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Decision-Making Impairments in Binge Drinking and Cannabis Use Among Young Adults

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Objective: The neurocognitive impairments related to binge drinking and cannabis use in youth are widespread. Decision-making abilities might also be altered but previous studies focused on a disjoint exploration of individuals with binge drinking habits and with cannabis use, and did not control for major confounding factors (e.g., comorbid psychopathological states or general cognitive level), generating contradictory results. In view of the key role played by decision-making impairments in the development of addictive disorders, sounder explorations of decision making are needed in subclinical populations. ***Method:*** A hundred university students divided in four groups (low drinkers, binge drinkers with no/low/high cannabis use, matched for demographic, psychopathological and cognitive abilities) performed the Iowa Gambling Task, a neuropsychological test measuring decision-making abilities under uncertainty/risk. ***Results:*** When compared with low drinkers, binge drinkers with no/low cannabis use did not show decision-making deficits. Conversely, when combined with high cannabis use, binge drinking was related to impaired decision making, as shown by (a) lower total scores at the Iowa Gambling Task, indicating less efficient decision making under uncertainty/risk and (b) increased entropy in the choices made throughout the task, demonstrating a lower ability to develop efficient decision-making strategies. ***Conclusions:*** When controlling psychopathological states and general cognitive level, binge drinking per se is not associated with decision-making deficits. Conversely, when combined with intense cannabis use, it is related to marked decision-making impairments, which could promote the evolution toward substance use disorders. These results emphasize the importance of considering various forms of excessive substance use together when exploring their interaction with cognitive deficits in youth. We also identified the mechanisms underlying such neuropsychological deficits, paving the way for targeted interventions.

Public Health Significance Statement

This study indicated that decision-making impairments, constituting a hallmark of addiction, are already present in young adults presenting joint binge drinking and high cannabis use habits but are conversely absent among binge drinkers with no/low cannabis use. These results suggest a specific harmfulness of alcohol/cannabis comorbidity on high-level cognitive abilities, which might facilitate the development and persistence of addictive disorders in adulthood.

Keywords: cannabis use disorder, alcohol use disorder, executive functions, impulsivity

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Binge drinking and cannabis use have long been associated with emotional, psychological, and interpersonal consequences (Bourque & Potvin, 2021; Carbia et al., 2018; Lannoy et al., 2021; Skumlien et al., 2021). More recent studies have also suggested that such excessive substance use might be related to neurocognitive impairments (Pérez-García et al., 2022; Zehra et al., 2018). A binge drinking episode is defined as the consumption of a large amount of alcohol in a short period of time, typically leading to drunkenness and a blood alcohol concentration of at least 0.08% (National Institute on Alcohol Abuse and Alcoholism, 2004). The threshold for a binge drinking episode is commonly defined as the consumption of 70 g of ethanol for men and 56 g for women within a 2-hr period (National Institute on Alcohol Abuse and Alcoholism, 2004). The binge drinking consumption pattern is characterized by the repetition of such drunkenness episodes, resulting in an alternation between intense alcohol intoxications and abstinence periods (Maurage et al., 2020). It constitutes a widespread alcohol consumption habit among university students and it is related to emotional (Lannoy et al., 2021) and neurocognitive (Pérez-García et al., 2022) modifications. Cannabis use disorder, beyond its acute effect on attention and memory, is also associated with long-lasting impact on cognition (Gorey et al., 2019; Kroon et al., 2021) and brain functioning (Zehra et al., 2018), while the extent of these neurocognitive deficits remains debated (Scott, 2023). Among these deficits, decision-making constitutes a key factor in view of its role in the development and persistence of substance use disorders (Koffarnus & Kaplan, 2018; Rolland et al., 2019).

Decision making refers to the cognitive processes enabling individuals to (a) identify the possible behavioral responses in situations requesting to perform a choice between various actions; (b) hierarchize them by estimating their respective costs and benefits, and (c) choose the adapted decision optimizing (inter)personal outcomes (Barned et al., 2021). It is thus an essential ability to optimize behaviors in everyday life, as it allows selecting the most appropriate course of action (Newell et al., 2022). Addictive states are frequently associated with impaired decision making, as they are characterized by a reduced ability to make efficient decisions when confronted with the substance: Patients presenting addictive disorders repeatedly favor immediate rewards (i.e., acute substance use), particularly in emotionally charged situations that provoke cravings or urges, despite the negative long-term consequences related to such consumption (Verdejo-Garcia et al., 2018). Maladaptive decision making is thus directly involved in the development or persistence of addictive states, through a reduced ability to correctly guide choices by balancing the short versus long-term benefits and costs of consumption, leading to sustained substance consumption despite its deleterious consequences. The most influential neuropsychological models of addiction encompass maladaptive decision making as a crucial theoretical and clinical process promoting continued substance use despite harmful consequences. For example, the influential dual-process models (Lindgren et al., 2019; Stacy & Wiers, 2010) posit that addiction results from erroneous decision making due to an imbalance between overactivated reward system (promoting craving and attentional bias toward the substance) and underactivated executive control system (reducing the ability to inhibit consumption behaviors), leading the individual to favor drug-related choices and hence favoring addiction maintenance. In the same vein, contemporary neuroscience models (e.g., Koob & Volkow, 2016; Zilverstand et al., 2018) identify disrupted decision making as an essential etiological factor for addictive disorders and an international Delphi consensus study spotted decision making as one of the seven primary constructs to be considered in the definition and evaluation of addictive disorders (Yücel et al., 2019). The Iowa Gambling Task (IGT, Bechara et al., 1994, 1997) is the most widely used neuropsychological tool to measure decision making in addictive disorders, as it allows to characterize the ability to make efficient decisions in situations involving uncertainty or risk and to progressively learn the most efficient strategy to optimize performance. In the IGT, participants must maximize their gains by drawing cards from decks, each card being related to a win and/or loss. Two decks are disadvantageous (i.e., high gains/high losses, with a negative total outcome in the long run) and two advantageous (i.e., low gains/low losses, with a positive total outcome). Participants are unaware of this gain/loss ratio across decks and must progressively infer these rules to optimize their strategy. The IGT has been largely applied in psychiatric and addictive disorders, identifying large-scale decision-making deficits (Gowin et al., 2018; Kovács et al., 2017).

Such widespread use of the IGT can be explained by a double asset of this task as (a) being based on close to real-life monetary gains/losses, it has high ecological value by mimicking everyday life situations during which a decision must be made in uncertain/risky circumstances, this decision being based on the correct evaluation of the alternatives and of their respective positive/negative consequences. The IGT thus efficiently models real-life decision making and is particularly adapted to explore decision making in addictive behaviors as it reproduces situations in which individuals have to choose between taking immediate reward (combined with higher losses in the long run, e.g., substance consumption) or delaying immediate gratifications (to promote higher long-term incomes, e.g., avoid consuming to have the positive impact of abstinence in the long run); (b) it capitalizes on a sound theoretical background, the “somatic marker hypothesis” (Bechara et al., 2005; Damasio, 1996). This model postulates that individuals, when confronted with situations where they must choose between various options under uncertainty/risk, estimate the positive/negative outcomes of their future actions through emotional or somatic markers, defined as anticipatory affective states generated through the reactivation of earlier experiences. Such theory is particularly adapted to addiction, as biased somatic markers might explain the repeated suboptimal choices made by individuals presenting an addictive disorder, impaired decision making potentially existing before the installation of such disorder and promoting its development (Olsen et al., 2015). Decision making could thus be impaired at the early stages of dysregulated substance use in young adults and promote the evolution toward severe addictive disorders by favoring repeated use generating immediate rewards despite negative long-term consequences.

Impairments in decision making have been documented in binge drinking (Carbia et al., 2018) and in cannabis use disorder (Kroon et al., 2021) among young adults. The IGT has been widely used to explore such decision-making abilities, but it generated contradictory results. In binge drinking, reduced total score at the IGT in comparison with no/low drinkers has been documented (Gilbertson et al., 2019; Mullan et al., 2011; Xiao et al., 2009; Yoo & Kim, 2016), particularly in the second part of the task, involving decision under risk (Johnson et al., 2008). This deficit appears to result from a lower sensitivity to losses (Bø et al., 2016), such insensitivity being underlid by impaired cerebral processing of negative feedback after money loss (Na et al., 2019) and being reduced under stress (Gullo & Stieger, 2011). More globally, lower IGT performance might be explained by modified activity in the amygdala and insula (Xiao et al., 2013). Longitudinal data confirmed that a sustained binge drinking consumption pattern is related to lower IGT performance (Goudriaan et al., 2007), and a twin study suggested that this impairment is a consequence of rather than a vulnerability factor for excessive alcohol use (Malone et al., 2014). However, other results found no decision-making deficits in the IGT among young adults engaging in binge drinking habits (Carbia et al., 2017; Xiao et al., 2011).

Cannabis use disorder has also been associated with reduced IGT performance in some studies (Alameda Bailén et al., 2012, 2014; Johnstone et al., 2024; O'Donnell et al., 2021; Whitlow et al., 2004). This decision-making deficit would vary with the age at which cannabis consumption started, individuals with early-onset consumption (i.e., before 16 years old) presenting the most strongly impaired IGT performance (Alameda-Bailén et al., 2018). This reduced IGT performance appears underlid by a more global difficulty to optimize decision making in order to maximize gains in at-risk situations (Pacheco-Colón et al., 2019) and by reduced brain activations following losses (Wesley et al., 2011). Results also suggested that poor decision making might constitute a vulnerability factor for cannabis use disorder, as a low IGT performance would increase the risk of social and personal problems resulting from such use (Gonzalez et al., 2015) and would also speed up the transition toward the consumption of other addictive substances (Lopez-Quintero et al., 2018). However, longitudinal studies (Pacheco-Colón et al., 2021; Thompson et al., 2023) showed no predictive value of IGT performance on future cannabis use. In line with binge drinking studies, many contradictory results have been documented as a large number of studies showed preserved IGT performance in young students presenting cannabis use disorder (Ajmera et al., 2021; Cousijn et al., 2013; Gonzalez et al., 2012; Lopez-Quintero et al., 2018; Pacheco-Colón et al., 2019; Thompson et al., 2023). Finally, a meta-analysis (Kluwe-Schiavon et al., 2020) suggested that cannabis use disorder has a significantly lower impact on IGT performance than other substance use.

The current literature related to IGT in binge drinking and cannabis use in young adults is thus characterized by highly conflicting results. Such discrepancies, hampering to determine the presence and characteristics of decision-making impairments in excessive substance use, might result from five critical limitations of previous studies: (a) a *lack of control of confounding psychopathological variables*. Indeed, many of the above-mentioned studies did not measure depression and anxiety in their samples, and the rare studies proposing these measures showed group differences but did not consider them in their statistical analyses (except Na et al., 2019; Xiao et al., 2013). Moreover, no study has proposed to match their experimental groups on mood disorders. Some discrepancies might thus result from the variable and uncontrolled influence of mood disorders on IGT performance. Indeed, psychopathological states, and centrally depression/anxiety disorders, are very frequent in populations of young adults presenting binge drinking/cannabis use (e.g., Kuntsche et al., 2017; Merino-Casquero et al., 2025; Wycoff et al., 2018) and have a well-established link with impaired decision making, notably in the IGT (Must et al., 2013; Zhang et al., 2015). It is hence crucial to control for depression/anxiety when exploring decision making in binge drinking or cannabis use, to ensure that the potential deficits observed are genuinely related to substance use disorder and not to the mere consequence of comorbid psychopathologies; (b) an *absence of control for general cognitive impairments*. Decision making is a high-level cognitive function capitalizing on lower level abilities (e.g., attention, memory). The presence of unmeasured deficits in these lower level cognitive functions might thus generate impaired IGT performance independent of decision-making abilities per se; (c) an *imprecise measure of substance use patterns*. Most studies did not use a standardized measure of binge drinking (e.g., binge drinking scores, Maurage et al., 2020; Townshend & Duka, 2005) nor a clear characterization of the frequency, intensity, and dangerousness of cannabis consumption, hence potentially including experimental groups with very different substance use, resulting in highly variable IGT results. Moreover, as nicotine is known to influence cognitive functions (Conti et al., 2019) and might thus modify IGT performance (Buelow & Suhr, 2014), it is crucial to measure and control the frequency/intensity of tobacco use; (d) *a superficial exploration of IGT results*. Most studies only compared groups on the global IGT scores, not even dissociating decision making under uncertainty (first part of the IGT) and risk (second part of the IGT), known to generate different results in substance use disorders (Brevers et al., 2014; Maurage et al., 2018). Moreover, no study computed the more recently developed IGT indexes (Ligneul, 2019; Worthy et al., 2013) allowing an in-depth exploration of the cognitive mechanisms underlying IGT performance; and (e) *a disjoint exploration of binge drinking and cannabis use*. Very few studies measured cannabis use among individuals with binge drinking habits or conversely (e.g., Ajmera et al., 2021; Goudriaan et al., 2007) and, to our knowledge, only one study in young students simultaneously considered the impact of binge drinking and cannabis use on IGT (Moreno et al., 2012), showing reduced performance in both substances use but without directly comparing them or exploring the role of their comorbidity. In view of the very high comorbidity between these addictive states in young adults (Shipley & Braitman, 2024), previous results in both binge drinking and cannabis use might have been contaminated by the unmeasured consumption of the other drug.

To overcome these limitations, we measured the IGT performance in four groups of young adults (i.e., university students) strictly matched for demographics, psychopathological states, and general cognitive level, namely low drinkers without binge drinking habits/cannabis use and three experimental groups with similar binge drinking habits but varying on cannabis use, respectively, presenting no/low/high cannabis use. We characterized binge drinking and cannabis use following gold-standard measures ensuring that all participants fulfilled the specific criteria related to the consumption pattern targeted. Specifically, we used (a) the largely accepted binge drinking score (Townshend & Duka, 2005) to characterize binge drinking habits, as it focuses on the measure of the three key specificities related to this consumption pattern (i.e., high consumption speed, high drunkenness frequency, high probability of drunkenness when drinking alcohol) and (b) the Cannabis Abuse Screening Test score (CAST, Legleye et al., 2011), widely used to measure the frequency and consequences of cannabis consumption. This design, combined with in-depth analyses of the IGT through specific performance indexes, allowed to explore for the first time the distinct and joint influences of binge drinking and cannabis use on decision-making abilities. We also performed correlational analyses to further document the links between IGT scores/indexes and substance consumption as well as psychopathological (i.e., depression, anxiety) and cognitive (i.e., impulsivity, general cognitive level) factors, as these variables are known to be modified in substance use disorders and to influence decision-making abilities. We formulated two hypotheses. First, as previous studies using the IGT in binge drinking or cannabis use in youth generated contradictory results, some identifying a deficit (Alameda Bailén et al., 2012, 2014;

Gilbertson et al., 2019; Johnstone et al., 2024; Mullan et al., 2011; O'Donnell et al., 2021; Whitlow et al., 2004; Xiao et al., 2009; Yoo & Kim, 2016) and others showing preserved IGT performance in binge drinkers (Ajmera et al., 2021; Carbia et al., 2017; Cousijn et al., 2013; Xiao et al., 2011) or cannabis users (Gonzalez et al., 2012; Lopez-Quintero et al., 2018; Pacheco-Colón et al., 2019; Thompson et al., 2023), we postulated that, when confounding psychopathological and cognitive factors are controlled for, no massive IGT performance deficit will be found in binge drinking, even when combined with low cannabis use. Second, as some previous results (Deniel et al., 2021; Jacobus et al., 2015; Winward et al., 2014) have shown that the comorbidity between binge drinking and high cannabis use was related to significant impairments in a wide range of cognitive functions (including flexibility and working memory which are key for efficient decision making), we hypothesized that binge drinkers presenting comorbid high cannabis use will present deficits at the IGT.

Materials and Method

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. Materials, data, and analysis code for this study are available by emailing the corresponding author. The study design and analyses were not preregistered.

Participants and Procedure

We selected 100 participants, divided into four groups of 25 individuals (17 women and eight men in each group, reflecting the higher proportion of women among first-year university students in France): individuals with low drinking habits (LD, presenting no binge drinking habits, low-risk alcohol consumption and no cannabis use in the past year), individuals with binge drinking habits but without cannabis use (BD, presenting a binge drinking consumption pattern without severe alcohol use disorder and no cannabis use in the past year), individuals with binge drinking habits and low cannabis use (CAN-LOW, presenting a binge drinking consumption pattern without severe alcohol use disorder and a low-risk/nonproblematic cannabis use), and individuals with binge drinking habits and high cannabis use (CAN-HIGH presenting a binge drinking consumption pattern without severe alcohol use disorder and a moderate-risk/potentially problematic cannabis use). The selection criteria for all groups are presented in Table 1 and the questionnaires used to determine alcohol/cannabis consumption are presented below. These data are part of a larger research project developed at the University of Caen Normandy (2018–2024—Alcohol and Drugs at Caen University) exploring the demographics, substance-consumption habits, and psychopathological symptoms of university students (Lannoy et al., 2020; Mange et al., 2021). A total of 214 students completed a neuropsychological evaluation in the laboratory, including the IGT and other cognitive tasks. Among them, we first selected participants fulfilling the following criteria: (a) being a first-year university student at Caen University (i.e., having 12 years of education level since starting primary school), as this population is particularly at risk for binge drinking and cannabis use, and being between 18 and 21 years of age, as we wanted to standardize the age and education level of our sample; (b) reporting alcohol use, namely having consumed alcohol at least once during the past 12 months; (c) having no family history of severe alcohol/cannabis use disorder (parents, siblings), as such family history is related with cognitive and brain modifications (e.g., Martz et al., 2022; Schmid et al., 2024) that would constitute a confound in our study; (d) having no current psychiatric or neurological disorder; (e) having no consumption of psychotropic medication or drug (excluding alcohol, cannabis and tobacco) during the past 12 months; (f) presenting preserved cognitive abilities, namely a score of 15 or higher at the cognitive total score of the BEARNI (Brief evaluation of alcohol-related neuropsychological impairment, Ritz et al., 2015); and (g) being fluent in French.

On this basis, we selected our participants and divided them into four groups using three measures, namely (a) the *Alcohol Use Disorders Identification Test* score (AUDIT, Saunders et al., 1993) measuring alcohol consumption, drinking behaviors, and alcohol-related problems (score range = 0–40); (b) the *Binge Drinking* score (Townshend & Duka, 2005), computed through the following formula: 4 × consumption speed in units/hr + drunkenness frequency (number of drunkenness episodes during the past 6 months) + 0.2 × drunkenness percentage (percentage of times being drunk compared with all drinking occasions); and (c) the CAST, measuring problematic cannabis use (score range = 0–24). We also selected our participants to propose a strict matching between our four groups on demographics (age, sex, education level) and psychopathological variables (State/Trait anxiety measured through the State-Trait Anxiety Inventory, STAI-A/STAI-B, Spielberger & Gorsuch, 1983 and depression, measured through the Beck Depression Inventory, Beck et al., 1961). Finally, the three experimental groups (BD, CAN-LOW, CAN-HIGH) were matched on their AUDIT and binge drinking scores.

All participants had abstained from any alcohol (as confirmed through a breathalyzer test) and cannabis consumption (as confirmed through a salivary test) during the 24 hr preceding the experiment to avoid any influence of acute substance consumption.

Table 1
Inclusion Criteria for the Four Groups (N = 25) Regarding Alcohol and Cannabis Consumption

Group	AUDIT score	Binge drinking score	Cannabis consumption (past 12 months)	CAST score
LD	<8	≤16	No	0
BD	<20	>16	No	0
CAN-LOW	<20	>16	Yes	<3
CAN-HIGH	<20	>16	Yes	>2

Note. AUDIT = Alcohol Use Disorders Identification Test; BD = binge drinkers without cannabis use; CAN-LOW = binge drinkers with low cannabis use; CAN-HIGH = binge drinkers with high cannabis use; CAST = Cannabis Abuse Screening Test; LD = low drinkers.

All participants gave their written consent before starting the survey. The research protocol was submitted to the approval of the Ethics Committee of the Caen–Normandie University. We strictly followed the Declaration of Helsinki (2008) and the ethical standards set by the American Psychological Association Ethical Principles of Psychologists and the Code of Conduct for the ethical treatment of human participants. At the end of the experiment, we debriefed participants about the study's objectives and procedure, and they received 30 euros as financial compensation.

We performed a post hoc power analysis to estimate whether the sample size was sufficient to test our main effect. This power analysis was performed in G-power 3.1.9.7. on our main analysis (i.e., a repeated-measure analyses of variance [ANOVA] with groups as between-subject factor and IGT parts as within-subject factors), computing the effect size (Cohen's $f = 0.29$) based on the η_p^2 of our main analysis. With four groups of 25 individuals, five measures (i.e., the five IGT parts) and an α of .05, the generated power ($1 - \beta$) to measure a main group effect is 0.976, confirming that we had far enough statistical power with our sample size.

Assessments

Questionnaires and Cognitive Measure

Participants completed a questionnaire measuring (a) *demographical variables*, namely age, sex, and education; (b) *substance consumption*; namely (c) for alcohol consumption, the AUDIT score, the Binge Drinking Score, the age at first consumption, the number of units per week (one unit corresponding to 10 g of pure ethanol), and the number of drinking days per week; (d) for cannabis consumption, the CAST score, the age at first consumption, the weekly consumption (in grams), and the number of consumption days per week; (d) for tobacco consumption, the Fagerström test score (Svicher et al., 2018, measuring tobacco dependence), the age at first consumption and the number of years of tobacco use; and (e) *psychopathological variables*, namely STAI-A/STAI-B, depression (Beck Depression Inventory) and impulsivity (Urgency–Premeditation–Perseverance–Sensation Seeking–Positive Urgency; Billieux et al., 2012). They also completed an evaluation of their global cognitive abilities through the BEARNI (Ritz et al., 2015), a screening tool specifically developed to measure the key cognitive functions frequently impaired in addictive states (visuospatial abilities, executive functions, ataxia, verbal episodic memory, and verbal working memory). The BEARNI has demonstrated high sensitivity in identifying cognitive deficits in individuals with alcohol use disorder and has been successfully used to detect subtle neurocognitive impairments in university students presenting binge drinking or cannabis use habits (Deniel et al., 2021).

IGT

We used a 100-trial paper-and-pencil version of the IGT (known to generate increased motivation and performance in comparison with the computerized version, notably because participants directly manipulate "money"; Overman & Pierce, 2013) where participants were first instructed that they will play a game during which they will have to draw cards from decks, resulting in money win/lost. The instructions specified that their task was to maximize net incomes (gain/loss ratio), that they can freely switch between decks at each trial, and that the gain/loss ratio varied across decks and was not random, with some decks leading to more advantageous outcomes. In line with most earlier studies using the IGT, we chose to explicitly inform participants of the presence of advantageous/disadvantageous decks (i.e., "Some decks are better than others") as such hint has been shown to improve performance (Fernie & Tunney, 2006). Participants were then given 2,000 euros (in facsimile money) and presented with four decks of 40 cards each (A, B, C, D). They were instructed to draw, for each trial, a card from one of deck, the back of each card indicating a gain (e.g., "you win 100 euros") and a potential loss (e.g., "you lose 75 euros"). Directly after reading the card, the experimenter added (for the wins) or asked the participant to give back (for the losses) the amount won/lost from the pile of money, so that the participant was constantly aware of the total money accumulated throughout the task. No feedback on performance was given during the whole task. Unbeknownst to participants, Decks A and B were disadvantageous, leading to higher gains (100 euros for each card drawn) but higher losses (between 150 and 350 euros for Deck A for the 3-5-7-9-10-12-14-15-17-18-22-24-26-27-28-31-32-33-37-38th cards of the deck; 1,250 euros for Deck B for the 9-14-21-32th cards), ending up in a negative net result (Table 2). Conversely, Decks C and D were advantageous, leading to lower gains (50 euros for each card) but also lower losses (between 25 and 75 euros for Deck C for the 3-5-7-9-10-12-13-17-18-20-24-25-26-29-30-34-35-37-39-40th cards; 250 euros for Deck D for the 10-20-29-35th cards), ending up in a positive net result.

To offer an in-depth analysis of the results, we computed (a) the total IGT score, as classically done, by subtracting the total number of cards drawn from disadvantageous decks (A + B) from the total number of cards drawn from advantageous decks (C + D). We also computed subscores using the same formula on subparts of the task (i.e., items 1–20, 21–40, 41–60, 61–80, and 81–100), as well as total gain, total loss and net gain; (b) a comparison of first (decision making under uncertainty) and second (decision making under risk) parts of the task by comparing the first 40 items to the 40 last ones (Brevers et al., 2014; Maurage et al., 2018); and (c) additional

Table 2

Gain per Card, Lost Probability, Minimum/Maximum/Mean Amount Lost per Trial, Mean Net Amount Won per Trial, and Total Amount Won for the Four Decks of the Iowa Gambling Task

Measure	A	B	C	D
Gain per card	100	100	50	50
Loss probability	50%	10%	50%	10%
Minimum amount lost	150	1,250	25	250
Maximum amount lost	350	1,250	75	250
Mean amount lost per trial	125	125	25	25
Mean net amount won per trial	−25	−25	25	25
Total amount won for the 40 cards	−1,000	−1,000	1,000	1,000

indices (Ligneul, 2019; Worthy et al., 2013) deepening the exploration of the strategy used by participants in the IGT, namely *win stay* (i.e., the proportion of trials in which participants selected again the same deck after a trial generating no loss), *lose shift* (i.e., the proportion of trials in which participants selected a different deck after a trial generating a loss), *H-choice* (i.e., a variable reflecting the entropy related to the choices made throughout the task, higher scores [score range = 0–2] indicating a more even exploration of the decks. A score of 2 would represent an even exploration of all decks [i.e., 25 cards drawn per deck] while a score of 0 would indicate that the participant constantly selected the same deck), *MI-successive choices* (i.e., a variable reflecting the autocorrelation of successive choices, higher scores implying that the choice in trial X + 1 is more predictable by the choice made in trial X) and *directed exploration* (i.e., DE, a variable reflecting the exploration tendency of participants, namely the frequency at which participants selected three different decks over three consecutive trials [DE3, chance level = .333] or four different decks over four consecutive trials [DE4, chance level = .094]).

Statistical Analyses

We performed statistical analyses using IBM SPSS Statistics (Version 25.0; IBM Corp., Armonk, New York). One-way ANOVAs were first conducted to perform between-group comparisons on demographic, substance consumption, and psychopathological variables, followed by post hoc t tests. Regarding experimental variables, we first performed two repeated-measures ANOVAs, both with groups (LD, BD, CAN-LOW, CAN-HIGH) as between-subject factor: one with the five subscores related to IGT parts (i.e., IGT scores for trials 0–20, 21–40, 41–60, 61–80, 81–100) as within-subject factors and one with decision making under uncertainty (IGT scores 0–40) and under risk (IGT scores 61–100) as within-subject factors. We then performed one-way ANOVAs to perform between-group comparisons on the new IGT indexes, followed by post hoc t tests. As sex differences have been reported on the IGT performance (Zanini et al., 2025), we also conducted one-way ANOVAs to explore sex differences in all our experimental measures. For the sake of clarity, the results section only describe significant post hoc t tests, all unpresented post hoc t tests being nonsignificant. α level was set at .05. We also performed correlational analyses on the whole sample using exploratory Pearson's correlations (uncorrected for multiple testing) to measure the links between experimental scores and substance consumption as well as psychopathological variables and cognitive abilities, both known to be modified in substance use disorders in youth and to modulate decision-making abilities.

Results

Demographic, Psychopathological, and Substance-Related Measures

As a result of the matching procedure, groups did not significantly differ regarding age, $F(3, 96) = 1.16$, $p = .327$, $\eta^2_p = .035$; sex, education level (12 years since starting primary school for all participants); state anxiety, $F(3, 96) = 0.31$, $p = .816$, $\eta^2_p = .010$; trait anxiety, $F(3, 96) = 0.25$, $p = .864$, $\eta^2_p = .008$; depression, $F(3, 96) = 0.55$, $p = .647$, $\eta^2_p = .017$; and cognitive abilities evaluated by the BEARNI, $F(3, 96) = 0.41$, $p = .746$, $\eta^2_p = .013$ (Table 3). Groups did not significantly differ for the negative urgency, $F(3, 96) = 2.16$, $p = .098$, $\eta^2_p = .064$; lack of premeditation, $F(3, 96) = 2.26$, $p = .087$, $\eta^2_p = .066$; and sensation seeking, $F(3, 96) = 1.73$, $p = .166$, $\eta^2_p = .052$; dimensions of the Urgency–Premeditation–Perseverance–Sensation Seeking–Positive Urgency, but we found significant differences for positive urgency, $F(3, 96) = 3.22$, $p = .026$, $\eta^2_p = .093$, where CAN-HIGH presented higher scores than LD, $t(48) = 2.91$, $p = .006$, Cohen's $d = 0.810$; and lack of perseverance subdimensions, $F(3, 96) = 2.87$, $p = .041$, $\eta^2_p = .083$, where CAN-HIGH presented higher scores than LD, $t(48) = 2.56$, $p = .014$, Cohen's $d = 0.734$; and BD, $t(48) = 2.03$, $p = .048$, Cohen's $d = 0.633$.

Regarding alcohol consumption, and as expected, groups differed for (a) *AUDIT scores*, $F(3, 96) = 20.79$, $p < .001$, $\eta^2_p = .394$, LD presenting lower scores than BD, $t(48) = 8.12$, $p < .001$, Cohen's $d = 2.290$; CAN-LOW, $t(48) = 7.91$, $p < .001$, Cohen's $d = 2.230$; and CAN-HIGH, $t(48) = 7.22$, $p < .001$, Cohen's $d = 2.046$; (b) *binge drinking scores*, $F(3, 96) = 18.16$, $p < .001$, $\eta^2_p = .362$, LD presenting lower scores than BD, $t(48) = 11.21$, $p < .001$, Cohen's $d = 3.169$; CAN-LOW, $t(48) = 8.58$, $p < .001$, Cohen's $d = 2.426$; and CAN-HIGH, $t(48) = 5.59$, $p < .001$, Cohen's $d = 1.581$; (c) *age at first consumption*, $F(3, 96) = 3.65$, $p = .015$, $\eta^2_p = .102$, CAN-HIGH presenting lower age than LD, $t(48) = 2.85$, $p = .006$, Cohen's $d = 0.806$; and BD, $t(48) = 2.47$, $p = .017$; Cohen's $d = 0.699$; (d) *number of alcohol units per week*, $F(3, 96) = 4.59$, $p = .005$, $\eta^2_p = .129$; LD presenting lower consumption than BD, $t(48) = 4.58$, $p < .001$, Cohen's $d = 1.296$; CAN-LOW, $t(48) = 3.36$, $p = .002$, Cohen's $d = 0.950$; and CAN-HIGH, $t(48) = 2.79$, $p = .007$, Cohen's $d = 0.790$; (e) *number of drinking days per week*, $F(3, 96) = 6.74$; $p < .001$; $\eta^2_p = .180$; LD presenting lower values than BD, $t(48) = 3.31$, $p = .020$, Cohen's $d = 0.943$; CAN-LOW, $t(48) = 3.22$, $p = .002$, Cohen's $d = 0.911$; and CAN-HIGH, $t(48) = 4.25$, $p < .001$, Cohen's $d = 1.206$.

Regarding cannabis consumption, as expected, groups significantly differ on CAST score, $F(3, 96) = 35.21$, $p < .001$, $\eta^2_p = .423$, as CAN-LOW and CAN-HIGH presented higher scores than LD and BD (who did not consume cannabis); CAN-HIGH also presenting higher scores than CAN-LOW, $t(48) = 5.93$, $p < .001$, Cohen's $d = 1.679$. Moreover, CAN-HIGH and CAN-LOW did not differ regarding age at first consumption, $t(48) = 1.89$, $p = .064$, Cohen's $d = 0.536$, but CAN-HIGH presented higher weekly consumption, $t(48) = 2.08$, $p = .043$, Cohen's $d = 0.591$; and number of consumption days per week, $t(48) = 2.50$, $p = .017$, Cohen's $d = 0.860$ than CAN-LOW.

Regarding tobacco consumption, in line with cannabis consumption results, groups significantly differ for the Fagerström score, $F(3, 96) = 11.52$, $p < .001$, $\eta^2_p = .296$, as CAN-HIGH presented higher scores than LD (who all presented a Fagerström score of 0); BD, $t(48) = 4.17$, $p < .001$, Cohen's $d = 0.984$; and CAN-LOW, $t(48) = 2.59$, $p = .013$, Cohen's $d = 0.655$; CAN-LOW and BD also presenting higher scores than LD. No group differences were found for the age at first consumption, $F(3, 35) = 1.42$, $p = .252$, $\eta^2_p = .109$; and the number of years of tobacco use among smokers, $F(3, 32) = 1.20$, $p = .326$, $\eta^2_p = .101$.

IGT

The repeated-measures ANOVAs with groups (LD, BD, CAN-LOW, CAN-HIGH) as between-subject factor and the five subscores

Table 3
Sample Characteristics on Sociodemographic, Substance Consumption, Psychopathological and Experimental Measures, and Mean (Standard Deviation)

Measure	LD (N = 25)	BD (N = 25)	CAN-LOW (N = 25)	CAN-HIGH (N = 25)	Group comparison
Demographic measures					
Age	18.24 (0.52)	18.52 (0.71)	18.36 (0.57)	18.28 (0.46)	NS
Sex ratio (female/male)	17/8	17/8	17/8	17/8	NS
Alcohol consumption					
AUDIT score	3.48 (1.58)	12.52 (5.34)	12.32 (5.36)	13.08 (6.45)	LD < BD/CAN-LOW/CAN-HIGH
Binge drinking score	7.64 (4.22)	36.85 (12.33)	34.11 (14.84)	40.54 (29.13)	LD < BD/CAN-LOW/CAN-HIGH
Age at first consumption	15.52 (1.69)	15.26 (1.44)	14.76 (1.30)	14.24 (1.48)	CAN-HIGH < LD/BD
Number of units per week	1.59 (1.12)	6.5 (5.24)	4.92 (4.83)	11.48 (17.67)	LD < BD/CAN-LOW/CAN-HIGH
Number of drinking days/week	1.12 (0.44)	1.77 (0.87)	1.80 (0.96)	2.38 (1.41)	LD < BD/CAN-LOW/CAN-HIGH
Cannabis consumption					
CAST score			0.60 (0.71)	7.16 (5.48)	CAN-HIGH > CAN-LOW > LD/BD
Age at first consumption			16.32 (0.95)	15.74 (1.20)	NS
Weekly consumption (in grams)			1.08 (1.88)	2.17 (1.81)	CAN-HIGH > CAN-LOW
Number of consumption days/week			0.88 (0.89)	2.25 (2.07)	CAN-HIGH > CAN-LOW
Tobacco consumption					
Fagerström score	0.00 (0.00)	0.83 (0.98)	1.13 (1.96)	2.48 (2.16)	CAN-HIGH > CAN-LOW/LD/BD CAN-LOW > LD
Percentage of tobacco smokers	8%	24%	60%	87%	CAN-HIGH/CAN-LOW > LD/BD
Age at first consumption	15.50 (0.71)	16.25 (0.76)	15.31 (1.25)	15.00 (1.46)	NS
Number of years of tobacco use	2.00 (1.41)	1.40 (0.55)	2.36 (0.92)	2.52 (1.42)	NS
Psychopathological/cognitive measures					
BDI	8.60 (5.82)	9.40 (3.83)	7.96 (5.79)	9.84 (6.65)	NS
STAI-A	40.60 (12.54)	43.44 (10.05)	43.08 (12.74)	43.56 (14.22)	NS
STAI-B	50.04 (12.81)	52.08 (8.70)	49.28 (12.42)	51.12 (14.75)	NS
UPPS-P					
Negative urgency	9.25 (2.88)	10.00 (2.48)	9.56 (3.00)	11.08 (2.43)	NS
Positive urgency	10.52 (2.19)	11.44 (2.16)	11.08 (2.52)	12.68 (3.06)	CAN-HIGH > LD
Lack of premeditation	7.12 (2.09)	6.92 (2.64)	7.96 (2.23)	8.56 (3.06)	NS
Lack of perseverance	7.00 (2.04)	7.24 (2.07)	8.00 (2.55)	8.80 (2.80)	CAN-HIGH > LD/BD
Sensation seeking	11.17 (2.99)	12.20 (2.63)	11.92 (2.63)	12.96 (2.89)	NS
BEARNI total score	21.58 (3.42)	22.27 (3.26)	21.52 (2.97)	21.30 (3.24)	NS
Experimental measures—IGT					
Total score	29.60 (21.87)	21.28 (18.31)	22.08 (15.86)	14.16 (20.13)	LD > CAN-HIGH
Trials 1–20	−1.36 (6.32)	−2.08 (5.43)	−4.00 (5.35)	−0.96 (6.17)	NS
Trials 21–40	5.20 (8.23)	2.88 (5.80)	1.44 (6.26)	1.04 (6.00)	NS
Trials 41–60	6.80 (6.66)	7.44 (4.42)	8.40 (8.16)	4.72 (7.66)	NS
Trials 61–80	10.64 (8.83)	5.92 (9.72)	9.12 (8.02)	4.40 (9.09)	NS
Trials 81–100	8.32 (9.41)	7.12 (9.80)	7.12 (7.92)	4.96 (10.25)	NS
Trials 0–40	3.84 (10.44)	0.80 (7.14)	−2.56 (7.45)	0.08 (6.54)	NS
Trials 60–100	18.96 (16.29	13.04 (13.42)	9.36 (15.57)	16.24 (13.21)	NS
Total gain	6,760 (546.77)	6,968 (457.78)	6,948 (396.46)	7,146 (503.31)	CAN-HIGH > LD
Total lost	6,475 (1288.5)	6,804 (960.19)	6,946 (960.79)	7,191 (993.41)	NS
Final money (start money: 2,000)	2,285 (786.34)	2,164 (586.57)	2002 (619.98)	1955 (555.61)	NS
Win-stay	0.59 (0.23)	0.52 (0.18)	0.54 (0.22)	0.51 (0.20)	NS
Lose-shift	0.53 (0.23)	0.55 (0.19)	0.60 (0.23)	0.55 (0.21)	NS

(table continues)

Table 3 (*continued*)

Measure	LD (N = 25)	BD (N = 25)	CAN-LOW (N = 25)	CAN-HIGH (N = 25)	Group comparison
H-choices	1.87 (0.09)	1.91 (0.07)	1.91 (0.05)	1.92 (0.07)	CAN-HIGH > LD
MI-successive choices	0.50 (0.35)	0.36 (0.26)	0.42 (0.34)	0.38 (0.27)	NS
DE3	0.19 (0.12)	0.21 (0.18)	0.20 (0.18)	0.21 (0.13)	NS
DE4	0.07 (0.05)	0.09 (0.13)	0.08 (0.09)	0.07 (0.06)	NS

Note. AUDIT = Alcohol Use Disorders Identification Test; BDI = Beck Depression Inventory; BEARNI = brief evaluation of alcohol-related neuropsychological impairment; CAST = Cannabis Abuse Screening Test; IGT = Iowa Gambling Task; NS = nonsignificant; STAI = State-Trait Anxiety Inventory; UPPS-P = Urgency–Premeditation–Perseverance–Sensation Seeking–Positive Urgency; BD = binge drinkers without cannabis use; CAN-LOW = binge drinkers with low cannabis use; CAN-HIGH = binge drinkers with high cannabis use; DE = directed exploration; LD = low drinkers.

of the IGT as within-subject variables revealed a main Group effect, $F(3, 96) = 2.71$, $p = .049$, $\eta_p^2 = .078$, as CAN-HIGH presented lower scores than LD, $t(48) = 2.59$, $p = .012$, Cohen's $d = 0.735$ (Figure 1). We also found a main Subscore effect, $F(4, 384) = 30.55$, $p < .001$, $\eta_p^2 = .241$, indexing the increasing performance between the first and second phase of the IGT, as the first subscore (Trials 1–20) led to lower scores than the second, Trials 21–40, $t(99) = 4.95$, $p < .001$, Cohen's $d = 0.751$; third, trials 41–60, $t(99) = 9.49$, $p < .001$, Cohen's $d = 1.395$; fourth, trials 61–80, $t(99) = 8.62$, $p < .001$, Cohen's $d = 1.252$; and fifth, trials 81–100, $t(99) = 7.82$, $p < .001$, Cohen's $d = 1.154$ subscores. The second subscore led to lower scores than the third, $t(99) = 4.43$, $p < .001$, Cohen's $d = 0.615$; fourth, $t(99) = 4.42$, $p < .001$, Cohen's $d = 0.607$; and fifth ones, $t(99) = 3.77$, $p < .001$, Cohen's $d = 0.521$. We found no Group × Subscore interaction, $F(12, 384) = 1.13$, $p = .331$, $\eta_p^2 = .034$.

The repeated-measures ANOVAs with groups as between-subject factor and the two parts of the IGT (decision making under uncertainty/risk) as within-subject variables revealed a main Group effect, $F(3, 96) = 2.92$, $p = .038$, $\eta_p^2 = .084$, as CAN-HIGH presented lower scores than LD, $t(48) = 2.59$, $p = .012$, Cohen's $d = 0.735$. We found a main subpart effect, $F(1, 96) = 66.25$, $p < .001$, $\eta_p^2 = .408$, the second part (decision under risk) leading to significantly higher scores than the first one (decision under uncertainty). We found no Group × Subscore interaction, $F(3, 96) = 1.42$, $p = .240$, $\eta_p^2 = .043$.

Regarding the new IGT indexes, groups significantly differed for total gain, $F(3, 96) = 2.71$, $p = .049$, $\eta_p^2 = .078$, as CAN-HIGH presented higher gains (i.e., higher total money earned) than LD, $t(48) = 2.59$, $p = .012$, Cohen's $d = 0.735$; and H-choices, $F(3, 96) = 2.89$, $p = .040$, $\eta_p^2 = .083$, as CAN-HIGH presented higher entropy in their deck choices than LD, $t(48) = 2.37$, $p = .022$, Cohen's $d = 0.620$, namely a more even exploration of the various decks. We found no significant group differences for total loss, $F(3, 96) = 1.99$, $p = .121$, $\eta_p^2 = .059$; net gain, $F(3, 96) = 1.39$, $p = .251$, $\eta_p^2 = .042$; win-stay, $F(3, 96) = 0.68$, $p = .566$, $\eta_p^2 = .021$; lose shift, $F(3, 96) = 0.52$, $p = .667$, $\eta_p^2 = .016$; MI-successive choices, $F(3, 96) = 1.01$, $p = .390$, $\eta_p^2 = .031$; DE3, $F(3, 96) = 0.08$, $p = .973$, $\eta_p^2 = .002$; and DE4, $F(3, 96) = 0.49$, $p = .690$, $\eta_p^2 = .015$.

Finally, we found no significant effect of sex on any IGT index (all $F < 3.62$, $p > .060$), except for lose shift, $F(1, 98) = 6.42$, $p = .013$, $\eta_p^2 = .061$, were females ($M = .59$, $SD = .22$) presented a higher value than males ($M = .48$, $SD = 19$), which means that women presented a higher tendency than males to change the deck selected after a trial generating a loss.

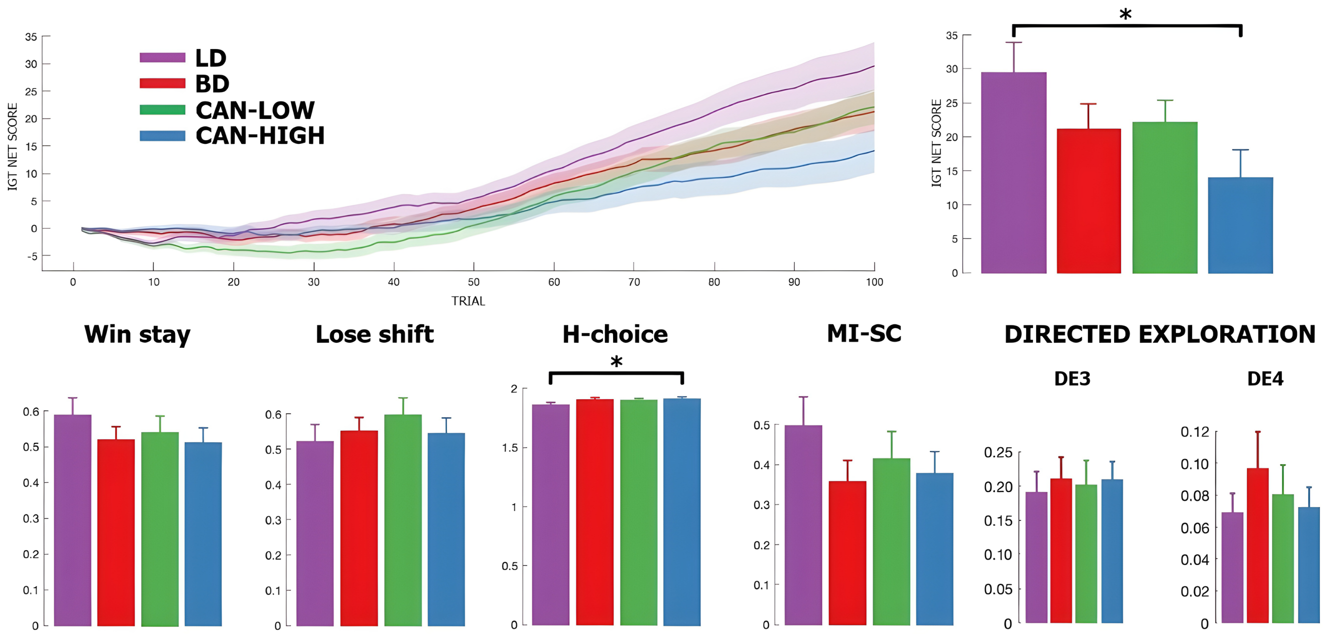
Correlational Analyses

As fully described in Table 4, exploratory Pearson correlations centrally revealed a significant pattern of correlations between IGT score/indexes and alcohol consumption (AUDIT score, binge drinking score), psychopathological states (trait anxiety, depression), and impulsivity subcomponents (lack of perseverance, sensation seeking).

Discussion

We conducted the first exploration of how chronic and excessive alcohol consumption (i.e., binge drinking) and/or cannabis use is related to decision-making impairments in young adults. A key asset

Figure 1
Experimental Results



Note. Mean (standard deviation) for the Iowa Gambling Task (IGT) indexes among the four groups, low drinkers, LD, in purple/stone gray (first columns); binge drinkers, BD, in red/dark gray (second columns); binge drinkers with low cannabis use, CAN-LOW in green/light gray (third columns); binge drinkers with high cannabis use, CAN-HIGH in blue/medium gray (fourth columns): net score after each trial (upper left part of the Figure), total net score (upper right part), and complementary indexes (lower part, presenting win stay [i.e., proportion of trials in which participants selected again the same deck after a trial without loss], lose shift [i.e., proportion of trials in which participants selected a different deck after a loss], H-choice [i.e., entropy index related to the choices made throughout the task], MI-successive choices [MI-SC; autocorrelation of successive choices] and directed exploration [DE]; frequency at which participants selected three/four different decks over three/four consecutive trials [DE3/DE4]). See the online article for the color version of this figure.
* $p < .05$.

of our approach, beyond the inclusion of participants simultaneously consuming both substances and the distinction of two levels of cannabis use, was that, unlike previous studies, we carefully selected our participants to propose a precise group matching on variables influencing decision making, namely age, sex, and education level, but also global cognitive abilities, depression, and anxiety. Such design, ensuring that the potential differences observed were associated with group differences in substance use, generated two main outcomes.

First, we showed that, when confounding factors are controlled for, binge drinking, even when combined with low cannabis consumption, might not be associated with significant decision-making impairments. Indeed, the BD and CAN-LOW groups, despite presenting moderate/intense binge drinking scores, did not show significant difference with LD in any experimental measure. The impaired IGT performance reported in some earlier studies (Gilbertson et al., 2019; Goudriaan et al., 2007; Johnson et al., 2008; Mullan et al., 2011; Xiao et al., 2009; Yoo & Kim, 2016) might hence be partly explained by confounding factors, including the presence of (a) *uncontrolled comorbidities*, notably anxiety and depression, frequently found in binge drinking and cannabis use (e.g., Curran et al., 2016; Feingold & Weinstein, 2021; Puddephatt et al., 2022) and related to impairments in decision making (de Siqueira et al., 2018; Miu et al., 2008); (b) *reduced cognitive abilities*, particularly for attention and memory, which have been repeatedly reported as impaired in binge drinking and cannabis use (e.g., Carbia et al., 2018; Curran et al., 2016) and are needed for efficient decision making; While it must be underlined that we did not directly test the influence of depression, anxiety and cognitive abilities on IGT performance, we indeed show that, when they are controlled for (i.e., when groups are matched on these variables), binge drinking per se is not associated with reduced IGT performance, suggesting an influence of these comorbidities on decision-making deficits; (c) *imprecise measure of consumption habits*, as most studies finding impaired IGT scores in binge drinking or cannabis use were based on unstandardized measures of substance use, potentially including individuals with other alcohol (e.g., heavy alcohol use, severe alcohol use disorder) and cannabis (e.g., severe cannabis use disorder) consumption patterns, but also with other substance use (e.g., cocaine), known to influence decision making. As a whole, our results add to previous debates regarding decision-making impairments in binge drinking by suggesting that this alcohol consumption pattern might not be associated with significant deficits in the IGT among young university students, even when accompanied by low cannabis consumption. Importantly, this result does not imply that binge drinking is not related to other cognitive deficits or that it does not have long-term pervasive impact on high-level executive functions like decision making. Indeed, the students included in the present study might have quite recent binge drinking habits (evaluated here on the past 6 months only), not yet associated

Table 4
Pearson's Correlations Between IGT Score/Indexes and Substance Consumption, Psychopathological and Cognitive Measures in the Whole Experimental Sample (N = 100), r (p)

IGT	AUDIT	BD score	CAST	BDI	STAI-A	STAI-B	UPPS-NU	UPPS-PU	UPPS-LPREM	UPPS-LPERS	UPPS-SS	BEARNI
Total score	**−.26 (.008)**	**−.24 (.018)**	−.05 (.723)	**−.28 (.005)**	−.09 (.383)	**−.22 (.027)**	−.10 (.323)	−.09 (.362)	−.09 (.386)	**−.25 (.011)**	**−.25 (.012)**	.13 (.199)
Total gain	**.26 (.008)**	**.24 (.018)**	.05 (.723)	**.28 (.005)**	.09 (.383)	**.22 (.027)**	.10 (.323)	.09 (.362)	.09 (.386)	**.25 (.011)**	**.25 (.012)**	−.13 (.199)
Total lost	**.27 (.006)**	**.22 (.027)**	−.01 (.918)	**.37 (.000)**	.15 (.144)	**.27 (.006)**	.10 (.324)	.11 (.262)	.15 (.131)	**.31 (.002)**	**.21 (.042)**	−.12 (.257)
Final money	**−.25 (.012)**	−.19 (.058)	.07 (.653)	**−.40 (.000)**	−.18 (.077)	**−.29 (.004)**	−.09 (.374)	−.12 (.241)	−.19 (.063)	**−.32 (.001)**	−.15 (.136)	.09 (.365)
Win-stay	**−.27 (.006)**	−.18 (.077)	.07 (.647)	.00 (.961)	−.02 (.829)	−.02 (.850)	.05 (.651)	.15 (.152)	−.09 (.376)	−.09 (.354)	−.06 (.565)	**.25 (.013)**
Lose-shift	**.20 (.045)**	.08 (.439)	−.18 (.223)	**.21 (.037)**	**.28 (.005)**	**.26 (.009)**	.08 (.440)	−.06 (.536)	.13 (.204)	.19 (.066)	−.06 (.536)	**−.27 (.006)**
H-choices	**.31 (.002)**	**.25 (.011)**	.01 (.965)	.11 (.274)	.04 (.708)	.07 (.503)	.10 (.305)	.03 (.743)	.08 (.412)	.14 (.160)	**.20 (.048)**	−.06 (.536)
MI-successive choices	−.17 (.082)	−.12 (.244)	.06 (.665)	−.18 (.072)	−.10 (.318)	−.13 (.189)	−.03 (.735)	.05 (.607)	−.15 (.146)	−.06 (.586)	−.04 (.682)	.17 (.098)
DE3	.13 (.204)	.18 (.066)	−.04 (.759)	.13 (.209)	.04 (.696)	.01 (.951)	.00 (.989)	−.14 (.172)	−.08 (.424)	−.04 (.705)	.11 (.270)	.06 (.541)
DE4	.12 (.234)	.12 (.229)	−.16 (.282)	.09 (.387)	−.01 (.920)	−.01 (.953)	−.08 (.407)	−.14 (.160)	−.11 (.272)	−.07 (.514)	.13 (.195)	.07 (.473)

Note. Significant results are in bold. AUDIT = Alcohol Use Disorders Identification Test; BD = binge drinking; BDI = Beck Depression Inventory; BEARNI = brief evaluation of alcohol-related neuropsychological impairment; CAST = Cannabis Abuse Screening Test; IGT = Iowa Gambling Task; LPERS = lack of perseverance; LPREM = lack of premeditation; NU = negative urgency; PU = positive urgency; STAI-A/B = State-Trait Anxiety Inventory; SS = sensation seeking; UPPS = Urgency–Premeditation–Perseverance–Sensation Seeking–Positive Urgency; DE = directed exploration.

with detectable neurocognitive impairments. Moreover, as proposed by the compensation hypothesis (Lannoy et al., 2019; Maurage, 2014), the cognitive deficits related to binge drinking might be partly masked, at the initial stages of substance abuse, by a compensatory activation of other brain areas (Campanella et al., 2013; Herman et al., 2019), leading to an absence of observable behavioral deficit. It should, however, be underlined that our exploratory correlational analyses do not align with our group comparisons by identifying a coherent pattern of associations between AUDIT/binge score and IGT indexes. Despite the absence of significant group differences on alcohol consumption measures, excessive alcohol consumption might still be related to subtle decision-making difficulties, undetected by our approach based on group comparisons. Our finding that binge drinking is not related to decision-making impairments should thus be interpreted with caution.

Second, we identified subtle impairments in decision-making abilities among individuals presenting comorbid binge drinking habits and high cannabis consumption (i.e., dependence risk as documented by the CAST questionnaire). Indeed, this group, when compared with LD, showed (a) *reduced total IGT score*, indexing a global deficit in decision making. Importantly, this deficit did not significantly differ between the two phases of the IGT (decision under uncertainty vs. risk), suggesting a global difficulty to optimize decision making, whether or not the task is related to uncertain or explicitly risky choices (Pacheco-Colón et al., 2019). Despite the lack of significant correlations observed here between IGT and CAST scores, this result is coherent with previous ones linking impaired IGT performance with the intensity/frequency of cannabis use (Gonzalez et al., 2012; Hermann et al., 2009), as we did not find such deficit in the CAN-LOW group. While no causal claim can be made on the basis of our cross-sectional design, our results are in line with studies suggesting that decision-making difficulties may be the consequence of excessive cannabis consumption rather than a vulnerability factor toward such consumption (Pacheco-Colón et al., 2021; Thompson et al., 2023). However, the increased impulsivity observed among CAN-HIGH individuals, and particularly the lack of perseverance, could also partly explain the lower IGT scores, as this impulsivity subcomponent was negatively correlated with IGT performance. Beyond the potential direct impact of intense cannabis consumption on decision making, preexisting vulnerability factors like increased impulsivity could lead to both increased cannabis use and impaired IGT performance; (b) *increased total gain*, which is the direct consequence of their increased tendency to promote risky choices (Decks A–B) generating both higher gains and higher losses, ending up in lower total score. This higher propensity to draw cards from risky decks does not seem related to reduced sensitivity to loss (as we found no group differences on the Lose shift index) but rather appears related to the general trend to value risky options and superficially attractive rewards among populations with substance use disorders (Verdejo-Garcia et al., 2018); and (c) *increased H-choices index*, indicating that CAN-HIGH individuals have higher entropy in their exploration of the decks, namely have a more scattered strategy and a lower tendency to optimize their choices by focusing on advantageous decks and neglecting disadvantageous ones. The insights of new indexes, beyond the mere use of total IGT score, allowed to deepen the understanding of the cognitive mechanisms involved in impaired decision making, by showing that such impairment is mostly underlid by higher entropy and lower strategic approach in deck selection throughout the task, rather than by increased sensitivity to loss, as previously suggested (Fridberg et al., 2010). More globally, while we did not explore cannabis use without joint binge drinking habits (as nearly all individuals using cannabis in our initial sample also consumed alcohol), our results clarify previous ones (Alameda Bailén et al., 2012, 2014; Johnstone et al., 2024; O'Donnell et al., 2021; Whitlow et al., 2004) by showing that, when combined with binge drinking, intense cannabis use is indeed related to impaired IGT performance. The previously contradictory results obtained regarding decision making in cannabis use (Ajmera et al., 2021; Cousijn et al., 2013; Gonzalez et al., 2012; Lopez-Quintero et al., 2018; Pacheco-Colón et al., 2019; Thompson et al., 2023) might be related to the fact that these studies included participants with low cannabis consumption and/or that impaired decision making is only found among individuals combining cannabis use with other excessive substance consumption like alcohol. The group differences reported in the present study could appear quite mild, but it has to be underlined that we only included subclinical populations of university students with quite recent alcohol/cannabis use habits and with high cognitive abilities, further underlining the significance of the deficits observed. Moreover, our strict matching between experimental groups on demographics, psychopathological variables, and alcohol consumption (no differences being observed for AUDIT, binge drinking score, but also regarding the number of units per week and the number of drinking days per week) further strengthens our results as the differential deficit observed between BD/CAN-LOW and CAN-HIGH groups cannot be explained by differences in the intensity or frequency of the drinking pattern. It should finally be underlined that, while tobacco consumption was obviously higher in individuals using cannabis than in LD/BD groups, tobacco-related indexes were not significantly correlated with any IGT index. This suggests that tobacco, despite having known consequences on cognitive habits (Conti et al., 2019), did not influence our results.

It should be acknowledged that (a) our choice to precisely match groups on consumption variables and confounding factors led to a relatively limited sample size, and we cannot totally exclude that some group differences, while not being statistically significant, might have influenced the results. This is particularly true for the alcohol consumption measures: While no significant differences were found between the binge drinking groups on these measures (AUDIT, binge drinking scores, number of units per week, and number of drinking days per week), the CAN-HIGH group presented higher scores on these variables than the BD/CAN-LOW ones, leading to the proposal that the IGT deficits observed in this group might be partly related to such increased alcohol consumption rather than to high cannabis consumption per se. This assumption is further reinforced by the exploratory correlational analyses showing significant links between alcohol consumption measures and IGT performance; (b) the exclusive focus on first-year university students with specific demographic, psychopathological, and consumption characteristics hampers the generalization of our results toward other populations frequently reporting binge drinking and/or cannabis use (e.g., general population of University students; adolescents); (c) while ethnicity was not measured as per French regulations, our sample might have predominantly included Caucasian participants, hence limiting the generalizability of our results to other participants; (d) the high intra-group heterogeneity on IGT performance, repeatedly observed in earlier studies, might have reduced the ability to detect more subtle group differences; and (e) the cross-sectional nature of our design hampers to draw any conclusion regarding the causal links between excessive substance consumption and decision-making impairments. Moreover, the IGT, despite being widely used in healthy and pathological populations and constituting a reliable measure of decision making, has long been criticized at theoretical and psychometric levels. At the theoretical level, the somatic marker hypothesis (Damasio, 1996), which constitutes the theoretical background of the IGT, has been criticized for its lack of empirical support and for the limited evidence regarding the causal links between impaired somatic markers and IGT performance (e.g., Dunn et al., 2006). At the empirical level, the construct validity and reliability of the IGT have been criticized on three main aspects, namely the absence of precise/concise definition of the decision-making dimensions evaluated, the lack of data proving its reliability, and the strong influence of personality and current mood/motivation on IGT performance (e.g., Buelow & Suhr, 2009; Schmitz et al., 2020). A last limit of our article is that, while our decision to propose a paper-and-pencil version of the IGT and to use hints in the instructions (i.e., the explicit mention that some decks were more advantageous than others, Fernie & Tunney, 2006) was based on a rationale choice to optimize motivation and avoid misunderstanding among participants regarding the aims of the task, it might have increased participants' performance, potentially reducing group differences.

Despite these limitations, the essential strength of our study is to clarify the links between decision making and binge drinking habits/cannabis use, which present very high comorbidity prevalence in young adults (Shipley & Braitman, 2024). Our results indicate that, when a strict control of confounding variables (e.g., psychopathological comorbidities) is applied, binge drinking, combined or not with low cannabis use, is not related to significant impairments in the IGT. Conversely, individuals who engage in both binge drinking and high cannabis use display lower performance, and particularly a higher entropy in the strategy used to perform the task. Such result, beyond clarifying how various substance use is related, separately or jointly, to decision-making deficits, offers the first insights regarding the cognitive mechanisms underlying IGT performance, offering new perspectives to further explore them in future studies using refined approaches.

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