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Patterns and transitions in substance use among young Swiss men: a latent transition analysis approach

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Abstract

This study investigates the potential stages of drug use. Data from the longitudinal Cohort Study on Substance Use Risk Factors were used (N = 5,116). Drug use (alcohol, tobacco and 16 illicit drugs) over the past 12 months was assessed at two time points. Patterns and trajectories of drug use were studied using latent transition analysis (LTA). This study's substantive contributions are twofold. First, the pattern of drug use displayed the well-known sequence of drug involvement (licit drugs to cannabis to other illicit drugs), but with an added distinction between two kinds of illicit drugs ("middle-stage" drugs: uppers, hallucinogens, inhaled drugs; and "final-stage" drugs: heroin, ketamine, GHB/GBL, research chemicals, crystal meth, and spice). Second, subgroup membership was stable over time, as the most likely transition was remaining in the same latent class.

Key words

Latent transition analysis; Patterns of drug use; Substance use; Trajectories.

Biographical sketches (50 words max/person)

Following an MSc in applied statistics in social sciences, and a Ph.D. in social and environmental psychology, **Stéphanie Baggio** is now interested in all sorts of questions surrounding risks, associated risk factors and protective factors. Her research currently focuses on substance use patterns.

Joseph Studer graduated in psychology at the University of Lausanne and then defended his doctoral thesis at the University of Geneva. As a scientific collaborator for the C-SURF study, his current research focuses on methodology and the psychological aspects associated with substance use.

Following a Ph.D. in differential psychology at the University of Rennes, **Stéphane Deline** is now interested in questions of individual differences, and the psychological and environmental factors which influence addictive behaviors and their evolution**.** His current research focuses on the non-medical use of prescription drugs.

A medical doctor, **Alexandra N'Goran** studied epidemiology at the University of Paris XI and worked on the INSERM-U687 project Eurostress, focusing on psychosocial factors related to work situations. She also worked as a consultant epidemiologist at Epicentre, in Paris, on various programs concerning epidemics.

After completing his M.Sc. in psychology, **Marc Dupuis** worked on different longitudinal studies at the University of Applied Sciences of Western Switzerland and Lausanne University Hospital. His current work as a junior researcher focuses on scale validation and the correlates of addictive behaviors.

Yves Henchoz obtained his Ph.D. in life sciences at the University of Lausanne's faculty of biology and medicine. He is interested in the physical activity and quality of life of various populations; his current research focuses on the associations between psychological and environmental factors and substance use.

Meichun Mohler-Kuo is a lecturer and head of the Mental Health and Social epidemiology unit at the Institute of Social and Preventive Medicine, University of Zurich. She trained at the Harvard School of Public Health. Her main research interests are the social and environmental determinants of health and social behaviors.

Jean-Bernard Daeppen is the head of the Alcohol Treatment Centre, a clinical and research unit of the Lausanne University Hospital. He also is an associate Professor at Lausanne University Medical School. His research activity focuses on early identification and treatment of alcohol use disorders.

Gerhard Gmel is head of the epidemiology and statistics section of the non-governmental, non-profit organization, Addiction Switzerland. He is a senior researcher at the Lausanne University Hospital's Alcohol Treatment Center. His main research interest is substance use epidemiology, particularly alcohol use.

Introduction

The ways in which adolescents and young adults initiate and progress through types of drug use is a well-studied topic (Hamburg, Kraemer, & Jahnke, 1975; Kandel, 1975; Kandel & Yamaguchi, 2002; Kandel, Kazuo Yamaguchi, & Laura Cousino Klein, 2006; Scholey *et al*., 2004). This progression usually goes from licit drugs use (alcohol and/or tobacco), to cannabis use, and finally on to the use of other illicit drugs (Fergusson, Boden, & Horwood, 2006; Kandel, 2002; Kokkevi, Richardson, Florescu, Kuzman, & Stergar, 2007; Pape, Rossow, & Storvoll, 2009; Pentz & Li, 2002; Wagner & Anthony, 2002; Willner, 2001; Wu, Schlenger, & Galvin, 2006). In contrast to this well-known and commonly agreed-upon sequence (Hamburg *et al*., 1975; Kandel, 1975; Kandel & Yamaguchi, 2002; Kandel *et al*., 2006; Scholey *et al*., 2004), the stages of involvement in illicit drugs other than cannabis remain vague. Indeed, illicit drugs other than cannabis are often aggregated into a single class (Kandel & Yamaguchi, 2002). As Kandel (2002) reported, it is difficult to establish an order of use among these drugs as they appear to be unstable (Hays, Stacy, Widaman, Di Matteo, & Downy, 1986; Windle, Barnes, & Welte, 1989). Heroin is sometimes described as the final stage of progression in drug use (Kandel, Kazuo Yamaguchi, & Cousino Klein, 2006; Valenzuela & Fernández, 2011; Wu *et al*., 2006). Cocaine, GHB/GBL and ketamine use also seem to be initiated at the end of this progression (Gross, Barrett, Shestowsky, & Pihl, 2002). A recent study identified two profiles of illicit drugs use, other than for cannabis (Baggio, Studer, Mohler-Kuo, Daeppen, & Gmel, 2013), separating "soft" or "middle-stage" drug users (who used uppers such as speed, ecstasy, cocaine; hallucinogens such as magic mushrooms or LSD; and inhaled drugs such as poppers or solvents) from "hard" or "final-stage" drug users (who used "soft" drugs, but also heroin, ketamine, GHB/GBL, research chemicals, crystal meth, and spice). However, this study had a cross-sectional design and thereby was unable to identify whether these profiles for drug users demonstrated any use progression through different illicit drugs. The current study aims to provide much more detailed information about the potential stages of illicit drug use (other than cannabis) in a longitudinal design.

Beyond this well-known sequence of involvement in drug use, some studies have reported that the use of a drug does not necessarily lead to the use of drugs that come later in the sequence (Kandel & Davies,

1992). One way of studying drug progression is to model transitions using latent transition analysis (LTA). LTA is a longitudinal extension of latent class analysis (LCA, Goodman, 1974; Lazarsfeld & Henry, 1968). LCA is a multivariate model that derives classes of individuals who share common patterns and describes sets of characteristics parsimoniously. LTA models transitions between these class memberships over time, and has been used often in recent substance use research (Cleveland, Lanza, Ray, Turrisi, & Mallett, 2012; Kam & Collins, 2000; Ko, Martins, Kuramoto, & Chilcoat, 2010; La Flair *et al*., 2013; Lanza, Patrick, & Maggs, 2010; Maldonado-Molina & Lanza, 2010; Patrick *et al*., 2009; Tang, Lanza, & Collins, 2001; White, Bray, Fleming, & Catalano, 2009). Several studies using LTA to examine transitions from one stage to another revealed that the most common pattern involved stopping at a particular stage and progressing no further along the drug use scale (Hawkins, Hill, Guo, & Battin-Pearson, 2002; Lanza *et al*., 2010; Patrick *et al*., 2009; Tang *et al*., 2001). This shows that substance use seems to be quite stable across time; the highest probability among the transition alternatives is that people remain in the same latent class (Collins, 2002; Hawkins *et al*., 2002; Kam & Collins, 2000; Lanza *et al*., 2010; Tang *et al*., 2001). Tobacco use was an exception; this showed less stable patterns, for which participants transitioned from tobacco use only, to both tobacco and alcohol use (Kam & Collins, 2000; Patrick *et al*., 2009; Tang *et al*., 2001). Progression is by no means inevitable (Kandel, 2002). Substance use in adolescents and young adults is often experimental and recreational; very few people progress to using illicit drugs other than cannabis (EMCDDA, 2009). Moreover, use of some drugs is initiated after the teenage years (average onset of heroin use, 22.1 years of age; cocaine use, 20.1 years of age; SAMHSA, 2012), and studies focusing on adolescence or very early adulthood may miss the initiation of such substance use. How quickly transitions between the use of different substances occurs is also interesting. Some studies assessed such closely related measures (fall and spring semesters in college students, Lanza *et al*., 2010; 8th and 9th grades students, Patrick *et al*., 2009; 9th and 10th grade students, Hawkins *et al*., 2002) that they may not have been able to catch transitions from one latent class to another, especially in teenage years.

This study's principal aim was to investigate the way in which young Swiss males in their early twenties changed their drug use. As the profiles of drug users described above (Baggio *et al*., 2013) were baseline data from the present study, we hypothesized that these profiles would also fit the follow-up data and that stages of drug use would first include alcohol use, then tobacco use, then cannabis use, followed by "middle-stage" illicit drugs and finally by "final-stage" illicit drugs (H1). As regards transition, following on from previous studies, we hypothesized that the most common transition in substance use would not actually be a transition, but would be to remain in the same latent class, as only a few people moved to illicit drug use (H2). Drug use over the past twelve months was used to test whether participants had stopped using drugs, and to also to investigate forward and backward transitions in substance use, the latter being an understudied topic. The ages of onset of alcohol, tobacco and cannabis use were also assessed, as these variables are known to be important ones for preventive purposes.

Method

Participants and procedures

The present study analyzed data collected from the Cohort Study on Substance Use Risk Factors (C-SURF). C-SURF is a longitudinal study designed to assess substance use patterns and their related consequences in young Swiss men. Participants were enrolled in three of Switzerland's six army recruitment centers, which cover 21 of the country's 26 cantons (including all French-speaking ones). These are located in Lausanne (French-speaking), Windisch and Mels (German-speaking). All young men of around 20 years old were eligible for study inclusion because attending army recruitment is obligatory in Switzerland. It is important to note that the recruitment centers were only used to enroll participants. Assessment of baseline and follow-up data was carried out outside the army environment, and independently of military service, civic service or no service at all. Baseline data were collected between August 23rd 2010 and November 15th 2011; follow-up data were collected between January 10th 2012 and April 15th 2013.

Participants who gave a written consent to participate in recruitment centers were invited two weeks later by mail or email to fill in a paper and pen or an online questionnaire, according to the favorite way they indicated in the written consent. The questionnaire lasted approximately 1 hour and included topics such as sociodemographic background, health, family background, substance use (alcohol, tobacco, cannabis, other illicit drugs, prescription drugs), personality and leisure time activities and sexuality. For follow-up, participants were again invited to fill in the questionnaire.

A total of 5,990 participants filled in the baseline questionnaire, and 5,223 (87.2%) filled in the follow-up questionnaire. Missing values were listwise deleted, and the final sample consisted of 5,116 participants (98.0% of the follow-up sample). More information on sampling and non-response can be found in Studer *et al.* (Studer *et al.*, 2013). Briefly, non-respondents used more alcohol, tobacco and cannabis than respondents, but the magnitude of the differences was small, indicating a small non-response bias. The study protocol (Protocol No. 15/07) was approved Lausanne University Medical School's Ethics Committee for Clinical Research.

Measures

Alcohol use. Alcohol use was assessed at both baseline and follow-up by asking participants if they had drunk any kind of alcohol in the past 12 months: "*During the last 12 months, did you have at least 1 drink of any kind of alcohol (not counting small tastes or sips)?"* Pictures of standard drinks containing approximately 10-12 g of pure alcohol were provided. Answers were coded as "used" or "not used". They were also asked at what age they had used alcohol for the first time.

Tobacco use. Participants were asked at both baseline and follow-up if they had smoked during the past 12 months: *"Have you smoked cigarettes in the past 12 months?"* Answers were also coded as "used" or "not used". Age of first tobacco use was assessed.

Cannabis use. Cannabis use was assessed at both baseline and follow-up by asking participants if they had smoked cannabis (hashish, marijuana or grass) during the past 12 months: *"Have you used any*

cannabis over the past 12 months?" Answers were coded as "used" or "not used". Age of first cannabis use was also assessed.

Illicit drug use. At both baseline and follow-up, fifteen questions measured use of illicit drugs over the past 12 months (*"Have you taken any of the following drugs in the past 12 months?"*); answers were coded as "used" or "not used". The substances were as follows: 1) hallucinogens, magic mushrooms, psilocybin, peyote, mescaline; 2) other hallucinogens (LSD, PCP/Angel Dust, 2-CB, 2-CI); 3) salvia divinorum; 4) speed; 5) amphetamine, methamphetamine, amphetamine sulfate (e.g. Dexedrine, Benzedrine); 6) crystal meth (ice); 7) poppers (e.g. amyl nitrite, butyl nitrite); 8) solvents for sniffing (e.g. glues, solvents and gases such as benzine, ether, toluene, trichloroethylene, nitrous oxide); 9) ecstasy, MDMA; 10) cocaine, crack, freebase; 11) heroin; 12) ketamine (Special K), DXM; 13) GHB/GBL/1,4-butanediol (BDB); 14) research chemicals (e.g. mephedrone, butylone and methedrone); and 15) spices or similar substances.

Statistical analyses

First, descriptive statistics were computed to estimate the prevalence rates of all drugs at baseline and follow-up. McNemar tests for related samples were computed for each substance at baseline and followed-up to assess whether there was an increase in the prevalence rates for each substance use. LTA was then used to derive classes of individuals who shared common patterns, and to model transitions between these classes over time. Two steps were used in the present study. To begin, at each time point, we tested alternative models for selecting the correct number of classes for the latent model (LCA at baseline, and LCA at follow-up). The number of latent classes was unknown, and fit indices for various models were used to assess the optimal number of classes. Bayesian information criterion (BIC), sample-size adjusted BIC (ABIC) and Akaike information criterion (AIC) were used, for which lower values indicate a better fit (Raftery, 1995). The Lo-Mendel-Rubin likelihood ratio test (LMR LRT) indicates whether a model with k classes is better than a model with k-1 classes (Lo, Mendell, & Rubin, 2001). A low p-value indicates that the model with k-1 classes has been rejected in favor of the model with k

classes. Two LTA were subsequently performed to test measure invariance across time. The first model constrained the item-response probabilities (used to assign each participant to the most likely latent class) to be equal across time (measurement-invariance model), and the second model had no restrictions (measurement-variance model). The likelihood-ratio statistic was given for each model. A Chi-square statistic between the measurement-invariance model and measurement-variance model was computed to determine whether the structure of substance use behavior differed across time. This was an important step from a conceptual point of view, i.e. the meaning of latent classes remains the same over time. It was also important from a statistical point of view, i.e. the fewer the parameters, the more stable the estimation (Lanza *et al*., 2001). Class membership and transition probabilities were discussed for the model that best fitted the data. Three kinds of information are provided: 1) probabilities of substance use in each class; 2) the percentage of users in each latent class; and 3) transition probabilities (e.g. changes of latent class membership between baseline and follow-up). These analyses were performed using SPSS 21 for descriptive statistics and the comparisons of proportions, and using Mplus 6 (Muthén & Muthén, 2010) for LTA.

Results

Preliminary results

The mean age of the participants was 19.97 ± 1.21 years at baseline and 21.26 ± 1.23 years at follow-up. Around 15 months separated baseline data collection from follow-up data collection. Respondents and non-respondents at follow-up did not differ by age (non-respondents at baseline: 20.24 ± 1.39). For 5 out of 18 substances (tobacco, cannabis, ecstasy, cocaine and heroin) non-respondents were more often substance users than respondents. Ages at first alcohol, tobacco and cannabis use were 14.42 ± 2.14 years, 14.70 ± 2.50 and 15.87 ± 1.90, respectively. Table 1 presents percentages of use for each drug at the two time points. Alcohol was the most commonly used substance (92.7% of the sample at both baseline and follow-up). Tobacco and cannabis were respectively the second and third most used substances (45.6% and 46.6% used tobacco, and 30.0% and 31.0% used cannabis, at baseline and follow-up, respectively).

Thus the use of these substances remained stable over time (alcohol: $p = .951$; tobacco: $p = .067$; cannabis: $p = .072$). With regards to other illicit drugs, these can be categorized into two groups. Hallucinogens (magic mushrooms, others hallucinogens, salvia divinorum), uppers (ecstasy, cocaine, speed, amphetamine/methamphetamine) and inhalants (poppers, solvents) showed higher prevalence rates than spice, ketamine, GHB/GBL, crystal meth, research chemicals and heroin, at both baseline and follow-up. For the first group (labeled "middle-stage drugs"), prevalence rates ranged between 1.8% and 3.4% at baseline and 2.1% and 5.2 % at follow-up. For the second group (labeled "final-stage drugs"), prevalence rates ranged between 0.3% and 0.5% at baseline and 0.7% and 0.9% at follow-up. Use of 9 out of 15 illicit drugs increased between the baseline and the follow-up. The most pronounced increases in illicit drugs were ecstasy (3.4% at baseline, 5.2% at follow-up, $p < .001$), cocaine (2.8% at baseline, 3.9% at follow-up, $p < .001$) and heroin (0.5% at baseline, 0.8% at follow-up, $p < .001$).

Insert Table 1 about here

Assessing the optimal number of latent classes

Six models were used on both the baseline and follow-up surveys, using latent class analysis to estimate the optimal number of classes. The fit indices are presented in Table 2. The five-class model was the best one for both the baseline and follow-up data because it demonstrated the best fit indices. Even if AIC decreased for the six-class model, the LMR LRT showed non-significant p-values for this model, and the BIC and ABIC increased. The next step was performed using a five-class model for both time points.

Insert Table 2 about here

Latent transition analysis: assessing measurement invariance

The Chi-square statistic was used to test the structure of measurement and to assess which between measurement-invariance model and measurement-variance model over time was the best model. The results showed χ^2 (90) = 47.07, $p = .99$. This non-significant p-value indicated that the structure of

substance use behavior did not change over time, i.e. the latent classes (for both baseline and follow-up) showed the same pattern. The measurement-invariance model was validated for use.

Latent transition analysis: examining patterns of drug use over time

In the first panel of Table 3, the item-response probabilities were thus constrained to be equal at baseline and follow-up for each of the five classes of substance use behavior. The first latent class was labeled '**alcohol users only**', because participants in this class had a high probability of alcohol use (.875) and low probabilities of other substance use (probability .045 and lower). The second latent class was labeled '**alcohol and tobacco users**' as participants in this class showed high probabilities of alcohol (.969) and tobacco (.929) use, but low probabilities for other substance use (probability .179 for cannabis use, and .018 and lower for all other illicit drugs). The third latent class was labeled '**alcohol, tobacco and cannabis users**' because participants had high probabilities of using these three substances (.989, .819 and .955, respectively), but not the other illicit drugs (probability .048 and lower). The fourth latent class was labeled '**alcohol, tobacco, cannabis and "middle-stage" drugs users**', who used many drugs (alcohol: .973; tobacco: .941; cannabis: .909; "middle-stage" drugs: from .119 to .697), but not "final-stage" drugs, for which probabilities were lower (probability .055 and lower). The fifth and final latent class referred to '**all drug users**', including both "middle-stage" and "final-stage" drugs (probabilities from .641 to .961) in addition to alcohol (.846), tobacco (.447) and cannabis (.449). Participants who were non-alcohol users (7.3% of the sample) mostly belonged to the second latent class (84.9% of them).

Users of alcohol only (class 1) were the most prevalent class (49.33% at baseline, 47.89% at follow-up), and all drugs users (class 5) were the least prevalent class (0.31% at baseline, 0.70% at follow-up). McNemar tests for paired samples were also performed for each latent class, comparing proportions of users at baseline and follow-up. Consistent with the first part of the analysis, differences in prevalence rates only increased significantly for the last two classes, including "middle-stage" drug users and "final-stage" drug users. The percentage of users in the three first classes (alcohol, tobacco and cannabis users) was stable over time (second class) or decreased significantly (first and third classes). Transition

probabilities contained in the third panel of Table 3 showed that the most common transition was not a transition at all, but rather to remain in the same latent class at baseline and follow-up. Indeed, the diagonal of the matrix (in bold font) shows this. Users of alcohol only (class1) at baseline had a probability of .896 of still being classified in this class at follow-up. The other classes also showed high probabilities for their membership to be stable over time (alcohol and tobacco users: .842; alcohol, tobacco and cannabis users: .898; alcohol, tobacco, cannabis and "middle-stage" drug users: .840), except for the class of all drug users. This was the least stable class, showing the highest probability of not remaining in the same class (.419). The second highest transition probability, with .183, was a move from the all drug user class to the alcohol only user class. The transitions from alcohol to alcohol and tobacco use, and from alcohol, tobacco and cannabis use to alcohol, tobacco, cannabis and "middle-stage" drugs use, were the most interesting ones. Participants had a probability of .080 of progressing from alcohol to alcohol and tobacco use (the second highest probability for alcohol users at baseline). On the other hand, participants had a probability of .120 of transitioning from alcohol and tobacco use to alcohol use only (the second highest probability for alcohol and tobacco users at baseline). The same pattern of transitions was shown for alcohol, tobacco and cannabis users, and for alcohol, tobacco, cannabis and "middle-stage" drugs users: the probability of progressing from the first to the second latent class was .058 (the second highest probability for alcohol, tobacco and cannabis users at baseline), whereas the probability of transitioning from alcohol, tobacco, cannabis and "middle-stage" drugs use to alcohol, tobacco and cannabis use was .061 (the second highest probability for alcohol, tobacco, cannabis and "middle-stage" drug users at baseline).

The ages of first use of alcohol, tobacco and cannabis were earlier for the last class, users of all drugs (10.69, 10.64 and 10.55 years old, respectively). Users who were part of the fourth class also showed early use of alcohol, tobacco and cannabis (12.98, 13.35 and 14.56 years old, respectively), whereas users of the first class (alcohol users only) showed later first use (14.90, 14.93 and 16.38 years old, respectively).

Discussion

Main findings

This study aimed to investigate the ways in which young adults, part of a sample of Swiss males, progress between the uses of different drugs. Transitions to both more and less drug use were investigated.

First, the results showed that participants exhibited high prevalence rates of alcohol, tobacco and cannabis use, which remain stable over time. Indeed, these three substances are often the first to be experienced during teenage years, and one can suppose that many of the 20 to 21-year-old participants had already experienced these substances. Nine out of 18 substances showed an increase in use between the baseline and follow-up. The substances that showed the highest increase in use were ecstasy, cocaine and heroin. This result is in accordance with the conclusions of previous studies (e.g. SAMHSA, 2012) which showed that the mean ages for first use of cocaine and heroin were 20.1 and 22.1 years old, respectively. Unfortunately, these studies (EMCDDA, 2009; SAMHSA, 2012) have no data for ecstasy and other illicit drugs, but the fact that most of the illicit drugs in our study showed an increase in use seemed to be in accordance with the idea that participants had reached an age at which they started to experiment with illicit drugs other than cannabis.

The results of LTA confirmed the validity of splitting illicit drugs other than cannabis into two separate classes (H1). A five-class model proved to have the best fit. The classes reflected the stages of involvement in drug use. The first class referred to users of alcohol only; the second class to users of alcohol and tobacco; the third class to users of alcohol, tobacco and cannabis; the fourth class to users of alcohol, tobacco, cannabis and "middle-stage" drugs; and the fifth class to all drug users (alcohol, tobacco, cannabis, "middle-stage" and "final-stage" drugs). Each class added substances to those used by the previous class. These results have been described already elsewhere (Baggio *et al*., 2013), but the present study also showed that there were two reasons why this pattern was quite stable. First, the latent classes were the same at baseline and follow-up (i.e. the same groups of users were found at both time points), and second, the structure of substance use behavior remained the same over time, with

measurement invariance across time (e.g. the classes were constituted in the same way, with same probabilities of each substance use at both time points).

An additional result was that there was no class of "non-users". This result contrasted with previous studies using LTA, which have usually shown a class of non-users (Kam & Collins, 2000; Lanza *et al*., 2010; Patrick *et al*., 2009; Tang *et al*., 2001). However, the participants in the current study were older than those mentioned above which focused on teenagers, and this enhanced the fact that this study dealt with involvement further along the drug course.

Furthermore, LTA did not show a progression within classes of substance use. The most common transition was not a transition at all, but rather participants remained in the same latent class: that is to say, they kept using the same drugs without adding new ones and transitioning to the next stage. This was despite the fact that the proportions of users of classes including "middle-stage" drugs and "final-stage" drugs increased between baseline and follow-up. This result was in accordance with hypothesis H2 and with previous studies which concluded that the most common pattern was to stop at a particular stage and not to progress further (Collins, 2002; Hawkins *et al*., 2002; Kam & Collins, 2000; Lanza *et al*., 2010; Patrick *et al*., 2009; Tang *et al*., 2001). However, even if the transitions mostly remained stable, one can see some interesting transitions between alcohol and alcohol/tobacco use, and alcohol/tobacco/cannabis and alcohol/tobacco/cannabis/" middle-stage" drug use. A non-negligible amount of participants progress from one class to the next (7.5% of alcohol users transitioned to alcohol/tobacco use, and 5.7% of alcohol/tobacco/cannabis users transitioned to alcohol/tobacco/cannabis/"middle-stage" drugs use). On the other hand, some participants also regressed from one class to the previous one (11.0% of alcohol/tobacco users transitioned back to alcohol use alone, and 6.4% of alcohol/tobacco/cannabis/"middle-stage" drugs users transitioned to alcohol/tobacco/cannabis use). Thus there were clearly two patterns of transitions that could occur when participants did not remain in the same latent class. Whereas some users progressed along the drug use course, others stopped using drugs and went back down to a previous latent class. This regression may be synonymous of experimental drug

use. Participants tried a drug, but after their experience they did not remain users and moved back down a stage in the drug use course.

To summarize, drug prevalence rates significantly increased for half of all the substances investigated, but this progression only concerned illicit drugs other than cannabis. Most users actually stayed within their latent class. One explanation may be that even though the use of some substances had increased, overall prevalence rates remained low, and only a small number of participants were users of "middle-stage" or "final-stage" drugs. As mentioned in the introduction, only a few people actually transitioned to illicit drug use (between 0.3% and 5.2% used illicit drugs other than cannabis in descriptive statistics, and the percentages of latent classes including "soft" and "hard" drugs were respectively 0.28% and 5.33%) (Kandel, 2002; EMCDDA, 2009), and the transition probabilities showed that the most common trajectories were not actually progressions in drug involvement.

Ages of first use of alcohol, tobacco and cannabis according to the different classes of drug users showed that the more participants used drugs, the younger they had probably been when they first experienced alcohol, tobacco and cannabis. This result was especially true for the last latent class of all drugs users, including "final-stage" drugs. On average, participants in this class had had their first experiences with alcohol, tobacco and cannabis in their teenage years. This result especially underlined the importance of early preventive actions—actions, which should no doubt continue with young adults, because drug users in their early twenties were more likely to remain in the same latent class and continue in their current drug use pattern, rather than reduce use.

Limitations

This study had several limitations. First, this study also focused on drug use over the past 12 months, without taking into account whether it was light or heavy use. This variable is undoubtedly a crucial one in any potential progression along the drug course, and should be considered in further studies. A second shortcoming is that no women could be included. Further investigations are needed to see whether the patterns and progression of drug use also fit women's substance use behavior. Finally, a last limitation

was that participants were a sample of males in their early twenties, with average age lower than average age of onset of heroin use (i.e. 22.1 years). Indeed, prevalence rates may be lower for "final-stage" drugs experienced later, resulting in separate latent classes. More studies with participants in their middle twenties and late twenties are needed to encapsulate transitions to "final-stage" drugs.

Conclusion

To conclude, the substantive contributions of this study are threefold. First, the pattern of drug use followed the well-known sequence of drug involvement (from licit drugs to cannabis, and then on to other illicit drugs), but a distinction was added between two kinds of other illicit drugs ("middle-stage" drugs: uppers, hallucinogens, and inhaled drugs; and "final-stage" drugs: heroin, ketamine, GHB/GBL, research chemicals, crystal meth, and spice). Second, there was no latent class of non-users. Participants belonged to at least the alcohol users' class. Third, latent class membership was stable over time as the most likely transition between baseline and follow-up was not a transition at all, but rather to remain in the same latent class. Progression along the drug course up to illicit drugs other than cannabis remains rare among participants in their twenties, since very few people move on to the use of the hardest drugs. Indeed, preventive action should focus on teenagers, including teenagers in their early teens, as young users were more likely to progress to illicit drug use.

References

Baggio, S., Studer, J., Mohler-Kuo, M., Daeppen, J.-B., & Gmel, G. (2013). Profiles of drug users in Switzerland and effects of early-onset intensive use of alcohol, tobacco and cannabis on other illicit drug use. *Swiss Medical Weekly, 143*.

Cleveland, M. J., Lanza, S. T., Ray, A. E., Turrisi, R., & Mallett, K. A. (2012). Transitions in first-year college student drinking behaviors: Does pre-college drinking moderate the effects of parent- and peer-based intervention components? *Psychology of Addictive Behaviors, 26*, 440-450.

Collins, L. M. (2002). Using latent transition analysis to examine the Gateway Hypothesis. In D.B. Kandel (Ed.), *Stages and pathways of drug involvement* (pp. 254-269). Cambridge: Cambridge University Press,.

EMCDDA. (2009). *Polydrug use: Patterns and responses*. Lisbon: European Monitoring Centre for Drugs and Drug Addiction.

Fergusson, D. M., Boden, J. M., & Horwood, L. J. (2006). Cannabis use and other illicit drug use: testing the cannabis gateway hypothesis. *Addiction, 101*, 556-569.

Goodman, L. A. (1974). Exploratory latent structure analysis using both identifiable and unidentifiable models. *Biometrika, 61*, 215-231.

Gross, S. R., Barrett, S. P., Shestowsky, J. S., & Pihl, R. O. (2002). Ecstasy and drug consumption patterns: a Canadian rave population study. *Canadian Journal of Psychiatry, 47*, 546-551.

Hamburg, B. A., Kraemer, H. C., & Jahnke, W. (1975). A hierarchy of drug use in adolescence: Behavioral and attitudinal correlates of substantial drug use. *The American Journal of Psychiatry, 132*, 1155-1163.

Hawkins, J. D., Hill, K. G., Guo, J., & Battin-Pearson, S. R. (2002). Substance use norms and transitions in substance use: Implications for the Gateway Hypothesis. In D.B. Kandel (Ed.), *Stages and Pathways of Drug Involvement* (pp. 42-64). Cambridge: Cambridge University Press.

Hays, R. D., Stacy, A. W., Widaman, K. F., Di Matteo, M. R., & Downy, R. (1986). Multistage path models of adolescent alcohol and drug use: A reanalysis. *The Journal of Drug Issues, 16*, 357-369.

Kam, C. M., & Collins, L. M. (2000). *Latent transition analysis of substance use among adolescents in the National Longitudinal Survey of Youth*. University Park, PA: The Methodology Center, The Pennsylvania State University.

Kandel, D. B. (1975). Stages in adolescent involvement in drug use. *Science, 190*, 912-914.

Kandel, D. B. (2002). Examining the gateway hypothesis stages and pathways of drug involvement. In D.B. Kandel (Ed.), *Stages and pathways of drug involvement: Examining the gateway hypothesis* (pp. 3-15). Cambridge: Cambridge University Press.

Kandel, D. B., & Davies, M. (1992). Progression to regular marijuana involvement: Phenomenology and risk factors for near-daily use. In M. D. Glantz & R. W. Pickens (Eds.), *Vulnerability to drug abuse* (pp. 211-253). Washington, DC, US: American Psychological Association.

Kandel, D. B., & Yamaguchi, K. (2002). Stages of involvement in the U.S. population. In D.B. Kandel (Ed.), *Stages and pathways of drug involvement: Examining the gateway hypothesis* (pp. 65-89). Cambridge: Cambridge University Press.

Kandel, D. B., Yamaguchi, K., & Klein, L. C. (2006). Testing the Gateway Hypothesis. *Addiction, 101*, 470-472; discussion 474-476.

Ko, J. Y., Martins, S. S., Kuramoto, S. J., & Chilcoat, H. D. (2010). Patterns of alcohol-dependence symptoms using a latent empirical approach: associations with treatment usage and other correlates. *Journal of Studies on Alcohol and Drugs, 71*, 870-878.

Kokkevi, A., Richardson, C., Florescu, S., Kuzman, M., & Stergar, E. (2007). Psychosocial correlates of substance use in adolescence: A cross-national study in six European countries. *Drug and Alcohol Dependence, 86*, 67-74.

La Flair, L. N., Reboussin, B. A., Storr, C. L., Letourneau, E., Green, K. M., Mojtabai, R., . . . Crum, R. M. (2013). Childhood abuse and neglect and transitions in stages of alcohol involvement among women: A latent transition analysis approach. *Drug and Alcohol Dependence*. In press.

Lanza, S. T., Patrick, M. E., & Maggs, J. L. (2010). Latent transition analysis: Benefits of a latent variable approach to modeling transitions in substance use. *Journal of Drug Issues, 40*, 93-120.

Lazarsfeld, P. F., & Henry, N. W. (1968). *Latent structure analysis*. Boston, MA: Houghton Mifflin.

Lo, Y., Mendell, N. R., & Rubin, D. B. (2001). Testing the number of components in a normal mixture. *Biometrika, 88*, 767-778.

Mackesy-Amiti, M. E., Fendrich, M., & Goldstein, P. J. (1997). Sequence of drug use among serious drug users: typical vs atypical progression. *Drug and Alcohol Dependence, 45*, 185-196.

Maldonado-Molina, M. M., & Lanza, S. T. (2010). A framework to examine gateway relations in drug use: An application of latent transition analysis. *Journal of Drug Issues, 40*, 901-924.

Muthén, L. K., & Muthén, B. O. (2010). *Mplus user's guide. Sixth edition*. Los Angeles, CA: Muthén & Muthén.

Pape, H., Rossow, I., & Storvoll, E. E. (2009). Under double influence: Assessment of simultaneous alcohol and cannabis use in general youth populations. *Drug and Alcohol Dependence, 101*, 69-73.

Patrick, M. E., Collins, L. M., Smith, E., Caldwell, L., Flisher, A., & Wegner, L. (2009). A prospective longitudinal model of substance use onset among South African adolescents. *Substance Use & Misuse, 44*, 647-662.

Pentz, M. A., & Li, C. (2002). The gateway theory applied to prevention. In D.B. Kandel (Ed.), *Stages and Pathways of Drug Involvement: Examining the Gateway Hypothesis* (pp. 139-157). Cambridge: Cambridge University Press.

Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology*, *25*, 111-163.

SAMHSA. (2012). *Results from the 2011 national survey on drug use and health: Summary of national findings*. Rockville, MD: Substance Abuse and Mental Health Services Administration.

Scholey, A. B., Parrott, A. B., Buchanan, T., Heffernan, T. M., Ling, J., & Rodgers, J. (2004). Increased intensity of Ecstasy and polydrug usage in the more experienced recreational Ecstasy/MDMA users: a WWW study. *Addictive Behaviors*, *29*, 743-752.

Studer, J., Baggio, S., Mohler-Kuo, M., Dermota, P., Gaume, J., Bertholet, N., . . . Gmel, G. (2013). Examining non-response bias in substance use research—Are late respondents proxies for non-respondents? *Drug and Alcohol Dependence*. In press.

Tang, Z., Lanza, S. T., & Collins, L. M. (2001). *Modeling adolescent substance use using latent transition analysis: The healthy for life data set*. University Park, PA: The Methodology Center, The Pennsylvania State University.

Valenzuela, E., & Fernández, M. (2011). The sequence of drug use: Testing the Gateway Hypothesis in Latin America. *The Journal of International Drug, Alcohol and Tobacco Research, 1*, 1-8.

Wagner, F. A., & Anthony, J. C. (2002). Into the world of illegal drug use: Exposure opportunity and other mechanisms linking the use of alcohol, tobacco, marijuana, and cocaine. *American Journal of Epidemiology, 155*, 918-925.

White, H. R., Bray, B. C., Fleming, C. B., & Catalano, R. F. (2009). Transitions into and out of light and intermittent smoking during emerging adulthood. *Nicotine & Tobacco Research, 11*, 211-219.

Willner, P. (2001). A view through the gateway: expectancies as a possible pathway from alcohol to cannabis. *Addiction, 96*, 691-703.

Windle, M., Barnes, G. M., & Welte, J. (1989). Causal models of adolescent substance use: An examination of gender differences using distribution-free estimators. *Journal of Personality and Social Psychology, 56*, 132-142.

Wu, L.-T., Schlenger, W. E., & Galvin, D. M. (2006). Concurrent use of methamphetamine, MDMA, LSD, ketamine, GHB, and flunitrazepam among American youths. *Drug and Alcohol Dependence, 84*, 102-113.

Table 1. Percentages of drug use and comparisons across time with McNemar test for related samples (N = 5,116)

	Baseline	Follow-up	McNemar p-value
Alcohol	92.7	92.7	.951
Tobacco	45.6	46.6	.067
Cannabis	30.0	31.0	.072
Hallucinogens/magic mushrooms	2.7	3.4	.007
Ecstasy	3.4	5.2	< .001
Cocaine	2.8	3.9	< .001
Salvia divinorum	2.1	2.0	.933
Poppers	2.5	2.7	.505
Solvents for sniffing	2.2	2.1	.596
Speed	2.4	3.1	.011
Other hallucinogens	2.1	2.6	.062
Amphetamine/methamphetamine	1.8	2.5	.001
Spice	0.5	0.7	.112
Ketamine	0.5	0.9	.008
GHB/GBL	0.5	0.8	.054
Crystal meth	0.4	0.7	.025
Research chemicals	0.4	0.8	.002
Heroin	0.3	0.8	< .001

Table 2. Comparisons of different LCA models for baseline and follow-up data

	Model	BIC	ABIC	AIC	LMR p-value
Baseline	One-class	27683	27625	27565	-
	Two-class	23928	23811	23687	.000
	Three-class	22773	22595	22408	.000
	Four-class	22625	22386	22135	.014
	Five-class	22363	22363	22048	.002
	Six-class	22779	22420	22041	.349
Follow-up	One-class	30811	30754	30694	-
	Two-class	25556	25439	25315	.000
	Three-class	24353	24175	23988	.000
	Four-class	23754	23485	23234	.000
	Five-class	23720	23421	23106	.007
	Six-class	23799	23440	23062	.205

Table 3. Five-class model of substance use

	Latent classes[2]				
	Class 1	Class 2	Class 3	Class 4	Class 5
Probability of substance use[1]					
Alcohol	.875	.969	.989	.973	.846
Tobacco	.015	.929	.819	.941	.447
Cannabis	.045	.179	.955	.909	.449
Hallucinogens/magic mushrooms	.002	.001	.048	.330	.882
Ecstasy	.002	.003	.018	.697	.961
Cocaine	.001	.004	.021	.514	.860
Salvia divinorum	.000	.002	.029	.204	.869
Poppers	.006	.018	.034	.171	.748
Solvents for sniffing	.006	.014	.028	.119	.709
Speed	.000	.004	.008	.434	.947
Other hallucinogens	.000	.001	.007	.371	.902
Amphetamine/methamphetamine	.001	.002	.005	.333	.938
Spice	.000	.000	.006	.034	.641
Ketamine	.000	.000	.001	.055	.847
GHB/GBL	.000	.000	.001	.042	.793
Crystal meth	.000	.000	.000	.033	.714
Research chemicals	.000	.000	.001	.039	.734
Heroin	.000	.000	.000	.030	.846
Percentages of latent class membership					
Baseline	49.33%[a]	26.00%[a]	20.35%[a]	4.01%[a]	0.31%[a]
Follow-up	47.89%[b]	26.42% [a]	19.72%[b]	5.28% [b]	0.70%[b]
Transition probabilities[3]					
Class 1	**.896**[4]	.080	.014	.005	.006
Class 2	.120	**.842**	.019	.017	.002
Class 3	.022	.015	**.898**	.058	.007
Class 4	.012	.065	.061	**.840**	.022
Class 5	.183	.085	.155	.158	**.419**
Ages of first use (for baseline classes)					
Alcohol	14.90	14.23	13.88	12.98	10.69
Tobacco	14.93	14.97	14.54	13.35	10.64
Cannabis	16.38	16.07	15.82	14.56	10.55

[1] Item-response probabilities constrained to be equal at baseline and follow-up.

[2] Class 1: alcohol users only; class 2: alcohol and tobacco users; class 3: alcohol, tobacco and cannabis users; class 4: alcohol, tobacco, cannabis and "middle-stage" drug users; class 5: all drug users, including "final-stage" drugs.

[3] Baseline: rows, follow-up: columns.

[4] Transition probabilities in bold font correspond to membership of the same latent class at each time point.

[a, b] McNemar test for each latent class was performed, comparing baseline and follow-up proportions. A same subscript letter denotes that proportions did not differ at baseline and follow-up, two different subscript letters denote that proportions differ at the .001 level (.002 for class 5).