Drug and Alcohol Dependence 283 (2026) 113122

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Interoceptive phenomenology of hangover: A proof of concept for bodily mapping in naturalistic study designs

Natascha Steiger [a], Olivier Desmedt [a,b], Pauline Billaux [a], Pierre Maurage [a], Mateo Leganes-Fonteneau [a,c,*]

[a] Louvain Experimental Psychopathology research group (LEP), Psychological Science Research Institute, UCLouvain, Louvain-la-Neuve, Belgium
[b] Institute of Psychology, University of Lausanne, Lausanne, Switzerland
[c] Developmental Psychopathology Department, Psychology School, University of Amsterdam, Netherlands

ARTICLE INFO

Keywords:
Alcohol use disorder
Bodily sensation
Interoception
Subjective alcohol effects

ABSTRACT

Background: Alcohol hangover is the most frequently reported adverse consequence of excessive drinking and can predict future alcohol use. While standard hangover measures capture physiological symptoms, they overlook how these sensations are perceived. We introduce a proof-of-concept for bodily mapping in naturalistic studies by characterizing hangover phenomenology in individuals who drink heavily.

Methods: Participants (N = 34) completed a baseline assessment. Then, using the emBODY tool, participants marked regions of activation and deactivation during several hangover sessions to generate topographical maps. These maps quantified the extent and intensity of hangover bodily sensations. Participants reported prior-night subjective intoxication and current hangover severity. Pre-registered linear mixed models and correlational analyses assessed within-subject associations with session-level variables and between-subject associations with individual drinking profiles.

Results: Topographical maps revealed hangover-related activation in the head, chest and abdomen and deactivation in the lower limbs. Intensity, but not extent, of bodily sensations was significantly associated with hangover severity, independent of subjective intoxication. Participants with high trait-level drinking scores reported more intense bodily sensations, more frequent hangovers, and stronger associations between sensation intensity and hangover severity, which also increased with age.

Conclusions: Bodily mapping captures meaningful interoceptive patterns linked to subjective hangover severity and individual drinking behavior, offering new insights into the somatic processes underlying vulnerability to alcohol misuse. Our results offer proof-of-concept establishing the usefulness and feasibility of body mapping in naturalistic designs. They also underscore its potential as a scalable, intuitive tool for investigating embodied processes in addiction research, where interoceptive dimensions remain underexplored.

1. Introduction

Alcohol hangover is the most frequently reported adverse consequence of excessive consumption and is characterized by a combination of mental and physical symptoms (Verster et al., 2020). Despite its prevalence, our understanding of the subjective bodily hangover experience remains limited. Retrospective self-report questionnaires and performance-based tasks have documented hangover-related symptoms such as thirst, nausea, and impairments in attention and memory (Prat et al., 2008; van Schrojenstein Lantman et al., 2017). While these instruments already incorporate bodily sensations (e.g., stomach pain, heart pounding, headache), they presuppose that participants can adequately verbalize these bodily experiences and rely on predefined item lists, which together offer constrained insights into where sensations are perceived and how they are distributed across the body.

To address this gap, bodily mapping emerges as a valuable tool for capturing the missing interoceptive dimension of subjective states. This methodology allows participants to indicate bodily sensations on a standardized body template, providing a topographical representation of ongoing affective and physical experiences without verbalization or

* Corresponding author at: Louvain Experimental Psychopathology research group (LEP), Psychological Science Research Institute, UCLouvain, Louvain-la-Neuve, Belgium.

E-mail address: mateo.leganes@uclouvain.be (M. Leganes-Fonteneau).

https://doi.org/10.1016/j.drugalcdep.2026.113122
Received 14 November 2025; Received in revised form 29 January 2026; Accepted 5 March 2026
Available online 11 March 2026

item-cued prompting. Moreover, given the physiological salience of hangovers, they offer an ideal gateway to examining bodily correlates underlying addictive processes. The ease of administering body mapping in real-world settings further supports its use as a naturalistic adjunct to current hangover scales, offering a complementary phenomenological dimension.

Bodily maps have recently been used to measure alcohol-induced bodily sensations in people who drink socially (Leganes-Fonteneau et al., 2025), characterize the bodily dimension of craving in severe alcohol use disorders (AUD) (Billaux et al., 2025a), and serve as a marker of laboratory-induced craving in people who binge-drink (Billaux et al., 2025b). Extending these previous works, we propose here the first characterization of subjective bodily sensations during hangover episodes, providing a proof-of-concept for the integration of bodily mapping tools into naturalistic designs.

Beyond phenomenological characterization, this approach may offer insights into individual vulnerability to future AUD, as previous studies have generated contradictory findings. Longitudinal studies have demonstrated that frequent and severe hangovers during adolescence and early adulthood, reflecting greater hangover sensitivity, predict later problematic drinking (Piasecki et al., 2005), while controlling for previous alcohol use (Courtney et al., 2018). Conversely, lower hangover severity, or hangover insensitivity, has also been associated with increased risk of future alcohol misuse (Rohsenow et al., 2011). Investigating hangover from a bodily perspective could clarify the processes through which hangover sensitivity feeds into risk for alcohol misuse.

Indeed, research across the multidimensionality of interoception, the top-down and bottom-up process by which the central nervous system senses, interprets, and integrates signals from within the body, consciously and unconsciously (Chen et al., 2021; Desmedt et al., 2025), offers a unifying framework for these lines of evidence. By supporting physiological homeostasis as well as higher-order functions such as decision-making, emotion regulation, and motivation (Tsakiris and Critchley, 2016), interoception has been linked to numerous neuropsychiatric conditions, including substance use disorders (Khalsa et al., 2018). In the context of alcohol, the role of interoception in shaping intoxication experiences has long been posited (Duka et al., 1998, 1999; Lovelock et al., 2021). More recent research examining ethanol-induced shifts in cardiac interoceptive indices track both subjective intoxication (Leganes-Fonteneau et al., 2019) and anticipated alcohol effects (Schmidt et al., 2013; Leganes-Fonteneau, 2024), highlighting the potential contribution of interoception in factors that feed into the etiology of addiction. The extent of subjective bodily sensations during intoxication likewise correlates with self-report indices of alcohol response, showing heightened stimulation and reduced sedation (Leganes-Fonteneau et al., 2025), aligning bodily sensations with classical markers of alcohol insensitivity (Schuckit, 1994). Extending this interoceptive lens to hangovers through bodily mapping in individuals who drink heavily, where repeated, high-intensity use is associated with cerebral and emotional vulnerabilities (Lannoy et al., 2019), could clarify how individual differences in the perception and integration of hangover bodily signals shape motivational responses underlying continued use.

This proof-of-concept study is the first to explore interoceptive phenomenology during alcohol hangovers using a mobile version of the emBODY mapping tool. Embedding this mapping in a naturalistic design captures hangover-specific interoceptive experiences in real time, avoiding the shortcomings of cardiac-based behavioral proxies (Billaux et al., 2025b; Desmedt et al., 2018) and complementing currently used questionnaires (Desmedt et al., 2022) with a phenomenological body-centered approach to hangover. In doing so, we link subjective bodily sensations directly to the hangover state, offering a clearer view of the bodily mechanisms involved, while providing foundational evidence for measures of bodily processes in future addiction research.

Considering the mixed literature on the role of hangover sensitivity in alcohol risk, and growing evidence that interoception shapes individual differences in alcohol response, we propose that the strength (intensity) and/or the spread (extent) of hangover sensations may be informative markers of the subjective hangover experience and of AUD vulnerability. Specifically, these indices may reflect salient delayed aversive bodily consequences of alcohol, potentially shaping subsequent motivation and decision-making around drinking. Accordingly, we test whether these body map indices relate to AUD risk, as measured through AUDIT, BD, AUQ and HSS scores. This also allows indexing the concurrent validity of this phenomenological perspective, together with subject-level variables known to impact hangover symptomatology such as age (Verster et al., 2021) and hours of sleep (Ayre et al., 2021).

Based on the topographical mapping of bodily sensations related to hangover in real time (namely the morning after alcohol consumption), we hypothesize that hangover episodes will show distinct and consistent patterns of bodily activation and deactivation, notably in the head, chest and abdomen, expected to reflect commonly reported hangover symptoms (e.g. headache, heart pounding, nausea). At the between-subjects level, we expect extent and intensity of bodily sensations to correlate with individual drinking patterns and hangover frequency. At the within-subjects level, we expect greater extent and intensity of these sensations to positively correlate with subjective hangover severity and self-reported intoxication.

2. Method

2.1. Participants

Participants were recruited in the United States through community advertisements and social media. Inclusion criteria required participants to be between 18 and 35 years and to engage in heavy episodic drinking, defined as consuming $\geq$4 drinks (14 g of ethanol/drink) within two hours for women and $\geq$5 for men, at least once in the previous month to ensure current active drinking. Additional criteria included a minimum weekly consumption of five drinks, a history of moderate to severe hangovers, and at least one alcohol-induced blackout in the past six months. Individuals with a self-reported history of mental health disorders or cardiovascular disease were excluded. No restrictions were imposed on Alcohol Use Disorder Identification Test (AUDIT) scores. No control group was included, as individuals who don't drink or only drink small amounts would not experience hangover episodes.

2.2. Measures

Bodily sensations experienced during hangovers were collected via an online smartphone emBODY tool adapted from Nummenmaa and colleagues (Nummenmaa et al., 2014, 2018). This tool presented participants with two blank human silhouettes, one for increased bodily sensation (activation) and the other for decreased bodily sensation (deactivation). Participants used their finger to color regions of the body where they perceived changes in sensation. Longer presses over a body area indicated higher intensity ratings, with the interface providing feedback by increasing the opacity of the paint.

Demographic information collected included age, gender, ethnicity, body weight, and height. Trait-level measures included the Hangover Symptom Scale (HSS; Slutske et al., 2003), assessing the frequency with which they experienced hangover symptoms over the past year, the AUDIT (Bohn et al., 1995) to screen for harmful or hazardous alcohol consumption in the past year, and the Alcohol Use Questionnaire (AUQ; Mehrabian and Russell, 1978), tailored to reflect prevalent US college drinking preferences. A separate binge drinking score was derived from the AUQ (Townshend and Duka, 2005).

To evaluate acute hangover symptoms following each drinking episode, participants completed state-level measures, including the Acute Hangover Severity Scale (AHSS; Penning et al., 2013), a measure of current hangover severity, and a self-report of their level of intoxication from the previous night from 0% (“not at all intoxicated”) to

100% (“extremely intoxicated”).

2.3. Study design and procedure

Ethical approval for this study was obtained from the Rutgers University Institutional Review Board for Human Research and all procedures adhered to the Declaration of Helsinki. All participants provided online informed written consent prior to participation. The study consisted of a baseline session and several follow-up hangover sessions per participant (mean number of sessions $= 3.147 \pm 0.72$, median $= 3$, range $= 1–5$). All data collection took place online, between July 2022 and May 2023.

Eligible participants were contacted via email and asked to complete a baseline session at least 48 h after the last alcohol consumption. Participants completed demographic questionnaires along with HSS, AUQ, and AUDIT and were familiarized with the emBODY tool, marking areas of bodily activation and deactivation after drinking water.

On subsequent weekends, participants received smartphone prompts each morning, asking whether they had reached intoxication the previous night (“Did you feel intoxicated while or after drinking last night?”). Those reporting intoxication completed a follow-up Qualtrics survey, including the AHSS, subjective intoxication level, and total hours of sleep. Participants then completed the emBODY tool again, this time indicating their bodily sensations during the hangover. Participants were prompted every weekend until at least three hangover sessions were completed.

2.4. Statistical analysis

Statistical analyses were pre-registered on OSF (https://doi.org/10.17605/OSF.IO/5EVMX). Any deviations from the plan are explicitly reported. All analyses were conducted in R. As preregistered, data were screened for outliers using residual diagnostics (Q-Q plots; studentized and Pearson-deleted residuals vs fitted values) and Cook’s distance (4/n), and influential data points were excluded.

2.4.1. Topography of bodily sensations of hangover

Topographical representations of bodily sensations were generated in MATLAB following the original methodology (Nummenmaa et al., 2014). For each participant and each session, bodily sensation maps were generated by using each data point collected through the emBODY tool. Each individual map represented the net difference between activation and deactivation sensations reported for that session (Fig. 1). For each of the 50,364-pixels in the body map, *t*-tests were performed across all participants, generating a statistical t-map that identified pixels with significant hangover bodily sensations. Significant pixels with a threshold of $p < 0.05$ were color-mapped, while non-significant values were represented in black. A false discovery rate (FDR) correction was applied to the pixelwise *t*-tests.

To quantify bodily sensations, two numeric indices were extracted from each body map for each participant. Extent of bodily sensations was computed as the proportion of painted pixels relative to the total number of pixels in the body map, reflecting the size of sensations across the body. Intensity of bodily sensations was computed by adding activation and deactivation values across all painted pixels, then dividing this sum by the number of painted pixels, reflecting the strength of these bodily sensations. A value of zero at any pixel could occur either if the pixel was not selected or if activation and deactivation values canceled each other out.

2.4.2. Between-subject analysis

To assess between-subject associations, extent and intensity metrics were averaged across all sessions per participant, resulting in one extent and one intensity score per participant. These scores reflect trait-level patterns of hangover-related bodily sensations. Spearman correlations were used to examine associations between trait-level bodily sensation metrics and trait-level alcohol use and hangover measures (AUQ, AUDIT, BD and HSS).

2.4.3. Within-subject analysis

To assess within-subject associations, linear mixed models (LMMs) were conducted using all available session-level data, to relate each session’s bodily sensations to concurrent subjective ratings. In the primary models, self-reported hangover severity (AHSS) was the dependent variable, with extent and intensity of bodily sensations as fixed effects. A second set of models treated extent and intensity of bodily sensations as the dependent variables, with subjective intoxication as the fixed effect. All models incorporated random intercepts for participants to account for repeated measures, while random slopes were excluded to reduce the risk of overfitting or singular-fit warnings.

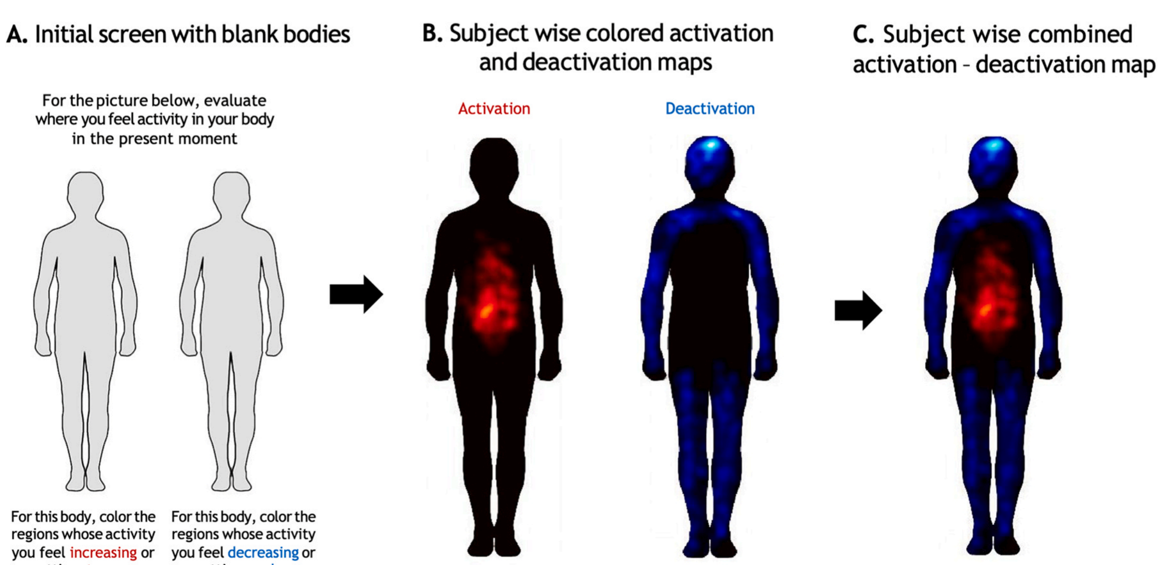

Fig. 1. *Overview of the emBODY Task and Analysis. Note.* A. Participants colored the initially blank body regions whose activity felt increasing (left body) and decreasing (right body) during hangover episodes. B. Subject wise activation and deactivation data points were represented in a body mask. C. Activation and deactivation maps were subsequently subtracted and combined into one body map for further statistical analyses.

2.4.4. Exploratory analysis

Pre-registered exploratory analyses included the generation of separate activation and deactivation body maps to assess differential topographic patterns. Additional within-subject LMMs were conducted incorporating an interaction term for age and hours of sleep.

Non-pre-registered analyses included quantifying the relationship between activation and deactivation maps across pixels for each session using correlation analyses and performing all analyses for activation and deactivation as separate dimensions. Between-subject independent samples *t*-tests were also conducted, comparing average extent and intensity of bodily sensations across low- and high- risk groups. These groups were defined separately for each trait-level alcohol measure to reflect past-year behavior, with AUQ, BD and HSS groups defined using median splits, and AUDIT groups using the established clinical cutoff of 15. Additional LMMs examined trait-level alcohol use measures as interaction terms.

3. Results

3.1. Demographics

A total of 37 participants were initially included in the study; however, three participants were excluded due to missing a minimum of three body maps, see Table 1 for descriptives.

3.2. Topography of bodily sensations during hangover

The combined body map of hangover (activation-minus-deactivation) reveals a cluster of activation-related colors (i.e., red-yellow) in the upper torso, particularly the chest and upper abdomen, indicating regions where activation exceeds deactivation. In contrast, deactivation-related colors (i.e., blue) are concentrated in the lower limbs, primarily in the thighs and calves, reflecting areas where deactivation dominates. The head and arms remain near zero (black), suggesting no consistent group-level difference between activation and deactivation in those regions (Fig. 2, left). Importantly, the separate activation map displays strong clusters in the upper torso, abdomen and head, indicating consistent sensations of increased bodily activation during hangover (Fig. 2, middle). The deactivation body map shows warm clusters primarily in the lower abdomen, lower limbs and hands, reflecting consistent sensations of reduced bodily activity (Fig. 2, right).

As a supplementary check, we performed spatial correlations across pixels between activation and deactivation maps for each session, which indicated a strong mirror relationship (median $\rho = 0.814$). Full details can be found in Supplementary Note S2.

Table 1
Participant Characteristics and Drinking Trait Scores.

Characteristics	Total n = 34
Age, years, mean (SD)	23.69 (4.16)
Sex, n (%)	
Male	22 (65%)
Female	12 (35%)
Race, n (%)	
White	15 (44%)
Asian	11 (32%)
Black or African American	8 (24%)
Drinking Traits	Total n = 34
HSS Score, mean (SD)	20.38 (11.03)
AUQ Score, mean (SD)	55.97 (33.33)
BD Score, mean (SD)	29.97 (12.91)
AUDIT Score, mean (SD)	15.62 (8.37)

Note. AUDIT = Alcohol Use Disorder Identification Test; AUQ = Alcohol Use Questionnaire; BD = Binge Drinking; HSS = Hangover Symptom Scale; SD = Standard Deviation

3.3. Between-subject analysis

A significant correlation was found between intensity of bodily sensations and age ($r = .201$, $p = .041$). In exploratory analyses of additional demographic variables, extent of bodily sensations differed by biological sex ($t = -2.258$, $df = 101.31$, $p = .026$), with higher mean extent in males, whereas race, weight and height did not yield any significant associations with body map indices ($ps \geq .201$).

Initial spearman correlations between trait-level drinking measures (AUQ, AUDIT and BD) and average extent and intensity of bodily sensations (one data point per participant; n = 34) revealed no significant associations, except for a positive association between BD score and extent ($r = .373$, $p = .035$). To explore potential group-level differences, we categorized participants into low- versus high-risk groups separately for each alcohol trait-level measure (cutoff scores: AUQ $\geq$ 44.5; AUDIT $\geq$ 15; BD $\geq$ 30.8). High-risk groups on AUQ and AUDIT reported significantly higher average intensity of bodily sensations during hangovers, and these effects remained significant after controlling for average subjective intoxication across sessions. No significant group differences were found in the average extent of bodily sensations (Table 2). Additional validity checks examining hangover frequency and subjective hangover severity as a function of alcohol risk group are presented in the Supplementary Material (Table S1). Overall, these results imply that participants at higher risk for AUD experience more intense bodily sensations of hangover together with increased hangover severity and frequency.

No significant correlations or risk group differences were found for the average extent or intensity of activation or deactivation sensations when analyzed separately (Supplementary Table S3).

3.4. Within-subject analysis

LMMs were conducted on extent and intensity of bodily sensations (one data point per session; n = 107) to examine how these metrics related to subjective ratings collected during the same session. Models revealed that session-level intensity of bodily sensations was significantly associated with hangover severity as DV ($p = .028$; Fig. 3A), whereas no significant effects were found when extent of bodily sensations was a predictor ($p = .248$; Fig. 3B). Furthermore, subjective intoxication from the prior night was not significantly related to either extent or intensity of session-level hangover bodily sensations as DVs ($p = .629$ and $p = .174$, respectively; Table 3).

To extend our between-subject findings that high-risk AUDIT and AUQ participants exhibited greater intensity of bodily sensations, within-subject analyses examined whether the significant association between session-level intensity and acute hangover symptom severity as a DV was modulated by trait-level alcohol use measures, age and hours of sleep. As shown in Table 4, significant interactions were observed for Intensity × AUQ ($p = .038$), Intensity × AUDIT ($p < .001$), and Intensity × Age ($p = .009$), and simple slope analyses reveal that the association between session-level intensity and AHSS was strongest among participants with high AUQ and AUDIT scores, and among older participants (Fig. 4). Importantly, both the AUQ and AUDIT interactions remained significant after accounting for subjective intoxication of the previous night ($p = .023$ and $p = .002$, respectively). The Intensity × Sleep interaction was not significant ($p = .419$). Overall, these results imply that the relationship between intensity of bodily sensations and acute hangover severity appears to be significantly modulated by older participants and those at higher risk, regardless of prior subjective intoxication.

Exploratory LMMs showed no significant effects for session-level extent or intensity of activation or deactivation sensations when analyzed separately (Supplementary Table S4).

Given the novelty of the approach, we lacked appropriate a-priori power analyses. Post-hoc analyses revealed power = .73 for between-subject correlational analyses and > .86 for *t*-tests. For within-subject

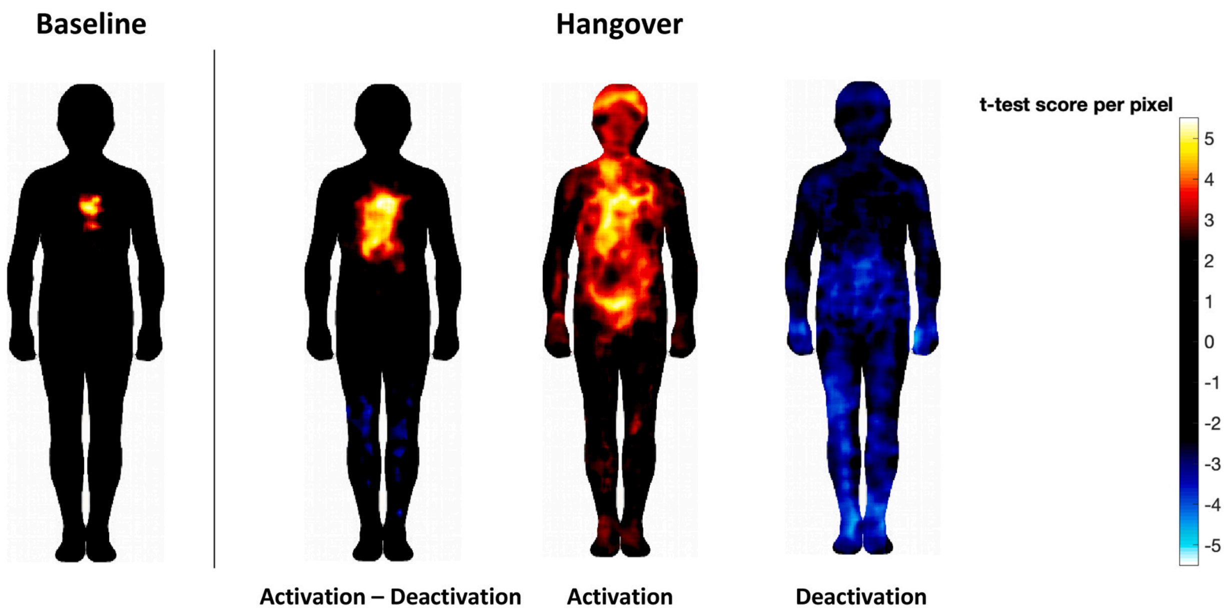

Fig. 2. *Group-Level T-Map of Bodily Sensations of Hangover. Note.* Difference between baseline (left), activation and deactivation (middle left), activation (middle right) and deactivation (right). Color intensity reflects the magnitude of t-values, with stronger values (positive or negative) indicating greater group-level effects. In the difference map, positive values indicate greater activation than deactivation, while negative values indicate the opposite. Black areas reflect non-significant regions ($p < .05$, FDR-corrected).

analyses, LMMs were low powered (.66), but final exploratory models revealed power > .95.

4. Discussion

4.1. Summary of key findings

The present study is the first to investigate the interoceptive correlates of alcohol hangover using body mapping within an ecologically valid design. Our findings reveal distinct topographical patterns of bodily sensations, with separate activation and deactivation maps capturing patterns that track standardized hangover questionnaire symptoms, indicating convergence with conventional measures (Slutske et al., 2003; Penning et al., 2013). Activation clustered in the torso, abdomen and head overlaps with symptoms such as heart pounding, thirst and headaches, whereas deactivation, prominent in the abdomen, limbs and hands, aligns closely with nausea and weakness. Beyond this convergence, body maps offer more precise localization of bodily sensations than self-report scales, providing a richer account of the hangover experience. The activation-minus-deactivation map provided an aggregation of these bodily signals, showing net activation in the chest and net deactivation in the lower limbs. These maps demonstrate the sensitivity of bodily mapping to reliably capture bodily processes in naturalistic settings without item-cued prompting or verbalization and highlights its potential in deepening our understanding of acute alcohol and other substance's embodied effects.

Consistent with our hypothesis, the intensity of bodily sensations reported during hangover episodes was significantly associated with hangover severity. This suggests that intensity of bodily sensations and subjective hangover severity may reflect parallel manifestations of the same underlying interoceptive processes. In contrast, no relationship was observed for the extent of bodily sensations or prior subjective intoxication, indicating that intensity of bodily sensations may be more phenomenologically salient to hangover perception than size.

While trait-level drinking scores showed generally weak linear associations with sensation intensity, exploratory group-level analyses revealed that the intensity of hangover bodily sensations was significantly associated with individual drinking profiles. Participants with higher AUQ and AUDIT scores not only reported more intense bodily sensations than those with lower scores but also showed stronger associations between sensation intensity and subjective hangover severity. Importantly, these effects remained significant after controlling for subjective intoxication, indicating that stronger bodily sensations were not solely driven by prior alcohol intake (Richards et al., 2024), or at least its perceived effects. This result is at odds with previous research showing that higher subjective intoxication is linked to more frequent

Table 2
Comparison of Bodily Sensation Measures as a Function of Risky Alcohol Consumption (Low vs. High).

Variables	Low risk mean (SD)	High risk mean (SD)	t-value	df	p-value	p-value (adjusted for intox.)
Intensity						
AUQ	-0.177 (0.780)	0.902 (1.129)	-3.045	24.892	.005**	.002**
AUDIT	-0.355 (0.812)	0.624 (1.004)	-3.048	29.804	.004**	.004**
BD	0.155 (0.606)	0.431 (1.490)	-0.684	20.085	.502	.459
Extent						
AUQ	27.601 (20.578)	31.764 (18.390)	-0.611	30.088	.546	.566
AUDIT	33.436 (20.347)	25.891 (17.150)	1.164	31.033	.253	.231
BD	24.352 (15.992)	34.821 (21.164)	-1.609	29.658	.118	.128

Note. Mean intensity reflects the average strength of bodily sensations; negative values indicate that deactivation exceeded activation. Mean extent represents the percentage of the body map that was colored. Low and high groups each comprised 17 participants. AUQ = Alcohol Use Questionnaire; AUDIT = Alcohol Use Disorder Identification Test; BD = Binge Drinking; SD = Standard Deviation

** $p < .01$.

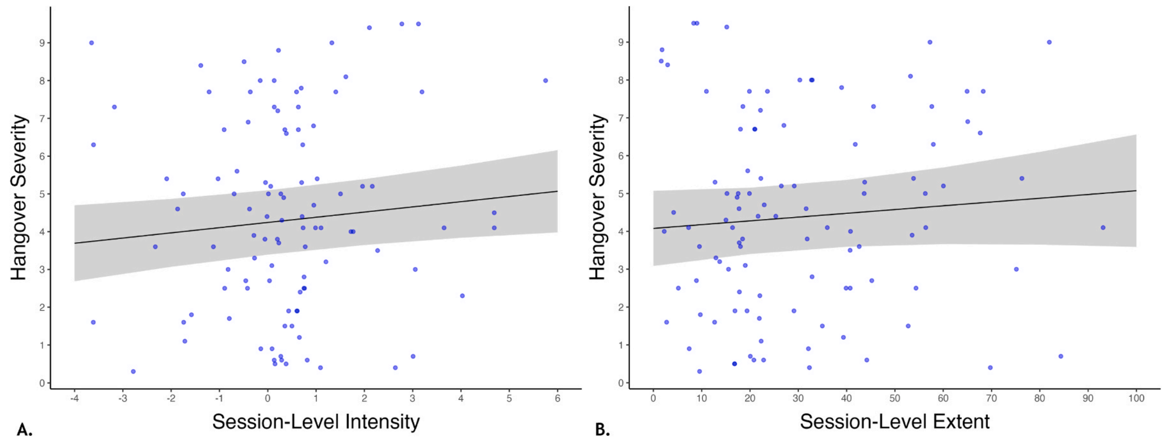

Fig. 3. *Association Between Intensity of Bodily Sensation and Hangover Severity. Note.* Scatterplot shows all session-level data points and the fitted regression line from a linear mixed model testing the association between A. hangover severity (AHSS) and intensity of bodily sensations (p = .028). B. hangover severity (AHSS) and extent of bodily sensations (p = 248). The shaded area represents a 95% confidence interval. Random intercepts were included for participants.

and severe hangovers (Vatsalya et al., 2018; Stangl et al., 2022). Our results suggest that interoceptive feedback during hangover is more pronounced in individuals vulnerable to problematic drinking, contributing to more severe hangovers present in those groups.

Additionally, older participants reported significantly greater intensity of bodily sensation, while age was not significantly related to consumption patterns in our sample, suggesting that older participants did not simply consume more. This finding contrasts with prior work showing reduced hangover severity with age (Verster et al., 2021), although that study relied on a single-item retrospective report compared to our real-time assessment of bodily sensations.

4.2. *Theoretical Implications*

Firstly, these findings challenge the common assumption that hangovers function as a natural deterrent to subsequent alcohol use. Despite experiencing more intense hangover bodily sensations, heavy drinking individuals in our sample still presented high levels of alcohol consumption. This observation aligns with previous findings of reduced punishment sensitivity in individuals who drink heavily (Jonker et al., 2014; Tapper et al., 2015). Our results tentatively extend this literature by suggesting a possible interoceptive mechanism for this reduced punishment sensitivity, namely a diminished translation of aversive bodily signals into behavioral avoidance. Furthermore, because these sensations emerge several hours after drinking, their motivational salience could be weakened by loss discounting, whereby the subjective cost of a negative outcome diminishes with temporal delay (Bailey et al., 2018; Boness et al., 2021). In parallel, heightened reward sensitivity may further blunt the impact of hangover sensations, particularly in young, non-clinical populations like ours, where intense interoceptive signals may be recontextualized within a broader social-affective framework (Creswell, 2021), through social bonding and positive memory reconsolidation (Abar et al., 2016; Mallett et al., 2008). Our findings suggest that these hangover-related bodily sensations may be incorporated into these reframing processes, potentially blunting their negative motivational impact. These hypotheses should be further tested by examining how bodily sensations of hangover interact with other etiological domains of AUD (Boness et al., 2021).

Secondly, our findings that heavy drinking participants with greater bodily sensations also reported more frequent hangovers could suggest a pattern of sensitization to hangovers, rather than tolerance, as alcohol consumption escalates (Verster et al., 2019). Whereas tolerance implies a diminished response to repeated exposure, our results suggest the opposite, with repeated hangover experiences appearing to be associated with increased bodily sensations in participants at higher risk. While people who generally drink more heavily may simply have consumed more alcohol, leading to more severe hangover episodes and thus stronger bodily sensations, this association persisted after

Table 3
Linear Mixed Model Estimates for Session-Level Outcomes.

Predictor	Fixed effect	Estimate	SE	df	t-value	p-value
AHSS ~	Intensity	0.138	0.061	72.481	2.246	.028*
AHSS ~	Extent	0.010	0.009	86.779	1.162	.248
Extent of bodily sensations ~	Subjective intoxication	0.036	0.075	86.748	0.484	.629
Intensity of bodily sensations ~	Subjective intoxication	-0.012	0.009	81.350	-1.372	.174

Note. Fixed-effect estimates from primary linear mixed-effects models testing associations between session-level hangover severity (AHSS) and intensity and extent of bodily sensations, including random intercepts for participants. AHSS = Acute Hangover Severity Scale; SE = Standard Error

[*] $p < .05$.

Table 4
Significant Interaction Effects from Exploratory Models.

Predictor	Interaction	Estimate	SE	df	t-value	p-value
AHSS ~	Intensity × AUQ	0.007	0.003	71.642	2.119	.038*
AHSS ~	Intensity × AUDIT	0.025	0.007	72.109	3.453	< .001***
AHSS ~	Intensity × BD	0.008	0.007	67.367	1.396	.167
AHSS ~	Intensity × Age	0.050	0.019	68.384	2.679	.009**
AHSS ~	Intensity × Sleep	0.008	0.004	97.999	1.979	0.419

Note. Significant interaction terms from exploratory linear mixed-effects models examining whether individual trait-level drinking measures, age and sleep moderate the session-level association between hangover severity (AHSS) and intensity of bodily sensation. Models included random intercepts for participants. AHSS = Acute Hangover Severity Scale; AUQ = Alcohol Use Questionnaire; AUDIT = Alcohol Use Disorder Identification Test; BD = Binge Drinking; HSS = Hangover Symptom Scale; SE = Standard Error

[*] $p < .05$.
[**] $p < .01$.
[***] $p < .001$.

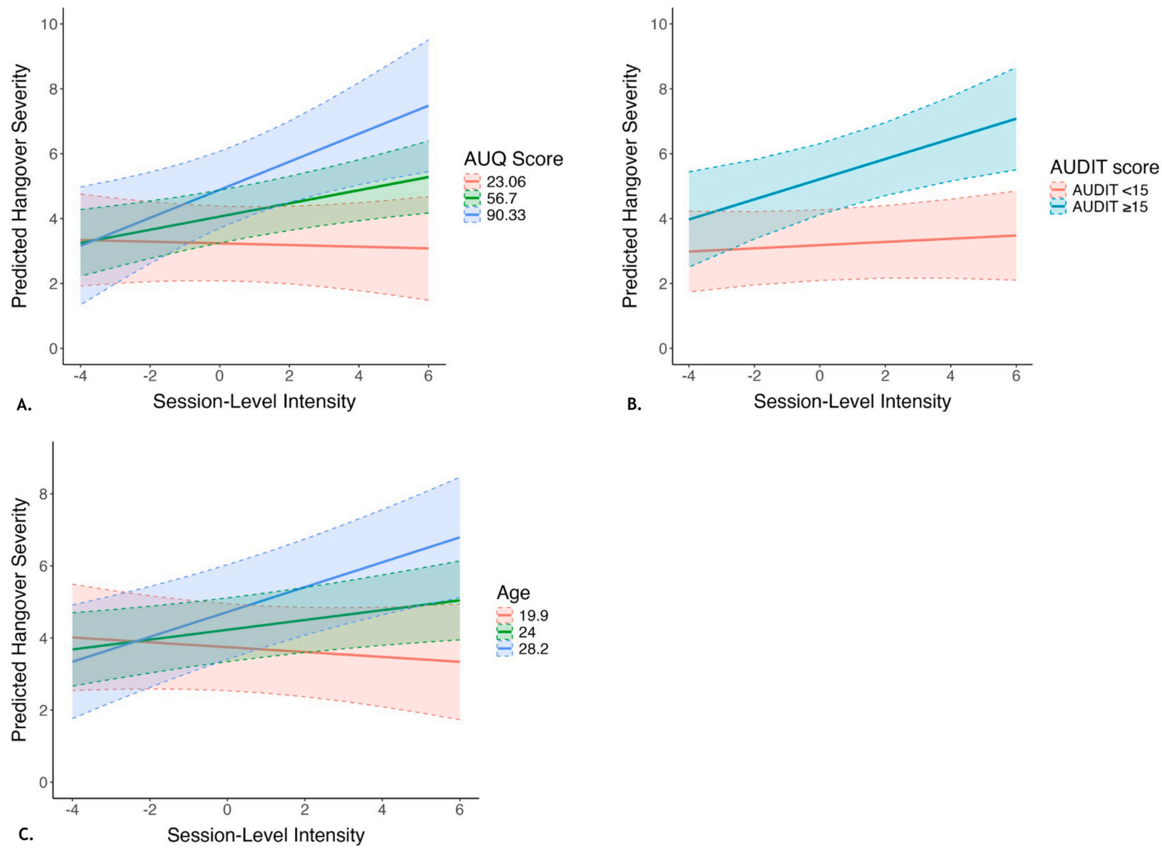

Fig. 4. *Predicted Hangover Severity by Intensity of Bodily Sensations Note.* Predicted hangover severity (AHSS) is plotted against session-level intensity of bodily sensation. Simple slope analyses are stratified by: A. AUQ scores at the sample mean and ± 1 SD. B. AUDIT scores using the clinical cutoff of 15. C. Age at the sample mean and ± SD. Shaded regions represent 95% confidence intervals.

accounting for subjective intoxication. We propose two speculative explanations for the apparent sensitization observed here. First, it may reflect accumulating physiological stress and alterations across repeated drinking episodes (Palmer et al., 2019), resulting in more severe bodily responses over time. Second, frequent hangover experiences may sharpen interoceptive predictions and increase awareness of post-intoxication states, allowing individuals who drink more heavily to identify and interpret these sensations better (Barrett and Simmons, 2015). Crucially, this increased reporting of negative bodily sensations does not appear to be linked with reduced alcohol use, lending further support to the hypothesis that aversive bodily feedback alone is insufficient to promote behavioral change. These hypotheses warrant additional examinations, obtaining concurrent objective measures of intoxication (King et al., 2025).

Finally, the moderation of intensity of bodily sensations by age may point to metabolic and physiological differences in ethanol processing and recovery (Meier and Seitz, 2008), likely contributing to prolonged recovery times and intensified bodily sensations among older participants. This suggests that interoceptive hangover experiences could reflect not only subjective interpretations but also physiological markers underlying individual differences.

4.3. Methodological considerations

The integration of a bodily mapping tool within an ecologically valid framework represents a significant methodological advancement, enabling real-time assessment of interoceptive experiences. Understanding subjective responses to alcohol in young people who drink heavily is especially relevant given their prevalence and offers an opportunity to examine early interoceptive alterations that may precede more advanced patterns of alcohol misuse. Nevertheless, several methodological constraints should be acknowledged. First, the small, predominantly male sample limits generalizability (Spooner et al., 2024). A larger sample would also allow for the identification of regions of interests (e.g. heightened sensations in the gut or head) and direct correlations between activation in those ROIs and scores from traditional questionnaires (Palser et al., 2021). Second, the lack of objective alcohol dose from the prior evening, relying only on subjective intoxication, may not accurately reflect alcohol exposure (de Andrade et al., 2023). Future work should record standard drink counts, time since last drink, and, where feasible, use objective indices such as breath alcohol concentration to support our results on hangover sensitivity. Third, we did not assess or control for concomitant use of other substances, medications or relevant comorbidities. However, participants were instructed to complete body maps specifically following alcohol-related hangovers. Finally, the use of the activation-minus-deactivation map should be considered. We chose this approach in line with Nummenmaa's original work on body maps of emotions and subjective feelings (Nummenmaa et al., 2014, 2018), yielding a single summary index of intensity in which positive values indicate predominant activation over deactivation, and negative values indicate the reverse. Thus, the combined map provides both a net intensity measure and direction of effect, justifying its role as our primary intensity index. Consistent with this rationale, correlation analyses within sessions showed strong coupling between activation and deactivation topographies, suggesting that the two maps largely reflect complementary, mirror-like patterns within episodes. The study instructions may have led participants to view the two ratings as complementary rather than independent, as they knew from the beginning they would complete both maps in each session. However, a practical consequence of this approach is that it can also attenuate symptom-specific signals when activation and deactivation co-occur, such as those related to headaches or nausea, which were only evident in the separate activation map. In addition, the models treating activation and deactivation as separate dimensions did not yield significant associations with our outcome measures. Future studies should move away from these activation-minus-deactivation indices towards newer approaches that capture sensation intensity in a more interpretable way for participant and researcher, and consider adding a valence component to better characterize the affective quality of reported sensations (Desmedt et al., In preparation).

4.4. Conclusion

Our findings demonstrate that interoceptive phenomenology during hangover episodes can be reliably captured using body mapping and are meaningfully associated with individual drinking behaviour. They extend existing knowledge on addictive processes by suggesting a measurable bodily component to hangover severity. This phenomenological approach to measuring bodily sensations can help build novel conceptualizations of addiction, where body-brain interactions feed into etiological processes. In this case, it seems that foregoing the negative bodily consequences of alcohol could participate in problematic patterns of alcohol use. More broadly, this study provides initial evidence for the utility of body mapping within naturalistic designs as a scalable tool to investigate how embodied states contribute to individual variability to alcohol's effects and potentially uncover new vulnerability markers for addiction.

CRediT authorship contribution statement

Steiger Natascha: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation. **Billaux Pauline:** Writing – review & editing. **Desmedt Olivier:** Writing – review & editing, Supervision. **Leganes-Fonteneau Mateo:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Maurage Pierre:** Writing – review & editing, Supervision.

Funding

This study was supported by a Pilot Grant from the Center of Alcohol and Substance Use Studies at Rutgers University.

Dr. Leganes-Fonteneau is supported by Marie Sklodowska-Curie - ILiAd, FNRS ISRA and ERC StG BodyCrave. Prof. Maurage, Dr. Desmedt and Pauline Billaux are funded by the FSR-FNRS.

Author disclosures

We are the authors of the manuscript submitted for publication to your Journal, the full list of authors is listed on the manuscript. This manuscript has a total length of 3993 words and contains four tables and four figures. The original material contained in the present manuscript has not been published elsewhere and is not currently under consideration for publication elsewhere. All authors have read and approved the manuscript for submission to Drug and Alcohol Dependence. They have made a substantial contribution to the conception, writing and intellectual content of the article. All of them have exercised due care in ensuring the integrity of the work. Moreover, all authors report no competing financial interest or potential conflicts of interest, and no financial relationships with commercial interests.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We wish to thank Prof. DiBello for the assistance in preparing materials.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.drugalcdep.2026.113122.

References

Abar, C.C., Mallett, Kimberly A., Turrisi, Robert, Abar, B., 2016. First- and second-hand consequences of alcohol in college: differential associations with later alcohol use. J. Subst. Use 21, 107–111. https://doi.org/10.3109/14659891.2015.1096621.

de Andrade, D., Button, K., Coomber, K., Taylor, N., Ferris, J., Curtis, A., Miller, P.G., 2023. Investigating the relationship between inaccurate blood alcohol concentration estimates, harm and other negative consequences. Drug Alcohol Rev. 42, 467–475. https://doi.org/10.1111/dar.13569.

Ayre, E., Scholey, A., White, D., Devilly, G.J., Kaufman, J., Verster, J.C., Allen, C., Benson, S., 2021. The relationship between alcohol hangover severity, sleep and cognitive performance; a naturalistic study. J. Clin. Med. 10. https://doi.org/10.3390/jcm10235691.

Bailey, A.J., Gerst, K., Finn, P.R., 2018. Delay discounting of losses and rewards in alcohol use disorder: The effect of working memory load. Psychol. Addict. Behav. 32, 197–204. https://doi.org/10.1037/adb0000341.

Barrett, L.F., Simmons, W.K., 2015. Interoceptive predictions in the brain. Nat. Rev. Neurosci. 16, 419–429. https://doi.org/10.1038/nrn3950.

Billaux, P., Cabé, N., Desmedt, O., Billieux, J., Herman, A., Jakubczyk, A., Kopera, M., Laniepce, A., Leganes Fonteneau, M., Wiśniewski, P., Lemière, C., Pitel, A.-L., Maurage, P., 2025a. Physical sensations of craving in binge drinking and severe alcohol use disorder: A phenomenological approach. Alcohol Clin. Exp. Res. https://doi.org/10.1111/acer.70087.

Billaux, P., Desmedt, O., Corneille, O., Luminet, O., Leganes-Fonteneau, M., Billieux, J., Maurage, P., 2025b. Validity concerns about the heartbeat counting task extend to alcohol use disorder: evidence from subclinical and clinical samples. Addict. Biol. 30, e70032. https://doi.org/10.1111/adb.70032.

Bohn, M.J., Babor, T.F., Kranzler, H.R., 1995. The Alcohol Use Disorders Identification Test (AUDIT): validation of a screening instrument for use in medical settings. J. Stud. Alcohol 56, 423–432. https://doi.org/10.15288/jsa.1995.56.423.

Boness, C.L., Watts, A.L., Moeller, K.N., Sher, K.J., 2021. The etiologic, theory-based, ontogenetic hierarchical framework of alcohol use disorder: a translational systematic review of reviews. Psychol. Bull. 147, 1075–1123. https://doi.org/10.1037/bul0000333.

Chen, W.G., Schloesser, D., Arensdorf, A.M., Simmons, J.M., Cui, C., Valentino, R., Gnadt, J.W., Nielsen, L., Hillaire-Clarke, C.St, Spruance, V., Horowitz, T.S., Vallejo, Y.F., Langevin, H.M., 2021. The Emerging Science of Interoception: Sensing, Integrating, Interpreting, and Regulating Signals within the Self. Trends Neurosci. 44, 3–16. https://doi.org/10.1016/j.tins.2020.10.007.

Courtney, K.E., Worley, M., Castro, N., Tapert, S.F., 2018. The effects of alcohol hangover on future drinking behavior and the development of alcohol problems. Addict. Behav. 78, 209–215. https://doi.org/10.1016/j.addbeh.2017.11.040.

Creswell, K.G., 2021. Drinking together and drinking alone: a social-contextual framework for examining risk for alcohol use disorder. Curr. Dir. Psychol. Sci. 30, 19–25. https://doi.org/10.1177/0963721420969406.

Desmedt, O., Maurage, P., Khalil, J., Leganes Fontenau, M., Billaux, P., Billieux, J., In preparation. InteroMap: A Novel Tool for Mapping Subjective Bodily Sensations. https://doi.org/10.31234/osf.io/qtudv_v1

Desmedt, O., Luminet, O., Corneille, O., 2018. The heartbeat counting task largely involves non-interoceptive processes: Evidence from both the original and an adapted counting task. Biol. Psychol. 138, 185–188. https://doi.org/10.1016/j.biopsycho.2018.09.004.

Desmedt, O., Heeren, A., Corneille, O., Luminet, O., 2022. What do measures of self-report interoception measure? Insights from a systematic review, latent factor analysis, and network approach. Biol. Psychol. 169, 108289. https://doi.org/10.1016/j.biopsycho.2022.108289.

Desmedt, O., Luminet, O., Maurage, P., Corneille, O., 2025. Discrepancies in the definition and measurement of human interoception: a comprehensive discussion and suggested ways forward. Perspect. Psychol. Sci. 20, 76–98. https://doi.org/10.1177/17456916231191537.

Duka, T., Stephens, D.N., Russell, C., Tasker, R., 1998. Discriminative stimulus properties of low doses of ethanol in humans. Psychopharmacology 136, 379–389. https://doi.org/10.1007/s002130050581.

Duka, T., Jackson, A., Smith, D.C., Stephens, D.N., 1999. Relationship of components of an alcohol interoceptive stimulus to induction of desire for alcohol in social drinkers. Pharmacol. Biochem. Behav. 64, 301–309. https://doi.org/10.1016/S0091-3057(99)00080-5.

Jonker, N.C., Ostafin, B.D., Glashouwer, K.A., van Hemel-Ruiter, M.E., de Jong, P.J., 2014. Reward and punishment sensitivity and alcohol use: the moderating role of executive control. Addict. Behav. 39, 945–948. https://doi.org/10.1016/j.addbeh.2013.12.011.

Khalsa, S.S., Adolphs, R., Cameron, O.G., Critchley, H.D., Davenport, P.W., Feinstein, J. S., Feusner, J.D., Garfinkel, S.N., Lane, R.D., Mehling, W.E., Meuret, A.E., Nemeroff, C.B., Oppenheimer, S., Petzschner, F.H., Pollatos, O., Rhudy, J.L., Schramm, L.P., Simmons, W.K., Stein, M.B., Stephan, K.E., Van den Bergh, O., Van Diest, I., von Leupoldt, A., Paulus, M.P., Ainley, V., Al Zoubi, O., Aupperle, R., Avery, J., Baxter, L., Benke, C., Berner, L., Bodurka, J., Breese, E., Brown, T., Burrows, K., Cha, Y.-H., Clausen, A., Cosgrove, K., Deville, D., Duncan, L., Duquette, P., Ekhtiari, H., Fine, T., Ford, B., Garcia Cordero, I., Gleghorn, D., Guereca, Y., Harrison, N.A., Hassanpour, M., Hechler, T., Heller, A., Hellman, N., Herbert, B., Jarrahi, B., Kerr, K., Kirlic, N., Klabunde, M., Kraynak, T., Kriegsman, M., Kroll, J., Kuplicki, R., Lapidus, R., Le, T., Hagen, K.L., Mayeli, A., Morris, A., Naqvi, N., Oldroyd, K., Pané-Farré, C., Phillips, R., Poppa, T., Potter, W., Puhl, M., Safron, A., Sala, M., Savitz, J., Saxon, H., Schoenhals, W., Stanwell-Smith, C., Teed, A., Terasawa, Y., Thompson, K., Toups, M., Umeda, S., Upshaw, V., Victor, T., Wierenga, C., Wohlrab, C., Yeh, H., Yoris, A., Zeidan, F., Zotev, V., Zucker, N., 2018. Interoception and Mental Health: A Roadmap. Biological Psychiatry Cognitive Neuroscience Neuroimaging 3, 501–513. https://doi.org/10.1016/j.bpsc.2017.12.004.

King, A.C., Fischer, A.M., Cursio, J.F., Didier, N.A., Lee, Z., Fridberg, D.J., 2025. Real-Time assessment of alcohol reward, stimulation, and negative affect in individuals with and without alcohol use disorder and depressive disorders. AJP 182, 187–197. https://doi.org/10.1176/appi.ajp.20240069.

Lannoy, S., Billieux, J., Dormal, V., Maurage, P., 2019. Behavioral and cerebral impairments associated with binge drinking in youth: a critical review. Psychol. Belg. https://doi.org/10.5334/pb.476.

Leganes-Fonteneau, M., 2024. Alcohol effects on interoception shape expectancies and subjective effects: a registered report using the heart rate discrimination task. Alcohol. Alcohol. 59, agae025. https://doi.org/10.1093/alcalc/agae025.

Leganes-Fonteneau, M., Cheang, Y., Lam, Y., Garfinkel, S., Duka, T., 2019. Interoceptive awareness is associated with acute alcohol-induced changes in subjective effects. Pharmacol. Biochem. Behav. 181, 69–76. https://doi.org/10.1016/j.pbb.2019.03.007.

Leganes-Fonteneau, M., Desmedt, O., Allen, M.G., Wiers, R.W., Maurage, P., 2025. Mapping acute alcohol effects on bodily sensations: A cross-dimensional interoceptive approach. J. Psychopharmacol., 02698811251338223 https://doi.org/10.1177/02698811251338223.

Lovelock, D.F., Tyler, R.E., Besheer, J., 2021. Interoception and alcohol: Mechanisms, networks, and implications. Neuropharmacology 200, 108807. https://doi.org/10.1016/j.neuropharm.2021.108807.

Mallett, K.A., Bachrach, R.L., Turrisi, R., 2008. Are all negative consequences truly negative? Assessing variations among college students' perceptions of alcohol related consequences. Addict. Behav. 33, 1375–1381. https://doi.org/10.1016/j.addbeh.2008.06.014.

Mehrabian, A., Russell, J.A., 1978. A Questionnaire Measure of Habitual Alcohol Use. Psychol. Rep. 43, 803–806. https://doi.org/10.2466/pr0.1978.43.3.803.

Meier, P., Seitz, H., 2008. Age, alcohol metabolism and liver disease. Curr. Opin. Clin. Nutr. Metab. care 11, 21–26. https://doi.org/10.1097/MCO.0b013e3282f30564.

Nummenmaa, L., Glerean, E., Hari, R., Hietanen, J.K., 2014. Bodily maps of emotions. Proc. Natl. Acad. Sci. 111, 646–651. https://doi.org/10.1073/pnas.1321664111.

Nummenmaa, L., Hari, R., Hietanen, J.K., Glerean, E., 2018. Maps of subjective feelings. Proc. Natl. Acad. Sci. 115, 9198–9203. https://doi.org/10.1073/pnas.1807390115.

Palmer, E., Tyacke, R., Sastre, M., Lingford-Hughes, A., Nutt, D., Ward, R.J., 2019. Alcohol Hangover: Underlying Biochemical, Inflammatory and Neurochemical Mechanisms. Alcohol. Alcohol. 54, 196–203. https://doi.org/10.1093/alcalc/agz016.

Palser, E.R., Galvez-Pol, A., Palmer, C.E., Hannah, R., Fotopoulou, A., Pellicano, E., Kilner, J.M., 2021. Reduced differentiation of emotion-associated bodily sensations in autism. Autism 25, 1321–1334. https://doi.org/10.1177/1362361320987950.

Penning, R., McKinney, A., Bus, L.D., Olivier, B., Slot, K., Verster, J.C., 2013. Measurement of alcohol hangover severity: development of the alcohol hangover severity scale (AHSS). Psychopharmacology 225, 803–810. https://doi.org/10.1007/s00213-012-2866-y.

Piasecki, T.M., Sher, K.J., Slutske, W.S., Jackson, K.M., 2005. Hangover frequency and risk for alcohol use disorders: evidence from a longitudinal high-risk study. J. Abnorm. Psychol. 114, 223–234. https://doi.org/10.1037/0021-843X.114.2.223.

Prat, G., Adan, A., Pérez-Pàmies, M., Sànchez-Turet, M., 2008. Neurocognitive effects of alcohol hangover. Addict. Behav. 33, 15–23. https://doi.org/10.1016/j.addbeh.2007.05.002.

Richards, V.L., Turrisi, R.J., Russell, M.A., 2024. Subjective intoxication predicts alcohol-related consequences at equivalent alcohol concentrations in young adults using ecological momentary assessment and alcohol sensors. Psychol. Addict. Behav. 38, 334.

Rohsenow, D., Howland, J., Winter, M., Bliss, C., Littlefield, C., Heeren, T., Calise, T., 2011. Hangover sensitivity after controlled alcohol administration as predictor of post-college drinking. J. Abnorm. Psychol. 121, 270–275. https://doi.org/10.1037/a0024706.

Schmidt, A.F., Eulenbruch, T., Langer, C., Banger, M., 2013. Interoceptive awareness, tension reduction expectancies and self-reported drinking behavior. Alcohol. Alcohol. 48, 472–477. https://doi.org/10.1093/alcalc/agt024.

van Schrojenstein Lantman, M., Mackus, M., van de Loo, A.J.A.E., Verster, J.C., 2017. The impact of alcohol hangover symptoms on cognitive and physical functioning, and mood. Hum. Psychopharmacol. Clin. Exp. 32, e2623. https://doi.org/10.1002/hup.2623.

Schuckit, M.A., 1994. Low level of response to alcohol as a predictor of future alcoholism. Am. J. Psychiatry 151, 184–189. https://doi.org/10.1176/ajp.151.2.184.

Slutske, W.S., Piasecki, T.M., Hunt-Carter, E.E., 2003. Development and initial validation of the hangover symptoms scale: prevalence and correlates of hangover symptoms in college students. Alcohol. Clin. Exp. Res. 27, 1442–1450. https://doi.org/10.1097/01.ALC.0000085585.81711.AE.

Spooner, R., Bird, J.M., Irigoras Izagirre, N., Clemente, R., Fernandez Fueyo, E., Budworth, G., Cocirla, D., Todd, J., Aspell, J., Leganes, M., Watling, D., Plans, D., Brewer, R., Murphy, J., 2024. Exploring sex differences in cardiac interoceptive accuracy using the phase adjustment task. Psychophysiology 61, e14689. https://doi.org/10.1111/psyp.14689.

Stangl, B.L., Vogt, E.L., Blau, L.E., Ester, C.D., Gogineni, A., Diazgranados, N., Vatsalya, V., Ramchandani, V.A., 2022. Pharmacodynamic determinants of hangover: An intravenous alcohol self-administration study in non-dependent drinkers. Addict. Behav. 135, 107428. https://doi.org/10.1016/j.addbeh.2022.107428.

Tapper, K., Baker, L., Jiga-Boy, G., Haddock, G., Maio, G.R., 2015. Sensitivity to reward and punishment: Associations with diet, alcohol consumption, and smoking. Personal. Individ. Differ. 72, 79–84. https://doi.org/10.1016/j.paid.2014.08.025.

Townshend, J.M., Duka, T., 2005. Binge drinking, cognitive performance and mood in a population of young social drinkers. Alcohol. Clin. Exp. Res. 29, 317–325. https://doi.org/10.1097/01.ALC.0000156453.05028.F5.

Tsakiris, M., Critchley, H., 2016. Interoception beyond homeostasis: affect, cognition and mental health. Philos. Trans. R. Soc. B Biol. Sci. 371, 20160002. https://doi.org/10.1098/rstb.2016.0002.

Vatsalya, V., Stangl, B.L., Schmidt, V.Y., Ramchandani, V.A., 2018. Characterization of hangover following intravenous alcohol exposure in social drinkers: methodological and clinical implications. Addict. Biol. 23, 493–502. https://doi.org/10.1111/adb.12469.

Verster, J.C., Slot, K.A., Arnoldy, L., van Lawick van Pabst, A.E., van de Loo, A.J.A.E., Benson, S., Scholey, A., 2019. The association between alcohol hangover frequency and severity: evidence for reverse tolerance? J. Clin. Med. 8. https://doi.org/10.3390/jcm8101520.

Verster, J.C., Scholey, A., van de Loo, A.J.A.E., Benson, S., Stock, A.-K., 2020. Updating the definition of the alcohol hangover. J. Clin. Med. 9. https://doi.org/10.3390/jcm9030823.

Verster, J.C., Severeijns, N.R., Sips, A.S.M., Saeed, H.M., Benson, S., Scholey, A., Bruce, G., 2021. Alcohol hangover across the lifespan: impact of sex and age. Alcohol. Alcohol. 56, 589–598. https://doi.org/10.1093/alcalc/agab027.