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Decision Making and Binge Drinking: A Longitudinal Study

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Abstract

Background: Behavioral decision making, as measured by the Iowa Gambling Task (IGT) is found to be diminished in individuals with substance dependence and other types of disinhibitory psychopathology. However, little is known regarding the relation between heavy alcohol use and decision-making skills in young adults. This study therefore investigated whether binge drinking is related to disadvantageous decision making, as measured by the IGT. We also examined the relation between decision making and impulsivity.

Methods: Latent class growth analysis was used to classify college students into 4 groups (each group *n* = 50, 50% male), based on their binge drinking trajectories over a 2-year time period (precollege through second year of college). Participants were 200 college students, divided in 4 subgroups: (1) low binge drinkers, (2) stable moderate binge drinkers, (3) increasing binge drinkers, and (4) stable high binge drinkers. A measure of decision making, the IGT, impulsivity questionnaires, and multiple indicators of heavy alcohol use were included.

Results: The stable high binge-drinking group made less advantageous choices on the IGT than the low binge-drinking group. Impulsivity was not related to decision-making performance. Decision-making performance did not differ by gender, but deck preferences and decision time patterns did differ; women preferred low frequency, high amount punishments to a greater extent than men.

Conclusions: Although disadvantageous decision making is related to binge-drinking patterns in emerging adulthood, this relation is independent of impulsivity. Additionally, the association appears attributable to those who engage in heavy (binge) drinking at an early age, but not to age of onset of drinking in general.

Keywords

Alcohol Use; Neurocognition; Reward Sensitivity; College Population; Gender

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Alcohol dependent individuals perform worse than controls on tests of neurocognitive functions. For example, persons with a history of alcohol dependence display disadvantageous decision making compared with persons without substance dependence (Bechara et al., 2001). Also, diminished executive functions, that is, self-regulatory functions necessary for goal-directed behavior, have been found in persons with alcohol dependence (for a review, see Giancola and Moss, 1998). Heavy social drinkers (i.e., 21 drinks or more per week) have also been found to display mild deficits on a variety of neurocognitive functions, such as attention, memory, and visuospatial abilities (for a review, see Parsons and Nixon, 1998).

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Notably, recent neurobehavioral addiction theories have highlighted relations between substance dependence and neural dysfunction, particularly in the ventromedial prefrontal cortex, striatum, and basal ganglia (Goldstein and Volkow, 2002). These brain areas are important in neurocognitive functions involving the evaluation and appraisal of positive and negative consequences, functions which play a role in decision making (Krawczyk, 2002). To date, however, no studies have examined the relation between different longitudinal patterns of alcohol use and decision making or other affective neurocognitive functions.

Decision-making skills may be especially important during late adolescence and young adulthood, as this is often a time of change, identity development, and educational and career development. In addition, young adulthood is often a period of heavy alcohol use. For example, a recent study reported that 23% of college students were frequent binge drinkers, and 44% engaged in binge drinking in the past 2 weeks (Wechsler et al., 2000). Some studies suggest that the adolescent brain may be particularly vulnerable to the harmful effects of alcohol. Recent studies indicate that binge drinking has a more detrimental effect on brain structure and functioning in adolescent, compared with adult rats (Crews et al., 2000; Monti et al., 2005). Notably, in humans, the pre-frontal lobes mature throughout adolescence, and into early adulthood (Casey et al., 2000). Therefore, decision-making skills, which rely on prefrontal lobe functioning, may be especially vulnerable to the effects of heavy alcohol use during adolescence.

Recent research has highlighted considerable variability in drinking patterns (Cho et al., 2001; Mundt et al., 1995; Searles et al., 2000), and it is unclear whether different drinking trajectories are differentially related to neurocognitive functioning. Therefore, in this study, 200 participants were selected from a large longitudinal study, based on their drinking course over a recent 2.5-year period. Four groups of college students were included, differing in onset and amount of binge drinking. Thus, we were able to investigate what patterns of heavy (binge) drinking were related to diminished decision making. In the alcohol and drug-use literature, an abundance of studies indicate that different developmental trajectories exist for binge drinking. These studies consistently find the existence of stable-low, increasing, and stable-high subgroups (Chassin et al., 2002; Hill et al., 2000; Tucker et al., 2003), with increasing and stable-high subgroups having a higher prevalence in college student samples (Schulenberg and Maggs, 2002). When different drinking trajectories are associated with differences in decision making, this could have consequences for the way in which prevention and intervention strategies target binge drinking, such as targeting groups with a specific binge drinking trajectory (Jackson et al., 2004).

Another possibility in explaining differences in decision-making abilities and drinking patterns, may be differences in age of onset of drinking. Differences in age of onset of drinking may indicate being in a more advanced phase of a progression of drinking behavior, or a more severe binge-drinking pattern. Therefore, the effect of age of onset of drinking was examined as well.

Recently, controversy surrounds the definition of binge drinking, as the traditional definitions of binge drinking (5/4 drinks per occasion) may be too low for patterns of binge drinking in college students (White et al., 2006). We sampled students on the traditional measure of 5 drinks within 1 sitting, and thus, this measure of binge drinking may underestimate heavy binge drinking. However, binge drinking and a measure of quantity/frequency of alcohol use in this college student sample are highly correlated. We therefore refer to heavy (binge) drinking, or to alcohol use trajectories, and not solely to binge drinking.

The current study thus examined relationships between several longitudinal patterns of heavy (binge) drinking, and decision-making skills in a sample of young adults. Decision making was studied using the Iowa Gambling Task (IGT; Bechara et al., 1999). In the IGT, participants play a computerized card game in which they attempt to develop a winning strategy by selecting cards from advantageous, as opposed to disadvantageous decks. Participants have to learn, over the course of the task, which decks are advantageous and which are disadvantageous. Disadvantageous choice patterns on the IGT have been found in a substantial number of studies of people with ventromedial prefrontal lobe damage (Bechara et al., 1994, 2001; but see Manes et al., 2002), and populations with a variety of disinhibited behaviors (Goudriaan et al., 2005; Grant et al., 2000; Rotherham-Fuller et al., 2004; van Honk et al., 2002; Whitlow et al., 2004).

Other factors have also been found to affect IGT performance. In particular, attention deficit hyperactivity disorder (ADHD) is negatively related to performance on decision-making tasks (Ernst et al., 2003a, 2003b; Murphy et al., 2001; Raghunathan and Pham, 1999) and is also associated with alcohol dependence (Farrell et al., 2001; Kessler et al., 1997). Higher impulsivity has been related to both poor IGT performance (Crone et al., 2003) and heavy alcohol use (Waldeck and Miller, 1997). A secondary aim of this study therefore was to investigate the influence of both externalizing psychopathological symptoms and impulsivity, on IGT performance.

We were also interested in the relation between gender and decision making. The literature on gender and IGT performance is mixed. Two studies of IGT performance have found that women perform less well than men (Bolla et al., 2004; Reavis and Overman, 2001), but other studies have not found gender differences in performance levels (Crone et al., 2003; Fein et al., 2004, 2006; Hooper et al., 2004). One of these studies *did* indicate a difference in frequency of punishment preference between girls and boys, with both girls and boys preferring lower frequency punishments of a higher amount, but girls having a stronger preference for this response option (Hooper et al., 2004). A brain imaging study reports that men and women also activated different orbitofrontal brain areas during IGT performance (Bolla et al., 2004). Our study consisted of a comparatively large young adult sample with equal gender distribution, and was thus especially suitable for studying the effects of gender on IGT performance and contingency preferences.

In summary, the current study is the first to examine relations between decision making and longitudinal heavy (binge) drinking patterns in a large, mixed-gender sample of young adults. In addition, this study examined the degree to which externalizing psychopathology, impulsivity and gender affected the IGT/binge-drinking relation. We aimed to determine whether low-binge drinkers differed from (a) students who engaged in moderate-binge drinking, (b) students who increased their binge drinking when entering college, (c) students who engaged in high-binge drinking both before entering college, and throughout the first 2 college years. We hypothesized that consistent high levels of binge drinking and heavy alcohol use would have a detrimental effect on decision making, as measured by the IGT.

MATERIALS AND METHODS

Participants

This study consists of a subgroup of 200 participants from an ongoing longitudinal study of college student health [The Intensive Multivariate Prospective Alcohol College-Transitions Study (IMPACTS)]. A detailed description of ascertainment success is reported in Sher and Rutledge (2007) but a brief overview is presented here. At baseline (wave 0: the summer before freshman year), all incoming students at the University of Missouri-Columbia ($N = 4{,}266$) were asked to complete a paper and pencil survey assessing their substance use and health-related behavior over the past 12 months. Eighty-eight percent ($N = 3{,}720$) of students completed the questionnaire at wave 0 (46% male, 90% Caucasian, mean age = 17.96). They were recontacted during the fall and spring of each year after entering college and asked to complete on-line, follow-up surveys assessing their substance use and health-related behavior over the past 3 months. There were 2,533 (68%), 2,450 (66%), 2,255 (61%), 2,482 (67%), 2,340 (63%), and 2,357 (63%) individuals remaining in the study at waves 1 to 6, respectively. The institutional review board of the University of Missouri-Columbia approved this study. All participants gave their informed consent before inclusion in the study.

We used latent class growth analyses (LCGA) to place each IMPACTS participant into a binge drinking group, using MPlus (Mutheén and Muthén, 1998–2006). Participants were classified based on their answers to the question “How many times in the past 30 days did you have 5 or more alcoholic drinks on one occasion” (answer options: “Never”; “Once in the past 30 days”; “2–3 times in the past 30 days”; “1–2 times a week”; “3–4 times a week”; 5–6 times a week”; “nearly every day”; “every day”; or “twice a day or more”). At waves 0 to 4, participants were classified as binge drinkers when they answered “2–3 times in the past 30 days” or any higher frequency, and as nonbinge drinkers when they answered “Once in the past 30 days” or “Never in the past 30 days.” Comparing the model fits of a 2-class [Bayesian Information Criterion (BIC) = 11,355.7), a 3-class (BIC = 11,297.3), a 4-class (BIC = 11,288.6), and a 5-class model (BIC = 11,308.3), a 4-class solution was chosen (model fit compared with a 3-factor model, Lo-Mendell-Rubin adjusted likelihood ratio test value: 23.47, $p<0.001$). There were 2,866 participants who participated in at least 2 waves. These participants were classified as either: (1) low-binge drinkers at all time points (36% of the sample, $N = 1{,}032$); (2) moderate-binge drinkers at all time points (30%, $N = 860$); (3) increasing binge drinkers, with low binge-drinking levels at wave 0, but increasing in binge drinking at wave 1, 2, 3, and 4 (10%, $N = 286$); (4) heavy binge drinkers from waves 0 to 4 (24%, $N = 688$).

For the purposes of the current study, we randomly sampled 25 male and 25 female participants from each of these 4 classes, on the condition that they had participated in all 5 waves up until that point, and invited them for participating in the currently reported neurocognitive study. To assure that alcohol use characteristics were similar between the subsample of persons included in the neurocognitive study and the full sample of the classes they were sampled from, we examined group comparisons of the binge-drinking question at the 5 waves, using a repeated measures ANOVA, with group (4), subsample (included versus not included) as between-subjects factors, and time (5 waves) as a within-subjects factor. For the non-binge-drinking group, the quantity/frequency measure of alcohol use was taken as a measure (“Alcohol use measures”), as the binge-drinking question had a floor effect. No significant main effects of group or interaction effects of time and group were found. Figure 1 shows the probabilities of engaging in frequent binge drinking (2 or more times/mo) for each group, across time. Figure 2 shows the number of alcoholic beverages per week (quantity/frequency measure of alcohol use) for the different groups for the entire study period. Table 1 shows the mean posterior probabilities of latent profile group membership. Table 1 indicates that the strongest separation among the profiles was present for the high and low binge-drinking groups (see boldface numbers). Table 2 shows demographic information for these 4 subgroups, along with information on their alcohol use and impulsivity scores. The 4 groups did not differ in age, gender, or ethnic background. The groups also did not differ on the ACT (American College Test). As expected, the groups differed in weekly alcohol use (quantity/frequency measure) at wave 1 [ANOVA; $F(3, 192) = 29.5$, $p<0.01$]. Specifically, the low binge-drinking o group differed from all the other binge-drinking groups ($p<0.01$). The age of a first full alcoholic beverage also differed across groups (ANOVA; $F(3, 188) = 6.75$, $p<0.01$). The low binge-drinking group had their first o alcoholic drink at a later age than the high binge-drinking group ($p<0.01$), and a trend was present for a later age at first drink when comparing the low binge-drinking group to the increasing binge-drinking group ($p = 0.08$). Past-month smoking habits did not differ between the 4 groups. Figure 2 indicates weekly alcohol use quantity for the 4 groups, the time period used to classify students in 1 of the 4 groups, and the time of administration of the IGT.

Iowa Gambling Task

A computerized version of the IGT was used, as described by Bechara et al. (1999). The IGT was administered at the end of the study period, between waves 5 and 6. In the IGT, subjects made a total of 100 card selections from 4 decks of cards. With each card selection, participants won and lost a predetermined amount of imaginary money (e.g., after selecting a card, a message appeared on the screen that said “You won (amount) dollars and you lost (amount) dollars.” Unbeknown to the participant, there were 2 disadvantageous decks (decks A and B), which were associated with large rewards, but also with large losses, and choosing these decks resulted in net losses over the course of the task. In contrast, there were 2 advantageous decks (decks C and D), which were associated with small rewards, but also small losses, and these decks resulted in a net gain over the course of the task. Participants had to learn which decks were advantageous in the long run. They selected a deck by clicking on 1 of the decks with the left mouse button. The task ended after 100 card selections were made. Each deck contained 60 cards. Reaction times were measured for each selection made. Participants were not given any actual money. Instructions included a “hint” that some decks were worse than others. Research has shown that the choice of real versus fake money does not influence performance on the IGT, when the hint condition is used (Bowman and Turnbull, 2003; Fernie and Tunney, 2006).

Within both the advantageous and the disadvantageous decks, 1 deck resulted in frequent small losses (disadvantageous deck A, advantageous deck C) and 1 deck resulted in infrequent large losses (disadvantageous deck B, advantageous deck D). As frequency of punishment could influence the groups differently, a preliminary analysis was performed to discover whether group or gender effects existed for the number of cards selected from decks with high or low punishment frequency.

The dependent measure for general performance on the IGT was the number of cards picked from the advantageous decks in the first 4 stages of the task (cards 1–20, 21–40, 41–60, and 61–80). Thirtynine participants (20% of the total sample) finished all the cards in a deck (predominantly C or D) in the fourth stage (cards 61–80). After finishing all cards in one of the decks, they started sampling cards from the 3 remaining decks again, thus producing an artifact in the data. Therefore, the last stage (cards 81–100) was not included in the analyses.[1] Feedback processing was investigated by analyzing decision-making time after net wins and losses, as well as response shifting after net wins and net losses. Decision-making time was computed as the time starting directly after presentation of the text “Choose a Card” on the computer screen, until the next button press. Thus, the time of reading the choice result, indicating wins and/or losses, was not included in the decision time.

Impulsivity Self-Report Measures

Impulsive Sensation Seeking Scale (ImpSS)—This subscale was taken from the Zuckerman-Kuhlman Personality Questionnaire (Zuckerman et al., 1993), and has 19 items (yes/no format). The task measures aspects of impulsivity and sensation seeking. The internal reliability ranges from 0.77 to 0.82.

Barratt Impulsivity Scale (BIS)—This 30-item scale (4-choice Likert type) has 3 subscales: motor impulsiveness, attentional impulsiveness, and nonplanning impulsiveness

[1]A very high correlation (Pearson's $r = 0.95$) was present between the total number of choices of the advantageous decks (trials 1–100) and the first 4 stages of the task (trials 1–80), for those persons who did not finish all cards in one of the advantageous decks.

(Patton et al., 1995). Adequate reliability has been established for the BIS-11, with Cronbach's a between 0.79 and 0.83. For the purposes of this study, only the total score was used.

Diagnostic Interview Schedule (DIS; Robins et al., 1998)—This structured interview contains questions assessing all DSM-IV diagnostic criteria. For this study, the following sections were included: alcohol use disorders (AUDs), substance use disorders (SUDs), pathological gambling, ADHD, conduct disorder (CD), oppositional defiant disorder (ODD), antisocial personality disorder (ASPD), anxiety disorders, depressive episodes (single or multiple), eating disorders, and obsessive–compulsive disorder (OCD). Table 3 shows the prevalence of these disorders in each binge-drinking group: alcohol abuse (mean = 1.5, range 1–4); alcohol dependence (mean = 3.8, 3–7); nicotine dependence (mean = 3.8, 3–6); cannabis abuse (mean = 1.23, 1–2); cannabis dependence (mean = 3.4; 3–4); CD (mean = 1.45, 1–4); ASPD (mean = 3.63, 3–6); anorexia nervosa (mean = 5.2, 4–6); bulimia nervosa (mean = 6); manic and/or depressive episodes (mean = 6.14, 4–7); panic disorder (mean impairment = 2, moderate); social phobia (mean impairment = 1.9, moderate); major depressive episode (mean = 7.4, 5–9); OCD (mean impairment = 1.75, mild/moderate). Because no participants were diagnosed with ADHD, ODD, or pathological gambling, these disorders were not included in Table 3. The prevalence of most of these disorders was low, and therefore we used symptom counts (rather than diagnoses) for most of the externalizing disorders (ADHD, CD, ASPD) and for internalizing disorders (anxiety disorders, depression, and OCD).

Alcohol Use Measures

In addition to our primary measure of binge drinking described earlier, and the DIS-IV interview measure of AUDs, we created a *heavy alcohol use composite score* comprised of the following IMPACTS items; (1) frequency of getting lightheaded or a little high on alcohol, (2) frequency of getting drunk, and (3) frequency of having 5 or more drinks at 1 sitting. These 3 questions had good reliability, with coefficient α ranging from 0.89 to 0.94 during the different data collection waves (waves 0–6). Furthermore, a quantity/frequency measure of alcohol use was included, based on a question on the average quantity of alcohol used on each occasion, and the average frequency of drinking occasions in a week.

Statistical Analyses

Omnibus repeated measures MANCOVAs were performed to detect overall group differences and group by factor (advantageous deck choices; frequency of punishment choices) interactions. The nature of overall group effects and group by factor interactions was investigated using pairwise group comparisons between the low binge-drinking group, and the 3 other binge-drinking groups (moderate, increasing, and high). All pairwise group comparisons were performed with a Bonferroni correction, and indicated with the corrected *p* value. The ACT composite score was used as a covariate in the MANCOVAs to control for general educational development, as education has been shown to affect IGT performance (Evans et al., 2004).

Feedback processing analyses focused on differences in overall response times, and response times after wins and losses. As the IGT involves learning a strategy, and most of the participants learned to choose the advantageous decks over time (see Fig. 3), response time analyses focused on the first 60 IGT choices, representing the first 3 learning stages, to avoid artifacts caused by fast response times after participants had learned to choose one or more of their "favorite" decks.

A regression analysis was performed to investigate the relation between drinking at different timeperiods and IGT performance. Separate analyses were performed for participants with and without a lifetime diagnosis of alcohol abuse or dependence, cannabis abuse or dependence, and nicotine dependence. Pearson's correlations were calculated between IGT performance and symptom counts of comorbid disorders and impulsivity measures.

RESULTS

Eight participants were excluded from analyses because their IGT data deviated more than 3 times the interquartile range from the 25th or 75th percentile. Logit transformations were performed on the data, as the distribution of the data deviated from normality: Logit (p+1) = ln [p+1/1 − p+1] (see also Yechiam et al., 2005). To facilitate comparison with other studies, we present original data in all figures. The binge-drinking variable, and the quantity/frequency measure of alcohol use, correlated highly in this college student sample, with Pearsons's r between 0.81 and 0.88 for each of these measures for the same data waves. Therefore, we refer to heavy (binge) drinking in this paper, as the effects of heavy drinking and binge drinking are not separable in this sample.

Iowa Gambling Task

Effects of Punishment Frequency—To examine whether frequency of punishment affected deck choice, a repeated measures ANCOVA was performed with stage (4 blocks of 20 trials) and frequency of punishment (high or low) as within-subjects factor and binge-drinking group as a between-subjects factor. An effect of frequency of punishment was present, $F(1, 184) = 175.8$, $p<0.001$, $\eta^2 = 0.49$. More cards were picked from infrequent punishment decks than from the frequent punishment decks. As a frequency by gender effect was present, $F(1, 184) = 14.31$, $p<0.01$, $\eta^2 = 0.07$, frequency of punishment was included in the IGT analyses below. No significant frequency by stage effect was present, $F(3, 182) = 0.94$, $p<0.42$, $\eta^2 = 0.01$.

IGT Decision-Making Performance—A repeated measures MANCOVA was performed, with binge-drinking group as a between subjects factor, stage (4 blocks of 20 trials) as a within-subjects factor and number of cards picked from the advantageous versus disadvantageous decks (advantageous), as well as number of cards picked from high frequency punishment versus low frequency punishment decks (frequency) as dependent measures. The ACT composite score was used as a covariate. Only main and interaction effects for group and gender are reported. An interaction between advantageous choices and group was found, $F(3, 184) = 5.40$, $p<0.01$, $\eta^2 = 0.08$, indicating that the groups differed with regard to the number of cards picked from the advantageous and disadvantageous decks. No interaction between stage and group was present. As can be seen in Fig. 3, all groups had positive slopes, indicating that they learned to choose the advantageous decks over time. Pairwise group comparisons revealed that low-binge drinkers selected advantageous decks more frequently than high-binge drinkers, $F(1, 92) = 12.86$, $p<0.01$, $\eta^2 = 0.12$. The low binge-drinking group did not differ from the moderate [$F(1, 89) = 4.33$, $p = 0.12$, $\eta^2 = 0.046$], or the increasing binge-drinking group [$F(1, 93) = 3.70$, $p = 0.16$, $\eta^2 = 0.038$]. An interaction between the ACT composite score and choices from the advantageous decks was found, [$F(1, 184) = 11.30$, $p<0.01$, $\eta^2 = 0.06$], indicating that participants with higher ACT composite scores chose more cards from the advantageous decks. Neither gender differences in advantageous deck choice, nor gender by group interactions were present. However, a gender by frequency effect was found, [$F(1, 184) = 14.31$, $p<0.01$, $\eta^2 = 0.07$], indicating that whereas both women and men preferred low frequency/high amount punishments, women preferred low frequency/high amount punishments to a greater degree then men (women: 70.0%; men: 60.5%).

Exploratory Analysis of Heavy Alcohol Use and IGT Performance

As noted earlier, the chronic high binge-drinking group differed from the low binge-drinking group on IGT performance. Notably, however, there were no IGT differences between the increasing binge-drinking group, or the moderate binge-drinking group, and the low binge-drinking group. As a result, we were interested in whether early heavy drinking was more predictive of IGT performance than later heavy drinking. To address this question, we conducted a regression analysis using our heavy alcohol use composite score (frequency of getting lightheaded or a little high on alcohol; frequency of getting drunk; frequency of having 5 or more drinks at 1 sitting) at waves 0 to 4 as independent predictor of IGT performance in a simultaneous multiple regression equation. As the heavy alcohol use composite scores could be highly correlated, data were checked for multicollinearity. Multicollinearity did not affect the regression estimation, as tolerance values ranged from 0.68 to 0.72. Results showed that the heavy alcohol use composite score at waves 0 ($\beta = -0.29$, $p<0.01$) and 2 ($\beta = -0.27$, $p<0.01$), but not at waves 1($\beta = 0.07$, $p = 0.41$), 3 ($\beta = 0.06$, $p = 0.66$), or 4 ($\beta = 0.12$, $p = 0.26$), were predictive of disadvantageous IGT performance.

Feedback Processing Analyses

Median reaction times after rewards and after net losses were calculated. An ANCOVA was performed with binge drinking group as a between-subjects factor and contingency (reward or loss) as a within-subjects factor. Response speed after losses was faster than after wins, $F(1, 180) = 19.20$, $p<0.001$, $\eta^2 = 0.09$. No group effects or group by contingency interactions were found. A significant effect of gender was present, $F(1, 180) = 9.37$, $p<0.01$, $\eta^2 = 0.05$, with women (RT = 715.1 ms, SD = 280.3 ms) responding slower then men (RT = 601.8 ms, SD = 231.7 ms). The effect of gender was qualified by a gender by contingency interaction, $F(1, 180) = 4.41$, $p<0.05$, $\eta^2 = 0.025$. Men tended to respond faster after losses than after wins (difference score = 96.1 ms), whereas in women, this effect was smaller (difference score = 33.0 ms).

IGT Response Shifting After Rewards and Net Losses

An ANCOVA with binge-drinking group as a between-subjects factor and contingency (wins and losses) as a within-subjects factor was performed to investigate whether wins or net losses resulted in change of deck choice on the next trial. Percentage of change after rewards or net losses was included as the dependent variable. An overall effect of contingency was present, $F(1, 180) = 412.3$, $p<0.01$, $\eta^2 = 0.70$. A higher percentage of change was present after losses than after wins. No group effect or group by contingency interaction was present. A gender effect was found, $F(1, 180) = 4.60$, $p<0.05$, $\eta^2 = 0.02$, which was qualified by a gender by contingency interaction, $F(1, 180) = 18.92$, $p<0.01$, $\eta^2 = 0.10$. Both men and women switched equally after wins (women: 36.5% change; men: 36.9% change), but women switched more than men after losses (women: 78.5% change; men: 63.9% change).

Comorbid Psychopathology

As a lower prevalence of alcohol abuse and dependence was present in the low binge-drinking group (see Table 3), compared with the other binge-drinking groups, a repeated measures MANCOVA was performed to investigate whether group differences were due to differences in lifetime AUDs. Persons with lifetime alcohol abuse/dependence were categorized in one group ($n = 64$), and participants without lifetime diagnoses ($n = 124$) were categorized in a second group. No group by advantageous choice interactions were present ($p = 0.28$), indicating that the presence or absence of a lifetime alcohol use/dependence diagnosis did not affect performance on the IGT. Similar analyses for the other diagnoses with a relative high frequency were also nonsignificant: cannabis abuse/dependence ($p = 0.52$), nicotine dependence ($p = 0.23$).

No significant correlations were found between IGT performance and (1) a symptom count of all externalizing disorder symptoms (ADHD, CD, ASPD, AUDs, cannabis abuse/dependence;

$r = 0.04$) and (2) a symptom count of internalizing disorder symptoms (depression symptoms, anxiety symptoms, and OCD symptoms; $r = -0.02$).

Age of Onset of Alcohol Use and IGT Performance

We ran post-hoc analyses on the effects of age of onset of alcohol use, and IGT performance, as the different binge-drinking groups differed on this variable (we thank an anonymous reviewer of an earlier version of this manuscript for suggesting this analysis). The relevant variables were entered in a series of regression analyses, using gender as a control variable. Age of onset of recreational alcohol use did not predict the total advantageous choices made on the IGT (standardized $\beta = -0.01$, $p = 0.86$), nor did age first got drunk (standardized $\beta = -0.02$, $p = 0.78$), or age of first full drink (standardized $\beta = -0.01$, $p = 0.94$). The quantity/frequency measure of alcohol use during precollege (wave 0) did predict advantageous choices on the IGT (standardized $\beta = -0.21$, $p = <0.01$), as did binge drinking during precollege (standardized $\beta = -0.20$, $p<0.01$). Thus, higher alcohol use, and higher binge drinking predict less advantageous decision making on the IGT.

Impulsivity and IGT Performance

Impulsivity scores on the Barratt Impulsiveness Scale and the Impulsivity/Sensation Seeking Scale differed among the 4 groups. Specifically, the moderate-binge and high-binge drinkers had higher scores on the Barratt Impulsiveness Scale than the low-binge drinkers. On the Impulsivity/Sensation Seeking Scale, the increasing binge drinkers and the moderate-binge drinkers had higher scores than the low-binge drinkers (see Table 2).

Correlations between the IGT performance measure and impulsivity and alcohol use measures were computed. No significant correlations were present between the IGT, and either the BIS or the ImpSS. However, significant correlations between the aggregated alcohol quantity/frequency measure for wave 0 to 4 with the BIS sumscore ($r = 0.19$, $p<0.05$) and with the ImpSS sum score ($r = 0.24$, $p<0.01$) were present. Similar correlations were found for the aggregate score of binge-drinking wave 0 to 4, with the BIS sumscore ($r = 0.18$, $p<0.05$) and with the ImpSS sum score ($r = 0.19$, $p<0.01$).

DISCUSSION

Heavy Alcohol Use and IGT Performance

The main finding of our study was diminished IGT performance in chronic high-binge drinkers versus students who are consistent low-binge drinkers. Moreover, heavy alcohol use at an earlier time (precollege; wave 0, and spring of the freshman year; wave 2) was more strongly related to diminished decision-making skills than heavy alcohol use in the period directly before IGT performance. As the indicators of alcohol use were stable over the college years before IGT performance (waves 1–4, see Table 2 and Fig. 2), the findings that earlier heavy alcohol use had a larger effect on IGT performance than later alcohol use, cannot be explained by a decrease in alcohol use during waves 1 to 4. Both heavy alcohol use before college (wave 0) and during spring of freshman year (wave 2) were related to IGT performance, whereas heavy alcohol use was not related to IGT performance for the start of the first college year (wave 1), and for waves 3 and 4. The absent relation during wave 1 could be related to temporarily unstable patterns of alcohol use, during the period of adjusting to college life (freshman year; autumn), with alcohol use patterns stabilizing again at wave 2 (freshman year; spring). Thus, a stronger relation between heavy alcohol use and diminished IGT performance seems to be present for late adolescence (ages 18–19), compared with young adulthood (ages 20–21), but a definite conclusion cannot be drawn.

The presence or absence of AUDs per se did not influence IGT performance. It may seem that these findings contradict research findings that indicate that alcohol dependence is associated with diminished neurocognitive functions. However, it should be noted that this college population, with relatively mild mean AD symptom count (3.8), and alcohol abuse symptom count (1.5), differed considerably from samples in studies on neurocognitive functions and alcohol dependence, which usually recruit older, chronic alcohol-dependent individuals in treatment settings. Our finding that heavy chronic (binge) drinking was associated with diminished IGT performance is consistent with studies showing that more prolonged, heavier alcohol use in alcohol dependent individuals is associated with decreased neurocognitive functions, compared with normal neurocognitive functions in alcohol dependent individuals with a less severe drinking pattern (Horner et al., 1999; Svanum and Schladenhauffen, 1986). In this study, a quantity/frequency measure of alcohol use, and binge drinking were associated with IGT performance, whereas none of the 3 measures of age of onset of alcohol use was related to IGT performance. Owing to the very high correlations between the quantity/frequency-based measure of alcohol use and binge drinking (Pearson's r between 0.81 and 0.89), it was not possible to discern whether the quantity/frequency of drinking, or the pattern of drinking, is of crucial influence for diminished IGT performance. However, we can conclude that heavy (binge) drinking is related to less advantageous decision making, and age of onset of alcohol use is not related to decision making.

Psychopathological symptoms did not influence IGT performance. Externalizing disorders in adolescence are associated with alcohol use and abuse (Marmorstein, 2006; Rohde et al., 2001; Stice et al., 1998), and earlier alcohol use or abuse may thus reflect a more deviant behavior, which could in turn lead to a spurious association between alcohol use and IGT performance. However, this argument was not confirmed in this study, as neither comorbid externalizing nor internalizing psychopathology were related to IGT performance. Likely, the low symptom counts, even among those diagnosed with a comorbid disorder, were related to this finding.

Impulsivity and IGT Performance

Differences in self-report measures of impulsivity were not related to IGT performance. Although one study in a student population found that high-impulsive and low-impulsive students differed in IGT performance (Crone et al., 2003), our study did not corroborate these findings. This could have to do with sampling method. The other study selected students from the most extreme scoring segments of a student sample, whereas our sample did not employ an extreme groups design. Also, the IGT is a decision-making task, in which an advantageous strategy has to be detected. Although impulsivity may influence decisions in the first series of choices on the IGT, its influence likely declines when the task progresses, unless extreme scoring groups are selected. Consistent with our findings, another study using an unselected sample also reported no association between impulsivity and IGT performance (Franken and Muris, 2005). Our finding that impulsivity is related to quantity/frequency measures of alcohol use and binge drinking, suggests that both decision making and impulsivity are related to higher levels of (binge) drinking, and that the contributions of these 2 factors are at least partly independent.

Gender and IGT Performance Strategy

This study included one of the largest samples (N = 200) of young men and women in the IGT literature. Our findings indicate that men and women perform equally well on the IGT, but that they implement different strategies. This finding contrasts with 2 other studies which found that women perform less well than men on the IGT (Bolla et al., 2004; Reavis and Overman, 2001), but is consistent with a recent study that found no gender differences in IGT performance in a sample of alcohol-dependent patients and a control group (Fein et al., 2006). In our study, no performance differences were found, but preferences for punishment contingencies differed between the sexes: Whereas both women and men preferred low frequency high punishments over high frequency low punishments, women preferred this choice pattern more than men. Notably, this gender difference has also been found in children and adolescents, suggesting that gender differences in contingency preference may persist over time (Hooper et al., 2004). Men responded more quickly than women, and this effect was stronger in men than in women, for responses after losses than for responses after wins. One of the studies investigating gender differences in decision making used brain imaging techniques, and reported that women tended to use the left dorsolateral prefrontal cortex, left medial gyrus, and temporal lobe, whereas men activated the right orbitofrontal cortex (Bolla et al., 2004). Thus, different choice strategies in men and women may relate to gender differences in the use of brain regions when performing this task.

Limitations

Some limitations of this study should be noted. Most critically, the IGT was only administered once in this study. Thus, poorer decision making could either be the result of prolonged binge drinking on brain functions, or diminished decision-making skills could already be present before the onset of binge drinking and promote early-onset binge drinking. Some studies suggest that performance on neurocognitive tasks involving evaluation of rewards and losses over time, are predictive of later development of substance abuse or addictive behaviors (Perry et al., 2005; Tarter et al., 2004; Vitaro et al., 1999). A recent study of relapse in alcohol dependence found that diminished decision making on the IGT was related to early relapse (Bowden-Jones et al., 2005). Thus, disadvantageous decision making may predispose for heavy alcohol use during adolescence and early adulthood, and prospective studies using decision-making paradigms are warranted.

Another limitation is the selection and classification of binge drinkers, who also differ on the amount of alcohol they consume per week. Thus, all conclusions in this paper refer to heavy (binge) drinking, as findings cannot be separated according to binge drinking or heavy drinking solely. This limitation was a practical one, as binge drinking and quantity/frequency of alcohol use, measured at the same data collection wave, were highly correlated in this sample of college students (Pearson's r = 0.81–0.89). In samples consisting of older adults, or non/college students, heavier alcohol use, in the absence of binge drinking, is likely to have a higher prevalence, and studies in such populations are warranted to disentangle relation between binge drinking, quantity of alcohol use, and decision making.

Finally, our study sample consisted primarily of Caucasian college students, all between ages 18 and 21, and caution is therefore required in generalizing to other populations. However, this study sample was representative of the college population of this large, midwestern, public university. Replication with other samples at different stages of development is clearly needed.

Diminished Decision Making and Alcohol Use: Cause or Effect?

Although the results from this study can be interpreted as an indication that disadvantageous decision making predisposes for heavy alcohol use, another possibility is that prolonged binge drinking (as present in the high binge-drinking group), or binge drinking during a developmental period in which the brain is especially vulnerable to damage by heavy alcohol use, caused less advantageous decision making. The regression analysis showed that earlier binge drinking (waves 0 and 2) was predictive of disadvantageous decision making on the IGT. Human and animal studies indicate that adolescence is a developmental period during which brain structures and functions have a higher vulnerability to the effects of heavy alcohol use, than during adulthood (Brown et al., 2000; De Bellis et al., 2000; Markwiese et al., 1998; Monti et al., 2005). However, this study cannot answer the question of cause and effect.

Administering the IGT at the start of adolescence, and at later time points, in a prospective design studying (sub)clinical AUDs, would allow researchers to answer the question of cause or consequence in the relation between alcohol use and IGT performance.

Conclusions and Suggestions for Future Research

Decision making relies on intact functioning of the ventromedial prefrontal cortices, and no other studies have studied the effects of chronic alcohol use on tasks tapping into these functions or brain areas. Our finding that high binge-drinking students show a more disadvantageous strategy on a decision-making task, indicates that more research is needed with regard to decision making and its neurophysiological correlates in different binge-drinking subgroups.

The mean number of drinks across the 6 different waves for students in the high binge-drinking group, ranged from 21 drinks a week precollege, to 13.5 drinks a week during the third college year. Deleterious effects of alcohol drinking are found in studies of binge-drinking groups using at least 21 drinks a week, but inconsistent findings are reported in studies where participants are drinking at lower levels (Parsons and Nixon, 1998). Our findings indicate that the threshold for effects of alcohol drinking on decision-making skills may be lower in adolescents/young adults. However, other decision-making tasks involving the weighing of immediate valence over shorter or longer time periods have not been studied in social drinkers so far, and more research is needed to corroborate these findings.

In conclusion, although a causal link has yet to be established, our findings indicate that binge drinking at a younger age, and prolonged binge drinking are associated with worse decision making.

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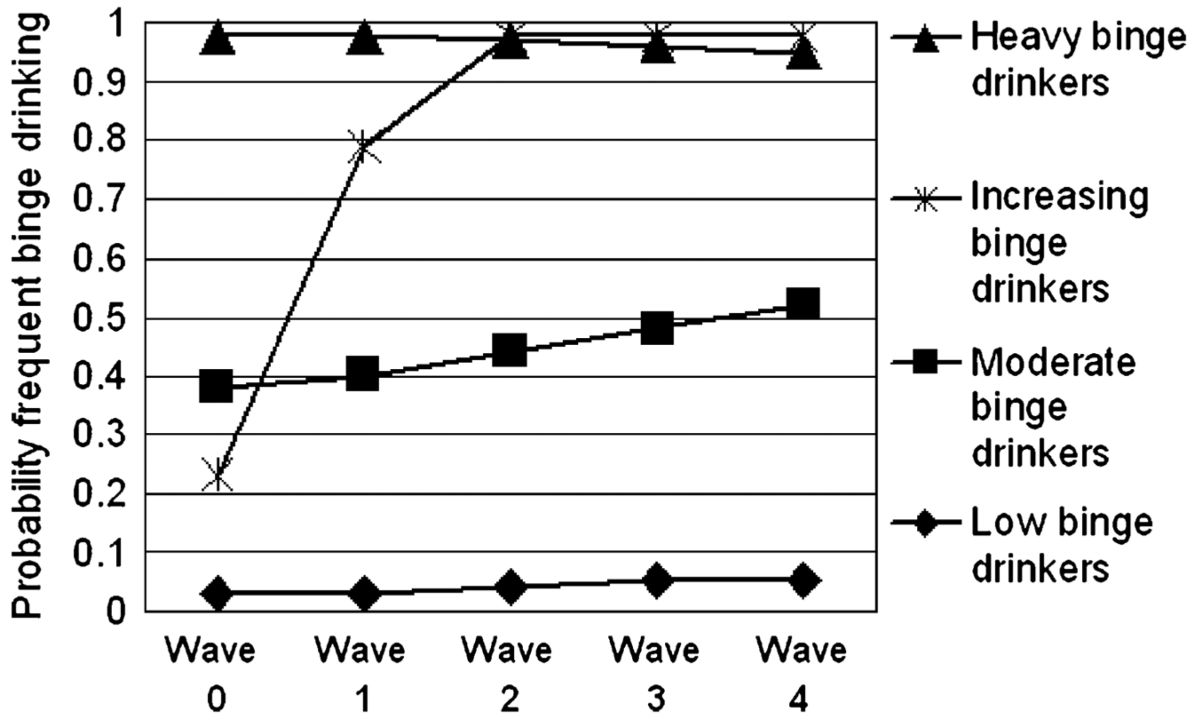

fig. 1.

Latent Class Analysis probabilities of heavy binge drinking (2 or more times/wk) at each wave, for the different binge-drinking groups.

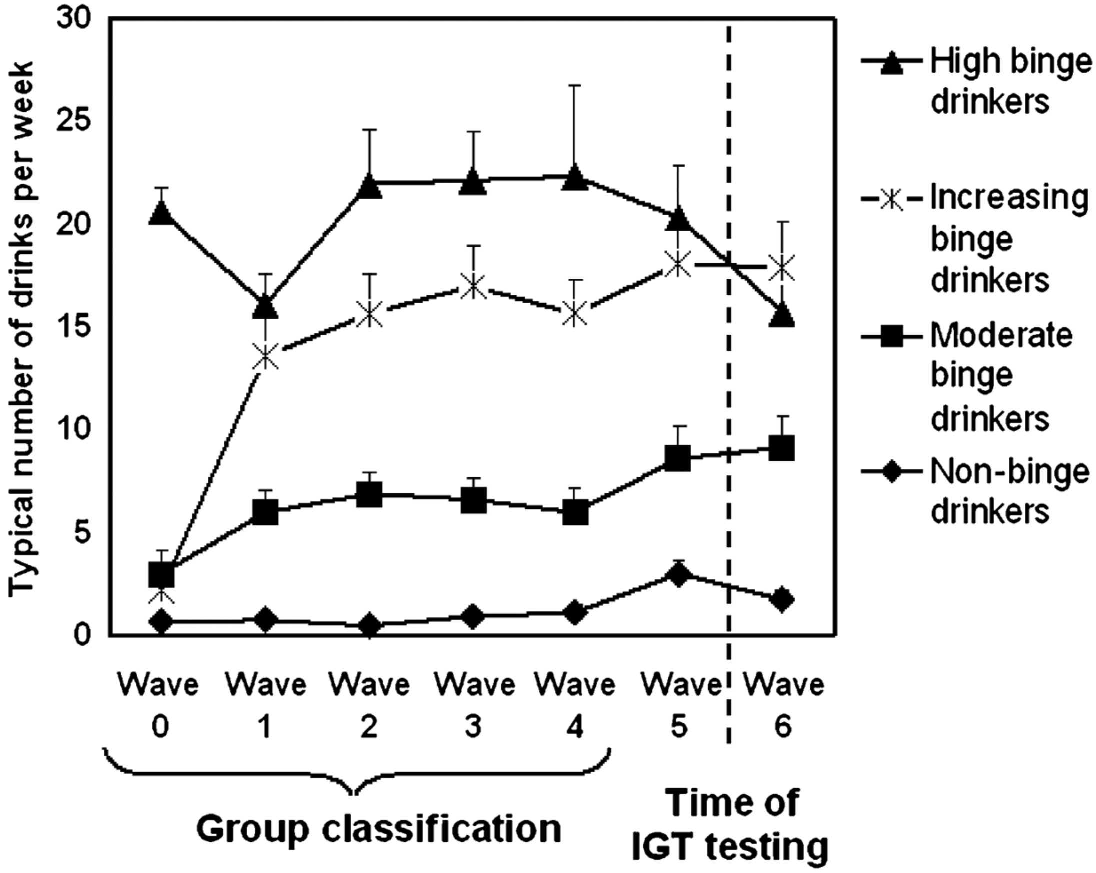

fig. 2.
Mean number of drinks per week, for college students in the 4 different binge-drinking groups, before and across the college period. Error bars are the standard deviations of the mean.

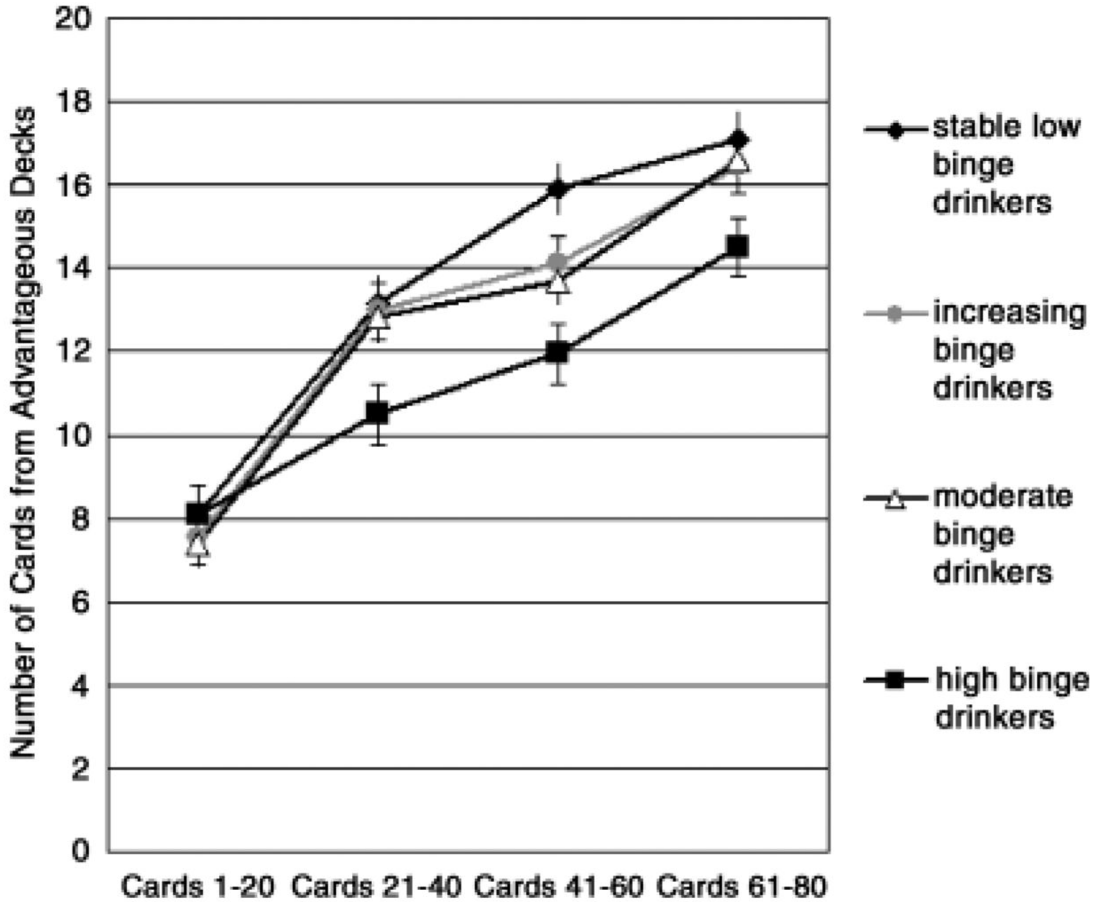

Fig. 3.
Advantageous minus disadvantageous choices on the Iowa Gambling Task, for the 4 consecutive stages of the task. Error bars are the standard errors of the mean.

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Table 1

Mean Posterior Probability of Latent Profile Group Membership

	High	Increasing	Moderate	Low
High-binge drinkers	**0.823**	0.077	0.099	0.001
Increasing binge drinkers	0.039	**0.708**	0.251	0.002
Moderate binge drinkers	0.046	0.064	**0.712**	0.179
Low-binge drinkers	0.000	0.005	0.112	**0.883**

Table 2

Demographic Variables for the 4 Binge-Drinking Groups

	Low-binge drinkers	**Moderate-binge drinkers**	**Increasing binge drinkers**	**High-binge drinkers**	
Age (SD)	19.9 (0.40)	19.9 (0.30)	20.0 (0.30)	20.0 (0.40)	NS
Ethnicity	94% Caucasian	94% Caucasian	98% Caucasian	96% Caucasian	NS
ACT composite score (SD)	27.2 (3.7)	26.6 (3.3)	26.7 (3.4)	26.9 (2.9)	NS
Multilineal FHA % 0/1/2[a]	68/30/2	75/21/4	62/30/8	62/28/10	
Drinks per week (wave 1)	1.24 (2.14)	4.74 (6.39)	14.00 (11.40)	17.96 (13.77)	$F_{(3, 192)} = 29.5$, $p<0.01$
Range of +5 drinks in 1 sitting/wk (waves 1–6)	0.16–0.28	1.17–1.88	2.58–2.82	3.04–3.16	Within group repeated binge-drinking effect: NS
Age first drink (SD)	15.6 (2.13)	14.9 (1.96)	15.0 (2.07)	13.8 (1.45)	$F_{(3, 188)}$ 56.75, $p<0.01$
Percentage nonsmokers last month (wave 4)	84	84	84	88	NS
Barratt Impulsiveness Scale	23.6 (7.35)	28.2 (6.94)	26.9 (10.9)	28.3 (8.64)	$F_{(3, 190)}$ 53.67, $p<0.05$
Impulsivity Sensation Seeking Scale	7.62 (3.52)	9.70 (3.80)	9.65 (4.10)	9.04 (3.86)	$F_{(3, 191)}$ 53.52, $p<0.05$

Numbers between parentheses are standard deviations (SD); FHA, family history of alcoholism.

[a] 0 = no family history of alcoholism present, 1 = either maternal or paternal multigenerational history of alcoholism present, 2 = both maternal and paternal history of alcoholism present.

Table 3

Lifetime DSM-IV Diagnoses for the 4 Binge-Drinking Groups

Lifetime DSM-IV diagnosis	Low-binge drinkers	Moderate-binge drinkers	Increasing binge drinkers	High-binge drinkers	Chi-square tests
Alcohol abuse	1	10	14	13	$\chi^2_{(3, 200)} = 11.9$, $p<0.01$
Alcohol dependence	3	4	8	16	$\chi^2_{(3, 200)} = 20.5$, $p<0.01$
Nicotine dependence	0	3	5	13	$\chi^2_{(3, 200)} = 21.7$, $p<0.01$
Cannabis abuse	1	2	2	10	$\chi^2_{(3, 200)} = 15.2$, $p<0.01$
Cannabis dependence	1	3	1	7	$\chi^2_{(3, 200)} = 8.51$, $p<0.05$
Conduct disorder[a]	0	3	1	1	$\chi^2_{(3, 200)} = 3.99$, $p=0.27$
Antisocial personality disorder	0	1	1	0	$\chi^2_{(3, 200)} = 2.02$, $p=0.57$
ASPD without CD	3	5	5	11	$\chi^2_{(3, 200)} = 6.82$, $p=0.08$
Anorexia nervosa	0	1	3	1	$\chi^2_{(3, 200)} = 3.90$, $p=0.27$
Bulimia nervosa	0	1	0	0	$\chi^2_{(3, 200)} = 3.01$, $p=0.39$
Manic or mixed episode	1	1	3	2	$\chi^2_{(3, 200)} = 1.63$, $p=0.65$
Panic disorder (including agoraphobia)	2	0	1	0	$\chi^2_{(3, 200)} = 3.72$, $p=0.29$
Social phobia	1	3	4	2	$\chi^2_{(3, 200)} = 2.11$, $p=0.55$
Generalized anxiety disorder	1	3	3	1	$\chi^2_{(3, 200)} = 2.08$, $p=0.56$
Major depressive episode	12	12	11	2	$\chi^2_{(3, 200)} = 9.39$, $p<0.05$
OCD	2	1	1	0	$\chi^2_{(3, 200)} = 2.04$, $p=0.56$

CD, conduct disorder; OCD, obsessive–compulsive disorder; ASPD, antisocial personality disorder.

[a] Except exclusion: No ASPD.