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Patterns of polysubstance use and simultaneous co-use in high risk young adults



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ABSTRACT

Background: Polysubstance use (PSU) is associated with worse prognosis and poorer physical and mental health compared to single substance use. The current study provides information about PSU patterns by examining a diverse range of alcohol/substance use behaviors ranging from low-level experimentation to indicators of severe abuse. In addition, the current study, for the first time, examines how simultaneous co-use of multiple substances cluster with other more commonly studied PSU behaviors.

Methods: Latent Class Analysis was used to identify patterns of substance use, in a sample of young-adults ($n = 2098$), using 25 items from the Semi-Structured Assessment for the Genetics of Alcoholism (SSAGA-II) including: items assessing severity of problems with alcohol, cannabis, stimulants, opiates, and sedatives; items assessing # of lifetime uses; items assessing simultaneous co-use of all combinations of substances. Then the association of class membership and age, antisocial and impulsive personality, experience seeking, anxiety, and neuroticism was examined using Multinomial Regression.

Results: Fit indices (i.e. AIC, SSABIC, and entropy) and interpretability of classes supported a five-class solution: “Low Problems” (32% of sample), “Alcohol Primary” (11%), “Alcohol and Cannabis” (25%), “Moderate PSU” (23%), and “Severe PSU” (9%). Simultaneous co-use behaviors discriminated between lower and higher severity groups. Externalizing personality constructs robustly predicted membership in the “Moderate” and “Severe” PSU classes compared to the “Alcohol Primary” class.

Conclusions: PSU patterns followed an additive pattern of use with lower severity classes using alcohol/cannabis and more severe classes using other illicit substances in addition. Co-use items provided valuable information about PSU severity.

1. Introduction

Epidemiological research and behavior genetic studies have identified a robust pattern of co-occurrence of multiple substance use disorders (SUD) and alcohol use disorders (AUD) (Bierut et al., 1998; Kandel, 2002; Krueger et al., 2005). In fact, data from the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC) found that the majority of individuals with an SUD had at least one other co-occurring SUD and that these individuals had worse prognosis than those with single SUD (McCabe et al., 2017). Polysubstance abusers have been shown to be at elevated risk for overdose, poor physical health, risky behaviors, and poor treatment response (Connor et al., 2014; Feigelman et al., 1998; Earleywine and Newcomb, 1997; Petry, 2001). Furthermore, individuals with SUD or AUD are at greater risk for other forms of psychological dysfunction such as mood and anxiety disorders (Kessler et al., 2005) with some studies suggesting the co-

occurring problems with multiple substances exacerbates current mental health problems (Connor et al., 2013; Hedden et al., 2010). Taken together, understanding assessment and etiology of polysubstance use behaviors should continue to be prioritized given the substantial public health risk and impact on our understanding of externalizing psychopathology.

Research suggests that alcohol and substance use problems are a manifestation of a broader externalizing dimension of psychopathology characterized by an inability to inhibit socially undesirable actions and restricted behaviors (Finn et al., 2009; Hicks et al., 2004; Iacono et al., 2008; Kendler et al., 1997; Krueger, 1999; Vollebergh et al., 2001). In this conceptualization, different externalizing disorders are viewed as indicators of this externalizing propensity, for example substance use dependence has been demonstrated to indicate higher externalizing severity than alcohol or nicotine dependence (Carragher et al., 2014). Although there is strong evidence for the existence and coherence of a

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general and continuous externalizing dimension, latent class analyses (LCA) that uncover discrete classes underlying substance use patterns provide additional knowledge about clusters of behaviors along this spectrum. Specifically, LCA provide a more “person centered” approach by identifying common patterns of use in individuals rather than just describing the relationship between latent constructs. Although an in-depth review of studies using latent class analyses of alcohol/substance use behaviors is beyond the scope of the current paper, studies in adolescents (see Tomczyk et al., 2016) and adults (see Connor et al., 2014) have supported classes of increasing usage of a variety of substances. Of substance users, lower severity classes tend to be characterized by alcohol, tobacco, and cannabis use, with higher severity classes using a variety of other substances in addition.

Despite the wealth of information pertaining to polysubstance use patterns already in the literature, the current study intends to address several knowledge gaps. The majority of previous studies have relied only on measures of use (e.g. use in the past 12 months) or DSM derived diagnoses. The current study examines a diverse array of substance use measures and symptoms ranging from minor experimentation to indicators of severe AUD/SUD for the following substances: alcohol, cannabis, stimulants, opiates, sedatives, hallucinogens, and “other” substances (e.g. ecstasy) in a high externalizing sample of young adults. This provides valuable information about patterns of severe use in addition to co-occurring subthreshold experimentation of substances. Furthermore, very few studies have been able to examine co-use (i.e. simultaneous use of two substances) of a variety of substances, with one study showing polysubstance users are very likely to report co-use in the previous 12-months in a representative Australian sample (Quek et al., 2013) and other studies showing high rates of co-use in smaller clinical populations (Herbeck et al., 2013; Olthuis et al., 2013). No study to our knowledge has utilized LCA to examine a wide variety of substance co-use that would allow for direct inspection of how these behaviors further inform our understanding of the clustering of PSU behaviors and serve to discriminate between individuals of different PSU severity. For example, it is possible that some individuals tend to participate in co-use of many substances compared to others. Perhaps these individuals are particularly sensation seeking leading them not only to use multiple substances, but also to maximize intoxication by using multiple substances in a very narrow timeframe. It is also possible that co-use items will serve as severity indicators discriminating between classes characterized by problematic use of substances from classes characterized by mild use or experimentation. In this case, simultaneous use of multiple substance may serve as markers of individuals who have progressed in terms of severity of PSU behaviors, making these items of particular assessment value. Furthermore, the current sample is particularly well suited to examine these questions given its high representation of externalizing disorders (~60% with AUD) and age distribution (mean age = 21.6), given research indicating that PSU is most common in young adults (Quek et al., 2013; White et al., 2013).

Lastly, after the identification of latent class structure, the current study will examine the association between continuous measures of externalizing (i.e. antisocial, impulsive, and experience seeking personality) and internalizing (i.e. trait anxiety and neuroticism) personality traits and the latent classes to aid in interpretation and validation of the identified classes. Research has repeatedly established the strong empirical and theoretical link between personality traits associated with behavioral disinhibition and problems with substance use management (Finn, 2002; Krueger et al., 2002; Sher and Trull, 1994). However, significantly less literature has examined the association between traits commonly associated with internalizing disorders (e.g. trait anxiety) and severity of PSU. Despite theoretical differences between externalizing and internalizing traits/disorders, research has demonstrated that the majority of dimensions of psychological dysfunction tend to covary together (Caspi et al., 2014; Caspi and Moffitt, 2018; Lahey et al., 2017). With this in mind, internalizing traits, in the current

sample, may serve as a marker for individuals who struggle both with anxiety/affect regulation in addition to impulse regulation and therefore be at risk for more severe substance use problems.

2. Methods

2.1. Sample characteristics

The current sample consisted of 2098 young adults ranging from 18 to 30 with a mean age of 21.6 ($SD = 2.65$) and was originally recruited for a study on risky decision-making and risk factors of externalizing psychopathology (Finn et al., 2014). The sample was intentionally recruited for an overrepresentation of externalizing problems with 58% of the current sample having an AUD, 45% with a Cannabis Use Disorder (CUD), and 23% with another illicit drug use disorder (DUD). In the current study, the majority of diagnoses (89% of the sample) were assessed using the Diagnostic and Statistical Manual of Mental Disorders fourth Edition (American Psychiatric Association, 2000) alcohol, cannabis, and drug abuse/dependence criteria, while the remaining sample utilized DSM-V (American Psychiatric Association, 2013) AUD, CUD, and other drug use disorder (DUD) criteria. In the current study, AUD, CUD, and other illicit DUDs include both DSM-IV abuse/dependence, and DSM-V AUD, CUD, and DUD diagnoses. This study was reviewed and approved by the Indiana University-Bloomington Institutional Review Board (IRB) and all participants gave informed consent.

2.2. Recruitment

Participants were recruited using flyers, advertisements in local newspapers, and business cards placed around the community, along with postings on the Indiana University student classifieds web page. The flyers and postings were designed utilizing the approach used by Finn et al. (2009) to obtain a sample with a large proportion and range of individuals with externalizing pathology specifically: alcohol use, alcohol problems, other substance use problems, and antisocial psychopathology. The postings and flyers asked for “adventurous, daring” individuals, “impulsive individuals”, “more reserved and introverted type person”, “social drinkers”, and persons who “got in a lot of trouble as a child” etc. Importantly, given that the majority of the sample was recruited for studies of alcohol misuse, individuals were not retained if they had externalizing diagnoses without an alcohol use disorder. Therefore, the current sample may have an underrepresentation of illicit drug use disorders without comorbid alcohol use problems.

2.3. Telephone screening interview

Those who responded to advertisements were screened via telephone to determine whether they met study inclusion criteria. Respondents who met study inclusion criteria could read and speak English, had at least a 6th grade education, did not report any history of severe head injuries, did not report a history of psychosis, had consumed alcohol on at least one occasion in their life, and were between ages 18 and 30. Participants were informed that they must abstain from using alcohol and other drugs for at least 12 h before study sessions.

2.4. Test session exclusion criteria

Before every testing session participants were required to meet a set of criteria before proceeding. All participants were required to (1) have no self-reported use of drugs or alcohol within the past 12 h prior to testing, (2) have gotten at least 6 h of sleep the previous night, (3) have a breath alcohol level of 0.0% (tested with an AlcoSensor IV, Intoximeters Inc., St. Louis MO), and (4) not be experiencing symptoms of withdrawal or of any illness. Subjects were rescheduled if they did not meet these criteria.

2.5. Diagnoses and alcohol/substance use measures

Participants were administered the Semi-Structured Assessment for the Genetics of Alcoholism (Bucholz et al., 1994) to assess lifetime diagnoses of AUD, CUD, and DUD. The SSAGA has demonstrated good construct validity when compared with other semi-structured interviews (Hesselbrock et al., 1999), good test-retest reliability (Bucholz et al., 1994), and inter-rater reliability (Bucholz et al., 1995, 1994). Twenty-five items from the SSAGA were chosen for latent class analysis that reflected a broad range of alcohol/substance patterns. Likert items were created to assess number of uses of cannabis, hallucinogen, stimulant, opiate, sedative, and “other” substances respectively. The “other” category was predominantly the use of ecstasy (MDMA) and nitrous oxide (“whip-its”), in addition to other substances not included in the other substance classes. The number of uses were binned into the following categories: 0 lifetime uses, 1–10, 11–50, 51–99, and greater than 99. These items were meant to capture subthreshold experimentation of substances not normally captured by diagnostic criteria. Severity of problems with alcohol, cannabis, stimulant, opiate, and sedative use was assessed using a summed symptom count of the five core diagnostic features for each substance respectively. In addition, to the symptom count and number of use items, 14 dichotomous items were utilized to examine specific substance use behaviors. These items assessed co-use of every combination of alcohol, cannabis, stimulants, opiates, sedatives, and using alcohol to “come down” from cocaine. In addition to several items that assessed negative consequences associated with severe substance use (e.g. overdose and negative drug interactions), which research has indicated are of particular concern in PSU and especially simultaneous PSU (Kerr et al., 2007). The list of items is provided in Table 1.

2.6. Personality measures

Antisocial personality was assessed using a lifetime problem count calculated by summing positive responses to relevant SSAGA-II

questions in the Antisocial Personality Disorder (ASPD) section of the SSAGA. Impulsive personality was assessed using the 19-item Impulsivity Scale I-7 Questionnaire, which has shown good intra-item reliability ($\alpha = .84$; Eysenck et al., 1985). Neuroticism was assessed using the 23 dichotomous-item neuroticism section of the Eysenck personality questionnaire (Eysenck and Eysenck, 1975), which has shown excellent test-retest reliability ($r = .92$; Sato, 2005). Trait anxiety was assessed using the 20 Likert-item Trait Anxiety Inventory (TAI) section of the State-Trait Anxiety Inventory (Spielberger, 1983), also with excellent test-retest reliability (average $r = .88$; Barnes et al., 2002). Lastly, Experience Seeking was assessed using the 10 forced-choice item experience seeking subscale of the Sensation-Seeking Scale (Zuckerman, 1979), which is meant to capture items that reflect a search for new experiences through a “non-conforming lifestyle” (Eysenck and Zuckerman, 1978).

2.7. Statistical analyses

R version 3.5.3 was used for these analyses (R Development Core Team, 2013), including use of the “poLCA” package for latent class analyses (LCA) (Linzer and Lewis, 2011), the “VGAM” package for multinomial regression (Yee, 2015), the “missForest” package for data imputation (Stekhoven and Bühlmann, 2012), and the “ggplot2” package for figure creation (Wickham, 2016).

2.8. Missing data and imputation

The current sample diagnostic interview, which was the source of the alcohol/substance use items, consisted of less than 1% missing data. This missing data was imputed using a random forest algorithm (Stekhoven and Bühlmann, 2012) using all other non-missing items. Random forest imputation has shown to outperform other commonly used methods of imputation and is considered highly accurate when imputing categorical data as in the current study (Stekhoven and Bühlmann, 2012; Waljee et al., 2013). Data were not imputed for

Table 1
Items used in LCA Analysis.

Item	Scoring
Symptom Count Items for Alcohol, Cannabis, Stimulant, Opiates, Sedatives	Summed criteria for each substance. Range (0–5)
(1) Did you ever need larger amounts of [substance] to get an effect or find that you could no longer get high on the amount you used to use?	
(2) Have you ever had such a strong desire for [substance] that it was hard to think of anything else?	
(3) Have you ever tried to stop or cut down on [substance] but found that you couldn't?	
(4) Have you ever given up or greatly reduced important activities while using [substance] like sports, work, or associating with friends or relatives?	
(5) People who stop, cut down, or go without drugs after using drugs steadily for some time may not feel well. These feelings are more intense and can last longer than the usual hangover. When you stopped, cut down, or went without [substance] did you ever experience any of the following problems for most of the day for 2 days or longer?	
Number of Lifetime Use items for Cannabis, Stimulant, Opiates, Sedatives, Hallucinogens, and Other substances	Total # of uses binned into 0, 1–10, 11–50, 51–99, > 99 Range (0–5)
How many times in your life have you used [substance]?	
Dichotomous Items	
Alcohol Binge: Have you ever gone on binges or benders when you kept on drinking for 2 days or more without sobering up, except for sleeping?	Dichotomous
Have you ever used 2 or more drugs together?	Dichotomous
- Alcohol and Cannabis	
- Alcohol and Stimulants	
- Alcohol and Opiates	
- Alcohol and Sedatives	
- Cannabis and Stimulant	
- Cannabis and Opiates	
- Cannabis and Sedatives	
- Stimulants and Opiates	
- Stimulants and Sedatives	
- Opiates and Sedatives	
Did you ever use alcohol to make yourself feel better when coming down from the effects of cocaine?	Dichotomous
Did you have any harmful effects from mixing alcohol and any drugs?	Dichotomous
Did using drugs cause you to have any other problems like an overdose?	Dichotomous

personality measures because these data were not missing at random, but were missing due to structural issues. Some individuals in the current sample simply did not complete any or the majority of the personality measures due to slight changes in the battery of measures to reduce subject burden. Individuals who did not complete a given personality measure(s) were removed from the multinomial regression utilizing that respective measure(s).

2.9. Latent class analysis

Latent class analysis was conducted using the twenty-five categorical substance use items using the “poLCA” package (Linzer and Lewis, 2011), which utilizes the expectation-maximization (EM) algorithm (Dempster et al., 1977). Models ranging from 3 to 6 classes were evaluated based on the theoretical interpretability of the classes, Akaike’s Information Criterion (AIC), Sample Size Adjusted Bayesian Information Criterion (SSABIC; Sclove, 1987), entropy statistic (Celeux and Soromenho, 1996), and the size of the classes. In general, lower AIC and SSABIC values indicate a better model fit. SSABIC has been shown to be a very reliable and useful statistic in decisions of the number of latent classes to retain (Nylund et al., 2007). Entropy is an index of the precision of assigning latent class membership (ranges from 0 to 1) with values near 1 indicating high precision of assignment.

After examination of the fitted latent class models, the posterior probabilities of group membership were used to assign participants to classes. Class membership was assigned based on the highest modal posterior probability of each participant (Linzer and Lewis, 2011).

2.10. Multinomial regression

Multinomial regression was used to assess the association between age, antisocial personality, impulsive personality, experience seeking, trait anxiety, and neuroticism with LCA defined classes.

3. Results

3.1. Latent class analysis: class identification

Table 2 presents the fit statistics for the fitted models ranging from 3 to 6 latent classes. AIC and SSABIC statistics supported retention of six latent classes. However, five latent classes produced a more interpretable solution. The six-class solution added another class that did not appear to be meaningfully different from the class characterized by alcohol and cannabis use described in the next paragraph, but merely was of slightly lower severity. The five-class model showed a large improvement over the four-class model in terms of AIC and SSABIC, while all models showed excellent entropy indicating strong precision in class assignment.

The five-class solution consisted for the following classes: a “Low Problems” class (32% of total sample) characterized by low to moderate alcohol use without significant indicators of alcohol use problems, minimal experimentation with other substances, and very low probability of illicit drug problems; an “Alcohol Primary” class (11% of sample) characterized by moderate to heavy alcohol use, alcohol

binging, mild to extensive experimentation with cannabis and stimulants in terms of # of uses without significant disorder symptoms, and mild to negligible experimentation of other illicit substances; a “Alcohol and Cannabis” class (26% of sample) characterized by light to heavy alcohol use, moderate to heavy cannabis use, high rates of alcohol and cannabis co-use, and light experimentation with other illicit drugs; a “Moderate PSU” class (23% of sample) characterized by moderate to heavy alcohol and cannabis use, high rates of co-use of alcohol and other substances, and substantial use of other illicit substances resulting in varying levels of SUD pathology; a “Severe PSU” group (9% of sample) characterized by heavy use of alcohol, cannabis, and all other illicit substances, high rates of substance co-use, and negative outcomes such as negative alcohol/drug interactions and overdoses. Table 3 presents the probability of response patterns for each item broken down by latent class. The average posterior probabilities for each class were “Low Problems” = 96%, “Alcohol Primary” = 91%, “Alcohol and Cannabis” = 95%, “Moderate PSU” = 96%, and Severe PSU” = 96%. Supplementary Fig. 1 provides a visual representation of the probabilities of response in each category of summed symptom items and the lifetime use items broken down by latent class. Supplementary Fig. 2 provides a visual representation of the probabilities of response for the dichotomous items broken down by latent class.

3.2. Multinomial regression results

Table 4 provides descriptive statistics of the measures used in multinomial regression analyses broken down by latent class, in addition to a breakdown of diagnoses by latent class. Table 5 provides the correlation between personality measures used in the current study. The “Alcohol Primary” class was chosen as the reference class to provide illustration of what factors may distinguish between single substance users (e.g. alcohol) and polysubstance users. Table 4 presents the odds ratios (OR) comparing all other latent classes to the “Alcohol Primary” class for the following measures age, antisocial personality, impulsive personality, experience seeking, trait anxiety, and neuroticism. In summary, measures of personality traits associated with externalizing psychopathology (i.e. antisocial, impulsivity, and experience seeking) were robust predictors of latent classes of high PSU severity compared to the “Alcohol Primary” class. Although, internalizing traits (i.e. anxiety and neuroticism) were also associated with more severe PSU classes, they were weaker predictors compared to externalizing measures.

4. Discussion

The current study aimed to identify common polysubstance use patterns and analyze what behaviors distinguish between classes of higher severity in a high-risk young adult population. LCA identified a five-class solution that followed an additive pattern of escalating PSU starting with a group with very low problems with any substance, followed by groups characterized by alcohol/cannabis use, and finally classes with heavy use of many drug classes. Items assessing co-use provide excellent discrimination between different levels of severity, indicating that individuals who use two substances simultaneously are very likely to have disordered use of both substances. Unsurprisingly, personality measures associated with externalizing pathology (antisocial, experience seeking, and impulsivity) were robust predictors of PSU compared to non-users. Interestingly, internalizing traits (trait anxiety and neuroticism) were elevated in the highest severity classes.

Latent class analysis based on class interpretability and relevant fit statistics identified a five-class solution. The first class labeled “Low Problems” can be characterized by mild to moderate alcohol use, experimentation with cannabis without features of problematic cannabis use, and negligible to nonexistent experimentation with other illicit substances. Interestingly, as shown in Table 4, about 24% of the “Low Problems” group had a diagnosed AUD. However, it is likely that

Table 2
Latent Class Analysis Fit Statistics.

Model #	df	AIC	SSABIC	Entropy
Model 3	1907	57108.51	56730.98	0.95
Model 4	1843	55723.41	55217.88	0.93
Model 5	1779	55197.14	54563.61	0.92
Model 6	1715	54715.51	53953.99	0.90

Model # = the number of latent class, df = residual degrees of freedom, SSABIC = Sample Size Adjusted Bayesian Information Criterion, AIC = Akaike’s Information Criterion.

Table 3
Response Probabilities for Each Latent Class.

Item	Low Problems	Alc. Primary	Alc. & Cannabis	Moderate PSU	Severe PSU
Sample %	32%	11%	26%	23%	9%
Items with Six Response Categories					
Alc Sx	.5/.37/.1/ .02/.01/0	.07/.19/.32/ .17/.16/.09	.16/.33/.27/ .15/.07/.01	.06/.24/.3/ .18/.15/.06	.05/.14/.18/ .24/.17/.22
Can Sx	1/0/0/ 0/0/0	1/0/0/ 0/0/0	.24/.33/.22/ .12/.07/.03	.12/.23/.22/ .17/.17/.08	.08/.18/.2/ .21/.19/.13
Stim Sx	1/0/0/ 0/0/0	.94/.03/.01/ .01/0/0	.96/.02/.01/ 0/0/0	.55/.18/.12/ .08/.04/.03	.13/.12/.16/ .08/.2/.31
OP Sx	1/0/0/ 0/0/0	.99/0/0/ .01/0/0	.99/.01/0/ 0/0/0	.72/.14/.07/ .03/.02/.01	.09/.15/.13/ .16/.16/.31
Sed Sx	1/0/0/ 0/0/0	.98/0/.01/ .01/0/0	1/0/0/ 0/0/0	.81/.1/.04/ .03/.02/0	.23/.27/.16/ .12/.14/.08
Items with Five Response Categories					
Can Use	.47/.41/.11/ 0/0	.1/.41/.39/ 1/0	.01/0/.02/ .53/.44	.03/0/.01/ .18/.78	.01/.01/0/ .06/.92
Stim Use	.97/.03/0/ 0/0	.48/.34/.14/ .01/.02	.5/.36/.13/ .01/.01	.04/.19/.36/ .2/.21	.01/0/.09/ .1/.8
OP Use	.99/.01/0/ 0/0	.71/.25/.02/ 0/01	.64/.3/.05/ .01/0	.06/.39/.41/ .08/.05	0/.01/.12/ .12/.76
Sed Use	.99/.01/0/ 0/0	.74/.23/.01/ .01/0	.71/.27/.02/ 0/0	.1/.45/.31/ .08/.05	.02/.02/.16/ .14/.66
Hal Use	.99/.01/0/ 0/0	.76/.23/0/ 0/0	.52/.42/.05/ .01/0	.12/.52/.3/ .03/.03	.08/.22/.25/ .17/.28
Other Use	.99/.01/0/ 0/0	.81/.17/.02/ 0/0	.69/.29/.02/ 0/0	.19/.55/.22/ .02/.02	.07/.23/.32/ .11/.26
Dichotomous Items					
Alc Binge	.93/.07	.37/.63	.62/.38	.36/.64	.20/.80
Alc for Cocaine	1/0	.98/.02	.98/.02	.71/.29	.47/.53
Alc + Can	.97/.03	.88/.12	.10/.90	.19/.81	.14/.86
Alc + Stim	1/0	.97/.03	.97/.03	.73/.27	.79/.21
Alc + OP	1/0	.88/.12	.88/.12	.58/.42	.34/.66
Alc + Sed	1/0	.96/.04	.96/.04	.64/.36	.37/.63
Can + Stim	1/0	.99/.01	.91/.09	.53/.47	.37/.63
Can + OP	1/0	1/0	.89/.11	.59/.41	.44/.56
Can + Sed	1/0	1/0	.98/.02	.75/.25	.63/.37
Stim + OP	1/0	1/0	1/0	.93/.07	.61/.39
Stim + Sed	1/0	1/0	1/0	.94/.06	.86/.14
OP + Sed	1/0	.99/.01	.99/.01	.93/.07	.75/.25
Alc + Drug Interaction	1/0	.87/.13	.93/.07	.71/.29	.54/.46
Drug OD	1/0	.99/.01	1/0	.94/.06	.53/.47

Cells show the probability of endorsing each response category broken down latent classes. Sample % = the proportion of sample in each latent class. First value in each cell is the probability of endorsing the first response category followed by probability of following subsequent responses after each slash. Alc = Alcohol, Can = Cannabis, Stim = Stimulants, Op = Opiates, Sed = Sedatives, Sx = diagnostic symptoms, Alc for Cocaine = Using alcohol to mitigate the effects of coming down from cocaine, Alc/Drug Interaction = individuals who had a negative interaction from mixing alcohol with another drug, + = the co-use of the two substances, Drug OD = Drug overdose.

despite having an AUD diagnosis, those in the “Low Problems” class actually have overall mild problematic substance use. Studies have shown that AUD criteria may diagnose individuals who actually have quite limited psychological dysfunction (Wakefield and Schmitz, 2015, 2014) and more stringent criteria should be considered to identify truly harmful alcohol/substance use. The second class identified was an “Alcohol Primary” class characterized by varying levels of alcohol use symptom severity (91% with AUD) and experimentation with cannabis and stimulants. Interestingly, the “Alcohol Primary” class only made up about 10% of the current sample. This is surprising given that the current sample was recruited primarily for individuals with alcohol misuse and simply allowed for co-occurring substance use. This highlights the importance of assessment of multiple substance use given the relative rarity of pathological alcohol use without significant levels of co-occurring use of other substances. The remaining three classes were consistent with previous literature that finds an additive pattern of polysubstance use starting with alcohol and cannabis use and then use of other illicit drugs such as stimulants, opiates, and sedatives (see

Connor et al., 2014 for review). This pattern of additive use may suggest that the identified classes are best conceptualized as meaningful slices of a general substance use severity dimension rather than truly discrete patterns of polysubstance use.

Multinomial regression results examined the association between age and personality traits associated with externalizing and internalizing disorders respectively. The “Alcohol Primary” class was chosen as the reference category in multinomial regressions to examine what distinguished more extreme polysubstance use from predominantly alcohol use alone. As shown in Table 4, the classes appeared very close in age with only the “Severe PSU” group being meaningfully older. This may indicate that the “Severe PSU” may simply be farther along in a developmental trajectory of severe substance use than other classes. Consistent with previous research (Agrawal et al., 2007), antisocial personality was a robust discriminator between classes, with the “Alcohol Primary” class have significantly higher levels of antisocial personality than the “Low Problems” group, but also significantly lower levels than the “Moderate PSU” and “Severe PSU” classes. A similar

Table 4
Multinomial Regression Results.

Measure	Alcohol Primary	Low Use	Alcohol + Can	Moderate PSU	Severe PSU
<i>n</i> (female)	213(92)	677(329)	537(299)	476(275)	195(120)
AUD Dx <i>n</i> (%)	193(91%)	163(24%)	367(68%)	346(73%)	145(74%)
CUD Dx <i>n</i> (%)	7(3%)	1(< 1%)	397(72%)	380(80%)	163(84%)
Drug Dx <i>n</i> (%)	14(7%)	0(0%)	26(5%)	251(53%)	188(96%)
Age (± SD)	21.67(2.45)	21.27(2.32)	21.24(2.38)	21.51(2.51)	23.84(3.66)
OR (<i>n</i> = 2098)	–	.94(.88, 1.0)*	.93(.88, .99)*	.98(.92, 1.04)	1.26(1.17, 1.34)
Antisocial (± SD)	7.65(5.81)	2.90(3.54)	7.85(6.12)	11.13(7.26)	17.90(8.88)
OR (<i>n</i> = 2094)	–	.77(.74, .80)	1.00(.98, 1.03)	1.08(1.05, 1.11)	1.19(1.15, 1.22)
Impulsivity (± SD)	9.80(4.65)	6.43(4.37)	9.07(4.48)	10.62(4.20)	12.37(4.18)
OR (<i>n</i> = 2018)	–	.84(.81, .88)	.97(.93, 1.00)	1.04(1.00, 1.08)*	1.15(1.09, 1.20)
Ex. Seeking (± SD)	5.95(2.24)	5.41(2.00)	6.32(2.25)	6.61(2.26)	7.15(1.98)
OR (<i>n</i> = 1826)	–	.90(.83, .97)**	1.08(1.0, 1.17)*	1.15(1.07, 1.26)	1.33(1.20, 1.48)
Anxiety (± SD)	42.09(10.49)	38.39(9.36)	40.05(8.90)	42.22(10.33)	46.61(10.74)
OR (<i>n</i> = 1810)	–	.96(.94, .98)	.98(.96, 1.00)*	1.00(.98, 1.02)	1.04(1.02, 1.06)
Neuroticism (± SD)	10.91(5.87)	7.55(5.19)	9.25(5.45)	10.95(5.59)	13.64(5.53)
OR (<i>n</i> = 1810)	–	.89(.87, .92)	.95(.92, .98)	1.00(.97, 1.03)	1.09(1.05, 1.13)

Dx = Diagnosis, AUD = Alcohol Use Disorder, CUD = Cannabis, Drug = other illicit drugs besides Cannabis, Antisocial = antisocial personality disorder measure, Ex. Seeking = Experience Seeking. The *n* value below each measure is the available *n* for each analysis. In the top row of each cell is the mean of the measure in each latent class along with standard deviation. Below is the Odds Ratio (OR) compared to the alcohol primary group for each given measure along with the 95% confidence intervals. The alcohol primary group served as the reference group for all analyses. Bolded values with asterisk are significant at $p < .001$, ** = $p < .01$, * = $p < .05$, non-bolded ORs = not significant at $p < .05$.

Table 5
Correlation of Personality Measures.

	Antisocial	Impulsivity	Ex. Seeking	Anxiety	Neuroticism
Antisocial	1.00	–	–	–	–
Impulsivity	0.46	1.00	–	–	–
Ex. Seeking	0.25	0.24	1.00	–	–
Anxiety	0.29	0.28	0.06*	1.00	–
Neuroticism	0.35	0.35	0.11	0.79	1.00

Pearson correlations. * = $p < .05$, not marked = significant at $p < .001$. Ex. Seeking = Experience Seeking.

pattern was observed with the measures of experience seeking and impulsivity. Overall, personality characteristics associated with externalizing pathology were lowest in the “Low Problems” class, and then increased in the “Alcohol Primary” and “Alcohol and Cannabis” classes, with the highest levels in the “Moderate PSU” and “Severe PSU” classes. Internalizing measures of personality (i.e. trait anxiety and neuroticism) were overall less strongly related to class membership than externalizing measures, however they did distinguish the highest severity class. Results indicated that the “Low Problems” class was associated with lower anxiety and neuroticism than the “Alcohol Primary” class. Only the “Severe PSU” class had higher levels of anxiety and neuroticism than the “Alcohol Primary” class. This supports the conceptualization that these classes are closely related to the general externalizing dimension of personality and pathology. Furthermore, individuals who struggle with both impulse regulation (e.g. substance use) and affect/anxiety regulation in tandem may be at particular risk to experience severe forms of psychopathology, in this case severe PSU.

Close examination of the latent class item probabilities in Table 3 (visually represented in Supplementary Figs. 1 and 2) shows several important insights related to polysubstance use patterns and co-use behaviors. Importantly, results demonstrate the importance in the assessment of multiple substances given that abuse of one substance is usually co-occurring with at least significant experimentation of other substances. The classes suggest an additive progression from alcohol and alcohol/cannabis, to introduction of stimulant, opiate, and sedative use, and eventually in some individuals’ harmful use of many substances. Therefore, experimentation with a class of drug associated with higher severity (e.g. opiates) mostly likely indicates already existing significant use of alcohol and cannabis. Furthermore, simultaneous co-

use items appear to be especially valuable markers of severity that discriminate between the identified classes. Simultaneous co-use of alcohol and cannabis was endorsed by about 50% of the current sample and interestingly is almost completely absent in the “Low Problems” and “Alcohol Primary” classes (see Table 4). This indicates that co-use of cannabis and alcohol is present in individuals who have at least had significant experimentation with both substances. Interestingly, moderate to high probability of simultaneous co-use of alcohol and any other illicit substance, co-use of cannabis with another illicit drug, or co-use of two illicit drugs besides cannabis were almost exclusively in the “Moderate PSU” and “Severe PSU” groups. This shows that simultaneous co-use of substances, with the exception of alcohol/cannabis, is an excellent indicator of high severity polysubstance use patterns. In summary, it appears that generally simultaneous co-use of substances is indicative of significant concurrent use of the given substances.

This study needs to be interpreted in light of its limitations. Given that the sample in the current study was collected for various studies of alcohol misuse and co-occurring externalizing problems, the current study likely has an underrepresentation of individuals with substance use problems in the absence of alcohol problems. Furthermore, the current study was not able to distinguish between abuse of prescription versus non-prescription drug use. The U.S. National Survey on Drug Use and Health reported that about 6% of Americans older than 12 years old have reported nonmedical prescription drug use (NMPDU) and 2.7% reported NMPDU in the past month (SAMHSA, 2013). Future work should aim to study NMPDU patterns of use and examine how these patterns compare to more commonly studied patterns of illicit drug use. The current study was only able to assess the co-use of two substances simultaneously. In addition, the current study is restricted to a sample of young adults (ages 18–30) and therefore may not generalize to patterns observed in for example older adults. The current study is also constrained by cross-sectional data. Future studies should examine the relative stability of these patterns across time and common progression from one class to the other. Given that a portion of the sample, for structural reasons, did not complete some personality measures, we chose to fit the LCA model with the full sample and then validate using a subset of the sample using multinomial regression. Simulation studies have shown that this approach may lead to down biased associations between measures and latent class membership (Vermunt, 2010), however we believe this approach allowed us to maximize our sample

for LCA estimation and present our results most clearly. Finally, LCA models have an assumption of local independence, meaning that there are not additional dependencies between items after accounting for class membership. Several studies have demonstrated that this may not always been practical in psychological research (Oberski et al., 2013; Reboussin et al., 2008). Future work should continue to analyze how these issues influence model estimation, however we believe given our consistency with previous findings our findings are unlikely driven by spurious effects caused by unaccounted for local dependence.

In summary, the current provides an illustration of common patterns of alcohol and illicit substance use in a large sample of high-risk young adults. Results indicated, consistent with previous research, that patterns of substance use are best conceptualized as increasingly severe additive substance use. Multinomial regression further validated this conceptualization by demonstrating the strong link between class membership and personality measures associated with externalizing pathology. Lastly, the current study demonstrates how simultaneous co-use behaviors serve as robust markers of severity that discriminate between different levels of polysubstance use.

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Contributors

All authors have read and approved the manuscript for submission to Drug and Alcohol Dependence; have made a substantial contribution to the conception, design, data collection, data analysis and data interpretation and a contribution to the writing and intellectual content of the article; and acknowledge that they have exercised due care in ensuring the integrity of the work.

Declaration of Competing Interest

No conflict declared.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.drugalcdep.2019.107656>.

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