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What is binge drinking? Insights from a network perspective

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ABSTRACT

This study aimed to delineate the specific characteristics of binge drinking habits by capitalizing on data-driven network analysis. Such an approach allowed us to consider binge drinking as a network system of interacting elements, thus identifying the key variables involved in this phenomenon. A total of 1,455 university students with excessive drinking habits were included in this study. We assessed the most critical features of binge drinking (i.e., the consumption of more than six alcohol units per occasion, drunkenness frequency, consumption speed), together with alcohol use and more general alcohol-related components of dysfunction and harm. All variables were considered in the network analysis. Centrality analysis identified drunkenness frequency as the most influential variable in the entire network. Community detection analysis showed three distinct subnetworks related to alcohol use, drunkenness, and dysfunction/harm components. Drunkenness frequency and blackout occurrence emerged as core bridge items in the binge drinking network. Drunkenness is recognized as the hallmark feature of binge drinking.

1. Introduction

Binge drinking is a pattern of episodic alcohol use characterized by strong alcohol intake during a short period. Previous research revealed that this habit is associated with risky behaviors in the short term (e.g., unsafe sexual practices, reckless driving; Hingson, Zha, & White, 2017) but that it might also foster the emergence of alcohol use disorder in the long run (Bonomo, Bowes, Coffey, Carlin, & Patton, 2004). Numerous studies have identified its deleterious consequences, showing disrupted brain activity (Cservenka & Brumback, 2017; Maurage, Petit, & Campanella, 2013), impaired cognitive functioning (particularly for memory and executive functions; Carbia, López-Caneda, Corral, & Cadaveira, 2018), and altered emotional processing (Lannoy et al., 2021). Nevertheless, contradictory results have also been observed (e.g., absence of executive deficits among binge drinkers; Bø, Billieux, Gjerde, Eilertsen, & Landrø, 2017; Hartley, Elsabagh, & File, 2004) and may be related to important interstudy variations in binge drinking criteria. Indeed, the absence of a consensual binge drinking definition currently compromises comparisons among existing studies as well as replication efforts. Moreover, various terms have been used to refer to similar habits, including binge drinking (see Courtney & Polich, 2009 for a review), hazardous drinking (Babor & Higgins-Biddle, 2001), heavy drinking (NIAAA, 2004), and risky single occasion drinking (Gmel, Kuntsche, & Rehm, 2011). In this paper, we systematically use "binge drinking" to characterize this behavior, as it is the most frequently used term to date (e.g., Kuntsche, Kuntsche, Thrul, & Gmel, 2017).

Regarding the definition of binge drinking, two main strategies have been used in previous studies to identify binge drinkers: quantitative alcohol consumption variables [e.g., using the Alcohol Use Disorders Identification Test (AUDIT) score or proposing minimum consumption intensity/frequency thresholds; NIAAA, 2004] or qualitative analysis of the drinking pattern (e.g., involving specific drinking characteristics such as drunkenness; Townshend & Duka, 2002).

On the one hand, binge drinking was initially framed by the 5/4 measure (Wechsler & Nelson, 2001)—that is, a binge drinking episode consisting of the consumption of at least four (for women) or five (for

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men) alcohol units on a single occasion. The National Institute for Alcohol Abuse and Alcoholism (NIAAA, 2004) then amended the criterion for the 5/4 measure by including the need to reach a blood alcohol concentration level of at least 0.08 gr/dl during a single drinking episode. However, this proposal did not consider binge drinking frequency. As the neurotoxic effects of alcohol are related to this factor, other works have used the frequency of binge drinking episodes as the primary dependent variable (e.g., Henges & Marczinski, 2012). In Europe, this definition has been adapted to the quantity of pure ethanol contained in one drink (10 gr in most European countries versus 14 gr of ethanol in the US). The most commonly used European threshold is thus the consumption of six or more alcohol units on one occasion (e.g., ESPAD, 2015; Hanewinkel et al., 2012), as assessed by the AUDIT. Recent research further suggests that considering six or more alcohol units on one occasion (for women) and seven or more alcohol units (for men) allowed for a reliable capture of binge drinking (Cortés-Tomás, Giménez-Costa, Motos-Sellés, & Sancerni-Beitia, 2017; Motos-Sellés, Cortés-Tomás, & Giménez-Costa, 2020), especially with a binge drinking frequency from 5 to 12 times in the last six months. Despite these improvements, the validity of this quantity criterion has been criticized, notably because it relates to neither alcohol-related problems nor to functional impairments associated with binge drinking (Pearson, Kirouac, & Witkiewitz, 2016). Indeed, this quantitative evaluation merges the drinking consequences in a common outcome, which hampers emphasis on the specificities of the drinking pattern, especially those related to intense acute alcohol intoxication (e.g., blackout, alcohol-related injuries).

On the other hand, a different approach has been developed to focus on more qualitative binge drinking characteristics (Townshend & Duka, 2002), i.e., by computing a binge drinking score based on consumption speed and drunkenness frequency. Cut-off scores have also been suggested to identify binge drinkers, these cut-offs being primarily based on the selection of the lowest and highest 33.3% of a sample of 245 young adults (Townshend & Duka, 2005). Although the use of this score has spread (e.g., Bø et al., 2017; Czapla et al., 2015; Kessler, Pajak, Harkin, & Jones, 2013), criticisms have also been raised regarding the validity of this index. Indeed, it has been shown that it poorly predicted harmful drinking patterns (Lake et al., 2015). Moreover, the consideration of higher versus lower binge drinking scores is highly dependent on the sample, which may lead to poor comparisons between research results (Bø, Aker, Billieux, & Landrø, 2016).

The absence of a consensual evaluation of binge drinking thus still strongly thwarts the development of this research field. Several conceptual works have tackled this issue and proposed updated definitions of binge drinking patterns. In particular, Maurage et al. (2020) have recently identified, relying on the above-mentioned definitions, six critical variables that should be considered in the operationalization and measurement of binge drinking: physiological symptoms (blood alcohol concentration level), psychological symptoms (self-reported drunkenness symptoms such as motor difficulties or memory loss), the ratio between binge drinking episodes and other drinking occasions (overall alcohol use), the frequency of binge drinking, the consumption speed, and the alternation between alcohol intoxication and withdrawal episodes. However, research still needs to evaluate how these distinct variables cohere together and their respective importance in binge drinking.

One of the key issues hampering the outcome of a definition might be related to the fact that current analytic approaches have simplified the binge drinking habit by tallying all its distinct constitutive features to achieve a sum score as index of binge drinking. However, such approaches do not allow consideration of the distinct features of binge drinking (e.g., morning drinking and memory loss should be differentially related to binge drinking) and their potential interaction (e.g., the frequency of drunkenness episodes may foster speed consumption and vice versa). Notably, this conceptual paucity is at odds with contemporary views of mental disorders, which emphasize the critical need to focus on the links between the components assumedly involved in mental disorders rather than on the component per se (Borsboom, 2017). To address this possibility, in the current study, we relied on network analytical framework to visualize and unfold the intricate relationships among the core features of binge drinking.

The network approach, initiated in psychiatry and psychopathology (e.g., Borsboom, Cramer, Schmittmann, Epskamp, & Waldorp, 2011; Schmittmann et al., 2013), has been recently applied to a wide range of domains (see Contreras, Nieto, Valiente, Espinosa, & Vazquez, 2019; Fried & Cramer, 2017 for reviews). Network analyses elucidate associations between nodes (psychiatric symptoms; Contreras et al., 2019), therefore allowing disorders to be visualized as network systems of interacting elements. We believe that viewing the variables related to binge drinking together with alcohol use and alcohol-related dysfunction/harm as interacting nodes can provide a radical new lens on these intricate relationships. As it constitutes the widest and easiest way to currently assess alcohol consumption, we particularly focused on self-reported variables of alcohol consumption. We had two main research questions. First, what are the central features of binge drinking in the network (that is, the most important variables to describe binge drinking)? It is worth noting that highly influential nodes are hypothesized to drive the instigation and maintenance of the network system (Borgatti, 2005). Second, are there separate subnetworks related to the specific alcohol consumption characteristics shown by binge drinkers, and if so, what are the variables that connect them? Accordingly, we tested whether the distinct nodes cohere as a unitary binge drinking network or instead constitute distinct subnetworks. We then explored the associations between alcohol-related variables to reveal the connections among binge drinking features. The combination of these analyses may thus offer viable heuristics in the identification of potent binge drinking variables and constitute a pivotal phase in the identification of targets ripe for evaluation, prevention, and intervention programs.

2. Material and Methods

2.1. Participants

A total of 4,198 French-speaking participants (UCLouvain; Belgium) were recruited through an online questionnaire sent by email to all university students. In this sample, we considered all participants aged between 18 and 30 years old (n = 4,073) and captured excessive drinkers by selecting people who drank six or more alcohol units on one occasion at least once a month during the last 6 months (n = 2,289). This consumption criterion currently constitutes the most recognized binge drinking variable in both experimental and epidemiological research (e.g., Archie, Zangeneh Kazemi, & Akhtar-Danesh, 2012; Poulton, Mackenzie, Harrington, Borg, & Hester, 2016). Finally, we excluded participants with missing data, leading to a final sample of 1,455 participants (52.4% women; mean age = 20.79 ± 2.36). All participants gave online consent before starting the survey and their anonymity was guaranteed (no personal data were collected, including Internet protocol addresses). The study protocol was approved by the local ethical committee and data collection was conducted in accordance with the Declaration of Helsinki.

2.2. Procedure and measures

The online survey (Qualtrics LLC, Provo, USA) assessed sociodemographic (age, gender, study year, and living environment) and alcohol consumption (an alcohol dose containing 10 gr of pure ethanol in Belgium) variables by using French-validated questionnaires. The AUDIT was first administered (Gache et al., 2005), measuring alcohol use (items 1–3) and alcohol-related problems (items 4–10) (see Table 1). To be consistent with the harmful dysfunction model of alcohol use disorder (Wakefield & Schmitz, 2015), we used the terminology of alcohol-related dysfunction/harm components to refer to the last seven

Table 1
Descriptive characteristics of the sample (n = 1,455).

Variable		Value
Demographic measures		
Age *(mean, SD)*		20.79 (2.36)
Gender ratio *(percentage; female/male)*		52.4/ 47.6
Study years *(percentage)*		
First university year		35.8
Second university year		13.9
Third university year		14.1
Fourth university year		18.9
Fifth university year		14.1
Higher than fifth university year[1]		3.3
Living environment *(percentage)*		
Alone		4.8
With parents		30.8
With other people outside the university campus		8.5
With other people on the university campus		50.2
With partner		4.6
Other		1.0
Alcohol consumption measures	*Range*	*Mean (SD)*
Alcohol Use Disorders Identification Test (AUDIT)	3–34	13.94 (5.91)
1. Drinking frequency	1–4	2.90 (0.68)
2. Drinking intensity	0–4	1.91 (1.35)
3. Drinking six or more alcohol units	2–4	2.77 (0.64)
4. Inability to stop drinking	0–4	0.92 (1.14)
5. Inability to do what is expected	0–4	1.31 (1.11)
6. Drinking in the morning	0–4	0.12 (0.44)
7. Guiltiness	0–4	1.12 (0.93)
8. Inability to remember	0–4	1.19 (1.03)
9. Injuries	0–4	1.11 (1.59)
10. Worries of relatives or doctors	0–4	0.58 (1.34)
Consumption speed	0.33–7	2.81 (1.27)
Number of times drunk (last 6 months)	0–140	12.67 (18.12)
Number of times completely drunk (last 6 months)	0–130	4.13 (10.43)
Percentage of drunkenness (last 6 months)	0–100	14.23 (18.08)

Note. [1] Higher than fifth university year comprised people still affiliated with the university because of enrolment in a complementary Master or PhD program.

AUDIT items. Binge drinking was then assessed with additional items (Townshend & Duka, 2002) that measured consumption speed (i.e., number of drinks per hour from one drink in 3 h to seven drinks per hour), the number of times participants had been drunk or completely drunk, and the percentage of drunkenness in the last 6 months (i.e., self-reported open answers). According to previous research on acute alcohol consumption (Gilbertson, Ceballos, Prather, & Nixon, 2009; Hoffman & Nixon, 2015), we aimed to identify two subjective levels of drunkenness, related to distinct behavioral and subjective consequences, by asking the following questions: (1) How many times have you been *drunk* in the past 6 months? (being drunk refers to loss of coordination, impaired self-control, nausea, or inability to speak clearly), (2) How many times have you been *completely drunk* in the past 6 months? (being completely drunk refers to loss of consciousness, vomiting, inability to remember what happened, or alcoholic coma). The de-identified data have been made available via the Open Science Framework (OSF) at https://osf.io/vmf83/.

2.3. Statistical analyses

2.3.1. Preliminary analyses and sample description

To support the exclusion of participants with missing data, we performed comparisons between students with no missing data and students with missing data on demographic and alcohol-related variables (supplementary analyses available on the OSF at https://osf.io/vmf83/). Descriptive statistics were also performed on personal and alcohol-related variables.

2.3.2. Network analysis

The R code for network analysis has been made available on the OSF (https://osf/vmd83/).

Network estimation. We estimated the network by using a Gaussian graphical model (Epskamp, Borsboom, & Fried, 2018) with a non-paranormal transformation (Liu, Han, Yuan, Lafferty, & Wasserman, 2012). In this network, edges signify conditional independence relationships among nodes (i.e., alcohol-related variables), while controlling for the effects of all other nodes (Epskamp & Fried, 2016). Blue lines represent positive associations between nodes, whereas red lines represent negative associations. The accuracy and stability of our network estimates were tested (Epskamp et al., 2018) and results were interpreted according to the model's accuracy check.

Expected influence centrality. To quantify the importance of each node in the entire network, we computed expected influence centrality (Robinaugh, Millner, & McNally, 2016). The expected influence of a node is the sum of the edge weights incident to a given node, including positive and negative values. Higher expected influence values indicate greater centrality (i.e., greater importance in the network). We performed bootstrap difference tests to investigate whether some nodes were significantly more important than others for expected influence centrality (Epskamp et al., 2018).

Community detection. As in prior network research (e.g., Bernstein, Heeren, & McNally, 2019; Heeren, Bernstein, & McNally, 2018) we tested whether the different variables cohere as one or multiple subnetworks. To do so, we implemented the spinglass algorithm, a modularity-based community detection algorithm suitable for uncovering the structure of relatively small networks with negative edge values (Traag & Bruggeman, 2009). This analysis allows identification of the number of edges in groups of nodes through the modularity (i.e., the number of edges within groups minus the expected number of edges in a comparable network shaped by randomly positioned edges; Newman, 2006).

Bridge expected influence. As in previous studies (Blanchard et al., 2021; Bernstein, Heeren, & McNally, 2019), we identified important nodes that serve as bridges (connections) between the resultant subnetworks by computing the bridge expected influence. This index is the sum of the edge weights connecting a given node to all nodes in the other subnetworks. It allows identification of nodes that, when activated, are most likely to activate nearby subnetworks (Jones, Ma, & McNally, 2019). Bootstrap difference tests were performed to compare nodes for bridge expected influence (Epskamp et al., 2018).

3. Results

3.1. Sample description

Results are described in Table 1. Preliminary analyses supported the reliability of including the subsample of participants with no missing data in the current study. No differences were observed between this sample and that observed for participants with missing data (see OSF for supplementary analyses: https://osf/vmd83/).

3.2. Network analysis

Network estimation and expected influence centrality. The resulting Gaussian graphical model is depicted in Fig. 1. To determine the importance of each node, we investigated whether nodes significantly differ in node expected influence centrality (Fig. 2). Results showed that being drunk had the highest centrality in the network (1.50), followed by the consumption of six or more alcohol units on one occasion (1.20), the inability to remember what happened during drinking episodes (1.00), and being completely drunk (1.00). These last three nodes did not differ significantly.

Community detection analysis. Three distinct subnetworks were identified in the binge drinking network (Fig. 1): the first relates to alcohol use (AUDIT 1-3) and consumption speed, the second includes variables related to drunkenness (being drunk, completely drunk, and percentage of drunkenness), and the third relates to dysfunction/harm

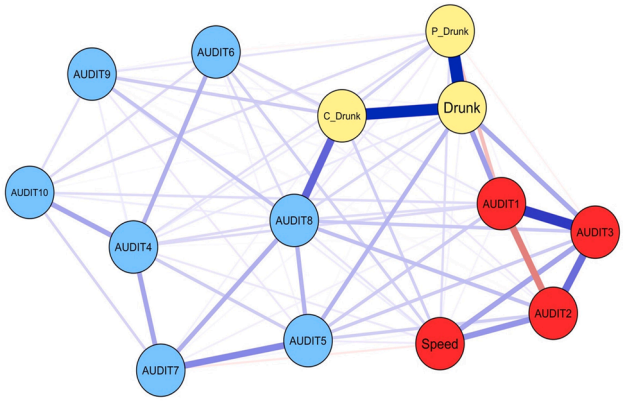


Fig. 1. This figure depicts three distinct clusters: alcohol consumption in red, drunkenness in yellow, and dysfunction/harm components in blue. Blue lines indicate positive relationships between nodes, whereas red lines indicate negative relationships. The thickness of the line represents the strength of the association between nodes. Drunk = frequency of episodes in which participants have been drunk in the last 6 months, C_Drunk = frequency of episodes in which participants have been completely drunk in the last 6 months, P_Drunk = percentage of drunkenness episodes in the last 6 months. For a description of AUDIT items, see Table 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

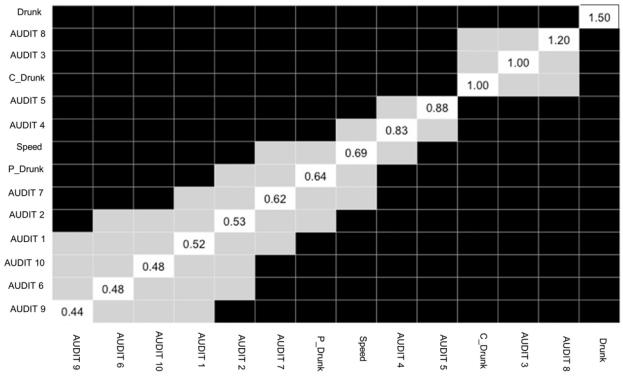


Fig. 2. This figure depicts expected influence centrality. Bootstrapped estimates are shown on the diagonal and comparisons between nodes on each part of the diagonal. Dark cases mean significant differences between two nodes (at the 0.05 level). Drunk = frequency of episodes in which participants have been drunk in the last 6 months, C_Drunk = frequency of episodes in which participants have been completely drunk in the last 6 months, P_Drunk = percentage of drunkenness episodes in the last 6 months. For a description of AUDIT items, see Table 1.

components (AUDIT 4–10).

Bridge expected influence. Three nodes were identified as bridge items, i.e., serving as connections between the different subnetworks (i.e., alcohol use, drunkenness, and dysfunction/harm): being drunk, the inability to remember what happened during drinking episodes (AUDIT 8), and being completely drunk (bridge expected influence values of 0.65, 0.65, and 0.58, respectively; see Fig. 3). Results thus underlined these variables as consolidating associations among all alcohol variables in the binge drinking network.

4. Discussion

In this study, we capitalized on existing binge drinking definitions to identify the constitutive features of binge drinking via network analysis. This data-driven approach has recently brought important benefits to the conceptualization of mental disorders (Borsboom, 2017). Given the absence of a consistent and commonly accepted definition of binge

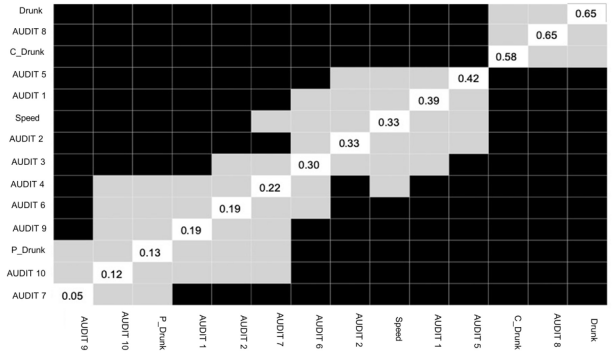


Fig. 3. This figure depicts bridge expected influence. Bootstrapped estimates are shown on the diagonal and comparisons between nodes on each part of the diagonal. Dark cases mean significant differences between two nodes (at the 0.05 level). Drunk = frequency of episodes in which participants have been drunk in the last 6 months, C_Drunk = frequency of episodes in which participants have been completely drunk in the last 6 months, P_Drunk = percentage of drunkenness episodes in the last 6 months. For a description of AUDIT items, see Table 1.

drinking, the application of network analysis to binge drinking habits may further clarify this field. We simultaneously considered classic self-reported approaches to binge drinking measures, namely those based on global alcohol-related components (i.e., alcohol consumption frequency/intensity and consequences) and those based on specific binge drinking variables (i.e., consumption of six or more alcohol units, drunkenness, and consumption speed). We selected a sample of excessive drinkers among university students, according to dominant binge drinking criteria (i.e., drinking six or more alcohol units on one occasion, at least once a month) to reliably identify the core features of binge drinking and improve its definition. Overall, our results showed the importance of subjective feelings and consequences of alcohol intoxication (drunkenness and blackout features) and provided a modest support for the six-unit threshold to define binge drinking.

In particular, we found that the network of binge drinking includes three distinct subnetworks: alcohol use, drunkenness, and dysfunction/harm components. Perhaps the most striking result was that drunkenness frequency emerged as the most influential node in both the entire network (i.e., expected influence) and in connecting the different communities together (i.e., bridge expected influence). This observation is at odds with previous binge drinking research (e.g., epidemiological studies; Johnson, Lee, Vinson, & Seale, 2013; Kanny, Liu, Brewer, & Lu, 2013), which mainly focused on the quantitative definition of binge drinking. However, it reinforces consideration of more qualitative aspects as proposed by Townshend and Duka (2002), who stated that binge drinking should not be defined according to alcohol consumption quantity/frequency, but rather to its specific features when compared with other alcohol consumption patterns. According to this proposal, binge drinking consists in intensive alcohol drinking to rapidly reach drunkenness. Drunkenness seeking has been largely shown in young people (Kuntsche et al., 2011; Morean et al., 2014). Here, drunkenness is clearly identified as the most important binge drinking feature. This result is likewise supported by the observed associations between being drunk and dysfunction/harm components (see Fig. 1). The only component not related to drunkenness was “morning drinking”, which is consistent with the assumption that binge drinking is not an indicator of severe alcohol use disorder (Baggio, Dupuis, Iglesias, & Daeppen, 2015; Rolland & Naassila, 2017) and contributes to counter previous concerns regarding the lack of construct validity of binge drinking definitions and the doubts related to its distinction from other excessive consumption patterns (Pearson et al., 2016). Specifically, regarding dysfunction/harm components, the inability to remember what happened during drinking episodes was identified as both a bridge item and a central

node. This finding supports the proposal that blackouts constitute a specific consequence of drunkenness and a core variable in binge drinking (e.g., Labhart, Livingston, Engels, & Kuntsche, 2018; Wombacher, Matig, Sheff, & Scott, 2019) and dovetails with the appearance of cognitive and cerebral impairments (Hermens & Lagopoulos, 2018).

Moreover, although the six-unit threshold is supported in the expected influence centrality (as were the inability to remember and being completely drunk), results of the network analysis question the usefulness of this widely used threshold. This cut-off is currently considered standard in most binge drinking research (ESPAD, 2015), yet some studies rather combine consumption speed and frequency of binge drinking episodes to offer a reliable definition (Lopez-Caneda et al., 2013; Poulton et al., 2016). However, the six-unit threshold does not appear to be dominant in the current binge drinking network. Indeed, our results support the importance of the quantity of alcohol use (i.e., to reach drunkenness episodes) but not the cut-off of six drinks, even in a subsample of participants selected according to this criterion. This observation, together with the lack of support for the consumption speed variable, underlines the need to adjust currently used operationalization and measurement of binge-drinking pattern. Another finding that may appear surprising is the negative association between the frequency and quantity items of the AUDIT. This may, in fact, be related to the binge drinking population and reflect the tendency to drink intensively but irregularly (not frequently).

The results of this study invite to the incorporation of subjective drunkenness states in the definition and assessment of binge drinking. Future studies should replicate the present results in different samples and offer support through temporal network analyses of intensive longitudinal designs and instantaneous evaluations of alcohol consumption (e.g., Ecological Sampling Methods; Aalbers et al., 2019). Studies should further elucidate the relations between binge drinking and drunkenness (e.g., respective influences of drunkenness/abstinence cycle and drunkenness intensity), as well as the role played by drinking frequency (e.g., regarding cognitive and brain dysfunctions). Importantly, as this study focused on self-reported measures, the evaluation of drunkenness remains subjective and should be improved in future research. An interesting perspective could be to rely on objective measures of binge drinking (evaluation of Blood Alcohol Concentration; Maurage et al., 2020). Future studies are also necessary to test the relevance of distinguishing the subjective states of being drunk and completely drunk.

On the other hand, the data-driven analysis conducted here allows refinement of the binge drinking definition. More precisely, our findings suggest that (1) a tailored approach that focuses on binge drinking specificities is better than a quantitative perspective that focuses merely on global alcohol consumption, (2) drunkenness is a core feature of binge drinking and blackout is a central consequence of this habit, and (3) the consumption of six or more alcohol units on one occasion appears to be an insufficient index to define binge drinking. For a more accurate and consistent binge drinking definition, our results thus call for consideration of drunkenness features together with alcohol use frequency and intensity. Drunkenness is identified as a core variable in the binge drinking network; combining it with more quantitative alcohol use variables will be necessary to define specific thresholds in order to characterize binge drinking according to age, gender, potential confounders (e.g., tolerance to alcohol effects; Sarala et al., 2019), and specific consequences (i.e., inability to remember). One way to go further in this direction could be to revise the initial proposal made by Townshend and Duka (2002) by offering a binge drinking score that considers drunkenness and alcohol use frequency/quantity and is weighted according to the strength values identified in the binge drinking network. Previous studies have indeed supported the predictive validity of weighting psychological symptoms on the basis of centrality values in network analysis (Boschloo, van Borkulo, Borsboom, & Schoevers, 2016), this approach could be particularly useful to offer a revised binge drinking score.

5. Contributors

SL, PM, and JB were responsible for the research implementation and acquisition. SL, SB, and JB design the current study and all authors participated in its construction. SL conducted literature searches and provided summaries of previous research studies. SB performed the statistical analysis, AH provided critical insights on the statistical analysis. SL wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

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Declaration of Competing Interest

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

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