Relations Among Adolescent Alcohol and Cannabis Co-Use, Adolescent Impulsive Traits, and Prospective Change in Impulsive Traits into Emerging Adulthood

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ABSTRACT

Models of personality suggest that adolescent substance use may be associated with adolescent impulsive traits as well as changes in impulsive traits from adolescence into emerging adulthood. However, little research has focused on how adolescent alcohol and cannabis co-use, an increasingly popular and risky substance use pattern, may relate to adolescent impulsive traits as well as changes in impulsive traits from adolescence to emerging adulthood. Therefore, the current study tested patterns of adolescent co-use and their links with adolescent impulsive traits and changes in impulsive traits into emerging adulthood. Data come from the Add Health study and encompassed two timepoints spanning adolescence (age 13-18) and emerging adulthood (age 19-25). A combination of latent profile analysis, mean comparisons, and latent difference scores were estimated. Results suggested that four profiles of co-users and alcohol-only users emerged, and profiles differed in levels of adolescent personality and prospective personality change. Importantly, frequent adolescent co-users had higher levels of adolescent sensation seeking and impulsivity, but also reported the steepest decline in both traits into emerging adulthood. Findings are discussed in terms of personality theory and public health implications.

Key words: = impulsivity; sensation seeking; personality change; co-use; alcohol use; cannabis

Alcohol and cannabis are the most frequently used psychotropic drugs in the U.S. (NIDA, 2020), and remain significant public health concerns. Rates are on the rise (Grant et al., 2017; Hasin, 2018; Meich et al., 2023; NIDA, 2020), and each are associated with adolescent and young adult negative consequences such as cognitive decline, impaired driving, and medical/mental health comorbidities (Cole & Saitz, 2020; Perkins et al., 2002; Meier et al., 2012; Volkow et al., 2014). Nevertheless, the co-use of alcohol and cannabis, defined as using both alcohol and cannabis at the same time [simultaneous use] or using both separately within a given time period [concurrent use]; Gunn et al., 2018; Gunn et al., 2022; Yurasek et al., 2017), confers risk for negative consequences (e.g., Green et al., 2019; Wardell et al., 2020; Waddell et al., 2021a; 2021b) and development of alcohol use disorder (AUD; e.g., Midanik et al., 2007; Waddell, 2021) above and beyond levels of drinking and demographic (age, sex) and psychosocial factors (e.g., family history of AUD, expectancies; Waddell, Blake, & Chassin, 2021; Waddell, Jager, & Chassin, 2022). Furthermore, rates of alcohol and cannabis co-use continue to rise in adolescents/young adults (e.g., McCabe et al., 2021), and thus it is vital to understand predictors and consequences of co-use to target via early age prevention efforts.

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Substance Use and Impulsive Personality Traits

Decades of research suggests that generalized impulsivity, defined as rash action with little regard for future consequences (Moeller et al., 2001), is cross-sectionally and prospectively associated with heavier alcohol and cannabis consumption in adolescents, young adults, and adults (e.g., Dick et al., 2010; Henges & Marczinkski, 2012; Stautz & Cooper, 2013; Waddell et al., 2021c; Wiers et al., 2010). Similarly, sensation seeking, defined as thrill and/or rewarding seeking (Zuckerman, 2007), is associated with substance use across developmental stages (e.g., Andrew & Cronin, 1997; Donohew et al., 1999; Kaynak et al., 2013; Magid et al., 2007; Waddell, Elam, & Chassin, 2022). Meta-analyses in adults and adolescents for both substances suggest that generalized impulsivity facets (e.g., a lack of premeditation and perseverance) were strongly associated with heavier alcohol and cannabis use, whereas sensation seeking was strongly associated with use frequency and any use (e.g., Coskunpinar et al., 2013; VanderVeen et al., 2016).

Despite robust literature on associations between impulsive personality traits and single substance use, relations between impulsive personality traits and alcohol and cannabis co-use are less often studied. Some studies suggest that adult and adolescent dual- and poly-substance users report higher levels of generalized impulsivity (Hammers & Suhr, 2010; Veredgo-Garcia et al., 2010), and some suggest that alcohol and cannabis co-users report higher levels of sensation seeking (Linden-Carmichael et al., 2019a; Koller et al., 2015). However, a recent study tested both late adolescent generalized impulsivity and sensation seeking as competing correlates of alcohol and cannabis co-use, which previous studies had not, and found that sensation seeking (but not impulsivity) was cross-sectionally related to adolescent alcohol and cannabis co-use (Waddell et al., 2021a). Put together, these studies indicate that adolescent heavier single substance use may be associated with generalized impulsivity, whereas frequency of use and/or co-using alcohol and cannabis together may be associated with adolescent sensation seeking.

However, no studies to date have tested whether there are differences in impulsive personality in certain alcohol and cannabis co-users from alcohol-only users during adolescence, as well as whether higher-risk co-using adolescents differ from other adolescent alcohol and cannabis co-users who have differing levels of use. One possibility is that adolescents who co-use alcohol and cannabis, regardless of frequency, may report higher sensation seeking, as the act of using two substances, even infrequently or rarely, may be perceived as thrilling and exciting. It is also possible, though, that more frequent adolescent use of alcohol and cannabis may be related to sensation seeking, considering strong links between frequency of single substance use and sensation seeking in adolescent and adult studies (Coskunpinar et al., 2013; VanderVeen et al., 2016).

Substance Use and Impulsive Personality Change

Furthermore, links between substance use and impulsive personality traits are more complex than a one-to-one directional effect. Although personality is thought to be a relatively stable construct, modern models of personality suggest shifts in personality across the lifespan, particularly during adolescence and emerging adulthood (McCrae & Costa, 1994; McCrae et al., 1999). Neurodevelopmental Imbalance and Dual Systems theories purport that adolescence is a time of peak levels of sensation seeking and impulsivity, due to increased reward-seeking in adolescence and later, more slowly developing top-down cognitive control (e.g., Defoe et al, 2019; Steinberg et al., 2010; Wasserman et al., 2020). These theories suggest normative declines in sensation seeking and impulsivity after adolescence, however there are several factors that may influence personality change over time, such as substance use.

One model of change proposed by Caspi et al. (2005) highlights the corresponsive principle, which asserts that personality traits that drive specific behaviors are strengthened and reinforced by engaging in the target behavior (i.e., substance use). Indeed, several studies have found that substance use, particularly alcohol, is a strong predictor of personality change into adulthood, particularly impulsivity (e.g., Ashenhurst et al., 2015; Littlefield et al., 2009; 2010; Hakulinen & Jokela, 2019). However, developmental timing plays an important role in

the prediction of personality change from substance use. For instance, Quinn & Harden (2013) found that age 15 heavier drinking was associated with less of a decrease in impulsivity and sensation seeking from age 15 to age 26. In addition, Quinn et al. (2012) found that age 17-19 heavier drinking was associated with increases in sensation seeking and impulsivity 4 years later. Nevertheless, it remains unclear whether the co-use of alcohol and cannabis in adolescence predicts personality change into emerging adulthood above and beyond levels of alcohol use. Considering undoubted links between adolescent sensation seeking and alcohol and cannabis co-use (e.g., Linden-Carmichael et al., 2019a; Waddell et al., 2021a), theory may suggest that higher risk alcohol and cannabis co-use in adolescence, characterized by frequent alcohol and cannabis use together either concurrently or simultaneously, may predict increased levels of sensation seeking into emerging adulthood.

The Current Study

Therefore, the current study tested whether alcohol and cannabis co-use (compared to alcohol-only use) was associated with higher levels of impulsivity and sensation seeking during adolescence, and whether adolescent alcohol and cannabis co-use was related to changes in personality from adolescence into emerging adulthood. The current study used two timepoints spanning adolescence (13-18 years old) and emerging adulthood (19-25 years old). Theory suggests that adolescence is a critical period to study the development and stability of personality traits (e.g., DeFoe et al., 2019; Steinberg et al., 2010), and that personality traits become stable during adulthood (Roberts et al., 2006). Thus, the current study tested effects during the transition from adolescence into emerging adulthood, a time of potentially rapid personality and behavior change. Furthermore, the current study used mixture modeling to obtain profiles of adolescent alcohol and cannabis co-users rather than using a dichotomy of any alcohol and cannabis co-use like previous studies have (e.g., Linden-Carmichael et al., 2019a; Waddell et al., 2021a). Investigating data-driven profiles of alcohol and cannabis co-use allows for a better test of the corresponsive principle (e.g., Caspi et al., 2005), as this allowed the current study to 1) differentiate adolescent

alcohol and cannabis co-users along a continuum rather than creating a dichotomy, 2) differentiate adolescent alcohol and cannabis co-users and alcohol-only users based upon their frequency of both alcohol use, binge drinking, and cannabis use as well as whether participants used both simultaneously (i.e., at the same time), and 3) use several variables to create categories of adolescent alcohol and cannabis co-use and alcohol-ony use rather than creating categories from a singular variable (i.e., cannabis use in alcohol users; see Lanza et al., 2022 for more details on mixture modeling of alcohol and cannabis co-use).

It was hypothesized that 4+ classes of substance users would emerge from analyses, representing lower risk alcohol-only users, higher risk alcohol-only users, lower risk alcohol and cannabis co-users, and higher risk co-users in adolescence (e.g., Waddell, 2022). Second, assuming these profiles were found, it was hypothesized that both classes of adolescent alcohol and cannabis co-users would report higher sensation seeking cross-sectionally, whereas higher risk adolescent alcohol-only users would report higher generalized impulsivity cross-sectionally. Finally, it was hypothesized that the higher-risk adolescent alcohol and cannabis co-users (i.e., more frequent, heavier use) would report increases in sensation seeking from adolescence to emerging adulthood.

METHODS

Participants

The current study used publicly available data from the National Longitudinal Study on Adolescent to Adult Health (Add Health). Add Health is a longitudinal survey that followed a representative cohort of United Stated high schoolers across four waves of data collection into adulthood. At Wave 1 (1994-1995), high schools around the U.S. were contacted about participation, and students within schools that consented answered a variety of questionnaires related to development, health, and wellbeing. Participants were followed up approximately one year later (Wave 2; 1996), and then again approximately five (Wave 3; 2001-2002) and ten (Wave 4; 2007-2008) years later. The current study used data from waves 2 and 3 to test changes in personality from adolescence into

emerging adulthood. Retention was 74.3% from wave 1 to wave 2, and 75.1% from wave 1 to wave 3. Participants who were age 13-18 at wave 2 and 19-25 at wave 3 were included. Furthermore, considering the current study focused on alcohol use, alcohol and cannabis co-use, and personality, participants for the current study were only included if they endorsed drinking alcohol. Participants (N=3,277) were a mean age of 16.43 (SD= 1.40) in adolescence and 21.34 (SD = 1.45) in emerging adulthood, were 52.9% female, and 32.5% reported being an ethnic/racial minority.

Measures

Demographics. Participants' age during adolescence (13-18) and sex (male vs. female) were assessed and included as covariates.

Alcohol Use. The current study assessed past-year alcohol use frequency and binge drinking frequency during adolescence. Participants were asked, "during the past 12 months, on how many days did you drink alcohol?" and "over the past 12 months, on how many days did you drink five or more drinks in a row" on a scale of 1 (every day or almost every day) to 7 (never). Items were reverse-scored so that higher scores indicated heavier drinking, and rescored on a scale of 0 (never) to 6 (every day or almost every day).

Cannabis Use. Adolescent cannabis use frequency was assessed by asking participants, "During the past 30 days, how many times have you used marijuana?" with responses ranging from 0 to 500 times; all values 30+ were coded as 30, such that a times per month cannabis was used (0 to 30+) variable was created. This variable has been used in other Add Health studies (e.g., Deutsch et al., 2020).

Simultaneous Alcohol and Cannabis Use. Adolescent simultaneous alcohol and cannabis use was assessed by asking participants, "Since [the last assessment one year ago], have you drunk alcohol when you were using drugs?", and "The most recent time you drank alcohol when you were using drugs, what kind of drugs were you using?", with marijuana as the first option.

Impulsive Personality Traits. Three items were used to measure impulsive personality traits. In adolescence, participants were asked to respond to the following items: "When making decisions, you usually go with your 'gut feeling' without thinking too much about the

consequences of each alternative", "You live your life without much thought for the future", and "You like to take risks" on a scale of (1) strongly agree to (5) strongly disagree. In emerging adulthood, participants were asked to respond to the following items: "You go with your "gut feeling" and don't think much about the consequences of each alternative", "you live your life without much thought for the future", and "you like to take risks" on a scale of (1) strongly agree to (5) strongly disagree. Thus, the wording for the "gut feeling" item slightly changed from adolescence to emerging adulthood, however measured the same construct on the same scale; this item has been used in other Add Health longitudinal research (e.g., Converse et al., 2018). Items were reverse scored so that higher levels were indicative of more impulsivity.

Several measurement models of personality with these items were considered. First, an overarching 'behavioral undercontrol" model (e.g., Sher et al., 1991) was considered where all three items loaded onto one latent factor. To test the structure and fit of this model, a measurement model was estimated where each item was specified onto a latent factor during adolescence and emerging adulthood, and latent factors across time points were allowed to freely covary. In addition, each of the three items were allowed to freely covary within timepoint. This model fit the data well (X2 (5) = 14.45, p = .01, RMSEA = .024, CFI = .99, TLI = .97, SRMR = .014). However, the factor loadings for "gut feeling" (adolescent b = .67, p < .001; emerging adult b = .60, p < .001) and "little thought for the future" (adolescent b = .50, p < .001; emerging adult b = .54, p < .001) were substantially higher than risk taking/sensation seeking (adolescent b = .39, p < .001, emerging adult b = .41, p < .001).

A second model was considered where (1) "gut feeling" and (2) "little thought for the future" were specified as indicators of a latent variable, whereas risk taking/sensation seeking was a single item. This model fits more in line with the dual systems model (Steinberg et al., 2008) and UPPS-P (Whiteside & Lynam, 2001), suggesting that sensation seeking/risk taking is a separate, yet correlated, personality construct. For the second model, since there were only two indicators of the latent variable, model constraints were used to extract the commonality between the two items. Furthermore, sensation seeking was

allowed to freely covary with the latent variable at the cross-sectional time point, and each of the three items were allowed to freely covary within timepoint. This model also fit the data well ($X2$ (7) = 64.74, p < .001, RMSEA = .05, CFI = .95, TLI = .90, SRMR = .047). The factor loadings for "gut feeling" and "little thought for the future" were high during adolescence (b = .58, p < .001) and emerging adulthood (b = .56, p < .001), and the latent factor was moderately correlated with sensation seeking in adolescence (r = .31, p < .001) and emerging adulthood (r = .34, p < .001).

Ultimately, the second model had higher factor loadings and was more in line with contemporary theory (Steinberg et al., 2008; Whiteside & Lynam, 2001) and past Add Health studies (Peach & Gaultnety, 2013; Lydon-Staley & Geier, 2018). Thus, impulsivity and sensation seeking/risk taking were treated as separate constructs[1]. The two-item combination will be referred to as impulsivity and sensation seeking/risk taking will be referred to as sensation seeking.

Data Analytic Plan

The current study used a combination of mixture modeling and structural equation modeling to test 1) patterns of alcohol and cannabis use during adolescence, 2) whether adolescent patterns of alcohol and cannabis use differentiate adolescent levels of impulsive traits, 3) the directionality of change in impulsive personality traits from adolescence to emerging adulthood, and 4) whether patterns of alcohol and cannabis use during adolescence are associated with prospective changes in personality from adolescence into emerging adulthood. Across all aims, full information maximum likelihood (FIML) was used to estimate missing data.

Aim 1:

First, a latent profile analysis of adolescent alcohol and cannabis use was estimated. Latent profiles were comprised of four variables representing one's alcohol use frequency (continuous), binge drinking frequency (continuous), cannabis use frequency (continuous), and simultaneous use of alcohol and cannabis (binary; yes/no). Thus, the latent profiles consisted of average means of continuous variables and likelihood of endorsing simultaneous use since it was a binary variable; likelihood above 50% was considered higher likelihood of reporting a 1 (i.e., simultaneous use) compared to 0 (i.e., no simultaneous use). All models were run with 50 random starts, and solutions with 1-6 profiles were considered. Latent profile enumeration was decided based upon both statistical and theoretical fit of latent profiles. Aikake Information Criteria (AIC) values, Bayesian Information Criteria (BIC) values, entropy values, the Lo-Mendell Rubin Adjusted Likelihood Ratio (LLR) test (Nylund et al., 2007) were used as indices of model fit. Smaller AIC/BIC values and higher entropy values are indicative of better model fit, and entropy values greater than .80 indicate adequate class separation (Bolck et al., 2004). A significant LLR test also suggests better fit than the previous solution (Nylund et al., 2007).

Aim 2:

Once the optimal profile solution was decided upon, we tested cross-sectional relations among profiles of alcohol and cannabis use and impulsive personality traits. We used the manual 3-step Bolck, Croon, and Hagenaars (BCH; Bolck et al., 2004) approach to examine profile differences in cross-sectional impulsive personality traits reported during adolescence. The BCH method provides estimates of mean differences in variables of interest (i.e., impulsive personality traits) by estimating singular pairwise differences among distal means within each profile. The BCH method takes into account classification error by assigning individuals to their most likely latent profile while also accounting for posterior probabilities. To execute pairwise comparisons, the model constraint command in MPlus was used

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[1]Although model fit comparisons are the typical way of comparing two models statistically, model fit comparisons were not appropriate for these models. Considering the complexity of modeling a latent variable with 2 indicators, several constraints were required to accurately parse out the commonality of the two items, and these constraints were not present in the 3-indicator latent variable model. In addition, a correlation between sensation seeking and the latent factor for each variable was specified in the 2-indicator latent variable model, which also was not present in the 3-indicator latent variable model. Thus, the two models were not fully nested, and the additional constraints of the 2-indicator model naturally would have led to a decrement in model fit. Rather, the current study used factor loadings and theoretical fit to decide on the optimal modeling approach for personality items.

to test whether the means of each impulsive personality trait within profiles differed from one another.

Aim 3:

Latent difference scores were estimated to test the directionality of change in impulsive personality traits. Latent difference scores were estimated in the following fashion: 1) the factor loading of the emerging adult value onto the difference score was set to one, 2) the regression of the emerging adult value on the adolescent value was set to one, 3) the correlation between the young adult value and the adolescent value was set to zero, 4) the variance of the emerging adult value was set to zero, 5) the intercept of the emerging adult value was set to zero while the intercept of the adolescent value was allowed to freely covary, and 6) the latent change score was correlated with the adolescent value. This approach effectively tests change from adolescence to young adulthood, which diverges from basic computed change scores in that the model-based error component is separate from the latent change parameter (McArdle & Grimm, 2010). Standardized betas are reported for univariate latent difference scores.

Aim 4:

Finally, we used a combination of the manual BCH method and latent difference scores to estimate whether adolescent alcohol and cannabis use profiles predicted personality change from adolescence into emerging adulthood. Thus, each profile vs. one another was estimated as a predictor of change in personality traits. In these models, adolescent age and sex were covaried and allowed to freely covary. In line with other models of alcohol use and personality change (Luchetti et al., 2018; Stephan et al., 2018), predictors of latent change scores will be interpreted in the direction of change. Thus, if a construct increases over time, a positive coefficient will be interpreted as an "more of an increase", whereas a negative coefficient will be interpreted as a "less of an increase". However, if a construct decreases over time, a positive coefficient will be interpreted as "less of a decrease", whereas a negative coefficient will be interpreted as "more a decrease".

RESULTS

Aim 1: Characterizing Patterns of Alcohol and Cannabis Co-Use

Latent profile solutions were fit starting with a 1-profile model through a 6-profile model (see Table 1). AIC and BIC values declined from the 1-profile through 6-profile solutions, and ΔBIC appeared to level off after the 4-profile solution. Entropy values remained high across all solutions (entropy>.948), and the LLR test was significant for the 2-profile (p<.001), 3-profile solutions (p<.001), and 4-profile solutions (p=.005). The 1- through 4-profile solutions all had >100 participants per profile, whereas the 5- and 6-profile solutions had profiles with as low as 2% of the sample. In addition, the 4-profile solution showed a substantial drop in AIC and BIC values, entropy, suggesting better fit than the 3-profile solution. Thus, we deemed the 4-profile solution to be the optimal fit to the data.

Profiles are described as follows: low-risk alcohol-only users (i.e., "alcohol only users"; N=2459, 75%), higher-risk alcohol users who experiment with cannabis (i.e., "experimental co-users"; N=581, 18%), higher-risk alcohol users who regularly use cannabis (i.e., "regular co-users"; N=116, 4%), and higher-risk alcohol users who very frequently use cannabis (i.e., "frequent co-users"; N=121, 4%). Alcohol-only users used alcohol occasionally (M=.84, SE=.05), but not did not use cannabis (M=.19, SE=.02) nor binge drink (M=.26, SE=.02). Experimental co-users reported monthly-to-weekly alcohol use (M=3.57, SE=.07) and binge drinking (M=3.31, SE=.14), but reported very infrequent cannabis use (M=.95, SE=.10) that had a low likelihood of being simultaneous with alcohol (28.3% likelihood). Regular co-users reported monthly-to-weekly alcohol use (M=3.30, SE=.16) and binge drinking (M=2.73, SE=.20), however reported using cannabis on average about 13.7 (SE=.54) times monthly and a high likelihood of using both simultaneously (67.2% likelihood). Frequent co-users reported monthly-to-weekly alcohol use (M=3.27, SE=.15) and binge drinking (M=2.80, SE=.19) and reported using cannabis on average 28.69 (SE= .32) times monthly and a high likelihood of using both simultaneously (64.8% likelihood; see Figure 1).

Table 1. *Model Fit Statistics for Latent Profile Analysis*

	AIC	BIC	ΔBIC	Entropy	Class Size (%)	LMR
1-class	47387.50	47430.16	---	1.000	100	---
2-class	41334.93	41408.07	6,022.09	.991	94, 6	< .001
3-class	37827.70	37931.31	3,477.39	.948	75, 19, 6	< .001
4-class	**35446.89**	**35580.97**	**2,350.34**	**.954**	**75, 18, 4, 4**	**.005**
5-class	34116.83	34281.39	1,299.58	.955	74, 16, 4, 4, 2	.29
6-class	32888.28	33.083.31	1,198.08	.960	73, 15, 5, 3, 3, 2	.13

Note. LMR = Lo-Mendell Rubin Loglikelihood Ratio Test; The 4-class solution was deemed to have the best statistical and theoretical fit.

Figure 1. *Latent Profile Analysis of Adolescent Alcohol and Cannabis Use*
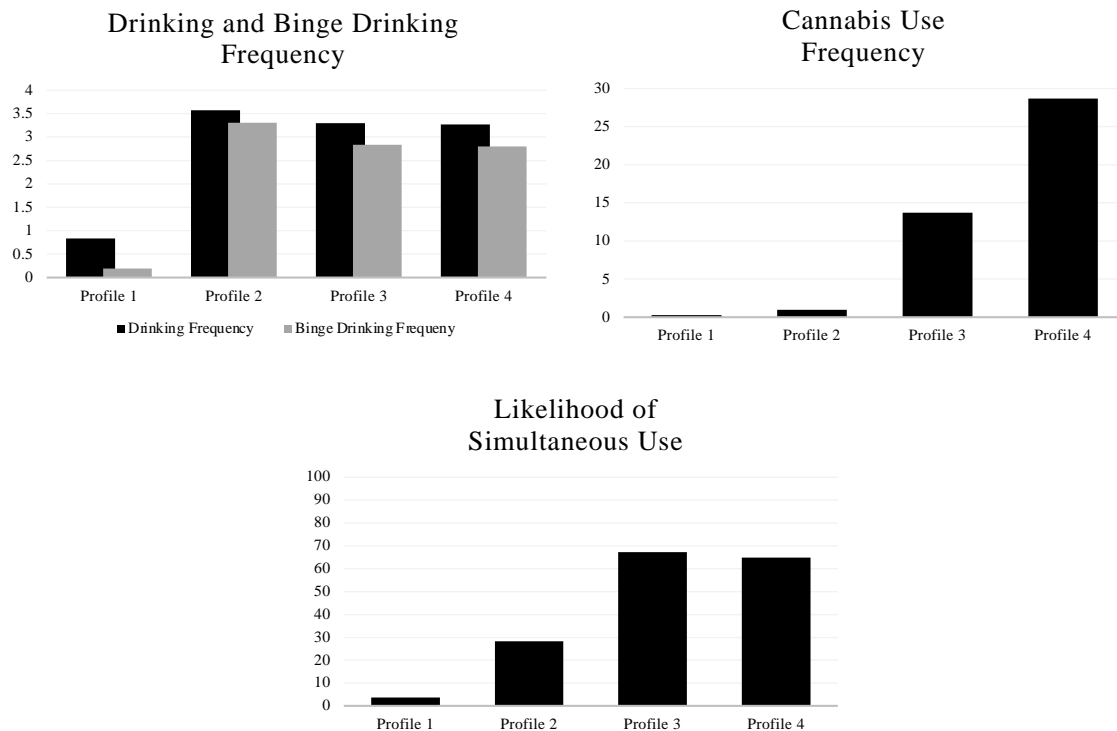
Note. Profiles were named the following: alcohol-only users (profile 1; 75% of sample), experimental co-users (profile 2; 18% of sample), regular co-users (profile 3; 4% of sample), and frequent co-users (profile 4; 4% of sample); N=2459 alcohol-only use, N=581 experimental co-use, N=116 regular co-use, N=121 frequent co-use.

Aim 2: Mean Differences in Impulsive Personality Traits During Adolescence

Frequent adolescent co-users (class 4) had higher levels of adolescent sensation seeking and impulsivity compared to alcohol-only users and experimental co-users, but did not differ in levels of adolescent sensation seeking nor impulsivity from regular co-users. Regular adolescent co-users reported higher levels of adolescent sensation seeking and impulsivity compared to alcohol-only users but did not differ in adolescent sensation seeking nor impulsivity from experimental co-users. Finally, experimental adolescent co-users reported significantly higher levels of adolescent sensation seeking and impulsivity compared to alcohol-only users (see Tables 2 and 3).

Table 2. *Mean Values for Adolescent and Emerging Adult Sensation Seeking and Impulsivity Among Profiles*

	Sensation Seeking		Impulsivity	
	Adolescent Mean	Emerging Adult Mean	Adolescent Mean	Emerging Adult Mean
Alcohol-Only	3.541	3.465	2.597	2.461
Experimental Co-Use	3.804	3.633	2.883	2.613
Regular Co-Use	3.946	3.418	3.078	2.679
Frequent Co-Use	4.08	3.568	3.150	2.858

Note. Sensation seeking was measured on a scale of (1) strongly disagree to (5) strongly agree; alcohol use frequency and binge frequency were largely identical across the three classes of co-users, with the main differentiating variable being cannabis frequency (see Figure 1); N=2459 alcohol-only use, N=581 experimental co-use, N=116 regular co-use, N=121 frequent co-use.

Table 3. *Mean Differences in Adolescent Sensation Seeking and Impulsivity Among Profiles*

Sensation Seeking	Mean Diff.	SE	*p-value*
Alcohol-only vs. Experimental Co-Use	.257	.060	< .001
Alcohol-only vs. Regular Co-Use	.404	.101	< .001
Alcohol-only vs. Frequent Co-Use	.558	.087	< .001
Experimental Co-Use vs. Regular Co-Use	.147	.124	.263
Experimental Co-Use vs. Frequent Co-Use	.301	.086	< .001
Regular Co-Use vs. Frequent Co-Use	.154	.137	.263
Impulsivity	Mean Diff.		*p-value*
Alcohol-only vs. Experimental Co-Use	.289	.050	< .001
Alcohol-only vs. Regular Co-Use	.470	.087	< .001
Alcohol-only vs. Frequent Co-Use	.569	.091	< .001
Experimental Co-Use vs. Regular Co-Use	.181	.098	.065
Experimental Co-Use vs. Frequent Co-Use	.280	.094	.003
Regular Co-Use vs. Frequent Co-Use	.099	.115	.388

Note. Models controlled for age and sex in the prediction of latent difference scores; N=2459 alcohol-only use, N=581 experimental co-use, N=116 regular co-use, N=121 frequent co-use.

Table 4. *Mean Differences in Latent Change of Sensation Seeking and Impulsivity Among Profiles*

Sensation Seeking	*Mean Diff.*	*SE*	*p-value*
Alcohol-only vs. Experimental Co-Use	.135	.066	.041
Alcohol-only vs. Regular Co-Use	.373	.125	.003
Alcohol-only vs. Frequent Co-Use	.465	.111	< .001
Experimental Co-Use vs. Regular Co-Use	.238	.146	.104
Experimental Co-Use vs. Frequent Co-Use	.330	.114	.004
Regular Co-Use vs. Frequent Co-Use	.092	.153	.546
Impulsivity	*Mean Diff.*	*SE*	*p-value*
Alcohol-only vs. Experimental Co-Use	.151	.047	.002
Alcohol-only vs. Regular Co-Use	.208	.115	.071
Alcohol-only vs. Frequent Co-Use	.248	.099	.012
Experimental Co-Use vs. Regular Co-Use	.057	.130	.659
Experimental Co-Use vs. Frequent Co-Use	.098	.100	.327
Regular Co-Use vs. Frequent Co-Use	.041	.145	.778

Note. Models controlled for age and sex in the prediction of latent difference scores; N=2459 alcohol-only use, N=581 experimental co-use, N=116 regular co-use, N=121 frequent co-use.

Aim 3: Change in Personality from Adolescence to Emerging Adulthood

Latent change scores for sensation seeking and impulsivity were estimated alongside one another. Both latent change parameters showed significant change from adolescence to emerging adulthood, such that levels of sensation seeking (b = -.13, SE = .03, p < .001) and impulsivity (b = -.17, SE = .02, p < .001) decreased from adolescence to emerging adulthood.

Aim 4: Co-Use Profiles as Predictors of Personality Change

The rate of decrease in sensation seeking from adolescence to emerging adulthood was higher for frequent adolescent co-users compared to alcohol-only and experimental co-users but not regular co-users. Similarly, the rate of decrease in sensation

seeking from adolescence to emerging adulthood was higher for regular adolescent co-users compared to alcohol-only but not experimental co-users, and the rate of decrease in sensation seeking from adolescence to emerging adulthood was higher for experimental co-users compared to alcohol-only users.

The rate of decrease in impulsivity from adolescence to emerging adulthood was higher for frequent adolescent co-users and experimental co-users compared to alcohol-only users. However, no other pairwise comparisons were statistically significant (see Table 4).

DISCUSSION

The current study aimed to examine whether adolescent alcohol and cannabis co-use was cross-sectionally and prospectively associated with impulsive personality traits, namely impulsivity and sensation seeking. The current study also sought to use a finite mixture modeling approach to differentiate adolescent co-users, which previous research has largely considered a dichotomy (0=non-co-user, 1=co-user).

There were several major findings. First, the mixture model suggested that a four-profile solution fit the data best: profiles were indicative of adolescent lower-risk alcohol-only use (i.e., alcohol-only use), higher-risk alcohol use with experimental cannabis use (i.e., experimental co-users), higher-risk alcohol use with regular cannabis use (i.e., regular co-users), and higher-risk alcohol use with frequent cannabis use (i.e., frequent co-users). Second, pairwise comparisons suggested that frequent adolescent co-users and regular co-users had the highest cross-sectional levels of sensation seeking and impulsivity. Furthermore, frequent adolescent co-users had significantly higher cross-sectional levels of sensation seeking and impulsivity than all adolescent groups except regular co-users, and both regular and experimental co-users had higher levels of adolescent sensation seeking and impulsivity than alcohol-only users. Lastly, and surprisingly, frequent adolescent co-users reported steeper declines in sensation seeking from adolescence into emerging adulthood compared to all profiles except regular co-users, and both regular and experimental adolescent co-users reported steeper declines in sensation seeking from adolescence into emerging

adulthood compared to alcohol-only users. Frequent co-users and experimental co-users also declined in impulsivity from adolescence into emerging adulthood at higher rates than alcohol-only users.

Findings related to the mixture model were largely in line with hypotheses. However, rather than a higher-risk adolescent alcohol-only profile emerging, a higher-risk adolescent alcohol use profile who experimentally used cannabis emerged. All adolescent co-user profiles examined had relatively similar rates of alcohol use and binge drinking, and thus the primary differentiating variable was cannabis use. Furthermore, experimental adolescent co-users reported using cannabis an average about 1 time over the past month, regular co-users reported using cannabis an average of about 13.7 times over the past month, and frequent co-users reported using cannabis an average of 28.7 times over the past month. Expectedly, both the adolescent regular (i.e., 14 times a month) and frequent (i.e., 28 times a month) profiles reported a higher probability of using alcohol and cannabis simultaneously. Thus, we believe this mixture model represents stronger measurement of adolescent co-use compared to some past studies, as experimental, regular, and frequent co-users would have all been treated the same in an analysis dichotomizing co-use as 0 = no co-use, 1 = co-use.

Cross-sectionally, hypotheses related to personality differences in adolescence were largely supported. Thus, regular and frequent adolescent co-users reported higher levels of adolescent sensation seeking and impulsivity during adolescence compared to experimental co-users and alcohol-only users. In addition, experimental adolescent co-users reported higher levels of adolescent sensation seeking and impulsivity compared to alcohol-only users. There were no pairwise differences between regular and frequent adolescent co-users, nor between regular and experimental co-users, though, in adolescent sensation seeking nor impulsivity. Findings replicate previous research suggesting that adolescent co-users have higher adolescent levels of sensation seeking and generalized impulsivity compared to alcohol-only users (e.g., Hammers & Suhr, 2010; Koller et al., 2015; Waddell et al., 2021a). Thus, adolescent co-users, from the continuum of experimental to frequent co-use, had

higher levels of both traits in adolescence compared to alcohol-only users. However, frequent adolescent co-users also had higher levels of both traits in adolescence compared to experimental co-users. On the contrary, both regular and frequent adolescent co-users did not differ in levels of either trait in adolescence. This is likely because both groups reported higher likelihood of simultaneous use in adolescence, which past research has suggested is related to heightened sensation seeking (Linden-Carmichael et al., 2019a). Put together, findings point to a complex mix of between- and within-group findings, as frequent adolescent co-users had higher levels of adolescent sensation seeking and impulsivity compared to both alcohol-only users (i.e., between-group) *and* experimental co-users (i.e., within-group). Previous research found between-group and within-group variability in relations between co-use (i.e., co-users vs. alcohol user, within co-users) and AUD (Waddell, 2021; Waddell, 2022) as well, and thus the current study points to personality as an important variable to target in mechanistic studies. In addition, providers may consider attending to sensation seeking and impulsive tendencies when working with adolescent co-users in a clinical setting when evaluating potential risk factors and intervention targets.

Prospectively, the current study found the opposite effect as hypothesized related to changes in personality traits. All three profiles of adolescent co-users reported steeper declines in sensation seeking into emerging adulthood compared to alcohol-only users, and frequent adolescent co-users also reported steeper declines into emerging adulthood compared to experimental co-users. Considering Caspi (2005)'s model of personality would suggest that adolescent co-use should increase one's sensation seeking, these findings were a bit surprising. There are several explanations, however, for these surprising yet important finding. First, considering adolescence is a time of peak sensation seeking (e.g., Defoe et al., 2019; Steinberg et al., 2010), it is not uncommon to observe a general trend in which sensation seeking levels decline over time. Furthermore, considering co-use is cross-sectionally related to sensation seeking, both in the current study and in past studies (e.g., Linden-Carmichael et al., 2019a; Waddell et al., 2021a), one interpretation

of findings may be that adolescent co-users already have such high levels of sensation seeking in adolescence that there is much more room to decline over time. This is supported by the cross-sectional analyses, showing that all adolescent co-users had higher levels of sensation seeking and impulsivity, and that frequent adolescent co-users also had higher levels of adolescent sensation seeking compared to experimental co-users and alcohol-only users. Second, it is possible that the measurement focus on risk taking within trait sensation seeking lead to high reporting endorsement of sensation seeking in this sample. Specifically, adolescents in the co-use profile may have been more likely to endorse high levels of risk taking that is captured in our measurement of sensation seeking, contributing to the ultimate finding. Although risk taking is a predominant theme in the construct of sensation seeking, changes in other aspects of sensation seeking, such as thrill/reward seeking, may be more related to co-use. Thus, adolescent past-year co-users may already have peak levels of risk taking, but they have more room to increase/grow in thrill/reward seeking behaviors that are less proximal during adolescence (e.g., parachute jumping, flying an airplane). Therefore, future research is needed to test study findings with larger measures of sensation seeking that consider multiple domains of the construct.

Similar to co-use and changes in sensation seeking, profiles indicative of frequent adolescent co-use and experimental co-use were associated with a steeper decline in impulsivity into emerging adulthood. Thus, findings were largely in line with sensation seeking findings, except that there were no pairwise differences between regular adolescent co-users and alcohol-only users in their rate of decline in impulsivity into emerging adulthood. Nonetheless, a similar explanation may be present as above, such that adolescents in profiles 2 and 4 reported higher levels of impulsivity in adolescence compared to alcohol-only users, leaving more room to decline into emerging adulthood. Importantly, it is surprising, though, that the regular adolescent co-use profile did not follow a similar pattern of analyses. Although the magnitude of mean differences was similar to that of experimental adolescent co-use, there was more error around this estimate worthy of further replication and extension. Thus, future research is needed to

affirm this pattern of findings. Clinically, the findings related to both sensation seeking and impulsivity changes from adolescents to emerging adulthood point to potentially important targets for interventions, especially adolescents engaging in frequent co-use. Clinicians should consider evaluating these traits in addition to substance use behavior at the beginning of treatment.

While the current study represents the first to examine relations among patterns of alcohol and cannabis use and cross-sectional impulsive traits as well as prospective change in impulsive traits, it is not without its limitations. One limitation to consider is the use of only three items to evaluate impulsive personality traits, as opposed to a full measure or screener. While single items or short form measures can be useful (Stephenson et al., 2003), particularly in large national datasets, future research should examine these effects using a more robust measure of impulsive traits. Second, it is possible that there is significant within-person variation when it comes to changes in personality across the lifespan and in certain situations (Fleeson, 2004); however, the current approach did not disaggregate between-person vs within-person change since two timepoints were used (Curran et al., 2012). Although we considered using three time points, the current study's focus was on the early transition to adulthood; in addition, several variables changed or removed in the prior and subsequent wave of Add Health data (particularly cannabis use and simultaneous use). Thus, future research should consider using random intercept cross-lagged panel modeling to evaluating how these variables vary within- and between-individuals into later timepoints of adulthood as well as their reciprocal relations. Similarly, the current study was unable to capture dynamic changes (e.g., assessments 6 months to a year a part; e.g., Wasserman et al., 2020) in personality during adolescence.

Third, the current study's measures of cannabis use frequency were past-month whereas measures of alcohol frequency were past-year; however, we believe that estimating density/frequency of cannabis use, compared to other studies that test "any" cannabis use (e.g., Haas et al., 2015; Patrick et al., 2018; Waddell et al., 2021a), was a strength despite non-ideal measurement. In addition, the item about simultaneous alcohol and cannabis use asked about the most recent time drugs were used with alcohol and could have been subject to measurement error. Thus, future research with more comprehensive, matched measures of alcohol and cannabis use are needed. The current study also did not consider cannabis-only, as it was focused on alcohol and cannabis co-use; incorporating co-use vs. cannabis-only would require a separate set of analyses (with cannabis use being an inclusion criterion rather than alcohol use), which would have substantially limited the sample and required double the analyses. Thus, future research on co-use vs. cannabis-only relations with personality is needed. Finally, the current study did not incorporate nicotine or other drugs into analyses, and future research should consider how additional polysubstance use patterns may affect impulsive personality traits.

Despite these limitations, the current study provides important information for models of substance use and personality as well as personality change. Findings evinced that all adolescent co-users had higher cross-sectional levels of adolescent sensation seeking and impulsivity compared to alcohol-only users that frequent adolescent co-users also had higher levels of adolescent sensation seeking and impulsivity compared to experimental co-users, potentially suggesting adolescent sensation seeking and impulsivity as a risk factor and intervention target for co-use. and. Furthermore, adolescent co-users reported a steeper decline in impulsive traits from adolescence into emerging adulthood, and there was some evidence to suggest that frequent adolescent co-users decrease in sensation seeking from adolescence into emerging adulthood at higher rates compared to experimental adolescent co-users, pointing to a likely complex relationship between rates of adolescent co-use and personality changes between adolescence and emerging adulthood. Overall, findings have implications for developmental models of personality change (e.g., Caspi et al., 2005), suggesting that growth/increases in personality traits could be blunted if one already has higher levels due to co-occurring risk behavior, and intervention or prevention strategies aimed at alcohol and cannabis co-use. Future research spanning the full range of adolescence and young adulthood are needed to affirm and extend the current findings.

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