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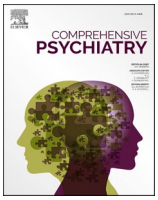

Changes in recreational drug use, reasons for those changes and their consequence during and after the COVID-19 pandemic in the UK

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ABSTRACT

Changes in drug use in the general population during the COVID-19 pandemic and their long-term consequences are not well understood. We employed natural language processing and machine learning to analyse a large dataset of self-reported rates of and reasons for drug use during the pandemic, along with their associations with anxiety, depression and substance use problems post-pandemic. Our findings revealed a transient decrease in drug use at the pandemic's peak, primarily attributed to reduced social opportunities. Conversely, some participants reported increased drug use for self-medication, boredom, and lifestyle disruptions. While users of psychedelics and MDMA had anxiety and depression rates similar to non-users, users of opioid agonists and depressants—representing one in ten active drug users—reported greater mental health challenges post-pandemic. These results suggest that a subset of active drug users with distinct profiles faces elevated risks, particularly for anxiety and depression, and may benefit from targeted support.

1. Introduction

The consequences of the COVID-19 pandemic for public health and society have received substantial attention over the past few years [1,2]. One prominent concern since the early days of the pandemic has been that there could be changes in the use of psychoactive drugs and that these changes could have longer term consequences with respect to mental health or other problems associated with substance use. Past research on this topic has primarily focused on how the pandemic affected vulnerable populations, including those with pre-existing substance use disorders [3]. Individuals with substance use disorders presented with notable psychopathological burden that was attributed to the lockdown-related disruption, including depression, anxiety, irritability and post-traumatic stress disorder – though there was variation depending on specific lifestyle circumstances [4]. However, less is known about changes in drug use among the broader general population, what the reasons for any such changes might have been, and whether those changes persisted beyond the pandemic or had notable lasting consequences for mental health.

It was proposed early in the pandemic that there could be an increase in drug use, including performance or image enhancing drugs, for either leisure or self-medication purposes [5,6]. These types of use have broad relevance as they are a common lifestyle choice covering both licit and illicit drugs [7]. However, people in these substance-use categories do not necessarily meet the criteria for substance-use disorders [8–10] and have received less attention in research.

Indeed, evidence to date provides a mixed picture regarding how drug use changed for the general population during the COVID-19 pandemic. In accordance with concerns that heightened mental distress, isolation, and job insecurity would lead to increased drug use [11,12], early data from the United States and Canada indicated a rise in substance use among habitual users, potentially driven by self-isolation challenges [13,14]. Furthermore, key workers, particularly in the hospitality sector, were reported to have increased their drug consumption, which could be attributed to the stress of working during the pandemic [15]. In a number of small scale studies, psychological stressors linked to

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the pandemic's onset were also identified as key factors in escalating substance use, with some individuals using drugs as a coping mechanism [16]. However, other reports provided more complex results, highlighting that additional free time was associated with increased cannabis use, whereas decreased social interactions contributed to a reduction in use of cannabis [17–19]. Additionally, a large European study noted that while cannabis use surged, the use of other illicit drugs did not significantly change [20]. Moreover, in England and Wales, there was a general downtrend in reported illicit drug use from March 2020 to June 2022, despite an uptick in reported lifetime usage [21]. An Italian study surveying individuals with substance use disorders and behavioural addictions found that drug craving during the first period of lockdown was generally low, though this negatively correlated with quality of life [4]. These complicated results likely reflect that peoples' behaviours and mental health were affected in diverse ways by the pandemic, highlighting the need for more nuanced analyses of data from large and inclusive population samples [22].

In addition to uncertainty regarding how drug use changed during and after the pandemic, it remains unclear whether those changes had longer-term consequences at the population level. One study predicted that the development of dysfunctional coping mechanisms during the pandemic would subsequently lead to increased vulnerability to problems associated with drug use, especially among younger people [23,24]. Economic strain, psychiatric diagnoses, poly-drug use, and COVID-19 mitigation strategies have also been identified as factors that might have influenced substance use behaviours during the pandemic, and relatedly could have contributed to the risk of someone developing a substance use disorder thereafter [25–27]. However, the longer term consequences among members of the general population whose drug use behaviours changed during and after the COVID-19 pandemic remain largely unknown. Most strikingly, at the time of writing, the results of studies providing an early depiction the impact the pandemic had on individuals remain mixed, majoritarily reflect the lived experience of specific population subsets, and do not provide of an account of post-pandemic mental health and substance use outcomes in relation to those originally observed.

Here, we addressed these knowledge gaps by analysing data from a large-scale online survey that examined how recreational drug use changed during and following the COVID-19 pandemic, from 2019 to 2023, as well as the reasons participants gave for these changes and their associations with depressive and anxiety symptoms and indicators of substance use problems. Participants were recruited agnostically, without specific reference to drug use, which provided an advantage of minimising recruitment bias towards individuals interested in drug-related studies. This approach also enabled comparison with a large control population that completed the same mental health assessments over the same period. We first quantified changes in patterns of drug use throughout the pandemic. We hypothesised that individuals who reduced their drug use during the pandemic would sustain these reductions and exhibit better mental health scores, whereas increased drug use would associate with worse mental health scores. We also hypothesised that the underlying reasons for changes in drug use would be diverse, and consistent with early literature, severe lifestyle disruptions linked to altered drug use patterns would be associated with worse mental health scores at that time. Furthermore, we anticipated identifying a subgroup whose altered patterns of drug use might place them at elevated risk for ongoing mental health and substance use problems post-pandemic. Using machine learning and natural language processing techniques, we systematically derived the reasons behind these behavioural changes from participants' own words and analysed their associations with concurrent anxiety and depression symptoms. Finally, we evaluated how current drug use behaviours post-pandemic associated with current anxiety, depression, and substance use problems.

2. Methods

2.1. Data collection

The original study cohort was recruited during an online citizen science collaboration with BBC2 Horizon, the Great British Intelligence Test [7,22,28–32], using articles in prominent positions on the BBC news and BBC homepage websites in January 2020. A second promotional drive placing articles in the same prominent locations was launched on May 2, 2020, aligned with a BBC2 Horizon documentary reporting preliminary cognitive results from the analysis of the initial data. Participants were able to sign up for further timepoints on completion of the baseline survey by providing their email address to be part of the cohort.

Out of $N = 346{,}780$ adults aged >18 years who completed the baseline survey ($N = 231{,}861$ in January–April 2020, $N = 114{,}919$ in May–June 2020), by January 2023 a total of $N = 95{,}441$ signed up to be recontacted for further timepoints, with this number accumulating over the course of the study (Supplementary Table 1). Emails were sent inviting participants to complete four follow up timepoints. This resulted in $N = 15{,}957$ in December 2020 (16,72 % of those re-contacted), $N = 12{,}920$ in June 2021 (13.59 % of those re-contacted), $N = 21{,}527$ in January 2022 (17.29 % of those recontacted) and $N = 26{,}873$ in January 2023 (21.17 % of those recontacted) datasets comprising complete questionnaires and where applicable (based on whether they declared to have used a recreational drug other than alcohol and tobacco at least once before the assessment and consented to answer more detailed questions about this) questions about their drug use. No attempt has been made to input data for individuals part of the re-contacted cohort who have not engaged with follow-up surveys. $N = 31{,}459$ participants completed one recontact timepoint, $N = 15{,}451$ participants completed two timepoints, $N = 6380$ participants completed three timepoints. $N = 3466$ participants completed all four recontact timepoints. A total of $N = 56{,}763$ out of the $N = 126{,}954$ ever recontacted unique participants completed at least one recontact timepoint.

This study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2008. All procedures described were approved by the Imperial College Research Ethics Committee (17IC4009) following an amendment on 29th June 2022 to the ethics application originally approved on 23rd August 2017. All participants provided electronic informed consent prior to completing the survey.

2.2. Inclusion/exclusion criteria

No exclusions in participant recruitment were made based on type of drug used, drug use frequency, race, ethnicity, location, occupation, education, or presence of neurological or psychiatric conditions. A breakdown of the sociodemographic characteristics is available in the Supplementary Materials -Supplementary Fig. 1.

2.3. Mood and anxiety self-assessment

Mood and anxiety were self assessed via items from the Patient Health Questionnaire (PHQ-9) [33] and GAD-7 [34] scales. To capture a broader temporal representation and be able to infer mental health challenge levels over a longer period of time, we asked participants to consider their symptoms for the month preceding the survey, which is a longer duration than the two-week period typically covered by the standard scales. We also enhanced the granularity of our measurement by broadening the scoring range to encompass a wider array of frequency levels that may be able to detect extremely frequent distressing mental health symptoms [7,22]. Specifically, participants were asked to assess the frequency of their symptoms over the past month using a scale from 0 to 6, where the points were defined as follows: '0-Never', '1-Almost never', '2-Once or twice a week', '3-Several times a week', '4-Daily', '5-Hourly', and '6-More often'. A factor analysis with one factor

was then used to determine a global mood and anxiety composite score from answers to all items (Supplementary Fig. 2).

2.4. Screening for substance use problems

Substance use problems were quantified using the 10-item version of the Drug Abuse Screening Test, which is designed to assess problems related to drug use other than alcohol or tobacco (DAST) [35]. This scale addresses issues related to polydrug use, inability to quit, psychological and social impacts, legal problems, and health consequences resulting from drug use. Participants provided binary (Yes/No) answers to each item. Each 'Yes' answer accounted for 1 point. The questionnaire was scored to reflect the DAST score. A score of 0 indicates no problems, a score of 1–2 indicates a low level of problems. A cut-off of 3 is typically used to indicate potential drug use issues. A score between 3 and 5 indicates a moderate level of problems, a score of 6–8 indicates a substantial level of problems, a score of 9–10 indicates a severe level of problems.

The DAST was selected as the screening tool for problems associated with drug use in this study due to its efficiency in administration, which is advantageous for large-scale online research, and its straightforward scoring system based on a 10-item binary (yes/no) response format. Its established use across diverse age groups, including undergraduate students, middle-aged adults, and older adults, also supports its suitability for our UK-based sample, which encompasses a broad age range [36].

2.5. Participants drug use and patterns of drug use changes

Data regarding participants' recreational drug use were collected in December 2020, June 2021 and January 2022 and January 2023. Participants were first asked whether they ever used a recreational drug that is not alcohol or tobacco - 'Have you taken a recreational drug before in your life? (This does not include alcohol, tobacco or caffeine)'. Those who responded 'yes' were then asked whether they would be willing to answer questions about their use of drugs. Those who responded favourably were then asked about their drug use since 2019. The frequency-of-use categories (infrequent, moderately frequent, and frequent) were set up to create a three-level breakdown that covered the low and high ends as well as the middle range of usage that could guide the interpretation of data-driven clusters based on frequency of use at different timepoints.

Individuals were classified into the following groups:

- Drug naive - individuals who never used drugs in their lifetime
- Individuals who used drugs but are unwilling to answer questions about it and were therefore removed from the analysis
- Historic drug users - individuals who have not used any drugs during the assessment periods 2019–2022 but reported previous recreational drug use
- People who used drugs during the assessment periods 2019–2022

Frequency of drug use:

- Infrequent drug use
  - once/year
  - 2–5 times/year
- Moderately frequent drug use
  - 6–11 times/year
  - monthly
- Frequent drug use
  - Weekly
  - Daily

2.6. Statistical analysis

All statistical analyses were carried out in Python.

Drug users were clustered in two ways - a) using Gaussian mixture modelling to cluster them based on the frequency of drug use at different timepoints before, during and after the peak of the COVID-19 pandemic; b) and since individuals tend to use more than one drug, using k-modes clustering to cluster them based on their specific choices of drugs during 2022. Full details are provided in Supplementary Materials - Supplementary Methods for Clustering.

The Latent Dirichlet Allocation (LDA) multicore implementation in *gensim* [37], which uses online LDA [38,39], was used to find latent topics in the free-text data. Full details for natural language processing are provided in Supplementary Materials - Supplementary Methods.

Chi-squared tests evaluated temporal variations in topic distributions. To determine effect size differences, ANOVA was applied to linear regression models, which predicted mood or substance use problem severity based on cluster labels. This analysis, along with ordinary least squares regression, was performed using statsmodels [40]. The magnitude of effect size differences was interpreted based on Sawilowsky's updated version of Cohen's notion of effect sizes in standard deviation (SD) units (0.1 SD = very small, 0.2 SD = small, 0.5 SD = medium, 0.8 SD = large, 1.2 SD = very large and 2.0 SD = huge) [41].

3. Results

3.1. Changes in drug use frequency

Participants self-reported their levels of recreational drug use in January 2023 (Fig. 1). Prior to the pandemic, more than half of those who declared having used a recreational drug at least once in their lifetime were infrequent users (<6 times/year). The majority of the infrequent users, but also a notable proportion of moderately frequent and frequent users stopped using drugs during the peak of the COVID-19 pandemic. However, once pandemic restrictions were no longer in effect, drug use reversed to levels similar to those pre-pandemic. A supplementary analysis revealed 19 data-driven clusters indicative of distinct patterns of changes in drug use during this period of time – spanning 2019 (pre-pandemic), 2020–2021 (peak-pandemic) and 2022 (after pandemic peak) (Supplementary Fig. 5). These clusters are based on usage patterns that are approximated based on the cluster features derived in a data-driven way. Upon visual inspection, the clusters were grouped into 13 general patterns based on similarity: historic users (N = 4426) who did not use drugs before, during or after the peak of the pandemic; stable frequent users (N = 249) based on joining the groups of stable daily and weekly users; infrequent and moderately frequent users before and after the peak of the pandemic who did not use drugs during the peak (N = 223) based on joining the group who used drugs approximately 2–5 times before and after and none during, and the group who used drugs approximately 6–11 times before and after and none during; infrequent users who mildly decreased use during the pandemic then bounced back after (N = 521) based on joining the group who used drugs approximately 2–5 times before the pandemic, once during and approximately 2–5 times after the peak and the group who used drugs approximately 6–11 times before the pandemic, approximately 2–5 times during the pandemic and approximately 6–11 times after the peak; infrequent users who stopped using drugs completely after the pandemic (N = 102); infrequent users who increased to frequent use during the pandemic then reduced their use after (n = 48); users with no pre-pandemic or pandemic drug use who started infrequently using drugs in 2022 (N = 489); frequent users who were stable before and during the pandemic then decreased use after (N = 270) based on joining the groups who were using drugs on a weekly basis before and during the pandemic then decreased use to approximately 2–5 times of 6–11 times respectively; infrequent users who stopped using drugs completely during the pandemic and after (N = 143), stable

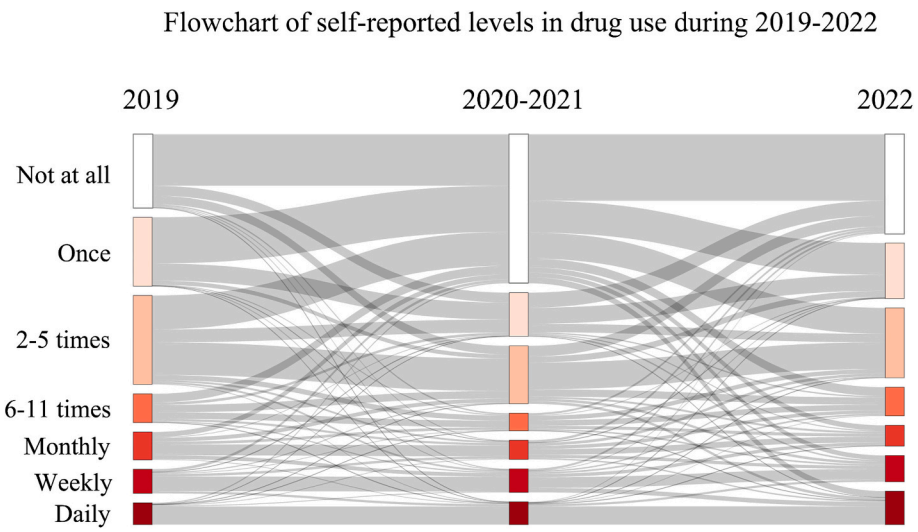

Fig. 1. Flowchart of self-reported changes in drug use during 2019–2022. Findings based on retrospective self-reported levels of use at different timepoints in January 2023, $N = 7602$ individuals.

infrequent to moderately frequent users ($N = 426$) based on joining three clusters of individuals who were stable in using drugs either once across all timepoints, approximately 2–5 times, or approximately 6–11 times respectively; moderately frequent users who increased to frequent use during the pandemic and maintained weekly/daily use thereafter ($N = 28$); moderately frequent users who increased to frequent use after the pandemic ($N = 11$), users who started infrequent use during the pandemic and maintained this level of use thereafter ($N = 176$).

Clusters indicative of changes in drug use were compared relative to drug naïve individuals on their anxiety and depression composite score and relative to historic drug users.(those who used drugs in the past but not since 2019) on their DAST score (Fig. 2). The worst anxiety and depression composite scores belonged to those who were moderately frequent users before the pandemic, increased to frequent use during and then maintained these levels (effect size 0.59SD, CI 95[0.22,0.96], F(1,24,189) = 9.75,$p < 0.001$), those with no pre-pandemic drug use who started infrequent use during the pandemic and maintained thereafter (effect size 0.34SD, CI[0.20,0.49], F(1,24,189) = 20.68, $p < 0.001$) and users with no pre-pandemic or pandemic use who started infrequent use after the pandemic (effect size 0.34SD, F(1,24,189) = 55.33, $p < 0.001$). These were followed by stable frequent users (effect size 0.27SD, CI 95 [0.15,0.40], F(1,24,189) = 18.37, $p < 0.001$) and those who used to be infrequent users then stopped after the pandemic (effect size 0.28SD, CI 95[0.09,0.48], F(1,24,189) = 8.17, $p < 0.01$). All clusters had worse

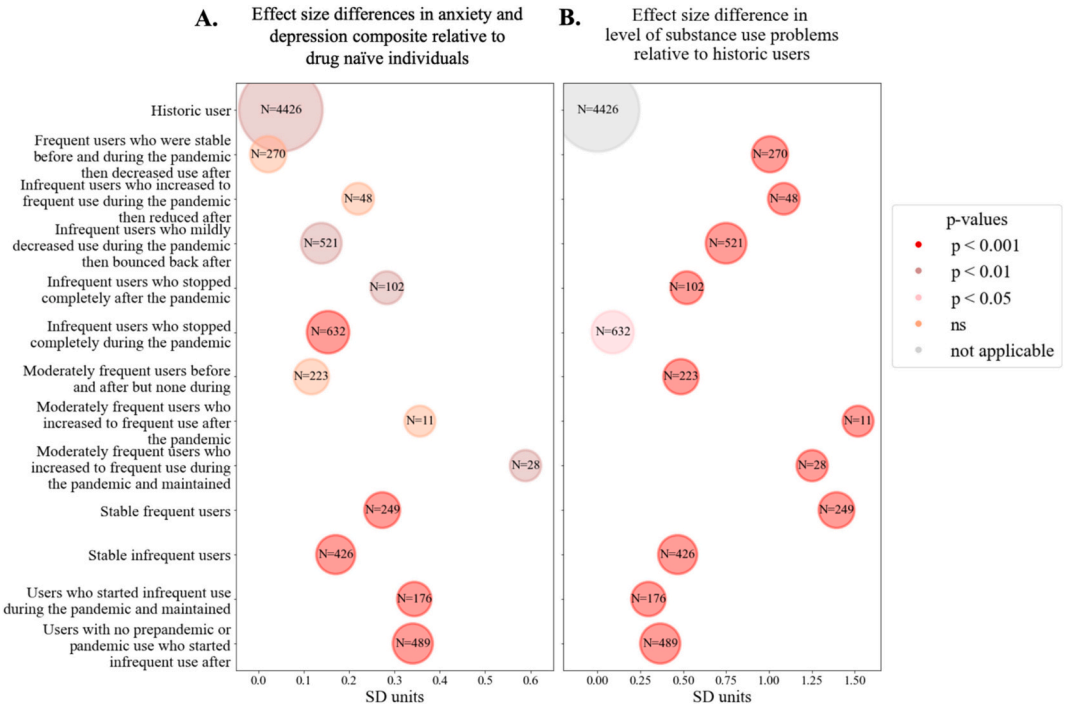

Fig. 2. Differences in current anxiety and depression composite score and level of substance use problems relative to drug naïve and historic users based on data-driven patterns of self-reported changes in drug use during 2019–2022. (A) Effect size differences in anxiety and depression composite relative to drug naïve individuals. (B) Effect size differences in level of substance use problems relative to historic users. For both plots the bubble size is proportional with the size of the cluster, which is also represented. The colour of the bubble indicates statistical significance.

DAST scores than historic users. The full analysis outputs are reported in full in Supplementary Materials Tables 2 and 3.

3.2. Self-reported reasons for changes in drug use frequency, and their relationship with mood during the pandemic

Out of $N = 6388$ responses from those who were drug users before 2020 and provided free text responses during the peak of the pandemic, $N = 2637$ (41.28 %) reported no change in drug use patterns, whereas $N = 1424$ (22.29 %) reported having stopped completely, $N = 1366$ (21.38 %) reported a reduction in use and $N = 961$ (15.04 %) reported an increase in use (Supplementary Fig. 3).

Free text analysis identified multiple self-reported reasons for either increasing or decreasing drug use during the acute stages of the COVID-19 pandemic. A majority of participants reported reduced or ceased drug use due to infrequent usage habits, absence of events such as festivals or club nights, health concerns, and decreased socialising. Conversely, increased drug use tended to be attributed to personal circumstances, changes in living situations, self-medication for mental health issues, boredom, the desire to feel good, and having more time alone (Table 1).

Based on the χ^2 analysis, we found these reasons fluctuated significantly in prevalence over time. Among those who reported less use/stopped use, Topic 1 ("Used to be a very infrequent user") dropped by ~10 % in incidence - from 36 % in December 2020 to 27 % in January 2022. Concurrently, Topic 3 ("Health concerns") emerged as an increasing cause for behaviour change, escalating from 20 % to 28 % over the same period. Among those reporting more drug use over the course of the pandemic, Topic 3 ("Self-medication for depression, anxiety, sleep problems") showed an initial increase from 13 % to 24 % in June 2021, though it decreased to 17 % by January 2022. It was also noteworthy that an increase in incidence, from 23 % in December 2020 to 25 % in January 2022 was seen for Topic 4 ("Boredom").

We carried out two linear regression analyses with the composite anxiety and depression score as a dependent variable: A) with the direction of change in drug use as predictors and B) with the specific reasons for those changes as predictors respectively (Fig. 3). All participants in all drug use groups (unchanged use, historic users, stopped use, used less or used more) had significantly worse composite depression and anxiety scores relative to drug naive individuals, and these results were consistent when also accounting for the confounding influence of alcohol and tobacco use in our models (Supplementary Materials Fig. 7). This was particularly pronounced for those who chose to use more drugs during the pandemic, where we observed an effect size difference of 0.45SD units relative to drug naive individuals (CI 95[0.39,0.52], $F(1,68,469) = 192.37, p < 0.001$), corresponding to a medium effect size. Using labels corresponding to specific reasons for changes in drug use revealed specific reasons associated with larger effect size differences in composite anxiety and depression scores. Specifically, there was a large 0.82SD effect size difference associated with using more drugs to self medicate for anxiety, depression or sleep problems (CI 95[0.66,0.98], $F(1,68,461) = 101.27, p < 0.001$), a medium 0.56SD effect size differences associated with increasing use due to boredom (CI 95[0.42,0.69], $F(1,68,461) = 65.23$, $p < 0.001$) and a medium 0.44SD effect size difference associated with increasing use due to changes in living situation (CI 95[0.25,0.62], $F(1,68,461) = 21.53$, $p < 0.001$). Full analysis is reported in Supplementary Tables 4 and 5.

3.3. Relationship between current composite anxiety and depression scores and substance use problems

At the time of assessment there was a small but significant correlation between composite anxiety and depression score and level of substance use problems (Pearson $r = 0.15$, $p < 0.001$) (Fig. 4A). Running an ANOVA on the anxiety and depression composite scores for participants grouped by level of substance use problems revealed a main effect of group ($F(4,7597) = 38.51, p < 0.001$) (Fig. 4B). Tukey post-hoc tests indicated this main effect was driven by significant differences between all groups with the exception of moderate and substantial and substantial and severe pairs, which followed a trend of worse anxiety and depression score with higher DAST scores. Tukey post-hoc tests are reported in full in the Supplementary Materials Fig. 8.

3.4. Data driven analysis of choice of drugs during 2022

K-modes clustering determined in a data-driven manner that members of the general public reported five common combinations of drug use in 2022. One of these clusters was further subdivided on inspection based on different patterns of psychedelics and MDMA usage (Supplementary Fig. 3). An individual could only belong to one cluster. These were:

- **Cannabis users.** All $N = 1112$ members use cannabis (100.00 %) with other substances being less than 5 % prevalence.
- **Cannabis and psychedelics users.** All $N = 167$ members use cannabis and psychedelics (75.45 % Psilocybin and 35.93 % LSD).

Table 1
Topic labels across timepoints. Reasons for using drugs less as well as for using more are provided alongside the sample size associated with each reason. Chi-squared statistics illustrating changes in topic distributions over time.

Change	Topic	Topic label	N Dec 2020	N June 2021	N Jan 2022	χ^2
Less use or Stopped	Topic 1	Used to be a very infrequent user	337 (36 %)	157 (27 %)	268 (27 %)	$\chi^2 = 32.88$, $p < 0.01$
	Topic 2	Lack of events/festivals/club nights	213 (23 %)	145 (25 %)	218 (22 %)	
	Topic 3	Health concerns	190 (20 %)	142 (24 %)	285 (28 %)	
	Topic 4	Less socialising	198 (21 %)	137 (24 %)	240 (24 %)	
More	Topic 1	Response to personal circumstances	60 (23 %)	39 (17 %)	59 (17 %)	$\chi^2 = 19.74$, $p = 0.03$
	Topic 2	Changes in living situation	33 (13 %)	26 (11 %)	54 (15 %)	
	Topic 3	Self-medication for depression, anxiety, sleep problems	34 (13 %)	55 (24 %)	61 (17 %)	
	Topic 4	Boredom	60 (23 %)	64 (28 %)	87 (25 %)	
	Topic 5	To feel good	31 (12 %)	20 (9 %)	38 (11 %)	
	Topic 6	More time alone	40 (16 %)	23 (10 %)	55 (16 %)	

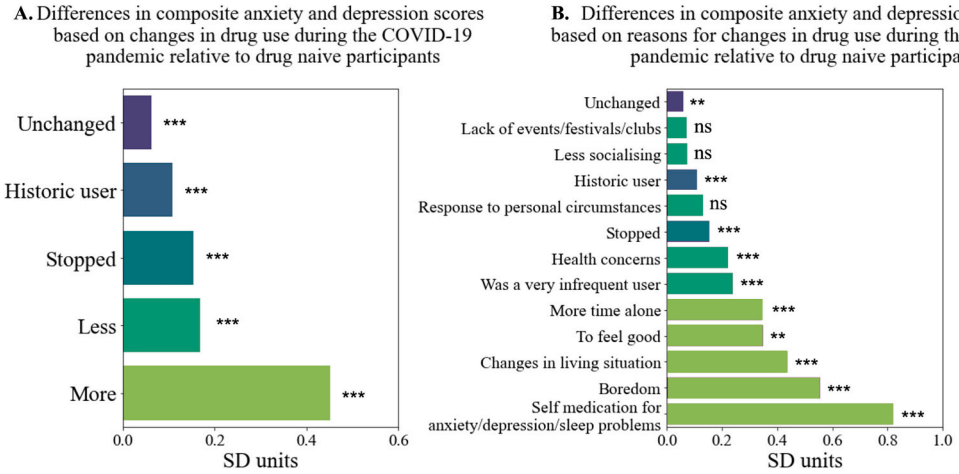

Fig. 3. Effect size differences in depression and anxiety self-assessment composite score collected during 2020–2021 in people who changed their drug use levels relative to non-users. Two linear regression models were run on the adjusted to sociodemographics composite mood score with each binary dummy-variable representing changes (**A**) and reasons for changes in drug use (**B**) as predictors. The group of participants who reported never using recreational drugs in their lifetime was the reference category. The y axis represents the beta coefficients from the regression associated with the effect size of each of the groups (the higher the effect size the more frequent the mood symptoms relative to the reference category). The significance star annotations represent the statistical significance of this effect size derived from running an ANOVA on the linear regression model. ns- not significant *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

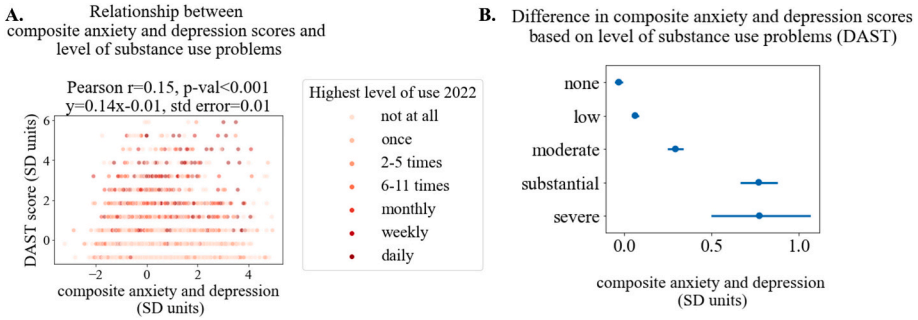

Fig. 4. Relationship between composite anxiety and depression scores and level of substance use problems in January 2023. **A.** Relationship between anxiety and depression scores and level of substance use problems. **B.** Difference in composite anxiety and depression score based on level of substance use problems derived from the DAST scale. Error bars represent standard error of mean.

- **Psychedelics and MDMA users.** $N = 116$ members reporting use of MDMA (41.23 %), psilocybin (magic mushrooms, 53.51 %) and/or LSD (20.18 %).
- **Stimulant and cannabis users.** The majority of $N = 509$ members used cocaine 92.73 %, MDMA (24.95 %) and/or Amphetamines (13.16 %), with many also using cannabis (42.24 %).
- **Depressant users.** $N = 233$ Members using opioid agonists (40.34 %), benzodiazepines (26.18 %), poppers (25.32 %) and/or prescription sleeping medicines (12.45 %).
- **High level polydrug users.** $N = 183$ members with high levels of use across multiple drugs including cannabis (89.07 %), Cocaine (84.15 %), MDMA (88.52 %), Ketamine (68.85 %) Psilocybin (58.47 %) and LSD (38.80 %) Nitrous Oxide (36.61 %) amphetamines (21 %), Poppers (21 %) benzodiazepines (18.03 %), 2C-X group (19.67 %) and opioid agonists (12.02 %).

3.5. Relationship between drug choices, current composite anxiety and depression scores and substance use problems

After adjusting for sociodemographic factors, alcohol use and tobacco use, ANOVAs showed a significant main effect of drug-choice cluster on composite depression and anxiety score ($F(7, 24{,}195) = 18.88$, $p < 0.001$), and a significant main effect of cluster on the level of substance use problems (DAST) ($F(6{,}7594) = 177.34$, $p < 0.001$) (Fig. 5). Post-hoc Tukey tests are reported in Supplementary Materials Figs. 9 and 10. Opioids, benzodiazepines and poppers users had the worst depression and anxiety scores, whereas polydrug users had the worst DAST scores.

4. Discussion

In this study, we investigated changes in self-reported rates of recreational drug use (excluding alcohol, tobacco, and caffeine) in a large general population sample that was recruited independently of an interest in participating in drug use related surveys, quantified the self-reported reasons for those changes using natural language processing, and their association with mental health and substance use problems post-pandemic. Our results showed that the COVID-19 pandemic had a substantial impact on drug use, with the majority trend in our sample being towards cessation or reduction in consumption during the peak of the pandemic, a result that accords with other recent studies [21,42,43]. Once restrictions in the UK had been relaxed in 2022, overall consumption rebounded towards pre-pandemic levels. Free text analysis indicated that common reasons for these changes pertained to diminished opportunities for social interaction when restrictions were in place, which accords with past research on recreational drug use [43–45]. A substantial proportion (43.67 %) of those who provided free text responses and were active drug users up until the pandemic

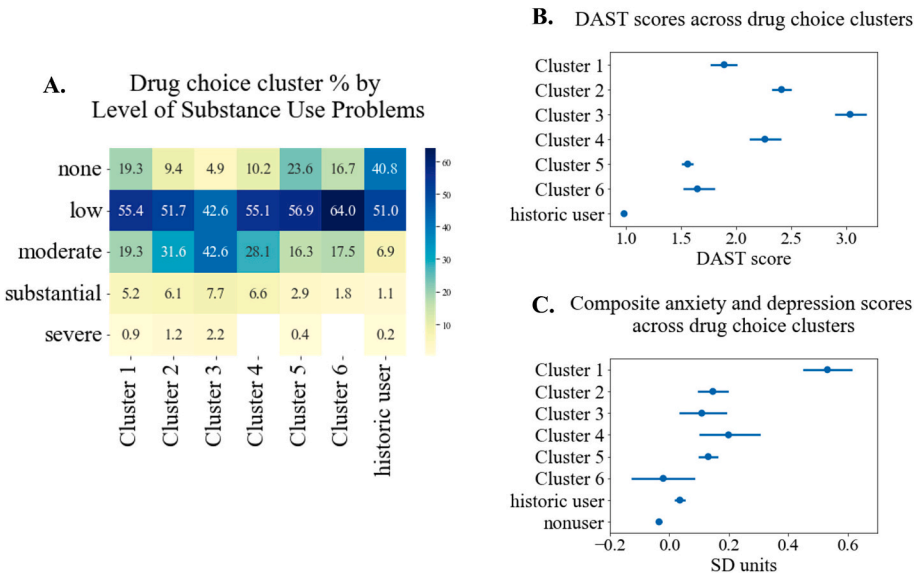

Fig. 5. Clusters of drug choices post-pandemic, and their relationship to composite anxiety and depression scores and level of substance use problems. The clusters represented are interpreted as follows: Cluster 1 - Opioid agonists, Benzodiazepines, Poppers ($N = 233$), Cluster 2 - Stimulants and Cannabis ($N = 509$), Cluster 3 - Polydrug ($N = 183$), Cluster 4 - Psychedelics and cannabis ($N = 167$), Cluster 5 - Cannabis ($N = 1112$), Cluster 6 - Psychedelics and MDMA ($N = 114$). **A.** Percentage distribution of level of substance use problems on the DAST scale within each cluster. **B.** Difference in DAST scores between clusters. **C.** Difference in composite anxiety and depression scores between clusters.

reported either cessation or a decrease in drug use, highlighting the disruption in pre-pandemic drug use patterns attributed to loss of social opportunity and changes in personal circumstance was not trivial.

Contrastingly, a significant minority of participants (15.03 %) showed increased drug use during the pandemic. Free text data revealed that these increases were attributed to self-medication, boredom, loneliness and changes in living situation. This is in line with other evidence suggesting that major disruptions to routine life during the COVID-19 pandemic motivated certain individuals towards increased drug consumption as a potentially maladaptive coping mechanism, e.g., to cope with lifestyle disruptions and loss of social opportunities [46,47]. Other influential factors like specific social dynamics such as the breakdown of relationships, may have also played a role [25,26].

It is known that depression and anxiety challenges were associated with levels of alcohol consumption during the pandemic [48]. Our present study reveals that there was also a clear association between recreational use of other drugs in that timeframe and symptoms of anxiety and depression. Those who reported their use increased during the pandemic had poorer mental health during the pandemic than those who never used drugs. However, this was also the case for people with a history of drug use who reported no longer using them, which accords with some past findings [49]. It is generally a challenge to disentangle causal relationships between drug use, mood and anxiety via survey studies [7]. However, the free text approach presents a unique set of evidence rooted in participant's lived experience that contextualises prior hypotheses that depression and anxiety can prompt increases in drug use [50–52]. Specifically, participants with the worst mental health scores during the pandemic time were those who reported using more drugs for self-medicating for depression, anxiety and sleep problems.

We also used the DAST scale to define the levels of substance use problems in our sample. This scale has a significant relationship with the addiction severity index [53]. The fact that higher DAST scores also correlated with higher levels of anxiety and depression symptoms could indicate a role in vulnerability to substance use problems for those suffering mental health challenges. For example, symptoms of anxiety and depression were most frequent among those with severe levels of substance use problems, as expected from other studies [54].

People in the general population who use drugs do so for different reasons and in different combinations. These different patterns pose a challenge for research with small scale or focused population samples, but they likely have relevance to mental health. Here, we used a data-driven approach to cluster and characterise people based on the most common patterns of drug choice during the post pandemic period. This analysis identified people who primarily use cannabis as the most common followed by people who used stimulants and cannabis. Other clusters included opioid agonists, benzodiazepines and poppers users; high-level polydrug users of stimulants, cannabis, dissociatives and psychedelics; a cluster of psychedelics and cannabis users; and a psychedelics and MDMA preferring cluster. That cannabis showed as the most prevalent choice accords with past UK-based research [21]. The fact that most clusters represented different patterns of polydrug use highlights the challenge in determining the relationship of specific drugs with mental health independent of each other [7].

When people were grouped according to these patterns of drug use the relationship to mental health problems was more evident than when grouping them by changes in levels of use. Most notably, clusters of 'opioid agonists, benzodiazepines and poppers users', 'stimulants and cannabis' and 'cannabis' had the worst anxiety and depression scores relative to those who never used drugs, and all clusters had worse DAST scores compared to historic users. At the other extreme, the 'psychedelics and MDMA' cluster had similar low rates of depression and anxiety symptoms to those who never used drugs, and a low DAST score (whereas past research indicates those who used psychedelics and cannabis had worse mental health scores than drug naïve individuals during the peak of the pandemic [7]). This contrasted with the psychedelics and cannabis cluster which had worse DAST scores and numerically worse anxiety and depression scores. A possible explanation for this difference could be the use of MDMA during the same period of time, or differential set and setting disruption within the contexts the drugs were used [7,55]. Determining whether the differential association between naturalistic patterns of drug use and mental health observed here reflects differential impact of drugs, different motivations underlying patterns of drug use (such as using psychedelics to self medicate for mental health issues vs. to improve wellbeing from a normal baseline) or environmental factors could be the basis for future longitudinal research [7,55,56].

The size of the opioid agonists, benzodiazepines and poppers cluster relative to other choices of drugs during 2022 is noteworthy as these

substances have not been reported in the national drugs misuse report conducted for that period of time [21]. This calls into question the reason behind this choice given that drugs such as opioid agonists are associated with worries of patients about addictive potential even when they are prescribed for medical reasons [57], and suggests these choices might be linked to increased availability either via medical or non-medical routes, which should be monitored. These substances in particular are associated with differing degrees of harm to users and those around them; opioid agonists such as heroin were reported to be the most harmful substances in the UK, second only to alcohol, and benzodiazepines to account for 3.6 times less harm than heroin [58]. Whilst this group did not rank highly on the DAST scale looking at levels of substance use problems, they displayed the highest incidence of depression and anxiety among the current drug choice clusters. This considered alongside the significant general correlation between level of depression and anxiety and level of substance use problems, this group of individuals emerges as a vulnerable group that should be identified, monitored and supported in the pandemic aftermath.

Our study focused on self-reported use of recreational drugs excluding alcohol and tobacco. Given most of the drugs we assessed are illicit in the UK, this could have affected the generalisability of our results to other countries due to differences in accessibility and legal statuses. Additionally, societal stigma might have led to underreporting. However, the anonymity of our survey and the option to decline answering drug use questions may have mitigated this limitation. Furthermore, as with all retrospective self-report studies, our findings might have been subject to recall bias, which could have affected the accuracy of participants' reported frequency of recreational drug use. Only up to a fifth of the total cohort of individuals who were recontacted completed a follow-up survey at a given time, and only a quarter of the overall cohort engaged with the follow-up surveys at all - which resulted in a sample less diverse than that originally recruited [22]. Our resulting sample, though large for a drug survey [59], skewed towards those with higher education and white backgrounds, although it had a better representation of ethnic minorities compared to many UK studies [60]. Due to the use of the BBC's online platform for participant recruitment, our sample may overrepresent individuals with higher education levels and greater internet access. This selection bias could limit the generalisability of our findings to broader populations, particularly those with limited digital access or lower educational attainment. Future studies should employ more diverse recruitment strategies to address this limitation. While we were able to characterise patterns of drug use in this sample, the proportions and effect sizes of associations might differ to those identified in a UK representative sample or in a sample. We also did not collect comprehensive pre-pandemic drug histories, which typically require in-depth interviews, due to the constraints of large-scale, online, unsupervised surveys where lengthy questionnaires on sensitive topics could affect participant retention; this leaves an open question about how patterns of use during the pandemic and beyond vary with an accumulation of experiences. Finally, we must be careful inferring causal relationships from observational data of this kind.

In summary, the relationship of drug use during and after the COVID-19 pandemic, with mental health symptoms was complex. Although for many people who use drugs their levels of consumption reduced during the pandemic before rebounding, a minority of individuals increased their consumption as a coping strategy during the pandemic, often prompted by mental health challenges. In the aftermath, it was choice of drugs as opposed to change in drug use that most strongly associated with poorer mental health score. In particular, those who reported primarily using opioid agonists, benzodiazepine and poppers in the period after the pandemic, representing a tenth of recreational drug users in our sample, showed elevated depression and anxiety scores relative to those who never used drugs, significantly higher DAST scores relative to historic users, and warrant additional attention.

CRediT authorship contribution statement

Maria Bălăeț: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ana Zadel:** Writing – review & editing, Writing – original draft. **Anne Lingford-Hughes:** Writing – review & editing, Conceptualization. **Louise M. Paterson:** Writing – review & editing, Conceptualization. **Samuel R. Chamberlain:** Writing – review & editing, Methodology, Conceptualization. **William Trender:** Writing – review & editing, Software, Methodology, Data curation, Conceptualization. **Peter J. Hellyer:** Writing – review & editing, Software. **Adam Hampshire:** Writing – review & editing, Supervision, Software, Conceptualization.

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Declaration of competing interest

AH is the founder and director of Future Cognition LTD and co-founder and co-director of H2 Cognitive Designs LTD, which support online studies and develop custom cognitive assessment software respectively. PJH is co-founder and co-director of H2 Cognitive Designs LTD. WT is an employee of H2 Cognitive Designs LTD. SRC receives an honorarium for editorial work at Elsevier journals (NBR and Comprehensive Psychiatry).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.comppsych.2025.152598.

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