A latent class analysis of cannabis use products in a general population sample of adolescents and their association with paranoia, hallucinations, cognitive disorganisation and grandiosity

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Abstract

Adolescents have access to a wide range of cannabis products with patterns of use becoming increasingly diverse. This study aimed to identify subgroups of adolescents in the general population who use similar types of cannabis and their association with psychotic experiences. Data on cannabis use were obtained from 467 adolescents aged between 16-17 years. Latent class analysis (LCA) identified groups of adolescents based on the type of cannabis used in the past 12 months. Univariate analysis explored differences in socio-demographics, substance use and mental health symptoms between groups. Multivariate analysis examined associations between class membership and psychotic experiences controlling for frequency and amount of cannabis. Finally, we explored the association between motives for cannabis and class membership using multi-nominal logistic regression. LCA identified 3 classes of adolescents: i) herbal only (47.9%); ii) skunk only (20.8%) and 3) mixed use (31.3%). Relative to non-users, skunk only use was associated with a 2-fold increase in paranoia (OR= 2.45, 95% CI = 1.29-4.63), along with, sleep disturbance and anxiety. Monthly cannabis use and consuming 2 or more joints on one occasion was associated with a 2-fold increase in hallucinations (OR =2.2; 95% CI =1.0-4.8 and OR =1.9; 95% CI = 1.2-3.2), but did not reach the Bonferroni corrected p-value. Expansion and conformity motives differentiated the mixed cannabis class from the herbal only class. The findings suggest that different subgroups of cannabis users exist in adolescence as defined by the type of cannabis consumed and are differentially related to psychotic experiences and motives for use.

Keywords: cannabis use; latent class analysis; psychotic experiences; sleep; motives; skunk

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Introduction

Cannabis is one of the most widely used recreational drugs in the world [1]. Despite stable prevalence of cannabis use globally, the drug is being used with greater frequency particularly among young people [2,3], with the number of adolescents receiving treatment for cannabis use in the UK and Europe increasing over the past decade [4]. Cannabis contains many different cannabinoids, but the two most researched are δ-9-tetrahydrocannabinol (THC) and cannabidiol (CBD). THC is responsible for the 'high' that users enjoy and feelings of euphoria, whilst CBD is non-intoxicating, can enhance learning, reduce anxiety and may have the potential to offset the psychotic-inducing effects of THC [5-7]. In the past decade the concentrations of THC in street cannabis have risen in Europe [8] and the USA [9], adolescents now have access to a wide variety of cannabis products with large differences in THC and CBD concentrations [10-11]. For instance, indoor grown cannabis (i.e. sinsemilla/skunk) dominates the illicit cannabis market in Europe and contains 13-15% THC with CBD levels often less than 1%. Outdoor grown cannabis known as 'grass' or 'weed' contains much lower amounts of THC (3-4%) with CBD levels less than 1%. Cannabis resin or 'hashish' has traditionally been considered a low potency cannabis product containing 6-7% THC and 4% CBD; although recent data has indicated a rise in THC concentrations to 15% [8] with CBD levels remaining stable or declining [12-13]. A highly potent cannabis product is cannabis concentrates which can contain up to 76% THC depending on the extraction technique [14]. Cannabis concentrates is an under-researched area with no data documenting its use in adolescents in the UK. A recent study demonstrated that 33% of 13-18 year olds in Arizona reported lifetime cannabis use with 24% reporting concentrate use [15]. However, Arizona is a state in which concentrates are often legally sold suggesting a higher prevalence compared to other states.

The use of highly potent cannabis products has now been associated with poor mental health and cannabis dependency [16-17]. In an online survey of adult cannabis users across 20 countries, individuals who consumed mainly cannabis concentrate products were more likely to have a life-time diagnosis of psychosis, depression or anxiety compared to users of low potency products [16]. Frequent or daily use of cannabis high in THC has been linked with the presence of paranoia, perceptual distortion and hallucinations [17-19] and an increased risk for and relapse to psychotic disorder [20,21]. The extent to which these findings may generalise to an adolescent population are unclear. Support for differences in the psychotic response to cannabis use among adult and adolescent users comes from a recent study. Mokrysz et al., (2016) [22] found that after consuming 8mg of THC both adolescents and adults scored higher in perceptual distortion and

manic symptoms compared to a placebo. However, adults reported greater increases in cognitive disorganisation suggesting that either adolescents are more resilient to the effects of THC or that these effects are a result of persistent use.

In order to inform policy decisions and to allow for the development of personalized tailored intervention there is a need to explore the reasons why adolescents choose to use different cannabis products. Motivational models would suggest that adolescents use cannabis to achieve a desired outcome [23,24]. For instance, motives can be defined as enhancing (*"to get high"*), coping (*"to deal with worries")* expansion (*"to achieve awareness"),* social (*"to make social events fun"*) or conformity (*"because friends use cannabis"*). Motives associated with internal reasons for use (i.e. enhancement, expansion and coping) are most strongly related to frequent and problematic use [25]. However, no previous studies have explored whether these motives differ according to the type of cannabis used.

Previous research has supported the existence of subgroups of cannabis users who use different types of cannabis and have differing patterns of use [17, 26-28]. Person-centered analysis utilizing latent class analysis can capture the heterogeneity within and between groups of individuals. Most studies that have defined classes by cannabis type have focused on regular adult cannabis users. We are unaware of any previous study that has characterized adolescent cannabis users purely on the basis of cannabis products used and explored variations across psychotic experiences and health related outcomes including sleep disturbance, depression and anxiety. To address this gap we used LCA to differentiate groups of adolescent cannabis users according to the type of cannabis used. In order to validate the LCA solution we compared rates of other substance use, mental health symptoms across latent classes. We investigated whether cannabis type was associated with psychotic experiences over and above frequency and quantity of cannabis use, while controlling for variables associated with psychotic experiences such as victimization, depression, anxiety, sensation seeking and sleep disturbance. Finally, we examined whether different motives for cannabis use differentiated the latent classes.

Methods

Participants and procedure

Forty-one further education schools or colleges in Greater London were contacted. Six colleges spread across six London boroughs in both densely populated and suburban areas, agreed to participate. All colleges were state funded. Students were invited to participate if they attended Year 12 (age range 16-17 years), provided with information and assent forms 2 weeks prior to the assessment date. The only individual-level inclusion criteria was providing student assent. 512 students were approached to take part in the survey, 27 students (5.4% of total sample) declined to participate and 18 students (3.5%) were excluded due to unreliable data providing a final sample of 467 participants (56.1% male, mean age 16.8 SD = 7 months). Students completed self-report questionnaires in classroom or assembly formats, measures were taken to maximize accuracy, including emphasizing confidentiality, anonymity regarding teacher/parent access and reliability checks.

Measures

Sociodemographics

Three questions comprising the Family Affluence Scale [29] assessed socio-economic status. Participants were asked whether they had *"their own bedroom"*, *"their own computer"* on a dichotomous scale (*"yes"* or *"no")* and the *"number of cars in their household"*, *("none"* to *"3 or more"*). Items were summed to provide a total score. Information on gender and ethnicity were obtained. Ethnicity was categorised into five groups (White, Black African, Black Caribbean, Asian and Mixed/Multiple).

Cannabis use.

Non-cannabis users were those who answered *"no"* to the question: *"Have you used any type of cannabis in the past 12 months?".* Participants were asked *"What type of cannabis they had used?"* with the following options: i) *"skunk";* ii) *"hashish or resin"*, iii) *"herbal*", iv) *"concentrates"* (i.e. *"shatter", "wax"*). For each type of cannabis participants were asked *"How often do you use that type of cannabis?"* on a 6-point response scoring scale *("never" to "daily")* and *"How many joints containing that type of cannabis do you consume on a typical occasion?"* On a 6-point response scale (*"none"* to *"more than five"*). A joint was defined as a *"rolled cannabis joint/cigarette/spliff"* (i.e. *"a joint that contains either cannabis or rolled cannabis and tobacco"*). Frequency of use was categorised into *"less than monthly"* and *"monthly or more"* with number of joints categorised into *"one or fewer"* and *"two or more joints*". Participants who reported multiple types of

cannabis were categorized according to their average frequency and number of joints scores. Age of first use, method of delivery *("with tobacco", "without tobacco", "vaporisor", "bong/pipe",* or *"edibles*") and size of joint *("0.125grams", "0.25 grams", "0.5 grams", "0.75 grams"* or *"1 gram"*) were also included. Joint size was categorized into *"0.25 grams or less"* and *"0.5 grams or more".* Picture prompts of different types of cannabis were used to aid the participants' recollection [30].

The 25-item Marijuana Motives Measure [31] comprises 5 subscales: enhancement, coping, conformity, social and expansion on a 5-point scale ranging from *"never"* to *"always".* Items are summed to create mean subscale scores range from 0-20. The MMM has been validated in young adult and adolescent populations [29] with good internal consistency shown in the current sample for each subscale (enhancement (α = 0.90, coping (α = 0.87), conformity (α = 0.71), social (α = 0.85), expansion (α = 0.89)).

Specific Psychotic Experiences Questionnaire (SPEQ).

The SPEQ assessed paranoia, hallucinations, cognitive disorganisation and grandiosity in the past 6-months. All measures were previously validated in a sample of 4,743 16-year-olds [32]. Five items from the Paranoia Checklist [33] assessed persecutory thoughts*: "under threat from others", "conspiring against me", "harm me", "has it in for me"* and *"detecting coded messages"* on a 6-point response scale (*"not at all", "rarely", "once a month", "once a week", "several times a week"* to *"daily").* Across paranoia the proportion of participants reporting monthly occurrence of paranoia ranged from 4.5% to 10.3% which is comparable to other adolescent samples [32]. Good internal consistency across items was demonstrated (α = 0.94). Hallucinations were assessed with 9 items from the Cardiff Anomalous Perceptions Scale [34] on a 6-point response scoring scale (*"not at all"* to *"daily"*). Across hallucinations, between 4.1% to 11.3% of participants reported monthly occurrence of hallucinations, comparable to similar adolescent populations [32] and the median prevalence reported in meta-analysis (7.5%, [35]). Following Freeman et al. [33] and due to the relative low frequency of item response the paranoia and hallucinations subscales were dichotomized into 0 or 1 (*"not at all/ rarely*" or *"at least monthly occurrence on at least two items"*). Good internal consistency was also shown (α = 0.87). Cognitive disorganisation was assessed with 11 items on a dichotomous response scale (yes, no) from the short Oxford-Liverpool Inventory of Feelings and Experiences [36]. Total scores ranged from 0-

11. Good internal consistency ($\alpha = 0.75$) was demonstrated. Grandiosity was assessed with items from the 'Myself' subscale of Cognition checklist [37] and the Peters Delusions inventory [38] on a 4-point scale ("*not at all", "somewhat", "a great deal", "completely").* Total scores ranged from 0-24. Due to positive skew grandiosity was square root transformed. Good internal consistency was demonstrated ($\alpha = 0.90$).

Victimisation

Three items assessed past 6-month frequency of bullying from peers (*"left me out of things on purpose", "excluded me from the group", "I was hit, kicked, pushed, shoved around"*) on a 5-point scale (*"none", "once or twice", "2/3 times a month", "once a week", "several times a week"*) from the Olweus Bully/Victim Questionnaire [39]. Items were summed to provide a total score. Good internal consistency was demonstrated ($\alpha = 0.90$).

Depression and anxiety

The 6-item depression and 6-item anxiety subscales from the Brief Symptom Inventory [40] assessed severity of symptoms in the previous 6 months on a 5-point scale (*"not at all", "a little bit", "moderately", "quite a bit", "often"*). Items were summed to provide a total score. Good internal consistency was shown for depression ($\alpha = 0.91$) and anxiety ($\alpha = 0.89$).

Sensation seeking

The 6-item subscale from the SURPS [41] assessed sensation seeking on a 4-point scale (*"strongly disagree", "disagree", "agree", "strongly agree"*). Items were summed to provide a total score. The SURPS has good concurrent, predictive and incremental validity in discriminating adolescents with early onset substance use [42]. Cronbach's alpha was found to be acceptable ($\alpha = 0.71$).

Sleep disturbance

Sleep disturbance was measured by the Pittsburgh Sleep Quality Index [43]. Participants were asked in the past month whether they had trouble sleeping in response to 10 fixed choice answers including *"waking early in the morning", "having bad dreams", "feeling too hot or cold"* on a 4-point rating scale (*"not in the past*

month", "less than once a week", "once or twice a week", "three of more times a week"). Total scores ranged from 0-24 Good internal consistency ($\alpha = 0.77$) was demonstrated.

Alcohol, tobacco and illicit drug use.

Three questions from the Smoking Drinking and Drug use Questionnaire [44] were used to ask participants how often they had an alcoholic drink on a 7-point scale ("*never", "a few times a year", "once a month", "once a fortnight", "once a week", "twice a week", "every day")* cigarette use *("never", "only once", "I used to smoke, but not now", "not as many as one a week", "1-6 cigarettes", "6-12 cigarettes", "more than 12 cigarettes"*). For cigarette use we included an additional response *"more than 12 cigarettes"* allowing for additional variability. Electronic cigarettes *("never", "once or twice", "I used to, but not now", "not every week", "once a week or more"*) in the past 6-months. We asked participants whether they had used the following illicit drugs: cocaine, amphetamines, ecstasy, LSD, magic mushrooms, GBH, legal highs, or synthetic cannabinoids (spice) on a yes/no rating scale.

Statistical methods

Firstly, a latent class analysis was performed to identify subgroups of adolescents who endorsed past 12 months use of cannabis. Models were fitted beginning with a one-group latent class model moving to a four-group model, accounting with clustering within schools, with random starting values, using maximum likelihood estimation in Mplus (version 8 [45]). The best fitting model was established using the Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC) and entropy. A lower value in the BIC and AIC indicates a more parsimonious model. Entropy is a measure of classification accuracy, with values close to 1 indicating a good separation of classes. Class size and interpretability was also considered. Secondly, using STATA version 15.1 (StataCorp, [46]) ANOVAs and Chi-square tests examined individual differences across classes in socio-demographics, psychotic experiences, depression, anxiety, victimisation, sleep disturbance and other substance use corrected for multiple comparisons by the Bonferroni post-hoc test. Thirdly, we investigated the association between latent class membership, amount and frequency of cannabis and psychotic experiences using logistic or linear regressions. Non cannabis users were the reference group. We correlated socio-demographics, mental health and other substance use variables with the four psychotic experience outcome variables using either Pearson's product moment correlations for continuous variables,

point biseral correlation and Phi coefficient for correlations between dichotomous and continuous variables (see Table S1). Covariates were included in the model fitting process if a significant correlation was shown. Variables were retained in the model if they significantly improved model fit as assessed by a lower BIC. Variable entry order was determined by univariate BIC scores with lower BIC scores representing better model fit (Table S2). Finally, we entered cannabis use motives into a multi-nominal logistic regression to examine class predictors. Due to the participants being nested within schools, estimates were adjusted using tests based on the Huber-White sandwich estimate of variance [47] which provided standard errors robust to within cluster correlation.

Results

Latent class analysis of past 12-month cannabis use

Out of 467 adolescents who responded to the survey, 144 (30.8%) reported past 12-month cannabis use. *As depicted by Figure 1, the majority of cannabis users (N=64; 44.4%) reported using only herbal cannabis. N = 29 (20.1%) reported using only skunk type cannabis with 20.8% (N=30) of cannabis users reporting both herbal and skunk cannabis. The remaining 21 (14.7%) of cannabis users reported using a combination of herbal, skunk, resin and cannabis concentrates.*

INSERT FIGURE 1 ABOUT HERE

A latent class analysis was performed and a 3-class model was selected on the basis of empirical fit indices (see Table 1), class sizes, interpretability and theoretical meaning. A decrease in the BIC and AIC between a 2 and a 3-class model was shown. Moving from a 3 to a 4-class model was not well supported with an increase in both the AIC and BIC and smaller classification accuracy (entropy = 0.56). Endorsement probabilities, i.e. the probability of reporting past 12 month use of specific cannabis products (see Figure 2), suggested that classes can be categorised as: 1) Herbal only (47.9%) who had a high probability of using herbal cannabis with a low probability of using all other types of cannabis, 2) Skunk only (20.8%) who had a high probability of using skunk cannabis, with a low probability of other types of cannabis and 3) Mixed group (31.3%) who had a high probability of both herbal and skunk cannabis with a moderate probability of using

resin and concentrates. Participants were assigned into their suggested classes based on their highest probability of membership known as posterior probabilities. Average class probabilities were good, 1.00 for the herbal only class, 0.95 for the skunk only class and 0.90 for the mixed cannabis class.

INSERT TABLE 1 AND FIGURE 2 ABOUT HERE

Comparisons by latent class in socio-demographics, substance use, mental health and cannabis use

Three sets of planned comparisons were performed, examining whether each latent class differed from non-cannabis users. As shown in Table 2, adolescents in the mixed class reported higher socio-economic status and white ethnicity, adolescents in the skunk only were more likely to be male and less likely to report Asian ethnicity compared to non-cannabis users. All cannabis users were more likely to report monthly alcohol use and cigarette use, but only the herbal and mixed classes reported higher rates of e-cigarette and other illicit drug use compared to non-cannabis users. In terms of mental health outcomes, there were no differences between groups in depression, anxiety or victimization. However, adolescents in the skunk only class were 2.1 times (Odds Ratio (OR) 2.1; 95% Confidence Interval (CI) 1.2-3.6) more likely to report monthly paranoia than non-cannabis users and were less likely to report instances of cognitive disorganization. Adolescents in the mixed class scored higher in sensation seeking and reported more sleep disturbance than non-cannabis users.

Comparisons between latent classes on different facets of cannabis use were also performed (Table 2). Compared to the herbal only class, the mixed class were more frequent users (OR= 3.2, 95% CI = 1.3-7.3), were more likely to consume 2 or more joints on a single occasion (OR = 3.7, 95% CI = 1.6-8.7), to report more social and expansion motives for use. Adolescents in the skunk only class were also more likely to consume 2 or more joints (OR = 3.8, 95% CI = 1.5-9.6), but were comparable in frequency of use. Skunk users were also more likely to report larger joint sizes (OR = 2.9, 95% CI = 1.1-7.5), compared to the herbal only class. Participants in both the mixed and skunk only classes had an earlier age of onset of use than participants assigned to the herbal only class.

INSERT TABLE 2 ABOUT HERE

A*ssociations between latent class membership and psychotic experiences*

As summarised in Table 3, a series of multiple regressions were performed to explore the association between latent class and psychotic experiences after adjusting for frequency and amount of cannabis used, other substance use and developmental psychopathology. Covariates were included in each model if univariate BIC scores improved model fit (Table S2). For paranoia, skunk only use was associated with a 2-fold increase in monthly reports of paranoia (OR= 2.45, 95% CI = 1.29-4.63). Sleep disturbance, anxiety and cigarette were entered and each individual variable improved model fit, although cigarette use did not reach the Bonferroni corrected significance level. There were no associations between type of cannabis use and hallucinations. However, both frequent use and consuming 2 or more joints on one occasion was associated with a 2-fold increase in hallucinations (OR =2.2; 95% CI =0.99-4.8 and OR =1.9; 95% CI = 1.2-3.2), but both measures failed to reach the Bonferroni corrected significant level. Depression and sleep disturbance were also associated with hallucinations. A negative association was demonstrated between skunk use, cognitive disorganization and grandiosity (see Table 3), but not at the Bonferroni corrected level. Anxiety and depression were positively associated with cognitive disorganisation with sensation seeking demonstrating a significant association with grandiosity.

INSERT TABLE 3 ABOUT HERE

Predictors of class membership

Multivariate analyses examined whether motives for use predicted membership of each class. As Table 4 shows, adolescents who comprised the mixed class were more likely to report expansion motives for cannabis use compared to participants assigned to the herbal and skunk only classes and less likely to report conformity motives than the herbal only class. Motives for cannabis use failed to distinguish the skunk only class from the herbal only class.

INSERT TABLE 4 ABOUT HERE

Discussion

We used latent class analysis to identify three subgroups of adolescents who use different types of cannabis from a general adolescent population sample. 47.9% of the sample were assigned to the herbal only class, 20.8% were assigned to the skunk only class and 31.3% were assigned to the mixed class. These findings demonstrate significant heterogeneity in the types of cannabis used by young people and highlights

the limitations shown in current cannabis assessment tools. There is a need to capture variability both in frequency and quantity of use but also in type of cannabis used by young people.

The classes showed important differences in socio-demographics, substance use and psychotic experiences. Adolescents who predominately reported low potency cannabis (i.e. herbal only class) were more likely to be female, report lower overall rates of other illicit drug use, were more likely to be infrequent cannabis users and had lower incidences of psychotic experiences compared to high potency users. In contrast, high potency skunk only users were more likely to be male, report moderate rates of alcohol and cigarettes, low rates of other illicit drug use and a 2-fold increase in paranoid thoughts compared to non-cannabis users. Our findings are consistent with epidemiological, patient and experimental research suggesting that the use of cannabis with concentrations high in THC and low CBD can increase an individual's risk of paranoid or persecutory thoughts [18-21]. Furthermore, the skunk only class were not distinguished by their reasons for using cannabis, but by consuming more joints containing cannabis, and for larger joint sizes. The current study utilized the measure of the number of joints consumed on a single occasion as a measure of quantity, but also of heavy episodic use. Previous research has documented adverse negative consequences of heavy episodic alcohol and drug use on adolescent health and wellbeing [48]. It is perhaps not surprising that adolescents are more likely to engage in heavy episodic cannabis use, given that the consumption of illicit drugs in young people tend to occur at social occasions with friends rather than at home alone. Nevertheless, this pattern of high risk cannabis use is particularly concerning given the evidence that the acute consumption of high amounts of THC has an adverse impact on verbal, episodic and working memory, attentional and emotional processing (see 49 for a review).

The mixed cannabis use class were distinguished by their sensation seeking, higher rates of other illicit drug use, sleep disturbance and their use of cannabis for expansion and social motives, suggesting the identification of a group of adolescents susceptible to early onset substance use as a result of thrill seeking and experimentation. Given that cannabis use motives are often related to treatment outcomes [50], by exploring the use of cannabis in response to feelings of expansion and social relationships we can develop targeted interventions for this group of adolescents. The mixed class did not demonstrate an increased risk for paranoid thoughts as demonstrated by the skunk only class, although no differences in amount or frequency of skunk cannabis consumed was found. CBD has been found to offset the psychotic-like symptoms induced in recreational cannabis use by THC in laboratory studies [51] and patient groups [52]. It is possible

that the use of cannabis with high CBD to THC ratios consumed by adolescents in the mixed group may have attenuated the psychotic-like response as reported by the skunk only users. However, this finding has not been consistent across all studies [53].

Consuming more than 2 joints on one occasion, along with monthly cannabis use was associated with hallucinations, although not at the corrected Bonferroni statistical significance level. Reports of hallucinations following exposure to cannabis in adults are mixed [54-56]. Whilst perceptual alterations in healthy individuals during the acute effects of THC are often described [57] hallucinogen-like effects are quite rare, with recent research reporting hallucinations in response to the use of synthetic cannabinoids [58], which are typically a full CB1 receptor agonists with greater potency than THC (a partial CB1 receptor agonist) in plant-based cannabis. In the current study, hallucinations were not shown to be associated specifically with high potency cannabis, suggesting that the presence of hallucinations was not solely due to high doses of THC on dopaminergic neurotransmission. Alternative mechanisms may include individual differences in genes such as the Catechol-O-Methyltransferase (COMT) and AKT1 gene [59] or in sensitivity to CB1 agonists that predict response to cannabis use.

Both cigarette and e-cigarette use was associated with paranoia which points towards the exposure to nicotine during adolescent brain development, potentially leading to modulation of the prefrontal cortical function and impacting on behavioural, neuronal and molecular phenotypes consistent with neuropsychiatric disorders (for a review see 60). This finding is of growing relevance given the increasing use and popularity of e-cigarettes amongst young people.

This study has several strengths. It is the first study to our knowledge that has investigated the heterogeneity of multiple cannabis products with a comprehensive range of psychotic experiences in an adolescent sample. Additional strengths include the rich and detailed questions on cannabis use with pictorial aids to enable accurate recall [30]. Limitations could be the failure to account for additional cannabis products such as medicinal cannabis products (CBD oil) [61]. The use of joints as a measure of amount might create difficulties for participants who do use this as a method of administration. A lack of methods to corroborate self-report information, but the assessment protocol allowed a confidential context for self-report, reliability checks embedded in the survey, producing highly valid and reliable substance use data. Given the nature of the adolescent population, this study included few daily users of cannabis which may limit the associations between frequency and psychotic experiences. Finally given this data is cross-sectional a causal association

between cannabis and psychotic experiences cannot be established. Additionally, we would like to highlight that this study was conducted within the UK which has a policy that the consumption and purchase of cannabis for recreational use is illegal. Therefore, generalizing the prevalence of use to countries with legal cannabis markets should be cautioned.

These findings demonstrate the importance of future studies using cannabis assessment tools that can account for variability in products currently used by young people today. In terms of public health, it suggests the need for greater education about the potential harms of different forms of cannabis while rapidly expanding commercial markets may provide an opportunity for regulation of both THC and CBD content.

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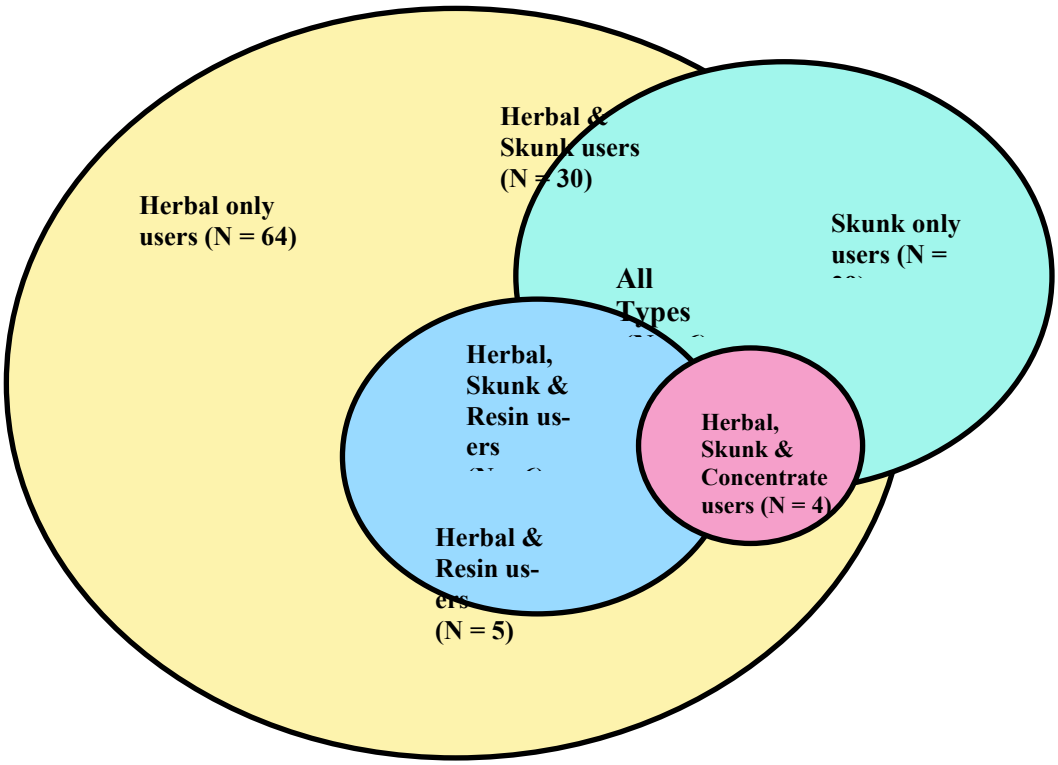
Figure 1. A Venn diagram demonstrating the multiple types of cannabis used by cannabis users (N =144).



- Herbal only users N = 64 (44.4%)
- Herbal and Skunk users N = 30 (20.8%)
- Skunk only users N = 29 (20.1%)
- Herbal, Skunk and Resin users N = 6 (4.2%)
- All Types N = 6 (4.2%)
- Herbal and Resin users N = 5 (3.5%)
- Herbal, Skunk and Concentrate users N = 4 (2.8%)

Figure 2. Endorsement probabilities for past 12-month cannabis type for each latent class

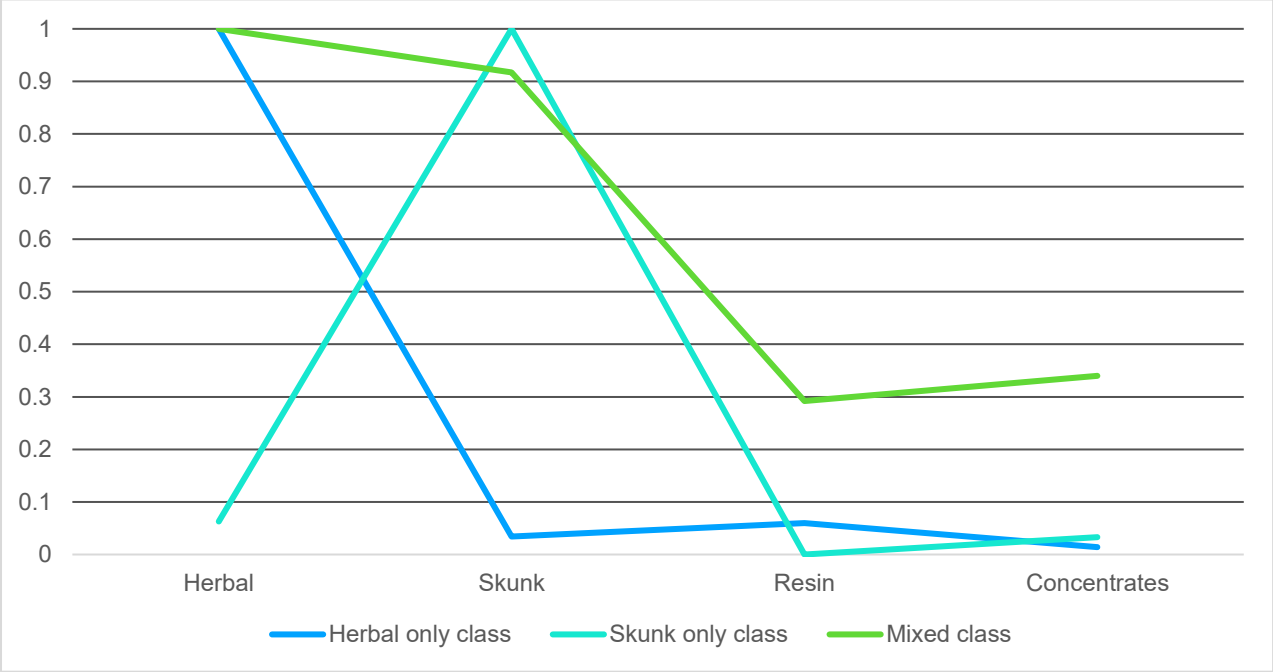


Table 1. Fit statistics for the 1-4 latent class models for type of cannabis used in the past 12 months.

Number of Classes	1	2	**3**	4
AIC	457.31	410.368	**410.346**	418.396
BIC	466.22	443.064	**431.147**	462.943
Adjusted BIC	456.72	408.997	**408.257**	415.479
Entropy	-	1.00	**0.91**	0.56
Average latent class probabilities	-	0.99-1.00	**0.90-1.00**	0.34-0.98

Note. Preferred solution in bold. AIC, Akaike information criterion; BIC, Bayesian information criterion.

Table 2. Socio-demographic characteristics, substance use, sensation seeking, victimisation, sleep disturbance, depression, anxiety, psychotic experiences and cannabis use across latent classes.

	Non-cannabis users (N =323)	**Herbal only (N=69)**	**Skunk only (N=30)**	**Mixed (N=45)**	**Test result (Pearson X^2 /ANOVA)**	**p value**
Age, years	16.8 (0.76)	16.9 (0.85)	17.0 (0.81)	16.8 (0.76)	F = 1.23	.29
Socio Economic Status	2.77 (0.97)	2.93 (0.75)	2.99 (1.36)	3.04 (0.82)*	**F = 3.13**	**.026**
Male	136 (42.1)	27 (39.1)	20 (66.7)*	22 (48.9)	**X^2 =7.83**	**.050**
Ethnicity					**X^2 = 39.14**	**.0001**
White	70 (21.7)	16 (23.2)	4 (13.3)	20 (44.4)*		
Black Caribbean	60 (18.6)	22 (31.9)	11 (36.7)	6 (13.3)		
Black African	105 (32.5)	24 (34.8)	14 (46.7)	10 (22.2)		
Asian	83 (25.7)	5 (2.9)*	1 (3.3)*	9 (20.0)		
Mixed, multiple	5 (1.5)	2 (2.9)	0	0		
Alcohol use					**X^2 = 95.85**	**.0001**
Once or twice a year	93 (28.8)	27 (39.1)	14 (46.7)	7 (15.6)		
At least monthly	50 (15.5)	24 (34.8)*	13 (43.3)*	32 (71.1)**		
Cigarette use	10 (3.1)	6 (8.7)*	5 (16.7)*	15 (33.3)**	**X^2 = 54.67**	**.0001**
E-Cigarette use	6 (1.9)	4 (5.8)*	2 (6.7)	9 (20.0)*	**X^2 = 31.02**	**.0001**
Other illicit drug use	8 (2.5)	13 (18.8)**	3 (10.0)	19 (42.2)*	**X^2 = 59.90**	**.0001**
Sensation Seeking	13.28 (3.16)	14.29 (2.5)	13.93 (2.7)	14.9 (2.5)*	**F = 5.55**	**.001**
Victimisation	1.68 (1.7)	1.70 (2.7)	1.07 (2.1)	1.60 (1.3)	F=0.99	.39
Sleep disturbance	5.49 (3.3)	5.97 (3.9)	4.57 (3.1)	7.36 (5.5)*	**F=3.02**	**.029**
Depression	8.21 (6.02)	8.07 (6.00)	7.87 (7.48)	9.98 (6.44)	F=1.21	0.31
Anxiety	7.32 (6.0)	7.43 (5.3)	6.01 (6.7)	8.58 (6.9)	F=1.13	0.34
Psychotic Experiences						
Paranoia						
At least monthly	51 (15.8)	16 (23.2)	9 (30.0)*	13 (28.9)	**X^2 =8.15**	**0.043**
Hallucinations						
At least monthly	90 (27.9)	25 (36.2)	10 (33.3)	19 (42.2)	X^2 =5.10	0.16
Grandiosity	7.49 (5.9)	7.01 (5.2)	7.60 (4.5)	8.09 (6.1)	F = 0.38	.76
Cognitive disorganisation	5.26 (2.7)	5.68 (2.9)	4.00 (2.9)*	5.87 (3.1)	**F = 3.25**	**.022**
Cannabis used						
Age of first use	-	15.4 (1.3)*	14.4 (1.8)*	14.3 (1.3)*	**F=10.13**	**.0001**
Frequency of use					**X^2 = 7.95**	**0.019**
Less than Monthly	-	56 (81.2)	19 (63.3)	26 (57.8)		
Monthly or more	-	13 (18.8)	11 (36.7)	19 (42.2)*		

Number of Joints					**X^2 = 12.52**	**0.009**
One or fewer	-	56 (81.2)	16 (53.3)	25 (55.6)		
Two or more	-	13 (18.8)	14 (47.7)*	20 (44.4)*		
Use of tobacco in joints	-	40 (60.6)	21 (70.0)	27 (60.0)	X^2 = 0.94	0.63
Joint size					**X^2 = 6.08**	**0.048**
0.25 grams or less	-	32 (52.5)	8 (27.6)	12 (34.3)		
0.5 grams or more	-	29 (47.5)	21 (72.4)*	23 (65.7)		
Coping Motives	-	3.04 (2.9)	3.36 (3.2)	4.22 (3.7)	F = 1.76	.175
Social Motives	-	6.69 (5.5)	6.03 (4.9)	9.27 (6.0)*	**F = 3.96**	**.021**
Expansion Motives	-	2.74 (3.4)	2.33 (2.5)	5.64 (5.9)*	**F = 7.86**	**.001**
Conformity Motives	-	1.45 (2.3)	1.97 (2.0)	1.34 (2.0)	F = 0.68	.504
Enhancement Motives	-	8.14 (5.8)	8.60 (5.3)	10.4 (5.7)	F = 2.30	.104

Data are n (%) or mean (SD).
ANOVA'S and Chi-square comparisons are corrected by Bonferroni post-hoc comparisons.

Table 3. Associations between latent class membership and psychotic experiences controlling for frequency, amount of cannabis, substance use, sleep, victimization and mental health symptoms.

		OR	Robust S.E.	95% CI	Z	P
Paranoia						
Latent Class	Herbal only	1.14	0.61	0.40-3.25	0.25	0.80
	Skunk only	**2.45**	**0.80**	**1.29-4.63**	**2.75**	**0.006**
	Mixed	1.14	0.98	0.21-6.10	0.15	0.88
Amount >2 joints on one occasion		1.22	0.89	0.29-5.09	0.79	0.27
Frequency >Monthly use		1.04	0.84	0.21-5.10	0.05	0.96
Sleep disturbance		**2.71**	**0.42**	**2.01-3.68**	**6.46**	**0.001**
Anxiety		**1.05**	**0.02**	**1.01-1.09**	**2.59**	**0.010**
Cigarette use		**2.66**	**1.16**	**1.12-6.26**	**2.24**	**0.025**
Hallucinations						
Latent Class	Herbal only	1.29	0.20	0.95-1.76	1.62	0.11
	Skunk only	1.04	0.60	0.34-3.21	0.07	0.95
	Mixed	0.76	0.34	0.32-1.83	-0.61	0.54
Amount >2 joints on one occasion		**1.93**	**0.50**	**1.16-3.21**	**2.54**	**0.011**
Frequency >Monthly use		**2.16**	**0.88**	**1.0-4.82**	**1.90**	**0.05**
	Depression	**1.13**	**0.02**	**1.08-1.18**	**5.79**	**0.001**
	Sleep disturbance	**2.05**	**0.40**	**1.40-3.02**	**3.66**	**0.001**
		B	**Robust S.E**	**95% CI**	**t**	**P**
Cognitive Disorganisation						
Latent Class	Herbal only	0.37	0.20	-0.15-0.89	1.84	0.12
	Skunk only	**-0.84**	**0.29**	**-1.58-0.10**	**-2.93**	**0.033**
	Mixed	-0.16	0.67	-1.88-1.56	0.39	0.82

Amount >2 joints on one occasion		0.29	0.35	-0.62-1.20	-0.81	0.46
Frequency >Monthly use		-0.06	0.46	-1.25-1.13	-0.12	0.91
Anxiety		**0.15**	**0.03**	**0.09-0.22**	**6.11**	**0.002**
Depression		**0.10**	**0.02**	**0.5-0.15**	**4.70**	**0.005**
Grandiosity						
Latent Class	Herbal only	-0.29	0.21	-0.85-0.27	-1.34	.24
	Skunk only	**-0.29**	**0.08**	**-0.49- -0.10**	**-3.82**	**.012**
	Mixed	-0.14	0.10	-0.40-0.11	-1.47	.20
Amount >2 joints on one occasion		0.33	0.22	-0.24-0.91	1.48	.20
Frequency >Monthly use		0.17	0.14	-0.20-0.54	1.19	.29
Depression		**-0.03**	**0.01**	**-0.05-0.02**	**-4.89**	**.005**
Sensation Seeking		**0.09**	**0.02**	**0.04-0.14**	**4.73**	**.005**

All Odds Ratios and Betas are adjusted for age, gender, ethnicity and Socio-Economic-Status. OR=odds ratio. B=unstandardized Beta. Reference group are non-user.

Bonferroni corrected p-values: Hallucinations, Grandisoity and cognitive disorganisation = 0.007; paranoia = 0.006

Table 4. Multi-nominal logistic regression examining the associations between cannabis use motives and latent class

	Herbal only V's Skunk only				Herbal only V's Mixed				Skunk only V's Mixed			
	B	Robust SE	95% CI	P	B	Robust SE	95% CI	P	B	Robust SE	95% CI	P
Coping Motives	0.08	0.13	-0.19-0.35	0.56	0.02	0.10	-0.17-0.21	0.85	-0.06	0.06	-0.17-0.05	0.28
Social Motives	-0.07	0.05	-0.17-0.04	0.21	0.01	0.05	-0.08-0.10	0.81	0.08	0.09	-0.11-0.26	0.41
Expansion Motives	-0.11	0.08	-0.27-0.04	0.15	**0.18**	**0.04**	**0.11-0.23**	**0.0001**	**0.29**	**0.06**	**0.16-0.41**	**0.0001**
Conformity Motives	0.11	0.14	-0.17-0.40	0.78	**-0.14**	**0.04**	**-0.21--0.06**	**0.0001**	-0.25	0.14	-0.53-0.03	0.085
Enhancement Motives	0.06	0.04	-0.02-0.14	0.12	-0.04	0.04	-0.12-0.04	0.29	-0.11	0.05	-0.21--0.01	0.047

B= unstandarised Beta; SE=Standard Error; CI=confidence Interval; All Betas are adjusted for age, gender, ethnicity and Socio-Economic-Status. Bonferroni adjusted p-value =0.01

Supplementary Table 1. Self-report indices of psychotic experiences and their associations with demographics, victimization, sleep disturbance, depression, anxiety, sensation seeking, and other substance use.

	Mean (SD), % (N)	**Paranoia**	**Hallucinations**	**Cognitive disorganisation**	**Grandiosity**
Male gender	43.9% (205)	.01	-.10*	-.11*	.08
White ethnicity	23.6% (110)	-.03	-.08	.18***	-.13**
Socio-economic status	2.85 (0.97)	.06	.02	.03	.02
Victimisation	1.5 (2.2)	-.01	.15**	.23***	-.11*
Sleep disturbance	6.1 (4.4)	.25***	.34***	.41***	-.02
Depression	8.33 (6.17)	.21***	.42***	-.57***	-.24***
Anxiety	7.38 (6.01)	.22***	.38***	.61***	-.18***
Sensation Seeking	13.62 (3.04)	.08	.02	-.02	.20***
Cigarette use	7.7 (36)	.19***	.05	.09	.01
Electronic cigarette use	4.5 % (21)	.13**	-.08	-.02	.01
Other illicit drug use	6.4% (30)	.11*	.05	.03	.08
Alcohol use	55.7% (260)	.05	.02	.11*	.02

*p <.05; **p<.01, ***p<.001.

Supplementary Table 2. Univariate Bayesian information criterion (BIC) values ranked in order from lowest to highest and change in BIC in brackets when included in each regression model.

Paranoia	**Univariate BIC**	**Hallucinations**	**Univariate BIC**	**Cognitive Disorganisation**	**Univariate BIC**	**Grandiosity**	**Univariate BIC**
Sleep disturbance	-2575.35 (-33.094)	Depression	-2360.68 (-79.358)	Anxiety	-787.04 (-213.245)	Depression	-1413.469 (-28.677
Anxiety	-2559. 47 (-2.596)	Sleep disturbance	-2340.60 (-22.186)	Depression	-755.55 (-15.866)	Sensation Seeking	-1404.846 (-19.297)
Depression	-2554.19 (0.411)	Anxiety	-2348.89 (0.385)	Sleep disturbance	-658.81 (-13.532)	Anxiety	-1400.68 (0.694)
Cigarette Use	-2545.83 (-5.610)	Victimisation	-2292.99 (-2.351)	Victimisation	-598.05 (-1.546)	Victimisation	-1391.616 (0.763)
e-cigarette use	-2539.44 (-3.028)			Alcohol use	-566.74 (0.847)		
Other illicit drug	-2538.27 (0.610)						