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Longitudinal patterns of amphetamine use from adolescence to adulthood: A latent class analysis of a 20-year prospective study of Australians

Gary C.K. Chan[a,*], Peter Butterworth[b,c], Denise Becker[d], Louisa Degenhardt[e], Emily Stockings[e], Wayne Hall[a], George Patton[c]

[a] Centre for Youth Substance Abuse Research, The University of Queensland, Australia
[b] Melbourne School of Population and Global Health, The University of Melbourne, Australia
[c] Melbourne Institute of Applied Economic and Social Research, The University of Melbourne, Australia
[d] Centre for Adolescent Health, Murdoch Children's Research Institute, Australia
[e] National Drug and Alcohol Research Centre, The University of New South Wales, Australia

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ABSTRACT

Background: To examine the longitudinal patterns of amphetamine use over twenty years from adolescence to the mid-thirties; and identify adolescent antecedents of future problematic patterns of use.
Design: Ten-wave longitudinal study following participants from age 15 to age 35 in Victoria, Australia. Participants (N = 1755; 47% males) first enrolled in the Victoria Adolescent Health Cohort Study in 1992.
Measurements: Outcome: Self-reported frequency of amphetamine use. Predictors: Gender, depression and anxiety, peer alcohol and tobacco use; self-reported alcohol, tobacco and cannabis use, self-reported adolescent antisocial behavior.
Findings: Three different longitudinal patterns were identified: Non-user (83.7%); Occasional user (14.5%); Regular user (1.8%). Among the two user patterns, amphetamine use was commonly initiated in late teenage years or early 20s, peaked at mid-20s, and declined substantially by mid-30s. Participants who used cannabis and had smoking peers during adolescence were at significantly more likely to become an occasional or regular user ($p < .05$).
Conclusion: Regular cannabis use and peer tobacco use during adolescence were the two strongest predictors of a longitudinal pattern of regular amphetamine use in the mid-30s. This suggests that prevention programs could be implemented around or before mid-adolescence and interventions to reduce amphetamine harms focus on high-risk individuals in their 20s when amphetamine use was at its peak.

1. Introduction

After cannabis, amphetamines are some of the most widely used illicit substances globally. In recent years, their use and associated harms have risen in some countries including Australia, China, Indonesia and Myanmar (Degenhardt et al., 2016; Lai et al., 2016; UNODC, 2013). Regular use of amphetamines, especially by injection or smoking, is strongly associated with psychoses, depression, intentional self-harm and suicide attempts (Darke et al., 2008; Marshall and Werb, 2010; Park and Haning, 2016). Amphetamines are cardiotoxic and are linked to hypertension, myocardial ischemia, arrhythmia, and infarction (Kaye et al., 2007; Yeo et al., 2007). They are also neurotoxic, and animal models suggest that their impact may be more harmful for adolescent users whose brains are undergoing rapid and extensive maturation (Buck and Siegel, 2015).

Longitudinal research on adolescent antecedents of amphetamine use among adolescents and young adult is very limited. Most research is based on cross-sectional data, with study participants derived primarily from high-risk populations such as adult drug users (e.g., Quinn et al., 2013), or street-involved young people (e.g., Uhlmann et al., 2014). Findings from these studies have limited generalizability to the broader population, and the cross-sectional studies (e.g., Chen et al., 2014) provide little information about the developmental course of amphetamine use. Studies of the correlates of amphetamine use were largely based on individuals over 20 years old, well past the age of initiation for most amphetamine users. Identification of key adolescent markers of regular use potentially provides important information for prevention and intervention programs to target high-risk adolescents at an earlier

* Corresponding author at: Centre for Youth Substance Abuse Research, The University of Queensland, Brisbane, QLD, 4072, Australia.
E-mail address: c.chan4@uq.edu.au (G.C.K. Chan).

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stage, reducing their risks of progressing to regular use and dependence.

In a previous report, we examined adolescent predictors of amphetamine use 10-years later in young adulthood (Degenhardt et al., 2007). This paper extends that work in two ways. First, we examine the natural history of amphetamine use with twenty years of data on the timing of initiation, escalation, and remission with a view to identifying potential windows for intervention. Given that previous studies on other substances such as alcohol and tobacco have shown distinct longitudinal patterns of use (Chan et al., 2013; Dutra et al., 2017), we expected to identify at least three subgroups, non-users, occasional and regular users, with different histories from adolescence to adulthood. Secondly, we investigate adolescent antecedents of regular and persisting adult amphetamine use, including other substance use, antisocial behaviors, depressive and anxiety symptoms, and peer substance use. These variables were chosen because they predict other substance use and can potentially be used for selective prevention and clinical screening. (Chan et al., 2017; Kelly et al., 2015, 2012)

2. Method

Between 1992 and 2014 we undertook a ten-wave cohort study of health in young people in the state of Victoria, Australia. At baseline, a representative sample of mid-secondary school adolescents was selected using a two-stage cluster sampling procedure. At stage one, 45 schools were chosen at random from a stratified frame of government, Catholic and independent schools, with a probability proportional to the number of Year 9 (age 14–15) students in the schools in each stratum. All schools approached provided consent at wave 1. At stage two, a single intact class was selected at random from each participating school. Six months later, we randomly chose a second class from the same schools. Thus, one class entered the study in the latter part of the ninth school year (wave 1) and the second six months later (wave 2). One school did not continue beyond wave 1 with a loss of 13 participants. Participants were subsequently reviewed at four six-month intervals between the ages of 15–18 years (waves 3–6) with four follow-up waves in adulthood, aged 20–21 years (wave 7), 24–25 years (wave 8), 28–29 years (wave 9) and 34–35 years (wave 10). Fig. 1 displays the flow of participants through the study. Further detail on this study design and sample is available elsewhere (Patton et al., 2014). Of 2032 eligible students, 1943 participated at least once in the adolescent phase. Twenty-five participants had missing data in amphetamine items in all waves and were excluded. A further 163 participants provided data in only one adult wave on amphetamine use and were also excluded. The current study was based on the remaining 1755 (47% males) who participated in at least one adolescent waves (Wave 2–6) and two adult waves (Wave 7–10). We used adolescent data from waves two to six because by study design more than half of the participants did not participate in wave one. All participants' parents or guardians provided written, informed consent before inclusion in the study. In the adult phase, all participants were informed of the content of the assessment in writing and gave verbal consent before being interviewed. The data collection protocols were approved by the Human Research Ethics Committee of the Royal Children's Hospital (Victoria, Australia).

2.1. Measure

2.1.1. Key variables

From wave 2 to wave 6, amphetamine use was measured using the item "How often do you use Speed/ amphetamine/ diet pills?" with the response scale Never/ Not in the past 6-months/ A few times a year/ Monthly/ Weekly/ Daily. Given that amphetamine use during adolescence was infrequent, responses to the amphetamine items from the 5-adolescent waves (Wave 2 to Wave 6) were recoded into a single variable "Any use during adolescence: Yes/ No" for the latent class analysis. In wave 7, participants were given a list of drugs and were asked "We would like to ask you whether you have used any (other than marijuana) drugs for non-medicinal purposes. Have you used any of these drugs, or something like it, in the past year? Yes/No". For amphetamines, the listed item was "Amphetamines (Speed, goey, uppers, oxblood, MDA, eve". In wave 8 to wave 10, a more detailed amphetamine item was included in the survey. Participants were asked the same question as in Wave 7, and were followed up with another question "Thinking about the past year, when you were using amphetamine most frequently, about how often did you use it? "Almost every day/ 3 to 4 days a week/ 1 to 2 days a week/ 1 to 3 days a month/ Less than once a month/ No use". The first 3- levels were combined due to small cell size and the final scales comprised of four levels (At least 1 or 2 days a week/ 1 to 3 days a month/Less than once a month/ No use).

2.1.2. Predictors

High-risk drinking was defined as having 5 or more standard drinks (each 10 g alcohol) on at least 1-day in the week prior to data collection.

Antisocial behavior was dichotomized according to whether there was a positive response to any of the 10-items from the Self Report of Early Delinquency Scale (Moffitt and Silva, 1988) which included behaviors such as property damage, theft, and interpersonal violence. Participants who reported involvement in two or more behaviors, or more than once of any one behavior, were coded as positive for antisocial behavior.

Tobacco use was measured using a 7-day retrospective diary and coded into three levels: Non-smoker/Less than daily/ Daily. *Cannabis use* was measured using the item "How often do you use marijuana?" and responses were coded into No use/ Less than weekly/ Weekly.

Symptoms of depression and anxiety were measured using the revised Clinical Interview Schedule (CIS-R) (Lewis and Williams, 1989). A score of 11 or above indicated the presence of symptoms of clinically significant depression and anxiety.

Peer alcohol and tobacco use were measured using the items "How

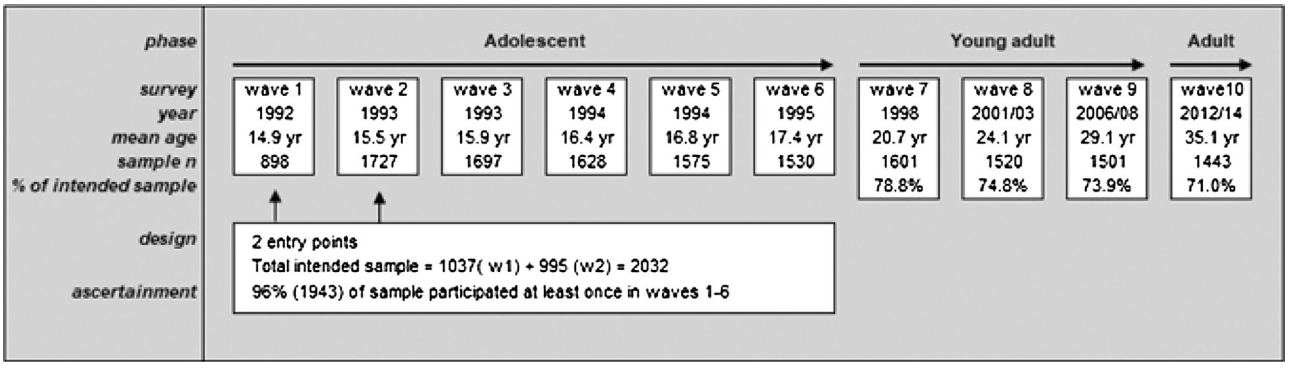

Fig. 1. Sampling and ascertainment in the Victorian Adolescent Health Cohort.1992–2014.

many of your friends do the following: Drinking alcohol/ smoke tobaccos" and the responses were coded None/Some/ Most or All.

2.2. Analysis

Latent class analysis (LCA) was used to identify longitudinal patterns of amphetamine use from adolescence to adulthood. This technique can identify subgroups in the population who showed different timing of initiation, escalation and remission over the 20 years study period. Latent class analysis was performed on the five amphetamine variables (the combined amphetamine measure in adolescent the phase and the amphetamine measure from Wave 7 to Wave 10). Model fitting compared four different models (from 2- to 5-class models). The number of classes was determined using information criteria (Akaike Information Criteria [AIC] and Sample size adjusted Bayesian Information Criterion [SSABIC]), likelihood ratio tests (Lo-Mendell-Rubin likelihood ratio test [LMR-LRT] and Bootstrap likelihood ratio test [BLRT]), and classification quality statistics (entropy and average posterior probabilities). A lower value of information criterion indicates a better balance between model fitting and model parsimony; a significant likelihood ratio test indicates the k-class model fits the data better than the model with k-1 classes; an entropy and an average posterior probability that is closer to 1 indicates clearer class separation and classification. Once the number of classes was determined, we examined the association between predictors at Wave 2 (the first wave in which most participated) and membership in each of the classes using multinomial logistic regression with the Vermunt's 3-step method (Vermunt, 2010). Missing data in the latent class analysis was handled using full information maximum likelihood estimates. In the subsequent logistic regression analysis, missing data in the predictor variables were imputed in 10 datasets using multiple imputation (Rubin, 2009). Ten datasets were imputed based on previous simulation study showing that it can provide sufficient power for our level of missing data (Graham et al., 2007). Analyses were conducted using Mplus 7.0 (Muthén and Muthén, 2014).

3. Results

Table 1 shows the prevalence of amphetamine use from wave 1 to wave 10. During adolescence (Wave 1 to Wave 6), the rate of past-year amphetamine use was less than 5%. It increased to 7.5% in Wave 7, peaked at Wave 8 (11.3%) and Wave 9 (11.2%) and declined to 6.1% in Wave 10.

Table 2 shows the fit statistics from the 2-class to the 5-class model. The AIC decreased successively from the 2-class to the 5-class model, but the decrease leveled off after the 3-class model. The SSABIC attained the lowest values for a 3-class model, indicating that the 3-class model provided the best balance between model fit and parsimony. The LMR-LRT indicated that the 3-class model fitted significantly better than the 2-class model but not worse than the 4-class model. The BLRT indicated that the 4-class model fitted the data better, but a comparison of the class solution between the 3-class and 4-class model indicated that the 4-class model yielded a class with extremely small size (prevalence less than 1%) and the 3-class model was more meaningful and interpretable. The entropy of the 3-class model was 0.84, and the average posterior probability was over 0.93. These statistics indicated that the 3-class model yielded clearly distinguishable classes which were chosen as the best fitting.

Fig. 2 (adolescent period and Wave 7) and Fig. 3 (Wave 8 to Wave 10) shows the class structure from the 3-class model. Results from the 3-class model are shown in two separate figures because of the changed amphetamine measure. The detailed estimated probabilities of use for each class are shown in Supplementary Table 1.

Pattern class 1 participants in this class had very low probabilities of amphetamine use from adolescence to adulthood (< 0.05). This class was labeled "Non-user" (N = 1469, 83.70%).

Pattern class 2 participants in this class had a moderate probability of amphetamine use in adolescence (0.27). The probabilities of past year use were 0.34 at age 21, increased steadily to 0.59 at age 29, and declined to 0.32 at age 35. Although participants in this class had a moderately high probability of using amphetamine in their 20s, they tended to use the drug occasionally, and the probability of increasing to weekly use was negligible (< .01). This class of participants was labeled "Occasional user" (N = 255, 14.53%).

Pattern class 3 participants in this class had a 0.48 probability of using amphetamines during adolescence. At age 21, the probability of past year use was 0.67, and this increased to 0.90 and 0.80 at age 24 and 29 respectively. At age 35, the probability of past year use declined to 0.42. In their 20s, participants in this class were regular users, with the probabilities of weekly use high at ages 24 (0.71) and 29 (0.60). This class of participants was labeled "Regular user" (N = 31, 1.77%).

Table 3 shows the frequency and proportion of participants in different amphetamine longitudinal patterns by each predictor. All predictors were measured at Wave 2 (M_{age} = 15.5). For ease of interpretation, in these analyses, participants were classified in amphetamine patterns by modal posterior probabilities and missing data was deal with pair-wise deletion. At the bivariate level, amphetamine patterns were strongly associated with gender, depression and anxiety, antisocial behavior, peer alcohol use, peer tobacco use, cannabis use, high-risk alcohol use and tobacco use (p < .001).

Table 4 shows the unadjusted results from the multinomial logistic regression. Compared to non-users, participants with depression and anxiety, who engaged in anti-social behavior, high-risk drinking, tobacco use and cannabis use, and had alcohol and tobacco using peers

Table 1
Frequency and percentage of amphetamine use.

	Never		Not in last 6 months		More than a few times a year		
	N	%	N	%	N	%	Total N
Wave 1 (M_{age} = 14.9)	756	98.95	5	0.65	3	0.39	764
Wave 2 (M_{age} = 15.5)	1532	97.52	16	1.02	24	1.46	1572
Wave 3 (M_{age} = 15.9)	1546	97.97	16	1.01	16	1.01	1578
Wave 4 (M_{age} = 16.4)	1494	98.1	10	0.66	19	1.25	1523
Wave 5 (M_{age} = 16.8)	1441	95.62	27	1.79	39	2.59	1507
Wave 6 (M_{age} = 17.4)	1419	96.33	14	0.95	40	2.72	1473
	Past year use						
	No		Yes				
Wave 7 (M_{age} = 20.7)	1472	92.52	119	7.48			1591
	Past year use						
	Not in last year		Less than once a month		More than 1 day a month		
Wave 8 (M_{age} = 24.1)	1341	88.75	122	8.07	48	3.18	1511
Wave 9 (M_{age} = 29.1)	1233	88.77	106	7.63	50	3.6	1389
Wave 10 (M_{age} = 35.1)	1344	94.05	63	4.41	22	1.54	1429

Table 2
Fit statistics of LCA models.

Number of classes	AIC	SSABIC	LMR-LRT	Bootstrap LRT	Entropy	Average posterior probability
2	4583.39	4636.14	< .001	< .001	0.790	0.948
3	**4550.33**	**4630.59**	**< .001**	**< .001**	**0.836**	**0.936**
4	4546.75	4654.53	0.129	< .001	0.845	0.920
5	4544.68	4679.99	0.724	.724	0.923	0.949

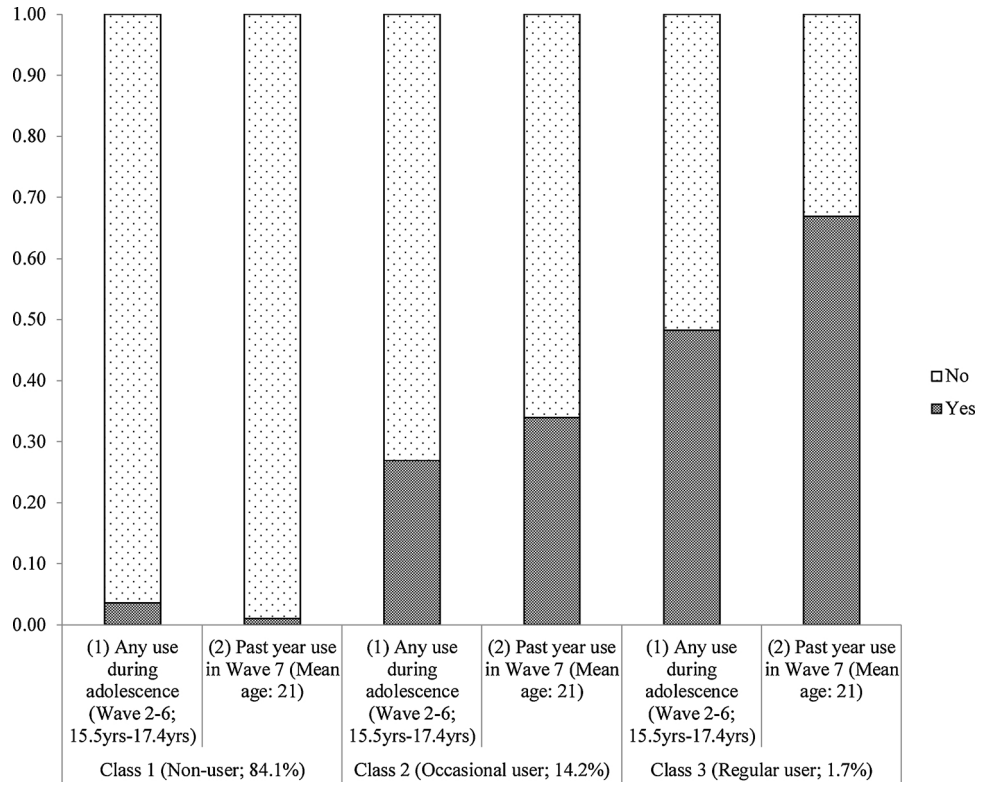

Fig. 2. Class structure of 3-class solution (Adolescent waves and wave 7).
Footnote: Amphetamine use was coded as Yes/ No in the adolescent phase and at wave 7. This figure shows probability of using amphetamine at these two time points by classes.

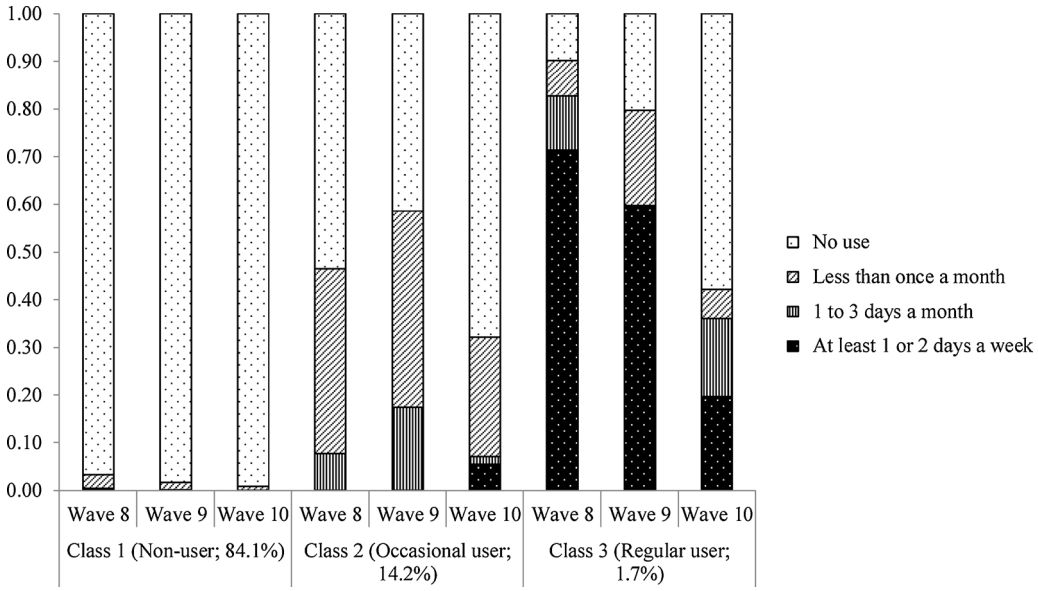

Fig. 3. Class structure of 3-class solution. (Wave 8–10).
Footnote: Amphetamine use was measured in a 4-point scale from wave 8 to 10 (No use/ Less than once a month/ 1 to 3 days a month/ At least 1 or 2 days a week). This figure shows probability of using amphetamine at these three time points by classes.

Table 3
Amphetamine longitudinal pattern classes by each predictor.

Gender	Non-users	%[a]	Occasional users		Regular users		Chi-sq
	N		N	%	N	%	
Male	685	44.65	123	62.44	15	62.5	24.55***
Female	849	55.35	74	37.56	9	37.5	
Depression and anxiety							
No	1119	73.19	121	61.42	12	50.00	17.41***
Yes	410	26.81	76	38.58	12	50.00	
Antisocial behaviors							
No	806	58.62	44	27.67	7	29.17	61.72***
Yes	569	41.38	115	72.33	17	70.83	
Peer alcohol use							
None	300	23.66	11	6.96	2	8.70	97.75***
Some	645	50.87	50	31.65	8	34.78	
Most	323	25.47	97	61.39	13	56.52	
Peer tobacco use							
None	309	24.31	13	8.33	0	0.00	78.11***
Some	681	53.58	69	44.23	7	30.43	
Most	281	22.11	74	47.44	16	69.57	
Cannabis use							
No use	1195	87.87	75	47.17	10	41.67	200.41***
Occasional use	133	9.78	62	38.99	10	41.67	
Weekly use	32	2.35	22	13.84	4	16.67	
High risk alcohol use							
No	1276	91.73	121	73.33	18	75.00	58.91***
Yes	115	8.27	44	26.67	6	25.00	
Tobacco use							
Non-smoker	1060	76.2	77	46.67	8	33.33	86.68***
Occasional smoker	202	14.52	48	29.09	11	45.83	
Daily smoker	129	9.27	40	24.24	5	20.83	

[a] These are column percentages (i.e. Column percentage adds to 100%). * $p < .05$; ** $p < .01$; *** $p < .001$.

were more likely to become occasional or regular amphetamine users ($p < .05$). Compared to occasional users, participants who had peers who used tobacco were more likely to become regular amphetamine users ($p < .001$).

Table 5 shows the adjusted results from the multinomial logistic regression. With reference to non-users, female participants were at much lower risk of becoming occasional or regular amphetamine users ($p < .01$). Depression and anxiety symptoms predicted becoming a regular user, and anti-social behavior predicted becoming an occasional user ($p < .05$). Both cannabis use and peer tobacco use were strongly predicted becoming a regular user ($p < .001$). With reference to occasional users, peer tobacco uses strongly predicted being a regular amphetamine user ($p < .001$).

We performed a sensitivity analysis with the full sample (N = 1922, including an extra 163 participants who provided only 1 or no data point on amphetamine use during the adult phase). The results were similar, but the classification quality from the latent class analysis was somewhat worse (with lower entropy and lower average posterior probability). For this reason, we have reported the analysis using participants with the most available data (N = 1755).

4. Discussion

The use of amphetamine has increased steadily in Australia over the past two decades and may have accelerated more recently (Degenhardt et al., 2016; Lai et al., 2016). These trends have prompted calls for research on the causes and life-course trajectories of amphetamine use in Australia.

In this study, we found that the majority of the population did not use amphetamine, but those who did commonly initiated use in their late teens or early 20s. A much higher proportion of regular than occasional users-initiated amphetamine uses during adolescence. This is consistent with research that earlier onset of substance use predicts heavier use in adulthood (Trenz et al., 2012). In both user groups (people who were occasional users and regular users), consumption peaked in their 20s and dropped substantially by their mid-30s. This suggests that there may be windows for preventive interventions in mid-adolescence when amphetamine is first used, or immediately before it is used. For those who have already initiated amphetamine use in adolescence, they may have already been exposed to a range of risk factors such as involvement with drug-using peers and culture; therefore harm minimization may be a realistic approach reduce the burden of amphetamine use. Interventions that aim to reduce amphetamine-related harms could target high-risk individuals in their early 20s, especially those who are regular cannabis users.

We also found that many amphetamine users were on the pathway of natural recovery. Among occasional users, 50% and 60% reported using amphetamine infrequently at the ages of 24 and 29, but this proportion dropped to 30% by age 35. For regular users, more than 70% reported weekly use at age 24, and this proportion dropped to 60% at 29 years and 20% at age 35. In fact, at the age of 35, nearly 60% of

Table 4
Unadjusted odds ratio from multinomial logistic regression.

	Reference: Non-user				Reference: Occasional user	
	Occasional user		Regular user		Regular user	
	OR	95% CI	OR	95% CI	OR	95% CI
Female	0.42***	(0.29, 0.62)	0.44	(0.18, 1.07)	1.05	(0.40, 2.74)
Depression and anxiety symptoms	1.86***	(1.28, 2.71)	2.98*	(1.27, 6.97)	1.60	(0.63, 4.02)
Anti-social behavior	4.91***	(3, 8.04)	3.96**	(1.51, 10.37)	0.81	(0.27, 2.39)
High risk drinking	5.00***	(2.99, 8.38)	4.34**	(1.62, 11.58)	0.87	(0.30, 2.46)
Tobacco use (Ref: non-smoker)						
Less than daily	3.73***	(2.31, 6.02)	8.55***	(3.15, 23.19)	2.29	(0.77, 6.81)
Daily	5.64***	(3.24, 9.82)	6.30**	(1.88, 21.1)	1.12	(0.31, 4.03)
Cannabis use (Ref: no use)						
Less than weekly	11.19***	(6.45, 19.41)	12.39***	(4.73, 32.44)	1.11	(0.39, 3.16)
Weekly or more	18.90***	(7.88, 45.29)	20.84***	(5.31, 81.87)	1.10	(0.29, 4.17)
Peer alcohol use (Ref: None)						
Some	2.20	(0.79, 6.17)	2.03	(0.34, 12.08)	0.92	(0.13, 6.62)
Most	11.34***	(4.5, 28.54)	7.59***	(1.38, 41.69)	0.67	(0.10, 4.49)
Peer tobacco use (Ref: None)						
Some	2.51*	(1.23, 5.12)	a***		a***	
Most	7.60***	(3.69, 15.63)	a***		a***	

[a]All participants in the regular user pattern class had peers using tobacco. The adjusted odds ratio was over 1000. *$p < .05$; ** $p < .01$; *** $p < .001$.

Table 5
Adjusted odds ratio from multinomial logistic regression.

	Reference: Non-user				Reference: Occasional user	
	Occasional user		Regular user		Regular user	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Female	0.37***	(0.22, 0.6)	0.30**	(0.12, 0.73)	0.81	(0.31, 2.13)
Depression and anxiety symptoms	1.62	(0.99, 2.65)	2.31*	(1.00, 5.3)	1.42	(0.59, 3.47)
Anti-social behavior	1.85*	(1.03, 3.32)	1.45	(0.53, 3.96)	0.78	(0.27, 2.32)
High risk drinking	1.04	(0.51, 2.12)	0.78	(0.25, 2.42)	0.75	(0.23, 2.45)
Tobacco use (Ref: Non-smoker)						
Less than daily	1.34	(0.7, 2.54)	2.63	(0.8, 8.62)	1.96	(0.56, 6.93)
Daily	0.98	(0.46, 2.11)	0.80	(0.21, 3.06)	0.82	(0.19, 3.46)
Cannabis use (Ref: no use)						
Less than weekly	5.29***	(2.7, 10.33)	5.46**	(1.62, 18.42)	1.03	(0.27, 3.88)
Weekly or more	7.09***	(2.6, 19.29)	7.85**	(1.72, 35.77)	1.11	(0.25, 4.97)
Peer alcohol use (Ref: None)						
Some	1.42	(0.40, 4.97)	0.29	(0.04, 1.97)	0.20	(0.02, 2.07)
Most	3.28	(0.92, 11.72)	0.34	(0.04, 2.58)	0.10	(0.01, 1.21)
Peer tobacco use (Ref: None)						
Some	0.93	(0.34, 2.53)	a***		a***	
Most	1.14	(0.37, 3.52)	a***		a***	

[a]All participants in the regular user pattern class had peers using tobacco. The adjusted odds ratio was over 1000. *$p < .05$; ** $p < .01$; *** $p < .001$.

regular users reported no further amphetamine use. These findings suggest that future research could usefully focus on why some individuals continue to use amphetamine regularly in their mid-30s.

The longitudinal patterns found in this study were in general consistent with those reported other substance research (Chan et al., 2013; Epstein et al., 2015), where an early onset class, a class with consistent moderate use and a class of non-user/ minimal use were reported. However, longitudinal patterns/trajectory studies of other substances often found more than these three patterns, possibly due to higher availability of these substances. For example, for alcohol use, in addition to the three common patterns, Chan et al. (2013) reported a small but substantial proportion of adolescents whose alcohol use quickly escalate over the course of adolescence, from using nearly no alcohol at the first year of high school to drinking more than three times a week by Grade 10. Such a pattern is much less likely for amphetamine due to its illegality and limited access.

In this study, we have also identified several adolescent antecedents of future amphetamine use. Cannabis use was the strongest single predictor of future amphetamine use. There are several possible explanations for this association. Proponents of the common liability model of addiction suggest that this association reflect the effects of underlying traits such as the propensity to use drugs (Vanyukov et al., 2012). Other researchers argue that adolescent cannabis use, particularly regular use and early onset, is a contributory cause of amphetamine use that acts through biochemical mechanisms (e.g., by increasing sensitivity to drugs), individual learning (e.g., initial positive experience with cannabis extending to other illicit drugs), and social learning and differential association (e.g., involvement with drug culture and drug-using peers who reinforce drug use) (Fergusson et al., 2006). There is support for both the common liability (Degenhardt et al., 2010) and causal explanations of the link between cannabis and other illicit substance use (Agrawal et al., 2004; Fergusson et al., 2006). Our finding that early regular cannabis use predicted amphetamine use over a 20-year period suggests that regular use identifies high-risk adolescents for selective and indicated prevention programs.

Having substance-using peers during adolescence was another strong predictor of regular amphetamine use in the mid-30s. In the unadjusted model, both peer alcohol and tobacco use were strongly predictive of future regular amphetamine use but only peer tobacco use remained highly significant in the adjusted model. In fact, all regular users had peers who use tobacco during their adolescence suggesting that having tobacco using peers might be a strong marker of involvement in peer groups that expose individuals to modeling of deviant behaviors such as illicit drugs use and reinforce these behaviors. Prevalence of tobacco use has been steadily decreasing since the collection of this data, and adolescent tobacco use is becoming more socially unacceptable (AIHW, 2014; Johnston et al., 2018; White and Bariola, 2012). Having peers who use tobacco may now be a stronger indicators of future amphetamine use.

Antisocial behaviors, tobacco use, and high-risk drinking were strongly associated with amphetamine use in bivariate analyses, but their effects were greatly reduced after adjusting for cannabis use and peer tobacco use. This pattern is likely to reflect the clustering of risky behaviors during the adolescent years (Jessor, 1991). Our results suggested that cannabis use and peer tobacco use were the strongest correlates of an underlying disposition to engage in risky behavior. The persistence of an association with depression and anxiety symptoms is consistent with the possibility of self-medication of mental health problems with amphetamines (Harris and Edlund, 2005).

Most comparisons of occasional and regular users were not statistically significant. Odds ratios for occasional vs. regular users increased for most covariates raising the possibility that the small sample size limited our ability to detect associations.

The key strengths of this study were its relatively large sample size, a follow up spanning from adolescence to adulthood, and a statewide-representative sample. There were also some limitations. The study used self-report, and it is possible that participant under-report of use may have introduced bias into the model estimates. Although common in epidemiological studies such as the Global School-based Student Health Survey (World Health Organization, 2018) and Australia's National Drug Strategy Household Survey (AIHW, 2017), the use of single items for measuring some constructs (e.g., peer's substance use) may have underestimated the association between exposure and outcome variables. Second, the assessment of amphetamine use differed between the adolescent and adult phases of the study. The latest adult survey, for example, specified a larger range of amphetamine terms, including "crystal meth, speed, goey, ice and uppers", reflecting changing patterns of use over time. In contrast, the adolescent phase only included "speed, amphetamines and diet pills" as examples. Given that amphetamine use was generally low during adolescence at the time of data collection, the smaller number of examples seems unlikely to affect the false negative rate (adolescents who used amphetamine but reported no use in the survey). Methamphetamine only became widely available in Australia after the completion of the adolescent data collection phase.

(Topp et al., 2002; Truong et al., 2015). Third, because the prevalence of amphetamine use increased across the study period, some of the increase over the adolescent period may reflect a cohort effect. However, such change is more likely to increase the prevalence of the occasional user and regular user classes and less likely to affect the longitudinal patterns that were the focus in this study given that life course patterns of amphetamine use were similar to those found for other substances such as alcohol (Chan et al., 2013).

5. Conclusion

There were three typical longitudinal patterns of amphetamine use in this Australian cohort. The majority of the sample were non-users (83.7%), followed by occasional users (14.5%) and regular users (1.8%). Users commonly initiated use in late teenage year or early 20s, and their use peaked in their mid-20s and declined by the age of 35. Prevention programs could be implemented around or before mid-adolescence and intervention programs to reduce amphetamine harms could be delivered to high-risk individuals at their 20s, namely, regular cannabis users and those whose peers used tobacco use during adolescence.

Conflict of interest

No conflict declared.

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Contributors

Chan, Hall, and Patton developed the research questions and gathered background information. Butterworth, Degenhardt and Stockings contributed to the theoretical framework and actively provided feedbacks in the research directions and the development of the manuscript. Chan undertook the statistical analyses. Becker and Patton contributed to the data collection. All authors approved of the final manuscript.

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.2018.08.042.

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