Original Paper

Tell me how you feel, I will tell you what you look at: Impact of mood and craving on alcohol attentional bias in binge drinking

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Abstract

Background: Alcohol-related attentional bias (AB) is thought to play a key role in the emergence and maintenance of excessive alcohol use. Recent models suggest that AB, classically considered as a permanent feature in alcohol use disorders, is rather modulated by temporary motivational states.

Aims: We explored the influence of current mood and craving on AB in binge drinking, through a mood induction procedure combined with eye-tracking measures of AB.

Methods: In Experiment 1, we measured AB (visual probe task with eye-tracking measures) among binge drinkers ($n=48$) and light drinkers ($n=32$) following positive, negative and neutral mood inductions. Participants reported subjective craving and mood before/after induction. In Experiment 2, we measured AB among the same binge drinkers compared with 29 moderate drinkers following alcohol-related negative, non-alcohol-related negative and neutral mood inductions.

Results: In Experiment 1, induced negative mood and group positively predicted subjective craving, which was positively associated with AB. We found no effect of induced positive mood nor a direct mood-AB association. In Experiment 2, the relationships AB presented with both induced negative mood and group were again mediated by craving. Inducing alcohol-related negative mood did not modify the mood-craving association.

Conclusions: Alcohol-related AB is not a stable binge drinking characteristic but rather varies according to transient motivational (i.e., craving) and emotional (i.e., negative mood) states. This study provides important insights to better understand AB in subclinical populations and emphasizes the importance of considering motivational and affective states as intercorrelated, to offer multiple ways to reduce excessive alcohol use.

Keywords

Attentional bias, binge drinking, mood, craving, eye-tracking

Introduction

Binge drinking, characterized by repeated alternations between intense intoxication episodes and abstinence periods, is an established alcohol consumption habit with specific characteristics (Archie et al., 2012; Crego et al., 2009; Maurage et al., 2020; Townshend and Duka, 2002). It is particularly widespread in youth and keeps on growing in prevalence among older adults in Western countries (Dormal et al., 2019). Many studies have underlined the early and long-lasting harmful consequences of this consumption pattern on cognitive and cerebral functioning (see Carbia et al., 2018; de Goede et al., 2021; Lannoy et al., 2019 for recent critical reviews). In view of this harmful impact, it appears crucial to understand the psychological mechanisms contributing to the emergence and persistence of binge drinking.

Attentional bias (AB), reflecting the preferential orientation of one's attentional resources towards alcohol-related stimuli, may constitute one such mechanism. Importantly, AB is posited to be part of a vicious circle in which repeated alcohol consumption leads to greater attraction towards alcohol-related cues, enhancing the desire to consume alcohol (i.e., craving) and ending up in increased drinking (Field and Cox, 2008; Field et al., 2009). Dominant theories in addiction postulated that AB would develop by associative learning, where alcohol-related stimuli acquire incentive-motivational properties caused by repeated alcohol exposures that progressively sensitize the dopaminergic system (Franken, 2003; Robinson and Berridge, 1993). These models further suggested that the neuroadaptations underlying behavioural sensitization (e.g., alcohol-related AB) are long-lasting and potentially permanent, and did not discuss the intra-individual variability of AB once installed. Field et al. (2016) have thus suggested that AB fluctuates alongside motivational states between and within individuals. They proposed that AB is the

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expression of the momentary motivational evaluation of alcohol-related stimuli, and would thus arise from momentary changes in evaluations of these stimuli that can be positive (e.g., when the incentive value of the substance is high), negative (e.g., when individuals have a goal to stop drinking), or both (e.g., when individuals experience motivational conflict).

Recent reviews corroborate this assumption by underlining the presence of intrapersonal AB fluctuations, particularly according to current motivational states affected by environmental and internal factors (e.g., stress or subjective craving; see Bollen et al., 2022; Christiansen et al., 2015a for reviews). Indeed, two between-subjects studies showed increased AB following stress induction in participants with coping motives for alcohol use (Field and Powell, 2007; Field & Quigley, 2009). More importantly, recent studies relying on eye-tracking measures showed that alcohol-related AB was only observed in regular and binge drinkers reporting high craving at testing time (Bollen et al., 2020; Field et al., 2005; Hobson et al., 2013). Subjective craving would thus be a core determinant of the magnitude of alcohol-related AB in subclinical populations. Altogether, the above-mentioned studies highlighted the key role played by current stress or motivational state on AB, and the need to consistently assess them when exploring AB, such states being stronger AB predictors than global alcohol consumption characteristics.

Another fluctuating factor that could influence AB is mood. Cognitive processes related to AB (e.g., approach biases, implicit memory associations) can be modified following negative emotional priming (Cousijn et al., 2014) or associated with mood-congruent motives (Salemink and Wiers, 2014). However, few studies investigated how mood could influence AB, either directly or through craving increase. In their between-subjects study, Emery and Simons (2015) randomly allocated participants to positive, negative or neutral mood conditions and asked them to perform a classical AB paradigm (i.e., visual probe task) before and after mood induction (i.e., combined emotional picture slides and music). Alcohol AB, assessed through reaction times, did not differ across mood induction conditions, but the reliability of the visual probe task was very low, which might explain the null findings. Following musically induced positive and anxious mood, Grant et al. (2007) showed that students with coping motives presented increased AB in the anxious condition (compared to positive mood condition), whereas students with enhancement motives showed the opposite findings. Using ecological momentary assessment (EMA), Emery and Simons (2020) then explored whether positive or negative changes of affective states led to increased AB by assessing mood and alcohol Stroop interferences for 28 consecutive days through smartphone reports. While no association was found between negative mood and AB, positive mood predicted increases in AB and alcohol use over the same day at within-person level. Moskal et al. (2022) used a similar design with EMA for 15 days to investigate the role of alcohol AB (assessed by a visual probe task) as a craving predictor. They showed that AB-craving associations were stronger as momentary positive mood and trait-like sad mood increased among men and, on the contrary, decreased among women. While those studies offered important insights on the influence of momentary states on alcohol AB, they were weakened by the very low reliability of their AB measures (i.e., manual reaction times). Moreover, previous studies had a very unspecific sample, as they recruited college students without further inclusion criteria related to alcohol consumption, simply assuming high consumption levels in this population. Finally, they did not investigate whether mood explicitly associated with alcohol use might impact differently craving and AB.

The present study aimed to further investigate the effects of craving and mood (both direct and through craving increase) on alcohol-related AB, by improving the reliability of AB measures in a specific population of binge drinkers with beer as favourite alcoholic beverage. To this end, we performed two experiments using personalized visual probe tasks (i.e., only beer pictures as alcohol-related stimuli) combined with eye-tracking measures, known to improve the reliability of AB measures (Bollen et al., 2020; Christiansen et al., 2015b; Field et al., 2009). All participants performed three sessions. For each session, the task was preceded by a combined mood induction procedure (MIP) with autobiographical recall and self-selected music listening, which is known to successfully induce both positive and negative affective states (Ellard et al., 2012; Vuoskoski and Eerola, 2012; Zhang et al., 2014). In Experiment 1, binge drinkers and light drinkers underwent positive, negative and neutral mood inductions. We firstly hypothesized that binge drinkers would present stronger alcohol-related AB compared to light drinkers (h1). Second, we wondered whether AB could be caused by changes in mood and craving (then leading to AB through the influence of drinking pattern) rather than being the direct consequence of the drinking pattern. In other terms, we hypothesized that induced positive and negative mood would enhance the magnitude of alcohol-related AB, especially among binge drinkers, and that this relationship between mood and AB would be mediated by subjective craving (h2). We indeed reflected that mood can either have a direct influence on AB or an indirect one through craving increase (Figure 1). In Experiment 2, to explore the influence of alcohol-related mood, we compared binge drinkers with moderate drinkers and allocated them to alcohol-related negative mood, non-alcohol-related negative mood and neutral mood conditions. We recruited moderate drinkers rather than light or non-drinkers to make sure that all participants would be able to recall autobiographical memories related to alcohol consumption. We hypothesized that binge drinkers would present stronger alcohol-related AB compared to moderate drinkers (h3). We also hypothesized that AB would be strengthened by non-alcohol-related negative MIP but reduced by alcohol-related negative MIP, as a result of alcohol devaluation (h4). Once again, the association between negative mood and alcohol AB would be mediated by subjective craving and moderated by group status.

Methods of Experiment 1

Participants

We recruited participants via an online screening questionnaire sent through social networks to students from UCLouvain (Belgium). First, we informed them that, following this screening, they may be invited to participate to a paid experience exploring the link between emotions and alcohol consumption. Second, we asked them to fill in questionnaires assessing alcohol-related disorders (Alcohol Use Disorders Identification Test; Saunders et al., 1993; French validation: Gache et al., 2005), binge drinking habits [i.e., consumption speed, drunkenness

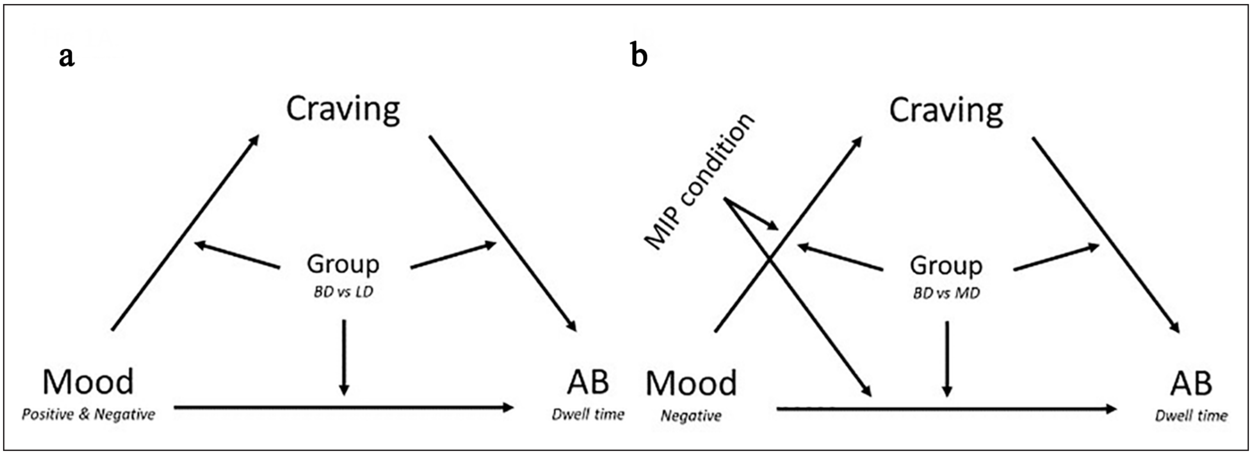

Figure 1. Conceptual models predicting alcohol-related AB. In Experiment 1 (a), positive and negative mood predict AB, with craving as mediator variable, and group status (binge drinkers versus light drinkers) as moderator variable. In Experiment 2 (b) negative mood predicts AB with craving as mediator variable, and group (binge drinkers versus moderate drinkers) and MIP condition (alcohol-related, non-alcohol-related, neutral) as moderator variables.
AB: attentional bias; MIP: mood induction procedure.

frequency and ratio, number of binge drinking episodes (i.e., drinking more than 6 units, a unit corresponding to 10 g of pure ethanol in Belgium) per week], socio-demographic (e.g., age, sex), drinking motives (Drinking Motives Questionnaire-Revised Short Form; French validation: Cooper, 1994) and other alcohol consumption variables (i.e., beverage preferences, number of alcohol units consumed per week, number of units per occasion, number of drinking occasions per week).

To be included in the study, they first had to meet the following criteria (evaluated through self-reported measures): having beer as preferred alcoholic beverage, absence of parental history of severe alcohol use disorder, absence of current psychological or neurological disorder, normal or lens-corrected vision, fluent French speaking. Moreover, we invited participants to take part in the experimental study only if they met the inclusion criteria for one of the two groups (binge drinkers vs. light drinkers). We constituted the inclusion criteria based on drinking habits and binge drinking score (Townshend and Duka, 2005), computed through the following formula: (4× consumption speed) + drunkenness frequency + (0.2× drunkenness percentage). Eighty-five participants (50 women and 35 men) took part in the experiment: 51 binge drinkers (binge drinking score >24, 2–3 drinking occasions per week, units per occasion >6, binge drinking episodes per week >1, beer drinkers) and 34 light drinkers (binge drinking score <12, 0.25–1 drinking occasions per week, units per week <3, units per occasion <3, no binge drinking episodes). People presenting a binge drinking score between 12 and 24 were thus not included.

We asked participants to refrain from consuming alcohol during the 24 h preceding the experimental sessions. To control for psychopathological comorbidities, they filled in questionnaires between sessions assessing depressive symptoms (Beck Depression Inventory; Beck et al., 1996) and anxiety (State-Trait Anxiety Inventory; French validation: Bruchon-Schweitzer and Paulhan, 1993). All participants provided their informed written consent before participating in the study and were not aware of the hypotheses tested. The study protocol adhered to the ethical standards established by the Declaration of Helsinki, and was approved by the Ethics Committee of the Psychological Sciences Research Institute (UCLouvain). At the end of the experiment, we debriefed participants, who received a financial compensation of 10 euros per hour.

Procedure

The experiment consisted of three 40-min sessions with different MIP, each separated by at least 24 h. The sessions' order was counterbalanced across participants to avoid potential learning and/or training effects. Participants were seated on a desk chair in front of a computer and tested individually in a quiet laboratory. The procedure (Figure 2) was identical across sessions: participants had to fill in online questionnaires assessing current alcohol craving (Visual Analogue Scale, VAS) and emotional state (Positive and Negative Affect Schedule; Watson et al., 1988) using Qualtrics software, before and after completing the MIP and after performing the visual probe task.

We used combined MIP with autobiographical recall and music listening to induce each mood. A few days before the experiment, participants sent by email the title of three music tracks making them feel in a positive mood, as well as three music tracks making them feel in a negative mood. At the start of the experiment, participants received instructions (Supplemental Appendix 1) to write down a happy memory (for positive MIP) or sad memory (for negative MIP), in which they did not consume any alcoholic beverage. For the neutral MIP, they were asked to write the itinerary they followed to arrive at the laboratory (Supplemental Appendix 2). After reading the instructions, participants received headphones and started listening to the correspondent playlist prepared by the experimenter. One playlist was made for each condition, comprising the music tracks selected by the participant for the negative and positive MIP and one song selected by the experimenter for the neutral MIP. We chose the song «Common Tones in Simple Time» by John Adam for the neutral MIP, as this song was reported to not evoke any emotion (Västfjäll, 2001). Participants were then asked to

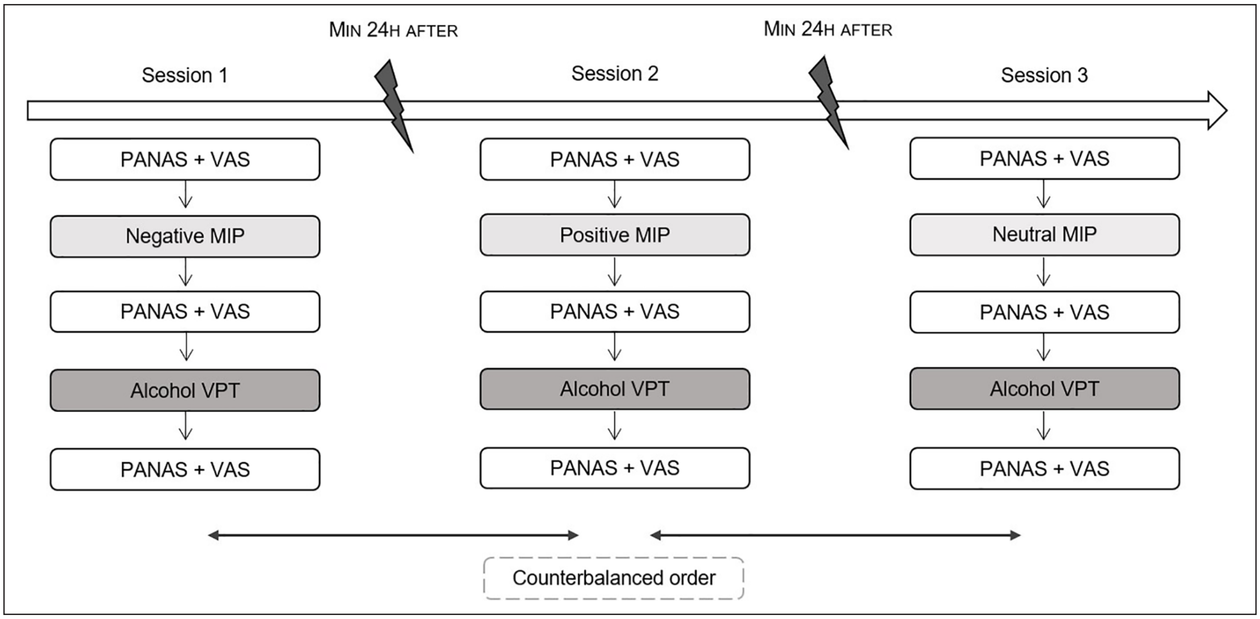

Figure 2. General experimental procedure of Experiment 1. MIP, Mood Induction Procedure; PANAS: Positive and Negative Affect Scale; VAS: Visual Analogue Scale; VPT: Visual Probe Task.

complete the recall task within 10 min. The experimenter stayed quiet and away from the participants to give them privacy during MIP.

For the experimental task, participants were seated on a desk chair, facing a desktop eye-tracker camera, and placed 60 cm away from a Dell PC equipped with a 21.5″ LCD screen (resolution 1920 × 1080; refresh rate 60 Hz). We reduced their head movements using a forehead and chin stabilizer. We controlled the presentation of the experimental task and its synchronization with the eye-tracking using OpenSesame software (version 3.1.6; Mathôt et al., 2012). We recorded eye movements using an EyeLink 1000 desktop-mounted eye-tracker (SR Research Ltd, Kanata, ON, Canada; sampling rate of 1000 Hz; average accuracy range 0.25–0.5°, gaze tracking range of 32° horizontally and 25° vertically). We set up a nine-point calibration of participant's eye gaze position at the beginning of the personalized visual probe task.

At the beginning of each trial, a central fixation dot appeared on the black background screen and participants had to fixate their gaze on it. Moreover, the fixation dot was used as drift check to confirm the reliability of the eye-gaze calibration. This instruction ensured that participants initially focused their visual attention at the centre of the screen in each trial. Once the eyes of the participant were detected at the centre of the screen, the fixation dot was removed and directly followed by the onset of two pictures (i.e., beer and soft drink pictures). They were displayed randomly on the left and right side of the computer screen for 2000 ms and then replaced by a probe (i.e., a white arrow on a black background, pointing up or down) appearing at the location previously occupied by one of the pictures. Participants had to respond to the orientation of the probe by pressing the 'up' or 'down' key on a keyboard, as quickly and correctly as possible. Each trial was separated by an inter-trial interval of random duration (500–1500 ms). Visual probes replaced the two types of pictures with equal frequency. The task contained 68 trials, including four practice trials that participants first completed, and lasted for 15 min. For each session, we presented a different set of stimuli to participants, leading to three versions of the task, administered in a counterbalanced order. This allowed to reduce a potential learning and practice effect in the last block of the last session.

Stimuli

We used 48 pairs of beer pictures (i.e., beer bottles) and matched non-alcoholic beverages pictures (i.e., water and soft drink bottles) without context for the different versions of the visual probe task (16 pairs per task). We used internet image search to develop stimulus sets including beer (by far the most consumed alcoholic drink among Belgian University students) and non-alcoholic beverages of familiar brands in Belgium. We systematically blurred the brand and writings of the beverage to avoid reading or semantic processing. We computed the physical properties of images using customized MATLAB scripts (The Mathworks, Inc. Natick, MA, USA). We then matched each picture pair on the following physical features: size (375 × 375 pixels), object size (proportion of non-white pixels), colour (contribution of red, green and blue colour channels to the non-white pixels) and complexity (proportion of pixels representing contour outlines as determined by a Canny edge detection algorithm; Canny, 1986). We performed mean comparisons (i.e., independent *t*-tests) to control for the influence of perceptual aspects on AB, but we observed no significant difference between beer and soft drink pictures for all these physical features ($p > 0.050$).

Data analysis

We performed a data reduction procedure for reaction times by removing trials with incorrect responses (0.014% of trials) and reaction times lower than 200 ms (0.002% of trials) or higher than

Table 1. Means and standard deviations of demographical and psychological variables in binge drinkers, light drinkers (Experiment 1) and moderate drinkers (Experiment 2).

	Binge drinkers (n=48)	Light drinkers (n=32)	Moderate drinkers (n=29)
Age	20.77 ± 1.84	21.41 ± 3.32	21.90 ± 2.38
Gender (M/W)	17/31	12/20	10/19
Depression	6.96 ± 5.46	5.19 ± 3.48	5.14 ± 5.07
Trait anxiety	45.67 ± 10.31	42.84 ± 9.39	43.59 ± 9.28
Impulsivity	49.27 ± 7.62	42.28 ± 9.84	46.41 ± 5.47
Enhancement motives	9.71 ± 2.84	4.45 ± 2.02	6.27 ± 2.86
Coping motives	5.38 ± 2.66	3.27 ± 0.88	3.53 ± 0.91

2000 ms (0.002% of trials). We removed the data from five participants before performing the analyses, as they did not make any eye movements towards stimuli in the different blocks, leading to a sample of 80 participants (48 binge drinkers, 32 light drinkers).

The dependent variables measured were (1) the *reaction time* to respond to probes appearing on the side of the screen congruent versus incongruent with alcohol-related stimuli; (2) the *first fixation location*, indicating the stimulus that was first fixated at the beginning of each trial (i.e., initial attentional capture); (3) the *second fixation location*, indicating how frequently the participant fixated a second stimulus after visiting the first one (i.e., attentional switch) and (4) the *dwell time*, the sum of fixation times on one of the stimuli during the whole trial (i.e., maintenance of attention). We computed AB scores for each measurement: the difference between the reaction times for probes congruent and incongruent with alcohol-related stimuli for *reaction time*, the percentage of first fixations towards alcohol-related stimuli for *first fixation location*, the percentage of second fixation on alcohol compared to no fixation after a first fixation on non-alcohol for *alcohol second fixation*, the percentage of second fixation on non-alcohol compared to no fixation after a first fixation on alcohol for *non-alcohol second fixation* and the percentage of fixation time spent on alcohol-related stimuli compared to non-alcohol stimuli for *dwell time*. We extracted the spatial and temporal parameters of eye movements using Eyelink® Data Viewer (SR Research Ltd). We qualified gaze samples as fixations or saccades according to the standard EyeLink algorithms.

We performed all statistical analyses using SPSS software package (version 27.0). First, we performed between-group comparisons (independent samples *t*-tests) on demographic and psychological variables. Second, we examined the efficacy of the MIPs by estimating linear mixed-effect models for positive and negative mood, including Time [just before MIP (pre-MIP) and just after MIP (post-MIP)] and Condition (positive, negative, neutral MIP) as within-subjects factors, Group (binge drinkers, light drinkers) as between-subjects factors and a random intercept by subject. We performed post-hoc analyses by rerunning the analysis separately for the different levels of Time or Condition with a Bonferroni-corrected p-value of $\alpha_{altered}=0.05/3=0.017$. Third, we estimated the internal reliability of our AB measures by computing Cronbach's alpha and considered it acceptable when being above the 0.70 conventional cut-off (Kline, 2013). Following a well-established procedure (Ataya et al., 2012; Christiansen et al., 2015b; van Ens et al., 2019), we calculated AB scores separately for each pair of pictures, leading to 48 AB scores for each AB measure within each version of the visual probe task. Fourth, we investigated our first hypothesis (h1: stronger alcohol-related AB among binge drinkers than light drinkers) by estimating linear mixed-effect models for behavioural (reaction time) and eye-tracking (first fixation position, alcohol second fixation, non-alcohol second fixation and dwell time) indices of alcohol-related AB with Group (binge drinkers, light drinkers) as between-subjects factor and a random intercept by subject. Fourth, we explored our second hypothesis (h2: induced positive/negative mood strengthen AB in binge drinkers) by estimating linear mixed-effect models for each AB measure. We investigated the relationship between post-MIP mood (positive or negative) and AB by including Group as moderator variable and post-MIP Craving as mediator variable in the model. To do so, we firstly estimated an initial linear mixed-effect model for Craving with Group, Positive mood, Negative mood and their interactions (Group × Positive mood, Group × Negative mood) as predictors. Then, we reran the model by removing each time the less significative interactions, until reaching a final model with exclusively significative interactions or no interaction (significance level set at 0.05). We estimated the indirect effects between mood and AB using the joint significance approach (RMediation package for mediation analysis; Tofighi and MacKinnon, 2011). We used the same procedure when predicting each AB measure with Craving, Group, Positive mood and Negative mood and their interactions (Group × Positive mood, Group × Negative mood, Group × Craving) as predictors. A power computation (performed in G*Power v3.1.9.7; Faul F, Kiel, Germany) indicated that a total sample size of 67 was required to perform linear multiple regressions with a total number of seven predictors, assuming a medium (f=0.25) effect size with 0.90 power and α=0.05, thus suggesting that our study was sufficiently powered.

Results of Experiment 1

Demographics and psychological variables

Binge and light drinkers did not significantly differ regarding age ($t_{43.733}=0.987$, $p=0.329$), anxiety ($t_{78}=1.242$, $p=0.218$) and depression ($t_{78}=1.625$, $p=0.108$). Binge drinkers showed higher scores for impulsivity ($t_{63}=3.339$, $p=0.001$), and for enhancement ($t_{53.473}=8.074, p<0.001$) and coping ($t_{43.201}=4.271$, $p<0.001$) drinking motives[1] (Table 1). Binge drinkers showed higher craving before MIP (VAS; $t_{77.880}=4.278$, $p<0.001$) and after MIP ($t_{75.997}=3.918, p<0.001$).

Table 2. Linear mixed-effect models on craving and attentional bias in Experiment 1.

Variables	*B*	SE	*t*	*p*	95% CI	
1. *Craving predicted from group, sex and emotions*						
Step 1 – Initial model						
Group	6.238	14.546	0.429	0.668	−22.439	34.915
Positive affect	0.343	0.250	1.372	0.172	−0.150	0.837
Negative affect	0.238	0.393	0.606	0.545	−0.537	1.014
Group × Positive Affect	−0.163	0.348	0.470	0.639	−0.849	0.522
Group × Negative Affect	0.588	0.469	1.252	0.212	−0.338	1.513
Step 2 – Final model						
Group	10.075	3.254	3.096	0.003	3.598	16.553
Positive affect	0.281	0.173	1.623	0.106	−0.060	0.623
Negative affect	0.670	0.214	3.128	0.002	0.248	1.093
2. *AB predicted from group, sex, craving and emotions*						
Step 1 – Initial model						
Group	−1.119	7.523	−0.149	0.882	−15.958	13.719
Craving	0.152	0.079	1.927	0.056	−0.004	0.307
Positive affect	−0.006	0.137	−0.046	0.964	−0.276	0.264
Negative affect	−0.104	0.204	−0.509	0.611	−0.506	0.298
Group × Positive Affect	0.022	0.184	0.121	0.903	−0.340	0.385
Group × Negative Affect	0.122	0.244	0.500	0.617	−0.359	0.604
Craving × Group	−0.048	0.088	−0.542	0.589	−0.221	0.126
Step 2 – Final model						
Group	0.887	1.636	0.542	0.589	−2.370	4.144
Craving	0.115	0.035	3.295	0.001	0.046	0.184
Positive affect	0.013	0.090	0.148	0.883	−0.164	0.191
Negative affect	−0.021	0.111	−0.190	0.850	−0.241	0.198

CI: confidence interval; SE: standard error.

Efficacy of MIP

Positive mood. The linear mixed model for positive mood revealed a Condition × Time interaction ($F_{2,355.657}=33.101$, $p<0.001$). Consistent with our predictions, positive mood increased from pre- to post-MIP in the positive condition ($b=3.28$, $t_{60}=6.069$, $p<0.001$), while it decreased after negative condition ($b=-4.14$, $t_{78}=7.374$, $p<0.001$) and did not significantly change after the neutral condition ($p>0.050$). Moreover, post-MIP positive mood was higher in the positive condition relative to negative ($b=-6.87$, $t_{144}=8.674$, $p<0.001$) and neutral ($b=-2.15$, $t_{145}=2.712$, $p=0.007$) conditions. We found no main effect of Group nor significant interaction between Group, Condition and Time (all $p>0.050$).

Negative mood. The linear mixed model for negative mood revealed a Condition x Time interaction ($F_{2,349.030}=35.815$, $p<0.001$). Consistent with our predictions, negative mood increased from pre- to post-MIP in the negative condition ($b=3.91$, $t_{78}=7.310$, $p<0.001$), while it decreased after positive ($b=-1.62$, $t_{60}=3.351$, $p<0.001$) and neutral conditions ($b=-1.75$, $t_{79}=5.203$, $p<0.001$). Moreover, post-MIP negative mood was higher in the negative condition relative to positive ($b=-5.46$, $t_{142}=8.904$, $p<0.001$) and neutral ($b=-5.27$, $t_{137}=9.422$, $p<0.001$) conditions. We also found a Group main effect ($F_{1,76.896}=7.598$, $p=0.007$), showing that binge drinkers generally reported higher negative mood than light drinkers ($b=3.047$, SE$=1.194$). Nevertheless, the efficacy of MIPs to induce negative mood did not differ between binge and light drinkers as no interaction was found between Group and Condition and Time (all $p>0.050$).

Alcohol-related AB

Internal reliability was low for reaction time ($\alpha=-0.301$), first fixation direction ($\alpha=-0.084$) and second fixation towards non-alcohol ($\alpha=0.620$). Conversely, it was high for other eye-tracking measures related to more controlled AB measures (second fixation towards alcohol: $\alpha=0.834$; dwell time: $\alpha=0.910$).

To test h1, we performed linear mixed-effect models to investigate group differences on alcohol-related AB. Models for the different AB scores revealed no main effect of Group, neither for reaction time ($F_{1,215}=0.081$, $p=0.776$), first fixation orientation ($F_{1,75.935}=0.076$, $p=0.783$), second fixation on alcohol ($F_{1,78.032}=1.383$, $p=0.243$], second fixation on non-alcohol ($F_{1,78.860}=0.029$, $p=0.866$) nor dwell time ($F_{1,71.668}=1.769$, $p=0.188$).

To test h2, we then included the moderator and mediator variables in linear mixed-effect models (Table 2). Our final models for craving and AB no longer contained any interaction terms. First, there was an indirect effect of Negative mood on dwell time AB score through Craving ($b=0.077$, SE$=0.035$, 95% confidence interval (CI)$=0.15$ to 0.22). The intensity of negative mood increases craving ($b=0.670$, SE$=0.214$, $F_{1,212.044}=9.784$,

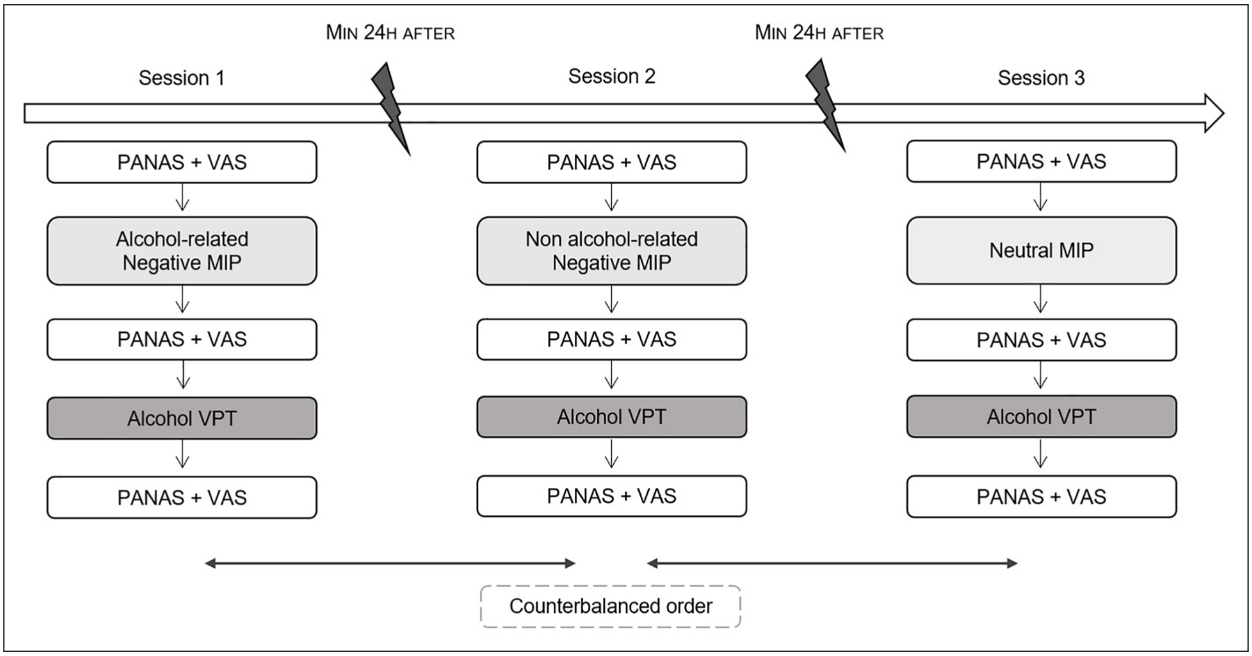

Figure 3. General Experimental procedure of Experiment 2.

$p = 0.002$), which in turn positively predicts alcohol-related AB ($b = 0.115$, SE = 0.035, $F_{1,206.264} = 10.857$, $p = 0.001$). Second, Craving was also predicted by the Group ($F_{1,78.639} = 9.586$, $p = 0.003$), as binge drinkers showed stronger craving than light drinkers ($b = 10.075$, SE = 3.254). We found no moderation effect of Group, no mediation effect of Craving between Positive mood and AB, nor direct effect of Group, Positive mood or Negative mood on dwell time AB score. We found no direct or indirect effect of those predictors on the other AB measures (all $p > 0.050$).

Discussion of Experiment 1

Our results revealed that the group (binge vs. light drinkers) did not predict alcohol-related AB differences, regardless of the AB measures used. However, both being binge drinkers and being in a negative mood predicted positively subjective craving, which in turn was positively associated with alcohol-related AB when measured through dwell time. In other terms, the relationships between binge drinking and negative mood and AB were not direct but mediated by subjective craving.

Surprisingly, we did not find any effect of positive mood on craving or on alcohol-related AB. As previous studies consistently reported that most young drinkers are motivated to drink for positive drinking-related reinforcements (i.e., enhancement and social drinking motives; Kuntsche et al., 2004, 2005, 2014), we expected most of our participants to present more craving and be more attracted by alcohol-related cues when being in a positive mood. However, such links might represent acquired associations between specific contexts (i.e., parties, social events) and the presence of alcohol (O'Hara et al., 2015). The pictures used as stimuli in our study, presenting isolated alcohol beverages without depicting any of these contexts, might not result in stronger AB following positive mood.

Capitalizing on the observed increased craving following negative mood induction, we further investigated this relationship in Experiment 2 and tested whether it could be modified when participants were explicitly asked to recall a negative autobiographical memory directly linked to alcohol (conversely to the memories evoked in Experiment 1). Indeed, using a MIP that directly associates negative mood and alcohol consumption might lead participants to evaluate alcohol negatively, and thus increase their negative alcohol expectancies. Similar to previous studies using taste devaluation, this procedure of alcohol devaluation could then reduce their subjective craving and/or visual attraction towards alcohol-related stimuli (Rose et al., 2013). To explore these hypotheses (h3–4), we conducted a second experiment with a novel negative MIP, in which participants had to recall an autobiographical memory characterized by strong negative emotions and intense alcohol use (i.e., alcohol-related negative MIP) and compared it with the non-alcohol-related negative and neutral MIP used in Experiment 1.

Methods of Experiment 2

Participants

The same group of binge drinkers took part in Experiment 2. We also selected 29 moderate drinkers (19 women, 10 men; binge drinking score < 12, drinking occasions per week > 1, units per week < 22, units per occasion < 3, no binge drinking episodes) using the same procedure as in Experiment 1.

Procedure

We used combined MIP with autobiographical recall and music listening for inducing alcohol-related negative mood. Participants were asked to send by email three music tracks making them feel in a

Table 3. Linear mixed-effect models on craving and attentional bias in Experiment 2.

Variables	*B*	SE	*t*	*p*	95% CI	
1. *Craving predicted from group, sex, MIP and negative emotions*						
Step 1 – Initial model						
Group	2.169	6.791	0.319	0.750	−11.224	15.562
MIP	2.460	3.561	0.691	0.491	−4.573	9.494
Negative affect	0.678	0.436	1.553	0.122	−0.183	1.538
Group × Negative Affect	0.312	0.382	0.816	0.415	−0.441	1.064
MIP × Negative Affect	−0.109	0.215	−0.504	0.615	−0.534	0.317
Step 2 – Final model						
Group	7.206	3.083	2.338	0.022	1.069	13.344
MIP	0.766	1.358	0.564	0.573	−1.916	3.448
Negative affect	0.747	0.197	3.800	<0.001	0.359	1.135
2. *AB predicted from group, sex, craving, MIP and negative emotions*						
Step 1 – Initial model						
Group	−2.947	2.999	−0.983	0.327	−8.861	2.966
Craving	0.064	0.058	1.096	0.275	−0.051	0.178
MIP	−1.644	1.475	−1.114	0.267	−4.558	1.271
Negative affect	−0.282	0.186	−1.519	0.131	−0.649	0.084
Group × Negative Affect	0.138	0.170	0.812	0.418	−0.197	0.473
MIP × Negative Affect	0.148	0.089	1.653	0.100	−0.029	0.325
Craving × Group	0.015	0.068	0.219	0.827	−0.119	0.149
Step 2 – Final model						
Group	−0.717	1.498	−0.479	0.633	−3.699	2.264
Craving	0.073	0.030	2.461	0.015	0.015	0.132
MIP	0.595	0.565	1.053	0.294	−0.521	1.711
Negative affect	0.001	0.089	0.001	0.999	−0.175	0.175

CI: confidence interval; MIP: mood induction procedure; SE: standard error.

negative mood. At the start of the experiment, participants received instructions (Supplemental Appendix 3) asking them to write down a sad memory, in which they consumed a high level of alcohol. The procedure for the non-alcohol-related negative and neutral MIPs and AB task were identical to Experiment 1 (Figure 3).

Data analysis

We performed data reduction procedure for reaction times by removing trials with incorrect responses (0.009% of trials), reaction times lower than 200 ms (0.001% of trials) or higher than 2000 ms (0.006% of trials).

We performed the same data analyses than Experiment 1 but also included the MIP (alcohol-related, non-alcohol-related, neutral) as within-subjects moderator variable in the models to test h4 (i.e., the alcohol-related nature of MIP would reverse the association between negative mood and craving or AB).

Results of Experiment 2

Demographics and psychological variables

Binge and moderate drinkers did not differ regarding anxiety (t_{75}=0.890, p=0.376), depression (t_{75}=1.455, p=0.150) and impulsivity (t_{75}=1.762, p=0.082). However, binge drinkers were younger (t_{75}=2.327, p=0.023) than moderate drinkers and showed higher scores of enhancement (t_{47}=3.892, p < 0.001) and coping ($t_{45.373}$=3.596, p < 0.001) drinking motives[2].

Binge drinkers showed higher negative mood before MIP (t_{75}=2.007, p=0.048) and after MIP (t_{75}=2.575, p=0.014) than moderate drinkers. They also showed higher craving before MIP ($t_{74.936}$=3.417, p=0.001) and after MIP (t_{75}=2.665, p=0.009). They did not differ regarding positive mood before MIP (t_{75}=1.603, p=0.113) or after MIP (t_{75}=0.909, p=0.366).

Efficacy of MIP

Positive mood. The linear mixed model for positive mood revealed a Condition × Time interaction ($F_{2,370}$ = 12.893, p < 0.001). Consistent with our predictions, positive mood decreased from pre- to post-MIP in the alcohol-related (b=−3.28, t_{66}=6.779, p < 0.001) and non-alcohol-related (b=−3.32, t_{79}=6.126, p < 0.001) negative conditions but did not change significantly after the neutral condition (p > 0.050). Moreover, post-MIP positive mood was lower in the alcohol-related (b=−3.45, t_{148}=4.877, p < 0.001) and non-alcohol-related (b=−3.71, t_{145}=5.594, p < 0.001) negative conditions relative to the neutral condition. We found no main effect of Group nor significant interaction between Group, Condition and Time (all p > 0.050).

Negative mood. The linear mixed model for negative mood revealed a Condition × Time interaction ($F_{2,370}$ = 19.932, p < 0.001). Consistent with our predictions, negative mood increased from pre- to post-MIP in the alcohol-related (b=3.21, t_{66}=4.780, p < 0.001) and non-alcohol-related (b=3.25, t_{79}=6.499, p < 0.001) negative conditions, while it decreased after neutral condition (b=−1.73, t_{80}=4.975, p < 0.001). Moreover, post-MIP negative mood was higher in the alcohol-related ($b=5.42$, $t_{150}=7.235$, $p<0.001$) and non-alcohol-related ($b=5.04$, $t_{146}=7.153$, $p<0.001$) negative conditions relative to the neutral condition. We also found a Group main effect ($F_{1,78.571}=8.230$, $p=0.005$), showing that binge drinkers generally reported higher negative mood than moderate drinkers ($b=2.986$, SE=1.335). Nevertheless, the efficacy of MIPs to induce negative mood did not differ between binge and light drinkers as no interaction was found between Group and Condition and Time (all $p>0.050$).

Alcohol-related AB

Internal reliability was low for reaction time ($\alpha=-0.520$), first fixation direction ($\alpha=0.004$), second fixation towards alcohol ($\alpha=0.536$) and non-alcohol ($\alpha=0.212$) measures, and high for dwell time ($\alpha=0.908$).

To test h3, we performed multilevel models to investigate group differences on alcohol-related AB. Models for the different AB scores revealed no main effect of Group, neither for reaction time ($F_{1,211}=0.418$, $p=0.519$), first fixation orientation ($F_{1,66.556}=0.872$, $p=0.354$) second fixation on alcohol ($F_{1,72.084}=1.194$, $p=0.278$), second fixation on non-alcohol ($F_{1,72.630}=1.409$, $p=0.239$) nor dwell time ($F_{1,73.272}=0.004$, $p=0.949$).

We then included the moderator and mediator variables in models to test h4 (Table 3). Our final models for craving and AB no longer contained any interaction terms. First, there was a significant indirect effect of Negative mood on dwell time AB score, mediated by Craving ($b=0.055$, SE=0.027, 95% CI=0.009 to 0.115). The intensity of negative mood increases the level of craving ($b=0.747$, SE=0.197, $F_{1,204.862}=14.441$, $p<0.001$), which in turn positively predicts alcohol-related AB ($b=0.073$, SE=0.030, $F_{1,204.617}=6.057$, $p=0.015$). Second, Craving was also directly predicted by the Group ($F_{1,77.711}=5.465$, $p=0.022$), as binge drinkers showed stronger craving than moderate drinkers ($b=7.206$, SE=3.083). We found no moderation effect of Group or MIP condition, nor direct effect of Group, Negative mood or MIP condition on dwell time AB score. We found no direct or indirect effect of those predictors on the other AB measures (all $p>0.050$).

Discussion of Experiment 2

In line with Experiment 1, the group (binge vs. moderate drinkers) did not predict alcohol-related AB differences for any measure used. However, both binge drinking habit and negative mood were positively associated with subjective craving – regardless of the negative MIP used – which in turn positively predicted AB when assessed through dwell time AB score. These findings again highlight the mediating role of subjective craving in the relationship between AB and negative mood. Importantly, the explicit instructions of recalling a negative memory related to strong alcohol consumption did not reverse the association between negative mood and craving as hypothesized, since participants were still more prone to report higher craving following the two types of negative MIPs.

The present findings could be explained by the fact that negative mood, whatever its source, played a higher role on the emergence of craving for alcohol than the devaluation of alcohol *per se*. This strong association between negative emotions and the desire to consume to reduce these emotions usually explain how the negative consequences of alcohol use (e.g., increase of anxious and depressive symptoms; Anker and Kuschner, 2019) do not result in functional avoidance of alcohol among binge drinkers, but rather in a persistent maladaptive attraction towards alcohol. Another explanation is that participants might not have directly associated their negative mood with their alcohol consumption during this memory. Hence, the alcohol-related negative MIP did not change their alcohol expectancies and did not impact their craving or AB.

General discussion

Altogether, results from our two experiments provide important insights into the understanding of alcohol-related AB in subclinical populations with excessive alcohol use. First, they replicate findings from many previous studies regarding the major role of craving on the intensity of alcohol-related AB. Indeed, a meta-analysis of 68 studies highlighted the positive association between craving level and AB magnitude (Field et al., 2009). More importantly, previous studies relying on eye-tracking measures even suggested that the intensity of subjective craving is a stronger determinant of AB than drinking habits, since they did not find any AB among regular or binge drinkers reporting no craving at testing time (Bollen et al., 2020; Hobson et al., 2013). In the same vein, the present study did not find any direct association between group status (binge drinkers vs. light or moderate drinkers) and AB, as this relationship was mediated by subjective craving. All these findings support the model of Field et al. (2016), defining AB as the expression of momentary motivational states regarding alcohol-related stimuli. Altogether, they posit that the presence of alcohol-related AB highly fluctuates according to transient states such as craving.

Since the presence and magnitude of AB depends on subjective craving in binge drinkers, it is important to highlight the core determinants of craving *per se*. The present study provides initial insights on this question by showing that participants were more likely to report craving when they endorsed binge drinking habits and experienced negative mood. Our findings relate with previous studies showing that laboratory manipulations of negative mood can provoke subjective craving, and that this effect was stronger in heavier drinkers compared to moderate ones (Blaine et al., 2019; Fox et al., 2007). This is consistent with the affective processing model of negative reinforcement (Baker et al., 2004), which suggests that the desire for alcohol consumption is predominantly motivated by the escape and avoidance of negative mood. Several meta-analyses supported this model by showing that experiencing negative mood was a relevant factor to elicit craving (Bresin et al., 2018; Cyr et al., 2022; Heckman et al., 2013; van Lier et al., 2018).

In line with previous studies in subclinical populations (see Bollen et al., 2022 for a review), alcohol-related AB in the present study was only predicted by our selected variables when indexed by eye-tracking measures, and more specifically by dwell time (i.e, overall fixation time on alcohol vs. non-alcohol stimuli). As this latter measure is known to reflect the processes related to controlled maintenance of attention, AB would thus appear at the later and more controlled stages of attentional processing in subclinical drinkers rather than being characterized by an early and involuntary hijacking of attention provoked by alcohol-related stimuli as postulated by dominant models in addiction

(Bechara, 2005; Wiers et al., 2007). However, this could also be due to the higher reliability of dwell time measure reported in the present study and in previous ones (Bollen et al., 2020, 2021; Christiansen et al., 2015b). Future studies on AB should systematically go beyond behavioural measures, centrally by using eye-tracking methods, but also develop novel paradigms to more reliably determine the automatic nature of AB.

Finally, our findings showed that binge drinkers reported higher negative mood at baseline and after MIP than moderate or light drinkers, which might be a direct after-effect of repeated alcohol exposures and binge drinking patterns (Koob, 2013) or related to differences in emotional regulation abilities highlighted by many previous studies in binge drinking (Lannoy et al., 2019). Whereas the efficacy of MIP was similar between groups, this finding makes it difficult to differentiate the respective impact of negative mood and drinking group status on craving or AB. Our study also presents some limitations. First, while our experimental sample showed the classically reported binge drinking consumption pattern, the use of the same binge drinking participants in the two experiments might have limited the generalizability of our findings. Second, we did not include drinking motives in our main analyses for statistical reasons, which prevented us from determining the role of this potential predictor. Third, our study might have not been sufficiently powered to detect smaller interaction effects. Fourth, while Experiment 2 investigated the role of negative devaluation on craving and AB through an alcohol-related negative MIP, we did not include explicit measures of negative alcohol expectancies. Finally, the MIP effect might have been partly related to demand characteristics and might have progressively vanished during the VPT task, the influence of mood induction thus potentially varying along the task. Future studies should extend the present results to other stimuli (e.g., beverages in a drinking context) and alcohol types (e.g., wine, spirits) and explore the influence of other variables (e.g., drinking motives) on the links between mood, craving and AB. However, our work draws some clinical avenues regarding prevention and intervention on excessive alcohol use. In view of these results, an ample panel of strategies (i.e., emotion regulation, cognitive regulation of craving, AB modification training) could show promise as targeted interventions on the interlinked determinants of alcohol use (i.e., negative mood, craving and AB; Gratz et al., 2015; Naqvi et al., 2015).

Conclusion

We provided insights on the interactions between alcohol-related AB, craving, drinking status and mood in a population of student drinkers, by showing that the association between negative mood, binge drinking habits and AB is mediated by subjective craving. These findings support previous studies and theoretical models suggesting that alcohol-related AB is not a stable characteristic of excessive alcohol use but is rather the behavioural artefact of transient evaluative states (e.g., craving). Additionally, our multilevel modelling approach identified which variables directly determine craving, and thus indirectly influence the magnitude of alcohol-related AB. Overall, these findings emphasize the importance of considering different motivational and affective states (i.e., subjective craving, mood and AB) as intercorrelated to offer multiple ways to reduce excessive alcohol use.

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Notes

1. Considering the major differences between groups on mood-congruent drinking motives (i.e., enhancement motives for positive mood, coping motives for negative mood), as well as the very low variability of scores of drinking motives in light drinkers, we decided to not include these motives in our multilevel approach model.
2. Considering the major differences between groups on mood-congruent drinking motives and the low variability of scores of drinking motives in moderate drinkers, we decided to not include these motives in our multilevel approach model.

Supplemental Material

Supplemental material for this article is available online

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