

The Effects of Alcohol Use on Antisaccade Performance

William T. Oliver

University of Georgia

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Alcohol abuse causes great economic and personal burden on individuals throughout the world each year. The annual cost of alcohol abuse in the United States is estimated to be over \$185 billion due to medical costs of those affected both directly and indirectly (Li, Hewitt, & Grant, 2004). Such a large economic impact can be put into perspective when one views statistics compiled by the National Institutes of Health. A study focused on U.S. prevalence and dependence found that 4.6% of the population fell under the DSM-IV criteria for alcohol abuse and 3.2% of the population for dependence (Grant, Dawson, Stinson, Chou, Dufour, & Pickering, 2004). For both prevalence and dependence, young adults ages 18-29 accounted for the large majority of the total figures for the U.S. population (Grant et al., 2004). Focusing on the neural mechanisms underlying alcohol abuse could provide a great service to those fighting this illness and contribute greatly to healthcare providers wishing to alleviate alcohol abuse in their clients.

A thorough study of the neural mechanisms underlying alcohol abuse in humans can be difficult to perform due to the often invasive procedures required to study its acute effects. In humans, behavioral methods have long been used to reach a better understanding of alcohol and its effects on the brain. With recent advances in neuroimaging allowing greater access into the human brain, this research, backed with years of behavioral data, is in a position to make much larger gains toward understanding the neural mechanisms that underlie alcoholism.

Previous longitudinal studies have focused on behavioral inhibition deficits in children as a predictor of problem drinking and illicit drug use (Nigg, Wong, Martel, Jester, Puttler, & Glass, 2006). Nigg and colleagues (2006) found that response inhibition could account for about 1% of the total drug and alcohol use; however, this suggests that behaviors even as early as 3-5 years

can predict future problems with alcohol use. Recent functional magnetic resonance imaging (fMRI) research using an antisaccade paradigm and focusing on youth aged 12-19 years found significant deficits in frontal regions of the brain believed to be involved in inhibitory control (McNamee, Dunfee, Luna, Clark, Eddy, & Tarter, 2008). Similar research found a negative correlation between neurobehavioral disinhibition (ND) scores and BOLD activations in frontal and supplementary eye fields (McNamee et al., 2008). These findings suggest an inability to utilize the regions involved in inhibitory control or possibly deficient cytoarchitectural support to such regions (McNamee et al., 2008). Although no significant relationship between antisaccade error rate and ND scores was found, BOLD activations in prefrontal regions during the antisaccade task could be used as a predictor of problems with inhibitory control. The relationship between ND scores and prefrontal activation in teens is likely due to incomplete neuronal development in these regions. Previous research focused on white matter neurodevelopment in prefrontal cortex suggests that myelination in these areas is not complete until the early twenties (Ashtari, Cervellione, Hasan, Wu, McIlree, & Kester, 2007; Giedd, 2004).

As stated above, younger drinkers (ages 18-29 years) account for a much larger percentage of total dependence and prevalence than all other age groups (Grant et al., 2004). This could be due to undeveloped frontal regions of the brain, namely dorsolateral prefrontal cortex, a region thought to be largely responsible for executive control functions required to successfully inhibit behaviors (Giedd, 2004). By using alcohol, young adults may be hindering these final stages of brain development, leading to the deficits in cognitive control and behavioral inhibition and contributing to the cycle of alcoholism. Research in long-term alcoholics, however, provides a paradox for the neural basis of alcohol abuse.

Post-mortem tissue samples taken from dorsal frontal cortex of long-term alcohol users demonstrated alterations of several gene families responsible for processes such as myelination, cell adhesion, and neurogenesis (Liu, Lewohl, Harris, Iyer, Dodd, & Randall, 2006). Liu and colleagues (2006) suggest that these defective gene expressions are the result of long-term alcohol use. An alternate explanation that cannot be ruled out, however, is that these genetic expressions were present prior to the person's consumption of alcohol and led to a deficient ability in inhibiting drinking behaviors.

The present study focused on the effects of alcohol abuse on a behavioral inhibition task known as an antisaccade paradigm. This task required the participant to make rapid eye movements to the mirror image of a peripheral target. The participant was instructed to inhibit the natural tendency to look toward an abruptly presented peripheral stimulus and instead direct his or her gaze towards the mirror image location (an empty point in space on the opposite side but the same distance from center).

Previous studies have shown marked impairments in antisaccade error rates and reaction times after acute administration of alcohol (Fillmore, 2004). Acute alcohol administration in high doses can have detrimental effects on both behavioral inhibition and motor performance (Fillmore, 2004). Long-term effects focused on these areas of interest, however, are largely unknown. Understanding the long-term effects that alcohol use has on the brain could prove useful in improving education, creating better treatment methods, and providing more useful screening methods used as a form of primary intervention.

It was predicted that long-term alcohol use would be correlated with inhibitory problems (quantified as more errors on antisaccade trials) and increased processing speed (longer reaction times during correct antisaccade trials). Three measures of alcohol use were employed: duration

of drinking in years, age of onset, and number of drinks throughout lifetime. Two eye movement variables were used: antisaccade error rate and reaction times for correct antisaccade trials. We then examined whether there were correlations among the measures of alcohol use and eye movements. Specifically, it was predicted that with earlier age of onset of drinking behavior, both antisaccade error rate and reaction times for correct antisaccade trials would increase. A positive correlation was also predicted between the other measures of alcohol use (duration of drinking in years and number of drinks throughout lifetime) and the eye movement measures (antisaccade error rate and reaction times).

## Method

### *Participants*

232 participants (140 females and 92 males) were recruited from the undergraduate research pool at the University of Georgia. Each participant was screened for a history of psychiatric illness and asked if their vision was normal or corrected-to-normal. Participants were thoroughly interviewed using several standard evaluations, including an assessment of drug and alcohol use.

### *Materials*

Past and current drug and alcohol screening was conducted using the Customary Drinking and Drug Use Record (CDDR; Brown, Meyer, Lippke, Tapert, Stewart, & Vik, 1998). This standard alcohol use interview assessed the participants' engagement in alcohol consumption, as quantified by variables such as current age, age of onset, number of drinks in lifetime, and number of drinks during a typical 24-hour period of drinking. For this study, the focus was on the duration of drinking in years, age of onset, and number of drinks throughout lifetime.

*Design and Procedure*

After completion of the interview process, participants were asked to perform the antisaccade task. Participants sat in front of the stimulus screen and placed their chins in a mounted rest which distanced them 70 cm from stimulus presentation and minimized head motion. During stimulus presentation, a head-mounted infrared eye-tracking system tracked participants' pupils.

Participants were given three blocks of prosaccade and antisaccade tasks. One task block consisted of prosaccade trials (48 trials), all presented randomly at either a five or ten degree visual angle from center. During the prosaccade tasks, participants were asked to fixate on the center stimulus (purple dot). The center stimulus then changed to yellow and moved right or left. Participants were instructed to follow the dot to its peripheral position (Figure 1). A second trial block consisted of antisaccade trials (48 trials) presented randomly at either a five or ten degree visual angle from center. During the antisaccade trials, participants were asked to fixate on the center stimulus (purple dot). The center stimulus then changed to blue to indicate an antisaccade trial and moved to a peripheral location. Participants were asked to look to the mirror image location of the peripheral target as quickly and accurately as possible (Figure 2). The final trial block consisted of a mixed condition in which participants were randomly presented with either blue or yellow dots (56 prosaccades and 48 antisaccades) to indicate which task they were to perform. These dots then moved to the random location at either five or ten degrees from center, and the head-mounted infrared camera tracked the participants' eye movements.

Saccade data were collected and analyzed using MATLAB software, and eye movements were scored for the number of direction errors (e.g. moving eye to the left when they should go to the right or visa versa) and reaction times for correct antisaccade trials (time in msec between

target appearance and eye movement). These data were examined to determine whether there was a correlation with the recorded data from the CDDR.

### Results

For each of the three variables of interest in the CDDR (lifetime number of drinks, age of onset, and duration of drinking in years), analyses were conducted across antisaccade error rates and reaction times for correct antisaccade trials. A significant negative correlation was found between the duration of drinking in years and the percent correct during antisaccade trials ( $R = -.19, p = .02$ ). A second correlation was found between the lifetime number of drinks and reaction time ( $R = .14, p = .04$ ) (see Figure 3). No other correlations were statistically significant ( $p > .05$ ).

### Discussion

The results of this study suggest that long-term consumption of alcohol has a negative effect on antisaccade task performance. Reduced behavioral inhibition is profound in individuals under acute administration of alcohol (Fillmore, 2004). Less is known, however, about how long-term alcohol use affects cognitive control. Alcohol abuse often involves marked impairments in an individual's ability to inhibit the desire to consume alcohol. Failure to inhibit the drinking behavior perpetuates the cycle of alcoholism. If researchers could understand the mechanisms underlying the required behavioral inhibition, a person engaged in alcoholism receiving properly revised treatment would become much more likely to abstain.

Although the antisaccade task is not equivalent to the complex behavioral inhibition that lies at the heart of alcoholism, it remains an effective measure of that inhibition. Impairments in simple behavioral inhibition tasks such as the antisaccade could provide a basic research structure for the more complex mechanisms underlying alcoholism. Gains in this area could lead to better forms of treatment and prevention of alcohol abuse.

This study demonstrated alcohol's effects on antisaccade error rate and reaction times during correct trials. The negative correlation between the duration of drinking and the percent correct during antisaccade trials indicates that participants who have been drinking for a longer duration of time performed more poorly on the antisaccade tasks. The positive correlation between the lifetime number of drinks and reaction time indicates that participants who drank more throughout their lifetime had slower reaction times during the antisaccade task.

Although antisaccade error rate speaks to an interesting behavioral inhibition perspective, increased reaction times may also be significant for the study of alcoholism and inhibition control. Increased reaction times suggest an increase in task difficulty from the participant's perspective and longer task processing latencies. Studies with habitual and non-habitual drinkers during a verb verification task in which both groups were primed with questions about socializing and drinking behaviors showed that habitual drinkers responded significantly faster to the randomly presented verb "drinking" (Sheeran, Aarts, Custers, Ravis, Webb, & Cooke, 2005). According to Sheeran and colleagues (2005), this goal-directed, automatic behavior manifests itself due to habit formation. The fast reaction times associated with habit formation, coupled with slower behavioral inhibition abilities, may make abstaining from alcohol use much more difficult.

fMRI research on alcohol use and the antisaccade task could be performed to learn whether there are differences in activation of frontal regions of the brain thought to be involved in executive functions. Previous fMRI research exploring the neural mechanisms critical for the antisaccade task has shown much higher activation in dorsal prefrontal regions as well as parietal areas during correct antisaccade trials compared to antisaccade errors (Ford, Golte, Brown, &

Everling, 2005). Long-term alcohol use may have an effect on similar regions of the brain, thereby causing the impairments on antisaccade performance shown by this study.

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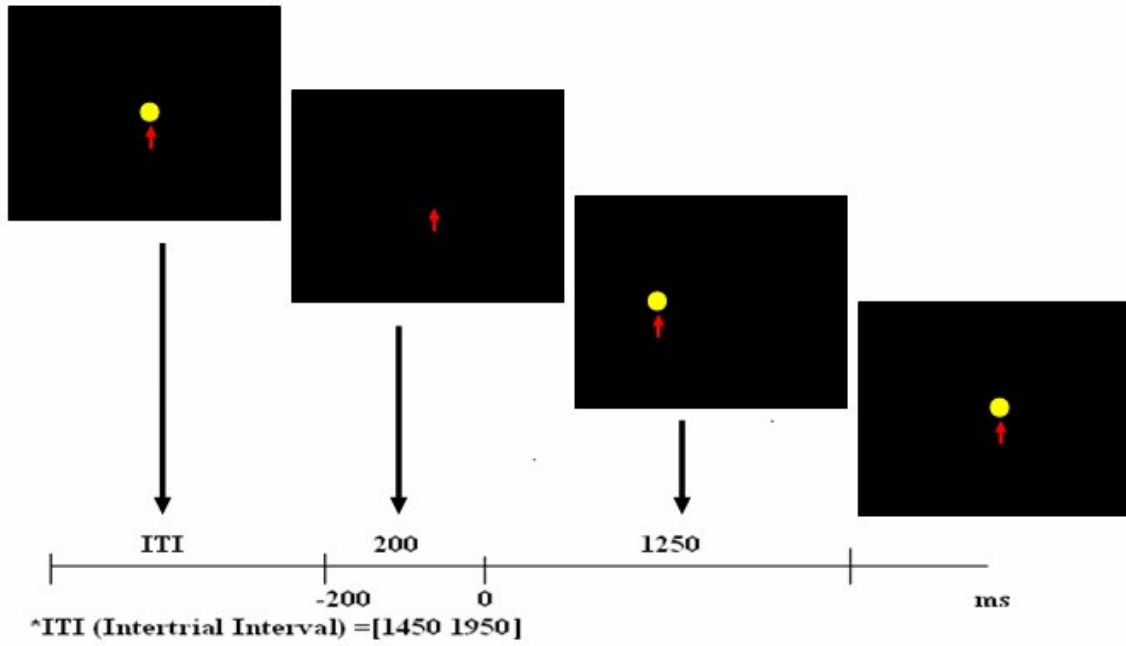


Figure 1. Prosaccade task

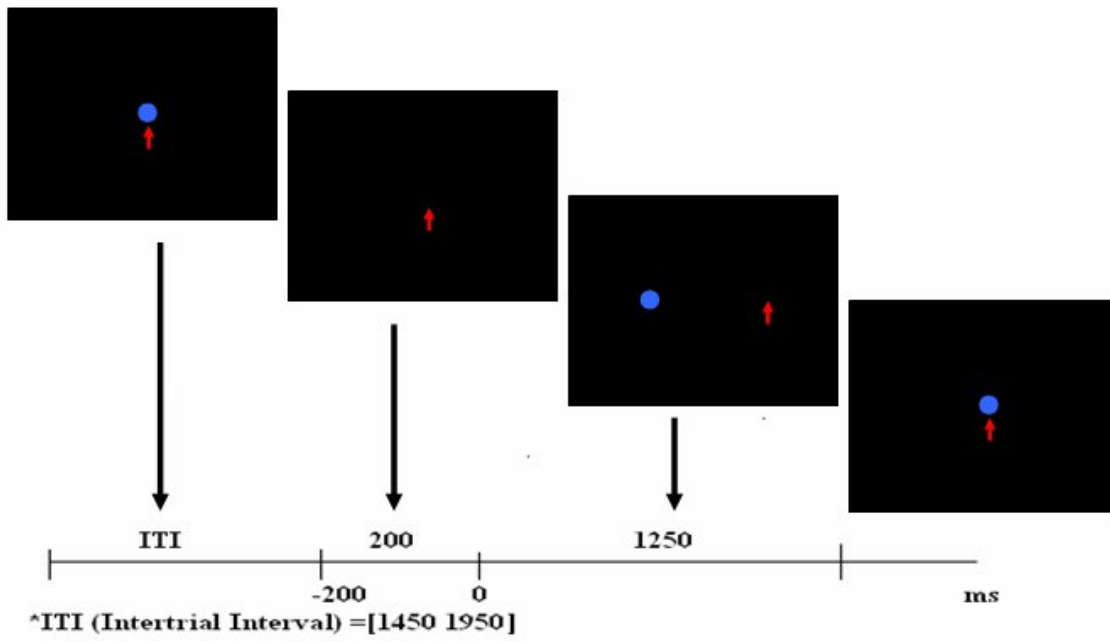


Figure 2. Antisaccade task

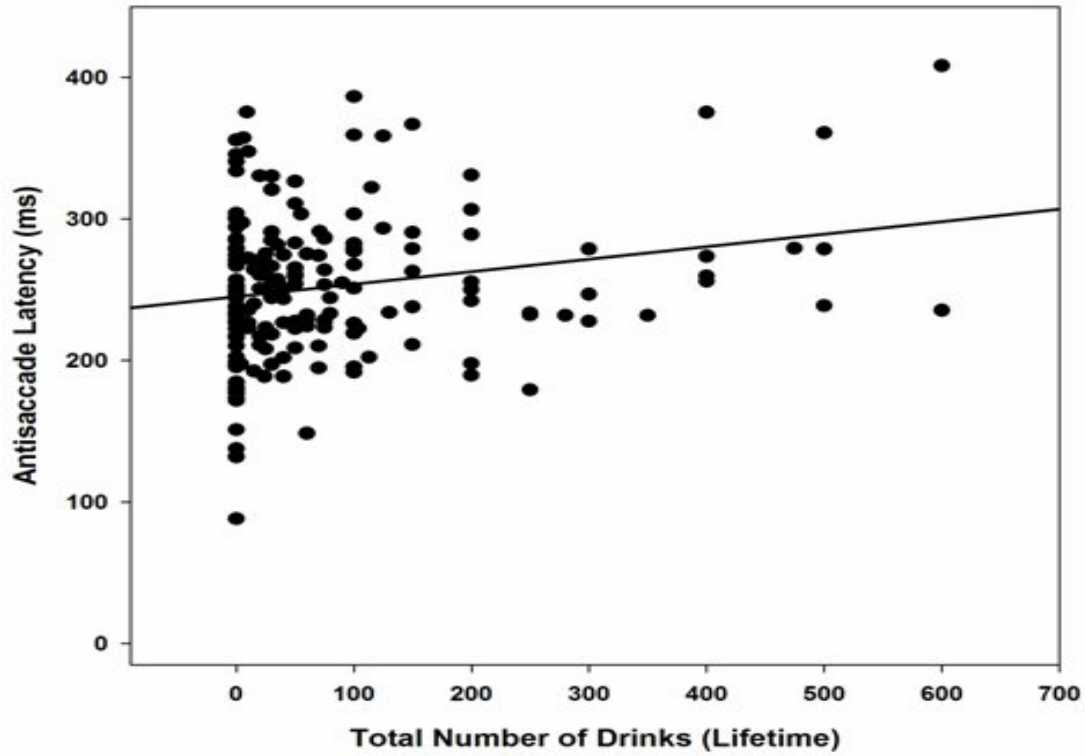


Figure 3. Number of drinks vs. reaction time (four extreme outliers with over 1000 drinks were excluded in order to enhance graph resolution)