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Effects of acute alcohol intoxication on executive functions controlling self-regulated behavior

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ABSTRACT

Alcohol consumption may lead to deficits in the executive functions that govern self-regulation. These deficits could lead to risk-taking behaviors; therefore, it is important to determine the magnitude of these deficits on executive functioning. The purpose of this experiment was to investigate the acute effects of alcohol on three of the executive functions that are hypothesized to affect self-regulation, which are inhibition, set shifting, and working memory, using a mixed-methods study design. The participants were 75 moderate or heavy drinkers between the ages of 21 and 35 who were randomized into one of three beverage conditions (control, placebo, or 0.65-g alcohol dose/kg body weight). Performance on working memory, set shifting, and inhibition were measured pre- and post-beverage consumption. The results showed only a significant interaction in the working memory data, as there was an increase in performance post-beverage relative to pre-beverage for the control participants as compared to the alcohol and placebo participants. It was concluded that the dose of alcohol (BAC = 0.063%) given to moderate to heavy drinkers was not sufficient to cause significant impairment in the executive functions tested. The results were further discussed and methodological concerns were considered, such as the low BAC achieved, practice effects, and insensitivity of tasks.

Executive functioning is a system of multiple functions that exert self-control over behaviors when interacting with the environment. Thus, executive functioning allows for deliberate behavior choices to be made by weighing the shorter- and longer-term positive and negative consequences of a behavior to allow for goals to be achieved (Lieberman, 2007). Insufficiencies or impairments in executive functions can lead to the increased occurrence of risky social behaviors, due to a decreased ability to self-regulate behavior (Finn & Hall, 2004). Neurologically, the prefrontal cortex sub-serves executive functioning, including cognitive processes such as working memory, behavior inhibition, integration of information, and planning (Luria, 1966, 1969). However, there is interconnectedness of these subcomponents with other brain areas, including the anterior cingulate cortex and the subcortical limbic system (Ardila, 2008; Jarmolowicz et al., 2013). Therefore, it can be concluded that all subcomponents are neurologically interrelated.

Alcohol intoxication is one factor that has been shown to cause deficits in executive functioning (Greenstein et al., 2010; Mintzer, 2007; Park et al., 2011; Ralevski et al., 2012; Weiss & Marksteiner, 2007). In addition, individuals aged 18–31 years are the most at risk for drinking heavily and for developing alcohol-related problems (Substance Abuse and Mental Health Service Administration, 2010). Individuals who engage in heavy drinking have a higher likelihood than moderate drinkers and abstainers of participating in high-risk (negative health or social consequence-related) behaviors (Cooper, 2002; Maisto, Carey, Carey, & Gordon, 2002; Maisto et al., 2004; Scott, Schafer, & Greenfield, 1999; Smith, Branas, & Miller, 1999). Both findings together raise the possibility that alcohol's acute effects on social and health-related behaviors are due, at least in part, to its effects on executive functioning and self-regulation. Accordingly, a better understanding of alcohol's specific acute effects on executive functions and self-regulation of behaviors is a significant public health goal.

Hofmann, Schmeichel, and Baddeley (2012) defined self-regulation as goal-directed behaviors. The authors argued that processes of self-regulation are governed by executive functions; these functions enable an individual to monitor his/her behavior and to interact with the environment in order to achieve desired

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behavioral outcomes. There are three subcomponents of executive functioning that are agreed upon as being primary subcomponents involved in governing the self-regulation of behavior, namely, working memory, behavioral inhibition, and set shifting (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; Hofmann et al., 2012; Miyake et al., 2000).

Working memory is used to keep information active in short-term memory for immediate retrieval, as well as to monitor, code, manipulate, and integrate new information with previously acquired information in order to achieve a goal (Miyake et al., 2000). Working memory is thought to help govern self-regulation through maintaining an active representation of goals, focusing attention on specific goals while resisting others, and blocking hedonistic desires (Hofmann et al., 2012). Studies examining the acute effects of alcohol on working memory have found working memory to be affected in a dose–response manner, with a higher blood alcohol concentration (BAC) resulting in more consistent impairments (BAC = 0.071% and above; Colflesh & Wiley, 2013; Dougherty, Marsh, Moeller, Chokshi, & Rosen, 2000; Saults, Cowan, Sher, & Moreno, 2007; Schweizer et al., 2006; Tarter, Jones, Simpson, & Vega, 1971). However, there seems to be ambiguity in reported findings when the BAC is below 0.070%, with some studies reporting no impairments in performance (Dougherty et al., 2000), and others reporting impairment at BACs below this level (Casbon, Curtin, Lang, & Patrick, 2003; Ilan & Gevins, 2001; Magrys & Olmstead, 2014). There have also been discrepancies in findings of impairment as a function of limb of the BAC curve. Saults et al. (2007) found impairment on only the ascending limb, while Schweizer et al. (2006) only found impairment on the descending limb. Still other studies reported impairment of performance on both limbs (Grattan-Miscio & Vogel-Sprott, 2005).

The second executive function is set shifting/cognitive flexibility, which is the ability to reallocate attention among multiple operations, tasks, or mental sets (Bridgett et al., 2013; Monsell, 1996). It is believed to govern self-regulation through a flexible reallocation of attention between different behavioral mechanisms in order to achieve a goal or multiple goals simultaneously. One common test of set shifting is the Trail Making Test (TMT; Jarmolowicz et al., 2013). Several studies have found that high doses of alcohol (BAC = 0.073% and above) tend to consistently result in impairments in performance on the TMT (Celio et al., 2014; Day, Celio, Lisman, Johansen, & Spear, 2013; Dry, Burns, Nettelbeck, Farquharson, & White, 2012; Duning, Kugel, Menke, & Knecht, 2008; Guillot, Fanning, Bullock, McCloskey, & Berman, 2010; Minocha, Barth, Roberson, Herold, & Spyker, 1985). Three studies did not find alcohol to have an effect at lower BACs (0.033%–0.068%; Boissoneault, Sklar, Prather, & Nixon, 2014; Dry et al., 2012; Duning et al., 2008). Several of these studies did not explicitly report the limb on which the tests were administered (Duning et al., 2008; Minocha et al., 1985), or were unable to report the limb due to collecting data using a field study design (Celio et al., 2014; Day et al., 2013). Other studies reported administering tasks on the ascending limb (Boissoneault et al., 2014), descending limb (Dry et al., 2012), and the peak of the BAC curve (Guillot et al., 2010). However, it is unclear whether the effect of limb impacts the acute effects of alcohol on set-shifting performance, as there were differences in the dose administered and the limb on which the tasks were administered.

A third executive function, behavioral inhibition, is the ability to inhibit a prepotent response and use a less dominant response (Bridgett et al., 2013; Hofmann et al., 2012; Miyake et al., 2000). Behavioral inhibition is thought to govern self-regulation due to its ability to actively suppress impulsive behaviors in order to attain goals (Hofmann et al., 2012).

Prior research has evidenced that moderate to high BACs (0.070% and above) are associated with impairment of different aspects of performance on a variety of behavioral measures of inhibition, such as increasing the number of errors (Abroms, Fillmore, & Marczinski, 2003; Anderson et al., 2011; Dry et al., 2012; Fillmore, Ostling, Martin, & Kelly, 2009; Van Dyke & Fillmore, 2014; Weafer & Fillmore, 2012), increasing stop-signal reaction time (Caswell, Morgan, & Duka, 2013; Fillmore & Vogel-Sprott, 1999; Gan et al., 2014), and increasing reaction time (Abroms et al., 2003; Weafer & Fillmore, 2012). Significant impairments have been reported on both the ascending and descending limbs of the BAC curve (Fillmore et al., 2009; Weafer & Fillmore, 2012). However, other studies did not find deficits in performance due to high levels of alcohol consumption (BAC = 0.089% and 0.098%, respectively; Dougherty, Marsh-Richard, Hatzis, Nouvion, & Mathias, 2008; Guillot et al., 2010). This discrepancy in findings may be the result of the sensitivity of different tasks. The two studies that did not report significant impairments used the same stop-signal task that featured a visual (instead of auditory) stop signal, which may not have been sensitive to the doses of alcohol given.

Inhibition has also been measured using the Stroop task. Several studies have shown that moderate to high doses (BAC = 0.071%–0.100%) of alcohol impair performance on this task (Curtin & Fairchild, 2003; Schweizer et al., 2006), while lower doses (BAC = 0.025–0.050%) do not appear to impair performance (Volkow et al., 2006).

Summary and hypotheses

In summary, the data support the conclusion that alcohol intoxication negatively affects working memory, inhibition, and set shifting. However, it is important to note that these deficits are modest and therefore can be difficult to detect. Higher levels of intoxication (BAC = 0.070% or higher) consistently impair executive functioning subcomponent performance, while lower levels (BAC = 0.035%–0.069%) cause inconsistent deficits in performance. There also appear to be differences in types of impairments in performance as a function of which limb of the BAC curve the tasks are administered, although performance impairments have been found on both limbs. In previous research, the placebo group's performance consistently did not change following beverage consumption or was superior to the higher dose of alcohol condition where relevant. These conclusions are based on studies that tested alcohol's acute effects on individual components of executive functioning using varied methodology, as studies differed in alcohol intoxication levels, settings, populations tested, limb of BAC curve when performance was tested, and the specific tasks that were used to measure executive functions. Overall, standardization in testing these three components together, while holding other factors constant, has the potential to provide clear evidence on how alcohol affects these behaviors that purportedly reflect executive functioning.

The purpose of this experiment was to test the effects of a moderate dose of alcohol on the three subcomponents of executive functioning that have been hypothesized to underlie self-regulation of behavior. Therefore, this experiment avoided the difficulty in comparing the results of experiments conducted using different doses, tasks to measure the same construct, and populations of participants. In the proposed experiment, young adult men and women were randomly assigned to one of three beverage conditions: control, placebo, or alcohol (dose of 0.65 g/kg). The goal was to raise participants' BACs to 0.070%, which was chosen because this level of alcohol intoxication has been consistently shown to impair the three components of executive functioning as well as to be highly relevant to common consumption levels of “social” drinkers on a given occasion. Participants completed tasks designed to measure set shifting, working memory, and inhibition,