Trinity College
Trinity College Digital Repository

Senior Theses and Projects   Student Works

Spring 2018

Influence of Alcohol on Time-Based Prospective Memory and Electrophysiological Measures in College-Aged Individuals

Christy C. Chan
Trinity College, Hartford Connecticut, christy.chan@trincoll.edu

Follow this and additional works at: https://digitalrepository.trincoll.edu/theses

Part of the Cognitive Neuroscience Commons

TRINITY COLLEGE

INFLUENCE OF ALCOHOL ON TIME-BASED PROSPECTIVE MEMORY AND
ELECTROPHYSIOLOGICAL MEASURES IN COLLEGE-AGED INDIVIDUALS

BY

Christy C. Chan

A THESIS SUBMITTED TO
THE FACULTY OF THE NEUROSCIENCE PROGRAM
IN CANDIDACY FOR THE BACCALAUREATE DEGREE
WITH HONORS IN NEUROSCIENCE

NEUROSCIENCE PROGRAM

HARTFORD, CONNECTICUT
May 10, 2018

Influence of Alcohol on Time-Based Prospective Memory and
Electrophysiological Measures in College-Aged Individuals

BY

Christy C. Chan

Honors Thesis Committee

Approved:

_____

Sarah Raskin, Thesis Advisor

_____

J. Harry Blaise, Thesis Committee

_____

Sarah Raskin, Director, Neuroscience Program

Date: _____

Table of Contents

Abstract

College students have higher rates of alcohol-use disorders (AUDs) than that of same-aged non-college students, with an estimated 31% of U.S. college students meeting the diagnostic criteria for alcohol abuse (Borsari *et al.*, 2007; Knight *et al.*, 2002). College age is also a critical period for brain development, including regions responsible for the development of prospective memory (PM), making the brains of college students vulnerable to the effects of alcohol. This study investigated the influence of alcohol on the underlying brain activity associated with PM in light- and heavy-alcohol-drinking college students. PM was measured with the Memory for Intentions Screening Test (MIST), which assesses both time- and event-related PM. The physiological measure was administered via computer and electroencephalography (EEG) in a time-based PM paradigm. Levels of alcohol use were measured with the Alcohol and Drug Use Survey. Participants were divided into three alcohol consumption categories – nondrinkers, light drinkers, and heavy drinkers. We found a relationship between these alcohol use classifications and PM, such that participants who were classified as light drinkers were less likely to perform well in comparison to that of non- and heavy drinkers. Participants' ability to recall the retrospective memory (RM) tasks suggested that the PM items were successfully encoded even though they may not have been carried out, and we did not observe a relationship between alcohol use classifications and RM.

Introduction

The present study aims to investigate the influence of alcohol on time-based prospective memory (PM) and electrophysiological measures in college-aged individuals. It is well known that college students have higher rates of alcohol-use disorders (AUDs) than that of same-aged non-college students, with an estimated 31% of U.S. college students meeting the diagnostic criteria for alcohol abuse (Borsari *et al.*, 2007; Knight *et al.*, 2002). College age is also a critical period for brain development, including regions responsible for the development of PM, making the brains of college students particularly vulnerable to the effects of alcohol.

Prospective Memory

PM is the ability to form and realize intentions after a time delay (Einstein & McDaniel, 1990). During this time delay, individuals are engaged in an ongoing task, or task that is unrelated to the PM task. Some everyday examples of PM include remembering to take medication and paying the bills on time. It is believed that PM can be separated into at least five phases: intention formation, a delay period where intention cannot be realized, a performance interval where intention should be realized, realization of intention, and monitoring success or failure (West & Ross-Munroe, 2002; Brandimonte *et al*., 2014).

There are two general types of PM: event-based PM and time-based PM. An event-based PM task is remembering to perform a specific action when an external event occurs, while a time-based PM task is remembering to perform a specific action after a period of time has passed or at a certain time (Einstein & McDaniel, 1990). With event-based PM, the external cue prompts remembering, where remembering is only appropriate with the occurrence of the external cue, while with time-based PM, there is no specific external cue so participants need to internally monitor and initiate the PM task. An example of event-based PM is remembering to

mail a letter when passing by a post office, and an example of time-based PM is remembering to take cold medication every six hours.

Several cognitive models of PM explain how attention may be managed between current and intended actions. McDaniel and Einstein (2000) suggest a multi-process framework where both voluntary and involuntary actions are accounted for to retrieve an intended action. PM retrieval is dependent on strategic or attention-demanding processes where people may strategically monitor the environment for the presence of the external cue, or rely on environmental conditions that can be used to prompt the intended action. Additionally, this multi-process framework suggests that PM performance is affected by factors such as the importance of the PM task, the nature of the cue and its relation to the intended action, the nature of the ongoing task, and individual differences in cognitive skill and personality. A second model proposed by Smith and Bayen (2004) is specific to event-based PM and describes a multinomial model that comprises two parameters of PM. The first parameter measures preparatory attentional processes and the second parameter measures retrospective memory (RM) processes. Thus, it is different from the multi-process theory in suggesting that there are no automatic processes, but rather all conditions are cognitive resource demanding. However, there is much debate over whether attentional regulation is due to a conscious approach or an automatic process (McDaniel & Einstein, 2000).

Brain Regions Associated with Prospective Memory

Neuroimaging studies have discovered a consistent involvement of rostral prefrontal cortex (rPFC) activation during PM paradigms (Burgess *et al.*, 2011). More specifically, Burgess *et al.* (2003) found significant decreases in regional cerebral blood flow (rCBF) in the superior medial aspects of the rPFC under PM conditions in comparison to during the ongoing task only.

However, lateral regions of the rPFC showed an increase in rCBF under PM conditions. These results suggested that the medial and lateral rPFC have different roles under PM conditions, where the medial rostral PFC is responsible for suppressing internally-generated thought, while the lateral rostral PFC is responsible for maintaining it. Similarly, Simons *et al.* (2006) and Benoit *et al.* (2012) found consistent hemodynamic changes under the PM condition, where activation of the lateral rostral PFC was found along with deactivation of the medial rPFC. Additionally, this pattern was more noticeable with high demands on intention retrieval, suggesting that the rostral PFC prioritizes attention between external events and internal thoughts. Aside from the rPFC (approximately BA 10), there is also frequent activation of the precuneus (BA 7), the parietal lobe (BA 40), and the anterior cingulate (BA 32) during PM tasks, as well as during different cognitive tasks (Simons *et al.*, 2006; Burgess *et al.*, 2011).

Studies have also found that some of the rostral PFC activations, medial or lateral, are insensitive to the form of the stimulus presented (for event-based PM tasks), the nature of the ongoing task, detection difficulty of the PM cue, or the difficulty of the intended action (Burgess *et al.*, 2003; Simons *et al.*, 2006). However, other studies found that there are certain characteristics of PM tasks that can elicit a difference in rPFC activations. For example, a time-based PM task may stimulate more medial activation of the rPFC than an event-based task. Time-event PM region specificity is also supported by Volle *et al.* (2011), who demonstrated that lesions to the right rPFC in humans can cause deficits in time-based PM tasks only. Other PM task characteristics include variation in implicit cues, the nature of the intention, and the form of the instruction given.

Electrophysiological Correlates of Prospective Memory

Although functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and positron emission tomography (PET) are common neuroimaging techniques, electroencephalography (EEG) can be used to measure the brain activity of dendritic populations. More specifically, event-related potentials (ERPs) are time-locked responses to specific internal or external stimuli, making them useful for localizing specific brain regions and activity associated with PM (West, 2011).

Three EEG components are associated with PM: parietal positivity, late positive complex (LPC), and slow wave (West, 2011). Parietal positivity is a prolonged positivity over the parietal region occurring between 400 and 1200 milliseconds (ms) post-stimulus onset (West *et al.*, 2001). Because parietal positivity has been observed when the PM task is embedded in ongoing tasks, it is believed that parietal positivity is responsible for distinguishing PM cues in the environment and is involved with the realization of a delayed intention (West *et al.*, 2001; West & Krompinger, 2005; West 2011). The second component, LPC, is also found most prominently over the parietal region, beginning around 400 to 500 ms after the onset of a stimulus and lasting for about a few hundred milliseconds (Friedman & Johnson, 2000). LPC was first observed in examining repetition or recognition effects of episodic memory, where ERPs of repeated or recognized items differed from newly presented stimuli. Repeated or recognized items evoked an ERP with increased positivity between 500 and 800 ms post-stimulus onset, and is now called LPC, or the parietal "old/new" effect (Smith & Guster, 1993; Rugg *et al.*, 1996). It is believed that the LPC is responsible for retrieving intention from memory (West, 2011). The third component, slow wave, reflects a difference for PM hits compared to PM misses, suggesting that

ERPs of PM misses, or unrealized intentions differ from ERPs of PM hits, and is interpreted as individuals seeing the cue, but not remembering the intended action (West, 2011).

Alcohol and Prospective Memory

Alcohol use has most often been studied in adults, with findings suggesting that persistent misuse of alcohol can result in brain shrinkage with reduced gray matter volumes in subcortical, dorsolateral, frontal, and parietal cortices (Kril & Halliday, 1998), inhibited prefrontal lobe functioning (Moselhy *et al.*, 2001), and in extreme cases, lead to cerebral atrophy (Alderazi & Brett, 2007). One PET study revealed that in heavy drinkers, there were normal values of glucose metabolic rates in most regions, but a significant reduced regional distribution index was found in the medial frontal cortex (Samson *et al*., 1886). Additionally, a single photon emission computed tomography (SPECT) study found in alcoholics, hypoperfusion areas on the SPECT scan, as well as significant reduction in cerebral blood flood in all of the brain lobes (Nicolas *et al.*, 1993). Research with rats has also demonstrated that alcohol decreases the number of cholinergic neurons in the basal forebrain, which leads to deficits in hippocampal function, potentially impacting memory consolidation (Garcia-Moreno *et al.*, 2001).

Alcohol use has also been found to affect PM performance. Leitz *et al.* (2009) reported that alcohol acutely produced global impairments on regular (habitual tasks), irregular (occasional tasks), time-based and event-based PM, as well as impaired episodic memory. Adults with alcohol abuse problems report more frequent PM complaints on a self-report measure, where heavy alcohol users reported 31.2% more problems with long-term PM than nondrinkers and 23.7% more problems that light-drinkers (Weinborn *et al.*, 2013; Ling *et al.*, 2003). Consistent with self-reports, individuals diagnosed with alcohol dependence showed significant impairment on event-based PM tasks relative to social drinkers (Griffiths *et al*., 2012).

Additionally, Platt *et al.* (2016) demonstrated that heavy drinkers performed significantly worse on regular and irregular time-based PM than matched controls.

While alcohol use and PM has also been studied in younger subjects, findings have been inconsistent. One study found that binge drinkers (ages 17-19) performed worse on the Prospective Remembering Video Procedure, an objective measure of everyday PM, compared to that of non-binge drinkers despite no significant between-group differences on long-term and short-term PM lapses (Heffernan *et al.*, 2010), while Heffernan and O'Neill (2012) later reported that emerging adult binge drinkers performed significantly worse on time-based PM, but not event-based PM than non-binge drinkers. Heffernan *et al*. (2006) also found that excessive drinkers (mean age 18.7) self-reported more functioning lapses with their long-term and short-term everyday PM compared to the matched low-dose control group. However, another study found that heavy drinking was associated with reduced performance on time-based PM tasks, but not event-based PM tasks using objective measures (Zamroziewicz *et al.*, 2017). Additionally, higher numbers of reported blackouts were associated with event-based PM, but not time-based PM. Due to the nature of self-reports and variance in PM tasks, it is difficult to extrapolate the effects of alcohol in younger subjects.

Influence of Alcohol on Time-Based Prospective Memory and Electrophysiological Measures of College-Aged Individuals

Many studies have aimed to find the effects of alcohol on PM performance, but mostly in adults. Additionally, effects of alcohol use have been studied in younger subjects, but have resulted in inconsistent findings. Because the college age (ages 18-25) is a critical period for brain development, including regions responsible for the development of PM, the brains of college students may be vulnerable to the effects of alcohol. Thus, it is important to

systematically study the effects of alcohol on college-aged individuals. In this study, we used the Memory for Intentions Screening Test (MIST) as the clinical measure of PM (Raskin, 2009). Furthermore, we are not aware of any study that examine the effects of alcohol on electrophysiological measures in college-aged individuals and determined the electrophysiological correlates of time-based PM in different groups of alcohol consumption levels. Therefore, we will also use a behavioral measure, similar to that of Cona *et al.* (2012), of time-based PM in conjunction with the EEG.

Questions and Hypotheses

i.   How do the behavioral measures of time-based PM compare to clinical MIST measures of PM?

     a. Heavy alcohol drinkers will perform significantly worse on time-based PM tasks in the MIST in comparison to non- and light drinkers.

     b. Heavy alcohol drinkers will perform significantly worse on the behavioral measure in comparison to non- and light drinkers.

ii.   What are the specific electrophysiological correlates of time-based PM in nondrinkers, light drinkers, and heavy drinkers?

     a. Amplitudes over the frontal electrodes will be reduced in heavy drinkers in response to PM cues in comparison to non- and light drinkers.

Method

This study was conducted at Trinity College in Hartford, CT and was approved by the IRB. The objective of this study was to investigate the influence of alcohol on time-based prospective memory and electrophysiological measures in college-aged individuals with the use of a clinical measure of PM (Memory for Intentions Screening Test, Raskin, 2009) and a time-based PM behavioral task modeled after that of Cona *et al.* (2012). For each subject, the experiment took approximately two hours to complete, with a self-report alcohol and drug use survey taking five minutes, the Memory for Intentions Screening Test (MIST) taking 30 minutes, and the time-based PM behavioral task taking 80 minutes, including preparation time.

Participants

Participants (n=48) were healthy right-handed individuals, aged 18-25 years old, with no neurological or psychological illness, at least 12 years of education, adequate visual and auditory function, and English-speaking.

All participants read and signed an IRB-approved informed consent form and were instructed that if at any point during the testing session they felt uncomfortable or wanted to stop, they could leave without penalty. Participant confidentiality was maintained by assigning all participants an identification number that was used on all testing forms. A demographic form was also used to collect background information, including age, years of education, sex, race, learning diagnoses, and current medications, as well as to ensure that participants qualified for this study. Demographic information collected from participants is presented in Table 1. Participants were compensated for their time through one of the following options of their choice: course credit (for Trinity College students), a $15 Barnes & Noble gift card, a $15 Goldberg's gift card, or a $15 Dunkin Donuts gift card.

Table 1. *Demographic Information*

Demographic variable	Nondrinker	Light Drinker	Heavy Drinker
Sex			
Male	3	6	10
Female	9	11	9
Age (years)	19.58 ± 1.38	19.53 ± 1.84	19.37 ± 1.21
Years of Education	13.50 ± 1.38	13.12 ± 0.99	13.11 ± 1.05
Race/Ethnicity			
Caucasian	2	3	12
African American	3	2	2
Hispanic	0	3	1
Asian/Pacific Islander	6	5	0
Native American/Alaskan Native	0	0	0
Multiracial/Multiethnic/Other	1	4	4

Classification of Alcohol Consumption Levels

With the use of an alcohol and drug use survey, alcohol consumption patterns from the past 12 months and drug use from the past month were self-reported and used to classify participants into different alcohol consumption groups. Data on use of other substances is presented in Table 2. The survey included the Mini-International Neuropsychiatric Interview and adapted questions from the Structured Clinical Interview for the DSM-IV (Sheehan & Lecrubier, 1998; First *et al.*, 2002). Some examples of questions asked were, "Did you need to drink a lot more in order to get the same effect that you got when you first started drinking or did you get much less effect with continued use of the same amount?" and "Were you intoxicated more than once in any situation where you were physically at risk, for example, driving a car, riding a motorbike, or using machinery?"

Nondrinkers (n=12) reported having never consumed alcohol or have drank 1-2 times in their lives, but not in the past 12 months. Light drinkers (n=17) did not meet criteria for Alcohol Use Disorder (AUD) or drank <50% of the weeks in the past 12 months. Heavy drinkers (n=19) met criteria for current AUD or drank ≥50% of the weeks in the past 12 months and binge drank

(≥4 drinks for females and ≥5 drinks for males) more than half of the number of drinking incidents reported.

Table 2. *Number of Days of Use of Other Substances in the Past Month*
(1 = Never; 2 = 1–2; 3 =3–5; 4=6–9; 5=10–19; 6=20 or More)

Substance Used	Range (days)	N of students reporting use		
		Nondrinker	Light Drinker	Heavy Drinker
Marijuana, hashish	1–6	0	4	15
Cocaine, crack, "speedball"	1–4	0	0	3
LSD[a]	1–2	0	0	1
Other hallucinogen	n/a	0	0	0
Crystal meth	n/a	0	0	0
Heroin	n/a	0	0	0
Opium	n/a	0	0	0
Inhalant	n/a	0	0	0
Ecstasy	n/a	0	0	0
PCP[b]	n/a	0	0	0
GHB[c]	1–2	0	1	0
Sleeping medication	1–3	0	0	2
Sedative/anxiety medication	1–6	0	1	0
Stimulant medication	1–4	0	0	1
Steroid	n/a	0	0	0
Cough medicine	1–6	2	3	5
Pain medicine	1–6	3	4	7

[a] Lysergic acid diethylamide. [b] Phencyclidine. [c] γ–Hydroxybutryic acid.

Clinical Measure of Prospective Memory

The clinical assessment of PM was the Memory for Intentions Screening Test (MIST) (Raskin, 2009). The MIST consists of eight PM tasks that are prompted throughout the assessment, while participants are working on a word puzzle as the ongoing task. The MIST includes event- and time-based tasks with 2-minute or 15-minute time delay tasks that required action or verbal responses. An example of an event-based task is, "When I hand you a red pen, sign your name on the word puzzle paper," and an example of a time-based task is, "In 15 minutes, tell me when I can call you tomorrow." After the completion of the eight PM tasks, participants were asked eight multiple-choice retrospective memory recall questions about the

tasks they were just asked to complete. Lastly, participants were asked to complete a final PM task with a more naturalistic 24-hour time delay.

For the time-based PM tasks, participants could score a maximum of two points if they completed the correct response at the correct time (±1 minute), one point if they completed the correct response at an incorrect time or an incorrect response at the correct time, or zero points if they completed an incorrect response at an incorrect time or had no response. For the event-based PM tasks, participants could score a maximum of two points if they completed the correct response to the appropriate cue, or zero points if they completed the incorrect response to an event-based cue or had no response. Participants could score a maximum of 48 points on the MIST, calculated by the summation of the following eight-point subscales: 2-minute time delay, 15-minute time delay, time cue, event cue, verbal response, and action response. Additionally, participants could score a maximum of eight points on the multiple-choice retrospective memory recall questions, where each correct answer is allotted one point. Lastly, participants could score a maximum of two points on the 24-hour time delay PM task, scored in the same manner as the other time-based PM tasks. The PM error was the total number of events that participants scored zero, while the total PM error was the total number of events that the participants scored zero or one. In total, the MIST took approximately thirty minutes to complete.

Electrophysiological Recording

The electrophysiological measures of time-based PM were examined using an electroencephalogram (EEG) machine. A Compumedics® Neuroscan™ Quik-Cap with 64 sewn-in electrodes and six external electrodes was used to record electrophysiological data. The recorded montage included the following scalp positions presented in Figure 1. Left and right eye movements and blinks were recorded with four of the six external electrodes secured with

Compumedics® v-shaped electrode washers on the sides of the participant's left (HEOL) and right (HEOR) eyes, and above (VEOU) and below (VEOL) the left eye. All electrodes were referenced to a reference electrode located at the center of the cap during recording. The remaining two external electrodes were placed on the participant's left (M1) and right (M2) mastoid bones to record the base connectivity of the scalp, which was subtracted from all recordings upon data analysis.
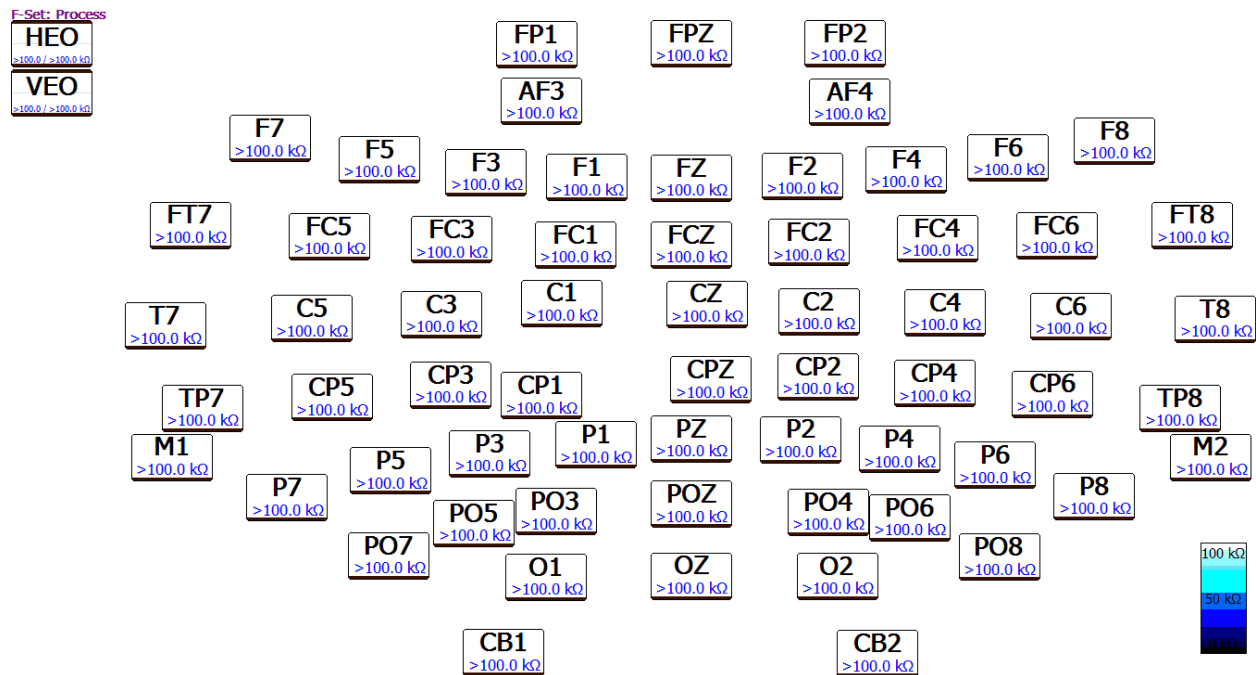

Figure 1. 64-e*lectrode impedance map in Curry 7*

Prior to placing the EEG cap on, participants were asked to wipe their forehead and around their eyes with an alcohol wipe to prepare their faces for the external electrodes, and abraded their scalp with a sterilized wide-tooth hairbrush to allow for better impedances during EEG recording. The EEG cap was then connected to the Neuroscan™ headbox, which was connected to the SynAmpRt amplifier, which had a 24-bit resolution, DC-3500-Hz bandwidth, filtered between 0.1 Hz and 100 Hz, with a low-pass 30 Hz filter, and a maximum sampling rate of 20 kHz. Curry 7 was then used to monitor electrode impedance. Before putting any gel in the

electrodes, the impedance reading for all electrodes were at 50.0 kΩ. A BD™ 10-mL syringe with a Luer-Lok™ tip and a BD™ 16-gage ¾ blunt square grind PrecisionGlide® needle was then used to fill electrodes with filled with Compumedics® NeuroMedical Supplies Quik-Gel™, which was prepared by mixing approximately 95 mL of Quik-Gel™ with 30 mL of water, and then warmed in the microwave for 45 seconds. Once electrodes were filled so that impedance was less than 20 kΩ, participants worked on the time-based PM behavioral task while the EEG was being recorded. In total, the electrophysiological recording setup took approximately thirty minutes, while cleanup took approximately 20 minutes.

Time-Based Prospective Memory Behavioral Task

The time-based PM behavioral task that participants completed on the computer during EEG recording was created using Stim® 2.0 and modeled after that of Cona *et al*. (2012). The ongoing task consisted a sequence of five white letters presented at the center of a black computer screen. Participants were asked to identify whether the second and fourth letters of the five-letter sequence (with the first, third, and fifth letter being the same) were same or different by hitting either the "n" key on the keyboard marked "SAME" or the "m" key on the keyboard marked "DIFF". For example, if participants saw "RTRTR", they would hit "SAME", whereas if they saw "RTRDR", they would hit "DIFF". There were 350 trials lasting 4,000 ms each. For each trial, a new five-letter sequence appeared on the screen for 300 ms or until the participant responded by hitting the key. After 300 ms or a response was given, a blank black screen was shown for a duration such that the combined time of the five-letter sequence screen and the black screen lasted as duration of 4,000 ms.

The intention formation trials occurred periodically and consisted of a displayed instruction asking participants to hit the red button on the keyboard (where a red sticker was

placed over the "z" key) after either two or five minutes had elapsed, which participants could monitor with a digital clock placed next to the computer. Participants had to hit the "c" key to acknowledge that they read and understood the PM task. Responses to the PM task were considered correct if the red button was hit within ±1 minute of the correct time. There were ten time-based PM tasks embedded – six two-minute time delay trials and four five-minute time delay trials. In total, the time-based PM behavioral task took approximately 30 minutes to complete.

Data Analyses

One-way ANOVA tests were used to compare the groups on the PM measures.

Results

Demographic Differences Among Alcohol Consumption Groups

A one-way ANOVA test revealed no significant differences between groups (Table 1).

MIST Performance

A one-way ANOVA test revealed significant differences between groups. Light drinkers performed significantly worse on time-based PM tasks compared to nondrinkers and heavy drinkers ($p<0.05$) (Figure 2).
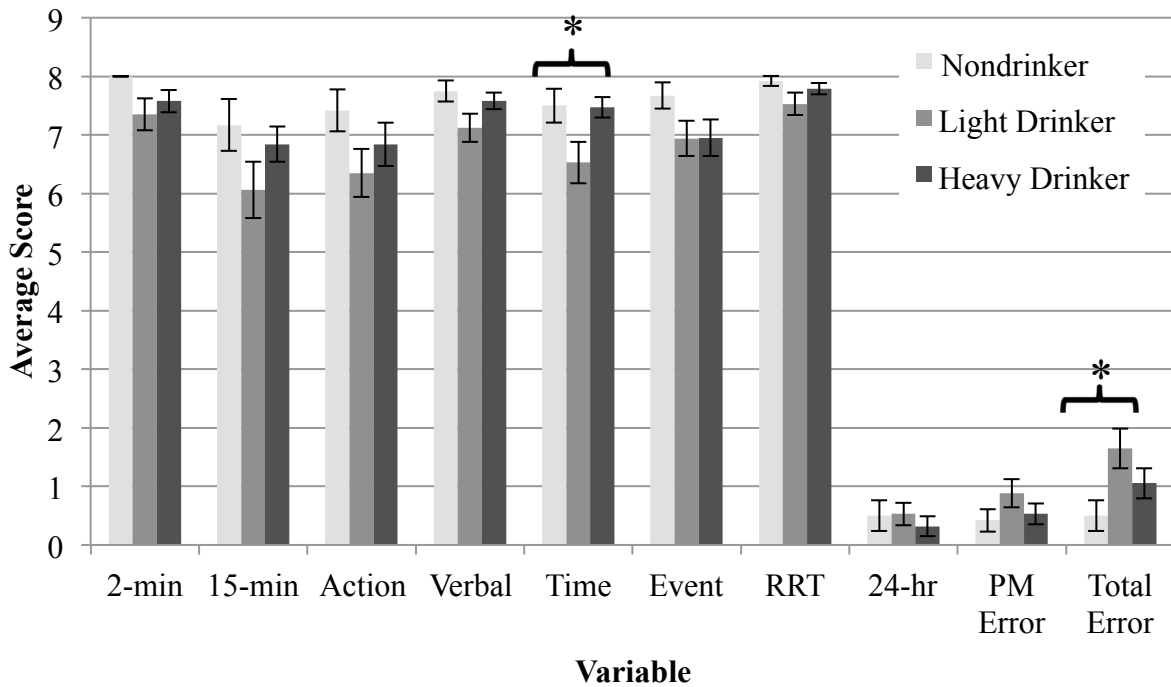

Figure 2. *Mean scores in performance on MIST variables in nondrinkers, light drinkers, and heavy drinkers (* p<0.05)*

Behavioral PM Task Performance

A one-way ANOVA test revealed no significant differences in the behavioral measure between groups (Figure 3). Groups did not perform significantly different in the accuracy and error of the two-minute time delay PM task ($p=0.112$; $p=0.112$). Similarly, groups did not

perform significantly different in the accuracy and error of the five-minute time delay PM task
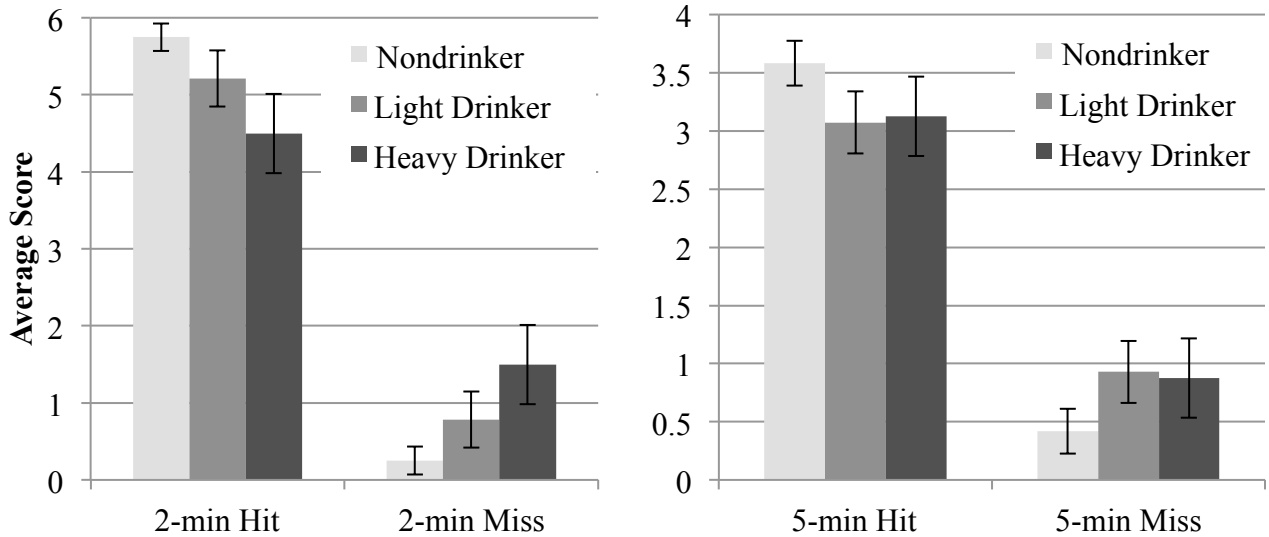(*p*=0.429; *p*=0.429).

Figure 3. *Mean performance in two-minute and five-minute time delay tasks in behavioral task in nondrinkers, light drinkers, and heavy drinkers*

A one-way ANOVA test showed that averaged electrophysiological recordings were significantly different between groups. With respect to realized N300 potentials, nondrinkers had significantly lower activation than light drinkers over the O2 electrodes (*p*<0.05), and significantly lower activation than light and heavy drinkers over the P3 and P4 electrodes (*p*<0.001; *p*<0.05) (Figures 4 & 5). With respect to unrealized N300 potentials, nondrinkers had significantly lower activation than light and heavy drinkers over the O2, P3, and P4 electrodes (*p*<0.001; *p*<0.05; *p*<0.001) (Figures 4 & 5). With respect to ongoing N300 potentials, nondrinkers had significantly lower activation than light and heavy drinkers over the O1, O2, P3, and P4 electrodes (*p*<0.05; *p*<0.001; *p*<0.001; *p*<0.001) (Figures 4 & 5). With respect to realized, unrealized, and ongoing LPC potentials, there were no significant differences between groups (Figure 6). With respect to realized slow wave potentials, light drinkers had significantly

lower activation over the FP1 electrode ($p<0.05$) (Figure 7). With respect to unrealized slow wave potentials, there were no significant differences between groups (Figure 7). With respect to ongoing slow wave potentials heavy drinkers had significantly higher activation than light drinkers over the FP1 and FP2 electrodes ($p<0.05$; $p<0.05$) (Figure 7).
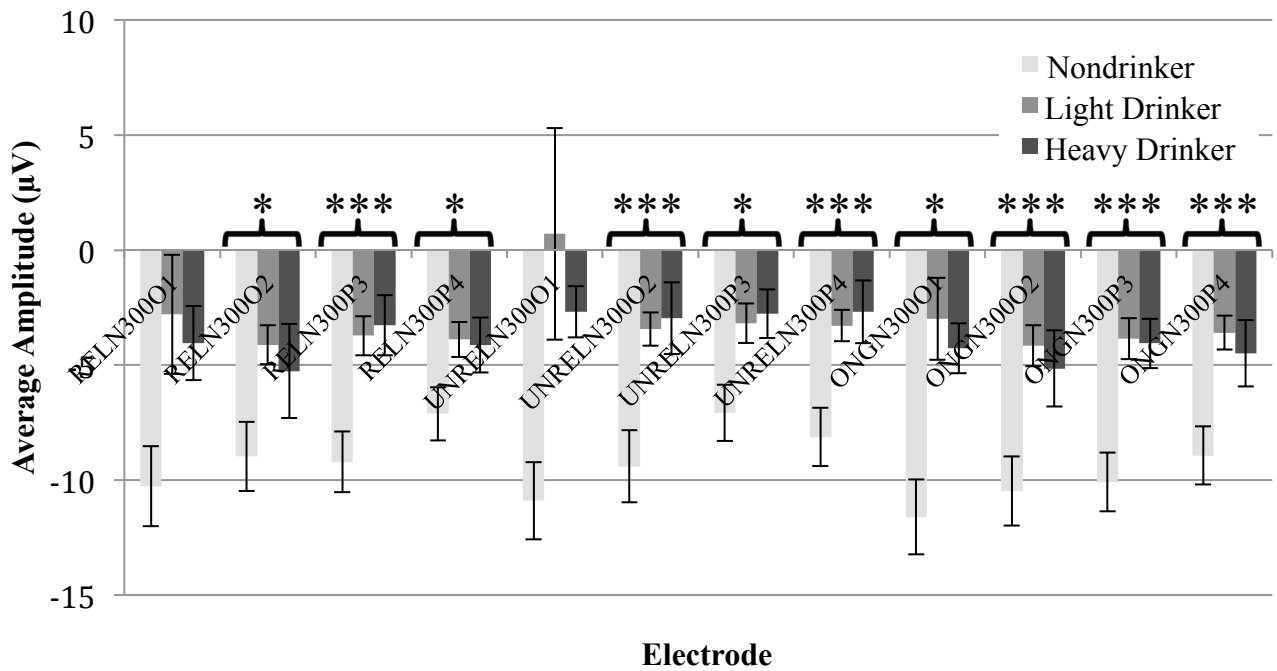

Figure 4. *Mean N300 amplitudes recorded from electrodes during the behavioral task in nondrinkers, light drinkers, and heavy drinkers (* p<0.05; ** p<0.01; ***p<0.001)*
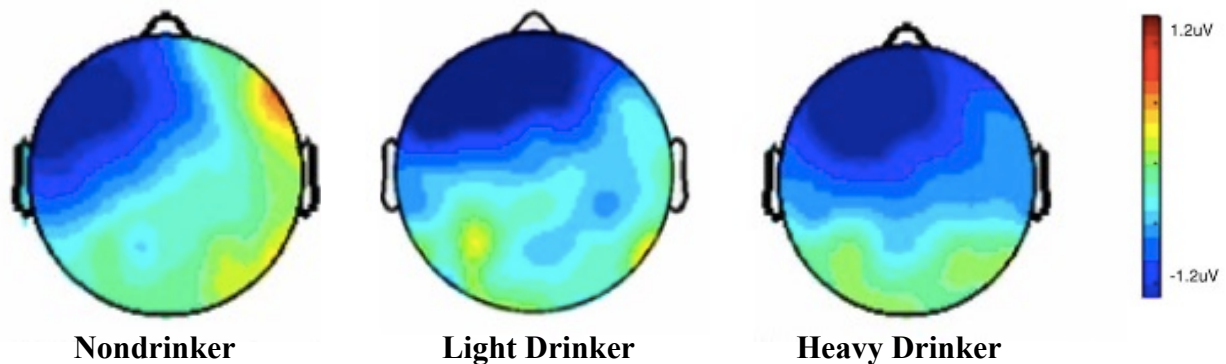
Figure 5. *Mean N300 amplitudes from electrodes during the behavioral task in nondrinkers, light drinkers, and heavy drinkers*
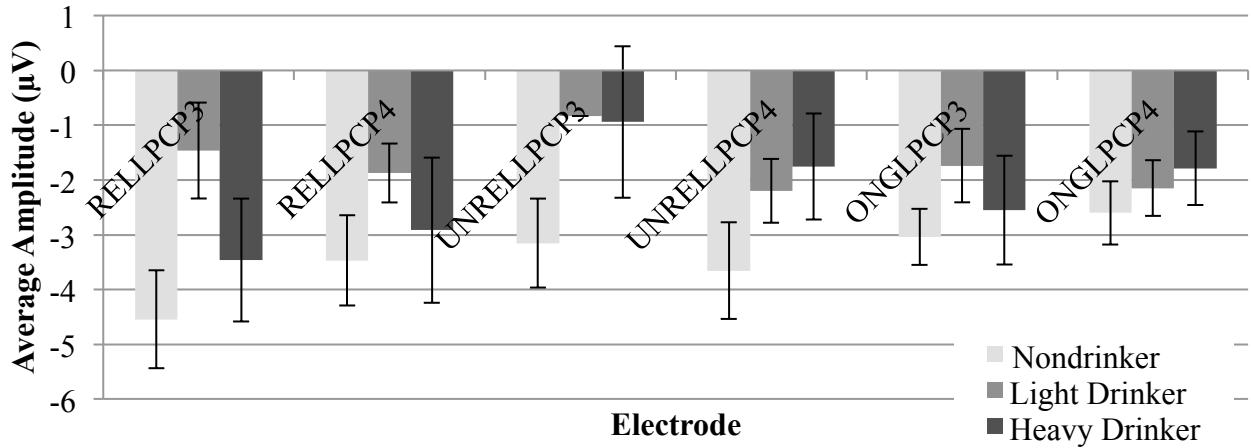
Figure 6. *Mean LPC amplitudes recorded from electrodes during the behavioral task in nondrinkers, light drinkers, and heavy drinkers*
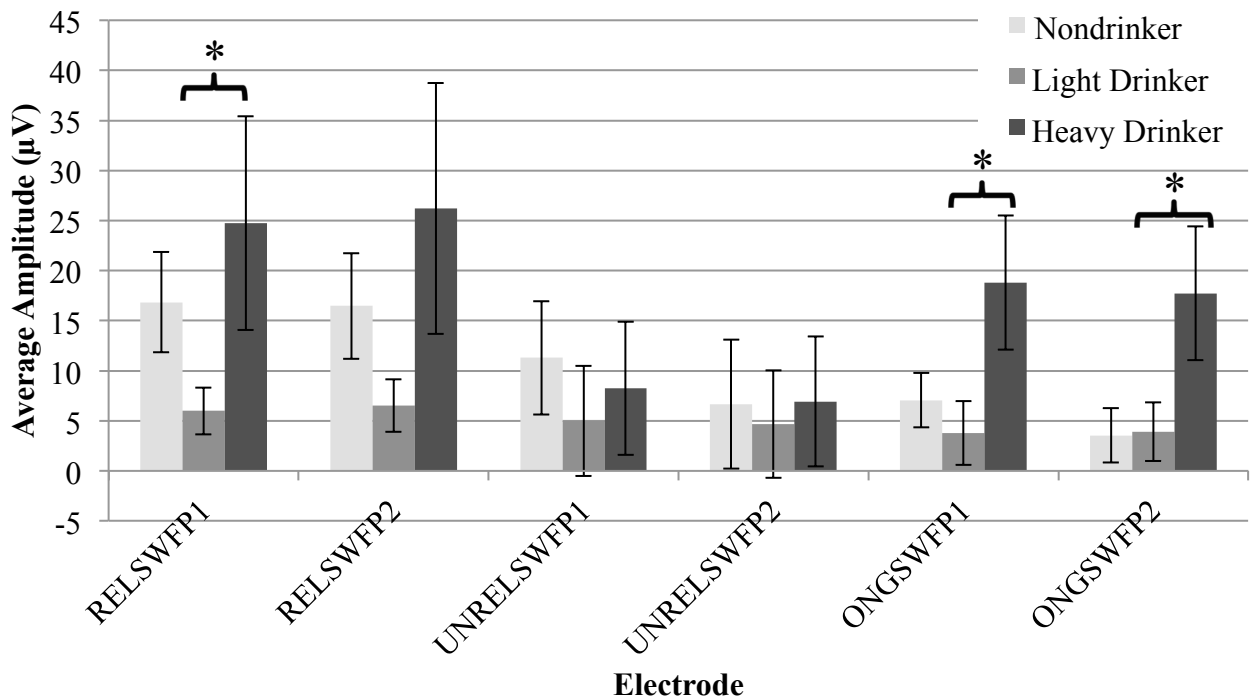

Figure 7. *Mean slow wave amplitudes recorded from electrodes during the behavioral task in nondrinkers, light drinkers, and heavy drinkers (* p<0.05)*

Discussion

This study aimed to compare time-based PM performance among college-aged individuals with different alcohol consumption patterns. Previous research aimed to find the effects of alcohol on PM performance in this population have resulted in inconsistent findings. In the present study, the clinical assessment of PM performance revealed no significant differences in performance between time-based and event-based tasks within groups, but light drinkers performed significantly worse on time-based PM tasks compared to non- and heavy drinkers. However, the behavioral measure of time-based PM showed no significant differences between groups.

Surprisingly, light alcohol consumption patterns were associated with poorer PM performance on time-based tasks in the MIST compared to both non- and heavy drinkers. Additionally, light drinkers made significantly more total PM errors than nondrinkers. Due to the self-initiated nature and difficulty of time-based PM tasks compared to event-based PM tasks, poorer performance in time-based tasks were expected (Craik, 1986). However, this finding in light drinkers is inconsistent with the literature, which suggested that heavy drinkers performed worse on time-based tasks compared to non- and light drinkers (Zamroziewicz *et al.*, 2017). Since RM scores for all groups were uniformly high, this was indicative of proper encoding of PM tasks and the intention to complete the delayed intention (Brandimonte *et al.*, 2014). Since college-aged individuals are more likely to report their most recent memory failure is that of the prospective nature rather than a retrospective one, retrospective memory is not the problem here (Kvavilashvili *et al.*, 2009). One possible explanation for comparable PM performance of heavy drinkers to that of nondrinkers is that heavy drinkers are more likely to experience PM lapses daily and have developed coping strategies to overcome these challenges (Heffernan *et al.*,

2006). Thus, the same strategies could be used to improve PM performance on the MIST. Additionally, heavy drinkers may recognize their own memory shortcomings and performed to the best of their ability to overcompensate. The opposite argument could be made for light drinkers who are less likely to experience PM lapses daily and therefore were not inclined to overcompensate on the MIST.

On the other hand, the time-based PM behavioral measure found no significant differences in performance between groups, a finding that again, is contradictory with the previous literature (Heffernan *et al*., 2006; Zamroziewicz *et al*., 2017). One potential explanation is the behavioral measure includes only two-minute and five-minute time delays, which may not be enough to emphasize any memory problems, especially those of long-term. Additionally, the time-based PM task is not reflective of everyday PM tasks, as the paradigm requires the participant to hit a red button after a short period of time, which could be perceived as an insignificant task to the participant. The MIST perhaps yields significant findings because the PM tasks vary, and also include fifteen-minute delays, a longer time delay.

The electrophysiological recordings in conjunction with the behavioral measure revealed significant differences. The choice of electrodes for analysis was based off of Cona *et al*.'s (2012) study, which revealed that FP1, FP2, P3, P4, O1, and O2 were the brain regions that were mainly active in time-based PM tasks. Significant differences in the N300 potentials where nondrinkers had reduced amplitudes compared to light and heavy drinkers were indicative of less activation in those regions, and therefore more efficiency. Since N300 potentials designate the detection of PM cues in the environment, nondrinkers may be expending less energy and attention while still carrying out a PM task accurately (West, 2011). There were no significant differences in LPC potentials, which signal the retrieval of intention from memory (West, 2011).

Thus, such retrieval of intention may not be necessarily affected by different alcohol consumption patterns. Significant differences in realized slow wave potentials over the frontal-parietal region with lower activation in light drinkers compared to heavy drinkers suggest inefficiency in switching focus from ongoing tasks to PM tasks (West, 2011). While this did not affect the PM performance of light drinkers in the behavioral measure, this could help explain their poorer performance on time-based tasks on the MIST. Additionally, heavy drinkers have significantly higher amplitudes of ongoing slow wave potentials over the frontal-parietal region than light drinkers, implying that heavy drinkers are better at disengaging from the ongoing task to focus on the PM task. On the other hand, this may be indicative of overcompensation, especially since there are no significant differences between non- and light drinkers. Additionally, this could help explain the unexpected PM performance of heavy drinkers on the MIST.

Conclusion

Results of the present study underscore the challenges in studying the influence of alcohol in college-aged individuals. Findings in both the clinical measure and behavioral measure were unexpected and inconsistent with the literature, but electrophysiological measures helped explain causes of high PM performance found in heavy drinkers.

Future studies should implement self-report measures of PM to verify that findings based on PM performance measures can be translated to daily functioning. In addition, different time delays should be examined to determine the threshold of sensitivity for different alcohol groups. This study was limited to two-, five-, and fifteen-minute time delays, which does not accurately capture time-based PM tasks endured on an everyday basis. Future studies should be conducted in a manner to reduce participant bias in regards to alcohol consumption levels and expected performance on memory tasks. Furthermore, data should be analyzed on a continuum of alcohol consumption patterns, as stringent alcohol groups may substantially reduce or hide true PM performance patterns. Future studies should also investigate the influence of alcohol on time-based PM performance in college students compared to that of individuals of similar ages not enrolled in college, to account for the effects of attending college on memory.

Acknowledgments

References

Alderazi, Y., & Brett, F. (2007). Alcohol and the nervous system. Curr. Diagno. Pathol., 13, 203-209.

Benoit, R.G., Gilbert, S.J., Frith, C.D., & Burgess, P.W. (2011). Rostral prefrontal cortex and the focus of attention in prospective memory. *Cerebral Cortex, 22,* 1876-1886.

Borsari, B., Murphy, J.G., & Barnett, N.P. (2007). Predictors of alcohol use during the first year of college: Implications for prevention. *Addict Behav., 32*(10): 2062-2086.

Brandimonte, M.A., Einstein, G.O., & McDaniel, M.A. (2014). *Prospective memory: Theory and applications*. Psychology Press.

Burgess, P.W., Scott, S.K., & Frith, C.D. (2003). The role of the rostral frontal cortex (area 10) in prospective memory: a lateral versus medial dissociation. *Neuropsychologia*, *41*(8): 906-918.

Burgess, P. W., Gonen-Yaacovi, G., & Volle, E. (2011). Functional neuroimaging studies of prospective memory: What have we learnt so far? *Neuropsychologia, 49,* 2246-2257.

Cona, G., Arcara, G., Tarantino, V., & Bisiacchi, P.S. (2012). Electrophysiological correlates of strategic monitoring in event-based and time-based prospective memory. *PLoS ONE, 7*(2): e31659. doi:10.1371/journal.pone.0031659

Craik, F.I., Klix, F., & Hagendorf, H. (1986). *A functional account of age differences in memory* (pp. 409-422).

Einstein, G.O., & McDaniel, M.A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 717-726.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, Janet B.W. (2002). Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition. (SCID-I/P) New York: Biometrics Research, New York State Psychiatric Institute.

Friedman, D., & Johnson, R.E. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Technique*. *51*, 6–28.

Garcia-Moreno, L.M., Conejo, N.M., Pardo, H.G., Gómez, M., Martín, F.R., Alonso, M.J., & Arias, J.L. (2001). Hippocampal AgNOR activity after chronic alcohol consumption and alcohol deprivation in rats. *Physiol. Behav., 72,* 115-221.

Griffiths, A., Hill, R., Morgan, C., Rendell, P.G., Karimi, K., Wanagaratne, S., & Curran, H.V. (2012). Prospective memory and future event simulation in individuals with alcohol dependence. *Addiction, 107,* 1809–1816.

Heffernan, T.M. (2008). The impact of excessive alcohol use on prospective memory: A brief review. *Current Drug Abuse Reviews, 1,* 36-41.

Heffernan, T.M., Clark, R., Bartholomew, J., Ling, J., & Stephens, S. (2010). Does binge drinking in teenagers affect their everyday prospective memory? *Drug and Alcohol Dependence, 109,* 73-78.

Heffernan, T.M., & O'Neill, T. (2012). Time based prospective memory deficits associated with binge drinking: evidence from the Cambridge prospective memory test (CAMPROMPT). *Drug Alcohol Dependence*, *123*, 207-212.

Heffernan, T.M., O'Neill, T., Ling, J., Holroyd, S., Bartholomew, J., & Betney, G. (2006). Does excessive alcohol use in teenagers affect their everyday prospective memory? *Clin. Effectiveness in Nursing, 9S3,* e302-e307.

Knight, J.R., Wechsler, H., Kuo, M., Seibring, M., Weitzman, E.R., & Schuckit, M.A. (2002). Alcohol abuse and dependence among U.S. college students. *Journal of Studies on Alcohol.*

Kril, J.J., & Halliday, G.M. (1998). Brain shrinkage in alcoholics: a decade on and what have we learned? *Prog. Neurobiol., 58*, 381-87.

Kvavilashvili, L., Kornbrot, D.E., Mash, V., Cockburn, J., & Milne, A. (2009). Differential effects of age on prospective and retrospective memory tasks in young, young-old, and old-old adults. *Memory*, *17*(2), 180-196.

Leitz, J.R., Morgan, C.J.A., Bisby, J.A., Rendell, P.G., & Curran, H.V. (2009). Global impairment of prospective memory following acute alcohol. *Psychopharmacology, 205*, 379-387.

Ling, J., Heffernan, T.M., Buchanan, T., Rodgers, J., Scholey, A.B., & Parrott, A.C. (2003). Effects of alcohol on subjective ratings of prospective and everyday memory deficits. *Alcoholism: Clinical and Experimental Research, 27,* 970–974.

McDaniel, M.A., & Einstein, G.O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Appl. Cognit. Psychol., 14,* S127-S144.

Moselhy, H.F., Georgiou, G., & Kahn, A. (2001). Frontal lobe changes in alcoholism: a review of the literature. *Alcohol & Alcoholism, 36*, 357- 68.

Nicolas, J.M., Catafau, A.M., Estruch, R., Lomena, F.J., Salamero, M., Herranz, R., Monforte, R., Cardenal, C., & Urbano-Marquez, A. (1993). Regional cerebral blood flow-SPECT in chronic alcoholism: relation to neuropsychological testing. *Journal of Nuclear Medicine*, *34*, 1452-1459.

Platt, B., Kamboj, S.K., Italiano, T., Rendell, P.G., & Curran, H.V. (2016). Prospective memory impairments in heavy social drinkers are partially overcome by future event simulation. *Psychopharmacology, 233,* 499–506.

Raskin, S.A. (2009). Memory for Intentions Screening Test: Psychometric properties and clinical evidence. *Brain Impairment, 10*, 23–33.

Rugg, M.D., Schloerscheidt, A.M., Doyle, M.C., Cox, C.J., & Patching, G.R. (1996). Event-related potentials and the recollection of associative information. *Cognitive Brain Research*. *4*(4): 297–304.

Samson, Y., Baron, J.C., Feline, A., Bories, J., & Crouzel, C. (1986). Local cerebral glucose utilisation in chronic alcoholics: a positron tomographic study. *Journal of Neurology, Neurosurgery and Psychiatry, 49,* 1165-1170.

Sheehan, D.V., Lecrubier, Y., Sheehan, K.H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R. & Dunbar, G.C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *The Journal of Clinical Psychiatry, 59*(Suppl 20), 22-33.

Simons, J.S., Schölvinck, M., Gilbert, S.J., Frith, C.D., & Burgess, P.W. (2006). Differential components of prospective memory? Evidence from fMRI. *Neuropsychologia, 44*, 1388–1397.

Smith, R.E., & Bayen, U.J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(4): 756-777.

Smith, M.E., & Guster, K. (1993). Decomposition of recognition memory event-related potentials yields target, repetition, and retrieval effects. *Electroencephalography and Clinical Neurophysiology*. *86*, 335–343.

Volle, E., Gonen-Yaacovi, G., de Lacy Costello, A., Gilbert, S.J., & Burgess, P.W. (2011). The role of rostral prefrontal cortex in prospective memory: A voxel-based lesion study. *Neuropsychologia, 49,* 2185-2198.

Weinborn, M., Woods, S.P., O'Toole, S., Kellogg, E.J., & Moyle, J. (2011). Prospective memory in substance abusers at treatment entry: Associations with education, neuropsychological functioning, and everyday memory lapses. *Archives of Clinical Neuropsychology, 26,* 746– 755.

West, R. (2011). The temporal dynamics of prospective memory: a review of the ERP and prospective memory literature. *Neuropsychologia, 49*, 2233–2245.

West, R., Herndon, R.W., & Crewdson, S. J. (2001). Neural activity associated with the realization of a delayed intention. *Cognitive Brain Research, 12*, 1–10.

West, R., & Krompinger, J. (2005). Neural correlates of prospective and episodic memory. *Neuropsychologia, 43*, 418–433.

West, R., & Ross-Munroe, K. (2002). Neural correlates of the formation and realization of delayed intentions. *Cognitive, Affective, & Behavioral Neuro. 2*(2): 162-173.

Zamroziewicz, M., Raskin, S.A., Austad, C.S., Wood, R.M., Rallahi, C.R., Sawyer, B., Leen, S., Tennen, H., Dager, A.D., & Pearlson, G.D. (2017). Effects of drinking patterns on prospective memory performance in college students. *Neuropsychology, 31*(2): 191-199.