



Alcohol intoxication alters cognitive skills mediated by frontal and temporal brain regions



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ABSTRACT

Alcohol intoxication affects frontal and temporal brain areas and may functionally impair cognitive processes mediated by these regions. This study examined this hypothesis by testing the effects of alcohol on sustained attention, impulsivity, and verbal memory. Sober and placebo control groups were used to distinguish pharmacological from expectancy effects of alcohol. One hundred nine university students were assigned to an alcohol (low, medium, or high dose), placebo or sober group. Moderate and high doses of alcohol impaired all cognitive measures. A gender effect was revealed in that alcohol impaired sustained attention in males, but not females. Both sustained attention and verbal memory exhibited a U-shaped pattern, in that the medium-dose alcohol group showed the greatest impairment. This study adds to knowledge about the effects of alcohol intoxication on frontally- and temporally-mediated cognitive function. These findings have specific relevance for heavy-drinking undergraduate populations, particularly in light of the fact that repeated alcohol administration produces persistent changes in brain neurocircuitry.

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1. Introduction

Alcohol intoxication is associated with decreased cognitive functioning (Peterson, Rothfleisch, Zelazo, & Pihl, 1990) that may lead to harmful behaviours, such as impaired driving, unprotected sex, and aggression (Naranjo & Bremner, 1993). Alcohol impairs cognitive functions that are mediated by frontal and temporal brain regions (Peterson et al., 1990; Weissenborn & Duka, 2003). For example, alcohol increases impulsivity (de Wit, 2009), impairs attentional processes (Dougherty, Marsh-Richard, Hatzis, Nouvion, & Mathias, 2008), and produces memory deficits (Naranjo & Bremner, 1993), all of which may lead to maladaptive behaviours associated with alcohol intoxication.

Despite this evidence, the effect of alcohol intoxication on these cognitive measures is not consistent across studies. For example, alcohol may or may not impair sustained attention (Koelega, 1995), depending on the dose (Davidson, Camara, & Swift, 1997) and sensitivity of the behavioural measure. At least some of these null findings may reflect low attentional demands of the tasks employed, which make them insensitive to the effects of alcohol (Dougherty et al., 1999). The effect of alcohol on impulsivity also depends on the behavioural measure, in that some tasks are reliably impaired by intoxication (e.g., behavioural inhibition),

whereas other measures, such as delay discounting, fail to show an effect of alcohol (de Wit, 2009). Discrepancies in research studies examining the effects of alcohol on cognition, therefore, may reflect methodological differences. In addition, few studies evaluate dose effects on cognitive processes or include an effective placebo condition that separates the pharmacological from expectancy effects of the drug.

The aim of the current experiment was to examine, in more detail, the effect of alcohol on three distinct measures of frontal and temporal lobe function: impulsivity, sustained attention, and immediate verbal memory. We included both sober and placebo control groups and tested individuals in behavioural tasks following low, medium, or high doses of alcohol. The study employed undergraduate students because this population exhibits patterns of frequent and heavy alcohol consumption that often leads to deleterious social and health consequences (Slutske, 2005).

2. Materials and methods

2.1. Participants

Participants were 109 university undergraduate students (56 male and 53 female) who were recruited using an introductory psychology subject pool as well as print advertisements on campus. During the recruitment process, individuals were informed that they may have to consume alcohol as part of the experiment. To be eligible for participation, students were required to be at

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least 19 years of age (the current legal drinking age in Ontario) and had to report drinking alcohol at least once per month. Exclusion criteria included a previous medical history contraindicating the use of alcohol, allergy to alcohol and/or use of medication that may interact with the effects of alcohol. Due to the deleterious effects of alcohol use during pregnancy, women were only permitted to participate if they were menstruating at the time of testing, or had not had sexual intercourse since their last menstruation. Participants were requested to fast for 3 h prior to testing in order to minimise variability in the rate of alcohol absorption. Participants were compensated with course credit through the introductory psychology subject pool or small cash remuneration (\$10).

2.2. Measures

2.2.1. Manipulation check

To measure the perceived level of alcohol intoxication, participants completed a modified version of the Drug Effects Questionnaire (de Wit, Soderpalm, Nikolayev, & Young, 2003; Ortner, MacDonald, & Olmstead, 2003) after the final drink was consumed. This brief self-report questionnaire asks participants to estimate how much alcohol they have consumed (number of bottles of beer) and, on a scale from 1 to 9, how intoxicated they feel, how much they enjoy how they feel and the extent to which they want more alcohol. This questionnaire served as a manipulation check to assess the effectiveness of the placebo condition.

2.2.2. Continuous performance test

The continuous performance test (CPT) is a measure of sustained attention (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). It is commonly used to identify deficits in attentional capacity, including those seen in pathological conditions such as schizophrenia and attention deficit hyperactivity disorder (Groom et al., 2008). The basic design of a CPT involves presenting participants with a series of stimuli (e.g., coloured dots) and instructing them to respond only to a particular stimulus (e.g., a blue dot) or to one stimulus followed by another (e.g., a blue dot followed by a red dot; Rosvold et al., 1956).

The specific CPT variant used in this study was the Immediate Memory Task (IMT), in which five-digit numbers were serially presented in the middle of a computer screen for 0.5 s with a 0.5 s delay between presentations. Participants were required to click the mouse button when two consecutive numbers were identical (Dougherty, Marsh, & Mathias, 2002). On each trial of the IMT, black digits (2 cm × 3.3 cm each) were presented against a white background and there was an equal probability of target stimuli (identical to the preceding number), catch stimuli (different from the previous number by only one, randomly-positioned digit), and filler stimuli (novel numbers) being presented. Filler stimuli always appeared following target or catch stimuli presentations.

The IMT yields several measures that tap different cognitive processes: correct detections, commission errors, filler errors, discriminability, and signal detection. Correct detection occurs when a participant responds appropriately to the target stimulus, which is a measure of sustained attention (Dougherty et al., 2002). Commission errors occur when a participant responds to 'catch' stimuli, those that are visually similar, but not identical, to the target stimulus. A higher frequency of commission errors is associated with impulsivity (Dougherty, Bjork, Marsh, & Moeller, 2000a).

Discriminability (d') on the IMT is a parametric measure of signal-to-noise that is operationalized as the ratio between commission errors and correct detections, where higher d' values represent better discrimination. Response bias is measured parametrically by beta, which ranges from under responding (high beta) to overly active responding (low beta; Dougherty et al., 2002). Finally, filler errors are responses made to novel stimuli,

which screens for incorrect completion of the task. Filler error rates above 2–3% indicate that a participant may not have understood the task demands.

2.2.3. Verbal learning and memory

The Hopkins Verbal Learning Test (HVLT) is a widely-used measure of verbal learning and memory, involving free recall of words (Brandt, 1991). The task uses a list of 12 words that, although randomly ordered, form three semantic groups. The administrator reads the words at a constant rate with 2 s separating each word and the participant is required to repeat as many words as they can remember, in any order. This process is repeated twice using the same list, each subsequent trial beginning immediately after the participant can no longer identify novel words. Each three-trial test takes approximately 5 min to complete. Participants receive a global score of all correct words identified across the three trials (maximum possible score of 36). Repetitions and intrusion errors are scored as incorrect responses.

2.3. Procedure

The experimental protocol was approved by the General Research Ethics Board (GREB) of Queen's University. All sessions were conducted with participants in singles or pairs between the hours of 1630 h and 2030 h in a laboratory that simulated a comfortable living room environment. Upon arrival, participants completed a questionnaire to verify eligibility and signed a consent form. All participants then were weighed and provided a baseline breath alcohol level (BAL). Blood alcohol concentrations were estimated through BAL using the Intoxilyzer 400D (CMI Inc., Owensboro, KY), a handheld breath alcohol testing instrument. Participants blew air through a mouthpiece into a fuel cell which measured the alcohol concentration in the expired breath. All individuals who participated in pairs were randomly assigned (on the individual level) to one of five beverage consumption groups: sober ($n = 36$); placebo ($n = 22$); or alcohol, which included low ($n = 17$), medium ($n = 16$) and high ($n = 18$) doses. Individuals who participated alone (i.e., the other scheduled participant did not attend) were not administered alcohol to maintain ecological validity because drinking alone occurs rarely (~15%) among university students (O'Hare, 1990). Thus, all single participants were in the sober group; however, not all participants in the sober group were alone. Before receiving their first beverage, participants were informed that they would be receiving alcohol (alcohol and placebo groups) or soda (sober group).

Participants in all beverage groups were administered three beverages across 45 min, and were told to consume each beverage steadily over 10 min. The alcohol groups (low-, medium- and high dose) were administered alcohol (0.63, 1.59 or 2.53 mL/kg, respectively) in drinks composed of calorie-free soda and vodka (40% alcohol) in a 2:1 ratio. The placebo group was given flattened tonic water in a glass rimmed with vodka, which lends the odour of alcohol without increasing an individual's BAL. The sober group was given calorie-free soda alone. During beverage consumption, participants watched DVDs of a popular television show and were not permitted to engage in another activity (e.g., studying).

Following beverage consumption, BAL was measured in participants in the alcohol and placebo groups, without showing the results to the participants. Participants in the alcohol and placebo groups then completed the manipulation check. Next, all participants completed the CPT and HVLT, in different rooms so that the participant completing the CPT could not hear the words being read for the HVLT. Administration of the cognitive tasks was counterbalanced within groups. Finally, all participants were paid and thoroughly debriefed, including explanation of the deception involved with the placebo condition, if applicable. Participants in

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