Full length article

Transitions in the use of multiple substances from adolescence to young adulthood

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ABSTRACT

Background: Research indicates that many adolescents frequently use multiple substances. This study examines stability and transitions in the use and co-use of multiple substances (cigarette, alcohol, marijuana, illicit drugs) from adolescence to young adulthood.
Methods: Data were collected biennially from 662 youth in six assessments across ten years (2003–2013). We used latent class analysis (LCA) to classify youth by substances used at each wave and used latent transition analysis (LTA) to examine transition probabilities across waves.
Results: At each wave, a three-class model best fit the data. Classes included a *poly-use* class, that had the highest probabilities of use among all substances, a *co-use* class, that had high probabilities of use of alcohol and marijuana, and an *alcohol-dominate* class that started with low probabilities of use among all substances but showed increasing probabilities of alcohol use, at later ages. LTA showed that the probability of remaining in the *poly-use* class was the most stable from one wave to the next, followed by the *alcohol-dominate* class, and the *co-use* class. The most transitions occurred for the *co-use* class, with more individuals transitioning to the *poly-use* class than to the *alcohol-dominate* class.
Conclusions: Strong stability among adolescent substance use classes was found between waves. Transitions were typically to classes using more substances, although, transitions to use fewer substances was evident for some individuals. Distinguishing stable and transitioning classes of substance use and co-use provides opportunities for prevention and intervention to disrupt high-risk use classes.

1. Introduction

The use of multiple substances during adolescence is a consistent predictor of substance use problems and adverse health and social outcomes in adulthood (Moss et al., 2014; Nelson et al., 2015). Research suggests that consumption of a single type of substance is rare, and many adolescents use multiple substances, referred to as poly-substance use (Moss et al., 2014; Tomczyk et al., 2016a). The heterogeneity in the types of substances used during adolescence has been documented in several cross-sectional studies (for review see Tomczyk et al., 2016a). While adolescence and young adulthood is a time of considerable experimentation and instability in the types of substances used, little research has examined transitions between different classes of substance use across this developmental period. A better understanding of transitions between classes of substance use and co-use across adolescence and young adulthood can inform the identification of high-risk use classes. The current study examines stability and change in substance use classes across six biennial assessments spanning ten years from adolescence to young adulthood.

Research consistently reports that levels of tobacco, marijuana, and heavy drinking increase across adolescence, peak in late adolescence and early young adulthood, and subsequently decline (Nelson et al., 2015). However, the types of substances used by an individual can vary over time, carry different levels of risk, and are differentially associated with short- and long-term health and social outcomes. Researchers using person-centered approaches like finite mixture models (e.g., Latent Class Analysis) have identified three to four substance use classes evident in adolescence (for review see Tomczyk et al., 2016a). Past studies of classes of use are typically cross-sectional and focus on tobacco, alcohol (or binge drinking), marijuana, and illicit drug use (Conway et al., 2013; Gilreath et al., 2015; Morean et al., 2016). Some studies have also examined classes of longitudinal use from adolescence to young adulthood using Growth Mixture Models (GMM), although these studies are limited to one or two substances (Jackson et al., 2008; Schweizer et al., 2014). A better understanding of the transitions in adolescent substance use and co-use could provide insight into the

extent to which substance use classes that begin in adolescence become entrenched or change in young adulthood.

Strong stability for each substance use class is expected based on previous research using Latent Transition Analysis (LTA; Chung et al., 2013; Lanza et al., 2010; Maldonado-Molina et al., 2011; Mistry et al., 2015). For example, Lanza et al. (2010) examined substance use transitions among first-year college students (mean age of 18.5 years) across two weeks, and identified four classes *non-use*, *cigarette use*, *binge drinking*, and *binge and marijuana use*. There was considerable stability in class membership in this short period. The *binge and marijuana use* class had the highest stability, followed by *non-use*, *binge drinking*, and *cigarette use*. Chung et al. (2013) also examined the transitions between three substance use classes for cigarettes, alcohol, and marijuana use for black and white females ages 13–17 (*no use*, *alcohol only*, and *polysubstance use*) annually across five waves. Findings also showed stability within substance use classes, and the polysubstance use class had the highest stability. Additionally, Mistry et al. (2015) examined transitions among three substance use classes (*non-users*, *alcohol and marijuana use*, and *alcohol, tobacco, and marijuana use*) across three waves of data spanning five years collected from youth in 10th grade (mean age of 15.9), and found higher rates of transitions during earlier waves compared to later waves. Taken together, these short-term studies show considerable stability in substance use class membership within adolescence. Identifying patterns of change in classes of substance use from adolescence to young adulthood can increase understanding of the number of youth that transition to use fewer or more types of substances. This provides evidence of the proportion of individuals who recover from adolescent experimentation with different substances and the proportion who evolve towards a high-risk use pattern by young adulthood.

In this study, we add to this literature by examining transitions among classes of four substances (i.e., cigarettes, binge drinking, marijuana, and illicit drugs) in a large sample followed for a decade from adolescence (ages 12–18) to young adulthood (ages 22–28). No study, to our knowledge, has examined latent transitions among use of these four substances from adolescence to young adulthood. Including illicit drug use will help to differentiate individuals who are characterized by a high-risk use pattern that may need more directed and individualized treatment options. Specifically, we examine the short- and long-term stability and changes in classes of substance use in adolescence and young adulthood. Most LTA studies are short term; an examination of substance use transitions across ten years will provide information on the stability or instability within and across classes of use. For example, stability may decrease in years leading into young adulthood for certain classes and may remain stable for others. We addressed the following questions: (1) What are the different classes of substance use among youth from adolescence to young adulthood? (2) To what extent do classes of substance use remain the same (stability) or change (transition) from wave to wave across a decade, spanning adolescence to young adulthood? (3) Are youth who change their substance use classes more likely to transition to a higher-risk use pattern or a lower-risk use pattern, and when is this transition most likely to occur? Finally, looking across ten years (from wave 1 to wave 6), we asked, (4) What is the probability of youth remaining in the same substance use class that they showed in adolescence?

2. Methods

2.1. Participants and procedures

Data are from the Victoria Healthy Youth Survey (V-HYS), a 10-year prospective longitudinal study of youth who were ages 12 to 18 in 2003 (W1; $N = 662$; 48% male $M_{age} = 15.5$, $SD = 1.9$). The sample was randomly recruited and represent the adolescent population in Victoria, BC (see Leadbeater et al., 2012 for details). In 2003, adolescents were recruited from a random community sample of 9500 telephone listings.

From this 1036 households with adolescents ages 12–18 were identified. Of the eligible households, 662 agreed to participate in the study. Youth were followed biennially across a decade (i.e., for six assessments; W6; $N = 478$; 45% male; $M_{age} = 26.8$, $SD = 2.0$). Retention rates were good at each wave: 87%, (W2), 81% (W3), 69% (W4), 70% (W5), and 72% (W6). Males were slightly more likely to be lost to follow-up compared to females (i.e., males comprised 48% of the sample at W1 and 45% at W6; χ^2 (1, 662) = 8.77, $p = .003$). Participants from higher socioeconomic status (SES) families (W1: $M = 6.79$, $SD = 1.66$; $F(1, 636) = 19.39$, $p < .001$) were more likely to be retained in the study compared to participants from lower SES families ($M = 6.05$, $SD = 1.94$).

Youth and the parent or guardian for those under age 18 gave written consent for participation at each wave, and participants received a gift certificate at each interview. A trained interviewer administered the V-HYS individually in the youth's home or another private place. To enhance privacy, the portion of the V-HYS questionnaire dealing with drug and alcohol use was self-administered and placed in a sealed envelope not accessible to the interviewer. The university's research ethics board approved the research protocol.

2.2. Measures

2.2.1. Demographic variables

Sex was coded such that males were the reference group. The age variables measured age in years. The Hollingshead Occupational Status Scale was used to assess socioeconomic status (Bornstein et al., 2003). Participants reported their parent occupations which were coded from 1 to 9 and the highest level of occupational prestige for either parent was used as the measure of SES.

2.2.2. Cigarette use

Youth indicated how many cigarettes they smoked in the past week. Response items included: 0 = none, 1 = 1 per week, 2 = less than half a pack, 3 = less than a full pack, 4 = more than a full pack.

2.2.3. Heavy episodic drinking

Heavy episodic drinking (HED) was assessed using a single item that asked, "How often they had five or more drinks on one occasion in the past year." Response options included: 0 = never, 1 = *a few times a year*, 2 = *a few times a month,* 3 = *once a week*, and 4 = *more than once a week.* The definition of a standard drink was provided and states "When we use the word 'drink,' it means: (1) one glass, bottle or can of beer, (2) one glass of wine or a wine cooler, or (3) one drink or cocktail with liquor" (see Evans-Polce et al., 2015).

2.2.4. Marijuana use

Youth indicated their frequency of marijuana use over the past year. Response items ranged from 0 = never, 1 = a few times per year, 2 = a few times per month, 3 = once a week, and 4 = more than once a week.

2.2.5. Illicit drug use

Using both formal and street names, participants were asked how often they used each of the following six illicit drugs in the past year: hallucinogens, amphetamines, club drugs, inhalants, cocaine, and heroin as 0 = never, 1 = a few times a year, 2 = a few times a month, 3 = once a week, and 4 = more than once a week. Responses were dichotomized. Due to low use rates across the six illicit drug types, we combined drug types into one dichotomized variable that captured whether adolescents had used any illicit drug over the past year.

2.3. Analysis plan

Latent Class Analysis (LCA) was used to identify the number of substance use classes that best fit the data at each of the six waves based

on individuals' cigarette use, heavy episodic drinking (HED), marijuana use, and illicit drugs (Masyn, 2013; Vermunt, 2010). Illicit drug use was treated as a dichotomous variable and cigarette use, HED, and marijuana use were treated as categorical variables in the latent class models. For each wave, we compared latent class models with 1 to 4 classes using several fit indices and considered the substantive interpretability of the classes and their similarity to previous literature (Nylund et al., 2007). The fit indices were -2 Log Likelihood (-2LL), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Consistent Akaike Information Criterion (CAIC), Approximate Weight of Evidence Criterion (AWE), Lo-Mendell-Rubin likelihood ratio test (LMRT), and Bootstrapped Log-Likelihood Ratio Test (BLRT). The latter two, LMRT and BLRT, compare the current latent class model with a model with k-1 class solution (e.g., 3-class vs. 2-class). We also examined the quality of the classifications using relative entropy values (i.e., degree of class separation). Entropy values near one indicate high certainty in classifications. We then examined demographic predictors of each class for each wave. Following, we examined transition probabilities between each wave and also from W1 to all waves (e.g., W1 to W3, W1 to W4, etc.) using LTA (Lanza et al., 2010; Lanza and Cooper, 2016; Nylund-Gibson et al., 2014). Considering the young age of the sample at baseline (12–18) and the length of the study (10 years), we expected a low-use class that would increase use over time. To capture this meaningful change, we did not constrain the indicator probabilities to be invariant over time. We instead allowed indicator probabilities to be freely estimated over time.

We took various steps to examine missing data patterns. We began by examining the extent to which missing data patterns for each substance (cigarette, HED, marijuana, illicit use) varied by sex (male or female) over time (W1–W6). Significant chi-square differences were found at each time point (except W4) that indicated that males reported more missing data over time for each substance. To adjust for potential bias introduced due to differences in missing data patterns for males and females we included sex (age and SES as well) as a covariate in our models. Next, we examined the extent to which missing data patterns for the substance use variables from W2–W6 were associated with W1 classes. No significant chi-square differences were found between W1 substance use classes and W2–W6 substance use variables. To further reduce potential bias due to missing data and non-normality, all models were run using Full Information Maximum Likelihood (FIML) with the robust Maximum Likelihood estimator (MLR) in Mplus 7.4 (Muthén and Muthén, 2017). FIML treats all observed indicators as latent factors allowing individuals to contribute whatever data they have available to the likelihood function and the MLR estimator makes adjustments to the standard errors.

3. Results

3.1. Classes of substance use at each wave

Results of LCA indicated that the three-class solution was the best fit at each of the six waves (see Table 1). At W3, the four-class solution had significantly better fit than the three-class solution according to the LMRT and the BLRT. However, the three-class model was substantively easier to interpret, was in line with the extant literature, and had 75 or more individuals represented within each class at each wave providing adequate coverage (see Table 2; Nylund et al., 2007). Hence, a three-class solution was selected for each wave. Entropy ranged from 0.71 to 0.83, indicating reasonably good class separation over time.

To describe the three classes at each wave, we plotted the item probabilities for cigarette use, HED, marijuana use, and illicit drug use (see Fig. 1(a–f)) and found similar patterns in classes for each wave. We labeled the class that had the lowest probabilities of use for all substances "alcohol-dominate," (63% at W1 and 43% at W6). For the alcohol-dominate class, HED was low at W1 but increased over time, and 50% of this class reported HED by W4. However, use of all other

substances in this group was low at each time point. We labeled the class with high probabilities of HED and marijuana, but low probability of tobacco or illicit drug use "co-use of Alcohol and Marijuana (referred to as co-use)," (26% at W1 and 27% at W6). We labeled the class with the highest probabilities across all substances as "poly-use" (11% at W1 and 30% at W6). For example, at W1 for the poly-use class, 62% used cigarettes, 90% engaged in HED, 100% used marijuana, and 72% used illicit drugs (see Fig. 1).

As shown in Table 3, females made up a larger proportion of the alcohol-dominate class at each wave. Co-use and poly-use classes had similar rates of females and males for W1 to W3. However, in subsequent waves, there were more females in the co-use group and more males in the poly-use group. Age differences were only found in the first two waves, with younger individuals over-represented in the alcohol-dominate class.

3.2. Latent transitions between substance use classes from wave to wave

3.2.1. Stability in class membership

The latent transition probabilities between waves are presented in Table 4. The probability of remaining in the alcohol-dominate class between waves ranged from 0.68 to 0.94. Stability was lower during adolescence (W1–W3) than young adulthood (W3–W6). The probability of remaining in the co-use class between waves ranged from 0.58 to 0.85. The stability of co-use was variable, with the highest probabilities occurring in adolescence (W1–W2) and young adulthood (W5 to W6). The probability of remaining in the poly-use class was stable and ranged from 0.70 to 0.94 between waves. The stability for poly-use was the lowest from W1 to W2, compared to W2 to W6. While these probabilities indicate considerable stability in class membership findings also showed some adolescents transitioned to different classes of use between waves.

3.2.2. Transitions between substance use classes

Transitions between classes tended to be in the direction of moving to higher-risk classes (i.e., forward transition). The probability of transitioning from the alcohol-dominate class to the co-use class ranged from 0.19 to 0.27 in the first four waves but was low during later waves (W4–W6; see Table 4). This suggested that more transitions occurred in adolescence than in young adulthood. The probability of transitioning directly from the alcohol-dominate class to the poly-use class was low at each wave. The probability of transitioning from the co-use to the alcohol-dominate class increased over time; however, it decreased from W5 to W6. The probability of transitioning from the co-use class to the poly-use class increased over time. The co-use class displayed forward transitions to the poly-use class more frequently than backward transitions to the alcohol-dominate class. The probability of transition from the poly-use class to the co-use class ranged from 0.01 to 0.29. Notably, 29% of the poly-use class at W1 moved to the co-use class at W2. However, the probability of transitioning from the poly-use class directly to the alcohol-dominate class was extremely low.

3.3. Transitions in classes from adolescence to young adulthood

Examining the continuity and discontinuity of adolescence substance use classes across a decade from W1 to W6 we found that the probability of remaining in the alcohol-dominate class was 0.53, the co-use class was 0.59, and the poly-use class was 0.54 (see Table S1). Overall, half of the sample (51%; $n = 339$) remained in the same class at W6 as they were at W1. More specifically, 33% of the sample remained in the alcohol-dominate class across all six waves, 12% remained in the co-use class at all waves, and 6% remained in the poly-use class at all waves. Some of these individuals had shifted to other classes between adjacent waves and then moved back to their original W1 class by W6. We tested this association for wave 1 and other waves as well (wave 1 and wave 3, etc.) and found very similar results.

Table 1
Model Fit Indices for 1 through 4 Latent Class Models from Wave 1 to Wave 6.

No. of Classes	−2LL	AIC	BIC	CAIC	AWE	Entropy	LMRT p value	BLRT p value
Wave 1								
1	3941.668	3967.668	4026.106	4039.106	4149.545	–	–	–
2	3362.236	3416.236	3537.608	3564.608	3793.980	0.863	.001	.001
3	3262.474	3344.474	3528.780	3569.780	3918.086	0.829	.001	.001
4	3235.156	3345.156	3592.396	3647.396	4114.635	0.849	.977	1
Wave 2								
1	4594.918	4620.918	4677.570	4690.570	4799.222	–	–	–
2	4017.588	4071.588	4189.250	4216.250	4441.911	0.820	.001	.001
3	3906.440	3988.44	4167.112	4208.112	4550.783	0.788	.363	.001
4	3881.888	3991.888	4231.570	4286.569	4746.251	0.809	.909	.333
Wave 3								
1	4714.188	4740.188	4795.930	4808.930	4916.672	–	–	–
2	4223.762	4277.762	4393.534	4420.534	4644.306	0.788	.001	.001
3	4142.400	4224.400	4400.202	4441.202	4781.004	0.721	.993	.001
4	4099.484	4209.484	4445.316	4500.316	4956.148	0.799	.745	.013
Wave 4								
1	4059.922	4085.922	4139.543	4152.543	4258.164	–	–	–
2	3687.128	3741.128	3852.494	3879.494	4098.861	0.771	.001	.001
3	3606.884	3688.884	3857.996	3898.996	4232.108	0.755	1	.001
4	3585.964	3695.964	3922.822	3977.822	4424.679	0.778	1	1
Wave 5								
1	3992.798	4018.798	4072.504	4085.504	4191.210	–	–	–
2	3658.898	3712.898	3824.441	3851.441	4070.984	0.786	.001	.001
3	3612.282	3694.282	3863.662	3904.662	4238.043	0.784	.002	.001
4	3585.076	3695.076	3922.293	3977.293	4424.511	0.802	.732	.200
Wave 6								
1	4040.150	4066.105	4120.300	4133.300	4239.451	–	–	–
2	3752.416	3806.416	3918.882	3945.882	4166.349	0.751	.001	.001
3	3703.720	3785.720	3956.502	3997.502	4332.284	0.707	.310	.001
4	3680.988	3790.988	4020.086	4075.086	4524.184	0.767	1	.500

Note: −2LL = Negative 2 log likelihood; AIC = Akaike Information Criteria; BIC = Bayesian Information Criteria; CAIC = Consistent Akaike Information Criteria; AWE = Approximate Weight of Evidence Criterion; LMRT = Lo-Mendell-Rubin Test; BLRT = Bootstrapped Log Likelihood Ratio Test.

For adolescents at W1 who transitioned to a different class by W6 (49%; *n* = 323), more transitioned forward to a higher risk class (36% of total sample) than backward to a lower risk class (13% of total sample). More specifically, 21% of adolescents in the *alcohol-dominate* class (W1) transitioned forward to the *co-use* class (W6), and 27% in the *alcohol-dominate* class transitioned forward to the *poly-use* class. Among the *co-use* class, 9% of adolescents transitioned backward to the *alcohol-dominate* class, and 33% transitioned forward to the *poly-use* class. Among the *poly-use* class, 22% of adolescents (W1) transitioned backward to the *alcohol-dominate* class (W6), and 25% of adolescents transitioned backward to the *co-use* class. Table S1 also shows transition probabilities from W1 to W3–W6 respectively that all show very similar transition probabilities.

4. Discussion

We examined transitions between classes representing the patterns of use and co-use of four substances (i.e., cigarettes, alcohol, marijuana, and illicit drugs) across six waves from adolescence (12–18 years of age) to young adulthood (22–28 years of age). We identified three classes that included an *alcohol-dominate* class comprised of youth who

initially had low use of all substances but showed increases in heavy episodic drinking over time, a *co-use* class comprised of youth who primarily used alcohol and marijuana, and a *poly-use* class comprised of youth who used all four substances. These three substance use classes are consistent with classes reported in previous research (Gilreath et al., 2015; Morean et al., 2016) and baseline proportions of adolescents in each pattern were also similar (see Tomczyk et al., 2016a). In the current study, at baseline, the *alcohol-dominate* class made up the largest class (63%), followed by *co-use* (26%), and *poly-use* classes (11%); however, from waves 4 to 6 the numbers of youth in the *co-use* and *poly-use* classes increased to similar proportions (between 26%–30% respectively), although the *alcohol-dominate* class remained the largest class.

Contrary to some past research (Lanza et al., 2010), a tobacco only or marijuana only class was not found in the current study. This may be due to differences in Canadian versus U.S. samples. However, rates of tobacco use have been declining rapidly among youth over the last several decades (CDC, 2016; Health Canada, 2016). Moreover, ample research shows that marijuana is typically co-used with alcohol (Merrin and Leadbeater, 2018; Moss et al., 2014; Tomczyk et al., 2016a). Health Canada statistics indicate that of the 17% of Canadian youth who

Table 2
Frequencies and proportions of modal class assignments for a 3 class solution from Wave 1 to Wave 6.

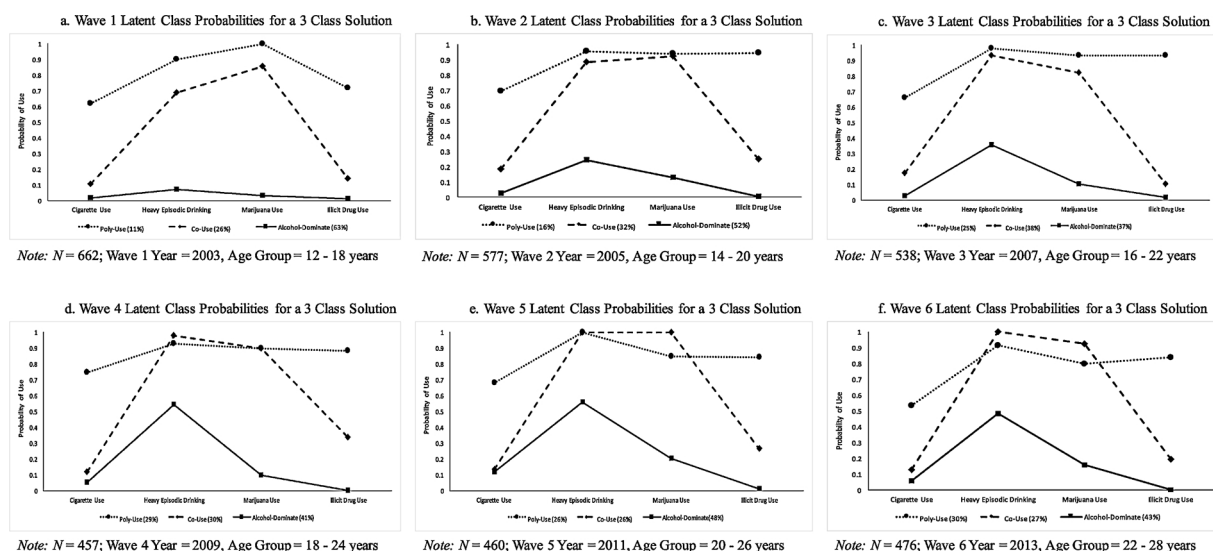| Classes	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6
Alcohol-Dominate	416 (0.63)	301 (0.52)	201 (0.37)	186 (0.41)	221 (0.48)	204 (0.43)
Co-Use	171 (0.26)	185 (0.32)	205 (0.38)	137 (0.30)	121 (0.26)	127 (0.27)
Poly-Use	75 (0.11)	91 (0.16)	132 (0.25)	134 (0.29)	118 (0.26)	145 (0.30)
N	662	577	538	457	460	476

Fig. 1. Latent class probabilities for a 3 class solution from Wave 1–6.

Table 3
Estimates, standard errors, and odds ratios of demographic variables predicting substance use classes from Wave 1 to Wave 6.

	Co-Use		Poly-Use	
	Est. (*SE*)	Odds Ratio	Est. (*SE*)	Odds Ratio
Wave 1				
Sex	−0.29 (0.21)	0.75	−0.62 (0.38)	0.54
SES	0.02 (0.06)	1.02	−0.19 (0.10)	0.83
Age	0.58*** (0.06)	1.78	0.74*** (0.10)	2.10
Wave 2				
Sex	−0.24 (0.20)	0.79	−0.50 (0.33)	0.60
SES	−0.10 (0.06)	0.91	−0.18 (0.09)	0.84
Age	0.35*** (0.06)	1.42	0.36*** (0.08)	1.44
Wave 3				
Sex	−0.47* (0.21)	0.63	−0.68 (0.26)	0.51
SES	0.00 (0.06)	1.00	−0.03 (0.08)	0.97
Age	0.11 (0.06)	1.11	0.13 (0.07)	1.13
Wave 4				
Sex	0.12 (0.26)	1.13	−1.66* (0.68)	0.19
SES	−0.07 (0.07)	0.93	−0.10 (0.12)	0.90
Age	−0.07 (0.06)	0.93	0.02 (0.10)	1.02
Wave 5				
Sex	−0.48* (0.21)	0.62	−4.08 (8.79)	0.02
SES	−0.04 (0.06)	0.96	−0.05 (0.18)	0.95
Age	−0.04 (0.05)	0.96	0.24 (0.19)	1.27
Wave 6				
Sex	−0.81** (0.30)	0.44	−1.37** (0.30)	0.26
SES	−0.08 (0.09)	0.92	−0.05 (0.09)	0.95
Age	−0.12 (0.07)	0.89	−0.08 (0.08)	0.92

Note: Alcohol-Only is the reference class. Males are the reference group for the sex variable. SES = socioeconomic status. We tested differences between Co-Use and Poly-Use, however, only one significant difference was found at Wave 4 for sex such that females reported higher odds of being in the co-use class compared to males (*b* = 1.78, SE = 0.78, *p* = .02, OR = 5.92). *p < .05, **p < .01, ***p < .001.

reported using marijuana in the last year, only 1% did not also use alcohol (Health Canada, 2016). Rapidly changing social norms and legislation raises questions about whether marijuana use will be substituted for or added to the types of substances an individual uses. Some studies have found that increasing levels of tobacco smoking are associated with increased marijuana use and vice versa over time (Badiani et al., 2015). The present study shows that marijuana is typically co-used with other substances which suggest that there may be a

Table 4
Latent transition probabilities from Wave 1 to Wave 6.

	Alcohol-Dominate	Co-Use	Poly-Use
Wave 1 to Wave 2			
Alcohol-Dominate	0.714	0.222	0.064
Co-Use	0.00	0.847	0.152
Poly-Use	0.009	0.291	0.699
Wave 2 to Wave 3			
Alcohol-Dominate	0.680	0.273	0.047
Co-Use	0.084	0.631	0.286
Poly-Use	0.00	0.060	0.940
Wave 3 to Wave 4			
Alcohol-Dominate	0.810	0.189	0.002
Co-Use	0.201	0.580	0.219
Poly-Use	0.052	0.128	0.819
Wave 4 to Wave 5			
Alcohol-Dominate	0.939	0.047	0.014
Co-Use	0.229	0.670	0.100
Poly-Use	0.078	0.009	0.913
Wave 5 to Wave 6			
Alcohol-Dominate	0.881	0.087	0.032
Co-Use	0.080	0.730	0.191
Poly-Use	0.006	0.136	0.859

propensity to add marijuana as a substance rather than substitute.

Previous research has found substantial continuity in the use of single substances from adolescence into adulthood (Hair et al., 2017; Terry-McElrath et al., 2017). However, we know less about changing classes of substance co-use across this important time of life when life-long health behaviors are often established. As such, we also examined the extent to which substance use classes that begin in adolescence become entrenched (i.e., stability) or change over time. Previous research suggests that, for many youths, substance use classes are established during adolescence (Terry-McElrath et al., 2017). Past research found considerable continuity within classes of substance use with up to 90% of youth remaining in the same substance use class (Tomczyk et al., 2016b). However, studies that examine transitions in classes of substance use and co-use only use two to three waves of data and are short-term spanning one to five years (Chung et al., 2013; Lanza et al., 2010; Maldonado-Molina et al., 2007; Mistry et al., 2015). In the current study, we examine transition across ten years and also found strong class stability from one wave to the next (range 0.58–0.94). Consistent with past research (Chung et al., 2013; Lanza et al., 2010), the chronic *poly-use* class was most stable, followed by the *alcohol-*

dominate class, and *co-use* classes. Onset of high-risk classes of poly-substance use during adolescence appear particularly detrimental for the long-term health and social outcomes of young people (Merrin and Leadbeater, 2018; Nelson et al., 2015; U.S. Department of Health and Human Services, 2016). The current study suggests that youth in the *poly-use* class may also be the most resistant to change. Further, these youth may be experiencing multiple concurrent risks or liabilities that predispose them to escalating use (Levine et al., 2017). Polysubstance use may also coincide with deviant individual behaviors and peer influences that sustain and reinforce continued use (Meldrum and Clark, 2015; Van Ryzin and Dishion, 2014). A better understanding of the risk factors for adolescent onset of polysubstance use is needed to address the individual and contextual issues that can exacerbate classes of use of multiple substances.

Despite the considerable stability from wave-to-wave, approximately half of the sample transitioned to a different substance use pattern over the decade of the study suggesting higher rates of instability then previously found in short term LTA studies. A higher proportion of adolescents transitioned to using more types of substances than to using fewer substances. Specifically, 36% of the total sample transitioned from a lower risk class (i.e., *alcohol-dominate, co-use*) to a higher-risk class (i.e., *co-use, poly-use*) whereas only 13% of the total sample transitioned to use fewer substances. These findings suggest that engagement in poly- and co-use was generally associated with forward transitions. Although, only 6% of the total sample started and remained in the poly-use class across the ten years of the study. The large numbers of youth who report the co-use of alcohol and marijuana echo concerns about the effects of using multiple substances that have been previously raised (Moss et al., 2014; Yurasek et al., 2017). The additive or synergistic effects of using multiple substances on adolescents' brain development and social and economic outcomes has not been well addressed (Levine et al., 2017). Growing evidence suggests that poly-substance use is associated with deviant behaviors and adverse health outcomes in adulthood (Connor et al., 2014; Morley et al., 2015). Transitions in types of substances used appear, in the current study, to be gradual, involving the addition or removal of one substance at a time and these changes were more frequent in adolescence than young adulthood. For example, few individuals made a direct transition from the *alcohol-dominate* class to the *poly-use* class or vice versa. Instead, individuals transitioning between the *alcohol-dominate* and *poly-use* were typically first classified in the *co-use* class. However, by wave 6, 57% of youth were using more than one substance (i.e., co-use or poly-use).

Many effective prevention programs are available that target single types of substance use. However, the current study found that many adolescents use two or more substances. Early identification of poly-substance use in adolescence could help identify groups of adolescents that present high-risk use and offer targeted intervention for these individuals. This developmental period provides an ideal opportunity for prevention as transitions between classes of use were evident across this time. Efforts may find success by tailoring preventive interventions to different types of users. For example, topics around safer use and how to assist friends in the case of an emergency (e.g., overdose) for co- or poly-users would be beneficial for reducing potential harms as they are actively using the substances. For alcohol-dominate users, efforts that attempt to prevent or delay onset of other substances may find success. Future studies are needed to identify individual and contextual risk factors that may distinguish among adolescents who remain in the same class or transition to a higher or lower risk pattern of use.

4.1. Limitations

Most of the participants in this study of Canadian youth were Caucasian, limiting the generalizability of the findings. The use of marijuana by young adolescents is higher in Canada than in any other country (UNICEF, 2013), possibly increasing the proportion of youth in

the co-use classes compared to other samples. Additionally, all data were self-report, and youth could minimize their reports due to social desirability. However, the stability in their reports at each wave was high and suggests considerable reliably in their self-reports. Moreover, baseline age ranged from 12 to 18 years old, and given the limited sample size we were unable to examine transitions for each age cohort. Given the age-related changes associated with the initiation of substance use future studies should examine transitions within age cohorts to tease apart effects of age. In addition, the uneven time frame of the substance use questions (e.g., cigarette use refers to the past week and illicit drug use refer to the past year) makes it difficult to understand the extent of polysubstance use and comparisons with past research.

4.2. Conclusions

We investigated transitions in types of substance use across ten years from adolescence to young adulthood. No previous study, to our knowledge, has examined transitions of multiple substances (i.e., cigarettes, HED, marijuana, and illicit drugs) across this important life transition. We found considerable (wave-to-wave) stability in classes of substances used, and transitions to using more varied types of substances (36%) were more likely than transitions to using fewer substances (13%) across this period. Polysubstance use develops over several years. Evidence-based prevention and treatment programs for adolescents that target single substances may need to address the co-use of multiple substances and provide education and harm reduction strategies to reduce health risks and motivate low-risk use pattern in young adulthood.

Contributors

Study concept, design, and statistical analyses were developed and conducted by Merrin. Authors (Merrin and Leadbeater) wrote the first draft of the manuscript. Thompson assisted in drafting the discussion section and editing the manuscript. All authors contributed to and have approved the final manuscript.

Role of the funding sources

Nothing declared.

Conflict of 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.2018.05.015.

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