



## Full length article

## Multiple substance use patterns in adolescents—A multilevel latent class analysis



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## ABSTRACT

**Background:** Multiple substance use among adolescents is associated with a number of negative consequences. Therefore, we aim to investigate multiple substance use patterns among young adolescents and identify possible multilevel predictors.

**Methods:** We analyzed a longitudinal sample of 2490 German students (51% male;  $M_{age} = 13.32$ ,  $SD = 0.57$ ) at 45 schools in four German states (Bremen, Hesse, North Rhine–Westphalia, Schleswig–Holstein), who completed two assessments in fall, 2010 and fall, 2013. We conducted multilevel latent class analysis for follow-up data on a variety of outcomes, and tested our final 3-class-model for possible baseline predictors. Follow-up substance use measures included lifetime use, current use, and amount of substance for cigarettes and alcohol. Baseline covariates comprised age, gender, socio-economic status, bullying, victimization, peer and parental use, type of school, and health certification of school.

**Results:** We identified three latent classes: non-users ( $n = 1541$ ; 61.9%), experimenters ( $n = 722$ ; 29.0%), and multiusers ( $n = 227$ ; 9.1%). Experimental consumption was predicted by higher baseline age ( $OR = 1.71$ ; 1.31–2.24), paternal drinking ( $OR = 2.89$ ; 1.23–6.79), and school type ( $OR = 2.57$ ; 1.83–3.61), while multiuse was predicted by peer smoking ( $OR = 2.94$ ; 1.80–4.80) and drinking ( $OR = 2.13$ ; 1.32–3.44), maternal drinking ( $OR = 6.26$ ; 2.02–19.43), bullying ( $OR = 1.69$ ; 1.15–2.48), higher age ( $OR = 1.92$ ; 1.40–2.62), and school type ( $OR = 4.76$ ; 2.75–8.24) compared to the non-users class.

**Conclusions:** Prevention and further research on multiple substance use need to concentrate on social influence models and behavior-related interventions, especially at schools without a college-preparatory track.

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## 1. Introduction

Substance use among adolescents is a serious issue, as it is often connected to social, financial, and health problems (World Health Organisation, 2014). Research shows that use of multiple substances is associated with even higher risks and worse consequences than single substance use (Kelly et al., 2015; Kokkevi et al., 2014), e.g., multiusers are more likely to fail at school (Kelly et al., 2015) than non-users or single substance users. In addition, according to the gateway hypothesis, excessive alcohol or tobacco use fulfills a gateway function for illicit drug use (Kandel et al., 1992), more recent studies prove an increased chance for such a pathway, if multiple substances are used (Maldonado-Molina and Lanza, 2010). However, most studies on adolescent substance use focus on one-dimensional outcomes, e.g., smoker versus non-smoker, or

frequent versus infrequent use, and thus neglect more complex use patterns. Even when multiple substances are accounted for, indicators for each substance are seldom combined in a methodologically sophisticated way, but rather analyzed via simple contingency tables, which makes consecutive testing very difficult due to low cell frequencies (Choquet et al., 2004). In recent years, latent class analysis (LCA) has emerged as a more popular way of empirically identifying ecologically valid substance use patterns among adolescents, and additionally allowing for predictors of class membership (Lanza and Rhoades, 2013).

Latent classes refer to homogenous subgroups among participants with similar response patterns. LCA is usually used iteratively, until the best empirical solution, i.e. number of classes is determined (Nylund et al., 2007). So far, LCA has been used to identify a variety of behavioral patterns in adolescent smoking (Guo et al., 2009), alcohol use (Connell et al., 2009; McBride et al., 2014), drug use (James et al., 2013), and risk behavior (Cook et al., 2015; Laska et al., 2009), all of which offer useful risk profiles for future prevention practice and research. Nevertheless, LCA studies on multiple substance use are scarce, and mostly limited to certain groups, e.g.,

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adolescents in treatment (Ramo et al., 2012), female adolescents only (Chung et al., 2005) or children in foster care (Shin et al., 2010). In addition, most studies on adolescent substance use include substance-related problems like sexual risk behavior or delinquent behavior into the LCA (Jackson et al., 2014; Laska et al., 2009), which is problematic, as consumption patterns and problems can no longer be clearly discerned, thus, it is difficult to interpret longitudinal associations between them. To our knowledge, there are only three longitudinal LCA studies with a general sample that analyze poly substance use behaviors exclusively (Kelly et al., 2015; Lamont et al., 2013; Lanza et al., 2010). They identify three to six latent classes, from no/minimal use, single substance use, to multiuse further differing with regards to substance (cigarette, alcohol, marijuana) and severity of use (light, moderate, heavy). Predictors for multiple substance and polydrug use vary between studies, but all of them include gender (males are more likely to be multiusers), low socio-economic status, age, victimization, and high parental and peer use (Kelly et al., 2015; Lamont et al., 2013; Lanza et al., 2010), hence these predictors will be included in our analyses.

Interestingly, none of these studies controlled for contextual effects like school or communal effects on class membership. Students of schools with poor health policy, for instance, express higher antisocial behavior (Patrick and Schulenberg, 2013; Perra et al., 2012), thus, a higher proportion of multiusers can be anticipated. In a multilevel LCA (MLCA) for adolescent smoking (Henry and Muthén, 2010), poor and tobacco cultivating communities predicted higher rates of heavy smokers, illustrating an important community level risk factor.

For these reasons, not only do we aim to corroborate previous LCA results in a sample of German students, but we also include school-level variables to predict individual class membership. Previous research revealed type of school, and school health policy as significant predictors for substance use levels via mixed-effects multilevel regression models. Students without college-preparatory education vis-à-vis students on a college-preparatory high school track, and students at schools with poor health policy (Bisset et al., 2007; Fletcher et al., 2008) were more likely to use multiple substances. Moreover, we examine a longitudinal sample of young adolescents with baseline values (5th grade) as predictors for substance use patterns at follow-up (8th grade) for two reasons: firstly, we obtain chronological rather than cross-sectional associations, which strengthen the postulated causal interpretation, secondly, students in mid-adolescence are more likely to vary in substance use patterns than younger adolescents (Donovan and Molina, 2013; Percy and Iwaniec, 2007), providing a broader spectrum of data for MLCA.

## 2. Material and methods

The baseline sample ( $N=3444$ ; 52% male) with a mean age of 10.37 ( $SD=0.59$ ) was recruited from 45 schools in four German states (Bremen, Hesse, North Rhine–Westphalia, and Schleswig–Holstein) at baseline assessment of the “Eigenständig werden” (“Becoming Independent”) prevention trial. This was a cluster-randomized controlled trial to assess effectiveness of a school-based program for grades 5 and 6, designed to delay onset of substance use and to foster development of personality among schoolchildren (Hansen et al., 2011).

In Germany, after finishing elementary school (grades 1–4), there are several different types of secondary schools to be attended that differ between federal states. In general, there are schools with a college-preparatory track, e.g., ‘Gymnasium’ and other schools or educational tracks. A ‘Gymnasium’ diploma is mandatory for further academic education, thus education is more academic-oriented and more demanding than other forms of schools/education.

36-month follow-up data of the remaining participants of both groups (intervention and control group) of the “Eigenständig werden” trial ( $N=2490$ ;  $M_{age}=13.32$  [ $SD=0.57$ ]; 51% male) was used to determine latent classes, while baseline values were used to identify significant predictors for latent class membership. Sampling process and sample characteristics are described in detail elsewhere (Hansen et al., 2011). Informed consent was obtained from all individual participants’ parents. The trial was approved and registered by the ethics committee of the Medical Faculty of the University of Kiel (AZ D 419/10) and approved by the Ministries of Education of the participating states.

### 2.1. Measures

All measures were assessed by self-report questionnaires.

**2.1.1. Substance use measures (follow-up). Lifetime alcohol use** was assessed via a single item (“Have you ever drunk alcohol, even a small sip?”) with answer categories 0 = no and 1 = yes.

**Lifetime binge drinking** was assessed by asking “How many times have you consumed five or more drinks on a single occasion in your life?” (never, 1, 2, 3–5, >6 times), answers were dichotomized into 0 = never, 1 = once or more.

**Lifetime drunkenness** was measured by asking how many times the respondent has been drunk (never, 1, 2, 3–5, >6 times), answers were dichotomized into 0 = never, 1 = once or more.

**Current alcohol use** was measured by asking on how many days the respondent consumed alcohol during the last month (none, 1–2, 3–5, 6–9, 10–19, 20–29, >29). Answers were dichotomized into 0 = 0–5 days, and 1 = more than five days.

**Amount of alcohol consumed** was measured by the number of alcoholic beverages on a typical, single occasion (0, <1, 1–2, 3–4, 5–6, >6), dichotomized into 0 = less than one (“no/light”), 1 = one or more (“heavy”).

**Lifetime smoking** was assessed by asking how many cigarettes have ever been smoked in life. Nine answering categories (“none” to “>100 cigarettes”) were dichotomized into 0 = none, and 1 = a few puffs or more.

**Current smoking** was measured by asking how frequently participants currently smoked (1 = I don’t smoke, 2 = less than once a month, 3 = at least once a month, but not weekly, 4 = at least once a week, but not daily, 5 = daily). Answers were dichotomized into 0 = 1–2 (“no/light”), and 1 = 3–5 (“heavy”).

**2.1.2. Predictors (baseline). Peer substance use** was assessed via a single item for smoking and drinking (“How many of your friends do smoke/drink alcohol?”). Answer categories for both comprise 0 = none, 1 = few, 2 = some, 3 = most, 4 = all of them. Answers were dichotomized into 0 = 0–1, and 1 = 2–4.

**Parental substance use** was separately assessed for smoking and drinking. Parental smoking was assessed via yes-no-questions (“Does your father smoke?”, “Does your mother smoke?”), with a single indicator for each (0 = no, 1 = yes). Based on these answers, we constructed an additional dichotomous indicator (0 = “not smoking”, 1 = “smoking” parents), parental alcohol use was assessed likewise.

**Bullying** was separately assessed for bullying ( $\alpha=0.71$ ) and victimization ( $\alpha=0.78$ ) since the summer holidays with three items, respectively on a five-point scale (0 = never, 1 = in total one or two times, 2 = two or three times a month, 3 = once a week, 4 = more than once a week). Answers for both bullying (“How often did you participate in laughing at other students?”, “How often did you participate in beating up other students?”, “How often did you participate in isolating other students?”) and victimization (“How often have you been laughed at by other students?”, “How often have you been beaten up by other students?”, “How often have you

been isolated by other students?”) were dichotomized (0 = never, 1 = other) for our analyses.

**School-level variables** were assessed by the participating schools' headmasters in a short questionnaire, answering specific questions regarding school structure. These dimensions included type of school with 0 = 'Gymnasium' (=secondary schools with a college-preparatory track) and 1 = 'other', and certification as 'healthy school' (0 = 'no', 1 = 'yes'). This certification is awarded to schools by each federal state, thus quality criteria differ between states, and yet, they are only given to schools with excellent health promotion programs in their curricula. Participation in the certification process is voluntary.

**Sociodemographic covariates** include age, gender, and socio-economic status (SES). While age and gender were measured by single items each, socio-economic status (SES) was measured by the Family Affluence Scale (Schnohr et al., 2008).

## 2.2. Statistical analysis

Multilevel latent class analysis (MLCA) was applied to identify latent classes among adolescent substance users, taking possible predictors on individual and school level into account, considering the nested structure of the data. For all purposes we used baseline predictor values and follow-up substance use classes. MLCA delivers up to four sets of parameters to convey information about the model: First, probabilities of prevalence for each latent class, second, response probabilities for all items in each class (=class indicators), third conditional probabilities for class indicators, and fourth, conditional class probabilities. While the first two are based on follow-up data, the latter two are dependent on baseline predictors.

However, in this study, we focused on conditional class probabilities, meaning the probability of belonging to one of the latent classes, and do not anticipate direct effects of predictors on indicator probabilities; nonetheless, they will be reported, if present. The underlying assumption of any LCA is a definite amount of homogeneous, mutually exclusive classes of behavior, variance within these classes is due to measurement error, postulating measurement invariance of latent classes. In order to find an adequate number of latent classes, we applied MLCA iteratively, starting with a parsimonious two-class model (“non-users” and “users”) without covariates, but with school-clustered structure based on existing research (Connell et al., 2010; Kelly et al., 2015) and successively increasing number of latent classes while comparing model fit. To determine model fit, there are a few useful criteria, namely Lo–Mendell–Rubin likelihood ratio test (LRT), Bayesian Information Criterion (BIC), which can be adjusted for sample size (SSABIC), entropy, and average latent class probabilities (ALCP; Finch and Bronk, 2011). LRT compares successive models to one another; a significant coefficient means a better fit for a model with one fewer classes. BIC and SSABIC describe parsimony of the model, the smaller the coefficient, the more parsimonious the model. Finally, entropy and ALCP evaluate the distinctness of classes and whether they are clearly distinguishable from one another. Both should be >0.80 for all classes to ensure satisfactory differentiation (Nylund et al., 2007). For iterative testing we used five sets of random start values to avoid local maxima in determining likelihood parameters (Nylund et al., 2007). All tests were based on  $\alpha = 0.05$ . We analyzed attrition to compare scores and frequencies for dependent and independent variables to identify potential bias, and reported adequate coefficients and effect sizes for all results (fit indices,  $\chi^2$ , and  $t$ ). All analyses were conducted using Mplus Version 7.2 (Muthén and Muthén, 2012). For MLCA, we used maximum likelihood estimation with robust standard errors.

Since we used multiple indicators for singular substances, we tested for local dependence of indicators. LCA postulates local

independence of indicators within classes, yet this assumption is often violated if, e.g., lifetime and current use of a single substance are measured, which leads to biased estimates of class and indicator probabilities (Reboussin et al., 2008).

## 3. Results

### 3.1. Distribution analysis

A descriptive overview of valid data for covariates at baseline and substance use measures at both measurement occasions can be found in Table 1. Except for lifetime alcohol use and amount of drinking, all substance use measures indicated that most students consumed seldom and in low amounts. Also, peer substance use and parental smoking was comparatively low at baseline, and only around 16% of students went to schools with health certifications, however, all other covariates were balanced. Socio-economic status ( $M = 17.92$ ,  $SD = 4.21$ , range = 2–24) was normally distributed. Missing data for all variables was lower than 5% and missing values were distributed randomly across subjects and variables (MCAR or MAR), thus we excluded cases with missing values from following analyses.

**Table 1**

Prevalences of valid data for substance use criteria (follow-up and baseline) and predictors (baseline values) of the remaining participants at follow-up assessment (fall 2013;  $N = 2490$ ).

Substance use	Baseline	Follow-up
Lifetime alcohol use		
No	1602 (65.0%)	706 (28.4%)
Yes	864 (35.0%)	1778 (71.6%)
Lifetime binge drinking		
Never	2244 (91.3%)	1965 (79.2%)
Once or more	215 (8.7%)	515 (20.8%)
Lifetime drunkenness		
Never	2429 (97.9%)	2266 (91.3%)
Once or more	51 (2.1%)	217 (8.7%)
Current drinking (last 30 days)		
0–5 days	2451 (98.4%)	1966 (79.2%)
>5 days	39 (1.6%)	516 (20.8%)
Amount (no. of beverages)		
Light	2430 (98.6%)	2069 (83.5%)
Heavy	34 (1.4%)	410 (16.5%)
Lifetime cigarette use		
None	2349 (95.3%)	1851 (74.8%)
At least a few puffs	116 (4.7%)	625 (25.2%)
Current smoking (last 30 days)		
Light	2453 (98.9%)	2330 (94.7%)
Heavy	25 (1.1%)	131 (5.3%)
Covariates at baseline	Category “0” (NO)	Category “1” (YES)
Peer drinking	2376 (97.3%)	65 (2.7%)
Peer smoking	2392 (97.4%)	64 (2.6%)
Parental drinking	836 (34.0%)	1620 (66.0%)
Mother	470 (19.1%)	1986 (80.9%)
Father	306 (12.5%)	2150 (87.5%)
Parental smoking	1760 (74.4%)	604 (25.6%)
Mother	1834 (74.3%)	634 (22.7%)
Father	1646 (66.8%)	819 (33.2%)
Bullying	1254 (56.0%)	986 (44.0%)
Victimization	863 (38.7%)	1368 (61.3%)
School type	1026 (41.2%)	1464 (58.8%)
Healthy school	2086 (84.4%)	385 (15.6%)

School type (0 = “Gymnasium”, 1 = other).

**Table 2**Fit indices for multilevel latent classes of adolescent alcohol and tobacco use ( $N = 2490$ ).

Indices	2 Classes	3 Classes	4 Classes	5 Classes
Free parameters	19	29	39	49
Log-likelihood	–6246.56	–6134.83	–6085.13	–6070.60
LRT	1760.70***	223.48***	99.44***	26.20
BIC	12,639.50	12,493.09	12,470.74	12,518.71
SSABIC	12,579.14	12,400.95	12,346.83	12,363.03
Entropy	0.90	0.72	0.70	0.68
ALCP	0.97–0.98	0.83–0.96	0.74–0.93	0.68–0.89

LRT = Lo–Mendell–Rubin likelihood-ratio test; BIC = Bayesian information criterion; SSABIC = sample size adjusted BIC; ALCP = average latent class probabilities.

\*\*\*  $p < 0.001$ .**Table 3**Fit indices and ALCP for conditional 2–5-class-models of adolescent alcohol and tobacco use including covariates ( $N = 2490$ ).

Indices	2 Classes	3 Classes	4 Classes	5 Classes
Free parameters	28	47	66	85
Log-likelihood	–6115.62	–5965.95	–5894.30	–5860.22
BIC	12,446.90	12,293.89	12,296.94	12,375.12
SSABIC	12,357.94	12,144.57	12,187.25	12,205.06
Entropy	0.88	0.73	0.71	0.69
ALCP	0.92–0.98	0.81–0.94	0.76–0.93	0.74–0.92

BIC = Bayesian information criterion; SSABIC = sample size adjusted BIC; ALCP = average latent class probabilities.

### 3.2. Attrition analysis

Attrition analysis revealed an individual level dropout of 28% between baseline ( $N = 3444$ ) and follow-up ( $N = 2490$ ). Dropouts were significantly older ( $t[3,433] = 5.48$ ,  $p < 0.001$ ), had a lower SES ( $t[3,439] = 4.46$ ,  $p < 0.001$ ), were more likely to be male ( $\chi^2 [1] = 16.64$ ,  $p < 0.001$ ), and scored higher in bullying ( $t[3,440] = 4.90$ ,  $p < 0.001$ ) and victimization ( $t[3,333] = 4.49$ ,  $p < 0.001$ ). However, no significant differences were found for type of school, certification or any substance outcome, peer or parental use, and neither dropout rates nor characteristics differed significantly between experimental conditions of the “Eigenständig werden” prevention trial.

### 3.3. Multilevel latent class analysis

To identify the correct number of latent classes of substance use, we tested multilevel models without covariates against one another. As seen in Table 2, overall model fit increased for multiple-class models (three to five classes), however, parsimony indices and entropy values highlight a model with three or four classes as most suitable. With regards to preliminary class-indicator probabilities, higher entropy and ALCP for a 3-class-model compared to a 4-class-model, and considering interpretability of classes, we chose a three class model for further analyses.

We also tested for local dependence of class indicators, but we did not find any significant bivariate residuals, which confirms that the assumption of local independence is valid and modeling constraints are not necessary (Reboussin et al., 2008). Because class indicator probabilities and fit indices change when including covariates, final indices for conditional 2- to 5-class-models with covariates are provided in Table 3. Log-likelihood, and parsimony indices BIC and SSABIC decreased, while entropy increased compared to a model without covariates, indicating a good fit. ALCP for all three classes were still good ( $>0.80$ ). Overall, a 3-class-model remained the best solution for our data.

These final three classes were labeled “non-users” (class 1,  $n = 1541$ , 61.9%), “experimenters” (class 2,  $n = 722$ , 29.0%), and “multiusers” (class 3,  $n = 227$ , 9.1%), with non-users being the largest group. Non-users reported lifetime alcohol use, but no recent substance use. Overall, indicator probabilities for each class (Fig. 1) depicted a high lifetime alcohol use among all classes, while probabilities for most other parameters were much higher in class 3

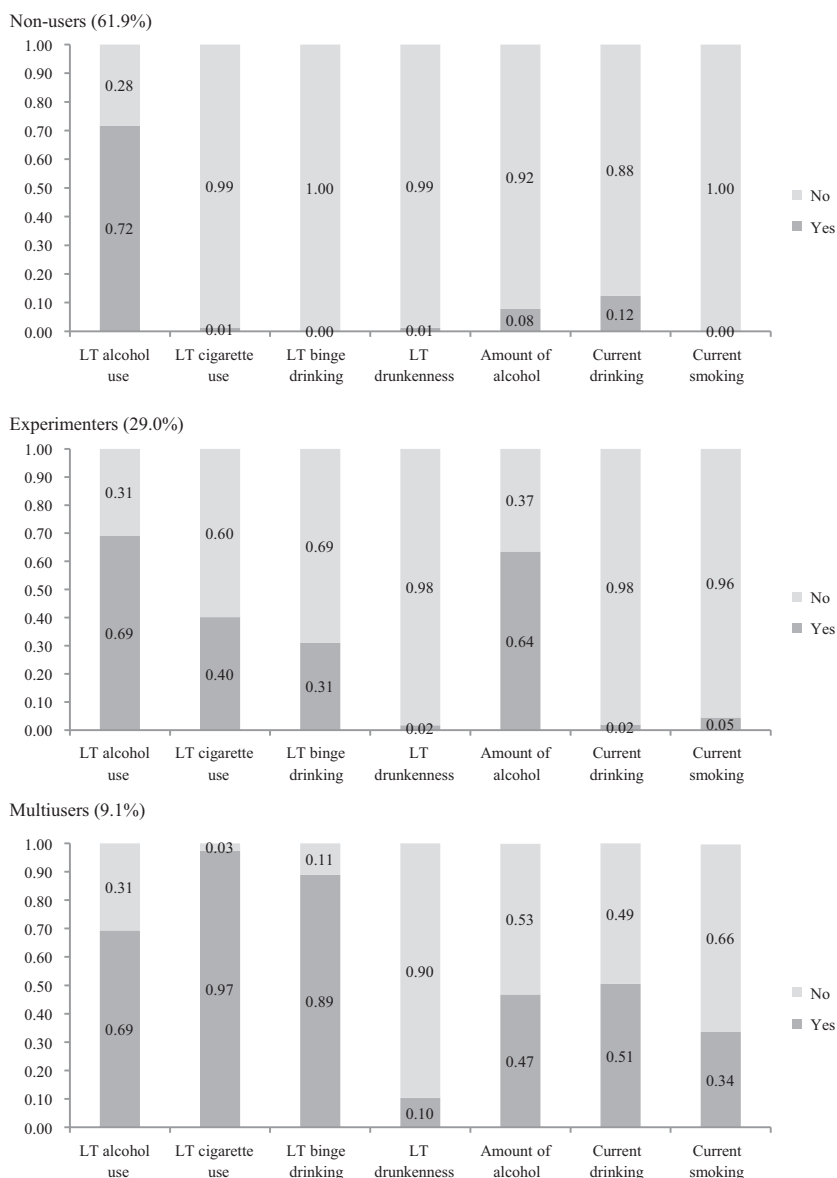
than in class 1 and 2, except for amount of alcohol consumed on a single occasion. Lifetime binge drinking was also higher in class 2 compared to class 1, thus we labeled them experimenters, as they seemed to be experimenting with amounts. Multiusers (class 3) exhibited more frequent drinking and smoking, and higher rates in lifetime smoking and binge drinking than both other classes, suggesting a hazardous consumption pattern.

Finally, we tested our final model for predictors via multinomial logistic regressions with class 1 (“non-users”) as reference class, thus the following results represent the odds to be in either class 2 or 3 compared to class 1, when exhibiting high predictor values (see Table 4). Being an experimenter rather than a non-user at follow-up is more likely if one’s father drank alcohol at baseline, if one was older, and did not attend a ‘Gymnasium’. Multiusers were likely to have such education as well, they were older at baseline, but in contrast to experimenters, they were more likely to have a mother who drank alcohol. In addition, they were more likely to have considered themselves bullies at baseline and have had more peers who smoked and drank alcohol than children in any other class. No other predictor was statistically significant.

## 4. Discussion

We found three classes of substance use patterns among early adolescents: non-users (61.9%), experimenters (29.0%), and multiusers (9.1%). Furthermore, we identified several predictors of class membership via prospective multinomial regressions. Going to a school other than a ‘Gymnasium’, higher baseline age, and having at least one drinking parent increased the likelihood to belong to one of the user classes. Meanwhile, adolescents with substance using peers at baseline, and those who reported bullying other students were more likely to be multiusers at follow-up.

These findings are mostly concordant with current literature. Our three classes reflect those of Kelly et al. (2015), who found no drug use, mainly alcohol use, and heavy use as patterns, while others (Lamont et al., 2013; Lanza et al., 2010) found additional classes comprising smoking (cigarette and marijuana use). Since we did not include illicit drugs, our classes are not exactly comparable to these studies, however, we identified numerous similarities to those classes that did not feature illicit drug use. Like most studies on underage drinkers, non-users to occasional users represented the largest portion of our sample; while multiusers were the



**Fig. 1.** Conditional indicator probabilities for substance use items (Yes = "1", No = "0") for all three classes at follow-up assessment ( $N = 2490$ ); LT = lifetime prevalence.

**Table 4**

Results of the conditional multilevel latent class analysis on level 1 latent class solution with class 1 ("non-users") as reference class for multinomial regressions.

	Experimenters vs. non-users		Multiusers vs. non-users	
	Odds ratio	95% CI	Odds ratio	95% CI
Level 1 Predictors				
Peer drinking	1.30	0.77–2.18	<b>2.13</b>	1.32–3.44
Peer smoking	1.41	0.80–2.49	<b>2.94</b>	1.80–4.80
Parental drinking	0.53	0.15–1.90	0.98	0.73–1.47
Mother	2.85	0.85–9.63	<b>6.26</b>	2.02–19.43
Father	<b>2.89</b>	1.23–6.79	2.35	0.85–6.47
Parental smoking	0.91	0.44–1.88	0.84	0.35–1.99
Mother	0.73	0.44–1.22	0.69	0.39–1.20
Father	1.03	0.55–1.92	0.86	0.42–1.74
Bullying	1.31	0.93–1.82	<b>1.69</b>	1.15–2.48
Victimization	1.10	0.80–1.51	0.75	0.50–1.12
Age	<b>1.71</b>	1.31–2.24	<b>1.92</b>	1.40–2.62
Socio-economic status	1.06	0.99–1.11	1.00	0.96–1.05
Gender	1.15	0.86–1.53	1.14	0.79–1.65
Level 2 Predictors				
School type	<b>2.57</b>	1.83–3.61	<b>4.76</b>	2.75–8.24
Healthy school	0.84	0.57–1.24	1.01	0.64–1.60

CI = confidence interval; significant results are written in bold type.



smallest, yet most critical group with regards to health and behavior (Dauber et al., 2011; Donovan and Molina, 2013; Jackson et al., 2014). In our study, students with higher bullying scores at baseline were more likely to be considered multiusers at follow-up. Bullying can be interpreted as a form of antisocial behavior, such is often associated with higher substance use, be it for enhancing or coping reasons (Cook et al., 2015; Monshouwer et al., 2012; Wanner et al., 2006). Considering the unfavorable prospects for multisubstance users' school life (Kelly et al., 2015), bullies and students in a consuming environment (i.e., consuming peers and mothers) are a core target group for early prevention. In accordance with existing LCA of drinking behavior, most children have already drunk alcohol at least once in their lives, e.g., a small sip up to one full beverage, even in the so-called "non-users" group (Donovan and Molina, 2008, 2013; Jackson et al., 2014). However, at follow-up, all other substance use measures for this class were low, concluding that it could have been a one-time thing, confirming previous findings. For future studies, we suggest discerning sippers and drinkers among young adolescents as defined by Donovan and Molina (2008, 2013), as it may help to distinguish classes and trajectories even better.

Though we found resembling results for substance use classes, there are some differences to existing literature, as we did not find any significant effect of gender, socio-economic status or victimization. We suspect this may be due to the fact that most studies on multiple substance users examined subpopulations like students of a certain ethnic background (Whitbeck and Armenta, 2015), students in foster care (Shin et al., 2010) or in treatment (Ramo et al., 2012). In the present study, our sample comprised a greater variety of students which could introduce more potential confounders into our data, thereby covering population effects. Also, the multiusers' class was comparatively small, making it more difficult to strategically conduct analyses with enough statistical power. Nonetheless, maternal alcohol and peer substance use were affirmed as strong social predictors of adolescent substance use (Simons-Morton, 2007). And yet, it is not entirely clear, whether the observed associations with peer use were due to socialization or selection processes, or both (Bauman and Ennett, 1996). Thus, further research is needed to clarify, whether peer should mainly be regarded as an indicator of or a risk factor for multiple substance use among adolescents.

Results for school-level variables were not completely in accordance with previous findings either: schools with health certification did not significantly prevent hazardous or experimental consumption patterns, although prevention is supposed to be one of its core elements—however, as a rather small portion of students ( $n = 385$ ) went to such schools, effect sizes are understandably small. Nevertheless, type of school displayed strong impact, as students that did not attend a 'Gymnasium' were much more likely to consume in hazardous ways.

#### 4.1. Strengths and limitations

We noticed a high dropout rate of 28%. Dropouts were mostly male, older, with lower SES, and higher bullying and victimization scores, all of which proved to be important predictors of multiple substance use in this or past studies (Kelly et al., 2015; Lamont et al., 2013; Lanza et al., 2010). Thus, we may have underestimated effects. There are no definite cut-offs for model selection in MLCA, hence our 3-class-model is yet to be replicated in a larger longitudinal sample, as are significant predictors of class membership. Also, the LCA solution strongly depends on the operationalization of use. We measured alcohol and cigarette use differently, which may have influenced the estimation process. Other studies operationalize substance use in different ways (Lamont et al., 2013; Lanza et al., 2010), which explains slight differences in class solutions. Besides, our study was carried out in German secondary

schools, developmental and social perspectives may be different for other cultures and school systems, for instance the US, where, e.g., legal drinking age (US: 21 years, Germany: 16 years), and school system are different. Finally, according to our participants, over 80% of their parents drink alcohol, which points to a potential bias of race/ethnicity or religion/culture. Highly religious adolescents, for instance, report significantly lower alcohol use (Wallace et al., 2003), thus future studies should always include appropriate measures of race/ethnicity and religion/culture to control for confounding effects.

Our study also has certain strengths. We recruited a large longitudinal sample of students at a critical age for substance use initiation from different school types. Moreover, as part of the "Eigenständig werden" trial, our data is retrieved from a cluster-randomized controlled trial which is also a field study with high external and internal validity. Additionally, we included previously researched influence factors in order to perform a thorough analysis of predictors and chose multilevel regression to incorporate the impact of hierarchical school structure into our analytic process, controlling for school-level effects, hence, increasing validity of our results.

#### 4.2. Future research

Multilevel latent class analysis offer varicolored possibilities of detecting higher level influences on student substance use patterns, such as school, neighborhood or community effects. Since limited secondary education proved a high risk for multiuse patterns, future research should examine within-school factors that foster such development via multilevel models to model educational imbalance properly. Also, more research is needed to investigate the dynamic of peer influence in the development of adolescent substance use, e.g., via cross-lagged studies that examine the reciprocal association between the development of social networks and multiple substance use in adolescence, and simultaneously control for possible individual-level as well as group-level confounders.

#### 4.3. Practical implications

Latent classes revealed almost 40% of our young adolescent sample as a high-risk group and a target for indicated prevention. Preventive efforts should focus on familial and peer influences, and be strengthened in particular for schools without a college-preparatory track. Additionally, students with early signs of deviant or antisocial behavior seem to be a high risk group for future substance use, thus, teachers, parents, and classmates should broach the issue of substance use, and encourage prevention at an early stage.

#### 4.4. Conclusions

We identified three latent classes of multiple substance use among young adolescents ( $N = 2490$ ; 51% male; mean age: 13.32): non-users ( $n = 1541$ ; 61.9%), experimenters ( $n = 722$ ; 29.0%), and multiusers ( $n = 227$ ; 9.1%). In a longitudinal approach, we found several baseline predictors for substance use patterns compared to non-users at follow-up. Experimental consumption was predicted by higher baseline age, paternal drinking, and school type, while multiple substance use was predicted by peer use, maternal drinking, bullying, higher age and school type. Finally, social influences play a crucial part in the development of hazardous consumption patterns among adolescents, thus, prevention and further research need to concentrate on social influence models and behavior-related interventions, especially at schools with lower educational standards.

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## Contributors

RH and BI designed the study and were responsible for data collection. ST conducted the statistical analysis and wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

## Conflict of interest statement

All authors declare that they have no conflicts of interest.

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