

Review

What We Talk About When We Talk About Binge Drinking: Towards an Integrated Conceptualization and Evaluation

Pierre Maurage^{1,*}, Séverine Lannoy², Jessica Mange³,
Delphine Grynberg^{4,5}, Hélène Beaunieux³, Ingrid Banovic⁶,
Fabien Gierski^{7,8} and Mickaël Naassila⁸

¹Louvain Experimental Psychopathology ResearchGroup (LEP), Psychological Science Research Institute, UCLouvain, Louvain-la-Neuve 1348, Belgium, ²Department of Psychiatry and Behavioral Sciences, Stanford University, Stanford 94305, CA, USA, ³Laboratoire de Psychologie Caen Normandie (LPCN; EA 7452), University of Caen Normandy, Caen 14032, France, ⁴SCALab UMR 9193, Sciences Cognitives et Sciences Affectives, University of Lille, CNRS, CHU Lille, Lille 59000, France, ⁵Institut Universitaire de France, Paris 75231, France, ⁶CRFDP EA 7475, University of Rouen Normandie, Rouen 76000, France, ⁷Cognition, Health, Society Laboratory (C2S-EA 6291), University of Reims Champagne Ardenne (URCA), Reims 51571, France, and ⁸INSERM UMR 1247, Research Group on Alcohol and Pharmacodependences, GRAP, University of Picardie Jules Verne, Amiens 80025, France

*Corresponding author: Université catholique de Louvain, Faculté de Psychologie, Place du Cardinal Mercier, 10, B-1348 Louvain-la-Neuve, Belgium. Tel: +32-10-474804; Fax: +32-10-473774; E-mail: pierre.maurage@uclouvain.be

Received 10 March 2020; Revised 17 April 2020; Editorial Decision 24 April 2020; Accepted 24 April 2020

Abstract

Rationale: Binge drinking (BD), characterized by recurring alternations between intense intoxication episodes and abstinence periods, is the most frequent alcohol consumption pattern in youth and is growing in prevalence among older adults. Many studies have underlined the specific harmful impact of this habit by showing impaired abilities in a wide range of cognitive functions among binge drinkers, as well as modifications of brain structure and function.

Aims: Several controversies and inconsistencies currently hamper the harmonious development of the field and the recognition of BD as a specific alcohol consumption pattern. The main concern is the absence of consensual BD conceptualization, leading to variability in experimental group selection and alcohol consumption evaluation. The present paper aims at overcoming this key issue through a two-step approach.

Methods and conclusions: First, a literature review allows proposing an integrated BD conceptualization, distinguishing it from other subclinical alcohol consumption patterns. Six specific characteristics of BD are identified, namely, (1) the presence of physiological symptoms related to BD episodes, (2) the presence of psychological symptoms related to BD episodes, (3) the ratio of BD episodes compared to all alcohol drinking occasions, (4) the frequency of BD episodes, (5) the consumption speed and (6) the alternation between BD episodes and soberness periods. Second, capitalizing on this conceptual clarification, we propose an evaluation protocol jointly measuring these six BD characteristics. Finally, several research perspectives are presented to refine the proposed conceptualization.

INTRODUCTION

Excessive alcohol consumption is a key public health problem worldwide (World Health Organization, 2018). Its cognitive and cerebral correlates have been investigated for decades, but this approach has long been focused on acute alcohol consumption (e.g. Bjork and Gilman, 2014) and severe alcohol use disorders (AUD; e.g. Bühler and Mann, 2011). Following preliminary data showing the deleterious impact of other consumption patterns (e.g. 'social' or intense episodic consumption), an expansion of the alcohol consumption modes investigated has occurred. This new experimental avenue has been reinforced by the nosographic switch from categorical (DSM-IV) to dimensional (DSM-5) AUD approach, integrating subclinical alcohol consumption patterns (i.e. mild/moderate AUD). Accordingly, studies have shown that, even at subclinical levels, excessive alcohol consumption (e.g. heavy or hazardous drinking) has massive physiological, psychological and cerebral consequences (e.g. Topiwala *et al.*, 2017).

Among these consumption patterns, binge drinking (BD) has raised as a major research topic due to its ubiquity and widespread effects (Rolland and Naassila, 2017). While some debates have long persisted regarding terminology (e.g. Moskalewicz, 2011; Ceballos and Babor, 2017), BD is now the dominant concept used to characterize individuals presenting excessive (i.e. leading to drunkenness) but episodic alcohol consumption (see Carbia *et al.*, 2018; Lannoy *et al.*, 2019a for recent reviews). The repetition of such drunkenness episodes results in an alternation between intense alcohol intoxications and abstinence periods, constituting a specific alcohol consumption pattern. BD pattern (i.e. the repetition of BD episodes) is the most prevalent alcohol-related habit among youth in Western countries (Dormal *et al.*, 2019), 40% of young adults reporting at least one BD episode per month during the last 6 months. Converging data have demonstrated the rapid and long-lasting psychological and cerebral impacts of BD pattern (Carbia *et al.*, 2018). The specific neurotoxicity of this habit results from the repetition of intoxication–abstinence cycles, leading to multiple withdrawals that are particularly harmful for the brain. This even led to the 'continuum hypothesis' suggesting that BD pattern might constitute the first step towards severe AUD: neurocognitive impairments would initiate the addictive vicious circle by reducing inhibitory abilities and increasing automatic attraction towards alcohol (Enoch, 2006). BD studies have thus gained a central position in the alcohol-related field, but several limits hinder their development.

Indeed, despite the global consensus that BD pattern is associated with reduced neurocognitive abilities, contradictory results have been reported (e.g. Bø *et al.*, 2016a) and the validity of the 'continuum hypothesis' is widely debated (Lannoy *et al.*, 2019a). These controversies are centrally resulting from inter-study inconsistencies on BD conceptualization, operationalization and measure. Beyond the general view that BD is characterized by episodic intense intoxications, massive variations exist across studies regarding the conceptualization of BD episodes and BD consumption mode. This provokes inconsistencies in the selection criteria applied and alcohol-related factors measured, leading to heterogeneity across studies regarding the BD population selected, hence influencing the results. There is thus a need to elaborate a consensual conceptualization of BD but also a reliable BD measure to be uniformly applied in future studies, ensuring their comparability. This paper aims, through a comprehensive literature review, to overcome these limits by (1) proposing an integrated description of the core characteristics of BD habits in youth, and (2) offering a short but complete protocol to

efficiently measure BD in future studies. We will then describe several research avenues proposing an experimental plan to validate and refine our proposals.

WHAT ARE THE CORE CHARACTERISTICS OF BD?

Current BD definition

Several attempts have proposed BD definitions (e.g. the NIAAA Workshops in 2001 and 2003) but the potential criteria are still debated (e.g. Special issues in Psychology of Addictive Behaviors—2001 and Addiction—2016). All definitions consider the quantity of alcohol consumed through blood alcohol concentration (BAC) or more generally standard alcohol dose measures (Table 1). Some also distinguish gender profiles (Wechsler *et al.*, 1995), focus on quantity (WHO), drinking speed (National Institute on Alcohol Abuse and Alcoholism, NIAAA) and/or frequency (Presley and Pimentel, 2006) or even propose supplementary parameters (e.g. percentage of drunkenness episodes, Townshend and Duka, 2002).

The NIAAA definition has emerged as the most consensual one. It focuses on consumption quantity and speed, defining BD as the consumption of $>56\text{ g}^1$ (women) or 70 g (men) of ethanol in less than 2 hours, bringing BAC to at least 0.08%. Three main arguments are supporting this definition: (1) it constitutes a relevant risk marker, due to its ability to identify high-risk samples and its predictive value regarding AUD development (Wechsler *et al.*, 1994); (2) it standardizes the use of a succinct term, namely, BD, conveying a consistent operationalization and offering an understandable framework to communicate risk-related concepts (Naimi *et al.*, 2003); and (3) the prevalence and correlates of BD measures based on this definition are well documented.

Despite its widespread use, this definition only considering drinking quantity and speed has been criticized in three main ways: (1) it approximates drinking quantity by the number of 'standard doses' consumed (which vary in ethanol content across countries, creating potential confusions) and ignores consumer's physical characteristics (such as tolerance, sex and body mass index) influencing the estimated BAC (eBAC); (2) it does not consider BD frequency, whereas this factor is crucial to differentiate low-risk and problematic drinking (Presley and Pimentel, 2006); and (3) it determines standardized cut-offs, which is useful for public health surveillance, populations comparisons and longitudinal studies, but has been criticized. Regarding cut-off usefulness, the issue is to focus either on a behavior (measured on a continuum) or on a classification according to this behavior (leading to dichotomized categories). Applying a cut-off on continuous data can generate erroneous dichotomization, considering people from different groups as qualitatively different and leading to low sensitivity or inaccurate labeling (Pearson *et al.*, 2016). Regarding cut-off threshold, even considering the link between BD and AUD as monotonic rather than linear, the threshold relevance is questionable. Pearson *et al.* (2016) argued that any cut-off distinguishing lighter from higher drinkers could obtain similar results, some other cut-offs even being more convincing (e.g. 84/98 g, Read

¹ To avoid any confusion due to variations across countries and studies regarding the terms used (e.g. alcohol 'doses', 'units', 'drinks') and their related alcohol content, these terms will be systematically converted in the corresponding number of grams of pure ethanol (the correspondence with doses/units/drinks is given in Table 1).

Table 1. Main current definitions of binge drinking and characteristics considered

Source	Cut-off quantity ^a	Adaptation criteria	Drinking speed	Reference period	Frequency	Country
Johnston <i>et al.</i> (2014) ^b	5+	—	—	2 last weeks	Once	USA
Wechsler <i>et al.</i> (1995)	4+/5+	Gender	—	—	Once	USA
NIAAA (2004) ^c	4+/5 + (56 g/70 g)	Gender	Within <2 hours	—	Once	USA
	0.08 g/dL BAC	—	Within <2 hours	—	Once	USA
Presley and Pimentel (2005)	4+/5 + (56 g/70 g)	—	—	—	3×/week	USA
Townshend and Duka (2005)	No cut-off (continuous score)	—	Number of doses per hour	Number of doses/week and drunkenness episodes in the last 6 months	Percentage of drunkenness episodes	UK
SAMHSA (2011) ^d	4+/5+	Gender	Within <2 hours	Past month	Once	USA
WHO (2014)	6 + (60 g)	—	—	—	Once	International

^aCut-off value corresponds to the minimum number of standard doses per occasion to be classified as binge drinker. When two values are presented, they refer to women vs. men standards.

^bData from monitoring the future between 1975 and now.

^cNIAAA: National Institute on Alcohol Abuse and Alcoholism (USA).

^dSAMHSA: Substance Abuse and Mental Health Services Administration (USA).

et al., 2008). Finally, no cut-off has been evidenced as presenting an optimal and stable external validity.

Several proposals have been made to overcome these issues: (1) computing eBAC rather than merely evaluating alcohol consumption in grams/doses; (2) going beyond quantity/speed measures by integrating other specific BD parameters (e.g. drunkenness frequency, Townshend and Duka, 2002); and (3) adapting cut-off use according to measure's aim (e.g. using a continuous measure to index treatment/intervention efficacy and using cut-offs for risk screening). A continuum approach of BD has also been proposed, determining multiple thresholds to measure high intensity/extreme BD (Hingson *et al.*, 2017). However, all these suggestions, focusing on the improvement of isolated BD dimensions, did not propose an integrated view encompassing all specific BD characteristics. In sum, the current proposals need to be improved to go beyond the mere consideration of drinking quantity/speed and to unify the scattered criteria used, in fine allowing a reliable inter-study comparison.

Proposal: identifying the core characteristics of BD

We put forward a comprehensive and straightforward BD conceptualization, combining quantitative and qualitative factors to distinguish it from other alcohol consumption patterns by focusing on its core characteristics. This proposal combine threshold (determining minimum/maximum BD criteria) and continuum (exploring intensity variations in BD habits) approaches. Following these general principles and capitalizing on existing literature, we consider that a BD episode is occurring when an individual (1) reaches an eBAC leading to physiological symptoms of drunkenness (quantitative factor, going beyond the number of ethanol grams consumed to consider sex and physical factors) and (2) reports psychological symptoms of drunkenness during this episode (qualitative factor, as the subjective response to an identical ethanol intake can strongly vary across individuals, e.g. Schuckit *et al.*, 2012). Moreover, to present BD, these episodes should represent a significant proportion of drinking occasions (i.e.

alcohol consumption should often be related to intense intoxications) and should have been repeatedly observed (i.e. constituting a frequent consumption pattern rather than isolated occasions) for at least 12 months. Finally, the consumption speed during these episodes should be high (i.e. fast enough to rapidly reach drunkenness), and such episodes should have alternated with abstinence periods (i.e. episodic excessive drinking, leading to intoxication/abstinence cycles). This threshold approach determining the belonging to the BD group will be completed by a continuum approach exploring the intensity of BD habits (see 'Proposal: towards a consensual BD measure' section).

This integrated BD conceptualization will allow unambiguously distinguishing this pattern from (1) 'Heavy drinking', namely, consuming at least 70 g of ethanol per occasion more than 5 days in the past month. Although some heavy drinkers might also fulfill BD characteristics, heavy drinking is associated with a higher consumption frequency threshold and does not consider self-reported drunkenness. (2) 'Hazardous/harmful drinking', namely, a repetitive pattern of alcohol consumption already leading to health consequences. This habit is identified through the Alcohol Use Identification Test (AUDIT) with scores >8 and is based on alcohol consumption intensity/frequency, here again without measuring consumption speed or drunkenness. (3) 'Social drinking', mainly based on drinking context and motivations, and globally capturing excessive drinkers (most often according to weekly alcohol consumption, e.g. Townshend and Duka, 2002) independently of the episodic or excessive nature of the consumption. Our proposal also supports the exclusive use of the term 'binge drinking' in future studies when measuring alcohol consumption patterns characterized by rapid and episodic alcohol intakes leading to drunkenness, and thus the abandon of imprecise terms (e.g. 'problematic drinking', 'extreme ritualistic alcohol consumption', 'risky single-occasion drinking', 'high-intensity drinking'). We also clearly distinguish BD from the classical alcohol consumption patterns evaluated by (1) the AUDIT, as the second/third items of the AUDIT are the only one related to BD evaluation, and (2) the 11 AUD DSM-5 diagnosis criteria, as even intense BD might

not lead to fulfill enough criteria for mild/moderate AUD. This dissociation between BD and AUDIT/DSM-5 evaluations is notably frequent among young people, who might have BD habits without presenting the neurobiological (withdrawal, tolerance), psychological (depression, loss of control) or interpersonal (family/professional impact, guiltiness) consequences evaluated by these tools, at least at short-/mid-term.

HOW CAN BD BE EVALUATED?

Current BD evaluation

All studies agree to consider BD as characterized by intense, fast and episodic alcohol consumption, but various ways exist to evaluate such drunkenness episodes. Indeed, beyond the conceptual variability addressed above, current studies differ regarding consumption assessment tools (Table 2). This section reviews the criteria and measures reported earlier, by considering all studies referring to BD (in title, abstract and/or keywords) and proposing psychological (e.g. cognition, motivation, personality, emotions) or neuroscience (e.g. electrophysiology, neuroimaging correlates) measures/interventions. The BD criteria/scores currently used can be grouped into three categories (Table 3):

- (1) SAMHSA/NIAAA criteria²: these criteria remain the most used but with massive variations in BD frequency/intensity (Table 3). Some studies (e.g. investigating BD-related psychological factors) just set a mere BD frequency threshold (usually at least one monthly BD episode), while others (e.g. exploring BD brain correlates) offered finer BD evaluation by determining BD subgroups according to intensity/frequency, beyond the SAMHSA/NIAAA criteria. However, as this first approach focuses on the occurrence of BD episodes (and not on the pattern's specificity), it was mostly based on classical tools unable to capture BD characteristics (e.g. Timeline Followback (TLFB), which do not measure consumption speed). Only very few studies combined NIAAA criteria with eBAC (Table 2).
- (2) AUDIT/AUDIT-C scores: numerous studies determined the presence of BD through the third AUDIT item, but few used the cut-off scores related to AUDIT/AUDIT-C. Indeed, although the validity of AUDIT/AUDIT-C to explore BD has been supported, this tool is not specific enough, as it does not assess drunkenness episodes or consumption speed, which are core BD characteristics. Moreover, studies reporting these BD-specific factors are heterogeneous in the way they evaluate them (e.g. choice of drunkenness criteria).
- (3) BD score: this score has the main advantage to consider BD-specific characteristics and can be used as a continuous variable or through cut-off scores. Various works computed this score, most often combined with SAMHSA/NIAAA criteria, through the proposed formula $[(4 \times \text{Consumption speed}) + \text{Number of drunkenness episodes} + (0.2 \times \text{Percentage of drunkenness episodes})]$ (Townshend and Duka, 2002, 2005). However, a large variability is also observed between studies using this score, notably regarding other alcohol-related measures (e.g. global consumption frequency/intensity beyond BD behaviors, BD habits duration).

² SAMHSA/NIAAA criteria are considered together as they are very close and often used indistinctly.

Proposal: towards a consensual BD measure

Measuring BD

We operationalize the core BD characteristics presented above through six criteria (Fig. 1) determining the presence/absence of BD (i.e. threshold approach, the compulsory conditions to be considered as binge drinker), which can also be used to explore differences among BD profiles (i.e. continuum approach, the variation in the intensity of BD habits):

- (1) Presence of 'physiological BD episodes': the 0.08% eBAC being classically considered as the drunkenness level, BD episodes will be operationalized as drinking occasions during which this minimal eBAC has been achieved during the last 12 months. This measure should go beyond the mere dose/grams approach used in most studies, at least by using the Widmark formula considering participants' sex and weight (see formula in Table 2). Ideally, the use of a revised formula also including other physical/demographic factors (Posey and Mozayani, 2007), usual stomach fullness when drinking (Finnigan *et al.*, 1998) and tolerance (e.g. estimation of lifetime alcohol consumption, Andreasson, 2016) would refine this eBAC measure.
- (2) Presence of 'psychological BD episodes': BD episodes will be considered as drinking occasions during which individuals self-report moderate (i.e. presence of walking/talking difficulties, behavioral/thoughts disinhibition and/or nausea; Andreasson, 2016) or intense (i.e. vomiting, blackout, strong hangover or even ethylic coma; Labhart *et al.*, 2018) drunkenness during the last 12 months. Self-reported drinking consequences should thus be evaluated to ensure the presence of drunkenness.
- (3) Ratio of BD episodes: BD being defined as an excessive alcohol consumption pattern, physiological/psychological BD episodes should represent at least 30% of the reported drinking occasions during the last 12 months.
- (4) Frequency of BD episodes: BD being considered as a recurrent alcohol consumption pattern, physiological/psychological BD episodes should have occurred at least twice per month during the last 12 months. This evaluation period appears as offering the best balance to evaluate average alcohol consumption (e.g. across course/exam/holiday periods in university students) while limiting the biases related to the delay between the behavior and its evaluation (Gmel and Daepfen, 2007). It is also coherent with the evaluation timeframe proposed by classical alcohol consumption measurement tools (e.g. AUDIT). It might be complemented by items measuring long-term consumption pattern (see next section) to have a more comprehensive view of lifetime alcohol consumption.
- (5) Consumption speed: BD being characterized by fast-paced consumption to reach drunkenness, BD episodes reported during the last 12 months should present a minimum eBAC increase of 0.04% per hour (allowing to reach the 0.08% eBAC in 2–3 hours).
- (6) BD episodes/soberness alternations: BD being characterized by episodic consumption, the mean number of abstinence days per week during the last 12 months should be at least 3, to ensure the presence of repeated drinking/withdrawal cycles and to avoid including people with more chronic consumption (and potentially with severe AUDs).

The more valid way to estimate these variables would be to systematically use ecological momentary assessment (EMA, Kuntsche

Table 2. Description of the main tools used to assess binge drinking

Tool	Description	Alcohol variables
Alcohol Use Disorders Identification Test (AUDIT)	General tool measuring consumption during the last 12 months (Babor <i>et al.</i> , 2001) Cut-off: scores ≥ 8 are related to hazardous drinking (Babor and Higgins-Biddle, 2001) Cut-off used to categorize binge drinking (e.g. Palfai and Ostafin, 2003; Van Tyne <i>et al.</i> , 2012)	Alcohol use frequency (AUDIT-1) Alcohol use intensity (AUDIT-2) Frequency of binge drinking episodes (AUDIT-3) Alcohol-related problems (AUDIT 4–10)
AUDIT-Consumption (AUDIT-C)	Three first AUDIT items, measuring binge drinking habits Cut-off: score ≥ 6 (Tuunanen <i>et al.</i> , 2007)	Alcohol use frequency (AUDIT-1) Alcohol use intensity (AUDIT-2) Frequency of binge drinking episodes (AUDIT-3)
Timeline Followback (TLFB)	Calendar of alcohol consumption (usually in the previous 3 months), offering a global view of drinking pattern (Sobell and Sobell, 1992; Sobell <i>et al.</i> , 1996)	Number of continuous drinking days/abstinence Number of drinking days Number of alcohol doses consumed Highest number of alcohol doses per occasion Number of binge drinking episodes Number of drunkenness episodes
Alcohol Use Questionnaire (AUQ)	Questionnaire measuring specific drinking pattern during the last 6 months (Mehrabian and Russell, 1978; Townshend and Duka, 2002)	Binge drinking score (Townshend and Duka, 2005): $(4 \times \text{Consumption speed}) + \text{Drunkenness frequency} + (0.2 \times \text{Drunkenness percentage})$
Personal Drinking Habits Questionnaire (PDHQ)	Questionnaire measuring typical alcohol consumption (intensity, weekly frequency and duration) (Vogel-Sprott, 1992)	Widmark formula to compute eBAC level (Watson <i>et al.</i> , 1981) (the highest level of Alcohol Grams consumed in one occasion/ $(\text{Weight} \times \text{Body water}^a)$)— $(\text{Metabolism rate}^b \times \text{Hours in which alcohol was drunk})$

^aThe water content in the human body, i.e. 0.68 for male and 0.55 for female.

^bThe metabolism rate is 0.15 g/h for male and 0.18 g/h for female.

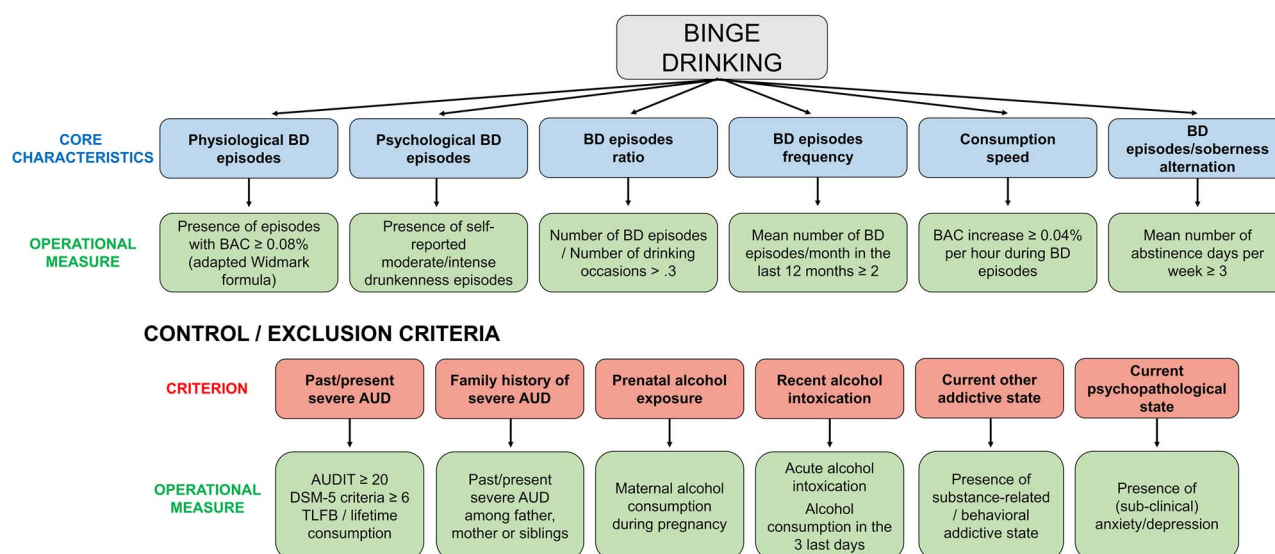
**Fig. 1.** Binge drinking criteria, associated operational measures and related exclusion/control variables.

Table 3. Description of the main binge drinking criteria/scores used in the current literature

	Assessment	Frequency	Intensity	Drinking episodes	Tools	Controls
SAMHSA/NIAAA criteria ^a	Post-hoc self-reported: <i>n</i> = 66	At least once occasions/month (1–16.4)	Doses/occasion (3.5–18.1)	Drunkennes Past month (2.2–4.8)	AUQ (9.8–58.7)	≤2 doses/month <3
	Ecological momentary assessment: <i>n</i> = 5		Doses/week (1.2–42.9)	Past 6 months (6.8–23.6)	AUDIT (6.1–16.5)	Occasions/week ≤2–6
			Doses/month (21.2–60.3)	Past year (13.8–29.4)	AUDIT-C (5.5–8)	Doses/occasion ≤2 doses/h
			Consumption speed (2–4.1)	Binge drinking Past 3 months (2.7–12.6)		No history of alcohol use
			Doses/2 hours (5.6–11)	Past 6 months (7–23)		
			Estimated BAC (0.10–27)	Past 3 years (4.9–99.9)		
AUDIT score ^b	Post-hoc self-reported: <i>n</i> = 8	Occasions/month (1–16)	Doses/occasion (4.54–16)	Drunkennes Past 6 months (8.4–9.8)	AUDIT (12.1–19)	AUDIT <7–8
AUDIT-C score	Ecological momentary assessment: <i>n</i> = 1	AUDIT-1 (2.3–2.9)	AUDIT-2 (2.6–3.2)		AUDIT-C (6.8–7.7)	AUDIT-C < 4
Binge drinking score ^d	Post-hoc self-reported alcohol use (last 6 months)	Occasions/week (.83–3.17)	Doses/occasion (2.3–10.8)	Drunkennes Past 6 months (4.5–23.6)	AUQ (25.2–58.7)	Binge drinking score ≤ 12
			Doses/week (2.4–38.2)		Score binge (7.9–54.4)	Binge drinking score ≤ 16
			Consumption speed (1.5–3.8)		AUDIT (5.6–17.2)	No history of alcohol use

Note. The numbers in italics below each characteristic represent the range of mean results observed across the studies reviewed. *n* = number of studies reviewed.

^aBased on the following studies: Adan *et al.* (2016), Ames *et al.* (2014), Banca *et al.* (2016), Bekman *et al.* (2013), Campanella *et al.* (2017a, 2017b, 2018b), Carlson *et al.* (2010), Cohen-Gilbert *et al.* (2017), Connell *et al.* (2015), Carpenter *et al.* (2019), Correia *et al.* (2016, 2019), Courtney and Polich (2010), Crego *et al.* (2009, 2012), Dulin *et al.* (2017), Ehlers *et al.* (2007), Gil-Hernandez and Garcia-Moreno (2016), Gil-Hernandez *et al.* (2017), Gonzalez *et al.* (2011), Goudriaan *et al.* (2007, 2011), Groefsema *et al.* (2019), Hallgren and McCrady (2013), Hartley *et al.* (2004), Heffernan and O'Neill (2012), Henges and Marcinski (2012), Jacobus *et al.* (2013), Jennison (2004), Jester *et al.* (2015), Johnson *et al.* (2008), Jones *et al.* (2016, 2017), Kachadourian *et al.* (2014), Keller *et al.* (2007), Laghi *et al.* (2012, 2019), Lannoy *et al.* (2017a, 2017b), Lisdahl *et al.* (2013), López-Caneda *et al.* (2012, 2013, 2014, 2017), Luquens *et al.* (2016), Maura *et al.* (2009, 2012, 2013), Morawska and Oei (2005), Morgenstern *et al.* (2016), Mora *et al.* (2013), Parada *et al.* (2012, 2014), Phillips *et al.* (2009), Piano *et al.* (2015), Poulton *et al.* (2016), Rooke and Hine (2011), Salas-Gomez *et al.* (2016), Sanhueza *et al.* (2011), Schweinsburg *et al.* (2011), Squeglia *et al.* (2011), Voogt *et al.* (2014), Wechsler *et al.* (1995), Weitzman *et al.* (2003), Worbe *et al.* (2014), Xiao *et al.* (2013), Yang *et al.* (2015), Yang and Nan (2019).

^bBased on the following studies: Ames *et al.* (2014), Kim and Kim (2019), Park and Kim (2018).

^cBased on the following studies: Black and Mullan (2015), Hermens *et al.* (2013b), Martins *et al.* (2017), McClatchley *et al.* (2014), Nouaman *et al.* (2018).

^dBased on the following studies: Bø *et al.* (2016a, 2016b, 2016c, 2017), Czaplak *et al.* (2015), Gierski *et al.* (2017), Hartley *et al.* (2004), Laghi *et al.* (2016), Lannoy *et al.* (2018a, 2018b, 2018c, 2019a, 2019b), Sanchez-Roige *et al.* (2014), Scaife and Duka (2009), Smith *et al.* (2017), Townshend and Duka (2005).

Table 4. Questionnaire estimating the presence of the six proposed BD criteria during the last 12 months

Measure	Item	Criteria estimated
Demographic variables	What is your sex? What is your weight?	Presence of 'physiological BD episodes' Consumption speed
Consumption frequency	How many days do you drink alcohol during a typical week?	BD episodes/soberness alternation
Consumption intensity	How many alcohol doses ^a do you drink on a typical drinking occasion?	Presence of 'physiological BD episodes'
Consumption speed	What is your consumption speed (number of doses per hour) during a typical drinking occasion?	Consumption speed
Drunkenness frequency	How many times have you been moderately (i.e. walking/speaking difficulties, disinhibition, nausea) or strongly (i.e. vomiting, blackout, strong hangover) drunk during the last 12 months?	Presence of 'psychological BD episodes'
	How many times during the last 12 months have you been drinking more than 'X' ^b alcohol doses in <2 hours?	Frequency of BD episodes
		Presence of 'physiological BD episodes' Frequency of BD episodes
Proportion of BD episodes	When you drink alcohol, what is the percentage of times you get moderately or strongly drunk?	Ratio of BD episodes

^aThe term 'alcohol dose/unit/drink' should be defined and exemplified at the beginning of the questionnaire (with potential variations across countries), as usually proposed in alcohol-related measures (e.g. AUDIT). Then, participants' self-reported measures should be converted in grams of ethanol to obtain a standardized and universal measure of alcohol consumption.

^bThe number of alcohol doses ('X') should be adapted for each country to correspond to 56 g (women) or 70 g (men).

and Labhart, 2013), measuring real-time consumption through brief assessments via smartphone during drinking occasions. However, as EMA is a demanding method that cannot be generalized yet, the presence of these criteria can be estimated through an eight-item self-reported questionnaire (Table 4).

These six criteria have been mentioned in previous studies (e.g. Piano *et al.*, 2017 for acute consumption criteria) but have never been simultaneously assessed in a single study to offer a clear-cut conceptualization of BD. We thus recommend future works to jointly use these criteria and their associated measures as a framework to evaluate BD habits, ensuring the specificity of the BD experimental group and inter-studies comparability. The use of these six variables, beyond establishing thresholds, will be useful in a continuum approach to explore the variation of BD-related psychological, cognitive and cerebral impairments according to each criterion.

As no reliable weighting of the six criteria is possible with the currently available data, we recommend exploring the respective influence of each criterion within BD groups (through correlational, cluster or network analyses) without merging these criteria in an artificial score. However, once the respective weight of each criterion in the global BD pattern will be established, these criteria might be integrated to propose a revised version of the BD score (Townshend and Duka, 2002, 2005). This revised score would propose empirically based BD subtyping according to thresholds related to the six criteria (e.g. low/moderate versus high/intense/extreme BD, Muraige *et al.*, 2012) and should overcome the current limits associated with the original score, as (1) it only considered a part of the criteria included in the present proposal; (2) its formula led to similar BD scores for individuals presenting very different alcohol consumption patterns

(e.g. identical BD score for individuals with similar consumption speed but respectively presenting drunkenness on 100% of the four drinking episodes or 20% of the 100 drinking episodes occurred during the timeframe considered); and (3) the BD categories (cut-off scores) proposed were only based on BD scores' distribution on the initial sample (Townshend and Duka, 2005). Hence, the stratification, based on statistical data rather than on actual consumption, is very likely to differ among samples. Would researchers already want to obtain a unified BD score, we thus encourage the inclusion of the six criteria to determine it and the distinction of BD subtypes through an analysis of the global drinking pattern, to overcome the limits associated with the initial BD score.

Determining biasing variables and exclusion criteria

The evaluation of BD should be completed by a control of biasing variables, to ensure that the observed results are specifically related to BD. To do so, we propose that upcoming BD studies should consider six factors (Fig. 1).

First, future studies should check that binge drinkers do not have past/present more global AUD. To do so, AUDIT/TLFB (encompassing the last year) constitute the minimal alcohol consumption measures and could be complemented by estimating long-term consumption factors (e.g. age at first drink, global lifetime consumption intensity/frequency). Indeed, many earlier studies included binge drinkers with very high AUDIT score, some of them potentially presenting undiagnosed severe AUD (Gmel *et al.*, 2011). To avoid such bias, future experimental protocols could include the DSM-5 criteria estimating AUD intensity to corroborate self-reported measures. To explore the specific influence of BD, the selection method should also check that participants do not present a family history of

severe AUD nor a suspicion of prenatal alcohol exposure. In studies performing cognitive or cerebral measures, the influence of acute alcohol consumption should also be considered to ensure that results are not contaminated by recent intoxication. The consumption in the week preceding testing could be controlled by confirming the absence of acute intoxication (using breathalyzer or blood measure) and by excluding people who consumed alcohol in the three preceding days. Finally, the presence of biasing comorbidities should also be explored, namely, (1) comorbid substance-related or behavioral addictive states, known to interact with alcohol-related effects, can be evaluated through a general screening tool (e.g. *Deleuze et al., 2015*); (2) psychopathological comorbidities frequently associated with AUD and having a well-established influence on psychological or cognitive processes can be evaluated through validated questionnaires (e.g. BDI, *Beck et al., 1996* for depression; STAI, *Spielberger et al., 1983* for anxiety). No general recommendation can be made regarding the choice to either control for these comorbidities or to exclude participants presenting them, as this choice can vary according to populations and study's aims. For example, epidemiological studies might include binge drinkers with comorbid cannabis use, as this is a very frequent BD comorbidity and as excluding these participants would lead to a biased vision of binge drinkers' characteristics. Conversely, neuroscience or neuropsychological studies exploring the specific impact of BD on brain structure/function should exclude binge drinkers with comorbid cannabis use (or consider them as a distinct experimental group) or at least control for this comorbidity to isolate the effects of alcohol.

Such control measures should also be applied to the control group, as non-drinkers might present atypical psychological, cognitive and cerebral profiles. The non-drinkers' category indeed merges people presenting a wide variety of abstinence reasons (including past excessive alcohol/drug consumption and potentially 'sick-quitters'), thus leading to a strong heterogeneity. We recommend to only include people with low alcohol consumption (AUDIT < 8), without BD episode in the past 12 months and without lifetime regular BD episodes.

MOVING FORWARD: EXPERIMENTAL PERSPECTIVES

The proposals presented above, whereas constituting a step forward in BD exploration, are obviously not conclusive. Future studies should reinforce their experimental support, notably by developing three experimental avenues:

- (1) Improving self-reported measures: the evaluation of our six criteria exclusively rely on self-reported measures, which are known to be quite imprecise (*Andreasson, 2016*) and potentially influenced by social desirability or cognitive/memory biases (e.g. underestimation of psychological drunkenness, particularly among youth). As these measures remain the most used in BD, their reliability/specificity should, however, be improved. This could be done through cross-sectional studies determining (a) the consistency across drinking measures but also between alcohol consumption and drinking consequences (e.g. between self-reported drunkenness episodes and hangover/blackouts) through reliability and correlational analyses and (b) the threshold at which measures (i.e. grams of ethanol per occasion, consumption speed, BD score) show the strongest coherence. The 56-70 g NIAAA criterion remaining the most commonly accepted constitutes a reliable basis to explore at which threshold the

BD score accurately reflects genuine BD habits. To support the specificity of BD criteria, it should also be tested if the participants identified with these criteria differ from those presenting AUD (measured through classical tools, e.g. AUDIT score ≥ 8). A more ambitious way to improve self-reported measures is to use repeated evaluations determining measure's stability (e.g. in a 12-month timeframe), which would imply longitudinal designs. Such designs would also allow distinguishing stable/persistent binge drinkers from ex-binge drinkers. We propose to consider as ex-binge drinker an individual who has been characterized as binge drinker according to the six criteria in the past but who has not presented any physiological or psychological BD episode during the 12 last months. EMA could further improve BD evaluation by reducing the biases generated by the delay between consumption and evaluation (*Gmel and Daepfen, 2007*). EMA could also be used to estimate drinking consequences at physiological/cognitive levels the next morning (*Labhart et al., 2018*) and to compute the reached eBAC during a typical drinking episode. Some preliminary studies have been conducted with this method, evaluating alcohol consumption or eBAC (*Carpenter et al., 2019*). However, before generalizing such EMA, follow-up assessments should check participants' compliance by testing at which frequency they actually report real-time consumption during alcohol intoxication.

- (2) Evaluating environmental and psychological factors: this would allow detecting complementary BD contributors. For example, regarding environmental factors, pregameing (i.e. massive at-home consumptions before going out) has been highlighted as a major BD risk factor in college students, above-and-beyond traditional consumption measures (*Haas et al., 2012*). Concerning psychological factors, drinking motives are a key determinant of BD behaviors, encompassing enhancement (i.e. drinking to experience positive emotions), social (i.e. drinking to celebrate during parties or social interactions), conformity (i.e. drinking to avoid being rejected by others) but also coping (i.e. drinking to face negative emotions) motivations, which might be differentially involved in BD. Validated questionnaires (e.g. revised drinking motive questionnaire, *Kuntsche et al., 2006*) can assess such motivations, which could also allow distinguishing different BD subtypes according to their main drinking motive. In the same vein, the precise influence of several psychological (e.g. impulsivity, self-esteem, personality traits) and interpersonal (e.g. social norms, group identity) variables on BD should be clarified.
- (3) Including neuroscience-based indexes in BD conceptualization/evaluation: a powerful way to strengthen the proposal that BD constitutes a specific consumption pattern is to identify its idiosyncratic impact on cognitive and brain functioning. This research line has been initiated in studies comparing binge drinkers with regular drinkers presenting similar global consumption (*Maurage et al., 2012*), but longitudinal studies should reinforce these results. For this purpose, participants should be recruited before the emergence of BD: cognitive and cerebral measures might be investigated before the appearance of BD and then at 6 (classical definition timeframe), 9, 12, 15, 18, 21 and 24 months. Such longitudinal designs have been initiated (e.g. *Ruan et al., 2019*) and could be extended to determine the progressive impairments in memory, attention and executive functions, but also in brain structure or functioning. Moreover, the influence of BD intensity on impairments' appearance should also be determined.

CONCLUSION

Capitalizing on a comprehensive literature review, we identified six core characteristics of BD, offering a sound conceptualization and a clear-cut distinction with other subclinical consumption patterns. These criteria have then been operationalized through recommendations for a valid BD evaluation, ensuring the reliability and comparability of future studies. Such combined conceptualization/evaluation, although still to be extended and refined, as underlined in the perspective section, is already of critical importance at (1) the theoretical level, by clarifying the concept, paving the way for its inclusion as a specific entity in future nosographies; (2) the empirical level, by overcoming the current heterogeneity across studies regarding inclusion/exclusion criteria and experimental BD group definition; and (3) the clinical level, by offering the opportunity to unambiguously identify BD populations, thus opening the gate to targeted preventive and prophylactic interventions.

ACKNOWLEDGEMENTS

We warmly thank Prof. Anne-Lise Pitel for her insightful comments on previous versions of the paper.

FUNDING

P.M. (Senior Research Associate) is funded by the Belgian Fund for Scientific Research (FRS-FNRS, Belgium). S.L. is funded by a grant from the Belgian American Education Foundation (BAEF). The REUNIRA network (national network of alcohol research) has been funded by the French mission fighting against drugs and addictions (MILDECA). The present work has been produced after three meetings of the REUNIRA work group. These funds did not exert any editorial direction or censorship on any part of this article.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

- Adan A, Navarro JF, Forero DA (2016) Personality profile of binge drinking in university students is modulated by sex. A study using the alternative five factor model. *Drug Alcohol Depend* 165:120–5.
- Ames SL, Wong SW, Bechara A *et al.* (2014) Neural correlates of a go/NoGo task with alcohol stimuli in light and heavy young drinkers. *Behav Brain Res* 274:382–9.
- Andreasson S (2016) Better options than self-report of consumption. *Addiction* 111:1727–8.
- Babor TF, Higgins-Biddle JC (2001) *Brief intervention for hazardous and harmful drinking: a manual for use in primary care*, first ed. World Health Organization, Geneva.
- Babor T, Higgins-Biddle J, Saunders J, *et al.* (2001) *The alcohol use disorders identification test: guidelines for use in primary care*, first ed. World Health Organization, Geneva.
- Banca P, Lange I, Worbe Y *et al.* (2016) Reflection impulsivity in binge drinking: Behavioural and volumetric correlates: Impulsivity in binge drinking. *Addict Biol* 21:504–15.
- Beck AT, Steer RA, Brown GK (1996) *Beck Depression Inventory Manual*, 1st edn. San Antonio: Psychological Corporation.
- Bekman NM, Winward JL, Lau LL, *et al.* (2013) The impact of adolescent binge drinking and sustained abstinence on affective state. *Alcohol Clin Exp Res* 37:1432–9.
- Bjork JM, Gilman JM (2014) The effects of acute alcohol administration on the human brain: insights from neuroimaging. *Neuropharmacology* 84:101–10.
- Black N, Mullan B (2015) An intervention to decrease heavy episodic drinking in college students: The effect of executive function training. *J Am Coll Health* 63:280–4.
- Bø R, Aker M, Billieux J, *et al.* (2016a) Binge drinkers are fast, able to stop—but they fail to adjust. *J Int Neuropsychol Soc* 22:38–46.
- Bø R, Billieux J, Gjerde LC *et al.* (2017) Do executive functions predict binge-drinking patterns? Evidence from a longitudinal study in young adulthood. *Front Psychol* 8:489.
- Bø R, Billieux J, Landrø NI (2016b) Binge drinking is characterized by decisions favoring positive and discounting negative consequences. *Addict Res Theory* 6:499–506.
- Bø R, Billieux J, Landrø NI (2016c) Which facets of impulsivity predict binge drinking? *Addict Behav Rep* 3:43–7.
- Bühler M, Mann K (2011) Alcohol and the human brain: a systematic review of different neuroimaging methods. *Alcohol Clin Exp Res* 35:1771–93.
- Campanella S, Peigneux P, Petit G *et al.* (2013) Increased cortical activity in binge drinkers during working memory task: A preliminary assessment through a functional magnetic resonance imaging study. *PLoS ONE* 8:e62260.
- Carbia C, Cadaveira F, Caamaño Isorna F *et al.* (2017b) Binge drinking during adolescence and young adulthood is associated with deficits in verbal episodic memory. *PLoS ONE* 12:e0171393. doi: 10.1371/journal.pone.0171393.
- Carbia C, Cadaveira F, Caamaño-Isorna F *et al.* (2017a) Binge drinking trajectory and decision-making during late adolescence: Gender and developmental differences. *Front Psychol* 8:783.
- Carbia C, Corral M, Doallo S *et al.* (2018b) The dual-process model in young adults with a consistent binge drinking trajectory into adulthood. *Drug Alcohol Depend* 186:113–9.
- Carbia C, López-Caneda E, Corral M, *et al.* (2018) A systematic review of neuropsychological studies involving young binge drinkers. *Neurosci Biobehav Rev* 90:332–49.
- Carlson SR, Johnson SC, Jacobs PC (2010) Disinhibited characteristics and binge drinking among university student drinkers. *Addict Behav* 35: 242–51.
- Carpenter RW, Padovano HT, Emery NN, *et al.* (2019) Rate of alcohol consumption in the daily life of adolescents and emerging adults. *Psychopharmacology (Berl)* 236:3111–24.
- Ceballos N, Babor TF (2017) Editor's corner: binge drinking and the evolving language of alcohol research. *J Stud Alcohol Drugs* 78:488–90.
- Cohen-Gilbert JE, Nickerson LD, Sneider JT *et al.* (2017) College binge drinking associated with decreased frontal activation to negative emotional distractors during inhibitory control. *Front Psychol* 8:1650.
- Connell AM, Patton E, McKillop H (2015) Binge drinking, depression, and electrocortical responses to emotional images. *Psychol Addict Behav* 29:673–82.
- Correas A, Cuesta P, López-Caneda E *et al.* (2016) Functional and structural brain connectivity of young binge drinkers: A follow-up study. *Sci Rep* 6:31293.
- Correas A, López-Caneda E, Beaton L *et al.* (2019) Decreased event-related theta power and phase-synchrony in young binge drinkers during target detection: An anatomically-constrained MEG approach. *J Psychopharmacol* 33:335–46.
- Courtney KE, Polich J (2010) Binge drinking effects on EEG in young adult humans. *Int J Environ Res Public Health* 7:2325–36.
- Crego A, Holguín SR, Parada M *et al.* (2009) Binge drinking affects attentional and visual working memory processing in young university students. *Alcohol Clin Exp Res* 33:1870–9.
- Crego A, Cadaveira F, Parada M *et al.* (2012) Increased amplitude of P3 event-related potential in young binge drinkers. *Alcohol* 46:415–25.
- Czapla M, Simon JJ, Friederich HC *et al.* (2015) Is binge drinking in young adults associated with an alcohol-specific impairment of response inhibition. *Eur Addict Res* 21:105–13.

- Deleuze J, Rochat L, Romo L, *et al.* (2015) Prevalence and characteristics of addictive behaviors in a community sample: a latent class analysis. *Addict Behav Rep* 1:49–56.
- Dormal V, Lannoy S, Maurage P (2019) Impact of exchange stay on alcohol consumption: longitudinal exploration in a large sample of European students. *Alcohol Clin Exp Res* 43:1220–4.
- Dulin PL, Alvarado CE, Fitterling JM *et al.* (2017) Comparisons of alcohol consumption by timeline follow back vs. smartphone-based daily interviews. *Addict Res Theory* 25:195–200.
- Ehlers CL, Phillips E, Finnerman G *et al.* (2007) P3 components and adolescent binge drinking in Southwest California Indians. *Neurotoxicol Teratol* 29:153–63.
- Enoch MA (2006) Genetic and environmental influences on the development of alcoholism: resilience vs. risk. *Ann N Y Acad Sci* 1094:193–201.
- Gierski F, Benzerouk F, De Wever E *et al.* (2017) Cloninger's temperament and character dimensions of personality and binge drinking among college students. *Alcohol Clin Exp Res* 41:1970–9.
- Gil-Hernandez S, Garcia-Moreno LM (2016) Executive performance and dysexecutive symptoms in binge drinking adolescents. *Alcohol* 51:79–87.
- Gil-Hernandez S, Mateos P, Porras C *et al.* (2017) Alcohol binge drinking and executive functioning during adolescent brain development. *Front Psychol* 8:1638.
- Glassman TJ (2010) Alcohol measures and terms: A perfect storm for chronic confusion. *J Am Coll Health* 58:397–9.
- Finnigan F, Hammersley R, Millar K (1998) Effects of meal composition on blood alcohol level, psychomotor performance and subjective state after ingestion of alcohol. *Appetite* 31:361–75.
- Gmel G, Daepfen JB (2007) Recall bias for seven-day recall measurement of alcohol consumption among emergency department patients: implications for case-crossover designs. *J Stud Alcohol Drugs* 68:303–10.
- Gmel G, Kuntsche E, Rehm J (2011) Risky single-occasion drinking: bingeing is not bingeing. *Addiction* 106:1037–45.
- Gonzalez VM, Reynolds B, Skewes MC (2011) Role of impulsivity in the relationship between depression and alcohol problems among emerging adult college drinkers. *Exp Clin Psychopharmacol* 19:303–13.
- Goudriaan AE, Grekin ER, Sher KJ (2007) Decision making and binge drinking: A longitudinal study. *Alcohol Clin Exp Res* 31:928–38.
- Goudriaan AE, Grekin ER, Sher KJ (2011) Decision making and response inhibition as predictors of heavy alcohol use: A prospective study. *Alcohol Clin Exp Res* 35:1050–7.
- Groefsema M, Luijten M, Engels R *et al.* (2019) Young adults do not catch up missed drinks when starting later at night—an ecological momentary assessment study. *Exp Clin Psychopharmacol* 27:160–5.
- Haas AL, Smith SK, Kagan K, *et al.* (2012) Pre-college pregameing: practices, risk factors, and relationship to other indices of problematic drinking during the transition from high school to college. *Psychol Addict Behav* 26:931–8.
- Hallgren K, McCrady B (2013) Interference in the alcohol Stroop task with college student binge drinkers. *J Behav Health* 2:112–9.
- Hartley DE, Elsabagh S, File SE (2004) Binge drinking and sex: Effects on mood and cognitive function in healthy young volunteers. *Pharmacol Biochem Behav* 78:611–9.
- Heffernan T, Clark R, Bartholomew J *et al.* (2010) Does binge drinking in teenagers affect their everyday prospective memory? *Drug Alcohol Depend* 109:73–8.
- Heffernan T, O'Neill T (2012) Time based prospective memory deficits associated with binge drinking: Evidence from the Cambridge prospective memory test (CAMPROMPT). *Drug Alcohol Depend* 123:207–12.
- Henges AL, Marcinski CA (2012) Impulsivity and alcohol consumption in young social drinkers. *Addict Behav* 37:217–20.
- Hermens DF, Lee RSC, De Regt T *et al.* (2013b) Neuropsychological functioning is compromised in binge drinking young adults with depression. *Psychiatry Res* 210:256–62.
- Hingson RW, Zha W, White AM (2017) Drinking beyond the binge threshold: predictors, consequences, and changes in the U.S. *Am J Prev Med* 52:717–27.
- Jacobus J, Squeglia LM, Bava S *et al.* (2013) White matter characterization of adolescent binge drinking with and without co-occurring marijuana use: A 3-year investigation. *Psychiatry Res Neuroimaging* 214:374–81.
- Jennison KM (2004) The short-term effects and unintended long-term consequences of binge drinking in college: A 10-year follow-up study. *Am J Drug Alcohol Abuse* 30:659–84.
- Jester JM, Wong MM, Cranford JA *et al.* (2015) Alcohol expectancies in childhood: Change with the onset of drinking and ability to predict adolescent drunkenness and binge drinking. *Addiction* 110:71–9.
- Johnson CA, Xiao L, Palmer P *et al.* (2008) Affective decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in 10th grade Chinese adolescent binge drinkers. *Neuropsychologia* 46:714–26.
- Johnston LD, O'Malley PM, Bachman JG *et al.* (2014) *Monitoring the Future national survey results on drug use*, Vol. I, 1975–2013 Secondary school students.
- Jones SA, Cservenka A, Nagel BJ (2016) Binge drinking impacts dorsal striatal response during decision making in adolescents. *Neuroimage* 129:378–88.
- Jones SA, Steele JS, Nagel BJ (2017) Binge drinking and family history of alcoholism are associated with an altered developmental trajectory of impulsive choice across adolescence. *Addiction* 112:1184–92.
- Kachadourian LK, Pilver CE, Potenza MN (2014) Trauma, PTSD, and binge and hazardous drinking among women and men: Findings from a national study. *J Psychiatr Res* 55:35–43.
- Keller S, Maddock JE, Laforge RG *et al.* (2007) Binge drinking and health behavior in medical students. *Addict Behav* 32:505–15.
- Kim EH, Kim MS (2019) An event-related potential study of error-monitoring deficits in female college students who participate in binge drinking. *Clin Psychopharmacol Neurosci* 17:80–92.
- Kuntsche E, Knibbe R, Gmel G, *et al.* (2006) Replication and validation of the drinking motive questionnaire revised (DMQ-R, Cooper, 1994) among adolescents in Switzerland. *Eur Addict Res* 12:161–8.
- Kuntsche E, Labhart F (2013) ICAT: Development of an internet-based data collection method for ecological momentary assessment using personal cell phones. *Eur J Psychol Assess* 29:140–8.
- Labhart F, Livingston M, Engels R, *et al.* (2018) After how many drinks does someone experience acute consequences-determining thresholds for binge drinking based on two event-level studies: optimal thresholds for binge drinking. *Addiction* 113:2235–44.
- Laghi F, Baiocco R, Lonigro A *et al.* (2012) Family functioning and binge drinking among Italian adolescents. *J Health Psychol* 17:1132–41.
- Laghi F, Baumgartner E, Baiocco R *et al.* (2016) Alcohol intake and binge drinking among Italian adolescents: The role of drinking motives. *J Addict Dis* 35:119–27.
- Laghi F, Bianchi D, Pompili S *et al.* (2019) Cognitive and affective empathy in binge drinking adolescents: Does empathy moderate the effect of self-efficacy in resisting peer pressure to drink? *Addict Behav* 89:229–35.
- Lannoy S, Benzerouk F, Maurage P *et al.* (2019) Disrupted fear and sadness recognition in binge drinking: A combined group and individual analysis. *Alcohol Clin Exp Res* 43:1978–85.
- Lannoy S, Billieux J, Dormal V, *et al.* (2019a) Behavioral and cerebral impairments associated with binge drinking in youth: a critical review. *Psychol Belg* 59:116–55.
- Lannoy S, Billieux J, Poncin M *et al.* (2017a) Binging at the campus: Motivations and impulsivity influence binge drinking profiles in university students. *Psychiatry Res* 250:146–54.
- Lannoy S, D'Hondt F, Dormal V *et al.* (2018b) Electrophysiological correlates of emotional crossmodal processing in binge drinking. *Cogn Affect Behav Neurosci* 18:1076–88.
- Lannoy S, Dormal V, Brion M *et al.* (2018a) Affective impairments in binge drinking: Investigation through emotional facial expression decoding. *Compr Psychiatry* 83:59–63.
- Lannoy S, Heeren A, Moyaerts N *et al.* (2017b) Differential impairments across attentional networks in binge drinking. *Psychopharmacology* 234:1059–68.

- Lannoy S, Maurage P, D'Hondt F *et al.* (2018c) Executive impairments in binge drinking: Evidence for a specific performance-monitoring difficulty during alcohol-related processing. *Eur Addict Res* 24:118–27.
- Lisdahl KM, Thayer R, Squeglia LM *et al.* (2013) Recent binge drinking predicts smaller cerebellar volumes in adolescents. *Psychiatry Res Neuroimaging* 211:17–23.
- López-Caneda E, Cadaveira F, Crego A *et al.* (2012) Hyperactivation of right inferior frontal cortex in young binge drinkers during response inhibition: A follow-up study. *Addiction* 107:1796–808.
- López-Caneda E, Cadaveira F, Crego A *et al.* (2013) Effects of a persistent binge drinking pattern of alcohol consumption in young people: A follow-up study using event-related potentials. *Alcohol Alcohol* 48:464–71.
- López-Caneda E, Rodríguez Holguín S, Corral M *et al.* (2014) Evolution of the binge drinking pattern in college students: Neurophysiological correlates. *Alcohol* 48:407–18.
- López Caneda E, Rodríguez Holguín S, Correas Á *et al.* (2017) Binge drinking affects brain oscillations linked to motor inhibition and execution. *J Psychopharmacol* 31:873–82.
- Luquiens A, Falissard B, Aubin HJ (2016) Students worry about the impact of alcohol on quality of life: Roles of frequency of binge drinking and drinker self-concept. *Drug Alcohol Depend* 167:42–8.
- Martins JG, de Paiva HN, Paiva PCP *et al.* (2017) New evidence about the “dark side” of social cohesion in promoting binge drinking among adolescents. *PLoS ONE* 12:e0178652.
- Maurage P, Bestelmeyer PE, Rouger J *et al.* (2013) Binge drinking influences the cerebral processing of vocal affective bursts in young adults. *Neuroimage Clin* 3:218–25.
- Maurage P, Joassin F, Speth A, *et al.* (2012) Cerebral effects of binge drinking: respective influences of global alcohol intake and consumption pattern. *Clin Neurophysiol* 123:892–901.
- Maurage P, Pesenti M, Philippot P *et al.* (2009) Latent deleterious effects of binge drinking over a short period of time revealed only by electrophysiological measures. *J Psychiatry Neurosci* 34:111–8.
- McClatchley K, Shorter GW, Chalmers J (2014) Deconstructing alcohol use on a night out in England: Promotions, preloading and consumption. *Drug Alcohol Rev* 33:367–75.
- Mehrabian A, Russell JA (1978) A questionnaire measure of habitual alcohol use. *Psychol Rep* 43:803–6.
- Morawska A, Oei TPS (2005) Binge drinking in university students: A test of the cognitive model. *Addict Behav* 30:203–18.
- Morgenstern M, DiFranza JR, Wellman RJ *et al.* (2016) Relationship between early symptoms of alcohol craving and binge drinking 2.5 years later. *Drug Alcohol Depend* 160:183–9.
- Moskalewicz J (2011) Between symbols and technicalities—a concept of binge drinking. *Addiction* 106:1047–8.
- Mota N, Parada M, Crego A *et al.* (2013) Binge drinking trajectory and neuropsychological functioning among university students: A longitudinal study. *Drug Alcohol Depend* 133:108–14.
- Naimi TS, Brewer RD, Mokdad A, *et al.* (2003) Binge drinking among US adults. *JAMA* 289:70–5.
- National Institute on Alcohol Abuse and Alcoholism (NIAAA, 2004). *Drinking Levels Defined*. <https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/moderate-binge-drinking> (accessed 21/05/2019).
- Nouaman MN, Vinikoor M, Seyd M *et al.* (2018) High prevalence of binge drinking among people living with HIV in four African countries. *J Int AIDS Soc* 21:e25202.
- Palfai TP, Ostafin BD (2003) Alcohol-related motivational tendencies in hazardous drinkers: Assessing implicit response tendencies using the modified-IAT. *Behav Res Ther* 41:1149–62.
- Parada M, Corral M, Mota N *et al.* (2012) Executive functioning and alcohol binge drinking in university students. *Addict Behav* 37:167–72.
- Park S, Kim MS (2018) An event-related potential study of spatial working memory in binge drinking college students. *PLoS One* 13:e0203696.
- Pearson MR, Kirouac M, Witkiewitz K (2016) Questioning the validity of the 4+/5+ binge or heavy drinking criterion in college and clinical populations. *Addiction* 111:1720–6.
- Petit G, Kornreich C, Dan B *et al.* (2014) Electrophysiological correlates of alcohol- and non-alcohol-related stimuli processing in binge drinkers: A follow-up study. *J Psychopharmacol* 28:1041–52.
- Petit G, Kornreich C, Maurage P *et al.* (2012) Early attentional modulation by alcohol-related cues in young binge drinkers: An event-related potentials study. *Clin Neurophysiol* 123:925–36.
- Phillips WJ, Hine DW, Marks ADG (2009) Individual differences in trait urgency moderate the role of the affect heuristic in adolescent binge drinking. *Personal Individ Differ* 47:829–34.
- Piano MR, Mazzucco A, Kang M, *et al.* (2017) Binge drinking episodes in young adults: how should we measure them in a research setting? *J Stud Alcohol Drugs* 78:502–11.
- Piano MR, Tiwari S, Nevoral L *et al.* (2015) Phosphatidylethanol levels are elevated and correlate strongly with AUDIT scores in young adult binge drinkers. *Alcohol Alcohol* 50:519–25.
- Posay D, Mozayani A (2007) The estimation of blood alcohol concentration: Widmark revisited. *Forensic Sci Med Pathol* 3:33–9.
- Poulton A, Mackenzie C, Harrington K *et al.* (2016) Cognitive control over immediate reward in binge alcohol drinkers. *Alcohol Clin Exp Res* 40:429–37.
- Presley CA, Pimentel ER (2006) The introduction of the heavy and frequent drinker: a proposed classification to increase accuracy of alcohol assessments in postsecondary educational settings. *J Stud Alcohol* 67:324–31.
- Read JP, Beattie M, Chamberlain R, *et al.* (2008) Beyond the “binge” threshold: heavy drinking patterns and their association with alcohol involvement indices in college students. *Addict Behav* 33:225–34.
- Rolland B, Naassila M (2017) Binge drinking: current diagnostic and therapeutic issues. *CNS Drugs* 31:181–6.
- Rooke SE, Hine DW (2011) A dual process account of adolescent and adult binge drinking. *Addict Behav* 36:341–6.
- Ruan H, Zhou Y, Luo Q, *et al.* (2019) Adolescent binge drinking disrupts normal trajectories of brain functional organization and personality maturation. *Neuroimage Clin* 22:101804.
- Salas-Gomez D, Fernandez-Gorgojo M, Pozueta A *et al.* (2016) Binge drinking in young university students is associated with alterations in executive functions related to their starting age. *PLoS One* 11:e0166834.
- Sanchez-Roige S, Baro V, Trick L *et al.* (2014) Exaggerated waiting impulsivity associated with human binge drinking, and high alcohol consumption in mice. *Neuropsychopharmacology* 39:2919–27.
- Sanhueza C, García-Moreno LM, Expósito J (2011) Weekend alcoholism in youth and neurocognitive aging. *Psicothema* 23:209–14.
- Scaife JC, Duka T (2009) Behavioural measures of frontal lobe function in a population of young social drinkers with binge drinking pattern. *Pharmacol Biochem Behav* 93:354–62.
- Schuckit MA, Smith TL, Kalmijn J, *et al.* (2012) Comparison across two generations of prospective models of how the low level of response to alcohol affects alcohol outcomes. *J Stud Alcohol Drugs* 73:195–204.
- Schweinsburg AD, Schweinsburg BC, Nagel BJ, *et al.* (2011) Neural correlates of verbal learning in adolescent alcohol and marijuana users: fMRI in adolescent users. *Addiction* 106:564–73.
- Smith KW, Gierski F, Andre J, *et al.* (2017) Altered white matter integrity in whole brain and segments of corpus callosum, in young social drinkers with binge drinking pattern. *Addict Biol* 22:490–501.
- Sobell L, Sobell M (1992) Timeline follow-back: A technique for assessing self-reported alcohol consumption, in Litten, R., Allen, J. (Eds.), *Measuring alcohol consumption: Psychosocial and biochemical methods*. Humana Press, Totowa, pp. 41–72.
- Sobell LC, Brown J, Leo GI, *et al.* (1996) The reliability of the Alcohol Timeline Follow back when administered by telephone and by computer. *Drug Alcohol Depend* 42:49–54.
- Spielberger DC, Gorsuch RL, Lushene R, *et al.* (1983) *Manual for the State-Trait Anxiety Inventory*, 1st edn. Palo Alto: Consulting Psychology Press.

- Squeglia LM, Schweinsburg AD, Pulido C, *et al.* (2011) Adolescent binge drinking linked to abnormal spatial working memory brain activation: Differential gender effects. *Alcohol Clin Exp Res* 35:1831–41.
- Substance Abuse and Mental Health Services Administration (SAMHSA, 2011) Results from the 2011 National Survey on Drug Use and Health: Mental Health Findings. <https://www.samhsa.gov/data/sites/default/files/2011MHFDT/2k11MHFR/Web/NSDUHmhfr2011.hth> (accessed 21/05/2019).
- Topiwala A, Allan CL, Valkanova V, *et al.* (2017) Moderate alcohol consumption as risk factor for adverse brain outcomes and cognitive decline: longitudinal cohort study. *BMJ* 357:j2353.
- Townshend JM, Duka T (2002) Patterns of alcohol drinking in a population of young social drinkers: a comparison of questionnaire and diary measures. *Alcohol Alcohol* 37:187–92.
- Townshend JM, Duka T (2005) Binge drinking, cognitive performance and mood in a population of young social drinkers. *Alcohol Clin Exp Res* 29:317–25.
- Tuunanen M, Aalto M, Seppä K (2007) Binge drinking and its detection among middle-aged men using AUDIT, AUDIT-C and AUDIT-3. *Drug Alcohol Rev* 26:295–9.
- Van Tyne K, Zamboanga BL, Ham LS, *et al.* (2012) Drinking motives as mediators of the associations between alcohol expectancies and risky drinking behaviors among high school students. *Cogn Ther Res* 36: 756–67.
- Vogel-Sprott M (1992) Alcohol tolerance and social drinking: Learning the consequences, first ed. Guilford, New York.
- Voogt C, Kuntsche E, Kleinjan M, *et al.* (2014) Using ecological momentary assessment to test effectiveness of a web-based brief alcohol intervention over time among heavy-drinking students: Randomized controlled trial. *J Med Internet Res* 16:e5.
- Watson PE, Watson ID, Batt RD (1981) Prediction of blood alcohol concentration in human subjects: Updating the Widmark equation. *J Stud Alcohol* 42:547–56.
- Wechsler H, Davenport A, Dowdall G, *et al.* (1994) Health and behavioral consequences of binge drinking in college. A national survey of students at 140 campuses. *JAMA* 272:1672–7.
- Wechsler H, Dowdall G, Davenport A, *et al.* (1995) Correlates of college student binge drinking. *Am J Public Health* 85:921–6.
- Weitzman ER, Nelson TF, Wechsler H (2003) Taking up binge drinking in college: The influences of person, social group, and environment. *J Adolesc Health* 32:26–35.
- Worbe Y, Irvine M, Lange I, *et al.* (2014) Neuronal correlates of risk-seeking attitudes to anticipated losses in binge drinkers. *Biol Psychiatry* 76:717–24.
- World Health Organization (2018) *Global Status Report on Alcohol and Health 2018*, 1st edn. Geneva: World Health Organization.
- Xiao L, Bechara A, Gong Q *et al.* (2013) Abnormal affective decision making revealed in adolescent binge drinkers using a functional magnetic resonance imaging study. *Psychol Addict Behav* 27:443–54.
- Yang B, Nan X (2019) Influence of norm-based messages on college students' binge drinking intentions: Considering norm type, regulatory mode, and level of alcohol consumption. *Health Commun* 34:1711–20.
- Yang C, Linas B, Kirk G *et al.* (2015) Feasibility and acceptability of smartphone-based ecological momentary assessment of alcohol use among African American men who have sex with men in Baltimore. *JMIR MHealth UHealth* 3:e67.