

# Hangover Predicts Residual Alcohol Effects on Psychomotor Vigilance the Morning After Intoxication

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## Abstract

**Objectives:** Both hangover and performance deficits have been documented the day after drinking to intoxication after breath alcohol concentration (BrAC) has returned to near zero. But few studies have examined the relationship between hangover and post-intoxication performance.

**Method:** We performed secondary analyses of data from a previously reported controlled cross-over laboratory study to assess the relationship of hangover incidence and severity to sustained attention/reaction time the morning after drinking to about 0.11 g% BrAC. Relationships were investigated while controlling for gender, type of alcoholic beverage (bourbon or vodka), and neurocognitive performance after placebo.

**Results:** Hangover severity and neurocognitive performance were significantly correlated. Participants reporting stronger hangover were more impaired than those reporting little or no hangover. Comparing any to no hangover showed a trend in the same direction of effect.

**Conclusions:** More intense hangover may indicate less fitness for duty in workers in certain safety-sensitive occupations, with implications for occupational alcohol policies.

**Keywords:** Hangover; Residual alcohol effects; Sustained attention; Reaction time; Vigilance

## Introduction

“Residual effects of intoxication” refers to any subjective, physiological, and/or behavioral effects of heavy drinking once breath alcohol concentration (BrAC) has returned to zero. Hangover is most accurately defined by symptoms including headache, nausea, and fatigue [34]. We use the term “hangover” to refer to the cluster of symptoms and “residual effects of alcohol” as a broader term covering neurocognitive and occupational impairment in the absence of blood alcohol the morning after intoxication. The causes of hangover are unknown, although several review articles discuss a number of hypotheses [31,48,40]. Some portion (25-30%) of the population appears to be hangover resistant across a variety of laboratory, clinical and survey investigations [15,16]. Little is known, however, about predictors or consequences of resistance to hangover. Hangover resistance was unrelated to gender, age, family history, or average daily volume among heavy drinkers [15].

Although findings are mixed, the residual effects of alcohol can result in occupational and neurocognitive performance impairment the next day [38,32]. Residual effects have been found on simulated industrial work tasks [49] driving-related skills and driving [37,19,45] and simulated aircraft piloting [25,26,27,30,42,43,51,50] other studies, however, did not find occupational performance effects [10,7,8,14,33,39]. Using neurocognitive tasks, adverse effects were found for codification and identification tasks [28] immediate and delayed (1h) free recall [46] visual, memory and intellectual processing [17,24] time-reaction error in a go-no-go task [1] sustained attention/reaction time [12] and choice reaction time [24,18], although negative results were found for some neurocognitive measures [11,20,22,46]. In several studies, BrAC was still around .04 g% when tested [e.g., 45], leading to a confound. When ensuring that BrAC was zero and comparing multiple tasks, we found the strongest effects for tests requiring both sustained attention and speed [14,35].

The present study investigates whether hangover severity or incidence is associated with the residual effects of alcohol in terms of neurocognitive performance. Two previous studies investigated the relationship of hangover severity to performance. One study found no association between hangover (using a measure of unknown reliability or validity) and psychomotor performance, as measured by choice reaction time, motor coordination, and attention [37]. The other, described below, found that hangover severity (measured on a validated scale) correlated with sustained attention/reaction time (univariate correlation), suggesting that hangover symptoms might contribute to impairment the day after intoxication [35]. Neither of these studies, however, controlled for factors that might also be associated with neurocognitive performance or asked whether absence of hangover meant absence of residual effects on performance.

We used data from the aforementioned randomized cross-over study [35] to determine if hangover severity or incidence were associated with impaired neurocognitive performance the morning after alcohol administration to a mean BrAC of 0.11 g%. Our previous studies have shown strong effects of intoxication on next-day sustained attention/reaction time in a psychomotor vigilance task [35,14], so this performance measure was selected for analysis. We

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previously reported the simple correlation of hangover severity and sustained attention/reaction time the day after intoxication [35]. Herein, we expanded that analysis and hypothesized that hangover incidence and severity would correlate with the neurocognitive performance scores in the morning, when controlling for other variables that could affect next-day performance scores, such as gender, type of alcoholic beverage (bourbon versus vodka), and baseline (placebo condition) neurocognitive performance.

## Methods

Procedures were approved by the Institutional Review Boards at Boston University Medical Center, Brown University, and the University of Michigan.

### Participants

Participants were 95 university students or graduates recruited in greater Boston. They were 21 to 33 years of age and met the following criteria: (1) no serious drinking problems (score < 5 on the Short Michigan Alcohol Screening Test [SMAST]) [36] or self-reported history of treatment for chronic alcohol problems; (2)  $\geq 5$  drinks on a single occasion ( $\geq 4$  if female) at least once 30 days prior to screening; (3) no health problems or current medication use contraindicated for alcohol; (4) fluent English; (5) currently attending, or recently graduated from, an institution of higher learning; and (6) negative pregnancy test and not nursing, if female. Females were not screened for menstrual cycle [44,29,3]. There were no significant differences in background characteristics by beverage type administered and genders did not differ significantly in quantity or frequency of typical drinking.

### Study design

The study used a double-blind within-subjects, crossover 2 X 2 X 2 design: alcohol content (alcohol vs. placebo) by order (alcohol on Day 1 vs. alcohol on Day 2) by high or low congener content (bourbon vs. vodka in the alcohol condition). Alcohol content was the within-subjects factor; congener and order were between-groups factors.

### Procedures

**Screening and pre-experimental preparation:** Participants responding to advertisements were screened including a physician examination. To reduce potential confounding by sleep pattern variations, participants were instructed to keep a sleep diary, wear an activity monitor, comply with a minimum regimen of 8 hours time in bed, retiring to bed no later than midnight, with confirmation call-ins to a time-stamped answering machine each evening and morning and, no napping for the three days prior to experimental sessions. Participants were required to abstain from alcohol, recreational drugs, sleep aids, and caffeine for 24-hours prior and food/beverages for 3 hours prior to their evening sessions. Individuals who failed to comply were rescheduled; those presenting with a positive BrAC were excluded from further participation.

**Session procedures and randomization:** Participants returned in groups of three to five for the first of three overnight experimental sessions one week after screening and informed consent. The first night was for sleep screening and acclimatization to polysomnography procedures and the other two were the experimental drinking sessions (a week apart). Participants were accurately told they would receive alcohol one night and placebo the other night, with a 50-50 chance of receiving alcohol the first night. Each night they reported at 4:00 p.m., compliance with pre-

laboratory regimens was checked, and they had a standardized dinner prior to randomization to beverage condition. Following the beverage administration from 8:30-10:00 p.m., BrAC tests were conducted periodically. At 11 p.m., participants had snacks and lights were turned out for an 8-hour opportunity to sleep. A licensed emergency medical technician observed participants throughout the night.

Participants were awakened each morning at 7:00 a.m. They completed the hangover measure, ate breakfast (no coffee), and were breath-tested. Between 8:00 and 8:30 a.m. they completed the neurocognitive test followed by other measures not reported here (start time delayed if BrAC > .01 until below that). Allowing an hour after waking avoids confounding by sleep inertia [41].

**Beverage administration:** Alcoholic beverage administration was designed to attain 10 g%, since this level is required for reliable hangover induction [4]. Total beverage volume was determined by dosing tables with the amount of beverage adjusted by gender per [13] and by weight (1.2 g/kg for men, 1.1 g/kg for women). Participants were breath-tested 15 minutes after completing two thirds of their portions. The ratio of actual to target BrAC was used to determine the additional amount of beverage administered for those below target. To enhance blinding, some placebo participants also received extra non-alcoholic beverage. The individual who prepared beverages and conducted breath tests had no other contact with participants; all other study assistants working directly with participants were blinded to participants' beverage assignments.

The alcoholic beverages were bourbon (101 proof Wild Turkey®, Austin Nichols Distilling Co., Lawrenceburg, KY) or 100 proof vodka (Absolut®, V&S Vin & Spirit, AB, Stockholm, Sweden), mixed with chilled caffeine-free cola (Coke®, The Coca Cola Co., Atlanta, GA), with a ratio of 1 part vodka or bourbon to 4 parts cola. The placebo for both of these beverages was chilled caffeine-free cola, in an amount equivalent to the alcoholic beverage, with a few drops of vodka or bourbon floated on top, designed to mask beverage color differences and taste. Participants received \$450.

### Measures

**Individual difference and screening measures:** Questionnaires assessed demographics and exclusionary criteria. Urine pregnancy tests used over-the-counter test cups. BrAC was assessed using Intoximeters' Alco-Sensor IV (Intoximeters, Inc., St. Louis, MO) automated handheld breath alcohol instrument. Recent drinking practices were assessed by asking: 1) "Considering all your drinking times in the past 30 days, about how often did you have any beer, wine or liquor?", rated from 1 "once a day" to 7 "did not drink" with each point anchored; and, 2) "In the past 30 days, on a typical day that you drank, about how much did you have to drink in one day?", rated from 1 to 8, with choices of 1 to 7 drinks and "8 or more drinks"; those choosing the latter were asked to give a number. One drink was defined as 12 oz of beer or wine cooler, 4 oz of wine or 1 oz of liquor. Average daily volume (ADV) was the product of these responses.

**Hangover:** Hangover severity was the mean score from the nine-item valid and reliable Acute Hangover Scale (AHS), with each symptom rated on an 8-point scale ranging from 0 (none) to 7 (incapacitating) [34]. Hangover incidence was defined as rating the first item, "hangover", as zero (none) vs. any other rating on the 8-point scale.

**Sustained attention/reaction time:** The handheld Psychomotor Vigilance Task (PVT; Ambulatory Monitoring, Inc, Ardsley, NY) [9] measured sustained attention/reaction time. Participants pressed a button with their preferred hand as quickly as possible in response to numbers scrolling on the screen, with a random 3-7 second inter-stimulus interval. Median reaction time in msec was scored.

**Data analyses:** The relationship of PVT scores the morning after alcohol administration to hangover incidence was investigated with multiple regression (least squares approach), with the single hangover rating coded as “yes” versus “no” as the predictor variable and entering gender, beverage type (bourbon versus vodka), average daily alcohol volume, and baseline PVT score under placebo condition as covariates. (PVT score under placebo condition was included to control for differences in participants’ attention/reaction time in the absence of alcohol.) The regression was repeated for severity of hangover symptoms by changing the predictor variable to AHS total score. Since the square semi-partial coefficient ( $sr^2$ ) indicated the percentage of variance for each variable when adjusted for all other variables, these also can be used to indicate effect sizes, with 2% of variance being small and 14% being medium [6].  $R^2$  is reported for each of the regression models.

## Results

Participant characteristics are shown in Table 1. The range for peak BrAC was .09 to .15 g%. In the alcohol condition, 21% reported no hangover (rating = 0 on the hangover question); 45% rated their hangover as mild (rating = 1-2); 34% as moderate (rating = 3-5); and none as severe (rating 6-7). As previously reported [35], mean of the median reaction time was significantly longer the day after alcohol relative to placebo ( $M = 229.8$  mls  $\pm 30.9$ ) versus 220.8 ms  $\pm 24.5$ ).

Mean (SD) or N (%)	
Male	37 (39%)
Age	24.5 (2.8)
White	79 (83%)
Black	3 (3%)
Asian	4 (4%)
Other or mixed race	9 (10%)
Number of drinks on a typical day	3.4 (1.5)
Maximum BrAC	0.11 (0.01)

BrAC = breath alcohol concentration, in g%  
N = 95

**Table 1:** Participant Characteristics and Within-Session Breath Alcohol Concentration.

Predictor	Beta	$sr^2$	F(1,89)
<b>Regression of hangover intensity (Model <math>r^2 = .66</math>)</b>			
Gender (female)	6.57	0.01	2.80
Bourbon (vs. vodka)	-1.96	0.00	0.24
Average daily alcohol volume	-2.38	0.00	1.05
PVT score, placebo condition	0.95	0.55	145.30***
Alcohol Hangover Scale	7.93	0.05	12.90**
<b>Regression of hangover incidence (Model <math>r^2 = .63</math>)</b>			
Gender (female)	7.07	0.01	2.93
Bourbon (vs. vodka)	2.01	0.00	0.25
Average daily alcohol volume	-2.59	0.00	1.12
PVT score, placebo condition	0.96	0.56	135.16***
Hangover item (yes/no)	9.65	0.02	3.72*

PVT Psychomotor Vigilance Task median reaction time

\* $p = .057$ .

\*\* $p < .001$ .

\*\*\* $p < .0001$

**Table 2:** Regressions of Alcohol Hangover Scale and of Hangover Incidence Predicting PVT Score the Day after Alcohol Administration, Covarying Gender, Beverage Type, Usual Drinking, and Placebo PVT Score.

Hangover Reported	Beverage Condition		
	Placebo Mean <sup>a</sup> (SE)	Alcohol Mean <sup>a</sup> (SE)	Placebo-Adjusted Alcohol Mean <sup>b</sup> (SE)
Yes (n = 75)	220.0 (2.9)	231.1 (3.6)	231.9 (4.4)
No (n = 20)	224.0 (5.6)	225.2 (7.0)	222.2 (2.2)

<sup>a</sup>Means adjusted for covariates (gender, alcohol beverage type, average daily drinking volume).

<sup>b</sup>Means adjusted for same covariates plus PVT score under placebo condition.

**Table 3:** Covariate-adjusted Mean of Median Reaction Time Scores in PVT by Beverage Condition and Hangover Incidence after Alcohol.

In regressions, hangover AHS score was a significant predictor of PVT score after alcohol, controlling for covariates; hangover incidence was borderline significant ( $p = .057$ ) (see Table 2 for details). Hangover incidence accounted for 2% and AHS accounted for 5% of residual variance in PVT score (small effect sizes). To illustrate the direction of effects for the trend for incidence, PVT scores by hangover incidence are shown in Table 3.

## Discussion

These results suggest a relationship between hangover incidence or severity and performance deficits the day after intoxication, although only a small amount of variance was accounted for by these variables. Our study cannot determine whether hangover was causally related to performance impairment. It might be that feeling worse was distracting or used up some cognitive resources, or that using the extra energy needed to engage in cognitive activities increased hangover discomfort. Alternatively, congeners (substances other than ethanol and water) in alcoholic beverages, various metabolites of congeners or alcohol, or alcohol-induced elevation in cytokine production may have a direct effect on the nervous system in addition to increasing hangover; thus, hangover and performance impairment could have been two separate but related residual effects of drinking to intoxication. These are, however, speculations given the absence of more complete knowledge of the etiology of hangover and residual alcohol effects. Our findings indicate that people who are resistant to hangover symptoms in terms of reporting no hangover may also be relatively resistant to residual alcohol effects on performance. The fact that the trend for hangover incidence missed significance may be due to the loss of power inherent in dichotomizing a variable, since people reporting no hangover showed virtually no change in PVT scores after alcohol compared to placebo and since the effects of greater severity are lost.

Many safety-sensitive occupations require that workers be able to pay close attention to a number of tasks over a period of time, and to respond quickly with the right choices (e.g., commercial pilots or monitoring assembly lines). Since the severity of hangover may be a useful indicator of impairment for workers in those safety-sensitive occupations, self-policing is one approach. Such workers should consider that heavy drinking could impair their performance the next morning and be more moderate on the nights before work. However, other policies might be needed for such occupations given that self-policing often is not sufficient. Given the association between intoxication and problems at work [21,2] and the residual alcohol effects on ability to operate aircraft or cars reviewed above, such residual impairment could have serious consequences [47]. The 8-hour “bottle to throttle” regulation for commercial aircraft pilots and air traffic controllers [5] is clearly insufficient as it allows pilots to work when affected by residual alcohol, [50] specifically tasks that require sustained attention with rapid decisions such as traffic avoidance [51]. Policy changes might be needed for safety sensitive occupations.



Limitations of this study include the restricted range of BrACs required for safety reasons, the young age of the participants, and not using measures of occupational performance. It is unclear why our result differed from those to [37] who found no correlation between hangover and psychomotor impairment the day after intoxication. We note, however, that their study was small compared to ours (30 vs. 95 participants) and thus results might have been affected by low statistical power. Nonetheless, these conflicting findings underscore the need for further research to explore the hangover/performance relationship.

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