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Behavioral Components of Impulsivity Predict Alcohol Consumption in Adults with ADHD and Healthy Controls

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Abstract

Background—The degree to which distinct behavioral components of impulsivity predict alcohol consumption is as yet not well-understood. Further, the possibility that this relation might be more pronounced in groups characterized by heightened impulsivity (i.e., individuals with ADHD) has not been tested.

Methods—The current study examined the degree to which three specific behavioral components of impulsivity (i.e., poor response inhibition, poor attentional inhibition, and increased risk-taking) were associated with quantity and frequency of alcohol consumption in a group of young adult social drinkers with ADHD (n = 33) and in a comparison control group (n = 21). Participants performed the delayed ocular return task (attentional inhibition), the cued go/no-go task (behavioral inhibition), and the Balloon Analogue Risk Task (risk-taking).

Results—Both poor behavioral inhibition and greater risk-taking were related to greater quantity of consumption in the entire sample, whereas poor attentional inhibition was related to greater quantity specifically among those with ADHD. By contrast, only risk-taking was associated with frequency of consumption, and this was found specifically in the control group.

Conclusions—These findings provide important information regarding the potential role of distinct behavioral components of impulsivity in drinking behavior, and highlight unique relevance of attentional impairments to drinking behavior in those with ADHD.

Keywords

behavioral impulsivity; alcohol consumption; ADHD

1. Introduction

It is now well established that impulsivity as a behavioral trait is associated with addictive behaviors, including drug abuse. Investigators have found that substance abuse disorders have a high comorbidity with personality disorders that are characterized by undercontrolled, disinhibited, and impulsive patterns of behavior, including antisocial, borderline, and histrionic disorders (e.g., Grekin et al., 2006; Moeller et al., 2002; Trull et al., 2004). The relation between impulsivity and substance use has been shown across several classes of drugs, including stimulants, opiates, and alcohol, and across multiple indices of impulsivity, including self-report, behavioral, and neuropsychological measures

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(for a review, see Verdejo-Garcia et al., 2008). With regard to alcohol use, impulsive personality traits have been associated with several risk indicators including a propensity to binge drink, a younger onset age of drinking, and increased risk of relapse in abstinent alcoholics (Bjork et al., 2004; Dom et al., 2006; Soloff et al., 2000).

Although there is a clear association between impulsivity and alcohol abuse, the specific behavioral mechanisms by which this trait might promote alcohol use are not well-understood. Impulsivity is a multi-faceted construct that encompasses several aspects of behavior, including difficulty in response inhibition, inability to delay gratification, impairments in time estimation, and increased risk-taking (Whiteside and Lynam, 2001). Although much impulsivity research has relied solely on self-report measures in the past, researchers are beginning to employ behavioral measures in order to assess different aspects of the construct. In the current study we examined the degree to which three distinct behavioral components of impulsivity predict alcohol consumption in terms of both heavy episodic use and frequency of drinking. These three components represent difficulty in response inhibition, poor attentional control, and a proclivity to reward-seeking or risk-taking. Further, we tested the possibility that these associations might be more pronounced in a group assumed to be characterized by heightened levels of impulsivity (i.e., individuals with ADHD).

Among the three components, difficulty in response inhibition is perhaps the most studied. The inhibition of behavior is an important function that sets the occasion for many other activities that require self-restraint and regulation of behavior, including excessive alcohol consumption. Laboratory tasks, such as the stop-signal and go/no-go task, have been developed to examine inhibition of behavior in a laboratory setting (e.g., Logan, 1994; Miller et al., 1991), and studies have begun to demonstrate a relationship between inhibitory control and drinking habits. For instance, Rubio et al. (2008) found that heavy drinkers displayed greater impairment of inhibitory control on the stop signal task compared to controls, and that impairment on this task predicted their degree of alcohol consumption at a 4-year follow-up.

Impulsivity is also characterized by poor attentional control, which refers to increased distractibility or failure to ignore irrelevant information. Control models have identified distinct inhibitory mechanisms that facilitate selective attention by directing cognitive resources away from irrelevant stimuli and towards relevant stimuli (Houghton and Tipper, 1994). Researchers have utilized tasks assessing the inhibitory control of attention, particularly through the examination of ocular response. Tasks such as the antisaccade and delayed ocular response task require subjects to inhibit making a reflexive saccade to the sudden appearance of a distracter object. The attentional problems associated with heightened impulsivity also have been suggested to contribute to alcohol abuse (Blume et al., 2005; Tarter et al., 2004). For example, psychophysiological studies show at-risk individuals display reduced P300 amplitudes to novel stimuli, suggesting compromised functioning of frontal areas involved in attention (Porjesz and Begleiter, 1990; Schandler et al., 1993; Weirs et al., 1998).

In addition to deficits of inhibition in the control of behavioral impulses and the selection of attention, impulsivity also appears to reflect a heightened sensitivity to reward. This component of impulsivity reflects “approach-type” tendencies, including increased risk-taking and sensation-seeking, with an apparent lack of concern over negative consequences. Specifically, engaging in risky behavior is defined as reward-seeking in the face of simultaneous threat for punishment or aversive consequences (Lejuez et al., 2002; Zuckerman and Kuhlman, 2000). Examples of risk-taking can include both positive behaviors, such as starting a new business, or negative behaviors, including unprotected sex or gambling one s entire paycheck on a single wager. Lejuez et al. (2002) developed a behavioral measure of risk-taking, known as the Balloon Analogue Risk Task (BART). On this task, a specific behavior (i.e., mouse clicks to inflate a balloon on the computer screen) is rewarded by monetary gain to a certain point. However, mouse clicking can also result in the balloon popping, resulting in loss of money. Therefore, greater balloon pumping is thought to indicate higher levels of risk-taking. Some research has shown an association between greater risk-taking on the BART and increased substance use, including alcohol use and alcohol-related problems in young adults (Lejuez et al., 2002; Fernie et al., 2010; Skeel et al., 2008).

Taken together, the findings provide evidence for an association of various behavioral components of impulsivity with heavy alcohol use. Such findings raise the possibility that these associations might be particularly evident in groups specifically characterized by high levels of impulsivity. One such group are those with attention deficit/hyperactivity disorder (ADHD). It is well-established that externalizing disorders, such as ADHD, pose risk for developing substance abuse disorders (Barkley, 2006; Flory and Lynam, 2003; Flory et al., 2003; Molina et al., 1999). Studies of adults with ADHD find lifetime rates of alcohol abuse disorders ranging between 21% and 53% (Barkley et al., 1996; Biederman, 2004). Moreover, there is also growing suspicion that heightened impulsivity might be a key behavioral mechanism that contributes to the elevated risk for alcohol abuse among individuals with ADHD (Fillmore, 2003; 2007). Stop signal and cued go/no-go tasks have demonstrated deficits of response inhibition in children with ADHD, and more recently in adults with the disorder (Alderson et al., 2007; Barkley, 1997; Bekker et al., 2005; Lijffijt et al., 2005; Oosterlaan et al., 1998; Tannock, 1998). Similarly, deficits in attentional inhibition have been observed in adults with ADHD (Ross et al., 2000). Research has also shown that adults with ADHD might demonstrate heightened reward sensitivity as evidenced by increased risk-taking behaviors, including risky sexual behavior and risky driving (Flory et al., 2006; Thompson et al., 2007).

The few studies conducted to date on the link between behavioral measures of impulsivity and alcohol consumption have focused on non-clinical samples of otherwise “healthy” young adults. Consequently, little is known about the extent to which heightened levels of impulsivity could contribute to heavy drinking behavior in populations characterized by poor self-control, such as young adults with ADHD. Moreover, few studies have sought to examine distinct behavioral components of impulsivity as separate contributions to alcohol abuse, particularly within this population. Given that ADHD is defined by problems of attention and undercontrolled behavior, such individuals should display marked deficits of inhibitory control and greater propensity for risk-taking that might also bear a close association to their patterns of alcohol use. As such, the relation between impulsivity and excessive alcohol consumption might be especially pronounced in these individuals compared with the general population.

Finally, little research has examined the degree to which behavioral components of impulsivity are associated with distinct measures of alcohol consumption (i.e., quantity vs. frequency). Quantity and frequency measures assess dissociable aspects of drinking habits that relate to different patterns of alcohol abuse that lead to alcohol-related problems (Midanik et al., 1996). For example, frequency measures can be indicative of drinking patterns motivated by physiological dependence, whereas measures of quantity might better assess loss of control problems that are indicative of heavy episodic drinking (Dawson, 1994; Wechsler and Isaac, 1992). Thus, the behavioral components of impulsivity could show differential associations to these two aspects of drinking behavior. To test these hypotheses, the present study examined the degree to which three specific behavioral components of impulsivity (i.e., poor response inhibition, poor attentional inhibition, and increased risk-taking) were associated with individual differences in frequency and quantity of alcohol consumption in a group of young adult social drinkers with and without ADHD.

2. Method

2.1 Participants

Thirty-three young adults with ADHD (16 men and 17 women; *M* age = 21.1 years, *SD* = 1.6) and 21 controls (12 men and 9 women, *M* age = 22.3, *SD* = 1.4) with no history of ADHD took part in this study. A chi-square analysis showed that gender makeup was independent of group, X^2 (1, *N* = 54) = 0.4, *p* = .54. The racial make-up of individuals with ADHD was as follows: African-American (*n* = 1), Asian (*n* = 2), and Caucasian (*n* = 30). The racial make-up of controls was: African-American (*n* = 3), Asian (*n* = 1), Caucasian (*n* = 16), and other (*n* = 1). Potential volunteers responded to study advertisements specifically seeking young adults between the ages of 19 and 25 with a diagnosis of ADHD and healthy controls of the same age for studies of cognitive and behavioral tasks. This age range was selected based on several considerations. First, heavy drinking behavior is highly prevalent among this age group (e.g., White et al., 2006). In addition, the maximum age of 25 avoids confounding neurocognitive impairment that might be due to a history of adult alcohol abuse, as well as age-related heterogeneity of neurocognitive functioning, owing to general cognitive decline across the life-span (Hasher et al., 1991; Tamm et al., 2002). All potential volunteers were required to have no history of head trauma or uncorrected vision problems. Only volunteers who reported regular alcohol consumption (at least two times per month) were included in the study. Participants were paid $40 for participation. The study was approved by the university Medical Institutional Review Board.

2.2 ADHD diagnosis confirmation

Individuals who indicated having a medical diagnosis of ADHD or attention deficit disorder (ADD) were asked a series of questions about their diagnosis and current treatment status. After providing informed consent, medical records of the participants were obtained to verify the medical diagnoses. Because most diagnoses of ADHD occur during childhood or adolescence it was important to exclude individuals who had been diagnosed in the past, but who no longer displayed symptoms as adults. Thus, the sample only included individuals who continued to report symptoms and who were still receiving treatment (i.e., a prescribed medication) for those symptoms at the time of study recruitment. This ensured sufficient severity of symptoms for those in the ADHD sample. Participants were asked to bring their prescription bottles to the familiarization session in order to verify that they were receiving current treatment for ADHD. The breakdown of medications among those with ADHD was as follows: Adderall™ (*n* = 11), Adderall XR™ (*n* = 10), Concerta™ (*n* = 3), Ritalin™ (*n* = 1), Dexedrine™ (*n* =2), Daytrana™ (*n* = 1), and both Adderall™ and Adderall XR™ (*n* =5). The half-life means for these medications range from three to thirteen hours. In order to examine performance in an unmedicated state, participants with ADHD were asked to refrain from taking their medication for 24 hours prior to the study. This allowed for the examination of actual deficits associated with ADHD, as opposed to studying the effects of medication on task performance. Compliance with this request was verified by self-report at the beginning of each session.

Additionally, ADHD diagnosis was confirmed by meeting symptom-based criteria on two of the three following scales: the Conners Adult ADHD Rating Scale-Long Form (CAARS-S:L; Conners et al., 1999), the ADD/H Adolescent Self-Report Scale-Short Form (Robin and Vandermay, 1996), and an ADHD Symptom Checklist of 12 ADHD symptoms that serve as diagnostic criteria according to the *DSM-IV* (American Psychiatric Association, 1994). All diagnoses were confirmed by a licensed clinical psychologist with over twenty years of experience in diagnosing ADHD. Three of the CAARS-S:L scales are based on well-established *DSM-IV* criteria of ADHD and have been used for adult ADHD diagnostic purposes in other research (e.g., Adler et al., 2006; Rybak et al., 2006). The items in this scale provide information on any experience of ADHD symptoms throughout adulthood. The diagnostic criterion for the CAARS-S:L is a T-score of greater than 65 on the ADHD symptoms scale. The ADD/H Adolescent Self-Report Scale-Short Form is specific to symptoms experienced in the past month, thus providing evidence that participants are currently experiencing the symptoms of ADHD. The diagnostic criterion for this scale is a score of 10 or higher. Sufficient psychometric properties have been demonstrated in both of these measures, and both have demonstrated criterion validity for identifying individuals with ADHD (Erhardt et al., 1999; Robin and Vandermay, 1996). Furthermore, these scales were chosen because of their emphasis on adult symptoms. The ADHD Symptom Checklist was created using *DSM-IV* symptoms and items that loaded highly on the ADHD symptoms factor on the YAQ-S (Young, 2004). The scale emphasizes symptoms present as an adult and includes six inattentive and six hyperactive symptoms. Participants rated the frequency of symptom occurrence as Not at all, Sometimes, Often, and Very Often. Any symptom occurrence rated as Often or Very Often was counted and a symptom count of four or greater was required to meet criterion for ADHD.

Diagnoses of each of the 33 ADHD participants were confirmed through all three diagnostic methods (i.e., medical records, ADHD medication prescription, and symptom-based questionnaire criteria). The control participants also completed each of the ADHD symptom-based scales, and none of these participants met criteria for ADHD. Mean scores for both groups on each scale are presented in Table 1.

2.3 Apparatus and materials

Three measures of behavioral impulsivity were administered: the cued go/no-go task, the delayed ocular return (DOR) task and the balloon analogue risk task (BART). All tasks were operated using E-prime experiment generation software (Schneider et al., 2002) and performed on a personal computer.

2.3.1 Cued go/no-go task—Response inhibition was measured by a cued go/no-go reaction time task used in other research to measure inhibitory control (e.g., Derefinko et al., 2008; Marczinski and Fillmore, 2003). The task requires finger presses on a keyboard, and measures the ability to inhibit the prepotent behavioral response of executing the key press. Cues provide preliminary information regarding the type of imperative target stimulus (i.e., go or no-go) that is likely to follow, and the cues have a high probability of signaling the correct target. Participants were instructed to press the forward slash (/) key on the keyboard as soon as a go (green) target appeared and to suppress the response when a no-go (blue) target was presented. Key presses were made with the right index finger. To encourage quick and accurate responding, feedback was presented to the participant during the inter-trial interval by displaying the words *correct* or *incorrect* along with the RT in milliseconds. A test required approximately 15 minutes to complete. The primary measure of this task was participants' proportions of inhibitory failures, measured as the proportion of no-go targets in which a participant failed to inhibit a response. These *p*-inhibition failure scores were averaged across cue condition (go and no-go).

2.3.2. Delayed ocular return (DOR) task—Attentional inhibition was measured by the DOR. This task involved eye movements, which are indicative of shifts of visual attention (e.g., Godijn and Theeuwes, 2003), and measured the ability of a subject to intentionally inhibit the tendency to make a reflexive saccade toward the sudden appearance of a visual stimulus on a computer screen (Ross et al., 1994; 2000; 2005). Saccades were recorded using a Model 504 Eye Tracking System (Applied Science Laboratory, Boston, MA, USA). Participants were seated in a darkened room and instructed to maintain focus on a fixation point. While participants attended to the fixation point, a bright target stimulus was briefly presented in the periphery. The onset of the stimulus in this context normally causes a saccade to be reflexively executed toward the stimulus (Peterson et al., 2004; Theeuwes et al., 1999). However, in the DOR task, subjects are instructed to “delay” looking at this stimulus (i.e., to intentionally inhibit the reflective saccade), and instead maintain their gaze on the fixation point until it disappears. The disappearance of the fixation point was the signal for participants to then make a saccade as quickly as possible to the location in which the target stimulus had appeared. A test consisted of 96 trials and required 7 minutes to complete. The primary measure of this task was the number of trials in which a participant failed to inhibit the reflexive saccade (i.e., premature saccades), indicating failure of attentional inhibition.

2.3.3. Balloon analogue risk task (BART)—The BART measured risk-taking (Lejuez, et al., 2002). Participants were told that they would have the opportunity to win real (not hypothetical) money by inflating balloons on a computer screen without popping them. One balloon was presented on the screen per trial. Each time a participant made a mouse click in a designated area on the screen, the balloon increased in size, and one cent was added to the participant s temporary “bank”. Participants could choose to stop pumping and collect the money earned from the balloon at any time, storing the money in a permanent “bank”. Participants were also told that the balloon could pop at any time (e.g., after one pump or after filling the entire screen), resulting in the loss of all of the money in the temporary bank. Both choosing to collect the money and balloon-popping resulted in the presentation of a new balloon and a new temporary bank. Twenty balloons were presented in a test. The primary measure of risk-taking was the average number of pumps across trials. Greater number of balloon pumps indicated greater levels of risk-taking, because each pump increased the risk of the balloon popping, resulting in the loss of money. Participants were given earned money at the completion of the study.

2.3.4 Assessment of alcohol consumption—Participants’ current, typical drinking habits were assessed by the Personal Drinking Habits Questionnaire (PDHQ; Vogel-Sprott, 1992). The primary measure of quantity obtained from this questionnaire was typical dose (milliliter of absolute alcohol per kilogram body weight typically consumed during a single drinking occasion). This provided the most informative indicator of individual differences in quantity of alcohol consumption in that it incorporated the amount of alcohol typically consumed, while also adjusting for individual body weight. Because the degree of functional impairment resulting from a specific quantity of alcohol can differ based on body weight, weight-adjusted dose provides a more direct measure of alcohol consumption in terms of its behavioral impact on the individual. The primary measure of frequency obtained from the PDHQ was weekly frequency (i.e., the number of drinking occasions per week). The three other drinking habit measures included: drinks (the number of standard alcoholic drinks [e.g., 1.5 oz of liquor] typically consumed per occasion); duration (time span in hours of a typical drinking occasion); and history of alcohol use (number of months of regular drinking).

2.4 Procedure

2.4.1 Intake/assessment session—This initial session served to acquaint volunteers with the laboratory and to gather background information. All participants were tested individually, and breathalyzer readings were obtained from all participants prior to both the familiarization and test sessions to ensure a zero breath alcohol content (BAC). After providing informed consent, participants were interviewed and completed questionnaires concerning their health status, alcohol and other drug use, and demographic characteristics. Intellectual functioning was also assessed by the Kaufman Brief Intelligence Test (Kaufman and Kaufman, 1990). Those who reported a diagnosis of ADHD provided a signed release of their medical records, and were interviewed regarding medications currently prescribed for the disorder.

Task instructions for the cued go/no-go and DOR were then explained, and participants completed one practice trial on each task. A single test is sufficient to become familiar with both tasks (Abroms et al., 2006; Marczinski and Fillmore, 2003). The BART did not require a learning phase. After the familiarization tests participants made appointments to attend the test session.

2.4.2 Test session—Participants returned to the lab to attend the test session in which their task performance was assessed. During this session, they were reminded of the requirements of the tasks. They completed the cued go/no-go task followed by the DOR task. Instructions for the BART task were then explained, followed by the performance of the task. All participants performed the tasks in this fixed order. After completing all tasks participants were debriefed and paid for their participation.

2.5 Data analyses

Group differences in each behavioral component of impulsivity were analyzed by independent samples *t* tests (ADHD vs. controls). The degree to which subjects' performance on each component of behavioral impulsivity related to both their quantity and frequency of alcohol consumption was analyzed by separate hierarchical regression analyses. Typical dose of alcohol consumption, as calculated from responses on the PDHQ, served as the dependent variable for the analyses predicting quantity, and weekly frequency of alcohol consumption served as the dependent variable for those predicting frequency. For all regressions, group classification (ADHD vs. controls) was entered as a categorical variable in Step 1. The behavioral component (i.e., p-inhibitory failures, premature saccades, or balloon pumps) was entered in Step 2, and the interaction term (group x p-inhibitory failures/premature saccades/balloon pumps) was entered in Step 3 to assess the unique variance accounted for by the interaction. The interactions were of particular interest because they could indicate group differences in the degree to which impulsivity was associated with alcohol use.

3. Results

3.1 Demographics, drinking habits, and drug use

Table 1 summarizes education, IQ scores, and drinking habits for the groups. The table shows that the groups did not differ in terms of level of education, $t(52) = 0.2$, $p = .82$, or verbal IQ, $t(52) = 1.3$, $p = .20$; however, the ADHD group scored lower than controls on the measure of non-verbal IQ, $t(52) = 2.2$, $p = .03$. The groups did not differ on any measure of drinking habits as reported on the PDHQ (*p*s > .35). The entire sample reported an average of 60.6 (*SD* = 27.8) months of regular drinking, ranging from four to 145 months, and a weekly frequency of 1.3 (*SD* = 1.0) drinking occasions per week, ranging from 0.03 to 4.0 occasions. For a typical drinking occasion, the sample reported a mean quantity of 4.2 (*SD* = 2.3) drinks, ranging from 1.0 to 9.0 drinks, a mean weight-adjusted dose of 1.0 ml/kg (*SD* = 0.5), ranging from 0.1 to 2.3 ml/kg, and a mean hourly duration of 3.5 (*SD* = 1.4) hours, ranging from 0.5 to 6.5 hours.

Reports of substance use (other than alcohol) in the past year were generally rare and comparable across groups. Of those with ADHD, 13 of 33 (39%) reported marijuana use in the past year, 3 of 33 (9%) reported use of psychedelics, 2 of 33 (6%) reported sedative use, and 1 of 33 (3%) reported use of analgesics. Of the controls, 8 of 21 (38%) reported marijuana use in the past year, 1 of 21 (5%) reported cocaine use, 1 of 21 (5%) reported use of inhalants, 1 of 21 (5%) reported use of psychedelics, and 1 of 21 (5%) reported sedative use.

3.2 Group differences in task performance

Mean scores for the groups on each measure of impulsivity are presented in Table 2. Individuals with ADHD displayed poorer attentional inhibition on the DOR task, $t(52) = 2.9$, $p < .01$, $d = .83$. Specifically, those with ADHD committed significantly more premature saccades ($M = 10.2$, $SD = 6.0$) than controls ($M = 5.8$, $SD = 4.5$). By contrast, no group differences were found in p-inhibitory failures on the cued go/no-go task or balloon pumps on the BART (*p*s > .63). Due to computer malfunction, three participants were unable to perform the BART, and therefore results from this task are based on $N = 51$ (30 adults with ADHD and 21 controls).

3.3 Correlations among behavioral components of impulsivity

In order to confirm that each of the behavioral measures of impulsivity did in fact measure distinct components of the construct, correlational analyses were performed to test for associations among each of the measures. No significant correlations were observed among the measures based on the sample as a whole (*p*s > .39) or in the individual groups (*p*s > . 35).

3.4 Relation of behavioral components of impulsivity to quantity of alcohol consumption

To test the relation of behavioral components of impulsivity to quantity of alcohol consumption, hierarchical regression analyses were conducted to examine each component separately. Results of each regression are presented in Table 3. The first examined the degree to which individual differences in typical dose were associated with attentional inhibition as measured by the DOR task. The regression revealed a significant group x premature saccade interaction, $F(3, 50) = 5.4$, $p = .02$, indicating that the relationship between premature saccades and alcohol consumption differed by group. Based on this interaction, two individual bivariate regressions were conducted to examine the association between premature saccades and alcohol consumption separately within each group. Among those with ADHD, there was a trend for premature saccades to correlate with typical alcohol consumption, $F(1, 31) = 3.7$, $p = .06$, accounting for 11% of the variance. The regression yielded a positive slope, $b = .03$ ($se = .02$), indicating that, among individuals with ADHD, those who committed more premature saccades (i.e., displayed poorer attentional inhibition) reported greater consumption of alcohol. By contrast, premature saccades were not significantly related to alcohol consumption in controls, $F(1, 19) = 2.5$, $p = .13$.

For behavioral inhibition as measured by p-failures on the cued go/no-go task, the regression analysis showed that p-failures accounted for a significant portion of variance in quantity of alcohol consumption, $F(2, 51) = 6.7$, $p = .01$. However, there was no interaction, indicating that the relation between p-inhibitory failures and alcohol consumption did not differ between groups. Thus, this relation was analyzed in the sample as a whole. Results showed that p-inhibitory failures accounted for 12% of the variance in alcohol consumption and the regression yielded a positive slope, $b = 3.8$ ($se = 1.5$), $p = .01$, indicating that, overall, those who committed greater p-inhibitory failures (i.e., displayed poorer behavioral inhibition) reported greater consumption of alcohol.

Regression analyses of risk-taking as measured by balloon pumps on the BART showed a trend towards a positive association between subjects' average number of balloon pumps and their quantity of alcohol consumption, $F(2, 48) = 3.5$, $p = .06$. A non-significant group x balloon pumps interaction indicated that the relation between balloon pumps and alcohol consumption did not differ between groups. Thus, this relation was analyzed in the sample as a whole. Results showed that balloon pumps accounted for 7% of the variance in quantity of consumption and the regression yielded a positive slope, $b = .01$ ($se = .01$), $p = .06$, indicating that, overall, there was a trend for those who displayed higher risk-taking on the task to report greater consumption of alcohol.

3.5 Relation of behavioral components of impulsivity to frequency of alcohol consumption

Separate regression analyses were performed in order to determine the degree to which each of the behavioral components of impulsivity was associated with weekly frequency of alcohol consumption, and the results of these regressions are presented in Table 4. The table shows that measures of attentional inhibition and response inhibition bore no significant relationship to drinking frequency in the sample as a whole, or in the groups separately. However, for risk-taking, balloon pumps on the BART showed a relation to frequency of consumption, $F(2, 48) = 3.9$, $p = .05$. Further, a significant interaction showed that this relation differed by group, $F(3. 47) = 4.0$, $p = .05$. Based on this interaction, two individual bivariate regression analyses were conducted. Among those with ADHD, balloon pumps were not significantly related to frequency, $F(1, 28) = 0.3$, $p = 0.60$. By contrast, balloon pumps did predict frequency among controls, $F(1, 19) = 7.0$, $p = .02$. The regression yielded a positive slope, $b = .04$ ($se = .02$), indicating that those who displayed greater risk-taking also reported a higher weekly frequency of alcohol consumption.

4. Discussion

The present study examined the association of three behavioral components of impulsivity to quantity and frequency of alcohol consumption in young adults with ADHD and healthy controls. Results showed that individuals with ADHD displayed deficits in attentional inhibition relative to controls, but that the groups did not differ in terms of behavioral inhibition or risk-taking. Further, subjects' performance on the behavioral measures of impulsivity was associated with individual differences in their typical alcohol consumption. With regard to quantity of consumption, both poor behavioral inhibition and increased risk-taking were related to greater levels of alcohol consumption for the entire sample, regardless of group. By contrast, a relation between attentional inhibition and quantity of consumption was observed only in those individuals with ADHD. For this group, those who reported greater levels of alcohol consumption also displayed poorer levels of attentional inhibition as measured by the DOR task. With regard to frequency of consumption, only risk-taking was found to be associated with individual differences, and this was evident only for those in the control group. For this group, those who reported a greater weekly frequency of alcohol consumption also demonstrated greater risk-taking on the BART. By contrast, neither poor behavioral inhibition nor poor attentional inhibition was significantly associated with frequency of consumption.

Evidence that increased quantity of alcohol consumption was associated with behavioral measures that tap individual aspects of impulsivity is an important finding that adds to previous evidence linking impulsivity and heavy drinking. In terms of inhibitory control, these findings are consistent with previous evidence for the potential role of both behavioral and attentional inhibition in heavy, binge drinking behavior (Marczinski et al., 2007; Weafer and Fillmore, 2008). Poor cognitive functioning in general has long been associated with excessive drinking in young adults (Parsons, 1986). What is new is evidence that specific inhibitory mechanisms of cognitive functions could be especially indicative of heavy episodic drinking. Subtle impairments in the operation of inhibitory mechanisms of behavior and attention could exert considerable influence over the ability to control alcohol use

(Fillmore, 2003). Specifically, terminating a drinking episode requires inhibition of ongoing alcohol-administration behaviors and the reallocation of attention away from alcohol-related stimuli. As such, poor inhibitory functioning could impair the ability to terminate a drinking episode, resulting in unregulated binge use. Further, the finding that neither attentional nor behavioral inhibition was related to frequency of alcohol consumption provides additional support for the specificity of the potential role of inhibitory mechanisms in heavy episodic drinking. Inhibitory control does not appear to relate to how often an individual chooses to drink. Instead, these mechanisms seem to bear the strongest association with the amount of alcohol consumed once a drinking episode has begun, possibly due to the role of inhibitory mechanisms in the ability to stop the ongoing act of alcohol consumption.

The finding that greater levels of risk-taking were also associated with increased alcohol consumption demonstrates that the relationship between impulsivity and heavy drinking is not driven solely by inhibitory deficits. Additionally, the finding that risk-taking predicts both quantity and frequency of consumption provides evidence that the components of impulsivity might differentially relate to distinct aspects of alcohol consumption. Risk-taking is thought of as a form of reward-seeking despite the potential for punishment or threat. Thus, individuals do not engage in risky behaviors solely because of an inability to inhibit or control the behavior. Instead, these individuals are also motivated by the potential for reinforcement of some kind, and likely less deterred than low risk-takers by the possibility of punishment. In terms of alcohol consumption, it could be that high risk-takers display a heightened sensitivity to the pleasurable, rewarding effects of alcohol and are simultaneously less deterred by the potential for heavy, frequent alcohol use to impair school or work performance or endanger relationships with family and friends. Although intuitively appealing, few studies have examined this relation utilizing behavioral measures. The current study adds to the existing preliminary data showing an association between heightened risk-taking on a behavioral measure and greater quantity and frequency of alcohol consumption (Lejuez et al., 2002; Fernie et al., 2010; Skeel et al., 2008), thus adding to the understanding of the mechanisms through which behavioral components of impulsivity, other than inhibitory control, might relate to alcohol use.

This study also highlights some important aspects of ADHD that might contribute to the risk for alcohol abuse in these individuals. Specifically, the unique components of impulsivity associated with heavy drinking in this population might be primarily attentional in nature. Those with ADHD showed poorer levels of attentional inhibition than controls, which is consistent with previous studies involving both children and adults with ADHD (e.g., Derefinko et al., 2008; Ross et al., 1994; 2000). Moreover, poor attentional inhibition was associated with increased alcohol consumption specifically in individuals with ADHD. Previous studies have implicated attentional processes as factors contributing to risk for alcohol and other drug abuse (Blume et al., 2005; Tarter et al., 2004). Although the specific behavioral mechanisms for the association are not clear, the focus on inhibitory mechanisms of attention in the present study offers some intriguing suggestions. For example, it is possible that the compromised inhibitory functioning of attention in those with ADHD could make it more difficult to inhibit one s attention toward alcohol-related stimuli in a drinking situation, such that these stimuli maintain greater influence on one s drinking behavior.

Problems associated with poor inhibitory control might also become exacerbated once drinking has begun. Alcohol is well-known for disinhibition, and sensitivity to the acute disinhibiting effects of the drug has been linked to increased quantity of alcohol consumption within an episode (Fillmore, 2003; Marczinski et al., 2007; Weafer and Fillmore, 2008). Further, past research examining sensitivity to the drug s acute disinhibiting effects as measured by the cued go/no-go task found that adults with ADHD demonstrate increased sensitivity to alcohol-induced disinhibition compared with controls (Weafer et al., 2009). It is possible that those with ADHD might also exhibit increased sensitivity to the disruptive effects of alcohol on attentional inhibition. Alcohol acutely impairs the ability to ignore distracting stimuli and maintain focus on relevant stimuli in healthy controls (Abroms et al., 2006). Such disruptive effects might be particularly pronounced in those with ADHD, such that their selective attention might be substantially compromised even following a small number of drinks. Taken together, these findings highlight a specific mechanism that might contribute to increased risk for heavy drinking in individuals with ADHD, particularly in terms of quantity of alcohol consumed once drinking has begun.

The current findings demonstrate several intriguing relationships between behavioral components of impulsivity and alcohol use in individuals with ADHD and controls. However, it is important to recognize that these are correlational, and that the causal links among ADHD, heavy drinking, and heightened impulsivity are not yet clearly understood. As proposed in the current paper, individuals with ADHD might engage in heavy drinking behavior as a result of their poor inhibitory control. However, one might argue for the reversed causal relationship, whereby excessive alcohol use leads to deficits of inhibition. Indeed, chronic heavy alcohol intake has been linked to impairment of frontal lobe functioning, including inhibitory control (Bates et al., 2002; Lyvers, 2000; Parsons and Nixon, 1998). However, these impairments are often observed in older adults who have been regularly consuming large quantities of alcohol for periods of over twenty years. Because the current study examined young adults who reported drinking alcohol regularly for an average of only five years, it is unlikely that the inhibitory deficits observed in this sample were a result of heavy alcohol consumption. However, future research involving longitudinal studies is needed in order to isolate the causal factors in these relationships.

It is also important to consider the generalizability of these findings, especially with regard to individuals with externalizing disorders for which impaired inhibitory control is implicated. In children, subtypes of ADHD (inattentive vs. combined) are well recognized for their different clinical profiles regarding the primary deficit of the disorder (attentional vs. impulsive). Specifically, some research suggests important differences between children of the inattentive subtype versus those with the combined type in the degree to which inhibitory deficits are manifest in attentional versus behavioral domains (Adams et al., 2008; Derefinko et al., 2008). As research allows for the subtypes of ADHD in adulthood to become more well-defined, these distinctions should be incorporated into future studies examining inhibitory mechanisms in adults with ADHD.

The medication state of those with ADHD also needs to be considered. It might be argued that the present findings underestimate the performance of these individuals because they were tested while off of their ADHD medication. However, not all adults with ADHD continue taking medication, and of those who do, many report inconsistent and unreliable adherence to the medication (Perwien et al., 2004; Safren et al., 2007). Medication might be used more often on the weekdays, during work or school where the symptoms of disinhibition are the most disruptive. However, most drinking episodes likely occur at night and on weekends, when these individuals might be less inclined to use medication. Thus, it is important to understand how impaired inhibitory control in an unmedicated state contributes to heavy drinking.

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Table 1

Mean Demographics, ADHD Symptom Scales, and Drinking Habits Scores by Group

	Group				Contrasts
	ADHD		Controls		
	M	***SD***	***M***	***SD***	
Demographics					
Education (years)	15.0	1.0	15.1	1.5	ns.
IQ: Verbal	103.6	10.2	107.0	7.3	ns.
IQ: Nonverbal	106.6	8.1	111.4	7.5	Sig*
ADHD Scales					
CAARS-S:L ADHD Symptom Scale	73.2	10.7	46.7	8.8	Sig***
ADD/H ASRS	21.1	5.5	6.1	4.2	Sig***
ADHD Symptom Checklist	6.8	2.8	1.0	1.6	Sig***
PDHQ					
Quantity (typical dose; ml/kg)	1.0	0.6	1.0	0.5	ns.
Frequency	1.2	1.0	1.5	1.1	ns.
Drinks	4.2	2.3	4.2	2.3	ns.
Duration	3.6	1.3	3.4	1.5	ns.
History	61.0	29.0	60.0	26.5	ns.

Note. Group contrasts were tested by independent samples *t* tests. Sig* indicates a significance value of $p < .05$. Sig*** indicates a significance value of $p < .001$.

Table 2

Mean Scores on Behavioral Measures of Impulsivity by Group

	Group				Contrasts
	ADHD		Controls		
	M	*SD*	*M*	*SD*	
Attentional inhibition (Premature saccades)	10.2	6.0	5.8	4.5	Sig**
Behavioral inhibition (P-inhibitory failures)	0.05	0.05	0.04	0.05	ns.
Risk taking (Balloon pumps)	46.1	15.5	44.1	13.1	ns.

Note. Group contrasts were tested by independent samples *t* tests. Sig** indicates a significance value of $p < .01$.

Table 3

Results from Hierarchical Regressions of Quantity of Alcohol Consumption on Behavioral Measures of Impulsivity

Behavioral Measure			**df**	**b**	**SE b**	**Δ R^2**
Attentional inhibition (Premature saccades)	Step 1	Group classification (ADHD vs. controls)	1, 52	0.03	0.16	.00
	Step 2	Premature saccades	2, 51	0.01	0.01	.01
	Step 3	Group x premature saccades	3, 50	0.07	0.03	.11*
Behavioral inhibition (P-inhibitory failures)	Step 1	Group classification	1, 52	0.03	0.16	.00
	Step 2	P-inhibitory failures	2, 51	3.82	1.48	.12*
	Step 3	Group x p-inhibitory failures	3, 50	−1.72	3.06	.01
Risk-taking (Balloon pumps)	Step1	Group classification	1, 49	0.02	0.16	.00
	Step 2	Balloon pumps	2, 48	0.01	0.01	.07
	Step 3	Group x balloon pumps	3, 47	−0.02	0.01	.05

Note.

* indicates a significance value of $p < .05$.

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Table 4

Results from Hierarchical Regressions of Frequency of Alcohol Consumption on Behavioral Measures of Impulsivity

Behavioral Measure			df	b	SE b	Δ R^2
Attentional inhibition (Premature saccades)	Step 1	Group classification (ADHD vs. controls)	1, 52	−0.27	0.28	.02
	Step 2	Premature saccades	2, 51	0.01	0.03	.00
	Step 3	Group x premature saccades	3, 50	0.03	0.06	.01
Behavioral inhibition (P-inhibitory failures)	Step 1	Group classification	1, 52	−0.27	0.28	.02
	Step 2	P-inhibitory failures	2, 51	2.38	2.81	.01
	Step 3	Group x p-inhibitory failures	3, 50	−3.21	5.84	.01
Risk-taking (Balloon pumps)	Step1	Group classification	1, 49	−0.31	0.27	.03
	Step 2	Balloon pumps	2, 48	0.02	0.01	.07*
	Step 3	Group x balloon pumps	3, 47	−0.04	0.02	.07*

Note.

* indicates a significance value of $p < .05$.