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Latent Profile Analysis of Heavy Episodic Drinking in Emerging Adults: A Reinforcer Pathology Approach

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Abstract

Background: Heavy episodic drinking (HED) is a major public health problem among emerging adults (individuals 18 to 25), but with considerable heterogeneity in concurrent substance use and psychopathology. The current study used latent profile analysis (LPA) to detect discrete subgroups of HED based on alcohol, other drug severity, and concurrent psychopathology. A reinforcer pathology approach was used to understand motivational differences among the latent subgroups.

Methods: Participants were 2 samples of emerging adults reporting regular HED, 1 Canadian ($n = 730$) and 1 American ($n = 602$). Indicators for the LPA were validated dimensional self-report assessments of alcohol severity, cannabis severity, other drug severity, nicotine dependence, depression, anxiety, posttraumatic stress disorder, and attention-deficit/hyperactivity disorder. Reinforcer pathology indicators were measures of alcohol demand, proportionate substance-related reinforcement, and discounting of future rewards.

Results: The LPA yielded parallel 3-class solutions in both samples. The largest subgroup was characterized by comparatively low substance severity and psychopathology (*Low overall severity*). The second largest subgroup was characterized by comparatively high alcohol and other drug severity (*excluding tobacco*) and high levels of psychopathology (*Heavy alcohol & high psychiatric severity*). The third subgroup exhibited high alcohol, smoking and intermediate levels of other substance use and psychopathology (*Heavy alcohol, smoking, & intermediate psychiatric*

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CONFLICT OF INTEREST

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severity). The *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* subgroups exhibited significantly higher alcohol demand, greater proportionate substance-related reinforcement, and steeper delay discounting.

Conclusions: Parallel latent subgroups of emerging adults engaging in HED were present in both samples, and the high-risk subgroups were significantly differentiated by the reinforcer pathology indicators. These latent profiles may ultimately inform heterogeneity in the longitudinal course of HED in emerging adults.

Keywords

Alcohol; Emerging Adults; Latent Profile Analysis; Behavioral Economics; Reinforcer Pathology

THE WORLD HEALTH Organization has reported alcohol use to be the third leading contributor to the global burden of disease (WHO, 2019), and heavy episodic drinking (HED; i.e., >4/3 drinks in an episode for males/females, respectively; NIAAA, 2019) is of particular concern because of its high prevalence. For example, in North America, 21.2% of Canadians and 26.1% of Americans aged 15+ years report HED in the past 30 days (WHO, 2019). The highest rates of HED are reported in the late teens and early twenties (i.e., emerging adults; Naimi et al., 2003), and it has been linked to a variety of adverse outcomes (e.g., lower academic achievement, risky sexual behavior, impaired driving, other substance use, and alcohol poisonings). Although individuals often “age out” of HED in the mid- to late-twenties, others exhibit persistent HED, which has been found to be associated with deficits in neurocognitive functioning and brain morphometry (Lisdahl et al., 2013; Squeglia et al., 2015).

Importantly, among individuals who report HED, there is considerable heterogeneity and evidence of latent subgroups (Chassin et al., 2004; Goudriaan et al., 2007; Shireman et al., 2015). For example, subgroups have been detected in terms of number of Alcohol Use Disorder (AUD) symptoms and alcohol-related problems (Beseler et al., 2012; Moss et al., 2007), and subpopulations can also be distinguished based on other drug use (Chiauzzi et al., 2013). Furthermore, subgroups have also been detected based on patterns of alcohol-related problems in conjunction with comorbid clinical symptoms of Post-Traumatic Stress Disorder (PTSD), depression, and anxiety (Cadigan et al., 2017). Overall, these findings suggest that the large population of individuals engaging in HED is comprised of smaller meaningful subgroups with distinct patterns of drinking, drug use, and concurrent psychiatric symptomatology.

Beyond subgroup identification, characterizing concurrent motivational patterns in subgroups using theoretically informed indicators may further enhance etiological models of alcohol misuse. One promising framework is a reinforcer pathology approach (Bickel et al., 2014; MacKillop, 2016), which situates addictive behaviors in the framework of behavioral economics, integrating learning theory, and microeconomics. From this perspective, the prepotent proximal determinants of substance misuse include the high reinforcing value of the drug, high proportionate psychosocial reinforcement from substance use (relative to alternative substance-free reinforcers), and high preference for smaller immediate rewards over larger delayed rewards. These constructs are often operationalized as alcohol demand,

proportionate alcohol reinforcement, and delay discounting (DD), respectively. *Alcohol demand* assesses preferred consumption under conditions of escalating response cost and has been positively associated with heavy drinking, alcohol-related problems, and AUD symptoms (Kiselica et al., 2016; Murphy and MacKillop, 2006). *Proportionate alcohol-related reinforcement* characterizes the amount of participation and enjoyment of psychosocial activities with and without alcohol. It captures the extent to which the overall proportion of reinforcing recreational activity is overlapping with alcohol involvement. Higher proportionate alcohol-related reinforcement is positively associated with alcohol misuse (Murphy et al., 2005), and lower reinforcement from substance-free activities is inversely associated with alcohol misuse (Correia et al., 2003). Finally, *DD* is a behavioral economic measure of the extent to which reinforcers lose value based on their delay in time. Here too, greater preference for immediate rewards has been robustly associated with alcohol and other substance misuse (Amlung et al., 2016). Within reinforcer pathology, drug demand and excessive DD are well established. Previous research has shown that problematic alcohol use results from an excessive valuation of the abused substance and an inability to delay gratification (Lemley et al., 2016). In some cases, individual's susceptibility to substance misuse has been demonstrated as an interaction between demand and DD (Weidberg et al., 2019). However, there are comparatively fewer studies examining an individual's allocation of time and enjoyment to alcohol use compared to alcohol-free behavior (proportionate substance-related reinforcement). This construct measures the extent to which there is a disproportionate reliance on alcohol-related reinforcement compared to more salutary alternative reinforcers and adds another motivational dimension. In other words, the triumvirate of a reinforcer pathology approach to alcohol misuse is excessive preference for immediate reinforcers (i.e., steep DD), high alcohol reinforcing value (i.e., high alcohol demand), and insufficient alternative reinforcers (i.e., high proportionate substance-related reinforcement). Therefore, examining all 3 constructs concurrently was anticipated to illuminate the sensitivities of the different reinforcer pathology facets, as well as where HED emerging adults exhibit vulnerabilities on these indices.

The current study used latent profile analysis (LPA) to examine heterogeneity in psychiatric and substance use symptoms among emerging adults reporting HED and to characterize the resulting groups using a reinforcer pathology approach. Specifically, in 2 independent samples, 1 Canadian and 1 American, the first goal was to investigate how distinct subgroups of drinkers were present based on drinking, drug use, and common comorbid psychiatric disorders. The second goal was to characterize the latent subgroups in terms of alcohol demand, proportionate substance-related reinforcement, and DD. This was both to clarify the nature of the subgroups based on motivational differences and to evaluate the relevance of applying a reinforcer pathology approach to understanding heterogeneity in this population. Although previous research has indicated that both psychiatric comorbidity and tobacco use are associated with elevated alcohol demand and DD (Amlung et al., 2019a, 2019b; Murphy et al., 2013), this study is the first to use a person-centered approach to evaluate all 3 core reinforcer pathology domains in the context of latent subgroups.

MATERIALS AND METHODS

Participants

Participants were 2 independent samples of emerging adults recruited from the general community in Hamilton, Ontario ($N = 730$), and Memphis, Tennessee ($N = 602$) using flyers and newspaper, online, and bus ads. These results have not been reported in any other publications to date. Although the samples are from independent studies, both cohorts had the following eligibility criteria in common: regular HED ($>4/3$ standard drinks for males/females; Butt et al., 2011) 2 days in the past month; fluency in written English; and no current or past psychotic disorders. The Canadian sample eligibility criteria also permitted only 1 instance of HED in a typical month when the individual also reported monthly cannabis use (8%). Age eligibility ranges also differed due to differences in legal drinking ages between Canada (age 19) and the United States (age 21). In the Canadian sample, participants were required to be between ages 19.5 and 23. In the American sample, participants were required to be between ages 21 and 24.9. Descriptive statistics for the 2 samples are presented in Table 1. Two Canadian participants were missing multiple measures and were excluded from further analysis. The American and Canadian samples were similar with respect to sex, years of education, number of harmful drinking and drug-related problems reported, and current symptoms of nicotine dependence. However, the American sample was significantly older, more ethnically diverse, lower in student composition, higher in binge drinking, and higher in cannabis severity (Table 1). Participants provided written informed consent followed by in-person assessments in the pertinent domains. All study procedures were reviewed and approved by the respective research ethics boards.

Measures

Substance Use and Psychiatric Severity Indicators.—Eight psychometrically validated indicators of substance misuse and other commonly comorbid forms of psychiatric disorders were collected: the Young Adult Alcohol Consequences Questionnaire (YAACQ; Read et al., 2006), Marijuana Consequences Questionnaire (MACQ; Simons et al., 2012), Drug Use Disorder Identification Test (DUDIT; Berman et al., 2005), Fagerström Test for Nicotine Dependence (FTND; Heatherton et al., 1991), Generalized Anxiety Disorder-7 (GAD-7; anxiety; Spitzer et al., 2006), Patient Health Questionnaire-9 (PHQ-9; depression; Kroenke et al., 2010), Post-Traumatic Stress Disorders Checklist for DSM 5 (PCL-5; McDonald and Calhoun, 2010), and the Adult ADHD Self-Report Scale (ASRS-v1.1; WHO, 2003). Extended descriptions are provided in Supplementary Materials. In the Canadian sample, 2 participants were missing 1 MACQ question, which were imputed using mean imputation. Participants also completed a comprehensive demographic questionnaire.

Reinforcer Pathology Measures.—To characterize the motivational profiles of observed latent subgroups, 3 reinforcer pathology measures were used. Alcohol demand was assessed with an Alcohol Purchase Task (APT; Murphy and MacKillop, 2006) using a standard instructional set and 30 price increments (\$0-\$40/standard drink). For efficiency, items were presented 5 per online page and additional pages were not presented if a participant reached breakpoint on the page; the termination criterion was page-based, not

item-based, to avoid communicating a direct contingency between responses and task duration. The presentation of these values in the 5 price blocks did not result in any response bias based on a review of the breakpoint frequencies. For the APT, intensity, $O_{\max}$, $P_{\max}$, and breakpoint were generated using an observed values approach (Murphy and MacKillop, 2006) and elasticity (alpha) was calculated using an exponentiated approach (Koffarnus et al., 2015); in the current study, k was tested at rates of 2, 3, and 4 to determine the greatest variance accounted for in the data by the equation. This was determined to be 4 and was held constant across participants. Participants were removed from the analysis for bounce, trend, and reversal from zero violations following the Stein and colleagues (2015) recommendations. Outliers were defined as values more than 4 standard deviations above or below the mean. Winsorization of outliers ($|Z| > 4$) was performed first at a price level and then at an index level, with outlier values recoded as .001 greater than the next highest nonoutlier value. Proportionate psychoactive substance reinforcement was assessed using a version of the Activity Level Questionnaire (Sigmon et al., 2010), a reinforcer survey that was modified to assess past-month activity frequency and enjoyment of 36 activities, both with and without alcohol or other drug involvement. The frequency and enjoyment ratings were multiplied to obtain a cross-product score that reflected the amount of reinforcement derived from the activity, both for substance-related and substance-free reinforcement (Murphy et al., 2005). Additionally, a substance reinforcement ratio was also calculated (substance-related reinforcement/[substance-related reinforcement + substance-free reinforcement]) to quantify the proportion of total reinforcement that involved alcohol or other drug use. DD was assessed using the 5-trial adjusting delay task (also known as Effective Delay 50; Koffarnus and Bickel, 2014), which posed choices between hypothetical smaller immediate rewards and larger delayed rewards; 2 larger delayed rewards were used, \$100 or \$1,000. Participants choose between the constant delayed amount and half that amount available now. The hyperbolic temporal discounting rate (k) was then inferred based on an individual's pattern of responding; the higher the k value, the more an individual discounts larger future rewards, favoring smaller immediate rewards. Extended descriptions are in Supplementary Materials.

Data Analysis

For each sample, LPA was conducted to classify the participants into statistically distinct groups based on a pattern of responses (Nylund et al., 2007). In order to examine variable scores on the same scale, all scores were standardized. All models were run using maximum likelihood robust estimation in MPlus (Muthén & Muthén, 2017). To determine an optimal class solution, each model was estimated by a sequential addition of classes; 2, 3, 4, 5, and 6 class structures were tested for best model fit. The Akaike information criterion (AIC), Bayesian information criterion (BIC), sample size adjusted BIC, Lo–Mendell–Rubin test (LMR), and entropy were used to assess model fit. Smaller AIC and BIC represent better fit (Kass and Wasserman, 1995). The Lo–Mendell–Rubin (LMR) was used to compare whether the current number of classes (k) is a better fit model compared to a model with $k - 1$ profiles; a significant test indicates that k -class model fits the observed data significantly better than the $k - 1$ class model. Lastly, entropy represents overall classification quality with values closer to 1 indicating better model classification (McCutcheon, 2002). An optimal class solution was selected using entropy, Lo–Mendell–Rubin, and theoretical

considerations (Nylund et al., 2007). Once an optimal class solution was selected, profile assignment probability was examined to inform classification precision. Finally, the profile-specific means for continuous outcomes were examined in relation to the reinforcer pathology variables using Wald's chi-square difference test (Asparouhov and Muthén, 2014), with conversion of chi-square in Cohen's d as a measure of effect size (Dunst et al., 2004).

RESULTS

Preliminary Analyses

For APT indices, using the Stein et al. criteria, 5 individuals (0.69%) were removed from the Canadian sample (analysis $n = 723$) and 16 individuals (2.66%) were removed from the American sample (analysis $n = 586$). To correct for positive skewness, an inverse transformation was performed for alpha and log₁₀ transformations were performed for DD k values. Zero-order associations among the latent indicators in both samples are in Supplementary Materials.

Latent Profile Analyses

In the Canadian sample, the LPA revealed that a 3-class solution was the best fit (Table 2). A 3-profile solution was deemed the optimal profile solution due to the following reasons: (i) the highest entropy value (in the Canadian sample); (ii) Lo–Mendell–Rubin tests was significant through the 3-profile model ($p < 0.05$) and then reached nonsignificance when the model was expanded to a 4-profile solution, suggesting that the inclusion of an additional profile did not provide significant improvement over the 3-profile model; (iii) 3 distinct and theoretically interpretable profiles emerged; and (iv) the 3-profile solution provided good classification certainty as reflected by entropy (0.93 to 96) and posterior probabilities for most likely class membership ranging from 0.944 to 0.995.

Figure 1A shows that there were 3 distinct and interpretable profiles. The average latent class probabilities for most likely profile membership are in Table 3 and were very high, approaching 1.0. Profile 1 was the largest (72.3%) and characterized by comparatively low levels of alcohol and other substance misuse as well as low levels of other psychopathology; therefore, the profile was designated as *Low substance use & low psychiatric severity (Low overall severity)*. Profile 2 (21.7%) was characterized by comparatively heavy alcohol, moderate levels of substance misuse and high levels of psychopathology (i.e., depression, anxiety, PTSD, ADHD); therefore, it was designated as *Moderate substance use & high psychiatric severity (Heavy alcohol & high psychiatric severity)*. Profile 3 was the smallest (6.0%) and characterized by heavy alcohol, high rates of smoking and moderate levels of substance misuse and psychopathology; therefore, it was designated as *Moderate substance use, smoking, and moderate psychiatric severity (Heavy alcohol, smoking, & intermediate psychiatric severity)*. Comparisons of demographic characteristics between latent profiles are in Supplementary Materials and primarily reveal that the *Low overall severity* subgroup reported a higher income and education than the *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* profiles.

In the American sample, the LPA revealed that a corresponding 3-class solution was the best fit (Table 2; Fig. 1B). The average latent profile probabilities are in Table 3 and again were very high. Profile 1 was the largest class (70.5%), followed by profile 2 (20.6%), and profile 3 was the smallest (8.9%). Comparisons of demographic characteristics between latent profiles are in Supplementary Materials and again primarily reflect higher income and education in the *Low overall severity* group.

Latent Profile Differences in Alcohol Reinforcing Value

In the Canadian sample, differences in the APT indices for the latent classes are in Table 4 and Fig. 2. For intensity, individuals belonging to the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups exhibited significantly higher unconstrained demand than those belonging to the *Low overall severity* group. For $O_{\max}$, individuals in the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups were willing to spend more on alcohol consumption than those in the *Low overall severity* group. For elasticity, individuals belonging to the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups had higher inverse alpha values than those in the *Low overall severity* group, indicating lower price sensitivity. For breakpoint, the price at which consumption was first fully suppressed was significantly higher in the *Heavy alcohol & high psychiatric severity* than *Low overall severity* group. For $P_{\max}$, no significant differences were present among the latent class groups.

In the American sample, differences in the APT indices for the latent classes are in Table 4 and Fig. 2. For intensity, individuals belonging to the *Heavy alcohol, smoking, & intermediate psychiatric severity* group exhibited higher demand than those belonging to the *Low overall severity* and *Heavy alcohol & high psychiatric severity* groups; and those in the *Heavy alcohol & high psychiatric severity* group exhibited higher demand intensity than those belonging to the *Low overall severity* group. No significant differences were present for the other indices among the latent class groups.

Latent Profile Differences in Proportionate Substance-Related Reinforcement

In the Canadian sample, differences in proportionate substance-related reinforcement across latent subgroups are in Table 4 and Fig. 2. Those in the *Low overall severity* group reported less reinforcement from activities while under the influence of alcohol/drugs than those individuals in the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups. For the reinforcement ratio, both the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups reported greater proportionate reinforcement from activities while under the influence of alcohol/drugs than those same activities when substance-free in comparison with the *Low overall severity* group. For substance-free reinforcement, those in the *Low overall severity* group reported more reinforcement from alcohol-free activities than those in the *Heavy alcohol & high psychiatric severity* group.

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less reinforcement from activities while under the influence of alcohol/drugs than those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups. For the reinforcement ratio, both the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups reported greater proportionate reinforcement from activities while under the influence of drugs than those same activities when substance-free in comparison with the *Low overall severity* group. For substance-free reinforcement, those in the *Low overall severity* group reported greater substance-free reinforcement than those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups.

Latent Profile Differences in Delay Discounting

In the Canadian sample, differences in DD across latent subgroups are in Table 4 and Fig. 2. For a large delayed reward (\$1,000), those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* group had significantly higher $\log_{10} k$ values than those in *Low overall severity* and *Heavy alcohol & high psychiatric severity* group; furthermore, those in the *Heavy alcohol & high psychiatric severity* group had higher $\log_{10} k$ values than those in the *Low overall severity* group. For a moderate delayed reward (\$100), those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* group had significantly higher $\log_{10} k$ values than those in *Low overall severity* and *Heavy alcohol & high psychiatric severity* groups; furthermore, those in the *Heavy alcohol & high psychiatric severity* group had higher $\log_{10} k$ values than those in the *Low overall severity* group.

In the American sample, differences in DD across latent subgroups are in Table 4 and Fig. 2. For a large delayed reward (\$1,000), those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* group had significantly higher $\log_{10} k$ values than those in *Low overall severity* and *Heavy alcohol & high psychiatric severity* groups. For a moderate delayed reward (\$100), those in the *Low overall severity* group had significantly lower $\log_{10} k$ values than those in *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups.

DISCUSSION

Given the considerable heterogeneity among emerging adults engaging in HED, the current study first sought to examine whether latent subgroups of substance use and mental health symptomology were present in 2 independent samples, 1 in Canada and 1 in the United States. Further, the study sought to characterize whether motivational differences were associated with the resulting typology using a reinforcer pathology approach. There were 2 major findings, the first being that the same 3 latent subgroups were clearly revealed in both the Canadian and American samples. The subgroups were named based on their level of alcohol risk relative to the other subgroups. Two reflected high-risk groups (*Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity*), and 1 group was comparatively low severity (*Low overall severity*). The 2 high-risk groups were characterized by higher levels of anxiety, depression, PTSD, ADHD, and/or smoking. It is not surprising to find that elevations in depression were also associated with elevations in anxiety and PTSD as there is considerable psychiatric comorbidity (Brady

et al., 2000). However, this is concerning as a triple comorbidity involving PTSD, depression, and anxiety has been associated with poor psychosocial outcomes (Ginzburg et al., 2010), increased substance-related consequences, and alcohol misuse (Burns and Teesson, 2002; Neupane et al., 2017). Overall, the current LPA findings suggest that emerging adults who engage in HED can be differentiated based on co-occurring substance misuse and mental health symptomology.

A second major finding was that the latent subgroups differed on measures of reinforcer pathology. With regard to alcohol demand, in the Canadian sample, individuals in the *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* groups displayed greater demand for alcohol on most indices (Fig. 2). More specifically, the *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* groups reported greater unconstrained alcohol consumption (intensity), higher total amount that they were willing to spend on alcohol ($O_{\max}$), higher price at which consumption fell to zero (breakpoint), and less sensitivity to alcohol consumption after increases in cost (elasticity) in comparison with the *Low overall severity* group. Likewise, in the American sample, the *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* groups reported greater unconstrained consumption than the *Low overall severity* group; this effect was even higher in the *Heavy alcohol, smoking, & intermediate psychiatric severity* group. Surprisingly, there were fewer group differences in the American sample. It is possible that sensitivity to price is contextually defined and that in the different catchment areas, price was not uniformly defined, which may have contributed to the lack of differences observed in the American sample. This interpretation is further supported by the finding that intensity, the metric least influenced by price, was particularly sensitive to group differences in both samples. Interestingly, a recent meta-analysis indicated that compared to the other demand indices, intensity was particularly useful in predicting alcohol misuse (Kiselica et al., 2016). Alternatively, it is also possible that differences between the Canadian and American groups reflect the possibility that the Canadian low-risk group was the lowest risk group across both samples, which might account for their relatively low level of alcohol demand across all metrics. The lower risk drinkers in the American sample still report relatively high demand and only differ from the higher risk American groups on intensity. Another consideration is that there are differences in the cost of living and the economic contexts (i.e., taxes on alcohol). This may have ultimately contributed to the differences in the sample, especially for the money-based measures that were used.

With regard to proportionate reinforcement, in both the Canadian and American samples the *Heavy alcohol & high psychiatric severity* and *Heavy alcohol, smoking, & intermediate psychiatric severity* groups exhibited greater proportion of substance-related reinforcement relative to total reinforcement than those in the *Low overall severity* group (Fig. 2H). In the American sample only, the *Heavy alcohol, smoking, & intermediate psychiatric severity* group reported less reinforcement from substance-free activities than the *Low overall severity* group. Consistent with the current findings, previous research has found that scoring high on depression, anxiety, PTSD, or ADHD symptoms was associated with greater substance-related reinforcement (Willner et al., 1998) and lower substance-free reinforcement (Acuff et al., 2018).

Lastly, with regard to DD, in both the Canadian and American samples, those in the *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity* groups displayed steeper DD than the *Low overall severity* group at both reward magnitudes (Fig. 2I,J). Interestingly, the Heavy alcohol, smoking, & intermediate psychiatric severity group displayed even steeper discounting than the *Heavy alcohol & high psychiatric severity* group. Since steep discounting is associated with both alcohol (Mitchell et al., 2005) and tobacco (Bickel et al., 1999) use, it is possible that the presence of both had a synergistic effect on discounting of future rewards or that higher discounting was associated with polysubstance use (Lipkus et al., 1994; Yoon et al., 2007). Separately, smokers have shown to score higher on steeper discounting of future rewards than nonsmokers even after controlling for comorbid drug and alcohol misuse (Bickel et al., 1999; Sweitzer et al., 2008). This suggests a degree of specificity between impulsive discounting and smoking. Furthermore, consistent with previous research, those scoring high on depression, anxiety, PTSD, or ADHD symptoms also exhibited more DD (Amlung et al., 2019a, 2019b; Engelmann et al., 2013; Takahashi et al., 2008; Xia et al., 2017).

Taken together, these findings suggest that discrete patterns of substance and mental health symptomology exist in smaller subgroups among heterogeneous samples of emerging adult heavy episodic drinkers. To our knowledge, this is the first study to demonstrate that DD, alcohol demand, and proportionate substance-related reinforcement jointly show associations to problematic substance use and psychopathology. These profiles may be valuable in viewing individuals beyond substance-specific behaviors (i.e., amount of alcohol consumption) within this age cohort, as it offers concurrent factors that account for variation in HED profiles. The need to consider mental health symptomology is a particularly important one. These findings concur with previous studies showing that young adults who experience substance-related problems also experience co-occurring mental health concerns (Hawke et al., 2018). Furthermore, results from the current study indicate a dysregulation in motivational processes, such that elevations in mental health symptomology or smoking might be associated with greater alcohol demand, greater delayed discounting, and a disproportionate reliance on substance-related reinforcement compared to alternative forms of reinforcement. This is concerning given that elevated alcohol demand, greater monetary allocation toward alcohol, greater proportionate substance-related reinforcement, and lower substance-free reinforcement have been associated with more persistent motivation to consume substances, substance misuse, and greater substance-related problems (Correia et al., 2003; MacKillop and Murphy, 2007; Murphy et al., 2005). Therefore, examining mental health and substance use concurrently is an important clinical consideration among emerging adults, and considering reinforcer pathology indices may offer a more nuanced view in addressing behavior change. Although observational in nature, these results also have clinical implications. Specifically, these findings implicate all 3 broad reinforcer pathology domains, but the implications of each are different clinically. For example, an individual's risk can be conceptualized as mapping on to immediacy of reward, alcohol itself, or a dearth of alternative reinforcers. Previously, individual domains have primarily been examined in clinical research. For example, previous research shows that individual indicators predict treatment intervention response (MacKillop and Murphy, 2007; MacKillop et al., 2015; Murphy et al., 2005) and that discounting-focused or substance-free

reinforcement-focused interventions are efficacious (Murphy et al., 2012; Murphy et al., 2019; Snider et al., 2016, 2018). These findings, however, suggest that conjointly considering all 3 facets of reinforcer pathology, and their associations with psychopathology, may be warranted for optimizing intervention impact.

The current findings should be considered in the context of study strengths and limitations. Strengths include the use of 2 samples from highly distinct geographic areas, moderately large sample sizes, broad assessment of both substance use and other psychiatric conditions using well-validated measures that were common to both samples, the integration of LPA and a reinforcer pathology perspective, and clear similarities among the findings. A limitation includes the use of psychiatric screening measures, which prevents directly determining diagnostic status, although this is mitigated by the fact that the measures used were well-validated and correspond well with diagnostic assessments (Kroenke et al., 2001; Spitzer et al., 2006). Moreover, capturing variability across the normative, subclinical, and clinical ranges was a desirable feature of these measures. A second limitation is that the purchase and DD tasks assessed hypothetical outcomes, although this is also mitigated by evidence of high correspondence between preferences for hypothetical and actual outcomes (Amlung et al., 2012; Amlung and MacKillop, 2015; Madden et al., 2003, 2004). Lastly, more broadly, a criticism of LPA is that the results can be sample specific. However, the use of a LPA approach was valuable for several reasons. First, it offers advantages over a variable-centered approach, because it identifies individual profiles by allowing patterns of individual characteristics to emerge from the observed data without making assumptions about whether certain classes of individuals exist. Second, since the LPA identifies patterns of multiple variables, it captures complex patterns that are obscured by traditional analyses, such as regression (Stanley et al., 2017). Lastly, replication of the LPA profiles in 2 samples from two different countries and which differed significantly on numerous variables supports the robustness of the profiles observed, suggesting generalizability.

In sum, the current study revealed 3 distinct subgroups in terms of substance misuse and psychopathology among emerging adults who regularly engage in HED. These subgroups differed significantly on measures of alcohol-related reinforcer pathology, albeit with some variability by measure and by country. Going forward, these findings set the stage for longitudinal questions, such as whether these subgroups and the reinforcer pathology indicators explain “aging out” of HED or its persistence beyond established predictors. These subgroups may also be clinically informative and set the stage for earlier longitudinal inquiry starting in adolescence, thereby effectively allowing for comparison of the onset of mental health to substance use symptoms to identify which indicators to target for prevention efforts. For example, the subgroup exhibiting *Heavy alcohol & high psychiatric severity* would appear to differentially benefit from interventions that target both substance misuse and concurrent comorbidities (e.g., Halladay et al., 2018) or from intervention approaches that directly address reinforcer pathology risk factors (Murphy et al., 2019). These longitudinal and clinical questions are speculative at this point, but the current study provides a clear basis for their subsequent pursuit.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.

Estimated standard mean (SEM) of latent profile indicators for the 3-profile solution. Panel (A) presents the Canadian sample ($n = 728$), and Panel (B) presents the American sample ($n = 602$). Note. YAACQ = Young Adult Alcohol Consequences Questionnaire, MACQ = Marijuana Consequences Questionnaire, DUDIT = Drug Use Disorder Identification Test, FTND = Fagerström Test for Nicotine Dependence, GAD = generalized anxiety disorder, PHQ = Patient Health Questionnaire-9, PCL = Post-Traumatic Stress Disorders Checklist, ADHD = adult attention-deficit/hyperactivity disorder.

Fig. 2.

Differences between profiles on the Alcohol Purchase Task, Alcohol-related Reinforcement Survey, and delayed discounting task. Mean (SEM) intensity (standard drinks; **A**), $O_{\max}$ (expenditure on alcohol; **B**), $P_{\max}$ (**C**), inverse alpha (**D**), and breakpoint (**E**), alcohol-related reinforcement (**F**), alcohol-free reinforcement (**G**), and alcohol-related reinforcement ratio (**H**), log10 k for \$100 (**I**) and \$1,000 (**J**) delayed rewards among individuals in the Low overall severity, *Heavy alcohol & high psychiatric severity*, *Heavy alcohol, smoking, & intermediate psychiatric severity* groups. Note. † represents a significant difference between *Heavy alcohol, smoking, & intermediate psychiatric severity* and Low overall severity; ‡ represents a significant difference between *Low overall severity* and *Heavy alcohol & high*

psychiatric severity; # represents a significant difference between *Heavy alcohol, smoking, & intermediate psychiatric severity* and *Heavy alcohol & high psychiatric severity*.

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Table 1. Descriptive Statistics and Frequencies of Participants in the Canadian ($n = 730$) and American ($n = 602$) Samples

Characteristic	Canadian sample		American sample		t or χ^2	p
	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %		
Age M (SD)	21.44 (1.19)	22.63 (1.03)			19.41	<0.001
Sex (% male)	47.4%	42.7%			2.95	0.09
Race						
% White/European	71.2%	47.0%			69.95	<0.001
% Black/African	2.5%	41.5%			28.90	<0.001
Student status (% student)	75.5%	47.2%			112.99	<0.001
Median household income	\$60,000 to \$74,999 CAD	\$30,000 to 44,999 USD				
Years of education	14.62 (1.82)	14.80 (2.16)			1.67	0.10
Heavy drinking episodes (per week)	1.29 (1.28)	1.64 (1.61)			4.46	<0.001
Drinks per week	11.29 (1.44)	17.35 (0.62)			3.61	<0.001
Cannabis use (% last month)	61.8%	53.7%			32.51	<0.001
Smokers (% last month)	34.2%	29.5%			3.40	0.07
$O_{\max}$	25.14 (17.25)	22.46 (16.44)			2.84	<0.01
$P_{\max}$	7.96 (6.26)	9.10 (8.33)			2.75	<0.01
Breakpoint	14.02 (7.83)	14.50 (9.01)			1.03	0.30
Intensity	7.96 (4.68)	8.29 (5.71)			1.12	0.26
Alcohol-free reinforcement	3.81 (1.60)	4.04 (1.79)			2.50	<0.05
Alcohol-related reinforcement	1.51 (1.48)	2.48 (1.94)			10.01	<0.001
Alcohol reinforcement ratio	0.26 (0.16)	0.36 (0.18)			10.29	<0.001
DD100(log10)	-2.13 (0.84)	-1.62 (0.95)			10.27	<0.001
DD1,000(log100)	-2.61 (0.80)	-2.09 (0.95)			10.56	<0.001

M , mean; SD, standard deviation.

Table 2.

Fit Statistics for Fitting a Latent Profile Model With Different Number of Classes in Emerging Adults in the Canadian and American Samples

	1	2	3	4	5	6
AIC						
Canadian sample	16,548.45	15,061.59	14,394.36	14,029.73	13,802.52	13,552.47
American sample	13,571.51	12,520.65	11,903.50	11,634.19	11,291.35	11,171.90
BIC						
Canadian sample	16,621.89	15,176.35	14,550.43	14,227.12	14,041.22	13,832.48
American sample	13,641.78	12,630.44	12,052.82	11,823.04	11,519.73	11,439.81
BIC (sample size adjusted)						
Canadian sample	16,571.08	15,096.96	14,442.47	14,090.58	13,876.1	13,638.78
American sample	13,590.99	12,551.08	11,944.88	11,686.53	11,354.64	11,246.15
Entropy						
Canadian sample	–	0.93	0.95	0.93	.94	.93
American sample	–	0.90	0.93	0.94	.96	.89
Lo-Mendell Rubin						
Canadian sample	–	1,479.91 ***	673.87 **	376.28	225.75	268.27
American sample	–	1,050.60 ***	624.30 *	282.40	183.26	27.59

AIC, Akaike information criteria; BIC, Bayesian information criterion.

*
p < 0.05,**
p < 0.01,***
p < 0.001.

Table 3.

Average Latent Profile Probabilities for Most Likely Latent Profile Membership N (Row) by Latent Profile C (Column)

	C = 1 Low overall severity	C = 2 Heavy alcohol, smoking, & intermediate psychiatric severity	C = 3 Heavy alcohol & high psychiatric severity
Canadian sample			
$N = 1$	0.986	0	0.014
$N = 2$	0.005	0.995	0
$N = 3$	0.038	0.001	0.961
American sample			
$N = 1$	0.972	0	0.028
$N = 2$	0.003	0.995	0.002
$N = 3$	0.054	0.002	0.944

Table 4.

Profile Differences Based on the Reinforcer Pathology Indices

	Canadian sample						American sample					
	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Heavy alcohol & high psychiatric severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Heavy alcohol & high psychiatric severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Low overall severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Heavy alcohol & high psychiatric severity versus heavy alcohol, smoking, & intermediate psychiatric severity	Heavy alcohol & high psychiatric severity versus heavy alcohol, smoking, & intermediate psychiatric severity
	Wald χ^2	<i>p</i>	<i>d</i>	Wald χ^2	<i>p</i>	<i>d</i>	Wald χ^2	<i>p</i>	<i>d</i>	Wald χ^2	<i>p</i>	<i>d</i>
Alcohol purchase task												
Intensity	11.55	0.001	0.26	12.64	<0.001	0.30	1.96	0.16	0.20	4.99	<0.05	0.19
$O_{\max}$	12.52	<0.001	0.27	12.62	<0.001	0.30	0.83	0.36	0.13	0.31	0.58	0.05
Inverse alpha	7.25	<0.01	0.21	6.37	<0.05	0.21	0.02	0.89	0.02	0.15	0.70	0.03
$P_{\max}$	3.58	0.06	0.15	.57	0.45	0.06	0.12	0.74	0.05	0.01	0.93	0.01
Breakpoint	5.38	<0.05	0.18	.04	0.84	0.02	1.04	0.31	0.14	0.39	0.53	0.05
Activity Level Questionnaire: proportionate substance-related reinforcement												
RF ratio	47.63	<0.001	0.55	22.28	<0.001	0.40	1.09	0.30	0.15	15.81	<0.001	0.35
Alcohol- related RF	26.76	<0.001	0.40	17.35	<0.001	0.35	1.72	0.19	0.19	7.83	<0.01	0.24
Alcohol- free RF	7.55	<0.01	0.21	.21	0.65	0.04	0.46	0.50	0.10	6.93	<0.01	0.23
Delay discounting												
Lg10 DD \$100	6.50	<0.05	0.20	17.94	<0.001	0.36	5.69	<0.05	0.34	6.68	0.01	0.22
Lg10 DD \$1,000	7.69	<0.01	0.21	14.76	<0.001	0.33	5.25	<0.05	0.33	3.04	0.08	0.15

DD, delay discounting; RF, reinforcement; Heavy alcohol, smoking, & intermediate psychiatric severity = Moderate substance use, smoking, & moderate psychiatric severity; Heavy alcohol & high psychiatric severity = Moderate substance use & high psychiatric severity; *d* = Cohen's *d*.