What we talk about when we talk about binge drinking:

Towards an integrated conceptualization and evaluation.

Pierre Maurage[1,*], Séverine Lannoy[2], Jessica Mange[3], Delphine Grynberg[4,5], Hélène Beaunieux[3], Ingrid Banovic[6], Fabien Gierski[7,8], Mickaël Naassila[8]

[1] *Louvain Experimental Psychopathology research group (LEP), Psychological Science Research Institute, UCLouvain, Louvain-la-Neuve, Belgium.*

[2] *Department of Psychiatry and Behavioral Sciences, Stanford University, Stanford, California, USA.*

[3] *Laboratoire de Psychologie Caen Normandie (LPCN; EA 7452), University of Caen Normandy, Caen, France.*

[4] *Univ. Lille, CNRS, CHU Lille, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, 59000 Lille, France*

[5] *Institut Universitaire de France, Paris, France*

[6] *CRFDP EA 7475, University of Rouen Normandie, Rouen, France.*

[7] *Cognition, Health, Society Laboratory (C2S - EA 6291), University of Reims Champagne Ardenne (URCA), Reims, France*

[8] *INSERM UMR 1247, Research Group on Alcohol & Pharmacodependences, GRAP, University of Picardie Jules Verne, Amiens, France.*

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*All correspondence should be sent to:

Pierre Maurage, Université catholique de Louvain, Faculté de Psychologie

Place du Cardinal Mercier, 10, B-1348 Louvain-la-Neuve, Belgium

Tel: +32 10 479245. Fax:+32 10 473774. E-mail: pierre.maurage@uclouvain.be

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.

1. Introduction

Excessive alcohol consumption is a key public health problem worldwide (WHO, 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 & Gilman, 2014) and severe alcohol use disorders (AUD, e.g., Bühler & 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 & Naassila, 2017). While some debates have long persisted regarding this terminology (e.g., Ceballos & Babor, 2017; Moskalewicz, 2011), 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., 2019 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., 2016) and the validity of the "continuum hypothesis" is widely debated (Lannoy et al., 2019). These controversies are centrally resulting from inter-studies 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 this limit by (1) proposing an integrated description of the core characteristics of BD habits in youth, and (2) offering a short but comprehensive

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.

2. What are the core characteristics of BD?

2.1. Current BD definition

Several attempts have proposed BD definitions (e.g., NIAAA workshops, 2001; 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 (NIAAA) and/or frequency (Presley & Pimentel, 2006), or even propose supplementary parameters (e.g., percentage of drunkenness episodes, Townshend & Duka, 2002).

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

Source	Cut-off Quantity[1]	Adaptation criteria	Drinking speed	Reference period	Frequency	Country
Johnston et al. (2014[2])	5+	-	-	2 last weeks	Once	USA
Weschler, et al., (1995)	4+/5+	Gender	-	-	Once	USA
NIAAA[3] (2004)	4+/5+ (56g/70g)	Gender	Within less than 2 hours	-	Once	USA
	.08g/dL BAC	-	Within less than 2 hours	-	Once	USA
Presley & Pimentel (2005)	4+/5+ (56g/70g)				3x/week	USA
Townshend & Duka (2005)	No cut-off (continuous score)	-	Number of doses per hour	Number of doses/week and drunkeness episodes in the last 6 months	Percentage of drunkenness episodes	UK
SAMSHA[4] (2011)	4+/5+	Gender	Within less than 2 hours	Past month	Once	USA
WHO[5] (2014)	6+ (60g)	-	-	-	Once	International

[1] Cut-off value corresponds to the minimum number of standard doses per occasion to be classified as Binge Drinker. When 2 values are presented, they refer to women vs. men standards

[2] Data from Monitoring the Future between 1975 and now

[3] NIAAA : National Institute on Alcohol Abuse and Alcoholism (USA)

[4] SAMHSA : Substance Abuse and Mental Health Services Administration (USA)

[5] WHO : World Health Organization

The NIAAA definition has emerged as the most consensual one. It focuses on consumption quantity and speed, defining BD as the consumption of more than 56g[1] (women) or 70g (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); (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 with 3 main issues: (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 & Pimentel, 2006); (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.,

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[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).

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., 84/98g, Read 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 like [e.g., drunkenness frequency, Townshend & Duka (2002)]; (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.

2.2. 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, 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 section 3.2.).

This integrated BD conceptualization will allow unambiguously distinguishing this pattern from: (1) "Heavy drinking", namely consuming at least 70g 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 higher than 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 & 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; (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 inter-personal (family/professional impact, guiltiness) consequences evaluated by these tools, at least at short/mid-term.

3. How can BD be evaluated?

3.1. 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 3 categories (Table 3):

(1) *SAMHSA/NIAAA criteria*[2]: 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 Follow Back (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).

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

(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 × Consumption speed] + Number of drunkenness episodes + [0.2 × Percentage of drunkenness episodes] (Towhnshend & 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).

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 et al., 2001). Cut-off: Scores ≥ 8 are related to hazardous drinking (Babor & Higgins-Biddle, 2001). Cut-off used to categorize binge drinking (e.g., Palfai & Ostafin, 2003; Van Tyne et al., 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 et al., 2007)	Alcohol use frequency (AUDIT-1) Alcohol use intensity (AUDIT-2) Frequency of binge drinking episodes (AUDIT-3)
Time Line Follow Back (TLFB)	Calendar of alcohol consumption (usually in the previous 3 months), offering a global view of drinking pattern (Sobell & Sobell, 1992; Sobell et al., 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 measuring specific drinking pattern	Binge drinking score (Townshend and Duka, 2005):

Questionnaire (AUQ)	during the last 6 months (Mehrabian and Russell, 1978; Townshend and Duka, 2002).	(4 x Consumption speed) + Drunkenness frequenc + (0.2 x Drunkenness percentage)
Personal Drinking Habits Questionnaire (PDHQ)	Questionnaire measuring typical alcohol consumption (intensity, weekly frequency, and duration) (Vogel-Sprott, 1992).	Widmark formula to compute estimated BAC leve (Watson et al., 1981) [the highest level of Alcohol Grams consumed in one occasion / (Weight x Body water[1])] – (Metabolism rate[2] x Hours in which alcohol was drunk)

[1] The water content in the human body, i.e., 0.68 for male and 0.55 for female
[2] The metabolism rate is 0.15g/h for male and 0.18g/h for female

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

Assessment	Frequency	Intensity	Drinking episodes	Tools	Controls
			Drunkenness		
		Doses/occasion	Past month (2.2-4.8)		
Post-hoc self-reported: n=66	At least once	(3.5-18.1) Doses/week (1.2-42.9)	Past 6 months (6.8-23.6) Past year (13.8-29.4)	AUQ (9.8-58.7) AUDIT	≤ 2 doses/month < 3 occasions/week ≤ 2-6
Ecological momentary assessment: n=5	occasions/month (1-16.4)	Doses/month (21.2-60.3) Consumption speed (2-4.1)	Binge drinking Past 3 months (2.7-12.6) Past 6 months	(6.1-16.5) AUDIT-C (5.5-8)	doses/occasion ≤ 2 doses/hour No history of alcohol use
		Doses/2h (5.6-11) Estimated	(7-23) Past 3 years (4.9-99.9)		

SAMHSA / NIAAA criteria [a]

			BAC
			(.10-.27)

AUDIT score [b]	Post-hoc self-reported: n=8	Occasions/month	Doses/occasion	Drunkenness	AUDIT	AUDIT < 7-8
Score ≥ 7-12	Ecological momentary assessment: n=1	*(1-16)*	*(4.54-16)*	Past 6 months	*(12.1-19)*	
		AUDIT-1	AUDIT-2	*(8.4-9.8)*	AUDIT-C	AUDIT-C < 4
AUDIT-C score [c]		*(2.3-2.9)*	*(2.6-3.2)*		*(6.8-7.7)*	
Score ≥ 4-6						

Binge drinking score [d]	Post-hoc self-reported alcohol use (last 6 months)	Occasions/week	Doses/occasion *(2.3-10.8)* Doses/week *(2.4-38.2)* Consumption speed *(1.5-3.8)*	Drunkenness	AUQ *(25.2-58.7)* Score binge *(7.9-54.4)* AUDIT *(5.6-17.2)*	Binge drinking score ≤ 12 Binge drinking score ≤ 16 No history of alcohol use
		(.83-3.17)		Past 6 months *(4.5-23.6)*		

Note. The numbers in italics below each characteristic represent the range of mean results observed across the studies reviewed. AUQ=Alcohol Use Questionnaire; AUDIT=Alcohol Use Disorders Identification Test; AUDIT-C=AUDIT-Consumption; n=number of studies reviewed.

[a] Based on the following studies : Adan et al., 2016 ; Ames et al., 2014 ; Banca et al., 2016 ; Bekman et al., 2013 ; Campanella et al., 2013 ; Carbia et al., 2017a; b ; 2018b ; Carlson et al., 2010 ; Cohen-Gilbert et al., 2017 ; Connell et al., 2015 ; Carpenter et al., 2019 ; Correas et al., 2016 ; 2019 ; Courtney & Polich, 2010 ; Crego et al., 2009; 2012 ;

Dulin et al., 2018 ; Ehlers et al., 2007 ; Gil-Hernandez & Garcia-Moreno, 2016; Gil-Hernandez et al., 2017 ; Gonzalez et al., 2011 ; Goudriaan et al., 2007; 2011 ; Groefsema et al., 2019 ; Hallgren & McCrady, 2013 ; Hartley et al., 2004 ; Heffernan et al., 2010 ; Heffernan & O'Neill, 2012 ; Henges & Marczinski, 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 ; Laghi et al., 2019 ; Lannoy et al., 2017a ; 2017b ; Lisdahl et al., 2013 ; López-Caneda et al., 2012; 2013; 2014; 2017 ; Luquiens et al., 2016 ; Maurage et al., 2009; 2012; 2013 ; Morawska & Oei, 2005 ; Morgenstern et al., 2016 ; Mota et al., 2013 ; Parada et al., 2012 ; Petit et al., 2012 ; 2014 ; Phillips et al., 2009 ; Piano et al., 2015 ; Poulton et al., 2016 ; Rooke & Hine, 2011 ; Salas-Gomez et al., 2016 ; Sanhueza et a., 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 & Nan, 2019.

[b] Based on the following studies: Ames et al., 2014; Kim & Kim, 2019; Park & Kim, 2018.

[c] Based on the following studies : Black & Mullan, 2015; Hermens et al., 2013b ; Martins et al., 2017; McClatchley et al., 2014; Nouaman et al., 2018.

[d] Based on the following studies: Bø et al., 2016a; b; c; 2017 ; Czapla et al., 2015 ; Gierski et al., 2017 ; Hartley et al., 2004 ; Laghi et al., 2016 ; Lannoy et al., 2018a; b; c; 2019a; b ; Sanchez-Roige et al., 2014 ; Scaife & Duka, 2009 ; Smith et al., 2017 ; Townshend & Duka, 2005.

3.2. Proposal: towards a consensual BD measure

3.2.1. Measuring BD

We operationalize the core BD characteristics presented above through 6 criteria (Figure 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 inside 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 & 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 & Daeppen, 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-pace 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 alcohol use disorders).

The more valid way to estimate these variables would be to systematically use Ecological Momentary Assessment (EMA, Kuntsche & 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 a 8-item self-reported questionnaire (Table 4). These 6 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 6 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 6 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 & Duka, 2002; 2005). This revised score would propose empirically-based BD subtyping according to thresholds related to the 6 criteria (e.g., low/moderate versus high/intense/extreme BD, Maurage 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 4 drinking episodes or 20% of the 100 drinking episodes occurred during the timeframe considered); (3) the BD categories (cut-off scores) proposed were only based on BD scores' distribution on the initial sample (Townshend & 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 6 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.

Table 4. Questionnaire estimating the presence of the 6 proposed binge drinking (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[1] 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? How many times during the last 12 months have you been drinking more than "X"[2] alcohol doses in less than 2 hours?	Presence of "psychological BD episodes" 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

[1] The 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.
[2] The number of alcohol doses ("X") should be adapted for each country to correspond to 56gr (women) or 70gr (men).

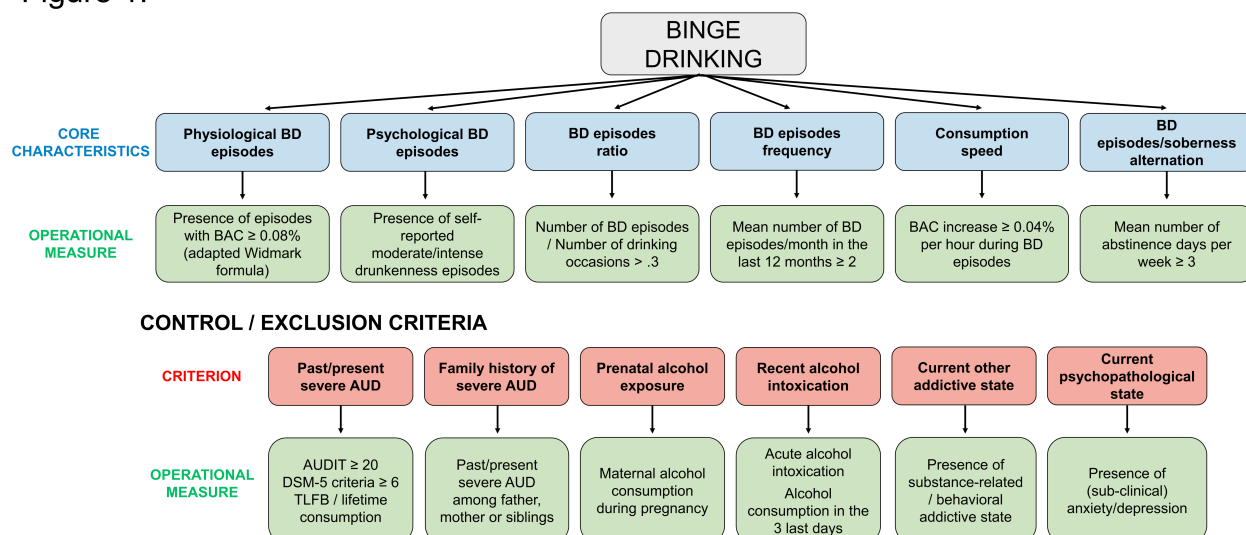*3.2.2. Determining biasing variables and exclusion criteria*

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 6 factors (Figure 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 3 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.

Figure 1.

BINGE DRINKING

CORE CHARACTERISTICS

Physiological BD episodes	Psychological BD episodes	BD episodes ratio	BD episodes frequency	Consumption speed	BD episodes/soberness alternation

OPERATIONAL MEASURE

Presence of episodes with BAC ≥ 0.08% (adapted Widmark formula)	Presence of self-reported moderate/intense drunkenness episodes	Number of BD episodes / Number of drinking occasions > .3	Mean number of BD episodes/month in the last 12 months ≥ 2	BAC increase ≥ 0.04% per hour during BD episodes	Mean number of abstinence days per week ≥ 3

CONTROL / EXCLUSION CRITERIA

CRITERION

Past/present severe AUD	Family history of severe AUD	Prenatal alcohol exposure	Recent alcohol intoxication	Current other addictive state	Current psychopathological state

OPERATIONAL MEASURE

AUDIT ≥ 20 DSM-5 criteria ≥ 6 TLFB / lifetime consumption	Past/present severe AUD among father, mother or siblings	Maternal alcohol consumption during pregnancy	Acute alcohol intoxication Alcohol consumption in the 3 last days	Presence of substance-related / behavioral addictive state	Presence of (sub-clinical) anxiety/depression

4. 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 3 experimental avenues:

(1) *Improving self-reported measures*: the evaluation of our 6 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., under-estimation 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; (b) the threshold at which measures (i.e., grams of ethanol per occasion, consumption speed, BD score) show the strongest coherence. The 56-70g NIAAA criterion remaining the most

commonly accepted, it 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 longitudinal 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 6 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 & Daeppen, 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, pregaming (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., Drinking Motive Questionnaire Revised, 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, 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.

5. Conclusion

Capitalizing on a comprehensive literature review, we identified 6 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; (3) the clinical level, by offering the opportunity to unambiguously identify BD populations, thus opening the gate to targeted preventive and prophylactic interventions.

Conflict of interest

The authors declare no conflict of interest.

References

Andreasson S (2016) Better options than self-report of consumption. *Addiction* 111:1727–28.

Beck AT, Steer RA, Brown GK (1996) *Beck Depression Inventory Manual*. 1st ed. Psychological Corporation, San Antonio.

Bjork JM, Gilman JM (2014) The effects of acute alcohol administration on the human brain: insights from neuroimaging. *Neuropharmacology* 84:101–10.

Bø R, Aker M, Billieux J, Landrø NI (2016) Binge drinkers are fast, able to stop – but they fail to adjust. *J Int Neuropsychol Soc* 22:38–46.

Bühler M, Mann K (2011) Alcohol and the human brain: a systematic review of different neuroimaging methods. *Alcohol Clin Exp Res* 35:1771–93.

Carbia C, López-Caneda E, Corral M, Cadaveira F (2018) A systematic review of neuropsychological studies involving young binge drinkers. *Neurosci Biobehav Rev* 90:332–49.

Carpenter RW, Padovano HT, Emery NN, Miranda R (2019) Rate of alcohol consumption in the daily life of adolescents and emerging adults. *Psychopharmacology* 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.

Deleuze J, Rochat L, Romo L, Van der Linden M, Achab S, Thorens G, Khazaal Y, Zullino D, Maurage P, Rothen S, Billieux J (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.

Enoch MA (2006) Genetic and environmental influences on the development of alcoholism: resilience vs. risk. *Ann N Y Acad Sci* 1094:193–201.

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, Daeppen 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.

Haas AL, Smith SK, Kagan K, Jacob T (2012) Pre-college pregaming: 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.

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.

Kuntsche E, Knibbe R, Gmel G, Engels R (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, Kuntsche E (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.

Lannoy S, Billieux J, Dormal V, Maurage P (2019) Behavioral and cerebral impairments associated with binge drinking in youth: A critical review. *Psychol Belg* 59 :116–55.

Maurage P, Joassin F, Speth A, Modave J, Philippot P, Campanella S (2012) Cerebral effects of binge drinking: Respective influences of global alcohol intake and consumption pattern. *Clin Neurophysiol* 123:892–901.

Moskalewicz J (2011). Between symbols and technicalities - a concept of binge drinking. *Addiction* 106:1047–8.

Naimi TS, Brewer RD, Mokdad A, Denny C, Serdula MK, Marks JS (2003) Binge drinking among US adults. *JAMA* 289:70–5.

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.

Piano MR, Mazzuco A, Kang M, Phillips SA (2017). Binge drinking episodes in young adults: How should we measure them in a research setting? *J Stud Alcohol Drugs* 78:502–11.

Posey D, Mozayani A (2007) The estimation of blood alcohol concentration: Widmark revisited. *Forensic Sci Med Pathol* 3:33–9.

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, Merrill JE (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.

Ruan H, Zhou Y, Luo Q, Robert GH, Desrivières S, Quinlan EB, Liu Z, Banaschewski T, Bokde ALW, Bromberg U, Büchel C, Flor H, Frouin V, Garavan H, Gowland P, Heinz A, Ittermann B, Martinot JL, Martinot MP, Nees F, Orfanos DP, Poustka L, Hohmann S, Fröhner JH, Smolka MN, Walter H, Whelan R, Li F, Schumann G, Feng J, IMAGEN Consortium (2019) Adolescent binge drinking disrupts normal trajectories of brain functional organization and personality maturation. *Neuroimage Clin* 22:101804.

Schuckit MA, Smith TL, Kalmijn J, Trim RS, Cesario E, Saunders G, Sanchez C, Campbell N (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.

Spielberger DC, Gorsuch RL, Lushene R, Vagg PR, Jacobs GA (1983) *Manual for the State-Trait Anxiety Inventory*. 1st ed. Palo Alto, Consulting Psychology Press.

Topiwala A, Allan CL, Valkanova V, Zsoldos E, Filippini N, Sexton C, Mahmood A, Fooks P, Singh-Manoux A, Mackay CE, Kivimäki M, Ebmeier KP (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.

Wechsler H, Davenport A, Dowdall G, Moeykens B, Castillo S (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, Castillo S (1995) Correlates of college student binge drinking. *Am J Public Health* 85:921–6.

World Health Organization (2018) Global status report on alcohol and health 2018. 1st ed. World Health Organization, Geneva.

Figure Caption

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