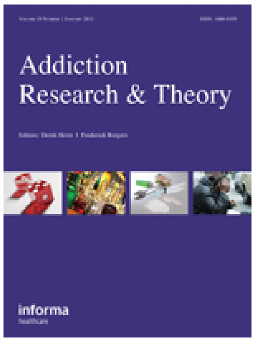

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Binge drinking is characterized by decisions favoring positive and discounting negative consequences

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ORIGINAL ARTICLE

Binge drinking is characterized by decisions favoring positive and discounting negative consequences

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ABSTRACT

Background: Decision making in binge drinkers is both risky and disadvantageous; however, previous operationalization of binge drinking has failed to capture the dimensionality of the phenomenon, differentiate drinking pattern from actual alcohol consumption and control for the influence of other substance use and general executive ability. Therefore, the aim of this study is to assess decision-making performance at various levels of binge drinking severity, while controlling for general executive ability and substance use.

Methods: A total of 121 students, aged 18–25, were assessed by means of the binge score derived from the Alcohol Use Questionnaire (AUQ). They completed the Iowa Gambling Task (IGT) and the Information Sampling Task (IST), to assess decision making under ambiguity and risk, respectively. The Letter Number Sequencing (LNS) task was used to control for the influence of general executive function.

Results: When controlling for general executive function and use of other substances, the binge score was predictive of risky decisions in the IST, but only when additional information was costly. In the IGT, the binge score was not predictive of advantageous decisions, but rather associated with decisions returning frequent losses in the first 40 trials of the tasks.

Conclusions: Explicitly presented probabilities for gain and reward makes binge drinkers accept higher degree of risk when making decisions. This could reflect a reward drive proneness, which is established as a risk factor for addictive behaviors. Sensitization to reward might impel binge drinkers to continue the pattern of alcohol consumption, despite the resulting negative outcomes.

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Introduction

Binge drinking is characterized by the consumption of large amounts of alcohol in a short period of time, leading to blood alcohol concentration (BAC) of 0.08 g percent or above, followed by periods of abstinence (Courtney & Polich 2009). While young people frequently report heavy drinking for social motives, and sometimes enhancement (Kuntsche et al. 2005), research has shown that this drinking pattern is associated with severe negative outcomes in both the public and the individual domain (Plant et al. 2009). Thus, binge drinkers seem to give priority to the positive consequences at the expense of their long-term welfare, and thus appear to display impulsive decision making.

Due to the continuous alternation between high levels of intoxication and abstinence, the binge drinking pattern serves to exacerbate the neurotoxic properties of alcohol, compared to alcohol consumption in general (Crews 2008). This is particularly worrisome as binge drinking peaks at the tail end of the key developmental period when the frontal brain areas underlying decision-making and higher-order cognitive function matures, without having yet reached full maturity (Crone & van der Molen 2004). Subsequently, binge drinking in young adulthood has been found to have deleterious impact on prefrontal neuronal systems associated with decision making and executive control (Maurage et al. 2012).

Dual process models, such as those formulated by Evans (2003), Strack and Deutsch (2004), or Bechara (2005), stipulates that in order to decide advantageously in numbers of different situations, an attuned interplay between controlled (executive) and automatic (motivational) processes are required. In binge drinkers, a shift in this balance was recently suggested, from reflective top-down controlled behavior, toward an over-activation in the reflexive bottom-up system (Lannoy et al. 2014). In real life, decisions are made under manifold situations, ranging from absence of any reliable information when anticipating outcomes of a choice (i.e. ambiguous decision making), to decisions where a given outcome could be estimated based on the available information (i.e. decision making under risk). In the former, decisions are made primarily based on intuition and gut-feeling (anticipatory emotional reactions triggered by this decision that at least partly depend on the outcomes associated with similar previous choices in the past (Damasio 1994)), while in the latter, cognitive calculations, or a combination of rational and emotional processes, are required in order to reach the optimal solution (Brand et al. 2006). This distinction between ambiguous or risky decision making is captured

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in tasks such as the Iowa gambling task (IGT; Bechara et al. 1997) and the Information Sampling Task (IST; Clark et al. 2006), respectively. In the IGT, lack of explicit response contingencies renders the subjects unable to calculate probabilities of loss and reward associated with their decisions (Bechara et al. 1997). However, participants might familiarize themselves with the response contingencies and gain a sense of the probabilities of reward and loss, and the decisions are therefore gradually evolving into ones involving risk and deliberative processes (Billieux et al. 2010). In other words, it is generally considered that that the first part of the IGT (i.e. trials 1–40) largely depend upon unconscious processes (e.g. the somatic marker hypothesis; Bechara et al. 1994), whereas the second part of the IGT (i.e. trials 61–100) also recruited controlled and effortful processes (Dunn et al. 2006; Persaud et al. 2007). While most studies using the IGT generally restricted their analysis to the number of 'advantageous' cards selected, the gain–loss frequency of the various decks have also been proposed as guiding subsequent choices (Lin et al. 2007). In contrast, the IST provides explicit information about the chances of gain and loss (Clark et al. 2006). A comprehensive study investigating how binge drinking might affect these different decision making processes is lacking.

Performance in decision making tasks is influenced by general executive ability, and working memory is in particular important for running mental calculations of various decisional outcomes (Brand et al. 2006). Previous evidence indicates that disadvantageous performance on the latter part of the IGT is associated with deficits in working memory performance in healthy subjects (Brevers et al. 2014), but see the review by Toplak et al. (2010) for contradictory results. Risky decisions are negatively correlated to working memory performance in both alcohol dependent individuals and healthy controls (Brevers et al. 2014). Importantly, working memory performance was also found impaired in young adult binge drinkers (Townshend & Duka 2005; Stephens & Duka 2008), implying that this factor has to be controlled for when studying decision making in binge drinking.

When compared to low binge drinking students (drinking five or more units of alcohol in one occasion monthly or less during a two year period), heavy binge drinkers (drinking five units of alcohol in one occasion 2–3 times in the past 30 days or any higher frequency during a two year period) were found to make fewer advantageous decisions in the IGT (Goudriaan et al. 2007). Disadvantageous decisions were found to predict heavy drinking two years later in young adult males, but not in females (Goudriaan et al. 2011). However, the limitation in both studies is that no information regarding general executive capacity was obtained. The same applies for the study by Mullan et al. (2011), where binge drinkers (defined by answering 'yes' to the question of participating in a binge drinking session over the past week) performed worse on the IGT compared to non-bingers.

Two studies have investigated decision making under risk in young adult binge drinkers by means of the IST (Townshend et al. 2014; Banca et al. 2016). Both utilized the IST, but only Townshend et al. (2014) detected less information gathering prior to decision making in binge drinkers compared to non-bingers. The inconsistent results may be due to lack of power in the study of Banca et al. (2016). On the contrary, Banca et al. found differences in the Beads task, which also indicated deficits in accumulating sufficient evidence prior to making a decision. The authors of both studies claim that the decision making tasks used do not recruit general executive capacities (e.g. working memory), but these studies do actually not control for their potential influence.

Another factor complicating the interpretation of previous studies is the various operationalizations of binge drinking used. All but one of the reviewed studies have failed to include a time limit for consumption, defining binge drinkers based on either number of drinks in a row, or 5+ units of alcohol per sitting. This complicates inferences with regard to heavy alcohol use vs. drinking pattern, and echoes the lack of consensus regarding definition of the condition within the field (Courtney & Polich 2009). The NIAAA (2004) defines binge drinking as consuming 4+/5+ units of alcohol within 2 h, but does not take into account the effect body composition and metabolism have on the influence of alcohol. Since the latter part of the definition, 'that brings BAC to 0.08 g percent or above' (p.3), is often omitted when the 4+/5+ criterion is applied rigorously; all will not reach BAC's high enough to qualify as binge drinkers. Moreover, studies indicated that the 4+/5+ measure classifies many college students as binge drinkers, even though their intoxication level were below conventional thresholds used to define drunkenness (Thombs et al. 2003). Another common classification of a binge- and a non-binge drinker is based on the binge score (Townshend & Duka 2005), derived from the last three questions of the AUQ (Mehrabian & Russell 1978), where the median split or 33rd percentile split of the sample's binge score is used to ascribe group membership (see e.g. Townshend & Duka 2005; Townshend et al. 2014). This approach considers levels of intoxication, but the split complicates both generalizations of the findings and replication studies, since results are invariably bound to the studied samples. In such a context, we propose that a more appropriate way of exploring the relations between binge drinking and decision making, is to quantify the severity of binge drinking, rather than assume a qualitative shift in performance once a given cut score is passed. This will be in line with an understanding of binge drinking as a dimensional phenomenon (Enoch 2006). Furthermore, the binge score is not bound to the number of drinks consumed. For instance, a person who drinks 10 units a week can have a low binge score if the drinks are spread evenly throughout the week. A high binge score will be obtained if they are all consumed within one evening. Thus, the binge score separates drinking pattern from overall consumption.

To summarize, the current knowledge about decision making processes in binge drinkers is complicated by inconsistencies in the definition of the condition, mixing for example heavy alcohol consumption and drinking to inebriation. Thus, it remains to be settled if prior findings of deficits in decision making are actually attributable to the binge-drinking pattern, or rather associated with high global amount of alcohol consumption. The influence of general executive functioning on decisional processes is not accounted for, leaving doubts as to whether decision-making deficits could be attributed to reductions in executive processes. Therefore, the objective of this study is to investigate if the severity of binge drinking is predictive of deficits in decision making, once global alcohol consumption and general executive functioning performance are controlled for.

Methods

Participants

One hundred and twenty-one students (including 62 females) in the Oslo area were recruited at the campus of the University of Oslo and via social media. All subjects reported regular alcohol consumption (the Alcohol Use Disorder Identification Test ≥1). See Table 1 for participant characteristics. Exclusion criteria included self-reported neurological illnesses, moderate or severe head injury, or any head injury within last six months; severe physical condition (e.g. diabetes or heart disease); psychiatric illness that require admission to hospital; attention deficit hyperactivity disorder or Asperger's syndrome; the use of any medication known to affect cognitive function (contraceptives, painkillers without need for prescription and antihistamines accepted); weekly consumption of illicit substances.

Alcohol

The Norwegian version of the Alcohol Use Disorder Identification Test (AUDIT; Saunders et al. 1993) was used to measure risky alcohol consumption. In Norway, one unit of alcohol contains 12.8 g of alcohol. Thus, question three of the AUDIT ('How often do you have six or more drinks on one occasion?') was adjusted to five drinks on one occasion, as suggested by Babor et al. (2001). To have an account of global alcohol consumption, rather than consequences of alcohol use and alcohol related problems, data from the three first items only, corresponding to AUDIT-C (Bradley et al. 2007), is included in the analyses.

Alcohol drinking pattern was assessed by the scores of the last three items (Table 1) of the AUQ (Mehrabian & Russell 1978), and calculated into a 'binge score' by means of the equation provided in the study by Townshend and Duka (2005). The specification with regard to 'drunk', generally corresponds to BAC's above 0.08 g/dl (Norwegian Institute of Public Health 2013), and may be considered proxy to the NIAAA definition.

Table 1. Descriptives of the study sample.

		M	*SD*
N (females)		121 (62)	
Age		21.7	2.1
AUDIT-C		5.7	2.2
Binge score		25.6	17.7
	number of alcohol units[a] per hour	2.1	1.1
	number of times drunk[b] last six months	9.6	11.5
	percentage drunk[b] of times drinking	37.2	27.3
Any use of other substances[c,d] *(n)*		47	

M: Mean; *SD*: Standard Deviation.
[a]1 unit of alcohol = 12.8 g of alcohol.
[b]Loss of co-ordination, nausea and/or inability to speak clearly.
[c]Including nicotine, cannabis, 'poppers', mushrooms, amphetamine, cocaine and MDMA.
[d]Data from one participant is missing.

Substance use

A short demographic interview was conducted in order to detect other potential types of substance use, like nicotine use or use of any other illegal substances. This was done in order to control for their potential effect on the study's variables (Verdejo-Garcia et al. 2007; Buelow & Suhr 2014). The variable was coded 0 (no use) and 1 (any use). See Table 1 for specification of types of substances.

Letter number sequencing (LNS)

The LNS from the Wechsler Adult Intelligence Scale – Fourth edition (Wechsler 2008) was included to assess the central executive of the working memory (Baddeley 2000). This task is frequently used as a control measure of general executive functioning (e.g. Rochat et al. 2012). The subjects were orally presented with combination of letters and numbers. The task was to repeat the numbers in ascending order, followed by the letters in alphabetical order (e.g. 9-L-2-A; correct response is 2-9-A-L). The variable of interest was the maximum span.

Information sampling task (IST)

The IST from CANTAB (Cambridge Cognition Ltd) was administrated to measure reflection impulsivity: the tendency to evaluate information before decision making. In a series of trials, the subjects were required to consecutively open boxes in a 5×5 matrix revealing colored squares, and then subsequently decide which of the two colors lay in the majority. The test was composed of two different conditions; fixed win (FW) and decreasing win (DW) presented in random order. In the FW condition, 100 points was won irrespective of number of boxes opened if the decision was correct. In the DW condition, a conflict between reinforcement and certainty was introduced, when the possible gain of 250 points was reduced by 10 for every box opened. To maximize reinforcement, the test taker must tolerate a high degree of uncertainty, since sampling information until a point of high certainty would yield very few points. In case the wrong color was chosen, 100 points were lost irrespective of number of boxes opened in both conditions. The color of the boxes was changed in every trial, and it was 10 trials per condition. The variables of interest for both conditions were the probability of being correct at the time of decision (see Clark et al. 2006 for a comprehensive description of the indexes computed).

Iowa gambling task (IGT)

The IGT (Bechara et al. 1999) is a computerized assessment simulating real-life decision-making by factoring uncertainty of premises and outcomes, as well as reward and punishment. The subjects were required to draw cards from one out of four decks of cards (A, B, C and D). Two of the decks (C and D) were advantageous returning small rewards, though even smaller punishments, resulting in a net gain over the course of the task, whereas the two others were disadvantageous returning large rewards, but even larger punishments, resulting in a net loss over the course of the task. The task instruction was to maximize profit. Also, the task was designed to differentiate between the preference for high frequency punishments (A and C) or low-frequency punishments (B and D), irrespective of amount loss. Accordingly, and in line with previous proposals (Lin et al. 2007), gain–loss frequency of the decks, and not only 'advantageous' choices based on actual gains and losses, has to be taken into account. The task ended when 100 draws were made, and the trials were compounded in five blocks of 20 trials each. The last two blocks (trails 61–100) were proposed to measure decision making under risk (because the reinforcement contingences were at least partly known), whereas the first two blocks (trials 1–40) measured decision-making under uncertainty (Brand et al. 2006; Billieux et al. 2010). The variables of interest were the number of advantageous choices (decks C + D)–(decks A + B), and the number of high frequent punishments (decks A + D)–(decks B–C) in trials 1–40 and trials 61–100, respectively.

Procedure

An initial online screening session was conducted by means of an online questionnaire concerning alcohol consumption, age and student status. Potential candidates were then contacted by telephone and screened for exclusion criteria. At testing, the subjects had abstained from alcohol for at least 48 h, from caffeine and nicotine for minimum 3 h and other substances for minimum seven days. A short demographic interview was conducted, before they completed the LNS, the IST and the IGT. The order of the FW and DW of the IST was randomized, as suggested in the manual. One of the authors and a trained research assistant administrated the tasks on a Dell Latitude D610 (CBS Interactive, San Francisco, CA) laptop computer with a 14.1″ LCD screen using 1024 × 768 pixels at 32 bit color quality. An external touch screen was installed for obtaining responses on the IST. On the IGT, the internal mouse pad was utilized.

The study was conducted in compliance with the Helsinki Declaration and the Ethical principles for Nordic psychologists, as issued by the Norwegian Psychological Association. All participants received both written and oral information about the project, and their right to withdraw at any time during participation. Informed consent was obtained orally and by signature. All participants received an electronic debit card worth 250 NOK (∼€30), independently of task performance.

Statistical analysis

All statistical analyses were performed with IBM SPSS 22. IST data from three female subjects were missing due to technical problems, and IGT was not performed by one male subject, who had detailed knowledge about the test. Five subjects finished all cards in one deck (60 cards) during the fourth block of the IGT, forcing an unintended change in strategy. Data from these subjects was therefore discarded from the analysis of trials 61–100.

The binge score and the IST *P* (correct) decreasing win condition were logarithmically transformed due to skewed distributions. Pearson correlations were used to assess the relationships between the six variables of decision making (the IST *P* (correct) decreasing win condition and fixed win condition, the IGT advantageous choices trials 1–40 and trials 61–100, the IGT frequently punished trials 1–40 and trials 61–100), including the letter number sequencing span (LNSS). In order to test the effect of specific predictor variables, while controlling for the influence of other predictors, hierarchical regression analyses were performed to predict decision making based on binge drinking. In step 1, LNSS and use of other substances were included, and in step 2 binge score was added.

When the binge score emerged as a significant predictor, the AUDIT-C was also included as covariate in step 1 to control for total amount of alcohol consumed. Residuals were investigated with the Shapiro–Wilk test to ensure that parametric assumptions were met. If not, bootstrapping with 1000 bootstrap samples were conducted as non-parametric alternative to ascertain the conclusion of the regression analysis. Confidence intervals (CIs) of the β's were reported. Pearson correlations between AUDIT-C and decision making variables were conducted in order to investigate the role of overall alcohol consumption for decision making. Alpha was set at 0.05 for all analyses. Marginally significant relations ($p < 0.1$) were also reported on. Results were not corrected for multiple comparisons, due to the increased risk of committing type II error (Rothman 1990).

Results

Relations between behavioral measures and descriptives

The correlations between all behavioral variables are reported in Table 2. Advantageous choices in the latter part of the IGT were marginally correlated with LNSS ($p = 0.096$). None of the other variables was significantly correlated to LNSS.

Decision making and binge drinking

Multiple hierarchical regression analyses were performed in order to predict decision making from the binge score, while taking into account the LNSS and other types of substance use as potential confounding factor (Table 3).

The IGT frequently punished trials 1–40 and the IST *P* (correct) decreasing win condition were both predicted by the binge score, but none was predicted by the LNSS or other substance use. Furthermore, none of the independent variables (binge drinking, LNSS and substance use) were significant predictors of the IGT advantageous choices trials 1–40, the IGT advantageous choices trials 61–100, the IGT frequently punished trials 61–10, or the IST *P* (correct) fixed win condition.

Table 2. Pearson correlations between behavioral measures for all participants.

	1	2	3	4	5	6
1. Letter number sequencing span						
2. IGT advantageous choices trials 1–40	0.059					
3. IGT advantageous choices trials 61–100	0.143	0.320[b]				
4. IGT frequently punished trials 1–40	0.023	0.009	0.073			
5. IGT frequently punished trials 61–100	−0.064	−0.013	0.211[a]	0.073		
6. IST *P* (correct) decreasing win condition	0.097	0.05	0.193[a]	0.036	−0.058	
7. IST *P* (correct) fixed win condition	0.146	0.066	0.220[a]	0.197[a]	0.104	0.305[b]

IGT: Iowa gambling task; IST: Information sampling task; The IST *P* (correct) decreasing win condition are logarithmically transformed.
[a]$p < 0.05$.
[b]$p < 0.001$.

Table 3. Hierarchical linear regression models for decision-making performance. 95% confidence intervals (CI) in brackets.

		Step 1					Step 2						
		b	SE *B*	β	*t*	*p*	*b*	SE *B*	β	*t*	*p*	Total R^2	ΔR^2
IGT advantageous choices trials 1–40	LNSS	0.496 (−0.583, 1.605)	0.558	0.082	0.889	0.376	0.393 (−0.756, 1.448)	0.558	0.065	−0.704	0.483	0.041	0.021
	Substance use	−1.530 (−4.096, 0.834)	1.158	−0.122	−1.322	0.189	−1.923 (−4.535, 0.443)	1.176	−0.153	−1.635	0.105		
	Binge score						1.229 (−0.627, 2.989)	0.774	0.150	1.588	0.115		
IGT advantageous choices trials 61–100	LNSS	1.367 (−0.310, 2.939)	0.899	0.143	1.520	0.131	1.445 (−0.197, 3.006)	0.910	0.151	1.588	0.115	0.024	0.003
	Substance use	−0.011 (−3.665, 3.360)	1.864	−0.001	−0.006	0.995	0.258 (−3.407, 3.524)	1.917	0.013	0.135	0.893		
	Binge score						−0.793 −3.315, 1.756)	1.262	−0.061	−0.628	0.531		
IGT frequently punished trials 1–40	LNSS	0.103 (−0.788, 1.247)	0.483	0.020	0.214	0.831	−0.029 (0.-907, 1.121)	0.477	−0.006	−0.060	0.952	0.052	0.047[a]
	Substance use	0.765 (−0.990, 2.696)	1.002	0.071	0.764	0.447	0.262 (−1.605. 2.190)	−0.019	1.020	0.261	0.801		
	Binge score						1.572 (0.184, 2.798)	0.002	0.645	2.380	0.019[a]		
IGT frequently punished trials 61–100	LNSS	−0.447 (−1.917, 1.026)	0.798	−0.053	−0.560	0.577	−0.453 (−1.848, 1.016)	0.810	−0.054	−0.560	0.577	0.007	0.000
	Substance use	−0.981 (−4.204, 2.190)	1.654	−0.056	−0.593	0.554	−1.002 (−4.281, 2.375)	1.705	−0.057	−0.588	0.558		
	Binge score						0.063 (−1.869, 2.135)	1.122	0.006	0.056	0.955		
IST *P* (correct) decreasing win condition	LNSS	0.012 (−0.006, 0.029)	0.010	0.106	1.145	0.255	0.014 (−0.003, 0.032)	0.010	0.131	1.419	0.159	0.066	0.039[a]
	Substance use	−0.030 (−0.071, 0.008)	0.021	−0.133	−1.438	0.153	−0.019 (−0.062, 0.022)	0.021	−0.086	−0.922	0.359		
	Binge score						−0.030 (−0.058, −0.003)	0.014	−0.205	−2.171	0.032[a]		
IST *P* (correct) fixed win condition	LNSS	0.020 (0.000, 0.041)	0.011	0.174	1.888	0.060	0.021 (.001, 0.042)	0.011	0.183	1.962	0.052	0.042	0.005
	Substance use	−0.023 (−0.069, 0.022)	0.022	−0.096	−1.045	0.298	−0.019 (−0.068, 0.025)	0.022	−0.080	−0.841	0.402		
	Binge score						−0.011 (−0.040, 0.020)	0.015	−0.072	−0.753	0.453		

IGT: Iowa gambling task; IST: Information sampling task; LNSS: Letter number sequencing span.
Analysis performed with logarithmically transformed binge score and IST *P* (correct) decreasing win condition.
CI 95% based on 1000 bootstrap samples.
[a]$p < 0.05$.

For exploratory purposes, where the binge score was a significant predictor, we included the AUDIT-C as predictor in the hierarchical regression analyses at step 1. This was done in order to control for the effect of absolute alcohol consumption. Though the binge score is partly independent from total alcohol consumed, there is still a strong correlation between binge score and the AUDIT-C ($r = 0.70$, $p < 0.01$), and we therefore checked for problems with multicollinearity. According to Allison (1999), the presence of multicollinearity may be confirmed when the variance inflation factor (which shows to what extent the variance of the coefficient is inflated by multicollinearity) is over 2.5 and the tolerance score is below 0.40. Despite figures approaching the specified values, the multicollinearity was not present in both the following regression analyses.

For the IGT frequently punished trials 1–40, none of the predictors remained significant (binge score: $\beta = 0.257$; $t\ (114) = 1.894$ $p = 0.061$; the AUDIT-C: $\beta = -0.048$; $t\ (114) = -0.345$;

$p = 0.731$; the LNSS: $\beta = -0.029$; t (114) $= -0.060$; $p = 0.952$; and substance use: $\beta = 0.033$; t (114) $= -338$; $p = 0.736$). For the IST P (correct) decreasing win condition, when controlling for the effect of absolute alcohol consumption, the binge score remained a significant predictor of the IST P (correct) decreasing win ($\beta = -0.272$; t (112) $= -2.053$; $p = 0.42$). None of the other independent variables were significant predictors of the IST P (correct) decreasing win condition (AUDIT-C: $\beta = 0.099$; t (112) $= 0.725$; $p = 0.470$; LNSS: $\beta = 0.130$; t (112) $= 1.405$; $p = 0.163$; and substance use: $\beta = -0.103$; t (112) $= -1.068$; $p = 0.288$), suggesting the uniqueness of the binge drinking pattern in affecting risky decision making.

Decision making and heavy alcohol consumption

In order to investigate if global alcohol consumption could account for previous findings of decision-making deficits in binge drinkers, the correlation with the AUDIT-C was considered. The AUDIT-C was marginally correlated with the IGT advantageous choices trials 60–100 ($r = 0.159$, $p = 0.089$), which contradicts previous findings emphasizing disadvantageous decision making in binge drinkers, when defined by heavy alcohol consumption. The following partial correlation emerges $r = 0.099$, $p = 0.291$, when we control for the effect of general executive ability and substance use on the relationship between IGT advantageous choices trials 60–100 and AUDIT-C.

IGT frequently punished trials 1–40 was also marginally correlated with the AUDIT-C ($r = 0.152$, $p = 0.097$). The following partial correlation emerges $r = 0.134$, $p = 0.15$, when we control for the effect of general executive ability and substance use on the relationship between IGT frequently punished trials 1–40 and the AUDIT-C. None of the other decision-making variables had significant associations to heavy alcohol consumption (r's ≥ 0.119 and p's ≥ 0.199).

Discussion

This study revealed that regular binge drinking affected decision making under sobriety when the odds are known and when there was a possible gain associated with taking risks, but not when this upside is absent. Also, when decisions are ambiguous, severity of binge-drinking behavior is associated with disregard of negative consequences, as evidenced by more picks from decks with frequent money losses. Surprisingly, the binge score was not associated with advantageous decision making, neither under ambiguity, nor under implicit risk. The dissociated effect of binge drinking on various decision making processes is neither attributable to differences in general executive function, nor to actual alcohol consumption or consumption of other substance. These results suggest a shift toward hypersensitivity to reward and disregard of the consequences under explicit response contingencies. This corroborates findings obtained in other types of substance abuse, demonstrating hyposensitivity to losses and hypersensitivity to rewards (Shiv et al. 2005). The tendency to give priority to positive consequences, as well as being insensitive to the negative consequences, might contribute to the continuation of the risky consumption pattern and give indications to why binge drinkers are at increased risk of developing alcohol dependence (Enoch 2006).

Binge drinking did not predict the ability to make advantageous choices in ambiguous situations or in situations where risk calculations are implicitly available. This contrasts prior studies conducted in young adult samples, where binge drinkers had less money remaining after 50 trials compared to non-binge drinkers (Mullan et al. 2011), and stable low binge drinkers outperformed stable high binge drinkers when it came to the number of advantageous choices made in 80 trials (Goudriaan et al. 2007). It is worth noting that the different scoring method and the different number of trials used in these previous studies made any attempt to compare them tentative. Also, both prior studies classified binge drinkers based on the frequency of self-reported drinking of five drinks or more per occasion, mixing drinking pattern and heavy consumption. In our sample, heavy drinking, as specified by AUDIT-C, a variable somewhat different from the one used to define binge drinking in previous studies, was actually marginally negatively associated with IGT performance, such that severe binge drinkers performed better than less severe binge drinkers. However, the results need to be taken into account with caution, and were further weakened when the relevant confounding factors were controlled for.

Binge drinking severity was initially predictive of decision making returning frequent losses. This decisional style has been associated with younger age groups (Beitz et al. 2014), and is tentatively indicative of delayed neuromaturational processes in binge drinkers. The style may also relate to previous studies where binge drinkers were found to have difficulty learning from aversive consequences (Stephens et al. 2005). According to the acquired preparedness model of alcoholism risk (Settles et al. 2010), an individual's personality determines his preparedness (i.e. readiness) for certain learning experiences from the environment. As an illustration, individuals scoring high on impulsivity may be more likely to acquire stimulating and rewarding experiences from drinking, and these positive, alcohol-related learning experiences facilitate them to maintain, and increase, their alcohol use over time, thus undermining the negative consequences. Nevertheless, the shift in strategy throughout the task indicates that the behavior of binge drinkers is, indeed, modified through experience. Downplay of the negative consequences may therefore only be valid at initiation. Although the finding was non-significant when the total amount of alcohol consumed was taken into account, the relation between binge drinking and frequent losses is of medium effect size, and thus worth reporting.

The finding of increased reflection impulsivity is partly overlapping with one of two other studies investigating risky decision making in young adult binge drinkers (Townshend et al. 2014; Banca et al. 2016), suggesting reflection impulsivity to play a central role in binge drinking severity. Nonetheless, the fact that risky decisions were predicted by binge drinking severity in the decreasing win condition only, illustrates that the willingness for risk is potentiated by the opportunity for gain, rather than due to an inability to calculate probabilities. This sensitivity to positive consequences is also in line with the alcoholism preparedness model (Settles et al. 2010), and sensitivity to positive consequences was found to correlate with harmful alcohol use in university students (Lyvers et al. 2009). Also, the experience of positive consequences did moderate the relationship between drinking and sensation seeking dispositions (Lang et al. 2012).

This study underlines the importance of targeting the valuation of positive and negative consequences attributable to binge drinking. It is in line with the view of Szmigin et al. (2008), coining the term 'calculated hedonism', in order to describe how young adult drinkers deliberately balance 'the physical risk of drinking and the impact on their social and cultural credibility of losing control in a drunken state with the desire to have fun and a good time with their friends' (s.365). Their results indicated that binge drinking is indeed calculated in order to achieve reward and excitement, and the present study expands the explanation by adding an initial downplay of the negative consequences, and overall greater emphasis on the positive consequences, of their behavior. Though binge drinkers do not appear rational in the formal logical sense, it is in line with several studies indicating binge drinkers to have sensation seeking dispositions (Coskunpinar et al. 2013), supporting heightened risk seeking proneness in this group of young adults. Of note, such an elevated risk seeking proneness is not attributable to deficits in general executive functioning, as demonstrated in this study.

The fact that the binge drinking was not related to general executive functioning contradicts previous findings (Townshend & Duka 2005; Stephens & Duka 2008). However, the impairment might be specific to the modality under investigation (e.g. visuospatial, and not verbal as in our study), and point toward the benefit of a more comprehensive and multi-model assessment of general executive functioning in future studies.

It is acknowledgeable that the present results relate to decisions made in the absence of current alcohol exposure. In order to generalize our findings in actual drinking contexts, further studies should test the influence of mild to moderate alcohol intoxication upon further decision-making processes in binge drinkers.

Conclusions

The binge score is predictive of risk proneness when there is a possible upside to the decision being made and the risk is explicitly presented. The binge score is neither predictive of making advantageous decisions in ambiguous situations, nor in situations of implicitly known odds, but predictive of insensitivity to frequent losses. Due to the preservation of general executive functioning, it is likely that the risky decision making stems from a shift in balance – away from sensitivity to negative consequences, toward an emphasis on positive consequences – rather than being a calculation problem.

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Disclosure statement

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