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RESEARCH ARTICLE

Assessment of contextualized reinforcement pathology in a community sample of young adult substance users

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Abstract

Background: Alcohol, tobacco, and cannabis are the most commonly used substances among young populations, often leading to polysubstance use, which correlates with problematic consumption and adverse health outcomes. The contextualized reinforcer pathology (CRP) model explains addictive behaviors through several constructs, including the following: drug demand, delay discounting (DD), and substance-free and substance-related reinforcement. Most previous studies have focused on a single CRP construct and the couse of only two substances. This study aimed to characterize three subgroups of young adults reporting past month use of alcohol only, alcohol + tobacco or cannabis, and alcohol + tobacco + cannabis, in terms of the three constituents of the CRP model.

Methods: Young adult students ($N = 1487$) completed CRP measures including the Alcohol Purchase Task, the Delay Discounting Task (for monetary rewards), and an abbreviated version of the Adolescent Reinforcement Survey Schedule-Substance Use Version (ARSS-SUV). ANOVA, chi-square, and Student's *t*-tests were conducted to analyze group differences in terms of the CRP model.

Results: Higher demand intensity ($p = 0.001$) and reinforcement from substance-related activities ($p < 0.001$) significantly predicted using alcohol + cannabis + tobacco compared to alcohol only use. DD and some alcohol demand indices (i.e., O_{max}, P_{max}, breakpoint and elasticity) were not associated with any substance use pattern.

Conclusions: Findings suggest that polysubstance use may enhance reward from leisure and social activities. Individuals with high reinforcement from substance-related activities or high alcohol demand should be delivered interventions promoting activities that are both reinforcing and serve as alternatives to substance use.

KEYWORDS
Alcohol Purchase Task, cannabis, delay discounting, substance-free reinforcement, tobacco

INTRODUCTION

Alcohol, tobacco, and cannabis are the most used substances among young populations in both the United States and Europe (Alcohol: 50%–60%; Tobacco: 23%–34%; Cannabis: 6%–26%) (European Monitoring Centre for Drugs and Drug Addiction [EMCDDA], 2022; National Drugs Plan [NDP], 2022; Substance Abuse and Mental Health Services Administration [SAMHSA], 2023).

Young adulthood (18–25 years) is a critical developmental period with the highest risk for engaging in health risk behaviors (Mahalik et al., 2013). At this stage, several bio-psycho-social factors appear conducive to substance use initiation (e.g., family history of substance use, enhanced reward sensitivity, sensation seeking; Sussman & Arnett, 2014); contextual factors are particularly relevant. First, there is significant independence from guardians and changes in social roles that include, among others, the transition to the workforce, caregiving, parenting, and identity formation (Wood et al., 2018). Second, alcohol and other drugs are readily available and accessible (e.g., at bars and concerts). Furthermore, substance use (particularly alcohol and cannabis) is normative in college and socially well-tolerated (Romm et al., 2022). Collectively, these factors underscore the relevance of considering a developmental lens and contextual risk factors. Polysubstance use, especially among young adults, is quite frequent and is associated with a greater likelihood of problematic consumption (Cohn et al., 2018; Romm et al., 2024; Yurasek et al., 2017) with both worse physical (Grodin et al., 2021; Ramo et al., 2012) and mental health outcomes (Cohn et al., 2018; Peters et al., 2012; Ramo et al., 2012; Yurasek et al., 2017).

Behavioral economics is a theoretical framework integrating principles from psychology and microeconomics. This approach has, in recent years, significantly advanced our understanding of substance use by establishing a solid theoretical and empirical foundation articulated through the contextualized reinforcer pathology (CRP) model (Acuff et al., 2023; Bickel et al., 2014). CRP employs three constructs to explain substance use (Acuff et al., 2023): (1) persistently high valuation of a reinforcer (drug demand), (2) excessive preference for immediate reinforcers despite long-term negative outcomes (delay discounting; DD), and (3) a high ratio of reinforcement derived from substance use compared to other reinforcing substance-free activities and commodities (alternative reinforcers).

All three constituents of the CRP model are associated with clinically relevant aspects of substance use, including frequency, quantity, and severity of use (Acuff et al., 2019; Amlung, Vedelago, et al., 2017; González-Roz, Jackson, et al., 2019), as well as treatment outcomes (Acuff et al., 2019, 2024; Exum et al., 2023; García-Pérez et al., 2022). Worth noting is recent research showing environmental reward is a risk factor for more frequent cannabis use as well as negative consequences related to both alcohol and cannabis in young adults, suggesting substance-free, and substance-related reinforcement could provide useful information for selective and environmental prevention (Coelho et al., 2024). More generally, DD, demand, and environmental reward are malleable as shown in clinical studies (García-Pérez et al., 2020; Murphy et al., 2019). Although this research suggests that intervening on these factors may lead to enduring reductions on substance use (Bickel et al., 2023; Murphy et al., 2019), further studies are needed to empirically assess whether they serve as risk factors for polysubstance use and substance use severity, specifically among young adults.

The vast majority of prior research framed under the CRP model has focused on users of only two substances (Amlung, MacKillop, et al., 2017; Businelle et al., 2010; García-Rodríguez et al., 2013; González-Roz, Postigo, et al., 2019; Jun & Fazzino, 2023; Meshesha et al., 2015, 2018; Minhas et al., 2020; Moallem & Ray, 2012; Naudé et al., 2021b; Ramirez et al., 2020; Yurasek et al., 2013), including individuals with alcohol-related problems or alcohol use disorders (Amlung, MacKillop, et al., 2017; Meshesha et al., 2015, 2018; Minhas et al., 2020; Moallem & Ray, 2012; Moody et al., 2016; Nieto et al., 2022; Yurasek et al., 2013). Findings show that couse of two substances correlates with decreased engagement in substance-free activities (Jun & Fazzino, 2023), decreased time spent in physical exercise or academic endeavors (Meshesha et al., 2015, 2018), and increased demand for alcohol (Amlung, MacKillop, et al., 2017; Minhas et al., 2020; Morris et al., 2018; Ramirez et al., 2020; Yurasek et al., 2013), as well as greater DD (García-Rodríguez et al., 2013; González-Roz, Postigo, et al., 2019; Minhas et al., 2020; Moallem & Ray, 2012). However, findings were not always consistent across studies, with studies reporting different statistically significant alcohol demand indices as well as no differences in substance-free reinforcement (Minhas et al., 2020) or DD (Businelle et al., 2010). In regard to tri-use of substances, Moody et al. (2016) investigated tobacco, alcohol, and cocaine use, including couse. Individuals who only used tobacco exhibited lower DD compared to other profiles (individually or in combination). Only two studies have characterized young adults who use alcohol, tobacco, and cannabis using the CRP model. Naudé et al. (2022) identified higher rates of DD among users of tobacco + alcohol and tobacco + cannabis compared to those who used alcohol and cannabis alone respectively, with no differences in DD observed between tobacco alone and those also using alcohol or cannabis. Nieto et al. (2022) showed that only alcohol users exhibited lower rates of DD compared to alcohol + cannabis and alcohol + cannabis + tobacco users.

In sum, this body of research highlights the complex interplay between polysubstance use patterns and reinforcer pathology, underlining the necessity for further exploration to fully elucidate the implications of these findings. All studies examining polysubstance use involving three or more drugs typically used a single behavioral economic measure. To our knowledge, none have provided a thorough characterization of polysubstance use involving all three CRP model variables (i.e., DD, drug demand and reinforcement ratio). Moreover, the vast majority of reinforcer pathology studies examining polysubstance use have examined only two substances (either alcohol, cannabis, or tobacco), with only a few examining more complex patterns of polysubstance use (exc. Moody et al., 2016; Naudé et al., 2022; Nieto et al., 2022). Additionally, a high degree of heterogeneity in study results has been observed, particularly for DD, which may be attributed to different DD task paradigms (e.g., Monetary Choice Questionnaires or adjusting choice tasks) (Amlung, MacKillop, et al., 2017; Businelle et al., 2010; García-Rodríguez et al., 2013; Minhas et al., 2020; Naudé et al., 2021b; Nieto et al., 2022) as well as the comparison of different samples within the same study (e.g., general population vs. clinical samples) (Businelle et al., 2010; Moody et al., 2016; Yurasek et al., 2013). Lastly, the bulk of polysubstance research using the CRF model has concentrated on individuals with alcohol-related problems or alcohol dependence (Amlung, MacKillop, et al., 2017; Meshesha et al., 2015, 2018;

Minhas et al., 2020; Moallem & Ray, 2012; Moody et al., 2016; Nieto et al., 2022; Yurasek et al., 2013). Few studies have examined only alcohol users, which may provide valuable information regarding who may be at risk of future polysubstance use. Collectively, these gaps in the literature limit our understanding of polysubstance use and preclude the identification of relevant behavioral economic correlates of polysubstance use.

Against this background, the aim of this study was to characterize drug use using the three constituents of the CRP model (i.e., alcohol demand, DD, and proportionate reinforcement from substance-free and substance-related activities) across three subgroups of young adults reporting past month use of alcohol only, alcohol + tobacco or cannabis use, and alcohol + tobacco + cannabis use.

MATERIALS AND METHODS

Participants and procedure

Initially, 2980 participants completed a digitalized assessment battery during September– November 2021 administered across three Spanish regions (Asturias, Aragón, and the Balearic Islands). Participants were recruited using printed flyers and posters as well as through digital platforms (i.e., radio, television, Instagram, and Twitter).

Inclusion criteria consisted of (1) being between 18 and 25 years old; (2) being engaged in tertiary education, including university and vocational programs; and (3) reporting past month alcohol use. Of the initial 2980 participants, 121 were excluded for being older than 25, and 1275 did not report any past month alcohol use. Additionally, 22 and 75 participants were removed for failing attentional control checks and being identified as duplicates, respectively. Thus, the final study sample was comprised of 1487 participants reporting past month alcohol use.

Coordinators at each recruitment site were approached and invited to take part in the study. Assessments were scheduled to occur during regular classroom hours. Upon acceptance into the study, research assistants administered an online assessment battery to participants using Lenovo® Table M7 tablets. The assessment battery required approximately 45 min to complete. During the classroom assessments, research assistants were physically present to ensure there was no interaction between participants. To verify the participants' level of engagement and attention to the task, four attentional control items (e.g., for this question choose 'sometimes') with four response options (i.e., hardly ever, sometimes, half of the times, most of the times, almost always) were incorporated into the battery assessment. Participants were required to answer at least two of four of these attentional control items correctly to be deemed satisfactory in terms of their effort and attention to the task. The majority of participants (92%) passed all attentional control items, while 8% had 75% correct responses (1 incorrect of 4 attentional control checks).

The research protocol with the identifier #191CER21 received approval from the Ethics Committee of the academic institution that received funding for the study. Prior to the commencement of the research, all participants duly provided written informed consent.

Instruments

Participants responded on sociodemographic, substance use-related, and behavioral economics variables. The sociodemographic variables were sex, age, and weekly discretionary income.

Substance use-related measures

Substance use variables included past month use of alcohol, tobacco, and cannabis, as well as frequency of past month binge drinking (i.e., 5 standard drinking units, 4 in the case of women, in a 2-h period), and average number of cigarettes and joints smoked per day. Three questionnaires were used to evaluate the weekly alcohol quantity, nicotine dependence, and hazardous cannabis use:

The Daily Drinking Questionnaire (DDQ)

The Daily Drinking Questionnaire (DDQ) (Collins et al., 1985) assesses the quantity of alcohol consumption (i.e., number of standard alcoholic beverages) typically consumed on each day of the week during the past month. Participants were classified as heavy drinkers according to the National Institute on Alcohol Abuse and Alcoholism (NIAAA) criteria, which define heavy drinking as consuming more than 14 drinks per week for men and more than 7 drinks per week for women.

The Heaviness of Smoking Index (HSI)

The Heaviness of Smoking Index (HSI) (Heatherton et al., 1989) assesses nicotine dependence in the last week (current use) using two criteria: self-reported time to the first cigarette of the day and the number of cigarettes smoked per day. The total score ranges from 0 to 6, facilitating the classification of nicotine dependence into low (0–1), medium (2–4), and high (5–6) levels.

The Cannabis Use Disorder Identification Test-Revised (CUDIT-R)

The Cannabis Use Disorder Identification Test-Revised (CUDIT-R) (Adamson et al., 2010) was used to assess hazardous cannabis use in the last 6 months. The CUDIT-R consists of 8 items using a 5-point Likert scale. The total score ranges from 0 to 32, with a higher score indicating more severe cannabis use. The CUDIT-R has high sensitivity (91%) and specificity (90%) for identifying the risk of cannabis use disorder, as indicated by a score of 12 or greater.

Behavioral economic measures

Alcohol Purchase Task (APT)

Participants completed the Alcohol Purchase Task (APT) according to original Murphy and MacKillop's (2006) instructions and were

asked to indicate the number of drinks they would consume at the following 29 prices in a typical drinking situation: €0 (free), €0.15, €0. 3, €0.6, €1, €2, €3, €4, €5, €6, €6.5, €7, €7.5, €8, €8.5, €9, €10, €11, €12, €13, €14, €15, €16, €20, €24, €28, €32, €34, and €36.

Delay discounting (DD)

The DD task consisted of a series of binary choices between an immediately available monetary reward (ranging from €5 to €995) versus a fixed reward of €1000 available at a fixed delay (i.e., 1 day, 1 week, 1 month, and 6 months) González-Roz et al. (2023). A value of the immediate option was adjusted using a heuristic developed by Du et al. (2002) until an indifference point was reached at each delay. The indifference point is defined as the price at which the subjective value of the smaller, immediate reward equals that of the larger, delayed reward. Assuming that rewards are at their full value when received immediately, if receiving €400 now is found to be subjectively equivalent to receiving €1000 after 6 months, one can conclude that the subjective value of the delayed €1000 has been discounted by €600. Participants were explicitly informed that they would not actually receive any of the monetary amounts mentioned during the task but were asked to respond as if the choices were real.

Adolescent Reinforcement Survey Schedule – Substance Use Version (ARSS-SUV)

An abbreviated version of the Adolescent Reinforcement Survey Schedule (ARSS-SUV) (Murphy et al., 2005) comprised of 32-items was employed to assess reinforcement associated with both substance-related and substance-free activities. Frequency and enjoyment of past month activities were assessed using 5-point Likert scales (ranging from 0 to 4). Frequency ratings spanned from 0 (0 times over the past 30 days) to 4 (25 or more times over the past 30 days), whereas enjoyment ratings varied from 0 (unpleasant experiences) to 4 (extremely pleasant experiences). The following is an example of an included item: "In the last month, how many times have you consumed alcohol or other substances while going out with friends?" The product of frequency and enjoyment ratings yielded a cross-product score (possible range of 0–16), reflecting the overall level of reinforcement derived from the activity. The variables of interest in this measure included the average reinforcement across all substance-free activities ($reinforcement_{non\text{-}drug}$), the average reinforcement across all substance-related activities ($reinforcement_{drug}$), and the overall reinforcement ratio, defined as $reinforcement_{drug}$ divided by the sum of $reinforcement_{non\text{-}drug}$ and $reinforcement_{drug}$. This ratio can range from 0 to 1, with higher values indicative of greater relative reinforcement received from substance-related activities over substance-free activities.

Data analysis

Participants were grouped into three different categories regarding the number of substances used in the past month: alcohol only users ($n = 848$), alcohol + tobacco or cannabis users ($n = 445$), and alcohol + tobacco + cannabis users ($n = 194$). The percentage of individuals in each group within this sample aligns with previous epidemiological studies (Cohn et al., 2018; National Drugs Plan (PNSD), 2022). The criterion of "past month use" to define groups of substance users has been widely employed in BE research (Naudé et al., 2021b; Nieto et al., 2022; Ramirez et al., 2020; Yurasek et al., 2013). The APT data underwent a comprehensive initial screening with the objective of identifying nonsystematic patterns in accordance with the guidelines by Stein et al. (2015). There were 68 missing cases and a total of six subjects were found to exhibit nonsystematic data, which was characterized by trend (i.e., negligible reductions, constant demand or increases in consumption). Consequently, these individuals were excluded from further analysis, leaving a total sample of 1413 for the APT analyses. Five demand indices were computed from the remaining data of APT: (1) Q_0, intensity of demand, alcohol consumption when price is at or near zero; (2) O_{max}, maximum output (i.e., most money spent on alcohol at a given price); (3) P_{max}, price at which O_{max} occurs; (4) breakpoint, lowest price at which alcohol is no longer purchased; and (5) α, a fitted parameter describing the rate of change in the slope of the demand function. All demand indices except α were observed. Elasticity was estimated by applying the exponentiated demand curve equation originally proposed by Koffarnus et al. (2015): $Q = Q_0 \times 10^{k(e^{-(Q_0 C-1)})}$. The value of k utilized for all participants in this study was set at 1.5, as estimated in accordance with the recommendations outlined by Farris et al. (2017). Additionally, an assessment of the APT raw data values was conducted to identify and address outliers. Subsequently, the APT dataset raw data were subjected to a standardization procedure, and the standardized values were juxtaposed against a critical threshold of $Z = \pm 4$. A total of 217 outliers, at price level, predominantly of high extreme values, were detected and subsequently recoded (the highest nonoutlying value plus 1).

The systematicity of DD data was evaluated using a modified version of Johnson and Bickel's (2008) criteria. Given the longest presented delay in the DD task (6 months) was relatively shorter than typically presented, violations of the Criterion 2 (i.e., overall decrease of at least 10% between the initial and final delay) were expected and observed ($n = 1246$). Therefore, nonsystematic data were based on Criterion 1 (indifference points cannot exceed those from the previous delay by more than 20%), resulting in 104 assessments being classified as nonsystematic and subsequently excluded from analysis. DD was calculated by taking the area under the curve generated from indifference points following a base-10 logarithmic transformation of delays (AUClogd, Borges et al., 2016), which helps alleviate the disproportionate influence of values derived from longer delays and increases sensitivity of the task, particularly at the extreme ends of the discounting continuum (Yoon et al., 2018). AUClogd can range from 0 to 1, with lower values indicative of greater discounting.

Descriptive statistics, analysis of variance (ANOVA), *t*-test, and chi-squared test were conducted to study differences between

study groups (i.e., alcohol only users, alcohol + tobacco or cannabis users, alcohol + tobacco + cannabis users) in terms of sociodemographic, substance use, and CRP model variables (i.e., APT, DD, and ARSS-SUV). The assumption of homoscedasticity of variances was tested with Levene's test; if this assumption was not met, the post hoc test used was Games–Howell instead of HSD Tukey due to its flexibility and suitability in cases when the former condition is violated. Statistically significant behavioral economic measures were introduced in the analysis of covariance (ANCOVA) to control for sex, heavy drinking episodes, and weekly quantity of alcohol (DDQ). Finally, to study the joint predictive value of the variables that in the univariate analyses were related to the pattern of substance use (i.e., $p \leq 0.05$), a multinomial logistic regression was carried out by the stepwise method. To reduce skewness ($M_{before} = 3.52$, $M_{after} = 1.51$) and kurtosis ($M_{before} = 16.68$, $M_{after} = 2.36$), the APT indices were transformed logarithmically. All statistical analyses were performed with SPSS (version 25, SPSS Inc., Chicago IL, USA). The level of significance for all statistical analyses was set at $p \leq 0.05$. Given that a total of 23 global analyses were conducted, the Bonferroni correction was applied to these analyses (i.e., $p < 0.05/23$, or $p < 0.0022$). A post hoc power analysis in G*Power 3.1 indicated that the study had a power of 0.9417 for detecting small effect sizes.

RESULTS

Sociodemographic differences across groups

Table 1 displays participants' characteristics across study groups. Among the total sample, 64% were women. Males (49%) were overrepresented in the alcohol + tobacco + cannabis group, whereas the proportion of females was higher (73.3%) in the alcohol + tobacco or cannabis group. Concerning substance use, the group using all three substances showed a higher percentage of binge drinking, heavy drinking, and weekly alcohol intake compared to their respective comparison groups. No significant differences were observed in hazardous cannabis use and nicotine dependence across groups.

Contextualized reinforcer pathology

Greater intensity of alcohol demand was observed among those using three ($M_{Q0} = 8.0$ drinks) or two ($M_{Q0} = 7.9$ drinks) substances compared to alcohol-only users ($M_{Q0} = 6.6$ drinks), but with a small effect size. Other indices of alcohol demand (i.e., breakpoint, O_{max}, P_{max}, and elasticity) were not significantly different across the substance user groups. No significant differences in reinforcement provided by substance-free activities ($reinforcement_{non\text{-}drug}$) were observed across the three groups. Notably, reinforcement from substance-related activities ($reinforcement_{drug}$) as well as the reinforcement ratio (relative ratio of reinforcement from drug vs. nondrug sources) were highest in the group that used all three substances ($M_{rdrug} = 2.2$; $M_{rratio} = 0.287$), followed by those who used two substances ($M_{rdrug} = 1.7$; $M_{rratio} = 0.249$), and lowest among alcohol-only users ($M_{rdrug} = 1.3$; $M_{rratio} = 0.197$). The magnitude of these differences was medium. No differences were observed in DD across the three study groups. After controlling for sex, heavy drinking episodes, and weekly alcohol consumption, the intensity of alcohol demand ($F_{2, 1407} = 2.103$, $p = 0.123$) and reinforcement from substance-related activities ($reinforcement_{drug}$) ($F_{2, 1407} = 3.377$, $p = 0.034$) were nonsignificant, whereas the reinforcement ratio remained significant ($F_{2, 1407} = 16.568$, $p < 0.001$).

Regression analysis (Table 2) showed that being male increased the likelihood of alcohol + tobacco + cannabis users' group membership (OR = 1.69; 95%CI = 1.20, 2.41) by 69% in comparison witg the alcohol users' group. Conversely, being female increased the odds of alcohol + tobacco or cannabis users' group membership by 68% (OR = 1.68; 95%CI = 1.28, 2.21). The occurrence of a binge drinking episode within the past month escalated the odds by 57% (OR = 1.57; 95%CI = 1.20, 2.05) of being an alcohol + tobacco or cannabis user, and by 131% (OR = 2.31; 95%CI = 1.56, 3.41) of being an alcohol + tobacco + cannabis user. Regarding weekly quantity of alcohol consumed, each standard drink corresponded to approximately an 11% increase in the likelihood of belonging to the alcohol + tobacco or cannabis users (OR = 1.09; 95%CI = 1.06, 1.12) or alcohol + tobacco + cannabis user group (OR = 1.12; 95%CI = 1.09, 1.15). For every point increase on reinforcement ratio, the odds of belonging to alcohol + tobacco or cannabis users (OR = 5.07; 95%CI = 1.97, 15.59) and alcohol + tobacco + cannabis users' group (OR = 24.31; 95%CI = 6.53, 90.48) increased by 5 and 24 times.

DISCUSSION

This study contributes to the understanding of substance use among young adults using the CRP framework. Results revealed that (1) Q_0 was higher among young adults using two or three substances (alcohol + cannabis + tobacco) compared to those using only one (alcohol), (2) reinforcement from substance-related activities was also higher in young adults using all three substances (alcohol + cannabis + tobacco) compared to those using only one (alcohol) or two substances (alcohol + tobacco or cannabis), and (3) DD of monetary rewards was not associated with any substance use pattern.

Young adults who reported using two or three substances (alcohol, tobacco, and cannabis) showed higher alcohol Q_0 relative to users of one substance (alcohol). Worth noting, the group using three substances showed the highest levels of alcohol use quantity, and heavy drinking episodes in the past month. One possible explanation of higher Q_0 observed among polysubstance users may be the synergistic psychoactive effects of simultaneous drug use, which could enhance the reinforcing value of each substance (Piasecki et al., 2011; Sokolovsky et al., 2020; Yurasek et al., 2017). The fact that only intensity of alcohol was associated with the number of substances used aligns with findings from a meta-analysis (Martínez-Loredo et al., 2021), which identify this index as the most

TABLE 1 Differences between substance use patterns.

	ALC ($n=848$)	ALC + TOB/CAN ($n=445$)	ALC + TOB + CAN ($n=194$)	F (DF)	p	η_p^2
Sociodemographic						
Age	19.3 ± 1.5^a	19.5 ± 1.6^a	19.4 ± 1.6^a	1.481 (2, 1484)	0.228	0.002
Sex (% women)	62.4^a	73.3^b	51.0^c	31.727 (2)[1]	<0.001	0.145
Weekly income	65.9 ± 177.8^a	57.5 ± 117.2^b	82.2 ± 167.7^c	1.593 (2, 1483)	0.204	0.002
Substance use measures						
BD (% yes)	39.5^a	61.3^b	74.2^c	105.65 (2)[1]	<0.001	0.258
HD (% yes)	19.3^a	42.2^b	46.9^b	104.468 (2)[1]	<0.001	0.256
DDQ	6.0 ± 4.9^a	9.6 ± 7.7^B	13.7 ± 13.1^C	99.8 (2, 1484)	<0.001	0.119
CPD[2]	–	2.81 ± 4.00^a	4.01 ± 5.65^b	−2.625 (293)[3]	0.009	0.258
HSI[2]	–	0.560 ± 1.03^a	0.650 ± 1.04^a	−0.983 (581)[3]	0.326	0.086
JPD[2]	–	$0.25 \pm .700^a$	0.42 ± 1.10^a	−1.073 (247)[3]	0.284	0.164
CUDIT-R[2]	–	6.2 ± 4.2^a	7.2 ± 5.8^a	−1.115 (248)[3]	0.266	−0.169
RP measures						
APT						
Intensity	6.6 ± 6.0^a	7.9 ± 7.7^b	8.0 ± 7.0^b	9.139 (2, 1410)	<0.001	0.013
Breakpoint	7.7 ± 6.5^a	7.2 ± 6.1^a	6.2 ± 4.9^a	0.680 (2, 1410)	0.507	0.001
O_{max}	13.8 ± 15.6^a	14.2 ± 13.9^a	13.5 ± 14.6^a	0.251 (2, 1410)	0.778	0.000
P_{max}	4.9 ± 5.1^a	4.4 ± 4.7^a	3.9 ± 4.3^a	0.549 (2, 1410)	0.577	0.001
Elasticity	0.764 ± 2.7^a	0.638 ± 2.5^a	0.61 ± 2.5^a	0.312 (2, 1410)	0.732	0.000
ARSS-SUV						
$Reinforcement_{non\text{-}drug}$	5.0 ± 1.6^a	4.9 ± 1.7^a	5.2 ± 1.8^a	2.028 (2, 1484)	0.132	0.003
$Reinforcement_{drug}$	1.3 ± 1.2^a	1.7 ± 1.4^b	2.2 ± 1.5^c	40.281 (2, 1484)	<0.001	0.051
Reinforcement ratio	$0.197 \pm .124^a$	$0.249 \pm .133^b$	$0.287 \pm .128^c$	49.907 (2, 1472)	<0.001	0.064
AUClog*d*	$0.872 \pm .152^a$	$0.864 \pm .147^a$	$0.855 \pm .170^a$	1.015 (2, 1440)	0.363	0.001

Note: Different superscripts (i.e., a, b, c) indicate a significant difference between groups in pairwise comparisons ($p<0.05$). Conversely, the same superscript denotes the absence of statistically significant differences between the groups.

Abbreviations: ALC + TOB + CAN, alcohol + tobacco + cannabis users; ALC + TOB/CAN, alcohol + tobacco or cannabis users; ALC, alcohol users; APT, Alcohol Purchase Task; ARSS-SUV, Adolescent Reinforcement Survey Schedule – Substance Use Version; BD, past month binge drinking prevalence; CPD, cigarette per day; CUDIT-R, Cannabis Use Disorder Identification Test – revised; DDQ, The Daily Drinking Questionnaire; HD, past month heavy drinking prevalence; HSI, Heaviness Smoking Index; JPD, joints per day; RP, reinforcer pathology.

[1]χ^2 instead of F, contingency coefficient instead of η_p^2.

[2]The means of these variables in the ALC + TOB/CAN group are calculated only for individuals who have used each of these substances in the past month, rather than for the entire sample.

[3]*T*-test instead of F, Cohen's d instead of η_p^2.

discriminative measure of volumetric alcohol, alcohol-related problems, and hazardous drinking.

Interestingly, participants who reported using two or three substances (alcohol, tobacco, and cannabis) also showed higher reinforcement from substance-related activities compared to alcohol-only users. This finding is key to understanding why young adults are more vulnerable to polysubstance use. It is possible that incentive sensitization might play an important role in accounting for heightened substance-related reward, particularly in this young population (Alvarez-Monjaras et al., 2019). First, attentional bias toward substance use is arguably enhanced in environmental contexts where young adults are typically involved (e.g., parties, chatting with friends, etc). Concurrently, participants who report polysubstance use inform on social networks that parallel their substance use, thus increasing substance use opportunities and subjective reward (Meisel et al., 2021). In this sense, the amplified effects of reinforcement from substance-related activities, such as complementary reinforcers, are primarily reinforcing because they facilitate social reinforcement and enhance engagement in interpersonal activities. For instance, some studies have found that the combined use of alcohol and cannabis, compared to the isolated use of either substance, is predicted by social reward expectations (i.e. social motives) for consuming both drugs (Arterberry et al., 2021; Jackson et al., 2021). Furthermore, substances not only act as primary rewards with direct psychoactive and social effects but also enhance the reinforcing properties of

TABLE 2 Regression model to predict substance use pattern.

Model[d]	ALC[a] vs. ALC + TOB/CAN OR (95%CI)	ALC[a] vs. ALC + TOB + CAN OR (95%CI)	ALC + TOB/CAN[a] vs. ALC + TOB + CAN OR (95%CI)
Sociodemographic			
Sex (women)[b]	0.593 (0.452, 0.779)	1.697 (1.195, 2.411)	2.862 (1.976, 4.144)
Drug measures			
BD (no)[c]	1.572 (1.205, 2.051)	2.308 (1.561, 3.411)	1.467 (0.973, 2.213)
DDQ	1.092 (1.064, 1.120)	1.119 (1.088, 1.151)	1.025 (1.005, 1.046)
ARSS-SUV			
Reinforcement ratio	5.069 (1.973, 15.592)	24.305 (6.529, 90.478)	4.333 (1.149, 16.339)

Abbreviations: ALC + TOB + CAN, alcohol + tobacco + cannabis users; ALC + TOB/CAN, alcohol + tobacco or cannabis users; ALC, alcohol users; ARSS-SUV, Adolescent Reinforcement Survey Schedule – Substance Use Version; BD, past month binge drinking prevalence; CI, confidence interval; DDQ, The Daily Drinking Questionnaire; OR, odds ratio.

[a]Reference category.

[b]Reference category, women.

[c]Reference category, "no".

[d]Model. $\chi^2_8 = 270.642$, $p < 0.001$; $R^2 = 0.207$.

nondrug behaviors (e.g., dancing) that occur in the same context as drug use. Nondrug behaviors as well as substance use thus function as conditioned stimuli for each other, further increasing the overall reinforcing effects of substance use and nondrug behaviors (Khoddam & Leventhal, 2016).

No significant relationship between DD and the number of substances used was observed in the current study, which may be partially explained by a ceiling effect of alcohol use (Moody et al., 2016). This result is consistent with results from previous clinical studies (Businelle et al., 2010; García-Rodríguez et al., 2013; Moody et al., 2016) and college student samples (Naudé et al., 2021a, 2021b), but contrasts with other findings (Minhas et al., 2020; Moallem & Ray, 2012; Nieto et al., 2022). Additionally, the severity of individual substance use may have a greater association with DD than the number of substances used (García-Rodríguez et al., 2013; Moody et al., 2016). In a study conducted among college students, Naudé et al. (2022) found steeper DD is associated with the use of multiple substances only when individuals endorse cigarette smoking in addition to either alcohol use or cannabis involvement, pointing to a central role of cigarette smoking in DD among those who report using multiple substances. In our study, the very low nicotine dependence in the sample could account for the lack of significant differences in DD between groups. Another potential explanation may be related to the use of monetary rewards in the discounting tasks. Recent research has shown that cross-commodity DD tasks using drugs, in which the commodity of the reinforcer differs in the immediate versus later option, provide a more ecologically valid assessment (Pritschmann et al., 2021), as they represent choice situations that occur in real contexts. Most available literature has used single commodity DD for money, but cross-commodity DD tasks using substances may prove useful in characterizing polysubstance use (Naudé et al., 2021a).

This study has several limitations. First, the cross-sectional design precludes establishing causal inferences and identifying the directionality of the relationship between behavioral economic indicators and polysubstance use. Second, the study relied on self-reported measures of drug use, which may introduce recall bias. Third, the study does not differentiate between types of couse, specifically simultaneous use (i.e., consuming substances at the same time, leading to overlapping effects) and concurrent use (i.e., consuming substances within the same timeframe, but without overlapping effects). This distinction is relevant, as previous research, such as Ramirez et al. (2020), has shown that simultaneous alcohol and cannabis use is associated with higher alcohol demand. Fourth, although the sample size is relatively high, the sampling method was nonrandom and limited to three Spanish universities and several vocational training centers. Therefore, the representativeness of the results cannot be guaranteed. Fifth, the fact that the number of participants specifically involved in couse and tri-use of substances was relatively smaller compared to those solely using alcohol could diminish the statistical power to detect effects. Sixth, the use of a fixed monetary value (€1000) and a maximum delay of only 6 months in the DD task may have constrained its ability to distinguish differences between substance user groups and resulted in overly shallow discounting rates. Seventh, it would have been advisable to design the ARSS-SUV survey in a way that focused exclusively on the reinforcement provided by alcohol, rather than including alcohol and other drugs. This approach would have allowed for a more precise isolation of alcohol's contextual reinforcing effect based on the substance user group.

CONCLUSIONS AND IMPLICATIONS

Despite these limitations, the current study extends prior research on the CRP model, showing that the intensity of alcohol demand

and the reinforcement ratio of substance-related versus substance-free activities are relevant markers of polysubstance use (i.e., alcohol + tobacco + cannabis) among young adults. Results from this study also revealed that DD of monetary rewards is not sensitive to both the number and type of substances used. Findings have value from the public health perspective as young adults identified with high reinforcement from substance-related activities, or with high intensity of alcohol demand, could be targeted for selective interventions focusing on delivering and promoting activities that are both reinforcing and serve as an alternative to substance use (Jun & Fazzino, 2023; Meshesha et al., 2018). At an environmental level, both the community and universities should offer a range of diverse, healthy, accessible, and affordable—or even free—services and activities that foster a sense of belonging and fulfillment without the need for substance use (Murphy & Dennhardt, 2016). Additionally, communication campaigns can play a pivotal role in challenging the perception that drug use is a normal part of social life while promoting new values and norms centered around substance-free leisure. By combining these efforts, we can reduce the reinforcing value of drugs and encourage healthier behaviors among young adults.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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