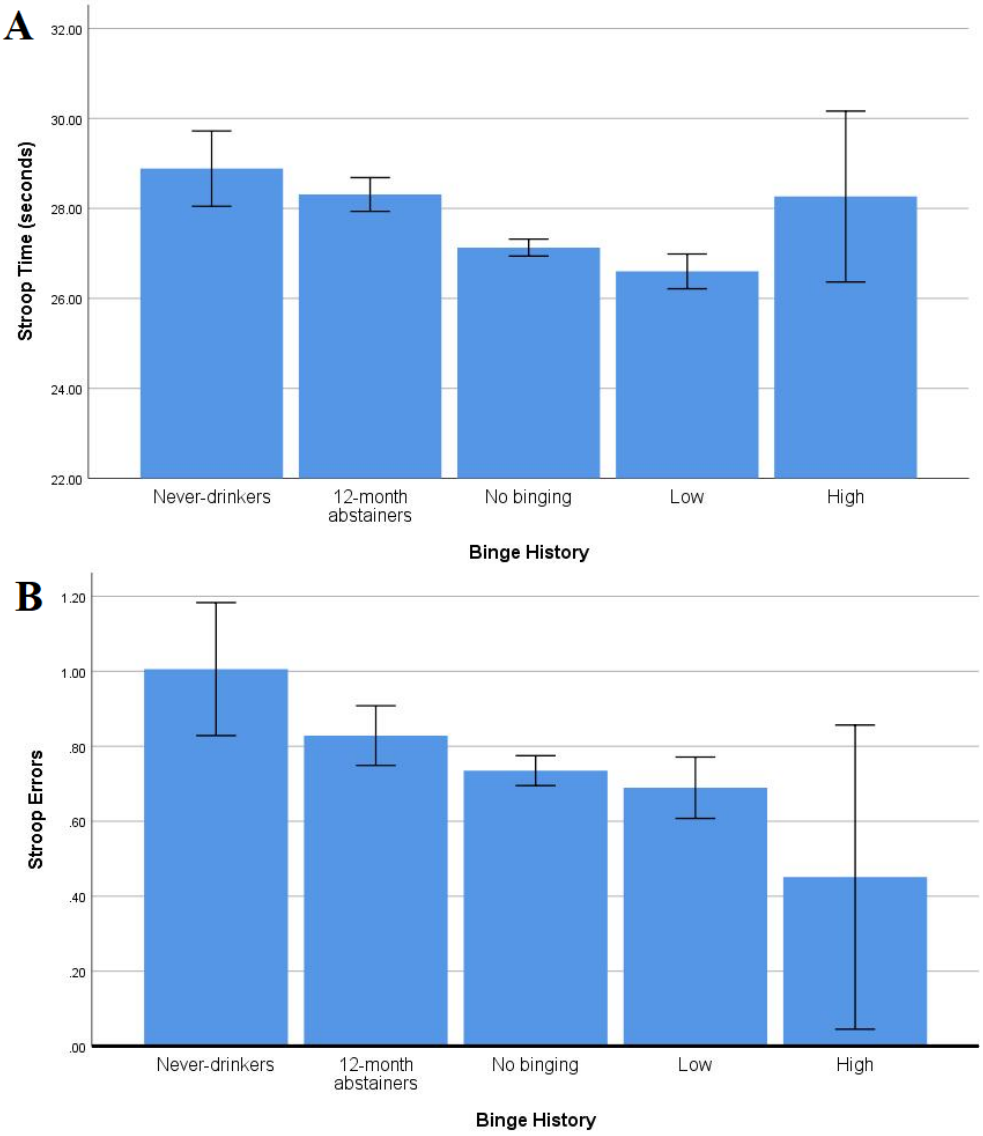
To investigate whether the effects of Binge History on Stroop Time or Error test scores change based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. With covariates included, there were no significant interaction effects (Table 29).

Binge History and the Mental Alternation Test.

There was a significant main effect of Binge History on MAT scores, $F(4, 16520) = 5.949$, $p < .001$ ($\eta_p^2 = .001$; Table 26). Post-hoc tests showed that never-drinkers had lower

Figure 55

Main Effect of Binge Drinking History on Stroop Time and Error Scores



Note. **A**. Never-drinkers and 12-month abstainers have higher (i.e., worse) Stroop Time scores than those who drink without binging or have a low-level history of binge drinking ($p < .001$). **B.** For Stroop Error, there were no significant group differences. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 29

ANOVA/ANCOVA Table: Examining Interactions Between Age, Sex, and Binge History for Stroop, MAT, and CRT Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
Stroop Time	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History	26.174	4, 20297	< .001	.005	2.945	4, 8692	.019	.001
Binge History x Age	1.388	12, 20297	.163	.001	1.009	12, 8692	.437	.001
Binge History x Sex	.902	4, 20297	.461	.000	.202	4, 8692	.937	.000
Binge History x Age x Sex	1.389	12, 20297	.163	.001	.193	12, 8692	.999	.000
Stroop Errors	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Binge History	9.944	4, 20212	< .001	.002	.350	4, 8662	.844	.000
Binge History x Age	1.567	21, 20212	.091	.001	1.052	12, 8662	.397	.001
Binge History x Sex	.816	3, 20212	.485	.000	1.126	4, 8662	.342	.001
Binge History x Age x Sex	.609	12, 20212	.836	.000	.528	12, 8662	.898	.001
MAT	*F*	*Df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Binge History	18.319	4, 19539	< .001	.004	1.168	4, 8337	.323	.001
Binge History x Age	.562	12, 19539	.874	.000	.786	12, 8337	.666	.001
Binge History x Sex	2.624	4, 19539	.033	.001	1.805	4, 8337	.125	.001
Binge History x Age x Sex	1.083	12, 19539	.369	.001	.804	12, 8337	.647	.001
CRT	*F*	*Df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Binge History	7.577	4, 20290	< .001	.001	.092	4, 8699	.985	.000
Binge History x Age	.765	12, 20290	.765	.687	.999	12, 8699	.446	.001
Binge History x Sex	.640	4, 20290	.634	.000	.336	4, 8699	.854	.000
Binge History x Age x Sex	1.177	12, 20290	.293	.001	.418	12, 8699	.958	.001

scores than those who drink without binging (p = .001) and than those with a low binge history (p = .002; Figure 56; mean scores in Appendix G5).

Follow-up analyses that included physical function, social engagement, and personality covariates showed that MAT scores were no longer significant with additional covariates, $F(4, 7152) = 3.503$, $p = .007$ ($\eta_p^2 = .002$; Appendix H5).

To investigate whether the effect of Binge History on MAT test scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 29. No interaction effects were significant.

Binge History and Choice Reaction Time (CRT).

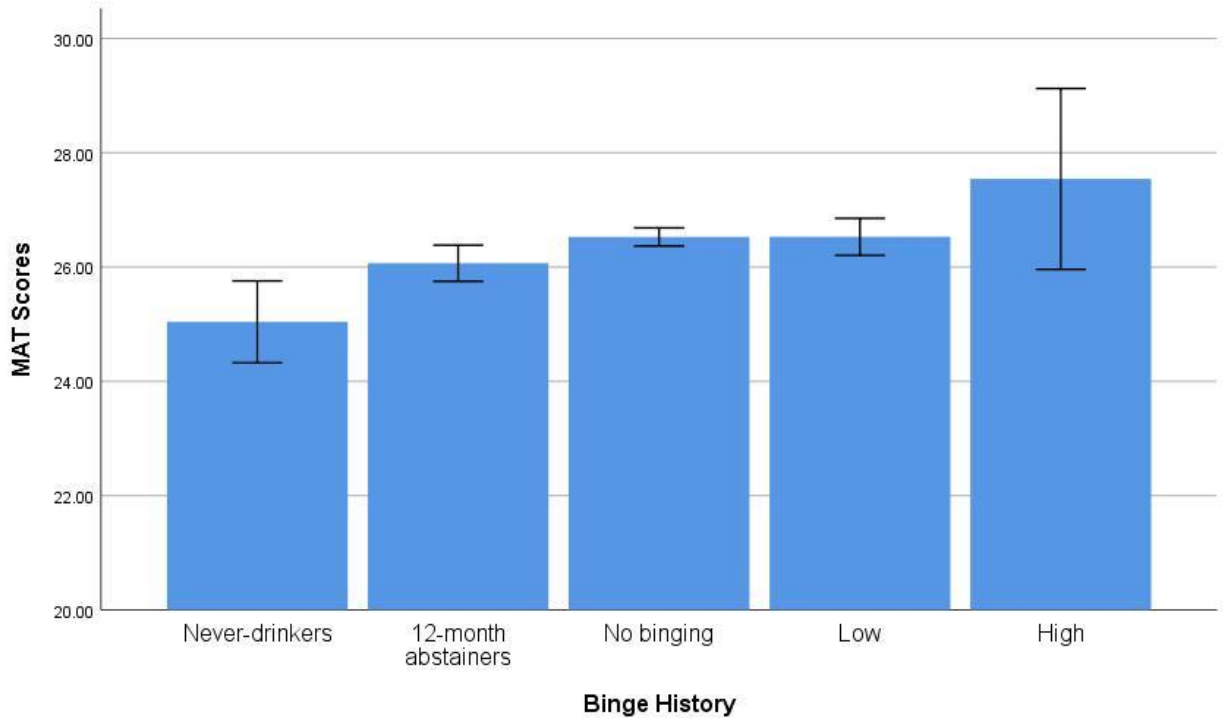
Mean scores for Choice Reaction Time as a function of Binge History are shown in Appendix G5). There was a significant main effect of Binge History on CRT scores, $F(4, 17099) = 3.804$, $p = .001$ ($\eta_p^2 = .001$; Table 26). However, post-hoc tests revealed no significant differences between groups at a level of $p < .001$ (see figure in Appendix K7).

Follow-up analyses showed that CRT scores were no longer significant with the additional covariates, $F(4, 7455) = 0.422$ $p = .793$ ($\eta_p^2 = .000$; Appendix H5), likely due to the covariate of physical function having a large effect on CRT scores (see Appendix I4 for the effect of this covariate on CRT without the influence of any alcohol use variables).

To investigate whether the effect of Binge History on CRT test scores changes based on sex or age group, ANOVAs/ANCOVAs explored interaction terms. The results are shown in Table 29. No interaction effects were significant.

Figure 56

Main Effect of Binge History on Mental Alternation Test Scores



Note. Never-drinkers had lower scores than those who drink without binging (p = .001). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Type of Alcohol Primarily Consumed

Alcohol Type and the Global Cognitive Composite Score.

When covariates were included, the effect was significant, $F(3,6734) = 5.954$, $p < 0.001$ ($\eta_p^2 = .003$; Table 8). Post-hoc Bonferroni tests indicated that red wine drinkers did not significantly differ from white wine or spirit drinkers ($p > .001$), but showed a nonsignificant trend for higher cognitive test scores than beer drinkers ($p = .002$). There were no differences between any other groups at the $p < 0.001$ significance level (see figure in Appendix K8).

Alcohol Type and REY I.

There was no significant effect of Alcohol Type on REYI scores, $F(3, 7367) = 1.776$, $p = .151$ ($\eta_p^2 = .001$; Table 30) and therefore no further follow-ups were required. Interaction terms were explored for age and sex (see Table 31). There were no significant interaction effects.

Alcohol Type and REY II.

There was no significant effect of Alcohol Type on REYII scores, $F(3, 7350) = 1.665$, $p = .172$ ($\eta_p^2 = .001$; Table 30) and therefore no further follow-ups were required. Interaction terms were explored for age and sex in Table 31. There were no significant results.

Alcohol Type and PMT.

There was no significant effect of Alcohol Type on PMT scores, $F(3, 7536) = 1.147$, $p = .329$ ($\eta_p^2 = .001$; Table 30) and thus, no further follow-ups were required. Interaction terms were explored for age and sex in Table 31. There were no significant interaction effects.

Alcohol Type and AFT.

There was no significant effect of Alcohol Type on AFT scores, $F(3, 7416) = 1.728$, $p = .159$ ($\eta_p^2 = .001$; Table 30) and therefore no further follow-ups were required. Interaction terms were explored for age and sex in Table 32. There were no significant interaction effects.

Table 30

ANOVA/ANCOVA Table: Main Effect of Alcohol Type on Cognitive Test Scores

	No covariates				Covariates = age, sex, education, HI, language, chronic conditions			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
REY I	34.263	3, 8280	< .001	.012	1.766	3, 7367	.151	.001
REY II	30.595	3, 8259	< .001	.011	1.665	3, 7350	.172	.001
PMT	1.055	3, 8488	.367	.000	1.147	3, 7536	.329	< .001
AFT	5.702	3, 8335	.001	.002	1.728	3, 7416	.159	.001
COWA	35.696	3, 8262	< .001	.013	6.843	3, 7337	< .001	.003
Stroop Time	17.857	3, 8443	< .001	.006	5.507	3, 7499	< .001	.002
Stroop Errors	13.888	3, 8404	< .001	.005	4.367	3, 7465	.004	.002
MAT	2.536	3, 8076	.055	.001	.656	3, 7214	.579	< .001
CRT	11.316	3, 8436	< .001	.004	.917	3, 7490	.432	.000

Table 31

ANOVA/ANCOVA Table: Interactions Between Age, Sex, Alcohol Type, and Memory Test Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
REYI	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	5.691	3, 8252	.001	.002	1.204	3, 3661	.307	.001
Type x Age	1.362	9, 8252	.200	.001	1.732	9, 3661	.076	.004
Type x Sex	.733	3, 8252	.532	< .001	1.400	3, 3661	.241	.001
Type x Age x Sex	.917	9, 8252	.509	.001	.992	9, 3661	.445	.002
REYII	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	7.521	3, 8231	< .001	.003	.721	3, 3644	.539	.001
Type x Age	1.638	9, 8231	.099	.002	1.204	9, 3644	.287	.003
Type x Sex	1.941	3, 8231	.121	.001	1.057	3, 3644	.366	.001
Type x Age x Sex	.701	9, 8231	.709	.001	.589	9, 3644	.807	.001
PMT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	1.681	3, 8460	.169	.001	1.742	3, 3769	.156	.001
Type x Age	1.318	9, 8460	.222	.001	1.634	9, 3769	.100	.004
Type x Sex	1.104	3, 8460	.346	< .001	2.721	3, 3769	.043	.002
Type x Age x Sex	1.007	9, 8460	.432	.001	1.408	9, 3769	.179	.003

Table 32

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Alcohol Type for Verbal Fluency Test Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
AFT	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	6.409	3, 8307	< .001	.002	.594	3, 3689	.619	.000
Type x Age	.671	9, 8307	.736	.001	1.419	9, 3689	.174	.003
Type x Sex	.670	3, 8307	.570	< .001	1.508	3, 3689	.210	.001
Type x Age x Sex	2.096	9, 8307	.027	.002	1.588	9, 3689	.113	.004
COWA	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	10.245	3, 8234	< .001	.004	1.933	3, 3673	.122	.002
Type x Age	1.521	9, 8234	.134	.002	.804	9, 3673	.613	.002
Type x Sex	1.910	3, 8234	.126	.001	1.852	3, 3673	.135	.002
Type x Age x Sex	1.023	9, 8234	.418	.001	.613	9, 3673	.787	.001

Note. AFT = Animal Fluency Test; COWA = Controlled Oral Word Association

Alcohol Type and COWA.

There was a significant main effect of Alcohol Type on COWA scores, $F(3, 7337) = 6.843$, $p < .001$ ($\eta_p^2 = .003$; Table 30). Post-hoc tests did not indicate any differences between the two types of wine. However, red wine drinkers showed a nonsignificant trend towards higher scores than beer drinkers ($p = .007$) and spirit drinkers ($p = .002$); white wine drinkers also showed a nonsignificant trend towards higher scores than spirit drinkers ($p = .005$; see Figure in Appendix K9). Interaction effects were explored for age and sex in Table 32. There were no significant interaction effects.

Alcohol Type and Stroop Scores

There was a significant main effect of Alcohol Type on Stroop Time scores, $F(3, 7499) = 5.507$, $p < .001$ ($\eta_p^2 = .002$; Table 31) and a nonsignificant trend for Stroop Error scores, $F(3, 7465) = 4.367$, $p = .004$, ($\eta_p^2 = .002$) when covariates were included.

For the Stroop Time scores, post-hoc Bonferroni tests showed red wine and white wine drinkers showed a nonsignificant trend towards lower (i.e., faster) scores than spirit drinkers ($p = .004$ and $p = .001$; see Figure 57). For Stroop Errors, post-hoc tests indicated that red wine drinkers showed a trend towards fewer errors than spirit drinkers ($p = .006$).

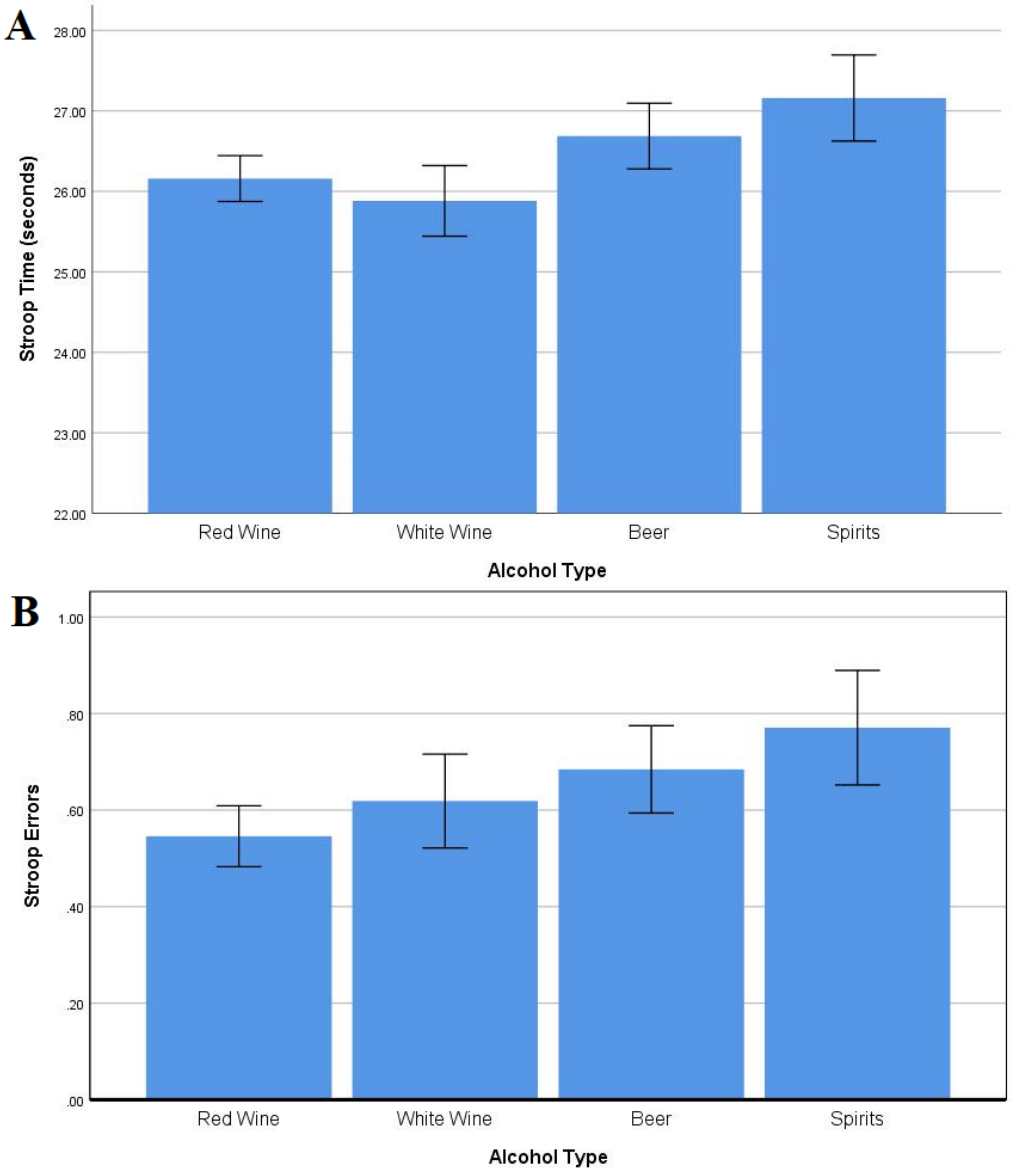
Interaction terms were explored for age and sex in Table 33. There was a trend towards a significant Age x Alcohol Type interaction for Stroop Error scores, $F(3, 3735) = 2.567$, $p = .006$, ($\eta_p^2 = .006$; see figure in Appendix K10).

Alcohol Type and MAT.

There was no significant effect of Alcohol Type on MAT scores, $F(3, 7214) = .656$, $p = .579$ ($\eta_p^2 = .000$; Table 33) and therefore no further follow-ups were required. There were no significant interaction effects (Table 33).

Figure 57

Main Effect of Alcohol Type on Stroop Time and Error Scores



Note. **A.** Stroop Time scores for white wine drinkers were better than spirit drinkers (p = .001). **B.** There were no significant group differences in Stroop Error scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Table 33

ANOVA/ANCOVA Table: Interactions Between Age, Sex, and Alcohol Type for Stroop, MAT, and CRT Scores

	No covariates				Covariates = education, HI, language, physical function, social composite			
Stroop Time	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alcohol Type	4.671	3, 8415	.003	.002	.481	3, 3753	.695	.000
Type x Age	1.918	9, 8415	.045	.002	.874	9, 3753	.548	.002
Type x Sex	.451	3, 8415	.716	.000	.260	3, 3753	.854	.000
Type x Age x Sex	2.093	9, 8415	.027	.002	.678	9, 3753	.729	.002
Stroop Error	*F*	*Df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Alcohol Type	5.508	3, 8367	.001	.002	.345	3, 3735	.793	.000
Type x Age	2.746	9, 8376	.003	.003	2.567	9, 3735	.006	.006
Type x Sex	1.266	3, 8376	.284	.000	.567	3, 3735	.637	.000
Type x Age x Sex	2.038	9, 8376	.032	.002	1.187	9, 3735	.298	.003
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
40s	1.154	3, 750	.326	.005	.412	3, 155	.745	.008
50s	3.693	3, 2698	.011	.004	.987	3, 1155	.398	.003
60s	4.235	3, 2698	.005	.005	.220	3, 1391	.882	.000
70s	8.419	3, 2246	< .001	.011	4.952	3, 1031	.002	.014
MAT	*F*	*Df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Alcohol Type	5.412	3, 8048	< .001	.002	.322	3, 3594	.809	.000
Type x Age	.703	9, 8048	.707	.001	.719	9, 2594	.692	.002
Type x Sex	1.313	3, 8048	.268	.000	1.278	3, 3594	.280	.001
Type x Age x Sex	1.612	9, 8048	.106	.002	.605	9, 3594	.794	.002
CRT	*F*	*Df*	*p*	η_p^2	*F*	*Df*	*p*	η_p^2
Alcohol Type	.694	4, 8408	.568	.000	.090	4, 3753	.966	.000
Type x Age	.831	9, 8408	.771	.001	.309	9, 3753	.972	.001
Type x Sex	.129	3, 8408	.943	.000	.246	3, 3753	.864	.000
Type x Age x Sex	.672	9, 8408	.735	.001	.165	9, 3753	.997	.000

Alcohol Type and CRT.

There was no significant effect of Alcohol Type on CRT scores, $F(3, 7490) = .917$, $p = .432$ ($\eta_p^2 = .000$; Table 30) and therefore no further follow-ups were required. Interaction terms were explored for age and sex in Table 33. There were no significant interaction effects.

Summary of Findings

A summary of the effect sizes for all significant findings is presented in Tables 34 and 35. All of the primary variables (i.e., age, sex, and alcohol use) were associated with one or more cognitive test scores. There was also evidence for a few interactions between the age, sex, and the various alcohol use variables in the way that they were associated with some cognitive test scores.

Table 34

Summary of Effect Sizes for All Significant (p < .001) ANOVA/ANCOVA Results without Covariates

	Global Cognition	REYI	REYII	PMT	AFT	COWA	Stroop Time	Stroop Error	MAT	CRT
Age	.233*	.111*	.115*	.069*	.110*	.026*	.171*	.047*	.065*	.088*
Sex	.004	.031*	.034*	-	.001	.004	.002	.001	.005	.002
Current Alcohol Composite	.020*									
Alcohol History Composite	.023*									
Drinks Per Week	.018*	.005	.003	.003	.009	.009	.008	.003	.007	.001
Frequency of Alcohol Use	.023*	.007	.006	.006	.017*	.014*	.015*	.008	.014*	.006
Binge Frequency	.036*	.012*	.011*	.013*	.022*	.011*	.026*	.008	.014*	.013*
Alcohol History	.017*	.007	.009	.006	.012*	.010*	.010*	.005	.010*	.004
Binge History	.022*	.009	.010*	.007	.013*	.007	.015*	.005	.008	.005
Alcohol Type	.007	.012*	.011*	-	.002	.013*	.006	.005	-	.004
Age x Sex	-	.001	-	.001	-	-	-	.001	-	-
DPW x Age		-	.003	.001	.001	-	.001	.002	-	-
DPW x Sex		-	-	-	-	-	< .001	-	-	-
DPW x Age x Sex		-	-	-	-	-	.001	-	-	-
Binge x Age		.001	.002	.002	-	-	-	-	-	-
Binge x Sex		-	-	-	-	-	-	-	-	-
Binge x Age x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age		-	-	.002	.002	-	-	-	-	-
Binge History x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age x Sex		-	-	-	-	-	-	-	-	-
Type x Age		-	-	-	-	-	-	-	-	-
Type x Sex		-	-	-	-	-	-	-	-	-
Type x Age x Sex		-	-	-	-	-	-	-	-	-

Note. Partial-eta squared of 0.01 indicates a small effect size, and 0.06 and 0.14 indicate moderate and large effect sizes, respectively. Dashes mark analyses which were not statistically significant; blank spaces indicate that no such analysis was conducted. Alcohol variable interaction terms that were not significant for any cognitive test scores were excluded from the table. Asterisks indicate effect sizes of small size or larger.

Table 35

Summary of Effect Sizes for All Significant (p < .001) ANOVA/ANCOVA Results with Covariates

	Global Cognition	REYI	REYII	PMT	AFT	COWA	Stroop Time	Stroop Error	MAT	CRT
Age	.165*	.068*	.074*	.052*	.066*	.007	.113*	.027*	.030*	.067*
Sex	.013*	.043*	.045*	-	-	.010*	.005	.003	.001	.002
Current Alcohol Composite	.008									
Alcohol History Composite	.009									
Drinks Per Week	.009	.003	.002	.002	.004	.006	.005	.002	.002	.001
Frequency of Alcohol Use	.011*	.004	.002	.003	.006	.007	.005	.003	.003	.001
Binge Frequency	.007	.002	.002	.003	.004	.004	.003	.001	.001	.001
Alcohol History	.008	.002	.003	.003	.004	.005	.003	.002	.002	-
Binge History	.006	.001	.002	.003	.004	.002	.003	.001	.001	.001
Alcohol Type	.003	-	-	-	-	.003	.002	.002	-	-
Age x Sex	.001	.001	.001	.001	-	.001	.001	.002	-	-
DPW x Age		-	-	-	-	-	-	-	-	-
DPW x Sex		.002	-	-	-	-	-	-	-	-
DPW x Age x Sex		.003	.002	-	-	-	-	-	-	-
Binge x Age		-	.004	-	-	-	-	-	-	-
Binge x Sex		-	-	-	-	-	-	-	-	-
Binge x Age x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age		-	-	.002	-	-	-	-	-	-
Binge History x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age x Sex		-	-	-	-	-	-	-	-	-
Type x Age		-	-	-	-	-	-	.006	-	-
Type x Sex		-	-	-	-	-	-	-	-	-
Type x Age x Sex		-	-	-	-	-	-	-	-	-

Note. Partial-eta squared of 0.01 indicates a small effect size, and 0.06 and 0.14 indicate moderate and large effect sizes, respectively. Dashes mark analyses which were not statistically significant; blank spaces indicate that no such analysis was conducted. Alcohol variable interaction terms that were not significant for any cognitive test scores were excluded from the table. Asterisks indicate effect sizes of small size or larger. Covariates include education, HI, language, and number of chronic conditions.

Discussion

Overview of Findings

Hypothesis 1 predicted that older adults would have lower cognitive test scores than middle-aged adults across all domains. This hypothesis was supported in all analyses with moderate to large effect sizes when sex, education, language, HI, and number of chronic conditions were statistically controlled. All cognitive test scores, including Global Cognition, were significantly lower in each successive decade of life starting from adults in their 40s to those in their 80s. In terms of individual tests, the age effect size was smallest for the COWA and largest for the REYII.

Hypothesis 2 predicted that women would outperform men on tasks assessing memory and verbal fluency. This was partly supported by the results of the present study. Women achieved higher scores than men on tests of auditory/verbal memory (RAVLT) but there were no significant sex differences for prospective memory. In terms of verbal fluency, women had higher scores than men on a test of phonemic verbal fluency (i.e., the COWA) but not semantic verbal fluency (i.e., AFT). Beyond the scope of our hypothesis, women also showed better performance on the Stroop task in terms of both time and error scores, while men had better performance than women on a test of attention/executive function (i.e., MAT) and choice reaction time (i.e., CRT). However, all of these latter sex differences (i.e., Stroop, MAT, and CRT) were very small in terms of effect sizes.

Hypothesis 3 predicted that low levels of alcohol consumption, but not high levels of use, would have a beneficial effect on cognitive test scores. A potential beneficial effect of alcohol on cognition was supported, but this benefit extended to, and usually included, the highest levels of alcohol use. Non-drinkers consistently achieved lower test scores than those who consumed alcohol at any level over the past 12 months, and no detrimental effect of higher levels of

drinking was observed. This beneficial effect of alcohol on cognition at high levels of use, and the lack of any evidence for a detrimental effect of alcohol on cognition, contradicted the original hypothesis.

Hypothesis 4 predicted that age, sex, and alcohol use interact with one another to influence cognitive performance. While some significant interactions were observed, the majority of these interactions had miniscule effect sizes (η_{p^2} = .001 to .006). Small effect Age x Sex interactions occurred for REYI, REYII, PMT, COWA, Stroop Time, and Stroop Error scores. REYI scores were further impacted by small effect size interactions between Drinks Per Week x Sex, Drinks Per Week x Age x Sex, Alcohol History x Age x Sex, and Binge History x Age x Sex. REYII was also influenced by very small effect size interactions between Drinks Per Week x Age x Sex and between Binge Frequency x Age. For prospective memory there was a Binge History x Age x Sex interaction (very small effect size), and there was also an Alcohol Type x Age interaction on Stroop Errors (small effect size).

This study found some interesting results that were neither anticipated nor included in the original list of hypotheses. Never-drinkers and 12-month abstainers scored lower on most, if not all, cognitive test scores than all levels of current alcohol users, including those who drink alcohol at levels surpassing the Canadian health recommendations for safe consumption (Butt et al., 2011). Additionally, when follow-up analyses were conducted to further investigate the apparent association between high levels of alcohol consumption and improved cognitive test scores, factors of social engagement, physical function, and personality were found to be associated with cognition to a large degree. In some (but not all) of these analyses, the effect of these factors was great enough to render the effect of alcohol use no longer statistically

significant, suggesting that these factors may account for or help explain the effect of alcohol on cognition in some cases.

Cognitive Test Scores Differ as a Function of Age and Sex

Hypothesis 1 was supported. For all cognitive tests, including the Global Cognition composite score, younger adults consistently achieved higher scores than older adults. The effect sizes for these analyses ranged from small (Stroop Error, MAT, PMT) to moderate (REYI, REYII, AFT, CRT, Stroop Time) to large (Global Cognition) when sex, education, language, HI, and number of chronic conditions were statistically controlled.

Age, sex, and verbal memory.

Age produced a significant main effect on verbal memory (REYI and REYII) as well as prospective memory (PMT) test scores. This is in alignment with previous results from both longitudinal and cohort studies that show age-related declines on a variety of memory tasks (Davis et al., 2013; Haaland, Price, & LaRue, 2003; Singer et al. 2003; Singh-Manoux et al., 2012). Replication of these results is valuable because a decline in memory test performance is a known factor associated with dementia and daily functional ability for those living with dementia (Estevez-Gonzalez et al., 2003; Schoenberg et al., 2006; Winblad et al., 2004).

The results of the present study revealed an average mean REYI/REYII score reduction of between one half a word to one word with each successive decade from age 40 to 80, when looking at the age effect alone. The means themselves are in line with previously reported RAVLT scores in cognitively healthy populations (Bernard et al., 1991; Bernard et al., 1993; Binder et al., 2003; Boon et al. 2005). However, score comparisons are made difficult due to the fact that the CLSA administered a heavily truncated version of this test which has not been used in previous studies. Conventionally, a minimum of five learning trials are completed in which

participants listen to a list of 15 words and then recall them immediately; the purpose of these trials is to measure the rate of learning. Delayed recall trials may be conducted at any interval, commonly between one and twenty-four hours. The CLSA participants completed only a single learning trial which measures immediate recall ability and one single delayed trial after a 5-15 minute interval. Therefore, immediate-recall scores from the CLSA must be compared to scores on only the first learning trial conducted in previous research if and when this score is reported, and there is no consistent standard that can be used to compare delayed recall scores to a similarly short-interval design. Comparisons between the present findings and past research is also difficult because the RAVLT is typically used in research to examine learning, prospective and retrospective interference effects, recognition, or temporal order of word recall and strategic reorganization of material. In contrast, RAVLT scores were used here as a strict measure of verbal memory (Boon et al., 2005; Vakil et al., 2010).

Lezak (1995) suggests that a cut-off score of 9 (over all five learning trials in the conventional RAVLT) is indicative of cognitive dysfunction. A few studies have used similarly modified versions of the task to distinguish dementia patients from healthy controls. Knopman and Ryberg (1989) conducted a test with only two learning trials, followed by a delayed recall trial after a 5-minute delay. Their results suggest that healthy individuals typically recall between five and eight words on the delayed trial, while those with diagnosed dementia or pre-dementia recall three or fewer words. This cut-off score reliably distinguished cognitively healthy from cognitively impaired participants. Similarly, Shoenberg et al. (2006) compared RAVLT scores among older adults with a variety of brain injuries and cognitive dysfunction and reported that scores of 2-4 on the first recall trial were associated with significant impairment. In another study comparing an adjusted WAIS-R score to scores obtained on the very first learning trial of

the RAVLT, a recall score of 5 was equated to a 45 to 65th percentile FSIQ scores for adults over 65 (Steinberg et al., 2005). Overall, REYI and REYII mean scores reported in the present study are in line with scores previously found in cognitively healthy populations at all age groups, and do not approach a level of clinical significance that would suggest cognitive impairment. Therefore, this decline in scores of one-half to one word per decade likely to reflect normal aging. The only exception may be for men in the 80s age group, specifically, who approached a mean immediate recall score of 4 in our study.

Some previous research has shown that variance in RAVLT scores increases with age (Boon et al., 2005; Davis et al., 2003). While this trend was observed for some other cognitive test scores in our study, RAVLT test scores appeared to maintain relatively stable variance across age groups as measured by standard error and standard deviation. This may be due, in part, to the uniquely large sample size provided by the CLSA. It may also be due to homogeneity in our population demographics, given that the majority of CLSA participants reported being highly educated and trended towards higher socioeconomic status, both of which have been suggested to influence cognitive test performance.

Sex differences in memory are supported in the present research. Some previous studies have reported strong effects of sex on RAVLT performance, with women outperforming men in healthy older adult samples (Gale et al., 2007) as well as older adults experiencing dementia (Sunderman et al., 2016). However, these results are not universal, with at least one study finding no differences between men and women on the RAVLT task (Correia & Osorio, 2014). Women, on average, recalled one word more than men for all age groups. These differences are not likely related to general differences in verbal ability or physical health. Rather, the sex difference in RAVLT performance has been suggested to reflect differences in strategic approaches to

encoding verbal information (i.e., mental organization of verbally presented information). While men often report organizing information serially, women report organizing information semantically (Gale et al., 2007; Kramer et al., 1988), and this strategy would be a particular advantage on the RAVLT given the content.

There is some evidence that hormones may be associated with differences in memory between men and women. Sex differences in memory task scores increase significantly after the onset of puberty. Additionally, women with hormonal deficiencies (e.g., congenital adrenal hyperplasia, Turner's syndrome) have lower verbal memory and working memory scores than control groups (Torres et al., 2006). However, among young adults, the effect of sex hormone levels does not seem to influence RAVLT scores. Women in the menstrual phase and those in the luteal phase of the menstrual cycle do not differ significantly in mean scores, but this was a between-subjects design (Dadin et al., 2008). If differences in RAVLT performance are related to circulating sex hormones, there would likely be a change in the size of the sex difference between younger and older adults given that women's hormone levels change after menopause. However, this was not evident in our results, and our findings are therefore more in line with an organizational/developmental effect of sex hormones on verbal recall to explain the sex difference in performance.

We found significant sex X age interactions for both REYI and REYII scores. Women in their 40s and women in their 50s did not differ from one another in terms of REYI scores, but all older age-groups showed a significant decline. For men, all age groups showed a significant decline from the previous decade group. Follow-up group comparisons did not reveal any significant identifiable differences in the association between age and REYII scores for men or for women. These cross-sectional findings may tentatively indicate that women begin to

experience age-related decline in verbal memory at an older age than men (i.e., women in their 60s and men in their 50s or earlier), and perhaps only once they have completed the menopausal transition. While the age effects were large in size, the effect sizes for sex X age interactions and REYI/REYII test scores were very small (η_{p^2} = .001).

Age, sex, and prospective memory.

Mean PMT scores in the present study did not differ between adults in their 40s and 50s, but decreased with each successive age group by a score of 0.2 to 0.5 out of a possible score of 9 (14-36% of the standard deviation). Prospective memory is considered to be a significant determinant of daily functioning, particularly for adults living with dementia (McDaniel et al., 1999; Thompson et al., 2010). It has been suggested to differ from other types of memory in that it requires a high degree of internal control, such as time or environment monitoring (Henry, 2004). Our findings are consistent with previous reports that prospective memory declines as a factor of age (Crystal & Wilson, 2015; Eusop-Roussel & Ergis, 2008; Gonneaud et al., 2011; Henry et al., 2004; Huppert, Johnson, & Nickson, 2000; Kliegel et al., 2016; Kretschmer-Trendowicz & Altgassen, 2016; Lecouvey et al., 2017; Thompson et al., 2010). Measures of prospective memory vary considerably across studies, and little research has been published using the Miami Prospective Memory Test scale included in the CLSA test battery. One publication reported that, within the CLSA participant pool, PMT scores decreased significantly with age; however, fewer than 8% of participants fell below the cut-off score of 5 which indicates impairment (Simard et al., 2017). The primary use of this scale is for the detection of significant cognitive decline indicative of lowered ability to live independently, and therefore likely has a high ceiling effect among cognitively healthy adults such as those included in the CLSA participant pool. Nevertheless, our results provide some evidence that prospective

memory declines with age even within a non-clinical population.

Some previous studies have suggested that younger adults outperform older adults on prospective memory tasks in a laboratory setting, but not in naturalistic settings (Niedźwieńska & Barzykowski, 2012). Some of these tasks in which older adults actually perform better or equal to younger adults include telephoning the experimenter at specific times over a period of four weeks (Devolder, Brigham, & Pressley, 1990; Poon & Schaffer, 1982; Moscovitch, 1982; Maylor, 1990) or mailing postcards to the experimenter (Patton & Meit, 1993). It has been suggested that older adults are more likely to organize external cues to act as reminders (e.g., keeping descriptive notes of the task on a calendar; Rendell & Craik, 2000). Given that older adults are believed to perform more poorly on time-based than event-based prospective memory tasks, the consistent use of self-arranged event-based reminders (e.g., alarms) may render this decrease in test performance clinically insignificant in terms of functional ability (d'Ydewalle et al., 2001). The PMT task included in the present study was event-based. Age-related declines in event-based performance may be the result of a weakened association between the cue and intended action (McDaniel & Einstein, 2000). It should be noted that the decline in PMT scores reported in this paper may reasonably be expected to weaken in a naturalistic setting when individuals create their own event-based cues to signal personally significant actions (e.g., going to an appointment) rather than arbitrary actions such as those used in our PMT task (i.e., removing money from an envelope and allocating different amounts between the participant and experimenter). Finally, the nature of the task(s) completed between the task instructions and the external cue to perform an action are important. More cognitively demanding ongoing tasks are associated with poorer response to event-based cues (Einstein, Smith, McDaniel, & Shaw, 1997; Martin & Schumann-Hengsteler, 2001). The tasks completed between PMT instructions and task

performance in this study were a series of unfamiliar cognitive tasks (Stroop, COWA, and CRT), which may require increased focus and attention compared to tasks completed in a more naturalistic setting. Thus, these intermediary tasks may have inflated the age-related decline on the PMT.

Age, sex, and verbal fluency.

Age produced a significant main effect on verbal fluency scores. Older age groups had significantly lower test scores than younger adults on both AFT and COWA tests. This is in alignment with results from earlier longitudinal studies using the same cognitive tests as the present study (Singer et al., 2003; Singh-Manoux et al., 2012).

For the Animal Fluency task assessing semantic verbal fluency, we report mean score changes of less than one word from 40s to 50s age groups, 1.7 words from the 50s to 60s age groups, 2.7 words from the 60s to 70s age groups, and 1.7 words from the 70s to 80s age groups (i.e., starting at a mean of 24.124 ± 6.502 in the 40s and declining to a mean of 17.197 ± 5.353 in the 80s).

The overall means obtained for each age group were comparable to previous AFT norms derived from healthy community-dwelling participants (i.e., Gladsjo et al., 1999). That study reported a mean score of 23 for adults between 35-49 and a mean score of 18 for adults 50 and over. In contrast, individuals with dementia or cognitive impairment associated with diabetes are reported to achieve scores between 10-15 on this task, and this is considered a reasonable cut-off range for determining cognitive dysfunction (Hall et al., 2010; Kinhuata et al., 2018; Long et al., 2014; Taylor & Phillips, 2008). It therefore seems unlikely that the decline observed in our analysis is reflective of cognitive impairment for any age group.

Our analyses suggested no main effect of sex on AFT scores. These results are supported by some previous research indicating that sex accounts for less than 1% of variance in both COWA and AFT scores (Tombaugh et al., 1999). However, other research has suggested that sex-based differences in semantic fluency scores may vary based on the content of the task. Men produce more words on tasks requiring them to name non-living things (e.g., professions, tools) while women produce more words when describing living categories such as fruit, but not animals (Laws, 2006; Van der Elst et al., 2006). Sex differences may be more apparent in the content (i.e., organizational strategies) rather than the number of items produced. It has been suggested that men produce words clustered into semantic subcategories, whereas women make more use of the category-switching strategy, to achieve similar overall test scores (Lanting et al., 2009; Weiss et al., 2006). More recent research suggests that when participants are instructed to switch categories frequently, women produce more switches than men and produce a higher number of total words overall, but no sex differences were observed under other task conditions (Scheuringer et al., 2017). The present study assessed fluency only through total number of items produced, which may have limited our ability to identify sex-based differences in performance due to process differences proposed by previous researchers.

For the COWA test assessing phonemic verbal fluency, mean scores decreased by 0.5 to 0.8 words per decade of age. The overall mean scores for all age groups (Appendix E2) were in line with means reported in healthy college students (13 words per trial; Ross et al., 2005) and higher than means reported for older adults in previous studies (10 words per trial; Gladsjo et al., 1999). Our findings also support previous research suggesting that healthy older adults show a greater decrease in semantic (AFT), rather than phonemic (COWA), verbal fluency (Meinzer et

al., 2009). Specifically, in the present study semantic AFT task had an age decline effect size of $\eta_p^2 = .066$ while the COWA age decline effect size was $\eta_p^2 = .007$.

Our study also found a significant main effect of sex on COWA scores favoring women, such that women generated one more word than men on average at every age grouping (i.e., each decade). Sex differences have been previously reported in content, such that women demonstrate more switching and men produce longer clusters when generating words. Resulting in fewer words produced by men overall (Weiss et al., 2006). This indicates that sex discrepancies in COWA scores could be the result of different information processing strategies, rather than simple cognitive ability differences in overall verbal ability and executive control. One meta-analysis of the effects of both age and sex on COWA scores in cross-sectional studies found a potential interaction between sex and age, and reported that women may not outperform men until they reach their 60s, which is due to a decline in performance for men in that age group (Rodriguez-Aranda & Martinussen, 2010). In contrast, our results indicated significant sex differences at every age group starting in the 40s. We found an Age x Sex interaction with a very small effect size ($\eta_p^2 = .001$); women's scores decreased starting in their 70s and showed a slower rate of decline than men's whose scores started to decrease in their 60s. This may suggest a slightly earlier decline in phonemic verbal fluency for men compared to women.

Age, sex, and attention/executive function.

Age produced a significant main effect on the tests assessing attention, executive function, and processing speed (i.e., Stroop Test, MAT, and CRT). These findings are consistent with previous research indicating that performance in these domains decrease with age, including Stroop Time and Error scores (Belleville et al., 2006; Belleville et al., 2007; Collette et al., 2009; Delis et al., 2001; Singh-Manoux et al., 2012; Troyer et al., 2007).

Our results suggest a medium to large effect of age (η_p^2 = .113) on the Stroop test as the mean time taken to complete the Stroop task increased by 2 to 5 seconds with each successive decade of life, with larger decreases occurring across the older age groups. The total range in mean scores between adults in their 40s and those in their 80s was a total of 15 seconds. Of all the tests examined in the present study, the age effect was highest with the Stroop time scores. The time scores observed in this study are similar to time taken for cognitively healthy older adults to complete the task in previous studies (e.g., Tremblay et al., 2016). The error rate in completing this task was low in all age groups, but increased from a mean of 0.25 errors in the 40s age group to a mean of 1.88 errors in the 80s age group with increasing rates of decline with successive decade. This is consistent with error rates reported in other studies (Delis et al., 2001).

Stroop Time and Error scores corrected for baseline speed remain positively correlated with age, suggesting that this relationship is not the consequence of simple physical slowing (Kane & Engle, 2003). Rather, there is likely to be an underlying cognitive cause, such as decreased response inhibition, which is targeted by the Stroop task. Therefore, decreasing Stroop performance with age may reflect a decreased ability to resist the dominant reading response. Alternatively, it may reflect an increased tendency to respond impulsively (Kane & Engle, 2003). Further evidence for these latter possibilities comes from the findings that older adults have a higher tendency than younger adults towards off-topic conversation (Arbuckle & Pushkar Gold, 1993) and to make more errors when asked to provide a word that is unrelated to a prompting sentence (Burgess & Shalice, 1997). Maintenance of a task goal, specifically, requires controlled attention; the Stroop task becomes more difficult (i.e., performance is impaired) when a high proportion of congruent color-words are included in the task because these items reinforce the dominant word-reading response (Kane & Engle, 2003; McCabe et al., 2007). This may be

particularly difficult for older adults due to the lifelong learning hypothesis applied to verbal fluency above (Ramscar et al., 2017) where older adults have a stronger affinity for dominant responses due to greater experience with word-reading. However, this notion has not been studied for applicability to the Stroop task specifically. The Stroop Task is appealing for use in older adult populations because it is relatively fast to administer to a population that fatigues more quickly than younger adults, and it has shown promise in its ability to distinguish between cognitively impaired dementia patients from healthy controls (Bayard et al., 2011).

There was also a significant main effect of sex on both Stroop Time and Error rates. Women had faster scores than men and produced fewer errors. These findings are supported by previous research on the interference trial of the Stroop task in large samples of older adults (N = 646 and N = 1856*;* Tremblay et al., 2016; Van der Elst et al., 2006). It has been suggested that this may be due to women having a faster processing speed than men rather than greater ability to inhibit responses (Camarata & Woodcock, 2006). However, Daniel et al. (2000) reported that, among adolescent and young adults, sex differences on the Stroop task were not apparent. Combined with our findings, this suggests the possibility that men's Stroop scores may start to decline earlier in life (i.e., prior to the 40s) and at a slightly faster rate than women's. However, further research is required to examine this possibility and to determine the underlying cognitive differences responsible for these findings. The present study appears to be the largest sample size for this kind of cross-sectional examination of the effect of age and sex on Stroop scores.

There were also significant Age x Sex interactions for Stroop Time and Error scores. With respect to time taken to complete the task, sex differences were apparent at every age level, and all age groups differed significantly from one another for both sexes. Follow-up analyses did not reveal any clear description of this interaction, likely because the effect size for the

interaction was extremely small (η_p^2 = .001). For Stroop Errors, sex differences were only evident for participants in the 80s age group. This effect size was small (η_p^2 = .016) and men made approximately one more error than women overall. To our knowledge, no previous published paper has examined the interaction between age or sex on either Stroop Time or Error scores. Our findings suggest that these sex differences may increase with advancing age.

The present study found that MAT scores decreased with age, and the size of mean score differences between age groups also increased with age. The difference is less than one word between adults in their 40s and 50s, 1.78 between adults in their 50s and 60s, 2.65 between those in their 60s and 70s, and 2.32 words between the 70s and 80s age groups. These findings build on the results of previous research, which indicates a decline occurs between the ages of 75 and 80 (McComb et al., 2010). While we observed differences between all age groups, the effect was largest between the oldest age groups. The overall mean scores for all age groups are in line with means reported in another study of older adult populations (McComb et al., 2009). Norms for this test are not widely accessible, as this particular test of executive function has not been widely used in research. Rather, the MAT is a relatively new oral version of the Trail Making Task intended for use in clinical work due to its ease and speed of administration, as well as the lack of reliance on visual and motor function. Thus, the MAT may be particularly useful with older adults as any physical limitations in older adults would be a disadvantage on the Trailing Making Task (Ruchinskas, 2003; Salib & McCarthy, 2002). The Trail Making Task also shows a significant effect of age, with performance declining as age increases (McCarrey et al., 2016). It has been suggested that MAT scores below 15 alternations in 30 seconds are indicative of impaired cognition based on a study where they examined both MAT scores and MMSE scores completed concurrently (Jones et al., 1993). The mean scores observed in the present study do

not approach this cut-off level even among the oldest adults, suggesting that this age-related decline is not reflective of impaired cognition. Nevertheless, the decline may be clinically significant for the older adults. These findings suggest that the MAT may be a fast and convenient tool for monitoring declines in executive function over time for the purpose of identifying risk of cognitive impairment.

Age had a significant main effect on choice reaction time, with all age groups differing significantly from one another such that older adults had slower reaction times than younger adults. These findings are consistent with earlier studies which suggest that choice reaction time decreases consistently with age (Anstey et al., 2007; Belak, 2010; Deary & Der 2007; Dear & Deary, 2006; Fozard et al., 1994). Simple reaction time is more resistant to age-related changes than more complicated tasks measuring disruptive or choice reaction time which require an additional response-selection step (Dykiert et al. 2012; Fozard et al., 1994). In the present study, mean choice reaction time decreased a mean of 41ms between the 40s and 50s age group, 74 ms between between the 50s to 60s and the 60s to 70s age groups, and 89 ms between the 70s and 80s age groups. Our findings indicate a slightly slower rate of age-related decline compared to previous estimates from the Baltimore Longitudinal Study on Aging (BLSA) that suggested choice reaction time begins decreasing in middle age at a rate of approximately 1.6ms per year (Fozard et al., 1994). This difference may be accounted for by the fact that our study compared mean scores across decades of life (i.e., cross-sectional) rather than yearly (i.e., longitudinal) change at the individual level. Furthermore, the present study analyzed data from a much larger pool of participants (N = 30, 097; age 45-85) than the BLSA study (N = 1,265) and we excluded participants who were younger than age 45 (as opposed to their age range of 17-96; Fozard et al.,

1994). Fozard and colleagues (1994) also administered an auditory signal to trigger a button-press response in participants, as opposed to the CLSA which relied on visual cues.

There are significant positive correlations between tests of cognitive function and choice reaction time, both in the results of the present study and in previous research (Deary, 2000; Deary & Der, 2007; Madden, 2001; Salthouse, 2000). It is therefore believed to be a measure of cognitive processing speed related to neurological function, and some age-related cognitive declines in other domains may be a consequence of a more general slowing in processing speed. However, as opposed to simply looking at mean reaction times, some research has indicated that intra-individual variability in reaction time over a number of trials increases with age and may be a better predictor of both cognitive decline and dementia risk (Belak et al., 2010; Dykiert et al. 2012; Hultsch et al., 2000; 2002). Variability remains a significant predictor of memory task performance and crystalized intelligence even after controlling for mean reaction time (Hultsch, MacDonald, and Dixon, 2002). Future research investigating the effects of age on choice reaction time may benefit from a within-subjects design across trials in order to capture these differences or control for their influence. Variance, as measured by standard error and standard deviation, did increase across age groups as mean reaction time increased in our findings.

We reported a significant sex difference in mean choice reaction time across age groups, with men demonstrating faster overall reaction times than women. Previous studies, including the Bonn Longitudinal Study of Aging, have also reported an advantage for men on choice reaction time tests in an older adult population (Der and Deary, 2006; Mathey, 1976). These studies show that women from middle to older age also demonstrate greater intra-individual variability across trials (Deary & Der, 2007; Der & Deary, 2006). In our sample, mean choice reaction times for men and women differed by only 17 to 26ms (for adults in their 40s to 50s) up

to 64ms (for adults in their 80s). While these sex differences are statistically significant, the overall sex effect size is very small (η_p^2 = .002), and it seems unlikely to have clinical significance in a cognitively healthy population. Furthermore, a study of younger adults demonstrated that while men have a faster movement time, women have a faster decision-making time, which minimizes differences in choice reaction time (Landaur et al., 1980). In children, no sex differences in intra-individual variability can be seen (Dykiert et al., 2012). Further understanding of potential age and sex differences in both mean reaction time and intra-individual reaction time variability is an important topic for the field of gerontology. Simple mean reaction time (as opposed to choice reaction time) has been suggested to be a significant predictor of fall risk among older adults, and a step-based reaction time (i.e., reacting with footstep movements rather than finger movements) may be particularly useful for assessing fall risk in clinical settings (Lord & Fitzpatrick, 2001).

Cognitive Test Scores are Influenced by Alcohol Use

Hypothesis 3 predicted that low levels of alcohol consumption, but not high levels of use, would have a beneficial effect on cognitive test scores. A potential beneficial effect of alcohol was supported, but this beneficial effect also extended to the highest levels of alcohol use across all alcohol variables that demonstrated a main effect on cognition (i.e., there were typically no differences in cognitive performance between moderate and high levels of the alcohol use variables). We found a main effect of both the Current Alcohol Use composite score and the Alcohol Use History composite score on cognition such that low estimates of alcohol use were associated with significantly lower Global Cognition scores than mid-to-high levels of use, but there were no significant differences among mid-to-high level groups, suggesting that cognition does not continue to improve with greater than moderate alcohol consumption. This same pattern

is also observed across the specific cognitive test in this study. These findings differ from many earlier studies which indicate that higher levels of alcohol use are associated with lower test scores (e.g., Liappas et al., 2007). However, our results do show a non-significant trend towards lower cognitive scores for the highest alcohol-use group when compared to those who consume alcohol at moderate levels. It is worth noting that our classification of moderate drinking is higher than drinking levels described as "moderate" in previous research. This nonsignificant trend is in line with previous studies of alcohol and cognition which depict an upside-down U shaped pattern of influence, with low-to-moderate users of alcohol obtaining the highest cognitive scores across domains when compared to non-drinkers and heavy drinkers (Galanis et al., 2000; Kaljmin et al., 2002; Mukamal et al., 2003; Solfrizzi et al., 2007). We observed significant main effects of all alcohol use variables (Drinks Per Week, Frequency of Alcohol Consumption, Binge Frequency, Alcohol Use History, Binge History, and Alcohol Type) on Global Cognition. An exception to the typical pattern of our results was the significant main effect of binge drinking on Global Cognition (see Figure 35), which showed a non-significant trend towards an upside-down U shape only until the highest-level of binge drinking frequency, which trended towards the high binge drinkers (binging four or more times per week) having better cognitive test scores than were found with lower frequencies of binge drinking.

The effects of alcohol, age, and sex on memory

All memory test scores were significantly associated with multiple alcohol use factors, including Drinks Per Week, Frequency of Alcohol Consumption, Binge Frequency, Alcohol Use History, and Binge Drinking History. There was no main effect of Alcohol Type (e.g., white wine, red wine, beer, or spirits) on any tests of the memory included in this study. Memory is a domain consistently reported to be influenced by alcohol use in older adults (Downer et al.,

2014; Hassing, 2008; Kalmijn et al., 2002; McDougall et al., 2007). While most studies have found that low levels of alcohol use are associated with the highest memory task performance and both non-drinkers and high users obtain the lowest scores (e.g. Antilla et al., 2004; Galanis et al., 2000), Kalmijn et al. (2002) did not report any detrimental effects on memory for the highest level of drinkers in their longitudinal study (8+ drinks per day). However, they note that participants in this group were slightly younger on average (45-70, *N*=1927) and were relatively highly educated in comparison to others.

Verbal memory scores on the RAVLT consistently differed between non-drinkers and drinkers for all alcohol use variables. While Drinks Per Week, Binge Frequency, Alcohol Use History, and Binge History showed no difference between levels of drinkers, both never-drinkers and 12-month abstainers had lower scores than low and moderate level drinkers for these variables. In contrast, the measure of Alcohol Frequency did reveal differences such that infrequent drinkers (less than once per month) had lower scores than those who consumed alcohol at all higher frequencies. For the Binge Frequency variable, those who reported drinking without binging in the past 12 months did not differ from those who reported binge drinking at any frequency. Altogether, the present results suggest that individuals who consume alcohol have higher verbal recall abilities than non-drinkers, but the overall amount of alcohol consumed (both currently and in the past) was not associated with the strength of this benefit.

While the total amount of alcohol consumed did not appear to have a dose-response effect on verbal memory, it is noteworthy that those who consumed alcohol infrequently (less than once per month) also did not show improved verbal memory scores over non-drinkers. suggesting that alcohol use frequency may be a more effective alcohol use measure for studying cognitive health than other variables (e.g., total amount consumed per week). These findings

support work from Nedergaard and colleagues (2012) which indicated that, in a mouse model, more frequent alcohol use (i.e., low-levels of *daily* alcohol consumption) were associated with improved cerebrospinal fluid circulation and drainage. The movement of cerebrospinal fluid plays a role in removing waste products, including the beta amyloid proteins associated with the development of Alzheimer's disease (Ilif et al., 2012). In addition, older adults show decreased flow of cerebrospinal fluid compared to younger adults (Attier-Zmudka et al., 2019), suggesting a possible explanation for why alcohol use might have a beneficial effect in older adults. Consistent low levels of alcohol consumption might therefore prevent the buildup of waste products in the CNS and might have an indirect beneficial effect on cognition, including memory. Low to moderate alcohol use has also been shown to decrease the risk of stroke in a meta-analysis of 157 studies (Reynolds et al., 2003). Because strokes often have a detrimental effect on cognitive performance, reduced risk of stroke is another potential mechanism that may lead to better cognition among older adults who consume alcohol at these levels.

We observed several significant interactions between age, sex, and the Drinks Per Week variable on RAVLT test scores. Men who do not drink alcohol had lower REYI scores than low and low-moderate drinkers, while women did not differ significantly by level of alcohol use. While the mean score differences across levels of alcohol use appeared larger for women than for men, higher within-group variance for women may explain the lack of statistically significant effects. There was a non-significant trend towards increasing mean REYI scores for women with increasing levels of alcohol use through to the highest level of drinking, compared to a relatively stable pattern of scores across higher alcohol use groups for men (Figure 16).

Men and women showed overall group differences in RAVLT scores (Figure 3), but this difference was not evident in the 40s age group. A 3-way interaction between Age, Sex, and

Drinks Per Week also revealed a stronger effect of alcohol use for women in their 70s compared to women at younger age groups such that older women who consumed higher levels of alcohol had higher/better scores than those who drank less alcohol. These findings suggest that sex differences in memory as a function of alcohol use may increase with advancing age, and that older women may show greater memory benefit than younger women by consuming alcohol. Kalmijn et al. (2002) similarly found an Alcohol x Sex interaction and reported that among older adults, women showed a stronger relationship between moderate alcohol consumption and memory performance than men. These findings were reproduced in the Whitehall II Longitudinal Study in the UK (Britton et al., 2004). While the effect sizes for interaction terms in the present study are quite small, they provide some evidence that the relationship between sex, alcohol use, and memory may also change as a function of age.

Prospective memory (i.e., PMT scores) was lowest among non-drinkers compared to drinkers across the alcohol use variables. In the case of Binge Frequency, those who drank without binging also had lower scores than individuals who engaged in binge drinking up to once a month, suggesting a potential benefit to infrequent binge drinking. PMT scores were also lower for those with a low-level of Alcohol Use History than those with a moderate level of Alcohol Use History. PMT is known to decline with advancing age (Crystal & Wilson, 2015; Eusop-Roussel & Ergis, 2008; Gonneaud et al., 2011; Henry et al., 2004; Huppert, Johnson, & Nickson, 2000; Kliegel et al., 2016; Kretschmer-Trendowicz & Altgassen, 2016; Lecouvey et al., 2017; Thompson et al., 2010) and previous research indicates that alcohol use negatively impacts prospective memory (Griffiths et al., 2017). Therefore, it is possible that any potential beneficial effect of alcohol use on prospective memory is more evident in groups with declining or lower prospective memory (i.e., women in their 70s).

After including additional follow-up covariates (social engagement, physical function, and personality factors) the main effects of alcohol use on PMT scores were no longer significant for any of the alcohol-use variables. Therefore, it seems that social engagement, physical function, and personality may help to explain the associations between alcohol and prospective memory.

The present findings are in conflict with some previous findings related to alcohol use and prospective memory. When heavy drinkers (consuming more than 14/21 drinks per day for women/men respectively) were compared to low-dose controls on a self-report questionnaire of prospective memory, chronic heavy use was associated with impairments among teenagers (e.g., more reported memory lapses in daily life; Heffernan et al., 2002). Other studies have reported detrimental effects of acute alcohol ingestion on PMT in adults aged 18-35 (Montgomery et al., 2011; Paraskevaides et al., 2010) and a detrimental effect of chronic high use on PMT in adolescents (Heffernan et al., 2006). Discrepancies may be due to the composition of the CLSA participant group. CLSA participants are generally highly educated and people were excluded from the study if they had a diagnosis of cognitive impairment. As previously discussed, the PMT exhibits a ceiling effect in non-clinical populations, and score differences across groups in the present study are small. However, the test was sensitive enough to reveal group differences in some of our analyses.

The effects of alcohol, age, and sex on verbal fluency

In the present study, COWA scores varied significantly as a function of all alcohol use variables and AFT scores showed a main effect of all variables with the exception of Alcohol Type. For both of these verbal fluency tests, individuals in the low-level drinking categories had higher scores than non-drinkers but lower scores than those who consume alcohol at moderate-

to-high levels, suggesting a potential dose-effect response with a beneficial impact of alcohol consumption on verbal fluency. These findings support some, but not all, previous research. Many researchers have found that higher levels of alcohol consumption are associated with improved letter fluency scores (e.g., COWA; Britton et al. 2004, Dufoil et al. 1997, Elias et al. 1999, Zimmerman et al., 2004) but found no effect of alcohol on category fluency (e.g., AFT; Britton et al. 2004, Espeland et al., 2006; Green et al., 2010; Reas et al., 2016). Furthermore, at least one study reported that, among middle-aged to older adults, higher alcohol consumption frequency as well as drinks per week were associated with lower phonemic fluency test scores rather than higher scores (Gross et al., 2011). Thus, while the present findings are largely consistent with past research suggesting a beneficial effect of alcohol on letter fluency in older adults, our study seems to be the first to report a beneficial effect on semantic fluency as well. This may be due to the large sample size (and higher power) included in our study.

Non-drinkers had lower AFT scores than consumers of alcohol across all variables. However, AFT scores also varied as a function of alcohol Frequency; those who consumed alcohol at high frequencies (4+ times per week) had higher scores than those who drank at moderate frequencies (2-4 times a month). Individuals who drank without binging also had lower AFT scores than those who binged alcohol at low levels (less than once per month). This suggests that increased frequency of alcohol consumption may have a benefit on category fluency test scores, as does a low level of binge drinking. COWA scores appeared to be more heavily influenced by alcohol consumption than AFT scores. While non-drinkers had lower scores than drinkers across the alcohol variables, there were also several differences between levels of alcohol consumption. Individuals who reported low-levels of alcohol use as measured by Drinks Per Week, Frequency, and Alcohol History had lower COWA scores than groups

reporting higher levels of consumption. There were also significant differences between moderate and high-level drinkers in terms of Frequency of use, such that those who consume alcohol 4+ times per week had the highest scores. Individuals who drank without binging had lower scores than those who binge drank at low, moderate, and high frequencies. All together, this pattern of verbal fluency test results suggests that performance on phonemic verbal fluency (COWA) is more strongly associated with alcohol consumption than scores of categorical/semantic verbal fluency (AFT). These findings align with previous results suggesting that alcohol influences COWA scores but not AFT scores (e.g., Britton et al. 2004).

It has been suggested that tests of phonemic fluency (such as the COWA) evaluate cognitive flexibility because they require the participant to produce a number of items in response to very minimal instructions. Neuroimaging and brain-lesion studies have related this kind of cognitive flexibility to functioning of the prefrontal cortex, particularly the left frontotemporal lobe (Henry & Crawford, 2004; Guorovitc et al., 2000). Dysfunction in this region of the brain has been reported in long-term heavy users of alcohol as measured by both frontal-lobe associated behaviour scales and neuroimaging studies (Lyvers et al., 2010; Moselhy et al., 2001). This contrasts with our findings, suggesting that while this region of the brain may be influenced positively by some patterns of alcohol consumption, chronic long-term alcohol use may lead to the opposite effect.

In contrast, category fluency stimulates greater activation of the left temporal cortex (Guorovitch, 2000) and temporal lobe lesions are associated with larger deficits in category fluency compared to letter fluency (Henry & Crawford, 2004). It therefore appears that these tasks may assess different cognitive domains - for example, cognitive flexibility versus vocabulary knowledge. Despite these differences, there is considerable overlap of both frontal

and temporal activation during all tasks of verbal fluency, and frontal lobe damage causes similar deficits in both test scores (Guorovitch, 2000; Henry and Crawford, 2004; Schwartz & Baldo, 2001).

The current binge drinking findings are particularly interesting because binge drinking has rarely been investigated for its unique contribution in the relationship between alcohol use and verbal fluency. Past published research has tended to define alcohol use on a scale of intensity (number of drinks consumed daily or weekly) and frequency. Variation in the alcohol-use ranges used to define groups may contribute to inconsistency among previously published results regarding alcohol use and cognition. For example, a category of 1to 4 drinks per day may or may not include binge drinking depending on the sex of the participants, and frequency measures do not innately contain information about the number of drinks consumed on a single occasion. Parada et al. (2012) investigated binge drinking frequency and cognitive test performance in a sample of Spanish-speaking university students. In contrast to our findings, they reported no significant influence of binge drinking on letter fluency. However, it is important to note the difference in age between the Parada study (young adults) and the CLSA sample (middle-aged to older adults) as well as a difference in sample size (N = 122; Prada et al., 2012). Confounding age-related differences (such as lifestyle, HI, and education) may account for some discrepancies in the results. Furthermore, the number of drinks consumed in a “binge” episode may vary by age, but this was not controlled in the present study. Our study appears to be the first to examine the effect of binge drinking on verbal fluency in an older adult population.

Alcohol Type had a significant main effect on COWA scores. Individuals who reported drinking only wine (red or white) within the past 12 months had higher COWA scores than both beer drinkers and spirit drinkers. It has been suggested that red wine, in particular, may slow age-

related cognitive decline (Corona et al., 2013; Panza et al., 2012) due to the presence of the naturally-occurring polyphenol resveratrol, which reduces neuroinflammation (Frozza et al., 2013) and raises cell metabolism (Gomes et al., 2013). Red wine may lower the risk of Alzheimer's dementia as a consequence of these biological effects (Granzotto & Zatta, 2014). Artnzen et al. (2010) reported an association between moderate wine consumption and improved cognition (i.e., verbal memory and digit-symbol coding) without making a distinction between red and white wine, although the mechanism behind the potential benefit to white wine has not been investigated. Another study reported contradictory results to the present study, suggesting that high consumption of wine leads to decreased performance in a variety of cognitive domains among older adults compared to those who drink lower quantities of wine (Haller et al., 2018). One important consideration is that patterns of alcohol use tends to vary by preferred alcohol type. In Canada, adults over the age of 15 consumed significantly more beer and spirits than wine between 1961 and 2016; however, levels of wine and spirit consumption grew approximately equal by 2016 (World Health Organization, 2018). In a Danish study with over 50,000 adult participants, the authors found that beer drinkers were more likely to drink at higher frequencies, but there were no differences in total alcohol intake across alcohol types (Gronbaek et al., 2000). Nevertheless, future research should take drinking patterns into consideration (i.e., total consumption and binge drinking frequency) when comparing the impacts of alcohol type on cognition or any other factor. Rimm (1996) has suggested that binge drinking may vary by preferred alcohol type; if wine is consumed in small doses (i.e., with meals) it may appear more beneficial than types of alcohol more commonly consumed in higher doses. Furthermore, preferred alcohol type may also be influenced by socioeconomic status, culture, country of residence, and social contexts (i.e., Rimm, 1996).

The effects of alcohol, age, and sex on executive function

All tests of executive function (Stroop Time, Stroop Errors, and MAT) were associated with variables assessing both current and past use of alcohol such that higher levels of alcohol consumption or history were associated with improved test performance. Stroop Time and Error scores also varied by alcohol type.

We saw no detriment to test scores at higher levels of alcohol use in terms of Stroop Time or Error scores, which is inconsistent with past research indicating that individuals with alcohol use disorders are impaired on a variety of tasks assessing executive function (Dao-Castellana, 1998; Fadari & Cox, 2006; Montgomery et al., 2012; Thoma et al., 2013; Wollenweber et al., 2012;), and with reports that show no influence of alcohol on Stroop Time scores (Schinka et al., 2002). However, it is noteworthy that there was no evidence of a beneficial effect at higher levels of alcohol consumption. In fact, the heaviest drinking groups showed a non-significantly lower mean performance than moderate users when some alcohol variables were examined (i.e., illustrated in Figures 18, 37, 46). It is possible that among a healthy community-dwelling population, the effect of alcohol use on Stroop scores is weaker than in clinical alcohol use disorder populations. This may be at least partly due to a higher typical amount of consumption in the high alcohol using groups in those with alcohol use disorders.

Across all alcohol use variables, Stroop Time and Error scores and MAT scores were poorest for non-drinkers. For the Frequency variable, there were additional differences between levels of alcohol use; individuals who consumed alcohol infrequently (less than once per month) had worse Stroop Time and Error scores than those who drank 2-3 times per month or more. Similarly, individuals who drank alcohol less than once per month had lower MAT scores than

those who consumed alcohol at higher frequencies. Participants who had a moderate-level alcohol use history also performed better than those with a low level of alcohol history. When additional covariates (i.e., physical function, social engagement, and personality factors) were included in the analyses, Stroop Error scores no longer showed an effect of Drinks Per Week, Alcohol Use History, or Binge History, but all other tests remained significant. It therefore seems that Stroop Time scores may be more susceptible to the effect of alcohol use than Stroop Error scores, and that Alcohol Frequency was the only measure of alcohol use sensitive enough to capture dose-effects of alcohol use on these three executive function tests at the level beyond capturing differences in cognition between drinkers and non-drinkers. This observation highlights a finding that stands out in Table 8, which is that, of all the alcohol variables examined in the present study, *frequency* of alcohol use appears to be the best and most sensitive indicator of alcohol's beneficial effects on cognition.

Stroop Time and Errors were also associated with Alcohol Type. In both cases, drinkers of red wine had better scores than drinkers of spirits. An interaction between Age, Alcohol Type, and Stroop Errors revealed that the benefit of red wine was only apparently for the 70+ age group. This is further evidence that older adults may be more susceptible than younger adults to any beneficial cognitive effects of alcohol. Beyond the potential beneficial effect of binging associated with different kinds of alcohol that has been discussed previously, it has been reported that wine drinkers have an overall lower rate of mortality compared to drinkers of other types of alcohol (Gronbraek et al., 2004). Both red and white wine drinkers also have a reduced risk of stroke (Truelsen et al., 1998), common colds (Takkouche et al., 2002) and cardiovascular disease (Wollin & Jones, 2002). This effect is also present for those who consume non-alcoholic red wine beverages (Chiva-Blanche et al., 2013) suggesting that health benefits of polyphenols

present in red wine may improve overall physical health, which is a known influence on overall cognition. This latter finding highlights the fact that studies investigating the effects of alcohol on cognition should take care to control for variables associated with overall health and nutrition.

Reaction time showed a significant main effect of all alcohol-related variables that reflect current alcohol use (Drinks Per Week, Frequency of Consumption, Binge Frequency) as well as the Binge History variable. However, in all cases, follow-up tests revealed the effect was no longer significant when additional covariates such as social engagement, physical function, and personality factors were considered. Both with and without covariates included, the effect sizes were very small.

Some previous studies have found that choice reaction time increases (i.e., gets worse) with low amounts of alcohol use, and then decreases (i.e., improves) again as alcohol use increases (Bond et al., 2001; Reid et al., 2006, Nurk et al., 2008; Ngandu et al., 2007). This pattern may be due to the fact that individuals who are dependent on alcohol demonstrate some attentional bias which may impair performance on all cognitive tasks (Field & Cox, 2008), and which may negate the initial beneficial effect of low-level alcohol consumption. In the current study, we did not control for alcohol dependency or health issues associated with alcohol abuse.

Alcohol Abstinence and Lower Cognitive Test Scores

The results of the present study indicated that that non-drinkers (including both never-drinkers and 12-month abstainers) performed worse than drinkers on all cognitive test scores. Similar results have been commonly reported in alcohol-cognition research (e.g., Bond et al., 2004; Galanis et al., 2000; Ganguli et al., 2005; Horvat et al., 2015; Kalapatapu et al., 2016; Kalmijn et al., 2002; Virtaa et al., 2010).

It has been suggested that there is a *poor-health bias* present in groups of non-drinkers. Many individuals report abstaining from alcohol for health reasons (Hassing et al., 2018; Rosansky & Rosenberg, 2020), which may result in having "control" groups of non-drinkers who experience health-related decreases in cognitive performance. However, the present study found that the *abstainer effect* was maintained in most analyses even after the inclusion of covariates assessing physical functioning (i.e., grip strength, timed walking and standing tests, standing balance time, and the number of chronic conditions). Our findings support the results of Anstey et al. (2005) who reported that non-drinkers continue to demonstrate lower cognitive test scores after controlling for physical measures such as lung function and grip strength. Additionally, Anstey et al. found that the abstainer effect was evident even among healthy young adults (age 20-24), suggesting that this effect is mediated by more than health status. Another proposed explanation of this phenomenon is that non-drinking control groups do not consistently differentiate between lifelong abstainers and those who have quit drinking, leading to the inclusion of participants who may already have experienced adverse alcohol-related physical and cognitive changes over the lifetime (Lobo et al., 2010). To control for this possible confound many current studies now make a point to differentiate between these groups, as has been done in the present work. Our results rarely showed a difference in cognitive test performance between never-drinkers and 12-month abstainers. Furthermore, when differences were observed, 12-month abstainers consistently performed better than lifelong abstainers. Therefore, our results suggest that a history of alcohol use is potentially beneficial rather than detrimental for cognition. Future research designs should attempt to better understand this phenomenon. Gathering information about reasons for quitting alcohol use (e.g., health reasons, cognitive changes, contraindicated medications, alcohol use disorders), reasons for never using alcohol, as

well as other differences between alcohol users and never-users may help to create more homogeneous non-drinking groups, help better understand the potential benefits of alcohol on cognition, and help identify any alternative explanations.

Horvat et al. (2014) found that when using a within-subjects design, participants who quit drinking during the course of the study had lower cognitive test scores relative to drinkers, and decreased scores compared to their previous performance level three to five years later. This may be due to several factors. First, recent abstainers may experience short-term withdrawal effects that influence cognition (Brooks et al., 2008). There is some evidence that mild withdrawal, with or without pharmacological intervention, produces impairment on a test of immediate free recall (Seifert et al., 2006). Studies in mice have demonstrated that alcohol withdrawal is associated with glucocortocoid dysfunction in the prefrontal cortex; activity in this region is associated with cognitive functions including executive function, memory, and verbal fluency (Dominguez et al., 2016). Symptoms of alcohol withdrawal may be more severe in older adults compared to younger adults (Brower et al., 1994); thus, this is an important consideration when conducting alcohol use studies in older adult populations. As an alternative explanation, the effect of alcohol use may be mediated by a variety of individual factors that make some participants more susceptible to a potential benefit than others; it is possible that individuals who benefit (or do not experience a detriment) are more likely to consume alcohol on a regular basis. Further research is required to address these questions.

Another potential explanation for the abstainer effect is a *social bias* in the formation of abstainer groups. Qualitative studies have suggested that lifelong abstainers endorse reasons such as public image, religious values, personal values, and beliefs about the ways that alcohol use affects behaviour (Hassing et al., 2010). Some research has suggested that the abstainer effect is

the consequence of social dysfunction. For example, a longitudinal study reported that, at age 21, lifelong abstainers were more likely to have a weak networks of friends, loneliness, and high likelihood of sexual abstention; by age 28, these same individuals had a higher prevalence of anxiety and depression, and were more likely to receive social assistance benefits (Vaughan et al., 2010). Our study statistically controlled for this potential confounding variable by including a measure of social engagement as a covariate in follow-up analyses. This variable was a composite score based on reports of the recency of social interaction, size of the social network, and frequency of participation in community and social events. We also controlled for HI and anxiety/depression (within the "number of chronic conditions covariate"). After accounting for these factors, alcohol use factors retained a significant main effect on cognitive test scores which suggests that the abstainer effect is not entirely accounted for by social participation levels.

A final potential explanation for the abstainer effect is that alcohol use has small but beneficial causal effects on cognition, with the strongest effects occurring for frequency of drinking on tests of verbal fluency (i.e., AFT and COWA). This explanation should be considered in light of the fact that the present study discriminated between never drinkers and previous drinkers, and the abstainer effect remained even after controlling for physical health/functioning and social engagement factors in addition to age, sex, education, language, HI, and personality factors. Given the many well-known adverse effects of alcohol (Carrington et al., 2009; Room et al., 2005), we do not suggest any practical/clinical recommendations based on this finding. However, a beneficial effect of alcohol on cognition (as compared to abstinence) might be explained by Nedergaard et al.'s (2012) findings that low-levels of *daily* alcohol consumption were associated with improved cerebrospinal fluid circulation and drainage in a mouse model. A hypothetical beneficial effect of alcohol on cerebrospinal fluid may be larger in

older (than younger) adults given evidence of reduced CSF flow in older adults (Attier-Zmudka et al., 2019).

Strengths and Limitations

Some limitations of the present study arise from the study design. First, in order to maximize the number of participants included in the analyses, individual comparisons were made between each alcohol use variable and each cognitive test score. This resulted in a large number of comparisons overall. Multiple comparisons within the same study can lead to an increased chance of reporting an erroneous positive result. As countermeasures to this limitation, we (a) first examined whether there was an overall effect for composite measures of cognition and alcohol to justify further analyses, (b) employed an *p*-value of .001 for each analysis, and (c) made use of the Bonferroni corrections for multiple comparisons whenever observing a significant main effect of alcohol use on cognition. This type of correction is very conservative; however, in cases where no group differences were identified in post-hoc analyses, caution should be taken in interpreting the results. This is particularly important to consider given that many of the effect sizes reported in our results are small or very small. While it is possible that the effects of alcohol on cognition are consistent enough to be detected in our sample, the presence of such small effect sizes raises the question of clinical or practical applicability in terms of identifying healthy or beneficial patterns of alcohol consumption. However, the consistency of the findings across cognitive and alcohol variables provides increases confidence in the findings.

Our results suggest that alcohol use, even at high levels, is associated with better cognitive function than abstaining from alcohol. Recommending alcohol use for its potential cognitive benefit carries some significant risks. Alcohol use has been consistently associated

with a large number of health problems, including impaired cardiovascular and liver function as well as increased risk of affective disorders and some types of cancer (e.g., Rehm et al., 2017). In addition, the small effect sizes in our study should be noted. While larger effect sizes have been noted in studies investigating the connection between alcohol use and the incidence of dementia, our results suggest that any potential benefit of alcohol use appears to be minor in a healthy older adult population. To mitigate the risk of misinterpretation of these results, we conducted additional follow-up analyses with covariates shown in the literature to account for variance in cognitive function, to assist in ruling out non-alcohol-related factors that may better account for group differences in cognitive test scores. This latter approach represents a strength of this study.

Another limitation associated with study design is the grouping of variables. Much of the existing research defines alcohol use broadly (e.g., less than one drink per day or more than one drink per day) which restricts interpretability. We opted to design alcohol use variables in a way that would permit the comparison of smaller, clearly-defined groups that would allow differentiation between adults who consume alcohol at a larger range of levels, resulting in multiple groups that could be defined as low, moderate, high, and very high levels of drinking. While this represents a strength of the study, another natural consequence of this decision was that in most of our analyses - particularly those requiring age and sex comparisons - there are unequal group sizes. Individuals who consume higher levels of alcohol, and those in the youngest and oldest age groups, tended to be smaller (less than 1000 participants) compared to the others. We noticed increased variability in these smaller groups, which may have limited our ability to detect changes in cognitive function across groups at high levels of alcohol use. Whenever possible throughout this section, attention has been drawn to general trends in the group means, regardless of statistical significance. It has been previously reported that increased

age and increased alcohol use are associated with greater variability in cognitive test scores; due to differences in group sizes, it remains unclear how much this increased variance is the consequence of age and alcohol use, and how much is the consequence of the analysis design.

The present study made use of data collected by CLSA. This raises some potential limitations in terms of participant recruitment and questionnaire administration. First, there is a risk of selection bias; participants self-selected into the study after being given information on the goals and aims of the CLSA. There may be personality, social, financial, or other differences in the type of person who chooses to participate in long-term and large-scale research projects compared to the general population. This is particularly important to consider when comparing the results of the present work to smaller community-based studies. Participants in the Comprehensive group of the CLSA participant pool were used for our analyses. These participants must live within traveling-distance to a CLSA data collection site, which means they must reside within or adjacent to a city center. These locations may provide CLSA participants with greater access to social and community resources compared to rural Canadians. Finally, some populations were excluded from CLSA recruitment; these include residents of the three Canadian territories, persons living on federal First Nations reserves, and members of the Canadian Armed Forces. While our study, and the CLSA, aims to provide comprehensive knowledge about a representative sample of Canadians, these important populations are missing from our work.

With the exclusion of the cognitive and physical tests conducted in the data collection centers, the remainder of the CLSA questionnaires required self-report from participants. Participants completed these questionnaires in 3-4 hour periods on average, which may lead to fatigue. Participants may therefore misunderstand or misreport their levels of alcohol use and

social interaction, among other factors. Individual cognitive differences may also account for increased false reporting among those with the lowest levels of cognitive function; this would introduce inaccurate data into our analyses. It is our hope that the use of a very large sample size (over 30,000 participants) will reduce any noise introduced by mistaken or false reporting.

While the CLSA aims to gather longitudinal data over a period of 20 years, the data available for analysis at the time of the present study was reflective only of baseline cross-sectional performance. Therefore, this is a cross-sectional study. Differences between age groups may reflect genuine differences in cognitive function with advancing age, but may also be confounded by generational differences that are not considered here.

The present study contains several significant strengths. First, we made use of a very large and current sample of Canadian older adults; this allowed us to gather information about a very broad sample of community-dwelling adults in all ten Canadian provinces. Apart from the exclusions mentioned previously, this sample is presumed to be relatively representative of Canadians as a whole by including individuals from different geographical regions and backgrounds. Participants were excluded from participation in the CLSA if they had a diagnosis of cognitive impairment prior to recruitment; this permits us to investigate the effect of alcohol use on cognitive performance for healthy older adults. In contrast, much of the research conducted to-date focuses on the relationship between alcohol use and the incidence of dementia or cognitive impairment. As the aging population of Canada continues to grow, understanding patterns and influences on healthy aging - not just cognitive impairment - will be valuable in terms of informing health guidelines and improving quality of life for the majority.

Our study contained a large battery of cognitive tasks, which allowed us to identify specific cognitive domains which may be influenced by alcohol use. In contrast, it is common in

research to rely on short-form cognitive screening (like the MMSE or the MOCA) to assess overall cognitive status. Screening tests are useful in detecting significant cognitive impairment, but lack the ability to assess individual cognitive domains. We also chose a broad range of alcohol use variables that would permit us to distinguish between differing patterns of alcohol use; Drinks Per Week and Alcohol Use Frequency are commonly used in the existing literature, but by including additional alcohol factors (such as Binge Drinking Frequency and Alcohol Use History) we were able to provide a broader understanding of the aspects of alcohol consumption which are uniquely associated with cognition. As previously mentioned, the inclusion of a relatively large number of groups in our alcohol-use variables also allows us to better differentiate between individuals who consume varying degrees of alcohol use. Previous research typically groups individuals into "low" or "high" drinking categories which vary considerably between studies (e.g., Antilla et al., 2004; Kalmijn et al., 2002; Mukamal et al., 2003). Approximately 18% of Canadians were classified as heavy drinkers in 2019 (Statistics Canada, 2020). By including multiple groups in the range of alcohol use commonly deemed "high" (e.g., over 10 drinks per week or binge drinking at least once per month) we were able to gain a better understanding of the effects of alcohol at some higher levels that are commonly observed in Canada.

We controlled for a large number of covariates that had the potential to account for associations between alcohol use and cognition (i.e., age, sex, education, language, HI, number of chronic conditions, physical function, social engagement, and personality factors). The inclusion of these covariates was helpful as it allowed us to determine (a) instances in which the effect of alcohol on cognition remained even with these additional factors controlled, and (b) possible explanations for some associations between alcohol and cognition. While inclusion of

these additional covariates may decrease our ability to identify legitimate influences of alcohol use on cognition, it also becomes more unlikely to achieve a false positive result when additional variance is accounted for by non-alcohol related factors. This prudence is particularly important when discussing potentially beneficial effects of a substance known to be strongly associated with other (non-cognitive) health problems.

Previous research has indicated that alcohol use, age, and sex are all independently associated with cognition. However, to our knowledge, this study is among the first to investigate potential interactions between alcohol use, age, and sex, on cognitive function.

Summary

While effects were typically small or very small, we found that alcohol use may be associated with better cognition in all domains examined, even after accounting for differences in age, sex, education, socioeconomic status, physical function, and social engagement. While we did not frequently observe significant differences across levels of alcohol use, there was a prominent abstainer affect such that non-drinkers achieved lower cognitive test scores than both previous-drinkers and those who consume alcohol. To date, research examining the effect of alcohol and cognition has yielded mixed results. Our results support the findings of others who propose a benefit of low to moderate alcohol use. Additionally, we did not find any adverse effects of alcohol use at high levels.

We observed some sensitivity differences across alcohol use variables in their associations with cognition. Of note, alcohol use frequency and the frequency of binge drinking demonstrated differences not only between non-drinkers and drinkers, but also among levels of alcohol consumption. This is tentative evidence that drinking *frequency* may have a greater influence on cognition than total amount of alcohol consumed per drinking occasion, and

indicates that these frequency variables may be of particular use in future studies examining alcohol use.

In terms of cognitive test scores, tests that assess memory (i.e., RAVLT) and executive function (i.e., the Stroop task and COWA) showed the most consistent association with alcohol use. These functions are particularly relevant to an aging population. Subjective memory impairment is a frequently reported cause of distress among older adults and may be a risk factor for more significant cognitive impairment in later life. Executive function (i.e., attention and verbal fluency measured by Stroop and COWA tests) is a crucial component of many daily tasks, such as driving, which contribute to independence and quality of life for aging adults.

We found some interactions of very small effect sizes that indicated that alcohol may affect men and women differently, and may affect them differently as a function of age. Greater understanding of these interactions would be helpful in modifying alcohol use guidelines for individuals with the goal of minimizing age-related cognitive dysfunction or decline. Future research is needed on this topic.

Overall, the results of the present study indicate that alcohol use at any level is associated with a small cognitive performance advantage (when sober). Given the cross-sectional nature of the study design, our findings should be interpreted with caution. The small effect sizes suggest that there may be non-alcohol related factors which may better explain the connection between alcohol consumption and cognition. However, the associations held significance even with numerous statistical controls and were consistent across many measures of alcohol and cognition. There is a need for future research into the underlying causes of the abstainer effect, as well as interactions between alcohol use and other factors known to influence cognition in an

aging population. Such research will be required to contextualize the health benefits and consequences of drinking alcohol across the lifespan.

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Appendix A

Table A1

Summary Information for Covariates

Covariate	Description
Education	Scale ranges from 1 to 8 and reflects the highest level of education attained. 1 = grade 8 or lower; 2 = grade 9-10; 3 = grade 11-13; 4 = secondary school graduate with no post-secondary education; 5 = some post-secondary education; 6 = trade certificate, diploma from vocational school, other non-university certificate, or university education below Bachelor's degree; 7 = Bachelor's degree; 8 = university degree above Bachelor's degree
Household Income (HI)	Scale is based on household income and ranges from 1 to 5. 1 = less than $20,000 per year; 2 = $20-50,000 per year; 3 = $50-100,000 per year; 4 = $100-150,ooo per year; 5 = over $150,000 per year
Chronic Conditions	Scale is a continuous count of the number of chronic conditions reported. Specific conditions include high blood pressure, heart disease, angina, heart attack history, peripheral vascular disease, stroke, mini-stroke, memory problems, Alzheimer's disease, Parkinson's disease, MS, epilepsy, migraines, ulcers, bowel disorder, bowel or urinary incontinence, cancer, mood disorder, anxiety, osteoporosis, back problems, underactive or overactive thyroid, kidney disease, or "other" chronic condition
Social Engagement (Social Composite)	Average of three z-scores taken from measures assessing social network size, frequency of social participation, and social recency variables; higher scores reflect higher levels of social engagement
Physical Function	Average of five z-scores acquired from physical tests including the timed up-and-go, standing balance, 4m walk, grip strength, and chair raise. Higher scores reflect stronger physical function.
TIPI scores (TIPI-O, TIPI-C, TIPI-E, TIPI-A, TIPI-ES)	There are 5 TIPI scores each assessing different personality trait. Each scale ranges from 1 to 7 where 1 reflects the lowest self-endorsement for the trait and 7 is the highest self-endorsement for the trait. Traits assessed are openness, conscientiousness, extraversion, agreeableness, and emotional stability.

Table A2

Summary Information for Cognitive Test Scores

Cognitive Score	Description
Global Cognition	Global Cognition is the mean of z-scores for all other cognitive tests and is intended to reflect overall cognitive functioning.
REYI (RAVLT-immediate)	REYI scores are derived from the immediate recall trial of the Rey Auditory Verbal Learning Test. After listening to a spoken list of 15 words, participants recall as many words as possible with no time limit. Scores reflect the number of correctly recalled words. This is a measure of short-term auditory/verbal memory.
REYII (RAVLT-delayed)	REYII scores are derived from the delayed recall trial of the Rey Auditory Verbal Learning Test. Five to ten minutes after completing the RAVLT immediate recall trial, participants again recall as many words as possible with no time limit. Scores reflect the number of correctly recalled words.
PMT (Prospective Memory)	The Prospective Memory Test requires participants to complete an event-based complex task. Scores range from 0 to 9 and are based on intention to perform the action following a cue, accuracy of task performance, and need for reminders.
AFT (Animal Fluency Task)	The Animal Fluency (or Animal Naming) task is a measure of semantic verbal fluency. Participants name as many animals as possible within 60 seconds and scores reflect the number of correct responses given.
COWA (Controlled Oral Word Association)	The Controlled Oral Word Association task is a measure of phonemic verbal fluency. Participants name as many words as possible beginning with a particular letter within 60 seconds over three trials. COWA scores are the mean number of correct responses over all three trials.
Stroop Time	Stroop Time scores are the number of seconds taken to complete the interference trial of the Stroop task, which requires participants to ignore irrelevant information (word reading) while performing a color naming task. Stroop scores assess attention/executive function.
Stroop Errors	Stroop Error scores are the number of errors made during the interference trial of the Stroop task. Stroop scores assess attention/executive function.
MAT (Mental Alternation Test)	The Mental Alternation Test requires participants to alternate letters and numbers in correct sequence (e.g., 1A-2B-3C) for 30 seconds. Scores are the number of correct alternations completed within the time limit and range from 0-52. This test is a measure of attention/executive function.
CRT (Choice Reaction Time)	The Choice Reaction Time task is a computer-based reaction time test requiring a button press in response to visual stimuli appearing on the screen. Scores are the average reaction times (in milliseconds) over all trials.

Table A3

Description of Alcohol Use Variables

Alcohol Use Variable	Description
Current Alcohol Composite	A composite score intended to reflect overall levels of current alcohol use (over the past 12 months); the sum of z-scores derived from alcohol frequency, binge frequency, and number of drinks consumed weekly
Alcohol History Composite	A composite score intended to reflect longer-terms pattern of alcohol use; the sum of z-scores derived from alcohol history and binge history variables
Drinks Per Week	Average number of drinks consumed in a typical week over the past 12 months. Scale ranges from 0 to 6. 0 = never-drinker; 1 = 12-month abstainer; 2 = low (1-7); 3 = low-moderate (8-21); 4 = high-moderate (22-30); 5 = high (31-50); 6 = very high (51+)
Alcohol Frequency	Average frequency of alcohol consumption over the past 12 months. Scale ranges from 0 to 5. 0 = never-drinker; 1 = 12-month abstainers; 2 = ≤ 1 per month; 3 = 2-4 times per month; 4 = 2-3 times per week; 5 = 4+ times per week
Binge Frequency	Average frequency of binge drinking (4+ drinks on one occasion for women, 5+ for men) over the past 12 months. Scale ranges from 0 to 6. 0 = never-drinker; 1 = 12-month abstainer; 2 = has consumed alcohol within the past 12 months without binge drinking; 3 = ≤ 1 time per month; 4 = ≤ 1 time per week; 5 = 2-3 times per week; 6 = 4+ times per week
Alcohol Use History	Measure of alcohol use history based on a comparison of current drinking habits (Drinks Per Week) to the heaviest period of alcohol use over the lifetime for each participant. Scale ranges from 0 to 5. 0 = never-drinker; 1 = 12-month abstainer; 2 = low (currently drinks less than 7 drinks per week and states this is the heaviest-ever period of alcohol use); 3 = moderate (currently drinks 8-21 drinks per week and states this is the heaviest period of use); 4 = high (currently drinks 22-45 drinks per week and states this is lower than the heaviest period of use); 5 = very high (currently drinks 45+ drinks per week and states this is lower than the heaviest period)

Binge Drinking History	Measure of binging history based on a comparison of current drinking habits (Binge Frequency) to the heaviest period of alcohol use over the lifetime. Scale ranges from 1 to 5. 1 = never-drinkers; 2 = 12-month abstainers; 3 = has consumed alcohol within the past 12 months without binge drinking; 4 = low (currently binge up to once a month and report this to be their highest-ever period of alcohol use); 5 = high (currently binge 4+ times per week and report this to be lower than their heaviest period of alcohol use)
Alcohol Type	Applies only to individuals who report drinking one type of alcohol within the past 12 months. Includes red wine, white wine, beer, and spirits.

Appendix B

Appendix B1

Alcohol Use Questionnaire

1. Have you ever drank alcohol?
    a. Yes
    b. No
    c. Don't know/no answer
    d. Refused
2. About how often in the past 12 months did you drink alcohol?
    a. Almost every day (incl. 6 times a week)
    b. 4-5 times a week
    c. 2-3 times a week
    d. Once a week
    e. 2-3 times a month
    f. About once a month
    g. Less than once a month
    h. Never
    i. Don't know/no answer
    j. Refused
3. In a typical week during the past 12 months, how many drinks of each of the following do you drink on weekdays, that is, from Sundays through Thursdays? [Record answer]
    a. Red wine
    b. White wine
    c. Beer
    d. Liquor or spirits
    e. Another kind of alcohol
4. In a typical weekend during the past 12 months, how many drinks of each of the following do you drink on weekends, that is, on Fridays and Saturdays? [Record answer]
    a. Red wine
    b. White wine
    c. Beer
    d. Liquor or spirits
    e. Another kind of alcohol
5. About how often during the past 12 months would you say you had [five, male] [four, female] or more drinks at the same sitting or occasion?
    a. Almost every day (incl. 6 times a week)
    b. 4-5 times a week
    c. 2-3 times a week
    d. Once a week
    e. 2-3 times a month
    f. About once a month
    g. Less than once a month
    h. Never
    i. Don't know/no answer
    j. Refused
6. How does your current consumption of alcohol compare to your heaviest period of drinking?
    a. About the same
    b. Less than the heaviest period of drinking

c. Don’t know/no answer
d. Refused

Appendix B2

Social Engagement Questionnaire

Now I'm going to ask you some questions about who lives in your household with you and what their relationship is to you. As well, I'm going to ask you about your children, whether they live with you now or not.

1. How many people, not including yourself, currently live in your household?

2. How many children do you have (i.e., living children whom you have given birth to or adopted, living stepchildren, or living children whom are your partner's children)?

3. When did you last get together with any of your children who live outside of your household?
    1. Within the last day or two
    2. Within the last week or two
    3. Within the past month
    4. Within the past 6 months
    5. Within the past year
    6. More than 1 year ago
    7. Not applicable, all children live in household
    8. Don't know/no answer
    9. Refused

4. How many, if any, living siblings (sisters, brothers) do you have?

5. When did you last get together with any of your siblings who live outside of your household?
    a. Within the last day or two
    b. Within the last week or two
    c. Within the past month
    d. Within the past 6 months
    e. Within the past year
    f. More than 1 year ago
    g. Not applicable, all children live in household
    h. Don't know/no answer
    i. Refused

6. About how many other living relatives (parents, grandparents, grandchildren, nieces, nephews, cousins, aunts, uncles) do you have?

7. When did you last get together with any of your other relatives who live outside of your household?
    a. Within the last day or two
    b. Within the last week or two
    c. Within the past month
    d. Within the past 6 months
    e. Within the past year
    f. More than 1 year ago
    g. Not applicable

h. Don't know/no answer
i. Refused

1.

8. Not counting family members, how many people do you consider close friends - that is, people you can confide in or talk about personal matters with?

9. When did you last get together with any of your close friends who live outside of your household?
    a. Within the last day or two
    b. Within the last week or two
    c. Within the past month
    d. Within the past 6 months
    e. Within the past year
    f. More than 1 year ago
    g. Not applicable
    h. Don't know/no answer
    i. Refused

10. How many of your neighbours do you know?

11. When did you last get together with any of your neighbours?
    a. Within the last day or two
    b. Within the last week or two
    c. Within the past month
    d. Within the past 6 months
    e. Within the past year
    f. More than 1 year ago
    g. Not applicable
    h. Don't know/no answer
    i. Refused

12. Aside from family members, close friends, and neighbours, about how many other people do you know personally (i.e., by name) through…
    Work or school
    Involvement in community activities and organizations
    Other activities

The next questions are about community-related activities that you may have participated in during the past 12 months. In the past 12 months, how often did you participate in…

1. Family or friendship-based activities outside the household?
    a) At least once a day
    b) At least once a week
    c) At least once a month
    d) At least once a year
    e) Never
    f) Don't know/no answer
    g) Refused

2. Church or religious activities such as services, committees or choirs?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don't know/no answer
   g) Refused

3. Sports or physical activities that you do with other people?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don't know/no answer
   g) Refused

4. Educational and cultural activities involving other people such as attending courses, concerts, plays, or visiting museums?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don't know/no answer
   g) Refused

5. Service club or or fraternal organization activities (e.g., Lion's club, Rotary, Kiwanis Club, Royal Canadian Legion)?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don't know/no answer
   g) Refused

6. Neighbourhood, community, or professional association activities?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don't know/no answer
   g) Refused

7. Volunteer or charity work?
   a) At least once a day
   b) At least once a week
   c) At least once a month

d) At least once a year
e) Never
f) Don’t know/no answer
g) Refused

8. Any other recreational activities involving other people, including hobbies, gardening, poker, bridge, cards, and other games?
   a) At least once a day
   b) At least once a week
   c) At least once a month
   d) At least once a year
   e) Never
   f) Don’t know/no answer
   g) Refused

Appendix B3

Ten Item Personality Inventory Questionnaire

1. I see myself as extraverted and enthusiastic
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

2. I see myself as critical and quarrelsome
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

3. I see myself as dependable and self-disciplined.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

4. I see myself as anxious and easily upset.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

5. I see myself as open to new experiences and complex.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

6. I see myself as reserved and quiet.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

7. I see myself as sympathetic and warm.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

8. I see myself as disorganized and careless.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

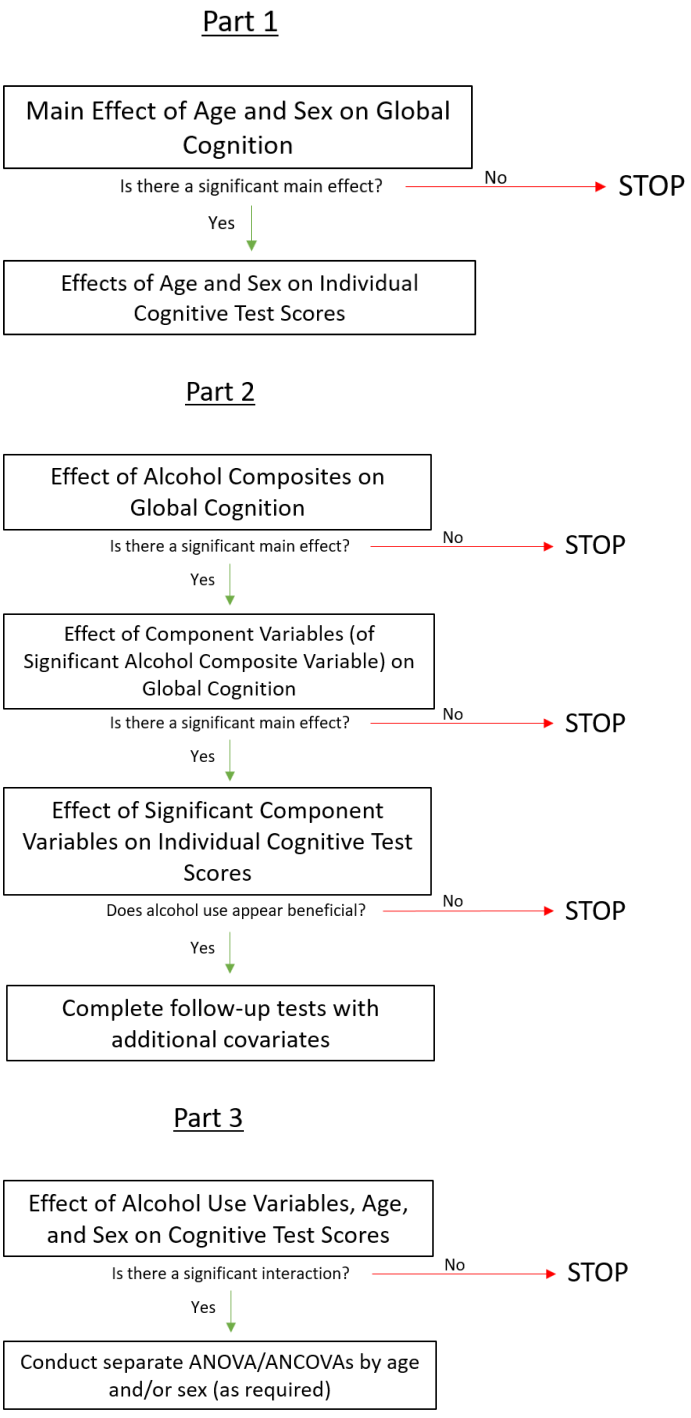
9. I see myself as calm and emotionally stable.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

10. I see myself as conventional and uncreative.
    a) Strongly disagree
    b) Moderately disagree
    c) Disagree a little
    d) Neither agree nor disagree
    e) Agree a little
    f) Moderately agree
    g) Strongly agree

Appendix C

Figure C1.

Summary of Analysis Procedure



Note: Parts 1, 2, and 3 of the analysis procedure were completed independently of one another.

Appendix D

Table D1

Spearman Correlations Between Covariates as a Function of Sex

	Age	Education	SES	Chronic Conditions	Social Composite	Physical Function	TIPI - O	TIPI - C	TIPI - E	TIPI - A	TIPI - ES
Age	-	-.198**	-.405**	.280**	.000	-.567**	-.075**	.006	0.052**	.040**	.059**
Education	-.043**	-	.366**	-.109**.	.160**	.242**	.154**	.023**	.036**	-.018*	.023**
SES	-.320**	.336**	-	-.237**	.138**	.390**	.082**	.098**	.122**-.	-.001	.072**
Chronic Conditions	.306**	-.071**	-.171**	-	-.054**	-.306**	-.006	-.089**	-.061**	-.018*	-.154**
Social Function	-.026*	.071**	.137**	-.020	-	.105**	.156**	.067**	.207**	.095**	.146**
Physical Function	-.546**	.121**	.318**	-.296**	.093**	-	.104**	.063**	.107**	-.009	.020*
TIPI - O	-.059**	.109**	.086**	-.024**	.115**	.102**	-	.097**	.277**	.139**	.158**
TIPI – C	.044**	.019*	.076**	-.062**	.059**	.017	.017	-	.083**	.166**	.241**
TIPI – E	-.029**	-.024**	.102**	-.041**	.231**	.065**	.065**	.087**	-	.085**	.148**
TIPI – A	.059**	.017*	-.010	-.028**	.086**	-.022*	-.022*	.168**	.082**	-	.340**
TIPI - ES	.042**	.065**	.115**	-.130**	.083**	.044**	.044**	.268**	.107**	.334**	-

Note: The Ten-Item Personality Inventory (TIPI) scores reflect TIPI subscales measuring openness (O), conscientiousness (C), extraversion (E), agreeableness (A), and emotional stability (ES). HI = socioeconomic status. Correlations for women appear below the diagonal, and correlations for men appear above.

** < 0.01; * < 0.05

Table D2

Spearman Correlations Between Cognitive Tests as a function of Sex

	Global Cognition	REYI	REYII	PMT	AFT	COWA	MAT	Stroop Time	Stroop Errors	Reaction Time
Global Cognition	-	.619**	.666**	.411**	.690**	.614**	.633**	-.642**	-.281**	-.470**
REYI	.680**	-	.685**	.184**	.374**	.292**	.294**	-.307**	-.181**	-.203**
REYII	.642**	.651**	-	.198**	.348**	.248**	.260**	-.306**	-.173**	-.213**
PMT	.392**	.185**	.186**	-	.220**	.141**	.181**	-.225**	-.142**	-.193**
AFT	.676**	.379**	.340**	.186**	-	.448**	.393**	-.420**	-.206**	-.245**
COWA	.624**	.311**	.239**	.122**	.434**	-	.402**	-.362**	-.178**	-.184**
MAT	.662**	.327**	.273**	.161**	.383**	.428**	-	-.449**	-.170**	-.248**
Stroop Time	-.671**	-.358**	-.330**	-.214**	-.396**	-.375**	-.478**	-	.320**	.351**
Stroop Errors	-.285**	-.189**	-.184**	-.128**	-.175**	-.184**	-.202**	.324**	-	.143**
Reaction Time	-.474**	-.224**	-.211	-.177**	-.242**	-.172**	-.246**	.362**	.139**	-

Note: Correlations for women appear below the diagonal, and correlations for men appear above. REYI = Rey Auditory Verbal Learning Test immediate recall; REYII = Rey Auditory Verbal Learning Test delayed recall; PMT = Prospective Memory Test; AFT = Animal Fluency Test; COWA = Controlled Oral Word Association; MAT = Mental Alternation Test

** < 0.01; * < 0.05

Table D3

Spearman Correlations Between Alcohol Use Variables Separated by Sex

	Current Alcohol Composite	Alcohol History Composite	Drinks Per Week	Alcohol Frequency	Binge Frequency	Alcohol History	Binge History
Current Alcohol Composite	-	.914**	.900**	.939**	.829**	.843**	.809**
Alcohol History Composite	.933**	-	.819**	.841**	.974**	.875**	.974**
Drinks Per Week	.913**	.872**	-	.829**	.667**	.818**	.658**
Alcohol Frequency	.885**	.846**	.822**	-	.678**	.790**	.741**
Binge Frequency	.818**	.964**	.668**	.585**	-	.785**	1.000**
Alcohol History	.917**	.909**	.924**	.838**	.820**	-	.773**
Binge History	.781**	.964**	.657**	.694**	1.000**	.797**	-

Note: Correlations for women appear below the diagonal, and correlations for men appear above. REYI = Rey Auditory Verbal Learning Test immediate recall; REYII = Rey Auditory Verbal Learning Test delayed recall; PMT = Prospective Memory Test; AFT = Animal Fluency Test; COWA = Controlled Oral Word Association; MAT = Mental Alternation Test

** < 0.01; * < 0.05

Table D4

Spearman Correlations Between Covariates and Cognitive Test Scores by Sex

Women	Global Cognition	REYI	REYII	PMT	AFT	COWA	Stroop Time	Stroop Error	MAT	CRT
Age	-.482**	-.303**	-.325**	-.258**	-.352**	-.165**	.495**	.222**	-.288**	.384**
Education	.346**	.254**	.233**	.082**	.313**	.295**	-.245**	-.188**	.224**	-.090**
SES	.378**	.254**	.220**	.152**	.290**	.235*	-.340**	-.186**	.249**	-.197**
Chronic Conditions	-.182**	-.115**	-.119**	-.069**	-.120**	-.081**	.201**	.116**	-.115**	.146**
Social	.121**	.103**	.061**	.036**	.100**	.122**	-.065**	-.023*	.092**	-.037**
Physical	.458**	.280**	.264**	.204**	.342**	.245**	-.433**	-.216**	.274**	-.358**
TIPI-O	.122**	.079**	.061**	.042**	.129**	.113**	-.102**	-.065**	.039**	-.054**
TIPI-C	.010	.005	-.008	.038**	-.011	-.007	-.039**	.006	.029**	-.009**
TIPI-E	.085**	.047**	.037**	.018*	.071**	.099**	-.066**	-.026**	.052**	-.050**
TIPI-A	-.002	-.004	-.014	.011	-.006	.022**	-.006	.001	.010	-.002
TIPI-ES	.042**	.030**	.011	.036**	.038**	.023**	-.016	-.007	.030**	-.021*
Men	Global Cognition	REYI	REYII	PMT	AFT	COWA	Stroop Time	Stroop Error	MAT	CRT
Age	-.486**	-.359**	-.364**	-.238**	-.323**	-.161**	.503**	.503**	-.257**	.390**
Education	.275**	.200**	.174**	.048**	.203**	.294**	-.183**	-.183**	.234**	-.055**
SES	.375**	.267**	.226**	.151**	.271**	.234**	-.324**	-.324**	.266**	-.210**
Chronic Conditions	-.188**	-.133**	-.134**	-.063**	-.102**	-.069**	.212**	.212**	-.177**	.160**
Social	.095**	.092**	.064**	.025*	.084**	.102**	-.068**	-.068**	.068**	-.038**
Physical	.426**	.294**	.268**	.190**	.303**	.202**	-.389**	-.389**	.238**	-.364**
TIPI-O	.091**	.054**	.046**	.024**	.100**	.104**	-.060**	-.060**	.025**	-.053**
TIPI-C	-.020**	-.019*	-.014	.031**	-.029**	-.022**	-.007	-.007	.015**	.025**
TIPI-E	.029**	.029**	.021*	-.005	.049**	.054**	-.023**	-.023**	.009	-.018*
TIPI-A	-.022*	-.014	-.002	-.018*	-.021*	.015	.023**	.023**	-.005	.027**
TIPI-ES	.046**	.038**	.037**	.022**	.038**	.016	-.030**	-.030**	.043**	-.028**

Note: The Ten-Item Personality Inventory (TIPI) scores reflect TIPI subscales measuring openness (O), conscientiousness (C), extraversion (E), agreeableness (A), and emotional stability (ES). REYI = Rey Auditory Verbal Learning Test immediate recall; REYII = Rey Auditory Verbal Learning Test delayed recall; PMT = Prospective Memory Test; AFT = Animal Fluency Test; COWA = Controlled Oral Word Association; MAT = Mental Alternation Test

** < 0.01; * < 0.05

Table D5

Spearman Correlations Between Covariates and Alcohol Variables by Sex

Women	Current Alcohol Composite	Alcohol History Composite	Drinks Per Week	Frequency	Binge Frequency	Alcohol History	Binge History
Age	-.130**	-.138**	-.084**	-.050**	-.248**	-.070**	-.132**
Education	.140**	.125**	.114**	.151**	.087**	.093**	.104**
SES	.278**	.267**	.228**	.256**	.235**	.212**	.217**
Chronic Conditions	-.153**	-.144**	-.123**	-.136**	-.140**	-.118**	-.117**
Social Function	.026*	.023	.028*	.037**	-.006	.026	.017
Physical Function	.209**	.218**	.165**	.170**	.233**	.157**	.188**
TIPI-O	.070**	.033**	.062**	.061**	.060**	.029*	.029**
TIPI-C	.039**	.038**	.039**	.049**	.008	.042**	.021*
TIPI-E	.106**	.072**	.094**	.086**	.093**	.068**	.054**
TIPI-A	-.030**	-.016	-.015	-.023**	-.037**	.000	-.016
TIPI-ES	.000	.019**	.001	.012	-.011	.012	.013
Men	Current Alcohol Composite	Alcohol History Composite	Drinks Per Week	Frequency	Binge Frequency	Alcohol History	Binge History
Age	-.064**	-.074**	-.029**	.045**	-.230**	-.039**	-.083**
Education	.057**	.142**	.064**	.121**	.000	.095**	.101**
SES	.183**	.221**	.166**	.181**	.180**	.178**	.176**
Chronic Conditions	-.088**	-.143**	-.076**	-.061**	-.122**	-.111**	-.111**
Social	.006	.007	.010	.011**	.002	.000	.008
Physical	.108**	.172**	.091**	.077**	.170**	.111**	.146**
TIPI-O	.028**	.022	.026**	.029**	.028**	.027*	.018
TIPI-C	.005	.042**	.007	.025**	-.015	.039**	.022*
TIPI-E	.061**	.026	.046**	.032**	.069**	.032*	.020
TIPI-A	-.040**	-.011	-.032**	-.021**	-.050**	-.033*	-.010
TIPI-ES	-.001	.042**	.006	.013	-.011	.022	.029**

Note: The Ten-Item Personality Inventory (TIPI) scores reflect TIPI subscales measuring openness (O), conscientiousness (C), extraversion (E), agreeableness (A), and emotional stability (ES). REYI = Rey Auditory Verbal Learning Test immediate recall; REYII = Rey Auditory Verbal Learning Test delayed recall; PMT = Prospective Memory Test; AFT = Animal Fluency Test; COWA = Controlled Oral Word Association; MAT = Mental Alternation Test

** < 0.01; * < 0.05

Table D6

Spearman Correlations Between Alcohol Covariates and Cognitive Test Scores by Sex

Women	Current Alcohol Composite	Alcohol History Composite	Drinks Per Week	Frequency	Binge Frequency	Alcohol History	Binge History
Global Cognition	.184**	.179**	.147**	.153**	.200**	.135**	.154**
REYI	.122**	.111**	.096**	.109**	.124**	.082**	.098**
REYII	.117**	.127**	.092**	.095**	.133**	.095**	.108**
PMT	.090**	.097**	.070**	.066**	.114**	.074**	.084**
AFT	.140**	.129**	.113**	.122**	.144**	.100**	.113**
COWA	.146**	.108**	.124**	.136**	.110**	.101**	.086**
Stroop Time	-.164**	-.156**	-.132**	-.131**	-.185**	-.113**	-.136**
Stroop Errors	-.112**	-.115**	-.087**	-.102**	-.104**	-.094**	-.092**
MAT	.129**	.128**	.108**	.111**	.129**	.102**	.106**
CRT	-.089**	-.105**	-.059**	-.054	-.136**	-.071**	-.095**
Men	Current Alcohol Composite	Alcohol History Composite	Drinks Per Week	Frequency	Binge Frequency	Alcohol History	Binge History
Global Cognition	.136**	.157**	.124**	.112**	.174**	.126**	.130**
REYI	.085**	.092**	.076**	.065**	.119**	.080**	.078**
REYII	.085**	.102**	.068**	.058**	.123**	.079**	.091**
PMT	.082**	.094**	.069**	.056**	.110**	.083**	.079**
AFT	.112**	.137**	.103**	.102**	.134**	.108**	.111**
COWA	.121**	.101**	.112**	.119**	.104**	.095**	.076**
Stroop Time	-.109**	-.137**	-.095**	-.072**	-.158**	-.106**	-.115**
Stroop Errors	-.072**	-.082**	-.060**	-.065**	-.085**	-.061**	-.074**
MAT	.088**	.108**	.085**	.089**	.096**	.085**	0.085**
CRT	-.061**	-.080**	-.042**	-.030**	-.120**	-.056**	-.075**

Note: Correlations for women appear below the diagonal, and correlations for men appear above. REYI = Rey Auditory Verbal Learning Test immediate recall; REYII = Rey Auditory Verbal Learning Test delayed recall; PMT = Prospective Memory Test; AFT = Animal Fluency Test; COWA = Controlled Oral Word Association; MAT = Mental Alternation Test; CRT = Choice Reaction Time

** < 0.01; * < 0.05

Appendix E

Table E1

Adjusted Mean (SD) Scores for Cognitive Tests Assessing Memory

	Age	Women	N	Men	N	All Participants	N
REYI	40s	6.91 (1.90)	1360	6.35 (1.83)	1238	6.64 (1.89)	2598
	50s	6.76 (1.93)	4352	5.98 (1.72)	4039	6.38 (1.82)	8391
	60s	6.34 (1.81)	4033	5.54 (1.70)	4157	5.93 (1.80)	8190
	70s	5.56 (1.74)	2346	4.71 (1.60)	2619	5.11 (1.72)	4965
	80s	4.89 (1.65)	759	4.08 (1.50)	811	4.47 (1.63)	1570
	Total	6.31 (1.89)	12850	5.49 (1.80)	12864	5.90 (1.89)	25714
		Women	**N**	**Men**	**N**	**All Participants**	**N**
REYII	40s	5.44 (2.22)	1363	4.62 (2.04)	1247	5.04 (2.18)	2610
	50s	5.13 (2.14)	4358	4.16 (1.97)	4037	4.66 (2.12)	8395
	60s	4.59 (2.05)	4033	3.58 (1.88)	4157	4.07 (2.03)	8190
	70s	3.73 (1.96)	2355	2.71 (1.74)	2594	3.20 (1.92)	4929
	80s	2.97 (1.86)	760	2.13 (1.59)	806	2.54 (1.78)	1566
	Total	4.61 (2.18)	12849	3.59 (2.01)	12841	4.10 (2.16)	25690
		All participants	**N**				
PMT	40s	8.77 (0.89)	2647				
	50s	8.74 (0.95)	8583				
	60s	8.56 (1.22)	8368				
	70s	8.07 (1.74)	5107				
	80s	7.52 (2.07)	1632				
	Total	8.48 (1.35)	26337				

Note: Cognitive test scores are the Rey Auditory Verbal Learning Test immediate (REYI) and delayed (REYII) recall trials and the Prospective Memory Test (PMT). Means are adjusted for the following covariates: education, HI, language, and number of chronic conditions. Means and SDs are only given as a factor of age or sex when the primary ANCOVA for a cognitive test indicated a main effect of age or sex.

Table E2

Adjusted Mean (SD) Scores for Cognitive Tests Assessing Verbal Fluency

	Age	All participants	N				
AFT	40s	24.12 (6.50)	2618				
	50s	23.38 (6.28)	8457				
	60s	21.63 (6.16)	8250				
	70s	18.89 (5.81)	5026				
	80s	17.20 (5.35)	1593				
	Total	21.65 (6.46)	25944				
		Women	**N**	**Men**	**N**	**All Participants**	**N**
COWA	40s	14.26 (4.05)	1354	13.77 (4.21)	1240	14.02 (4.13)	2594
	50s	14.05 (4.06)	4357	13.30 (4.17)	4022	13.69 (4.13)	8379
	60s	13.50 (4.20)	3997	12.87 (4.20)	4108	13.18 (4.21)	8105
	70s	12.52 (4.20)	2340	12.06 (4.33)	2622	12.28 (4.27)	4962
	80s	12.28 (4.27)	765	11.44 (4.27)	818	11.84 (4.29)	1583
	Total	13.51 (4.19)	12810	12.83 (4.27)	12810	13.17 (4.24)	25623

Note: Cognitive tests include the Animal Naming Test (AFT) and Controlled Oral Word Association test (COWA). Means are adjusted for the following covariates: education, HI, language, and number of chronic conditions. Means and SDs are only given as a factor of age or sex when the primary ANCOVA for a cognitive test indicated a main effect of age or sex.

Table E3

Adjusted Mean (SD) Scores for Cognitive Tests Assessing Attention/Executive Function

Test	Age	**Women**	**N**	**Men**	**N**	**All Participants**	**N**
Stroop Time	40s	20.67 (5.91)	1382	21.36 (6.33)	1257	21.00 (6.12)	2639
	50s	22.80 (6.30)	4446	23.47 (7.65)	4102	23.12 (7.00)	8548
	60s	26.65 (12.44)	4126	27.06 (8.27)	4195	26.85 (10.55)	8321
	70s	30.98 (10.55)	2396	32.08 (10.95)	2670	31.56 (10.78)	5066
	80s	35.40 (12.33)	778	36.92 (12.48)	841	36.19 (12.43)	1619
	Total	26.02 (10.55)	13128	27.05 (9.86)	13065	26.53 (10.23)	26193
Stroop Error	40s	0.26 (0.95)	1372	0.25 (0.84)	1253	0.25 (0.90)	2625
	50s	0.36 (1.24)	4432	0.37 (1.02)	4086	0.36 (1.14)	8518
	60s	0.61 (1.89)	4112	0.62 (1.68)	4174	0.61 (1.79)	8286
	70s	1.13 (2.68)	2381	1.16 (2.70)	2651	1.14 (2.69)	5042
	80s	1.56 (3.12)	776	2.20 (4.18)	837	1.89 (3.71)	1613
	Total	0.64 (1.94)	13083	0.71 (2.04)	13001	0.68 (1.99)	26084
MAT	40s	28.59 (8.32)	1351	29.71 (9.12)	1233	29.12 (8.73)	2584
	50s	27.93 (7.90)	4341	29.32 (8.70)	3982	28.60 (8.32)	8323
	60s	26.12 (7.92)	3991	27.50 (8.59)	4084	26.81 (8.29)	8075
	70s	23.21 (8.22)	2303	25.02 (8.70)	2546	24.16 (8.52)	4849
	80s	21.16 (8.51)	730	22.49 (8.54)	785	21.85 (8.55)	1515
	Total	26.18 (8.33)	12716	27.47 (8.94)	12630	26.83 (8.66)	25346

Note: Cognitive test scores include Stroop Time and Error Scores and the Mental Alternation Test (MAT). Means are adjusted for the following covariates: education, HI, language, and number of chronic conditions.

Table E4

Adjusted Mean (SD) Scores for Choice Reaction Time

Age	**Women**	**N**	**Men**	**N**	**All Participants**	**N**
40s	755.24 (165.22)	1370	729.89 (155.12)	1257	743.11 (160.94)	2627
50s	792.71 (177.41)	4427	775.11 (201.71)	4114	784.24 (189.69)	8541
60s	869.12 (270.50)	4093	849.15 (226.54)	4208	859.00 (249.37)	8301
70s	945.75 (259.37)	4101	919.96 (248.56)	2686	932.13 (254.02)	5087
80s	1054.35 (464.08)	773	990.65 (298.29)	843	1021.12 (387.75)	1616
Total	856.33 (260.42)	13064	838.09 (234.93)	13108	847.19 (248.15)	26172

Note: Means are adjusted for the following covariates: education, HI, language, and number of chronic conditions.

Appendix F

Table F1

Mean (SD) Scores for Global Cognition as a Function of Alcohol Use Composite Scores

Alcohol Use Variable	Alcohol Use Composite Score (z-scores)	Global Cognition	N
Current Alcohol Composite	-2 to -1	-.12 (.63)	2971
	-1 to 0	.01 (.59)	7564
	0 to1	.11 (.57)	8085
	1 to 2	.13 (.50)	1995
	2 to 3	.11 (.53)	374
	3 to 4	.02 (.55)	152
	Total	.04 (.58)	21141
Alcohol History Composite	-3 to -2	-.16 (.67)	465
	-2 to -1	-.10 (.61)	2021
	-1 to 0	-.12 (.65)	485
	0 to 1	.03 (.60)	5814
	1 to 2	.17 (.53)	1138
	2 to 3	-.01 (.64)	37
	3 to 4	-.08 (.54)	33
	Total	.00 (.60)	9993
Drinker Type	Red Wine	.09 (.57)	2930
	White Wine	.08 (.56)	1329
	Beer	.01 (.58)	1683
	Spirits	-.05 (.57)	802
	Total	.05 (.57)	6744

Note. The Current Alcohol Composite is the mean z-score for Drinks Per Week, Alcohol Use Frequency, and Binge Drinking Frequency scores. The Alcohol History Composite is the mean z-score for Alcohol Use History and Binge Drinking History variables. Groups for both variables represent individuals who fall within a set range of z-scores (e.g., from z = -1 to z = -2). The Global Cognition variable represents the mean z-score of all nine cognitive test scores, with higher scores indicating better cognitive performance. Means are adjusted for the following covariates: age, sex, education, HI, language, and number of chronic conditions.

Table F2

*Adjusted Mean (*SD) *Scores for Global Cognition as a Factor of Current Alcohol Use Variables*

Alcohol Use Variable	Alcohol Use Categories	Global Cognition	N
Drinks Per Week	Never-drinkers	-.16 (.69)	465
	12-month abstainers	-.06 (.61)	7011
	Low	.09 (.57)	10159
	Low-moderate	.11 (.55)	4999
	High-moderate	.09 (.52)	510
	High	.010 (.53)	258
	Very High	.10 (.60)	50
Frequency of Alcohol Consumption	Never-drinkers	-.16 (.67)	465
	12-month abstainers	- .11 (.62)	2506
	≤ 1 per month	-.05 (.60)	4388
	2-4 times per month	.08 (.57)	5013
	2-3 times per week	.14 (.55)	4931
	4+ times per week	.08 (.56)	6263
Frequency of Binge Drinking	Never-drinkers	-.16 (.67)	465
	12-month abstainers	-.11 (.62)	2506
	Non-binging	-.02 (.60)	9769
	Up to once a month	.17 (.53)	6275
	Up to once a week	.16 (.51)	1507
	2-3 times per week	.09 (.49)	421
	4+ times per week	.07 (.56)	244

Note. The Global Cognition variable represents the mean z-score of all nine cognitive test scores, with higher scores indicating better cognitive performance. Means are adjusted for the following covariates: age, sex, education, HI, language, and number of chronic conditions.

Table F3.

Adjusted Mean (SD) Scores for Global Cognition as a Factor of Past Alcohol Use Variables

Alcohol Use Variable	Alcohol Use Categories	Global Cognition	N
Alcohol History	Never-drinkers	-.16 (.67)	465
	12-month abstainers	-.10 (.61)	2021
	Low	.03 (.60)	6521
	Moderate	.10 (.56)	2421
	High	.08 (.55)	317
	Very High	-.06 (.54)	61
Binge History	Never-drinkers	-.16 (.67)	465
	12-month abstainers	-.11 (.62)	2506
	No binging	-.02 (.60)	9769
	Low	.17 (.52)	2505
	High	-.03 (.55)	98

Note. The Global Cognition variable represents the mean z-score of all nine cognitive test scores, with higher scores indicating better cognitive performance. Means are adjusted for the following covariates: age, sex, education, HI, language, and number of chronic conditions.

Appendix G

Table G1

Adjusted Mean (SD) Scores for Each Cognitive Test as a Function of Drinks Per Week

Drinks Per Week	REYI	N	REYII	N	PMT	N
Never-drinkers	5.69 (1.95)	540	3.78 (2.27)	534	8.15 (1.67)	557
12-month abstainers	5.72 (1.91)	7647	3.97 (2.14)	7649	8.38 (1.47)	7827
Low	6.04 (1.90)	11059	4.23 (2.19)	11042	8.51 (1.32)	11321
Low-moderate	5.92 (1.84)	5431	4.10 (2.08)	5438	8.58 (1.20)	5556
High-moderate	5.90 (1.78)	549	4.06 (2.01)	546	8.59 (1.21)	563
High	5.75 (1.82)	283	3.92 (2.17)	281	8.61 (1.19)	287
Very High	5.57 (2.13)	56	3.52 (1.85)	54	8.72 (9.66)	67
Total	5.90 (1.89)	25565	4.10 (2.16)	25544	8.48 (1.35)	26178
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Never-drinkers	19.55 (6.90)	543	12.61 (4.34)	537	28.96 (11.13)	552
12-month abstainers	20.76 (6.51)	7738	12.58 (4.30)	7619	28.02 (11.72)	7774
Low	21.99 (6.41)	11129	13.33 (4.16)	11034	25.85 (9.14)	11262
Low-moderate	22.34 (6.32)	5485	13.70 (4.17)	5396	25.65 (11.43)	5536
High-moderate	22.42 (6.13)	557	13.52 (4.47)	551	25.73 (8.44)	561
High	22.28 (6.39)	286	13.54 (4.52)	276	26.11 (8.26)	284
Very High	21.65 (6.07)	54	12.78 (4.30)	64	29.39 (9.29)	67
Total	21.65 (6.46)	25792	13.18 (4.24)	25477	26.53 (10.22)	26036
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Never-drinkers	1.05 (2.52)	550	24.74 (9.15)	519	898.82 (266.16)	550
12-month abstainers	0.87 (2.36)	7742	25.63 (8.74)	7570	863.29 (240.79)	7778
Low	0.59 (1.81)	11221	27.27 (8.57)	10858	838.65 (261.41)	11254
Low-moderate	0.56 (1.71)	5510	27.74 (8.48)	5375	838.73 (230.86)	5524
High-moderate	0.53 (1.79)	558	27.51 (8.54)	542	828.15 (199.15)	559
High	0.53 (2.13)	281	28.08 (8.00)	283	832.33 (209.74)	287
Very High	1.121 (1.83)	66	25.46 (9.25)	54	898.33 (320.79)	66
Total	0.68 (1.99)	25928	26.83 (8.66)	25201	847.16 (247.96)	26018

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Table G2

Adjusted Mean (SD) Scores for Each Cognitive Test as a Function of Alcohol Frequency

Alcohol Use Frequency	REYI	N	REYII	N	PMT	N
Never-drinkers	5.69 (1.95)	540	3.78 (2.27)	534	8.15 (1.67)	557
12-month abstainers	5.59 (1.89)	2764	3.77 (2.14)	2756	8.29 (1.58)	2838
≤ 1 per month	5.75 (1.91)	4785	4.03 (2.15)	4794	8.43 (1.40)	4922
2-4 times per month	6.03 (1.90)	5438	4.24 (2.19)	5428	8.51 (1.31)	5553
2-3 times per week	6.08 (1.85)	5370	4.29 (2.12)	5363	8.57 (1.23)	5472
4+ times per week	5.91 (1.88)	6808	4.06 (2.14)	6807	8.52 (1.29)	6985
Total	5.90 (1.89)	25705	4.10 (2.16)	25682	8.48 (1.35)	26327
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Never-drinkers	19.55 (6.90)	543	12.61 (4.34)	537	28.96 (11.13)	552
12-month abstainers	20.50 (6.60)	2790	12.53 (4.33)	2769	28.80 (10.95)	2813
≤ 1 per month	20.76 (6.43)	4854	12.48 (4.26)	4785	27.75 (11.01)	4893
2-4 times per month	21.77 (6.43)	5482	13.23 (4.19)	5409	25.90 (8.97)	5528
2-3 times per week	22.44 (6.29)	5388	13.44 (4.14)	5321	25.08 (11.50)	5440
4+ times per week	22.20 (6.39)	6878	13.71 (4.21)	6793	26.21 (8.80)	6957
Total	21.65 (6.46)	25935	13.17 (4.24)	25614	26.53 (10.22)	26193
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Never-drinkers	1.05 (2.52)	550	24.73 (9.15)	519	898.82 (266.16)	550
12-month abstainers	0.94 (2.52)	2803	25.46 (8.94)	2725	878.18 (237.86)	2823
≤ 1 per month	0.89 ± (2.38)	4870	25.50 (8.69)	4747	859.85 (259.03)	4889
2-4 times per month	0.61 ± (1.83)	5510	27.12 (8.46)	5357	835.41 (257.09)	5518
2-3 times per week	0.51 ± (1.61)	5414	27.75 (8.58)	5282	820.66 (220.12)	5547
4+ times per week	0.57 ± (1.74)	6927	27.52 (8.50)	6709	851.53 (253.33)	6935
Total	0.68 (1.99)	26074	26.83 (8.66)	25339	847.14 (248.06)	26162

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Table G3

Adjusted Mean (SD) Scores for Each Cognitive Test as a Function of Binge Frequency

Binge Frequency	**REYI**	**N**	**REYII**	**N**	**PMT**	**N**
Never-drinkers	5.69 (1.95)	540	3.78 (2.27)	534	8.15 (1.67)	557
12-month abstainers	5.60 (1.89)	2764	3.77 (2.14)	2756	8.29 (1.58)	2838
No binging	5.78 (1.93)	10675	3.97 (2.17)	10659	8.39 (1.45)	10963
≤ 1 time per month	6.15 (1.84)	6785	4.37 (2.12)	6797	8.65 (1.09)	6927
≤ 1 time per week	6.04 (1.80)	1627	4.30 (2.05)	1636	8.66 (1.07)	1655
2-3 times per week	5.76 (1.64)	460	4.08 (1.88)	459	8.65 (1.17)	470
4+ times per week	5.97 (2.00)	270	4.08 (2.27)	266	8.66 (1.08)	277
Total	5.89 (1.89)	23121	4.09 (2.15)	23107	8.48 (1.35)	23687
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Never-drinkers	19.55 (6.90)	543	12.61 (4.34)	537	28.96 (11.13)	552
12-month abstainers	20.50 (6.60)	2790	12.53 (4.33)	2769	28.80 (10.95)	2813
No binging	21.17 (6.40)	10773	12.96 (4.26)	10676	27.50 (11.53)	10895
≤ 1 time per month	22.74 (6.36)	6845	13.64 (4.16)	6737	24.65 (8.00)	6894
≤ 1 time per week	22.85 (6.09)	1641	13.77 (4.18)	1610	24.42 (7.73)	1655
2-3 times per week	21.89 (5.82)	464	13.40 (4.25)	458	25.23 (8.06)	470
4+ times per week	21.25 (6.34)	272	13.44 (4.14)	267	27.31 (9.08)	272
Total	21.64 (6.46)	23328	13.17 (4.25)	23054	26.59 (10.32)	23551
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Never-drinkers	1.05 (2.52)	550	24.73 (9.15)	519	898.82 (266.16)	550
12-month abstainers	0.94 (2.52)	2803	25.46 (8.94)	2725	878.18 (237.86)	2823
No binging	0.76 (2.15)	10852	26.40 (8.61)	10505	865.62 (274.81)	10890
≤ 1 time per month	0.48 (1.55)	6865	27.95 (8.53)	6718	813.52 (213.44)	6886
≤ 1 time per week	0.46 (1.56)	1644	27.82 (8.53)	1607	817.17 (214.84)	1646
2-3 times per week	0.45 (1.19)	468	27.55 (8.33)	448	812.20 (231.12)	468
4+ times per week	0.74 (2.36)	269	27.31 (8.07)	265	851.45 (241.11)	276
Total	0.68 (2.01)	23451	26.84 (8.67)	22787	848.05 (249.83)	23539

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Table G4

Adjusted Mean (SD) Scores for Each Cognitive Test as a Factor of Alcohol History

Alcohol History	**REYI**	**N**	**REYII**	**N**	**PMT**	**N**
Never-drinkers	5.69 (1.95)	540	3.78 (2.27)	534	8.15 (1.67)	557
12-month abstainers	5.57 (1.90)	2229	3.72 (2.15)	2221	8.32 (1.54)	2297
Low	5.97 (1.92)	7076	4.23 (2.19)	7077	8.42 (1.42)	7227
Moderate	5.96 (1.83)	2625	4.15 (2.07)	2622	8.58 (1.22)	2664
High	5.73 (1.82)	345	3.86 (2.04)	344	8.59 (1.240	354
Very High	5.76 (1.91)	67	3.79 (2.09)	66	8.53 (1.19)	77
Total	5.88 (1.90)	12882	4.10 (2.16)	12864	8.43 (1.41)	13176
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Never-drinkers	19.55 (6.90)	543	12.61 (4.34)	537	28.96 (11.13)	552
12-month abstainers	20.61 (6.60)	2249	12.51 (4.31)	2246	28.80 (10.91)	2277
Low	21.30 (6.54)	7139	13.07 (4.25)	7049	26.69 (10.13)	7179
Moderate	22.19 (6.35)	2647	13.80 (4.21)	2593	25.79 (13.98)	2652
High	22.56 (6.11)	348	13.52 (4.44)	347	25.78 (8.92)	352
Very High	21.42 (6.99)	67	12.53 (4.36)	72	27.76 (8.53)	76
Total	21.32 (6.55)	12993	13.11 (4.28)	12844	25.95 (11.20)	13088
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Never-drinkers	1.05 (2.52)	550	24.73 (9.15)	519	898.82 (226.16)	550
12-month abstainers	0.94 (2.57)	2270	25.48 (8.90)	2201	878.83 (244.32)	2285
Low	0.71 (2.06)	7156	26.39 (8.82)	6969	857.00 (286.04)	7184
Moderate	0.54 (1.79)	2643	27.76 (8.26)	2592	846.64 (234.74)	2655
High	0.45 (1.59)	348	27.54 (8.83)	337	826.15 (218.20)	351
Very High	0.72 (1.42)	75	25.30 (9.10)	67	839.09 (226.83)	78
Total	0.72 (2.12)	13042	26.47 (8.77)	12685	859.53 (266.77)	13103

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Table G5

Adjusted Mean (SD) Scores for Each Cognitive Test as a Factor of Binge History

Binge History	REYI	N	REYII	N	PMT	N
Never-drinkers	5.69 (1.95)	540	3.78 (2.27)	534	8.15 (1.67)	557
12-month abstainers	5.60 (1.89)	2764	3.77 (2.14)	2756	8.29 (1.58)	2838
No Binging	5.78 (1.93)	10675	3.97 (2.17)	10659	9.39 (1.45)	10963
Low	6.17 (1.87)	2709	4.47 (2.11)	2709	8.66 (1.08)	2755
High	5.78 (1.95)	108	3.80 (2.22)	106	8.46 (1.37)	109
Total	5.81 (1.92)	16796	4.01 (2.17)	16764	8.41 (1.43)	17222
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Never-drinkers	19.55 (6.90)	543	12.61 (4.34)	537	28.96 (11.13)	552
12-month abstainers	20.50 (6.60)	2790	12.53 (4.33)	2769	28.80 (10.95)	2813
No Binging	21.17 (6.40)	10773	12.96 (4.26)	10676	27.50 (11.53)	10895
Low	22.61 (6.41)	2734	13.66 (4.09)	2689	24.60 (7.97)	2733
High	20.94 (6.55)	108	12.90 (3.98)	105	28.78 (10.26)	107
Total	21.24 (6.49)	16948	12.99 (4.26)	16776	27.30 (11.00)	17100
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Never-drinkers	1.05 (2.52)	550	24.73 (9.15)	519	898.82 (266.16)	550
12-month abstainers	0.94 (2.52)	2803	25.46 (8.94)	2725	878.18 (237.86)	2823
No Binging	0.76 (2.15)	10852	26.40 (8.61)	10505	865.62 (274.81)	10890
Low	0.45 (1.56)	2727	27.71 (8.52)	2676	824.28 (220.80)	2738
High	0.57 (1.24)	105	27.04 (8.51)	106	866.75 (257.98)	109
Total	0.75 (2.15)	17037	26.41 (8.70)	16531	862.15 (261.17)	17110

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Table G6

Adjusted Mean (SD) Scores for Each Cognitive Test as a Factor of Alcohol Type

Alcohol Type	REYI	N	REYII	N	PMT	N
Red Wine	6.05 (1.92)	3227	4.30 (2.21)	3320	8.50 (1.32)	3287
White Wine	6.17 (1.88)	1433	4.35 (2.19)	1429	8.49 (1.33)	1468
Beer	5.65 (1.81)	1828	3.83 (2.05)	1827	8.53 (1.27)	1869
Spirits	5.69 (1.84)	889	3.83 (2.06)	884	8.43 (1.44)	922
Total	5.93 (1.88)	7377	4.14 (2.16)	7360	8.50 (1.32)	7546
	AFT	**N**	**COWA**	**N**	**Stroop Time**	**N**
Red Wine	21.64 (6.34)	3256	13.48 (4.17)	3205	26.04 (9.05)	3278
White Wine	21.36 (6.26)	1442	13.71 (4.04)	1436	25.92 (8.59)	1465
Beer	21.70 (6.49)	1836	12.54 (4.35)	1823	26.42 (9.49)	1850
Spirits	20.88 (6.15)	892	12.60 (4.26)	883	28.07 (10.31)	916
Total	21.51 (6.43)	7426	13.18 (4.23)	7347	26.36 (9.26)	7509
	Stroop Errors	**N**	**MAT**	**N**	**CRT**	**N**
Red Wine	0.51 (1.41)	3263	27.04 (8.54)	3169	840.87 (241.05)	3263
White Wine	0.63 (1.92)	1459	26.65 (8.32)	1405	868.82 (328.61)	1462
Beer	0.67 (2.06)	1842	26.96 (9.09)	1784	821.69 (219.43)	1860
Spirits	0.89 (2.36)	911	26.26 (8.58)	866	859.66 (230.84)	915
Total	0.62 (1.82)	7475	26.85 (8.64)	7224	843.86 (254.99)	7500

Note. Means are adjusted for the following covariates: sex, age, education, HI, language, and chronic conditions.

Appendix H

Table H1

Follow-up ANCOVAs on the Effect of Drinks Per Week on Cognitive Test Scores with Additional Covariates

	F	*df*	*p*	η_p^2
REY I	2.956	6, 11136	.007	.002
REY II	3.024	6, 11118	.006	.002
PMT	1.707	6, 11433	.115	.001
AFT	4.697	6, 11232	< .001	.002
COWA	14.216	6, 11144	< .001	.008
Stroop Time	11.516	6, 11390	< .001	.006
Stroop Errors	2.224	6, 11349	.036	.001
MAT	6.165	6, 10976	< .001	.003
CRT	.326	6, 11383	.924	.000

Notes. Main effect of the Drinks Per Week variable on cognitive test scores. Covariates are sex, age, education, HI, language, chronic conditions, social interaction, physical function, TIPI personality factors (openness, extraversion, agreeableness, conscientiousness, emotional stability).

Table H2

Follow-up ANCOVAs on the Effects of Alcohol Frequency on Cognitive Test Scores with Additional Covariates

	F	*df*	*p*	η_p^2
REY I	5.575	5, 11184	< .001	.002
REY II	4.344	5, 11167	< .001	.002
PMT	2.991	5, 11484	.011	.001
AFT	7.917	5, 11282	< .001	.003
COWA	18.807	5, 11190	< .001	.008
Stroop Time	14.871	5, 11440	< .001	.006
Stroop Errors	5.012	5, 11399	< .001	.002
MAT	7.070	5, 11024	< .001	.003
CRT	.300	5, 11434	.913	.000

Notes. Main effect of the Frequency of Alcohol Use variable on cognitive test scores Covariates were sex, age, education, HI, language, chronic conditions, social interaction, physical function, and TIPI personality factors (openness, extraversion, agreeableness, conscientiousness, emotional stability).

Table H3

Follow-up ANCOVAs on the Effects of Binge Frequency on Cognitive Test Scores with Additional Covariates

	F	*df*	*p*	η_p^2
REY I	2.465	6, 10043	.022	.001
REY II	1.716	6, 10026	.113	.001
PMT	2.077	6, 10315	.052	.001
AFT	3.313	6, 10129	.003	.002
COWA	3.497	6, 10057	.002	.002
Stroop Time	4.844	6, 10271	< .001	.003
Stroop Errors	.910	6, 10233	.486	.001
MAT	2.849	6, 9890	.009	.002
CRT	.477	6, 10271	.826	.000

Notes. Main effect of the Binge Drinking Frequency variable on cognitive test scores. Covariates were sex, age, education, HI, language, chronic conditions, social interaction, physical function, and TIPI personality factors (openness, extraversion, agreeableness, conscientiousness, emotional stability).

Table H4

Follow-up ANCOVAs on the Effect of Alcohol History on Cognitive Test Scores with Additional Covariates

	F	*df*	*p*	η_p^2
REY I	.905	5, 5725	.477	.001
REY II	1.493	5, 5718	.189	.001
PMT	.519	5, 5878	.762	.000
AFT	4.120	5, 5780	.001	.004
COWA	6.724	5, 5743	< .001	.006
Stroop Time	6.132	5, 5854	< .001	.005
Stroop Errors	1.704	5, 5839	.130	.001
MAT	3.868	5, 5630	.002	.003
CRT	.760	5, 5862	.579	.001

Notes. Main effect of the Alcohol History variable on cognitive test scores. Covariates were sex, age, education, HI, language, chronic conditions, social interaction, physical function, and TIPI personality factors (openness, extraversion, agreeableness, conscientiousness, emotional stability).

Table H5

Follow-up ANCOVAs on the Effect of Binge History on Cognitive Test Scores with Additional Covariates

	F	*df*	*p*	η_p^2
REY I	.579	4, 7284	.678	.000
REY II	1.499	4, 7263	.200	.001
PMT	1.205	4, 7480	.306	.001
AFT	3.966	4, 7347	.003	.002
COWA	2.226	4, 7297	.064	.001
Stroop Time	6.425	4, 7442	< .001	.003
Stroop Errors	.943	4, 7419	.438	.001
MAT	3.503	4, 7152	.007	.002
CRT	.422	4, 7455	.793	.000

Notes. Main effect of the Binge Drinking History variable on cognitive test scores. Covariates were sex, age, education, HI, language, chronic conditions, social interaction, physical function, and TIPI personality factors (openness, extraversion, agreeableness, conscientiousness, emotional stability).

Appendix I

Table I1

Main Effects of Social, Physical, and Personality Factors on Memory Test Scores

REYI	***F***	***df***	***p***	η_p^2
Social Function	39.755	4, 15087	< .001	.010
Physical Function	271.773	4, 25580	< .001	.041
TIPI-O	16.650	12, 27283	< .001	.007
TIPI-C	1.750	12, 27564	.050	.001
TIPI-E	18.244	12, 27442	< .001	.008
TIPI-A	5.150	12, 27551	< .001	.002
TIPI-ES	3.434	12, 27564	< .001	.001
REYII	***F***	***df***	***p***	η_p^2
Social Function	18.710	4, 15067	< .001	.005
Physical Function	206.433	4, 25555	< .001	.031
TIPI-O	11.738	12, 27271	< .001	.005
TIPI-C	1.812	12, 27546	.041	.001
TIPI-E	13.936	12, 27419	< .001	.006
TIPI-A	3.662	12, 27510	< .001	.002
TIPI-ES	2.965	12, 27543	< .001	.001
PMT	***F***	***df***	***p***	η_p^2
Social Function	6.062	4, 15512	< .001	.002
Physical Function	250.343	4, 26349	< .001	.037
TIPI-O	7.210	12, 27995	< .001	.003
TIPI-C	5.268	12, 28284	< .001	.002
TIPI-E	5.303	12, 28150	< .001	.002
TIPI-A	2.684	12, 28226	< .001	.001
TIPI-ES	3.647	12, 28295	< .001	.002

Note. Effect of all follow-up covariates on cognitive test scores with the exclusion of alcohol variables. Higher levels of social engagement, physical function, openness, and conscientiousness were associated with higher scores on all memory tests. Agreeableness scores were associated with REYII scores. Mid-level extraversion scores were associated with lower scores than low or high levels of extraversion for all tests. Post-hoc tests did not reveal memory score differences as a function of emotional stability for any tests.

Table I2

Main Effects of Follow-Up ANCOVAS Examining Social, Physical, and Personality Factors on Verbal Fluency Scores

AFT	*F*	*df*	*p*	η_p^2
Social Function	31.973	4, 15231	< .001	.008
Physical Function	658.506	4, 25828	< .001	.093
TIPI-O	37.364	12, 27527	< .001	.016
TIPI-C	3.444	12, 27835	< .001	.001
TIPI-E	22.297	12, 27705	< .001	.010
TIPI-A	40409	12, 27783	< .001	.002
TIPI-ES	6.163	12, 27833	< .001	.003
COWA	*F*	*df*	*p*	η_p^2
Social Function	47.002	4, 15089	< .001	.012
Physical Function	221.088	4, 25648	< .001	.033
TIPI-O	31.443	12, 27248	< .001	.014
TIPI-C	3.626	12, 27522	< .001	.002
TIPI-E	35.134	12, 27394	< .001	.015
TIPI-A	5.861	12, 27446	< .001	.003
TIPI-ES	3.529	12, 27518	< .001	.002

Note. Effect of all follow-up covariates on cognitive test scores with the exclusion of alcohol variables. For both tests of verbal fluency, higher levels of social and physical function, openness, and conscientiousness were associated with higher cognitive test scores. Mid-levels of extraversion were associated with higher scores than low and high levels of extraversion. Post-hoc tests did not indicate significant group differences at any level of agreeableness or emotional stability.

Table I3

Main Effects of Follow-Up ANCOVAS Examining Social, Physical, and Personality Factors on Executive Function Tests

Stroop Time	*F*	*df*	*p*	η_p^2
Social Function	19.629	4, 15440	< .001	.005
Physical Function	791.291	4, 26222	< .001	.108
TIPI-O	19.060	12, 27846	< .001	.008
TIPI-C	4.909	12, 28133	< .001	.002
TIPI-E	23.732	12, 28001	< .001	.010
TIPI-A	3.267	12, 28076	< .001	.001
TIPI-ES	5.098	12, 28133	< .001	.002
Stroop Error	*F*	*df*	*p*	η_p^2
Social Function	2.529	4, 15381	.039	.001
Physical Function	195.503	4, 26103	< .001	.029
TIPI-O	10.365	12, 27729	< .001	.004
TIPI-C	1.325	12, 28012	.196	.001
TIPI-E	8.091	12, 27885	< .001	.003
TIPI-A	2.143	12, 27959	.012	.001
TIPI-ES	2.511	12, 28014	.003	.001
MAT	*F*	*df*	*p*	η_p^2
Social Function	22.008	4, 14838	< .001	.006
Physical Function	413.065	4, 25175	< .001	.062
TIPI-O	9.068	12, 26863	< .001	.004
TIPI-C	5.191	12, 27142	< .001	.002
TIPI-E	14.585	12, 27017	< .001	.006
TIPI-A	2.583	12, 27097	.002	.001
TIPI-ES	9.981	12, 27148	< .001	.004

Note. Effect of all follow-up covariates on cognitive test scores with the exclusion of alcohol variables. For all tests of executive function, higher social function, physical function, and conscientiousness was associated with improved test performance. Mid-levels of extraversion were associated with poorer test performance compared to low and high levels of extraversion for all tests. Post-hoc tests did not indicate significant differences in test scores as a factor of agreeableness or emotional stability.

Table I4

Main Effects of Follow-Up ANCOVAS Examining Social, Physical, and Personality Factors on CRT

CRT	*F*	*df*	*p*	η_p^2
Social Function	3.076	4, 15409	.015	.001
Physical Function	527.419	4, 26218	< .001	.074
TIPI-O	8.180	12, 27828	< .001	.004
TIPI-C	2.794	12, 28108	.001	.001
TIPI-E	6.026	12, 27975	< .001	.003
TIPI-A	1.557	12, 28054	.097	.001
TIPI-ES	3.684	12, 28109	< .001	.002

Note. Effect of all follow-up covariates on cognitive test scores with the exclusion of alcohol variables. Increased levels of social function, physical function, openness, and conscientiousness are associated with faster reaction times. Mid-level extraversion scores are associated with faster reaction times than both high and low levels of extraversion. There are no differences in CRT scores for different levels of agreeableness or emotional stability.

Appendix J

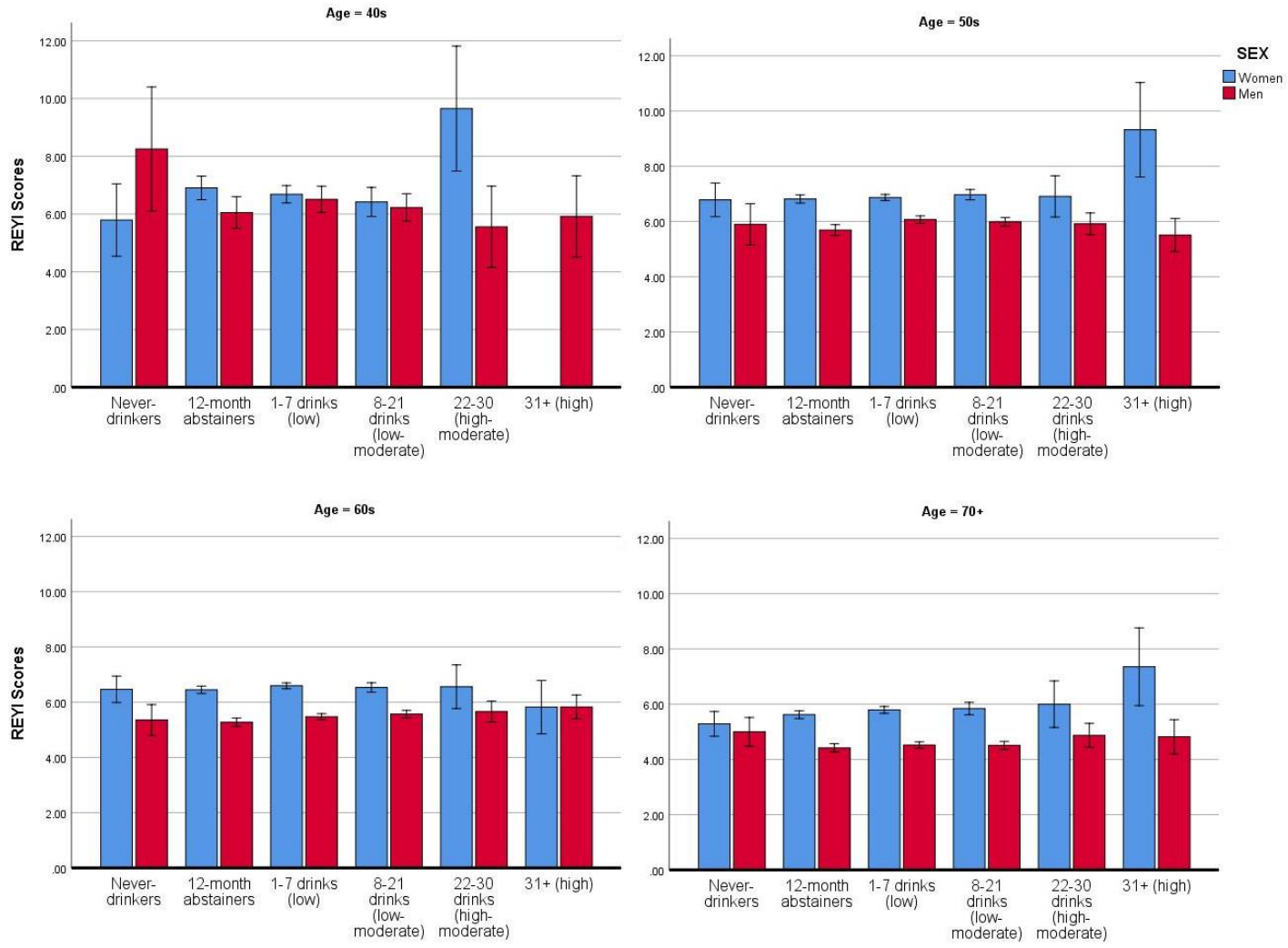
	Global Cognition	REYI	REYII	PMT	AFT	COWA	Stroop Time	Stroop Error	MAT	CRT
Age	.165	.068	.074	.052	.066	.007	.113	.027	.030	.067
Sex	.013	.043	.045	-	-	.010	.005	.003	.001	.002
Current Alcohol Composite	.008									
Alcohol History Composite	.009									
Drinks Per Week	.009	.003	.002	.002	.004	.006	.005	.002	.002	.001
Frequency of Alcohol Use	.011	.004	.002	.003	.006	.007	.005	.003	.003	.001
Binge Frequency	.007	.002	.002	.003	.004	.004	.003	.001	.001	.001
Alcohol History	.008	.002	.003	.003	.004	.005	.003	.002	.002	-
Binge History	.006	.001	.002	.003	.004	.002	.003	.001	.001	.001
Alcohol Type	.003	-	-	-	-	.003	.002	.002	-	-
Age x Sex	.001	.001	.001	.001	-	.001	.001	.002	-	-
DPW x Age		-	-	-	-	-	-	-	-	-
DPW x Sex		.002	-	-	-	-	-	-	-	-
DPW x Age x Sex		.003	.002	-	-	-	-	-	-	-
Binge x Age		-	.004	-	-	-	-	-	-	-
Binge x Sex		-	-	-	-	-	-	-	-	-
Binge x Age x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age		-	-	.002	-	-	-	-	-	-
Binge History x Sex		-	-	-	-	-	-	-	-	-
Binge History x Age x Sex		-	-	-	-	-	-	-	-	-
Type x Age		-	-	-	-	-	-	.006	-	-
Type x Sex		-	-	-	-	-	-	-	-	-
Type x Age x Sex		-	-	-	-	-	-	-	-	-

Note. Effect sizes for all statistically significant analyses ($p < .001$). Partial-eta squared of 0.01 indicates a small effect size, 0.06 indicates a medium effect size, and 0.14 indicates a large effect size. Dashes mark analyses which were not statistically significant; blank spaces indicate that no such analysis was conducted. Interaction terms that were not significant for any cognitive test scores were excluded from the table.

Appendix K

Figure K1

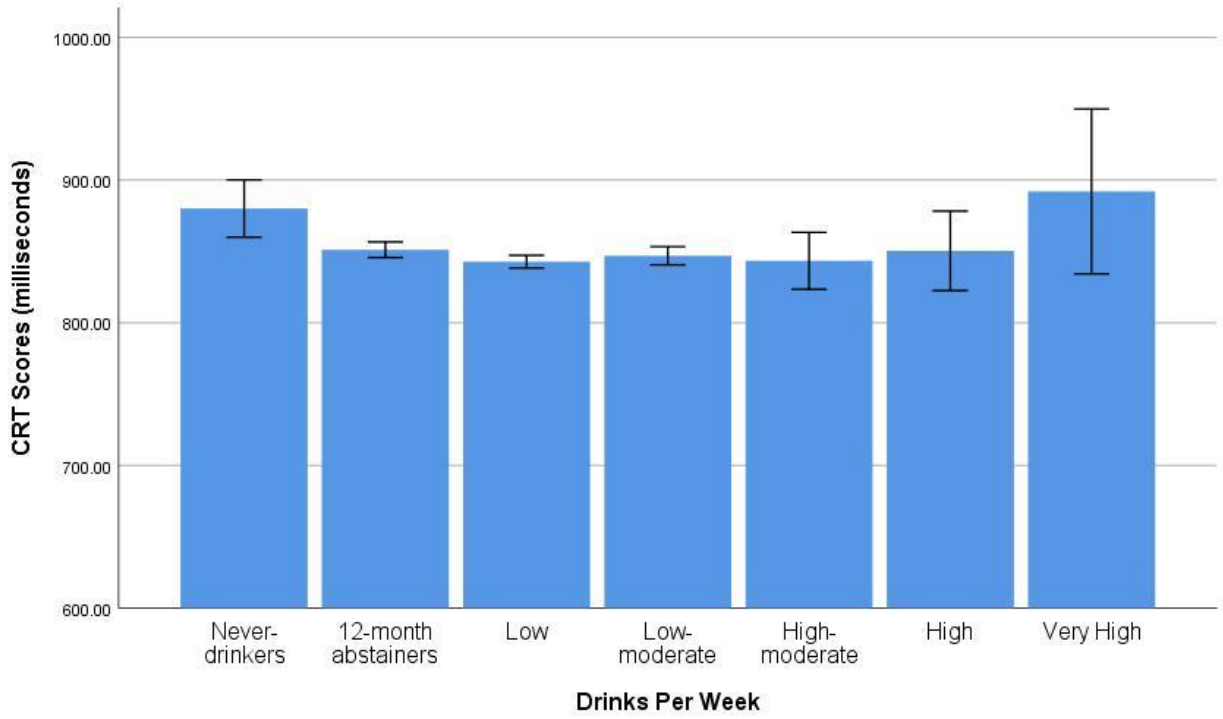
3-way Interaction between Age, Sex, and Drinks Per Week on Immediate Recall scores



Note. Sex differences in scores for the Rey Auditory Verbal Learning Test immediate recall trial (REYI) varied as a function of age and Drinks Per Week. Among 12-month abstainers, low-level and low-moderate drinkers, women outperformed men at every age ($p < .001$). Among high-moderate drinkers, women only outperform men within the 40s age group ($p < .001$). Among high-level drinkers, women only outperformed men in the 50s age group ($p < .001$). Covariates included educations, HI, language, education, physical function, and social participation.

Figure K2

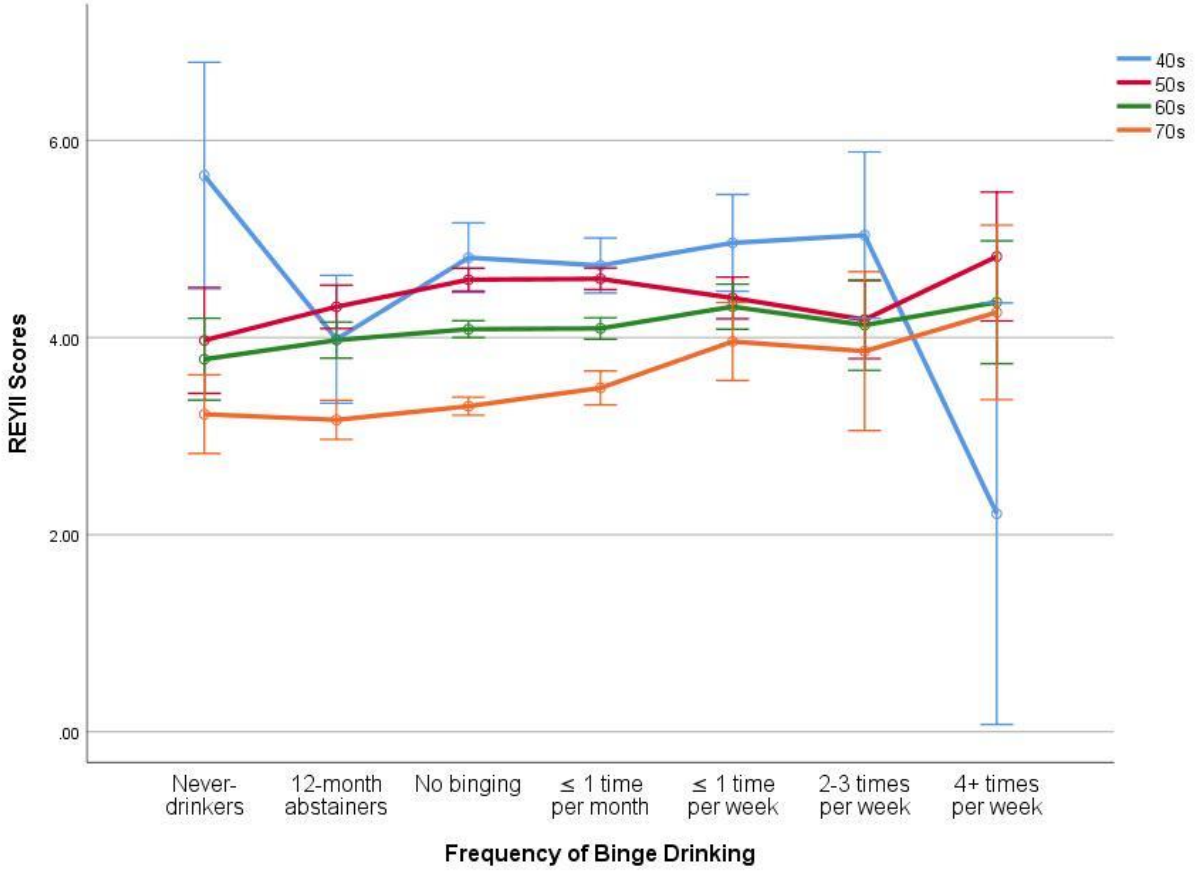
Main Effect of Drinks Per Week on Choice Reaction Time Scores



Note. Mean CRT scores differed significantly as a factor of Drinks Per Week. Never-drinkers trended towards slower reaction times than low-level drinkers (p = .006). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Figure K3

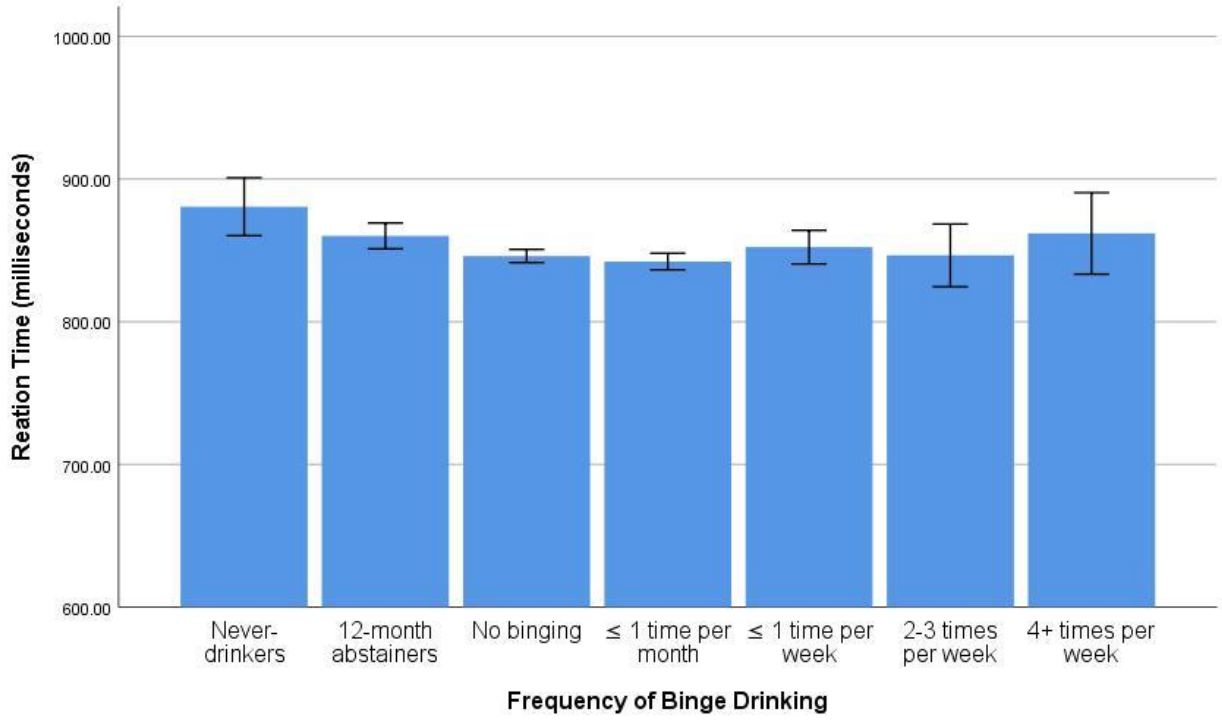
REYII Scores are Affected by a Binge x Age Interaction



Note. Only adults in their 70s showed a significant effect of binge drinking on REYII scores ($p < .001$). Among this age group, 12-month abstainers trended towards lower scores than those who binge from more than once a month up to once per week ($p = .006$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and chronic conditions.

Figure K4

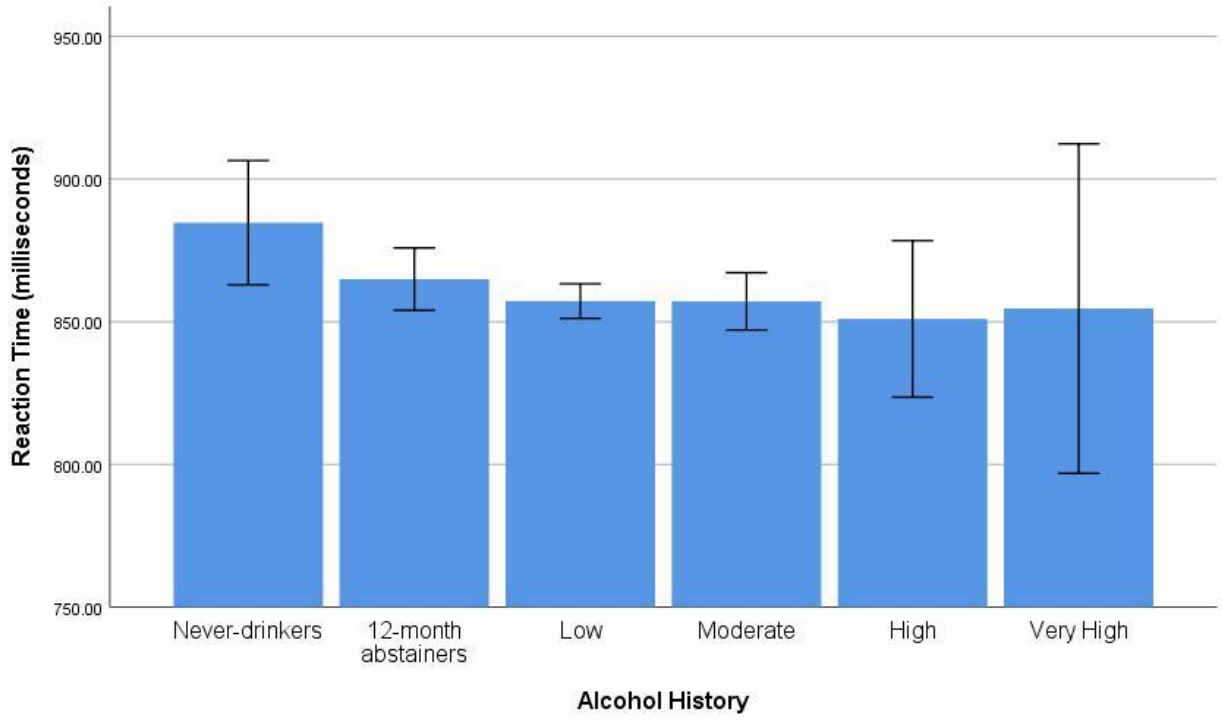
Main Effect of Binge Frequency on Choice Reaction Time Scores



Note. Binge-drinking up to once a month was associated with faster/better CRT scores when compared to never-drinkers (p= .006). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure K5

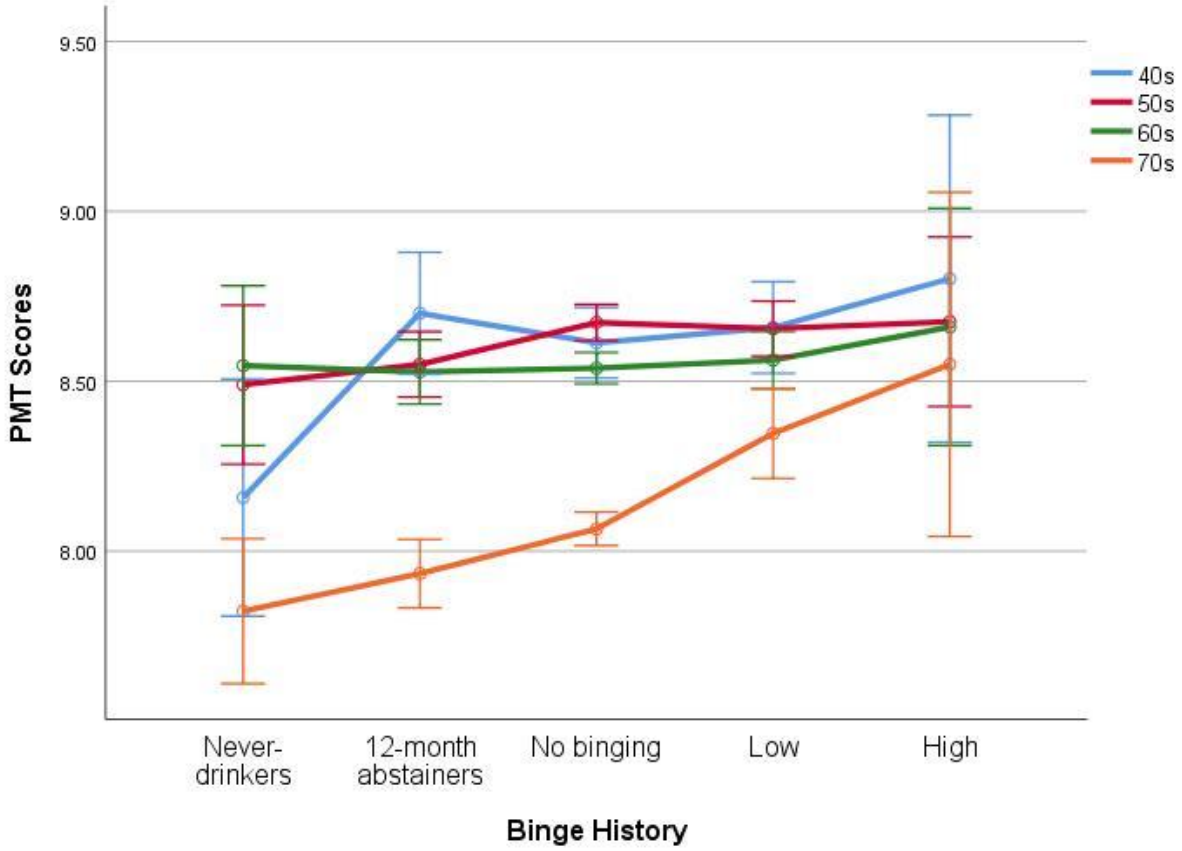
Choice Reaction Time (CRT) Scores as a Function of Alcohol Use History



Note. There was no overall main effect of Alcohol Use History on CRT scores. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions

Figure K6

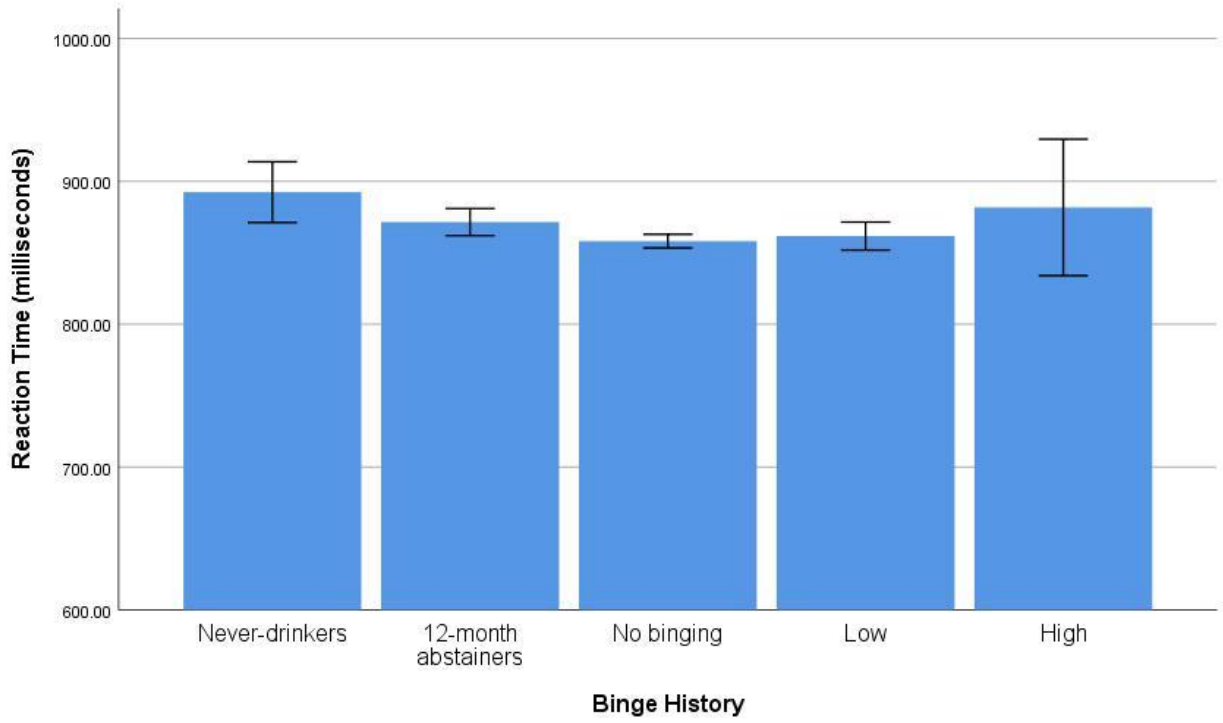
Interaction Between Binge Drinking History and Age for Prospective Memory Test Scores



Note. The change in PMT scores as a function of Binge History and Age approached significance (p = .004). However, post-hoc tests did not reveal significant differences between PMT scores for different levels of Binge History among any age group. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure K7

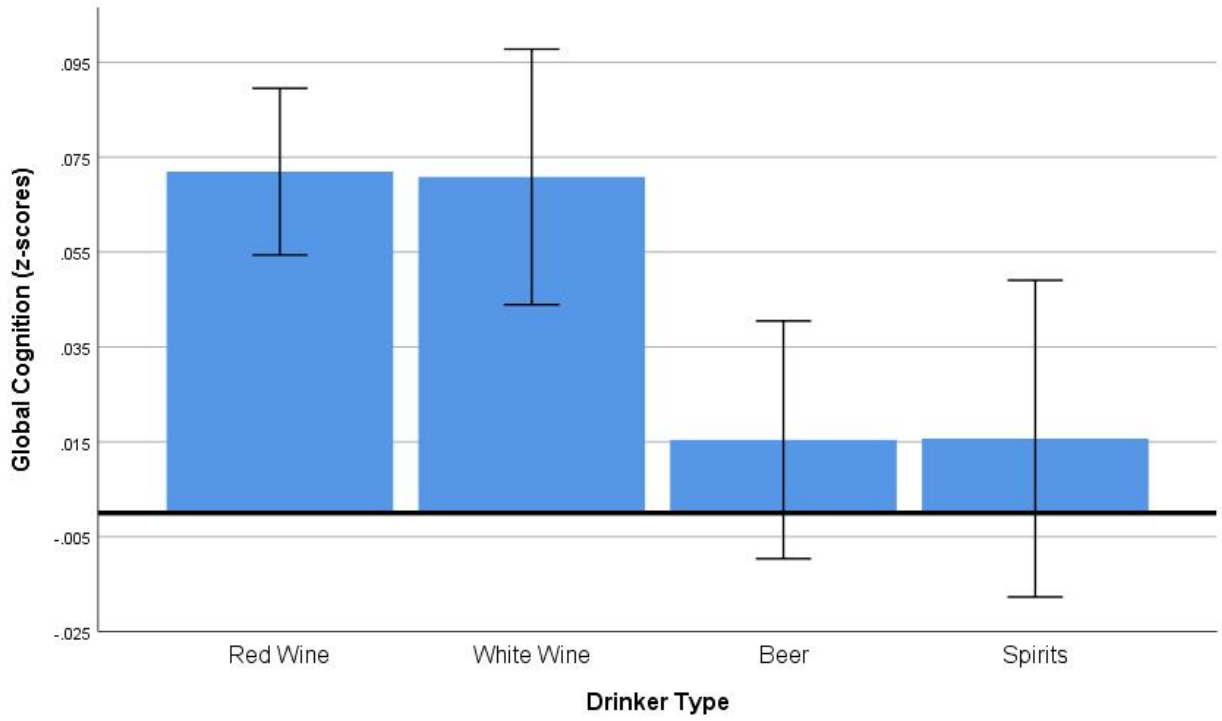
Main Effect of Binge Drinking History Choice Reaction Time Scores



Note. While there was a main effect of Binge History on Choice Reaction Time scores ($p < .001$) post-hoc tests did not reveal any significant group differences. Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure K8

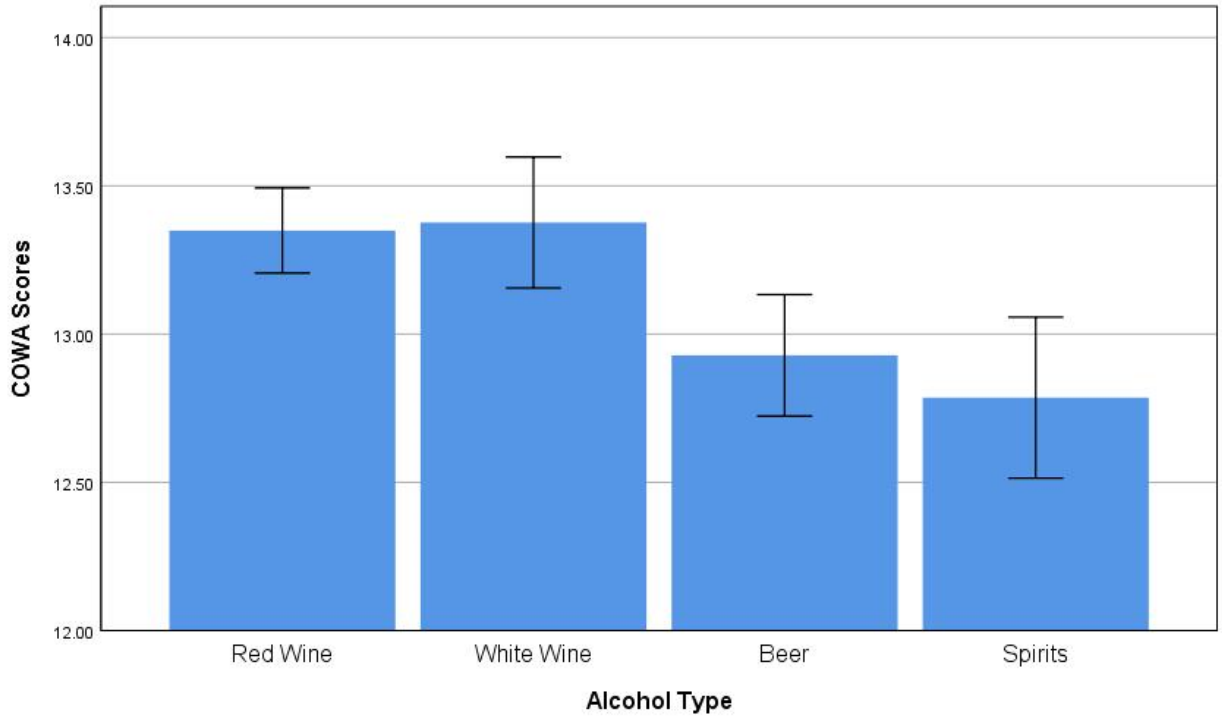
Main Effect of Alcohol Type on Global Cognitive Composite Scores



Note. Red and white wine drinkers showed a nonsignificant trend towards higher Global Cognition scores than beer drinkers (p = .002). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure K9

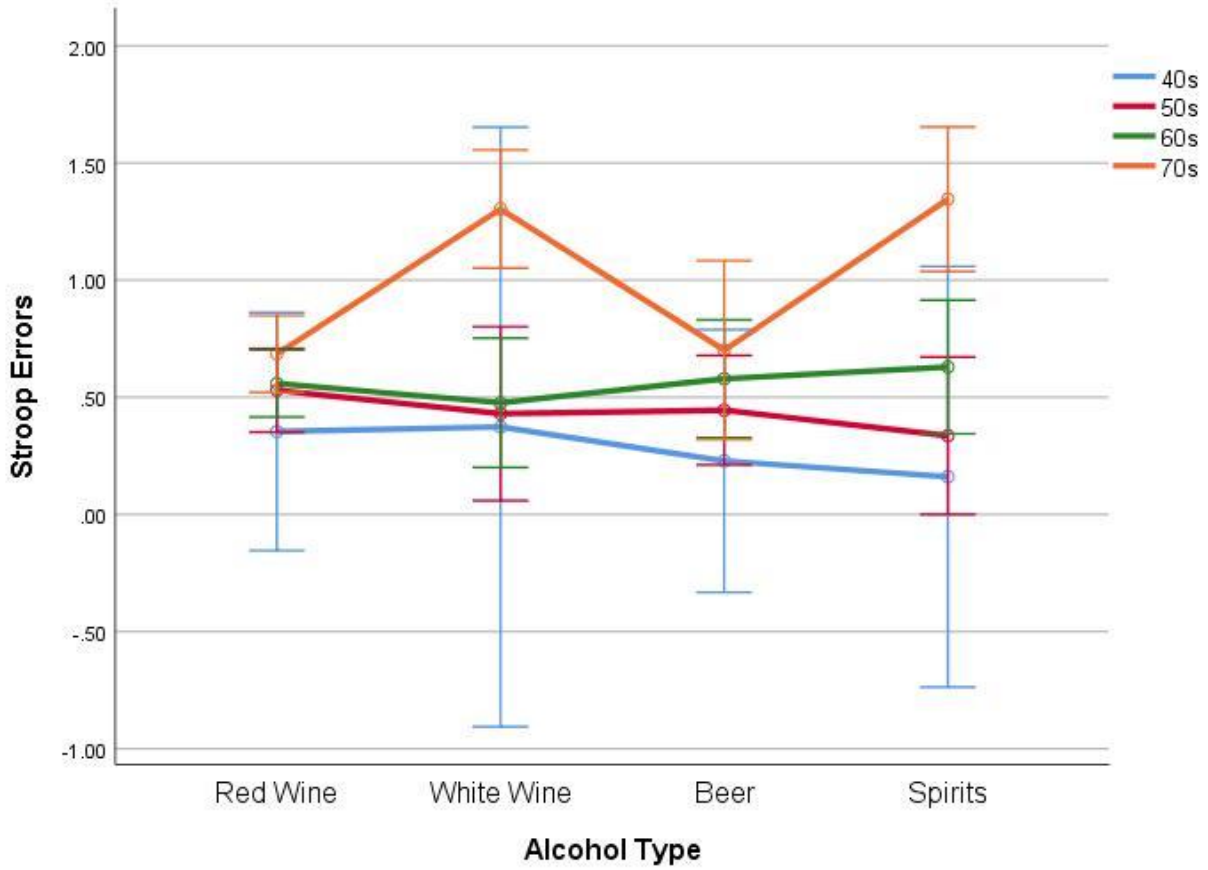
Main Effect of Alcohol Type on COWA Scores



Note. Scores for the Controlled Oral Word Association test (COWA) trended towards significance. Red and white wine drinkers had higher scores than beer and spirit drinkers (p = .002 to p = .007). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.

Figure K10

Interaction Between Age and Alcohol Type Primarily Consumed on Stroop Errors



Note. The effect of Alcohol Type on Stroop Errors was strongest for the 70+ age group, $F(3, 1031) = 4.952$, $p = .002$, ($\eta_p^2 = .014$). Among adults in their 70s, red wine drinkers reported fewer errors than white wine drinkers ($p < .001$) and spirit drinkers ($p = .001$). Error bars reflect ± 2 SE. Covariates included age, sex, education, HI, language, and number of chronic conditions.