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# Effects of Drinking Patterns on Prospective Memory Performance in College Students

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## Abstract

**Objective—**Traditional college students are at a critical juncture in the development of prospective memory (PM). Their brains are vulnerable to the effects of alcohol.

**Methods—**123 third and fourth year college students, 19-23 years old, completed the Self-Rating Effects of Alcohol (SREA), Modified Timeline Follow-back (TFLB), Brief Young Adult Alcohol Consequences Scale (BYAACS) and Alcohol Effects Questionnaire (AEQ) once per month on a secure on-line database, as reported elsewhere (Dager, et al., 2013). Data from the six months immediately prior to memory testing were averaged. In a single testing session participants were administered the Mini International Neuropsychiatric Interview (MINI-DSM-IV-TR), measures of PM (event-based and time-based), and retrospective memory (RM). Based on the average score of six consecutive monthly responses to the SREA, TLFB and AEQ, students were classified as non-drinkers, light drinkers, or heavy drinkers (as defined previously, Dager, et al., 2013). Alcohol-induced amnesia (blackout) was measured with the BYAACS.

**Results—**We found a relationship between these alcohol use classifications and time-based PM, such that participants who were classified as heavier drinkers were more likely to forget to perform the time-based PM task. We also found that self-reported alcohol-induced amnesia (blackouts) during the month immediately preceding memory testing was associated with lower performance on the event-based PM task. Participants' ability to recall the RM tasks suggested the PM items were successfully encoded even when they were not carried out, and we observed no relationship between alcohol use and RM performance.

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Sarah Raskin has a financial disclosure as the author of the Memory for Intentions Test.

**Conclusion—**Heavy alcohol use in college students may be related to impairments in PM.

**Keywords**

prospective memory; episodic memory; binge drinking; alcohol; adolescence

## Introduction

Prospective memory (PM) is a form of episodic memory, and involves the ability to remember to carry out an intention at some future point in time (Brandimonte, Einstein, & McDaniel, 1996; Kvavilashvili & Ellis, 1996). PM is vital in daily life for functions such as taking medications, turning off the stove, completing assignments, and maintaining appointments, and it is more highly correlated with performance on daily tasks than traditional memory measures (Wilson, 1987). Recent studies have suggested that PM may be affected by heavy alcohol use (e.g., Weinborn, Moyle, Bucks, Stritzke, Leighton, & Woods, 2011). The current study examined PM performance in college students as a function of alcohol use.

PM may require time-cued remembering (e.g., remembering to return a phone call at 3:00 pm) (Levy & Loftus, 1984; Wilkens & Baddeley, 1988), or may be prompted by an event-cue (e.g., remembering to take a roast out of the oven in response to the oven timer) (Einstein & McDaniel, 1990; Harris & Wilkens, 1982; Kvavilashvili, 1992). McDaniel and Einstein's (2000) multiprocess theory posits that the strategic encoding, monitoring, and retrieval demands of a given PM task will likely vary by these characteristics of the target cue. Thus, in most studies, event-based tasks have been found to be easier for individuals to perform, most likely because time-based tasks require the person to perform more self-initiated monitoring and retrieval in order to bring the intention to mind and check a clock or watch (Glisky, 1996; Park, Morrell, Hertzog, Kidder, & Mayhorn, 1997; Sellen, Louie, Harris, & Wilkins, 1997). PM is hypothesized to place more demands on self-initiated monitoring and retrieval processes as compared to retrospective memory (RM) (e.g., McDaniel & Einstein, 2007). In fact, PM is dissociable from RM at the neural (e.g., Simons, Scholvinck, Gilbert, Frith, & Burgess, 2006), cognitive (e.g., Salthouse, Berish, & Siedlecki, 2004), and functional (e.g., Woods, Moran, Carey, Iudicello, Gibson, Atkinson, and the HNRC Group, 2008) levels.

PM is presumed to encompass a variety of cognitive processes (e.g., Smith & Bayen, 2004). This includes the formation of the intention, strategic monitoring during the retention interval, recognition of the external cue, and an effortful and controlled search for retrospective recall, otherwise referred to as self-initiated retrieval. Finally, the actual recall and execution of the intention occurs and the PM task is (or is not) completed successfully. Thus, all measures of PM have a delay between the encoding and retrieval of the prospective task; there must be no explicit prompt when the occasion to act occurs; and there must be a separate ongoing activity (e.g., Einstein & McDaniel, 1990).

Imaging studies have suggested that PM depends on rostral prefrontal cortex (rPFC) functioning, and, in particular, Brodmann area 10 (Benoit *et al.*, 2011). rPFC has been shown to be engaged during the delay period that occurs between the intention formation and the execution of the intention (Burgess, Gonen-Yaacovi, & Volle, 2011). Brain activation during PM tasks has been distinguished from activation in areas associated with vigilance, dual task performance, and working memory (West, 2008). Not surprisingly, damage to prefrontal regions can significantly impair PM functioning (Okuda, Fujii, Yamadori, Kawashima, Tsukiura, & Fukatsu, 1998; Crews, He, & Hodge, 2007; Sowell, Delis, Stiles, & Jernigan, 2001; Burgess, Alderman, Volle, Benoit, & Gilbert, 2009), and PM impairments have been measured in neurological disorders that are presumed to include dysfunction of prefrontal structures (Raskin, Buckheit, & Waxman, 2011; Raskin, Woods, Poquette, McTaggart, Sethna, Williams, & Troster, 2012; Raskin, Maye, Rogers, Correll, Zamroziewicz, & Kurtz, 2014).

In addition, these frontal structures and associated connections continue to develop past adolescence and may be especially vulnerable to the neurotoxic effects of alcohol during this time (Crews and Boettiger 2009; Jacobus and Tapert 2013), which may put college aged students at particular risk (Dager *et al.*, 2013). Adolescents with alcohol use disorder (AUD) demonstrate smaller prefrontal cortex volumes (Medina, McQueeny, Nagel, Hanson, Schweinsburg, & Tapert, 2008; Thomasius, Petersen, Buchert, Andresen, Zapletalova, Wartberg, Nabeling, & Schmoldt, 2003) and binge drinking in adolescence has been associated with increased prefrontal and parietal blood oxygen level-dependent (BOLD) functional magnetic resonance imaging (fMRI) response but decreased hippocampal BOLD response during verbal learning, perhaps reflecting over-engagement of task-related frontoparietal systems in order to compensate for deficient medial temporal involvement (Schweinsburg, McQueeny, Nagel, Eyler, & Tapert, 2010).

There is evidence that the adolescent hippocampus is also particularly vulnerable to heavy drinking (e.g., Welch, Carson, & Lawrie, 2013), and alcohol effects on the hippocampus could also contribute to retrospective aspects of PM failures. In particular, it has been suggested that alcohol blackouts may be related to alcohol effects on the hippocampus. To our knowledge, the relationship between alcohol-induced amnesia (blackouts) and PM has not been investigated in adolescents or emerging adults, yet blackouts are reported to occur commonly (White, Signer, Kraus, Swartzwelder, 2004). Blackouts do not necessarily follow binge drinking although they are associated with a sudden rise in blood alcohol level (Wechsler, Lee, Kuo, 2002), an effect that has also been shown to disrupt frontal lobe-mediated memory functions (Weissenborn & Duka, 2003) and hippocampal ones (Welch et al., 2013).

In developmental studies, emerging adults (ages 17-20) tend to outperform adolescents (ages 13-16) on PM tasks (Wang, Kliegel, Yang, & Liu, 2006; Ward, Shum, McKinlay, Baker-Tweney, & Wallace, 2005). In particular, tasks high in self-initiated processing and low in environmental support are especially challenging for adolescents (in this study, ages 11-14) (Wang, Liu, Altgassen, Xiong, Akgun, & Kliegel, 2011). This improvement in PM efficiency may be related to the development of controlled behavior in general. Thus, any factors that may influence the maturation of brain functions, such as alcohol consumption, could affect the development of PM in this period of life (Wang *et al.*, 2011).

Alcohol consumption, in fact, is not trivial in this age group. Individuals between the ages of twelve and twenty account for eleven percent of all alcohol consumed in the United States, with 90 percent of alcohol consumption in this age group being characterized as heavy drinking (Centers for Disease Control, 2010). Binge drinking (i.e., five or more drinks for males and four or more drinks for females in a single drinking episode) is especially prevalent in college-aged students, with more than 44 percent of these individuals binge drinking every two weeks and more than 19 percent of these individuals binge drinking more than three times per week (Chen, Dufour, & Yi, 2004).

The relationship between PM performance and alcohol use has been studied most often in adults. Generally, adults with substance use problems report more frequent PM complaints, both in self-report and naturalistic PM daily tasks (Weinborn, Moyle, Bucks, Stritzke, Leighton, & Woods, 2011). In one study heavy alcohol users reported 31.2 percent more problems with long-term PM than non-drinkers and 23.7 percent more problems than individuals who report drinking small amounts of alcohol (Ling, Heffernan, Buchanan, Rodgers, Scholey, & Parrott, 2003). Heavy drinkers with a diagnosis of alcohol dependence have been found to perform more poorly on measures of event-based PM when compared to social drinkers (Griffiths, Hill, Morgan, Rendell, Karimi, Wanagaratne, & Curran, 2012), and time-based PM when compared to matched control participants (Platt, Kamboj, Italiano, Rendell & Curran, 2016). Binge drinkers have been reported to have deficits in time-based PM on the Cambridge Prospective Memory Test (CAMPROMT) (Heffernan & O'Neil, 2012).

In studies of younger subjects, self-report findings have been mixed. One recent study found that short-term binge drinking participants ages 17-19 did not self-report more PM lapses than those who did not binge drink (Heffernan, Clark, Bartholomew, Ling, & Stephens, 2010), but a previous study of binge drinking participants ages 16-19 found that they did (Heffernan, Bartholomew, & Dip, 2006). In a group of emerging adults (mean age 18.7) who were chronic alcohol users and whose alcohol consumption was long-term and heavy, as opposed to the short-term binge drinkers, global impairments in PM were also reported (Heffernan, O'Neill, Ling, Holroyd, Bartholomew, & Betney, 2006).

In studies that have used a standardized clinical measure of PM (Memory for Intentions Screening Test; Raskin, 2009), rather than self-report, substance use was associated with poorer performance in adults (Weinborn, Woods, O'Toole, Kellogg, & Moyle, 2011) and emerging adults (ages 16-18) (Winward, Hanson, Bekman, Tapert, & Brown, 2014). In particular, participants who reported higher levels of alcohol consumption had more difficulties with the time-based tasks and made more omission errors as well as task substitutions (Weinborn et al., 2011). Performance on the time-based items of the MIST also predicted risk-taking behaviors in both adults with substance use disorder and college-aged drinkers (Weinborn, Moyle, Bucks, Stritzke, Leighton, & Woods, 2013).

Although studies have examined how excessive alcohol consumption in college-aged students affects PM performance, more examination of this issue is necessary. Most studies have relied upon self-reports of PM, the accuracy of which is not known. Additionally, there are limited comparisons of PM between different cohorts, including non-drinkers, low to moderate drinkers, and heavy drinkers, in studies using college-aged samples.

The primary aim of this study is to determine the effects of drinking behavior on PM functioning in college students. More specifically, the aims are to determine if heavy drinking, including binge drinking, has an effect on either time- or event-based PM and to determine if frequency of blackouts has a relationship with time- or event-based PM.

## Methods

### a. Participants

Participants were 123 third and fourth year undergraduate college students between the ages of 19 and 23 years (M=20.42 ± 0.92 years). All attended a small liberal arts college, and were originally recruited to participate in a larger NIAAA-funded study BARCS (Brain and Alcohol Research in College Students) (Dager *et al.*, 2013). Initial recruiting was accomplished via school email, flyers, and classroom visits. Exclusion criteria included history of central neurological disorders, head injury accompanied by loss of consciousness of over 1 hour, or concussion within 30 days of participation. Each participant was individually consented with IRB approved consent forms and assigned a randomly generated ID number to protect their identity. Demographic information collected from participants is presented in Table 1.

### b. Measures

**i. Alcohol Use Assessment—**BARCS participants received via email a link to a series of secure monthly online questionnaires. Included in these were the Modified Timeline Follow-back (TFLB) (Sobell, Maisto, Sobell, & Cooper, 1979), Self-Rating Effects of Alcohol (SREA) (Schuckit, Tiff, Smith, Wies-Beck, & Kalmtin, 1997), Brief Young Adult Alcohol Consequences Scale (BYAAS) (Kahler, Hustad, Barnett, Strong, & Borsari, 2008) and Alcohol Effects Questionnaire (AEQ) (Rohsenow, 1983). For the current study, data were averaged for each questionnaire completed monthly during the six months immediately preceding memory testing.

The primary variables of interest acquired from these measures were frequency of alcohol consumption, frequency of binge drinking, the number of times the person experienced an alcohol-related blackout (using the scale from the BYAACS as follows: 1 = Never; 2 = 1-2 times; 3 = 3-5 times; 4 = More than 5 times), and the maximum number of drinks consumed in one sitting. Current and past Diagnostic and Statistical Manual (DSM-IV-TR) diagnoses for psychotic, anxiety, mood, and substance use disorders were ascertained using the Mini-International Neuropsychiatric Interview (MINI) (Sheehan, Lecrubier, Sheehan, Amorim, Janavs, Weiller, Hergueta, Baker, & Dunbar, 1998). Data on frequencies of diagnoses from the MINI are presented in Table 2. Data on use of other substances is presented in Table 3.

**ii. PM Assessment—**PM tasks were embedded within the BARCS testing session. The time-based measure occurred during the self-assessment alcohol use online survey of the BARCS testing session. At the start of the survey, participants were asked to record the current survey question on a colored sheet of paper in their testing packet after fifteen minutes of working on the survey. In order to establish salience for this task, participants were told that the experimenter was tracking the timing of the survey to ensure that it was not excessive in length. The ongoing task was determined to be a sufficiently distracting as it sought detailed information about life stress, mood, as well as alcohol and drug use. Thus, the time-based PM task was to record the current survey question, the time delay was fifteen minutes, and the ongoing task was a self-assessment online survey.

The event-based measure was also administered during the BARCS testing session, in this case during the computer-administered Java Neuropsychological Test (JANET) (http://janet.glahngroup.org). At the start of the computerized task, participants were instructed to hand the "cash voucher" located in their testing packet to the experimenter as soon as they had completed the computerized task. Salience was attached to this task by having the experimenter explain to participants that in order to be compensated for their participation in the study, they needed to turn in the "cash voucher." The ongoing task, which measured perceptual motor speed, incidental learning, executive function, and impulsivity, was determined to be a sufficiently demanding ongoing task. Thus, the event-based PM task was to hand the "cash voucher" to the experimenter, the time delay was the amount of time that it took the participant to complete the JANET task (typically ten to fifteen minutes) and the ongoing task was the JANET, a computerized test of cognition.

Items were scored as either zero or one. For the time-based task, no implementation of the PM task, incorrect implementation of the task, or correct implementation of the task at the incorrect time was scored as zero and the correct implementation of the PM task was scored as one. For the event-based task, no implementation of the PM task or incorrect implementation of the task was scored as zero and correct implementation of the task in response to the appropriate cue was scored as one. Although neither PM task has been used in previous studies, both are modeled after the types of tasks that are in the Memory for Intentions Test (MIST; Raskin et al., 2010). As this was part of a larger study (BARCS) it was not possible to include a test the length of the MIST. A series of pilot studies were performed to create tasks at a level of difficulty that avoided either ceiling or floor effects, though no formal validation study was undertaken.

**iii. Retrospective Recognition Memory Assessment—**Participants were also asked to complete a brief retrospective recognition questionnaire. Through two multiple-choice questions, participants were asked to identify the correct PM tasks that they had been instructed to complete. These were included to be sure that participants had understood and encoded the task instructions successfully. Correct responses were scored as one and incorrect responses were scored as zero.

**iv. Defining Alcohol Groups—**Participants were divided into three alcohol consumption categories based on responses to the TLFB, AEQ and SREA and the AUD diagnosis based on published criteria (Dager *et al.*, 2013). Non-drinkers were those who reported they had never consumed alcohol. Light drinkers (1) did not meet current or past criteria for an AUD and (2) drank <50 % of the weeks during the preceding 6 months as determined from the average of surveys received during the six months immediately preceding the memory testing session. Heavy drinkers either (1) met criteria for a current AUD or (2) drank ≥50 %

of the weeks in the preceding 6 months and binge drank for more than half of the number of drinking incidents reported.

Descriptive findings related to the drinking behavior of each of these groups are presented in Table 4 along with a series of one-way analyses of variance (ANOVAs) with Tukey Honest Significant Difference (HSD) post hoc mean difference scores that demonstrate the differences between the groups on self-report measures of drinking behavior. A scatterplot of the blackout data is presented in Figure 1.

### c. Analyses

Chi Square Goodness of Fit Tests were used to compare the groups on the prospective memory and retrospective memory measures. A correlational analysis was used to examine the relationship between number of blackouts in the past month and PM performance.

## III. Results

### Demographic Differences among Drinking Groups

A Chi Square Goodness of Fit Test revealed significant differences in gender distribution across groups ($\chi^2$ (2) = 6.65; p = 0.036). Post-hoc Bonferroni Confidence Intervals (family $\alpha$ level= 0.05) indicated that significantly fewer females (20%) than males (40%) were categorized as heavy drinkers, (see Table 1). There were no significant differences in ethnic distribution, racial distribution or age across groups.

### PM and RM Performance on Time-Based and Event-Based Tasks

Chi Square Goodness of Fit Tests revealed that participants performed significantly better overall on the time-based than event-based tasks of PM ($\chi^2$ (1) = 17.472; p<0.01). Performance on RM tasks did not differ between time-based and event-based cues ($\chi^2$ (1)=0.23; p>0.05).

### Influence of Sex on PM and RM Performance

There was no sex performance difference either on the PM time-based task (male mean=0.74, s.d.=0.44) (female mean=0.75, s.d.=0.44) (F(1,121)=.023, p=0.88) or on the PM event-based task (male mean=0.50, s.d.= 0.06) (female mean=0.49, s.d.=0.50) (F(1,121)=.009, p=.92).

### Drinking Patterns and PM and RM Performance

A Chi Square Test of Independence was conducted to evaluate the difference among the three drinking groups on their performance on the PM tasks (time-based, event-based). The between-group difference was significant $\chi^2$ (2, N=123) = 12.06, *p<01* for the time-based tasks with a moderate effect size (*d* = 0.65), but not for the event-based tasks $\chi^2$ (2, N=123) = 0.58, n.s. (see Table 5).

Follow-up pairwise comparisons were conducted for the time-based task to determine which groups differed significantly from each other, using the Bonferroni approach to control for

Type I error (overall Family $\alpha$=0.05). Compared to heavy drinkers a higher proportion of non-drinkers scored correctly on the time-based PM task.

Comparisons of performance on time-based events by drinking behavior reveals non-drinkers had a higher proportion of correct responses than heavy drinkers (see Table 5). Table 6 provides the Chi Square and significance values.

There were no significant differences between the three groups on either of the RM tasks (time: $\chi^2$ (2, N=123) = 5.16, p=0.08; event: $\chi^2$ (2, N =123) = 2.10, p=.35) (see Table 7).

### Influence of Alcohol Incidents (Blackouts)

Pearson bivariate correlation revealed a significant relationship between number of blackouts in the preceding month and performance on the event-based PM task (r (112) = 0.21 p<05), but not the time-based PM task (r (112) = 0.13; p> 0.05). Figure 1 shows the relationship between numbers of blackouts and score on the event-based task. There was no significant relationship between either of the RM tasks and blackouts (time: r (112) = 0.10; p=.92 and event: r (112) = 0.25; p =.81).

## Discussion

This study aimed to compare PM performance among college-aged individuals with different drinking patterns. Although previous research has examined PM and alcohol consumption in this population, most PM measures have been self-report and have not compared different drinking patterns. The PM performance measures implemented in the present study included both a time-based and an event-based task. Overall, participants performed better on the time-based than the event-based PM tasks. Different indicators of drinking behavior had differential effects on PM performance. Heavy drinking was specifically related to the greatest impairment in time-based PM performance. Blackouts were specifically related to event-based PM performance.

An unexpected finding was that participants overall performed better on the time- than the event-based PM tasks. Most previous examinations of performance-based PM have reported better performance on event-based than time-based tasks (Raskin, 2009). In fact, surprisingly, alcohol consumption has been linked to superior performance on an event-based PM task without effects on a time-based PM task (Arana, Blanco, Meilan, Perez, Carro, & Gordillo, 2011). The difficulty of time-based tasks may reflect that participants are expected to self-initiate a response at a specific time in the absence of other cues (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Presumably, the healthy young adult sample in the current study did not have difficulty with time monitoring during the time-based task. It is possible that, given their tight schedules as college students, they are in the habit of monitoring time. More likely, because the two PM measures utilized different ongoing tasks, the attention demands of the ongoing task during the event-based trial may have made it particularly challenging. The ongoing task during the event-based trial was a series of cognitive assessments that, by their nature, require considerable attention. The ongoing time-based task was a self-report survey from which it may have been easier to disengage.

RM scores were consistently high, indicating that the PM measures in this study were properly encoded, and that the appropriate degree of PM "intentionality" was achieved (Burgess, Quayle, & Frith, 2001). The processes underlying this retrospective component of PM are not fully developed in adolescence, but performance falls in older adulthood (Zollig, West, Martin, Altgassen, Lemke, & Kliegel, 2007). Thus, the high level of retrospective performance by the emerging adults in the present study suggests that this age group may be more efficient in the retrospective aspect of PM than the prospective aspect. However, these tasks were quite simple with only a single RM task to be recalled at one time. Thus, tasks with a greater RM load may prove more challenging for this age group.

Drinking behavior was related to time- but not event-based PM. Specifically, drinking was related to impaired time-based PM performance and impairment was greater for heavier drinkers in a dose-dependent manner. This is consistent with previous findings using the CAMPROMT (Heffernan & O'Neil, 2012) and the MIST (Weinborn et al., 2013; Winward et al., 2014). Because the time-based tasks may be more heavily dependent on PFC structures, it may be that they are more sensitive to alcohol effects. These impairments have also been related to inefficient self-initiation, which may result in difficulties with detection of appropriate cues (Griffiths, Hill, Morgan, Rendell, Karimi, Wanagaratne, & Curran, 2012). This suggests that PM may be a useful avenue to explore in attempts to understand the relationship among impulsivity and initiation of alcohol abuse.

In general, our findings are consistent with other studies that have demonstrated that social drinkers tend to be less impaired than heavy drinkers on PM measures. Alcohol users who consume excessively show more errors on long-term, short-term, and internally cued PM on the PM Questionnaire (PMQ), a self-report measure of PM (Heffernan & Bartholomew, 2006) and heavy users have been found to be 30 percent more likely to report compromised PM abilities (Arana *et al.*, 2011; Ling *et al.*, 2003). Beyond this dose-dependent effect, chronic alcoholism appears to be associated with greater cognitive impairment than sporadic heavy alcohol consumption although irregular alcohol consumption can be enough to provoke some degree of cognitive impairment (Sanhueza, Garcia-Morena, & Exposito, 2011).

We also found that alcohol-related blackouts were related to event- but not to time-based PM. Blackouts are associated with a rapid rise in blood alcohol and some researchers have theorized that they are due to impaired memory consolidation (Rose & Grant, 2010). It has long been presumed that PM requires adequate hippocampal activity in addition to that of PFC (Poppenk, Moscovitch, McIntosh, Ozcelik, & Craik, 2010) but that the role of the hippocampus is in remembering the content of the task to be remembered whereas PFC is involved in remembering to remember (e.g., Umeda, Nagumo, & Kato, 2006). Because event-based tasks have more content to be remembered (i.e., both the cue and the intention) it is possible that reduced hippocampal functioning could selectively affect these items.

Numerous studies have uncovered deficits in time- but not event-based PM. To our knowledge no prior study has yielded a dissociation in which varied aspects of alcohol use affect time-based PM and event-based PM differentially. There is some evidence to suggest that time and event-based PM are mediated by separate brain networks. For example, in one study while both event- and time-based PM induced activation in the posterior frontal and parietal cortices, and deactivation in the medial rostral prefrontal cortex, there was activation specific to each condition (Gonneaud, Rauchs, Groussard, Landeau, Mezenge, de La Sayette, Eustache, & Desgranges, 2013). Occipital areas were more activated during event-based PM, while a network comprising the dorsolateral prefrontal cortex, the cuneus/precuneus and, to a lesser extent, the inferior parietal lobule, superior temporal gyrus, and the cerebellum, was more activated in time-based PM. Zollig, West, Martin, Altgassen, Lemke, & Kliegel (2007) suggested that occipital activation in event-based tasks reflected target checking or cue detection while the regions activated in the time-based tasks reflected time-estimation and monitoring.

### Implications

The present study is limited by the nature of the PM measures. It is likely that the ongoing tasks were not of equal difficulty and thus comparisons between the tasks are difficult to interpret. In addition, only simple performance measures were used and these tasks were limited to a single time-based item and a single event-based item, both of which were binary, limiting the range of data collected. Future studies might investigate this question with standardized measures like the MIST, laboratory measures or self-report measures in conjunction with each other.

The present study found that alcohol consumption patterns differentially affected time-based PM performance in a sample of college students. A linear model of alcohol consumption and PM performance in this age group developed by Arana and colleagues (2011) revealed that while the first and second predictors of PM performance were the self-reported quantity of alcohol use, the third predictor was number of years since first alcohol use. Additionally, a link between hippocampal volume and age of first alcohol use has been reported (Casey & Jones, 2010). Certainly, lifetime history of alcohol use needs to be taken into consideration when extrapolating on cognitive repercussions of alcohol consumption.

Future work implementing both performance and self-report measures of PM may be useful to verify that the findings of based on PM performance measures can be extrapolated to daily functioning. Additionally, further examination of the structural and functional underpinnings of PM at this age may help reveal mechanisms of this possible cognitive resilience.

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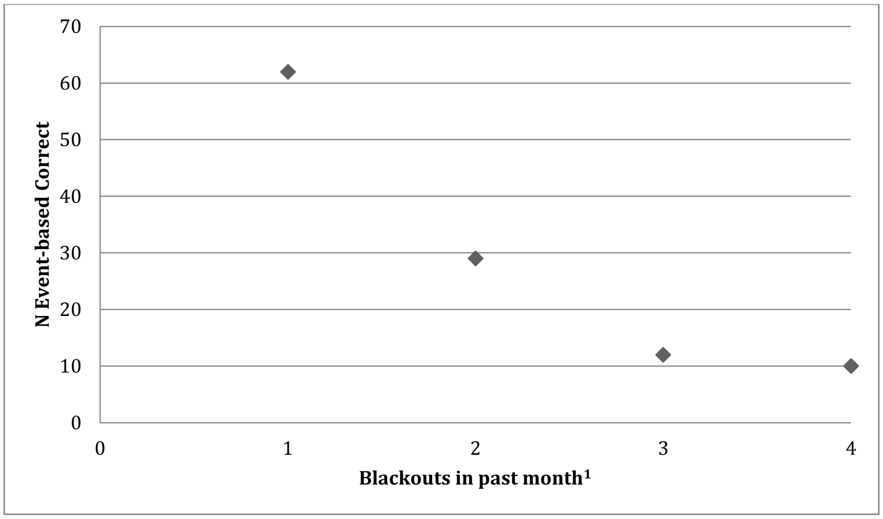


**Figure 1. Number of individuals with correct responses on the event-based task by blackouts**
[1]Blackouts 1=never; 2=1-2 times; 3=3-4 times; 4=5 or more

## Table 1

**Demographic information by group membership**

| | | Non Drinker | Light Drinker | Heavy Drinker | $\chi^2$ | *Cramer's V* |
|---|---|---|---|---|---|---|
| Sex | Female | 23 | 30 | 13 | 6.65* | 0.480 |
| | Male | 17 | 17 | 23 | | |
| Ethnicity | Non-Hispanic/Latino | 20 | 58 | 32 | 2.71 | 0.198 |
| | Hispanic/Latino | 3 | 9 | 1 | | |
| Race | Caucasian | 28 | 30 | 24 | 4.76 | 0.177 |
| | African American | 4 | 10 | 2 | | |
| | Asian | 6 | 10 | 4 | | |
| | Other | 2 | 2 | 1 | | |

* $p<.01$

**Table 2**

**Frequencies of diagnoses from the Mini International Neuropsychiatric Interview (MINI)**

| | Non-drinker | Light Drinker | Heavy Drinker | $\chi^2$ | Cramer's V |
|---|---|---|---|---|---|
| Alcohol Dependence | 0 | 6 | 11 | 9.16** | 0.31 |
| Alcohol Abuse | 0 | 0 | 8 | 13.64** | 0.42 |
| Substance Use Disorder | 0 | 2 | 4 | 0.98 | 0.12 |
| Mood Disorder | 3 | 5 | 2 | .686 | 0.10 |
| Anxiety Disorder | 0 | 0 | 0 | n/a | n/a |
| Psychotic Disorder or Anti-Social Personality Disorder | 3 | 4 | 2 | 0.84 | 0.17 |

** $p<.001$

## Table 3

**Number of days of use of other substances in the past month (1=never; 2=1-2; 3=3-5; 4=6-9; 5=10-14; 6=20 or more)**

| | Range (days) | N of students reporting use | | |
|---|---|---|---|---|
| | | Non Drinker | Light Drinker | Heavy Drinker |
| Marijuana | 1-6 | 1 | 8 | 11 |
| Cocaine, crack | 1-2 | 0 | 1 | 0 |
| LSD[1] | n/a | 0 | 0 | 0 |
| Other hallucinogen | 1-2 | 0 | 1 | 1 |
| 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 | 1-2 | 0 | 1 | 1 |
| PCP[2] | n/a | 0 | 0 | 0 |
| GHB[3] | n/a | 0 | 0 | 0 |
| Sleeping medication | 1-2 | 0 | 0 | 0 |
| Sedative/Anxiety medication | 1-3 | 0 | 2 | 1 |
| Stimulant medication | 1-2 | 0 | 2 | 1 |
| Steroid | n/a | 0 | 0 | 0 |
| Cough medicine | n/a | 0 | 0 | 0 |
| Pain Medicine | 1-2 | 0 | 1 | 0 |

[1] Lysergic acid diethylamide

[2] Phencyclidine

[3] Gamma-Hydroxybutyric acid

## Table 4

**Means (standard deviations) and ranges, overall one-way ANOVAs, pair-wise comparisons (Tukey HSD), and effect sizes for drinking behavior of the three groups**

| | Non Drinker *M (SD)* | Light Drinker *M (SD)* | Heavy Drinker *M (SD)* | Non Drinker-Light Drinker | Non Drinker-Heavy Drinker | Light Drinker-Heavy Drinker | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| On how many days did you have a drink of alcohol in the past 30 days? | 0.00 (0.00) 0-0 | 4.57 (3.91) 0-15 | 5.27 (4.89) 0-20 | 4.50** | 5.27** | 0.77 | 0.23 |
| One how many days did you engage in heavy drinking (4 or more drinks for females and 5 or more drinks for males) in the last 30 days? | 0.00 (0.00) 0-0 | 3.04 (3.00) 0-12 | 5.77 (5.12) 0-20 | 3.04* | 5.77** | 2.73* | 0.27 |
| Number of blackouts experienced in the last 30 days (1=never; 2=1-2 times; 3=3-4 times; 4=5 or more times) | 1.00 (0.00) 1-1 | 1.72 (0.87) 1-4 | 2.25 (1.00) 1-4 | 0.78**b | 1.26** | 0.48* | 0.29 |
| What is the largest number of drinks containing alcohol that you have consumed in a 24-hour period at any time in your life? [1 drink= one 12-oz. beer, one 5-oz. glass of wine, one 12-oz. wine cooler, or 1 oz. of liquor. | 0.00 (0.00) 0-0 | 5.68 (5.02) 0-20 | 8.00 (6.29) 0-20 | 5.56** | 8.00** | 2.43+ | 0.27 |

+ $p<.05$;

* $p<01$;

** $p<.001$

## Table 5

Performance of the three groups on the PM tasks.

| Time-Based Task | Non Drinker | Light Drinker | Heavy Drinker | $\chi^2$ | *Cramer's V* |
|---|---|---|---|---|---|
| Correct | 36 | 36 | 20 | 12.06* | 0.313 |
| Incorrect | 4 | 11 | 16 | | |
| Percent Correct | 90.0 | 77.0 | 55.6 | | |
| Event-Based Task | | | | | |
| Correct | 18 | 25 | 18 | 0.58 | 0.069 |
| Incorrect | 22 | 22 | 18 | | |
| Percent Correct | 45.0 | 53.2 | 50.0 | | |

* $p<.01$

**Table 6**

**Chi-Square and p-values for the comparisons between groups on the time-based PM task**

| | Pearson Chi-Square | df | p-value |
|---|---|---|---|
| Non-drinkers vs Light drinkers | 2.721 | 1 | .099 |
| Light drinkers vs Heavy drinkers | 4.112 | 1 | .043 |
| Non-drinkers vs Heavy drinkers | 11.593 | 1 | .001 |

**Table 7**

Performance of the groups on the RM tasks.

| Time-based Task | Non Drinker | Light Drinker | Heavy Drinker | $\chi^2$ | *Cramer's* |
|---|---|---|---|---|---|
| Correct | 33 | 39 | 23 | 5.16 | 0.205 |
| Incorrect | 7 | 8 | 13 | | |
| Percent Correct | 82.5 | 82.9 | 63.8 | | |
| Event-based Task | | | | | |
| Correct | 34 | 36 | 27 | 2.10 | 0.131 |
| Incorrect | 5 | 11 | 9 | | |
| Percent Correct | 87.2 | 76.6 | 75 | | |