DRUG CHECKING AT MUSIC FESTIVALS IN BRITISH COLUMBIA

Interior Health

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1) Executive Summary

Since 2003, the AIDS Network Kootenay Outreach and Support Society (ANKORS), now partnered with Interior Health and the British Columbia Centre on Substance Use, has been offering free drug checks to attendees at music festivals like the Shambhala and Bass Coast held in British Columbia, Canada. Drug checking is a free harm reduction service that allows service users to bring drugs and have their compositions checked using technologies such as Fourier-transform infrared spectroscopy (FTIR). Service users are then shown the results, allowing them to make informed decisions regarding the drug's use. To understand the impact of such services, ANKORS created survey sheets for service users, technicians, and advisors to record information during their transactions. Data has been collected regarding where drugs are obtained, what service users think they are, whether or not the FTIR results concord, and what the service user then determines to do with the drug.

Based on the studied dataset, some of the key findings of the data analysis are:

- It was discovered that the percentage of new service users accessing the drug checking services increased from 52% in 2018 to 70% in 2019.
- The two drugs most commonly brought by the same service user during the same visit at Shambhala are MDMA and LDS, and the most common drug additive is one of the many possible forms of sugar.
- There is no statistically significant difference between what a service user believes a drug to be and the spectroscopy analysis.

Researchers also conducted unsupervised learning to look for patterns, specifically utilizing various clustering algorithms to draw inferences from the data. Additionally, various ensemble and boosting algorithms were conducted to predict whether or not a service user will discard their drug as well as to predict what service users will decide to do with a drug after getting the results of the drug check.

The results of the exploratory data analysis were clear enough, but the results of both the supervised and unsupervised learning approaches were inclusive. Further research could involve experimenting more with variable selection, aggregating multiple datasets over many years, or asking more specific questions on the survey sheets, and suggestions are made for data collection that would facilitate this future research. An appendix is included that explains, to the general reader, the supervised, and unsupervised techniques that were utilized.

2) Acknowledgement

We thank the steering committee from Interior Health, (AIDS Network Kootenay Outreach and Support Society) ANKORS, and British Columbia Centre on Substance Use (BCCSU)—Ellen Korol, Chloe Sage, Barbara Gauthier, Jaime Arredondo, Jennifer Driscoll, Jessica Bridgeman, and Lesley Coates—for their assistance and collaboration.

3) Introduction

Music festivals have grown more popular in recent years and have been a place for people to enjoy music, dance, and art. Being in an altered state of mind is commonly associated with raves and music festivals, and the associated substance use is difficult to prevent (Michelow and Dowden, 2013). From the early days of rave and festival organizers began to develop essential risk reduction services and messaging aimed at promoting responsible substance use and reducing potential for associated risks and harms (Michelow and Dowden, 2013). ANKORS, a harm-reduction organization has been providing drug-checking services since 2003 across North America. People accessing ANKORS services are referred to as “service users” or “SU” in this report.

Drug checking is a free harm reduction intervention that provides service users with information regarding a drug's composition and the presence of adulterants, so they can make better decisions regarding how to use it (McCrae, 2019). The drug checking is typically laboratory-quality purity testing using various chromatography techniques conducted both on-site at venues and in offsite laboratories (Michelow and Dowden, 2103). Drug checking services have been provided in some regions of Europe since 1992 (Ontario, 2017), but Canada has given them greater attention in recent years because the country is experiencing a public health crisis of drug-related overdoses. In response to the overdose public health emergency, Interior Health has recently been able to support and enhance the drug checking services ANKORS has been providing in festival settings since 2004, including the Shambhala Music Festival held annually in Salmo and the Bass Coast (Music) Festival held in Merritt (Sage, 2020).

The Shambhala Music Festival is an electronic music festival held in the summer (late July-early August) in British Columbia. It is internationally recognized as a world class event and it's one of the largest and longest established electronic music festivals (Michelow and Dowden, 2013). The festival lasts 6 days with approximately 18,000 attendees (including volunteers and paid staff). Bass Coast Music Festival is a both local and international music festival with approximately 6,500 attendees (Merritt Herald, 2019). It is quickly rising within Canada’s outdoor festival circuits (McGowan, 2015). Both of these festivals allied with multiple community-based organizations to bring a range of harm reduction services to the festivals (Michelow and Dowden, 2013).

4) Project Motivation

There has been a heightened interest in public health to look for best practices for harm reduction outreach and drug checking services (Michelow and Dowden,2013). The idea of our project is to better understand the components for harm reduction program offered at the music festivals and to further improve the data collection methods to get a better insight of the drug checking services at music festivals. There is also a need to provide ANKORS with easily understandable graphics so that they may easily visualize the results at Shambhala and Bass Coast.

5) Dataset

5.1) Data Collection Methodology

The Data Collection Form (DCF) is a physical form that was completed at Shambhala and Bass Coast. The survey hours were chosen from previous years' experience at the festivals and the testing booth was open from 3pm until midnight (Michelow and Dowden,2013).

The DCF consists of two sections, one for service users and another for Technician/Harm Reduction Volunteers. DCF consisted of the following: It asked service users if they would consent to research, if they had used drug checking services before, what they believed the drug was (Belief), and for whom they were getting it tested. After testing was completed, a volunteer/technician used the DCF to record the results of the drug checks, which usually included Fourier-transform infrared spectroscopy (FTIR) results. They also noted the service user's reaction: whether or not they were surprised, if they were satisfied with the service, and, based on the result, what they intended to do with the drug. Finally, a Harm Reduction Volunteer indicated on the DCF whether or not the service user then discarded the drug in their presence, added their initials and any final comments. The anonymous, interviewer-administered questionnaire consisted of a short, 2-page (single-sided) instrument (Michelow and Dowden, 2013). See Appendix C for survey samples for Shambhala and Bass Coast 2019.

5.2) Data

The data studied in this report were collected at Shambhala (2017-2019) and Bass Coast 2019 during interactions with service users while they were getting the drugs checked. During the 2017-19 period, the survey questions in DCF evolved along with the drug checking technologies. As a result, both 2019 datasets are using FTIR methodology to perform drug checking. See Appendix A for details of the testing methods used. Additionally, until this research, statistical work on the 2019 datasets had not yet been made broadly available. Accordingly, this gave more attention to the 2019 datasets than the 2018 and 2017 years.

Terminology

An attempt has been made to only use the word *drug* when talking about an item a service user brings for checking, and *substance* when defining the composition of the drug. Thus, a drug can contain multiple substances. Finally, in the 2019 datasets, the following six substances were given their own codes for smoother analysis, and therefore receive greater attention: MDMA, MDA, Ketamine, Cocaine, Methamphetamine, LSD. Collectively, these six substances will be referred to as *the sextet.*

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6) Research Questions

With the help of interactive visualizations, and insights/predictions from data analysis and machine learning models the following research questions are posed in this report:

Service users:

- *How many festival attendees access the drug checking service?*
- *What proportion of them consent to research?*
- *What gender(s) do they identify with?*
- *Where do service users say they have obtained the drugs?*
- *Who are they testing for?*

Substances:

- *What do service users expect their drug to be?*
- *To what degree do the point of care check results correspond with service users' expectations?*
- *When service users bring more than one drug to get checked, what combinations of drugs are they bringing (looking at the 2019 data only)?*
- *When multiple substances are found in one sample, what substances are found together?*
- *What changes do we see in choice of drugs over the three-year period (Shambala only)?*

Substance Prediction:

- *How frequently do the checks confirm the service user's expectation (matching); how frequently and when do service users report being surprised?*

Changes in Behaviour:

- *How frequently does the drug belong to a different category than expected?*
- *When they discover that they do not have the drug they thought they did, what do they say they will do with the drug? Do they say they will behave differently (do they say they will take more or less of it, dispose of it, use it with a friend, change how they take it, or take naloxone training)?*
  - *Does this behaviour change depend on the type of drug expected and what it turns out to be?*
  - *Is this difference bigger when the drug turns out to be in a different category?*
  - *How does this difference interact with how surprised the service user is?*
- *When they are surprised, how often does a service user discard the drug in the presence of the volunteer?*

7) Methodology

Using the datasets, the goal was to perform data analysis that will involve identifying common patterns within the responses and analyze them in order to achieve research objectives. The datasets used consisted of only structured data that was primarily populated with binary data. The programming languages that were chosen for implementation are R and Python due to its code readability and the powerful library it supports for statistical analysis and machine learning.

Exploratory Data Analysis

Exploratory Data Analysis (EDA) played an important role in describing and summarizing our data without making any assumptions about the content of either of the music festivals. Using our analysis of the EDA highly investigated questions can be answered regarding the service users at the music festivals as well as the substances that could be of interest for further research purposes.

Machine Learning Techniques

In addition, machine learning techniques to make further predictions and to identify trends in how service users respond to drug checking services at music festivals. See Appendix B for details of the machine learning techniques.

Unsupervised Learning: These are the set of techniques used to identify groups within the data. The models used for the predictions were mixture models, k-means clustering, and based on the results, only one was chosen.

Supervised learning: These techniques allow us to predict labels based on the given data. The models used for the predictions were ensemble learning methods (Random Forest and CatBoosting).

Data Visualization

Visualizations were used to tell stories about the surveys collected at both Shambhala and Bass Coast. For this project, Plotly and Dash was used to create web-based visualizations for aesthetic and user-friendly purposes. The dashboard was deployed onto the web so that it can be accessed by any user. Heroku (cloud platform service) was used to host the web application on the cloud. Dashboard: https://ankorsdrugchecking.herokuapp.com/

8) **Analysis of Result**

8.1) Longitudinal analysis for Shambhala (2017-2019)

Over the past three years, the festival has had an attendance of approximately 17,000 in each of the last three years (almost 12,000 tickets sold and 5000 staff, volunteers, and performers). Similarly, the number of drug checks at the Shambhala festivals has been fairly steady over the last three years.

- Shambhala 2017: 2749 checks
- Shambhala 2018: 3174 checks
- Shambhala 2019: 3067 checks, with 1538 testing episodes (before 2019, the number of testing episodes was not recorded)

In 2019, DCF collected information based on testing episodes per day. The popularity of using drug checking service increased per day as well as the number of substances that were checked by the service users. (Table 1)

Date	Episodes	Substances Checked
6-Aug-19	7	19
7-Aug-19	240	561
8-Aug-19	282	616
9-Aug-19	359	681
10-Aug-19	312	606
11-Aug-19	338	584
Total	1538	3067

Table 1. Testing episodes and substances checked at Shambhala

Changes in Service Users' Previous Drug Checking Service Experience Over Time

In terms of festival experience, there is a difference in the proportions overtime (Figure 1). The majority of service users were experienced in 2017-2018. While in 2019, the majority were not. In 2017 and 2018, if a service user brought multiple drugs, they were each recorded as a separate entry in the data. Beginning in 2019, it was possible to indicate when one service user was checking multiple drugs. As a result of that, although 3067 checks were done in 2019, for the first time, we can say that there were only 1538 service users. Hence, if a service user's previous drug checking experience is analyzed by a testing episode, then the visual is slightly different. The proportion of yes and no for 2019 will be very similar.

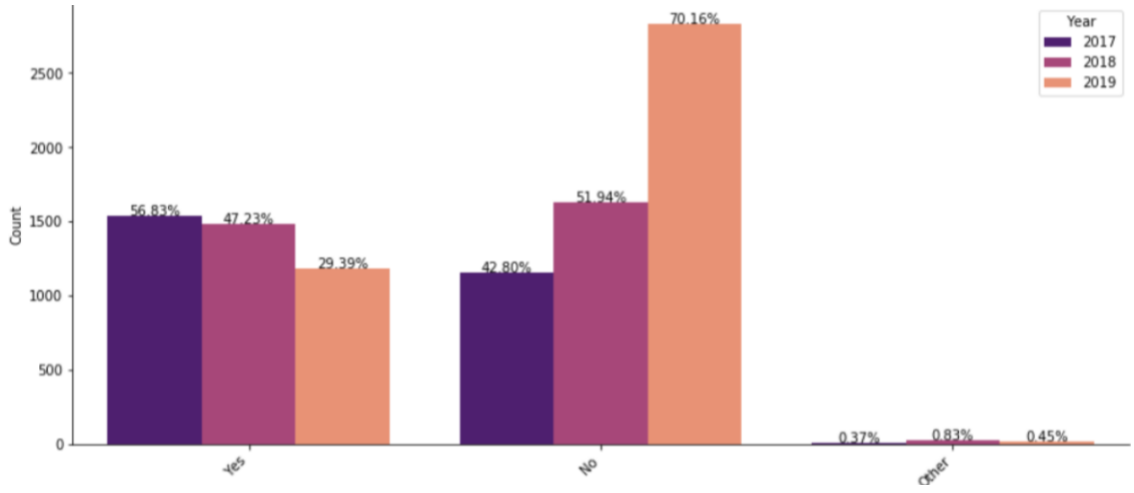

Figure 1. Service user's Previous Drug Checking Experience (2017-19)

"Other" category

In each of the three years, an additional question was asked regarding previous drug checking service use. In 2017 and 2019, service users could respond that they didn't know if they'd used

drug checking services before. On the hand, in 2018, the "other" category represents people who said they had used the services before in the same festival that year, causing the number to rise.

Two proportion Z-tests confirmed that the difference is statistically significant with 95% Confidence Interval. The researchers do not know why this difference exists, but possibilities include:

- Increased awareness of drug checking services. In 2019, the harm reduction program advertised more actively than formerly, and was featured in a video that was part of the introduction to the festival. This may have led to more people trying drug checking for the first time.
- Increased awareness due to the opioid overdose crisis due in part to warnings like the one issued by Vancouver Island's chief medical officer Dr. Richard Stanwick in June 2019 (Van der Zwan, 2019).
- A change in the way users were counted. In 2017 and 2018, if a service user brought multiple drugs, they were each recorded in separate rows, presumably with the service user's information duplicated. Beginning in 2019, it was possible to indicate when one server user was checking multiple drugs. As a result of that, although 3183 checks were done in 2019, for the first time, we can say that there were only 1528 service users.
- It is conceivable that veteran festival attendees wait in line with many drugs, while the newcomers wait in line with one. This would inflate the number of service users with previous experience with the 2017 and 2018 style of keeping records, but give us the correct number of new users in 2019. If the newly established 2019 practice is maintained, future years may continue to show percentages more like the 2019 percentages.

Evolving drug testing technologies overtime

Two types of tests were featured at Shambhala in 2017, the colorimetric and Raman tests. Using the colorimetric tests, it can be determined that MDMA/MDA is the most frequently identified substance in service user's samples (Figure 2). In contrast, Raman spectroscopy testing was utilized for its effectiveness in finding cocaine in drugs (Figure 3).

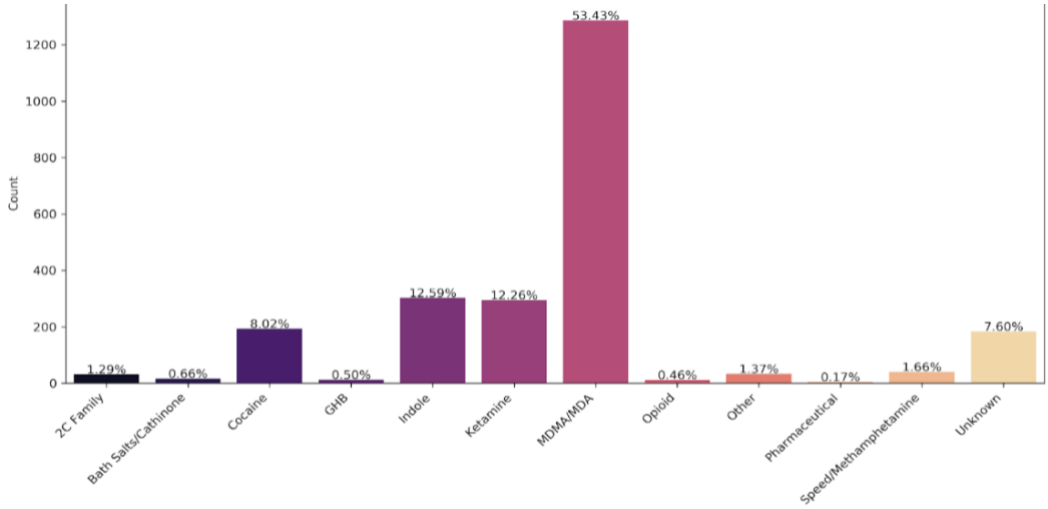

Figure 2. Shambhala 2017 Colorimetric Results

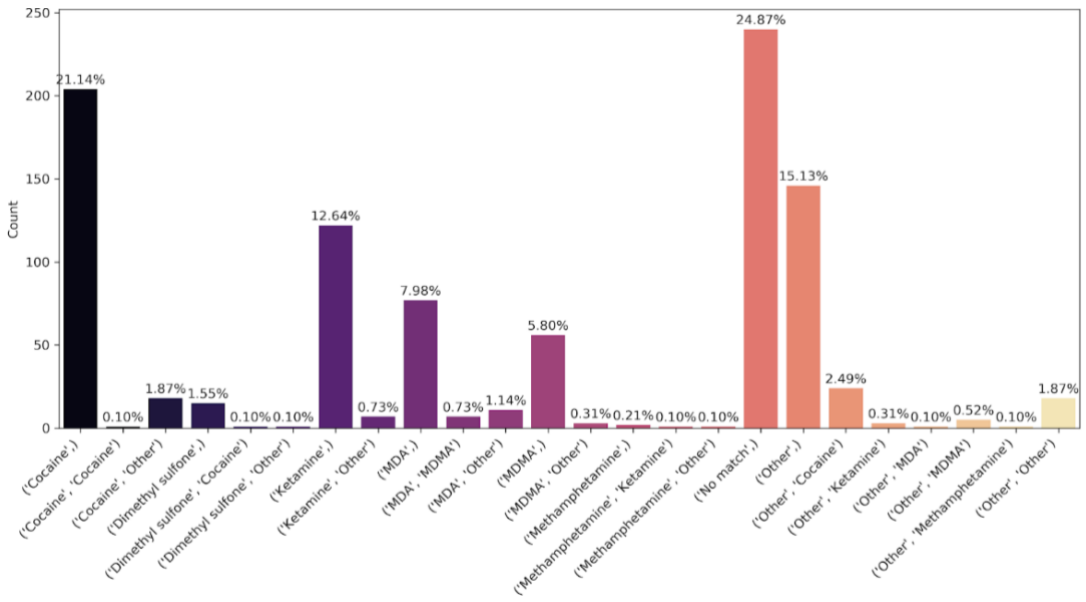

Figure 3. Shambhala 2017 Raman Results

The Harm Reduction Services at Shambhala were able to obtain five FTIR machines in 2018. FTIR machines offer superior performance and output (Siesler, 1980), but as a result it is difficult to know how to meaningfully compare the datasets of 2017 with those of 2018 or 2019. Accordingly, Figure 4. compares FTIR drug results at Shambhala for 2018-2019, focusing on the sextet.

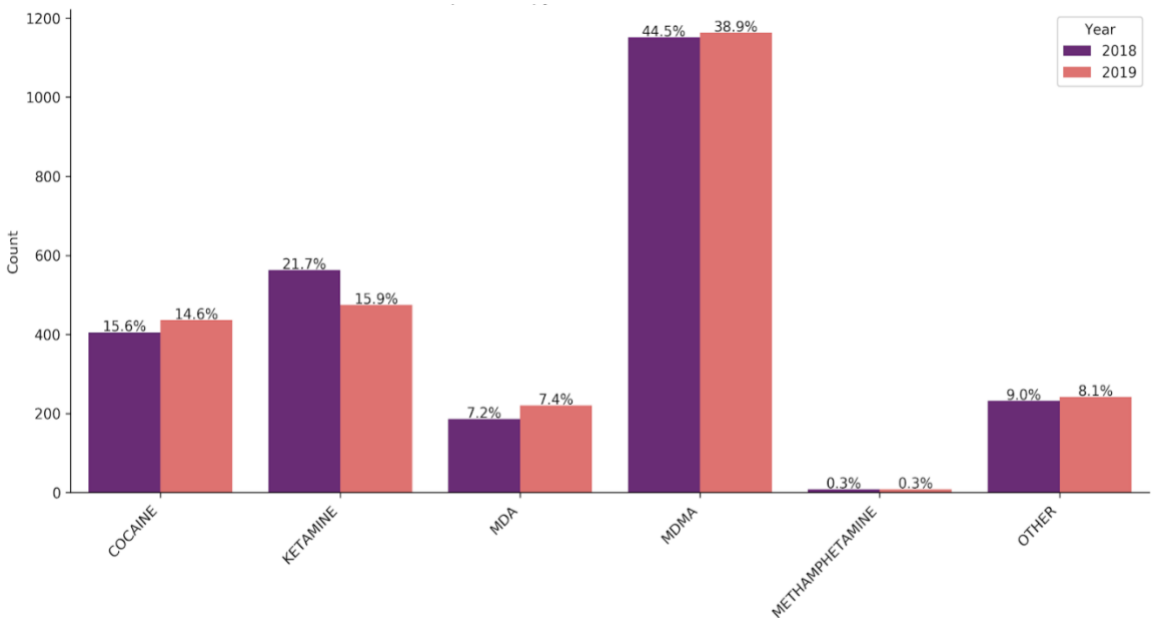

Figure 4. Shambhala 2018-19 FTIR Primary Results

8.2) Service Users

<u>Demographic of the Festivals</u>

Researchers discovered that 99.6% of service users consented to research at Shambhala and 99.7% at Bass Coast. The high participation rate is a reflection of data entry instructions, where surveys that indicated that consent was not given were not entered into the dataset. Shambhala 2019 was the first festival wherein the DCF contained "Trans" as an option. It was discovered that at Shambhala Festival, 66% of service users self-identify as men, 32% women, and 2% as nonbinary, transgendered, or unknown(Figure 6). 55% percent of Bass Coast service users self-identify as men, 42% women, and 3% as nonbinary or unknown (Figure 6). Two proportion Z-tests confirmed that the gender difference is statistically significant with 95% Confidence Interval.

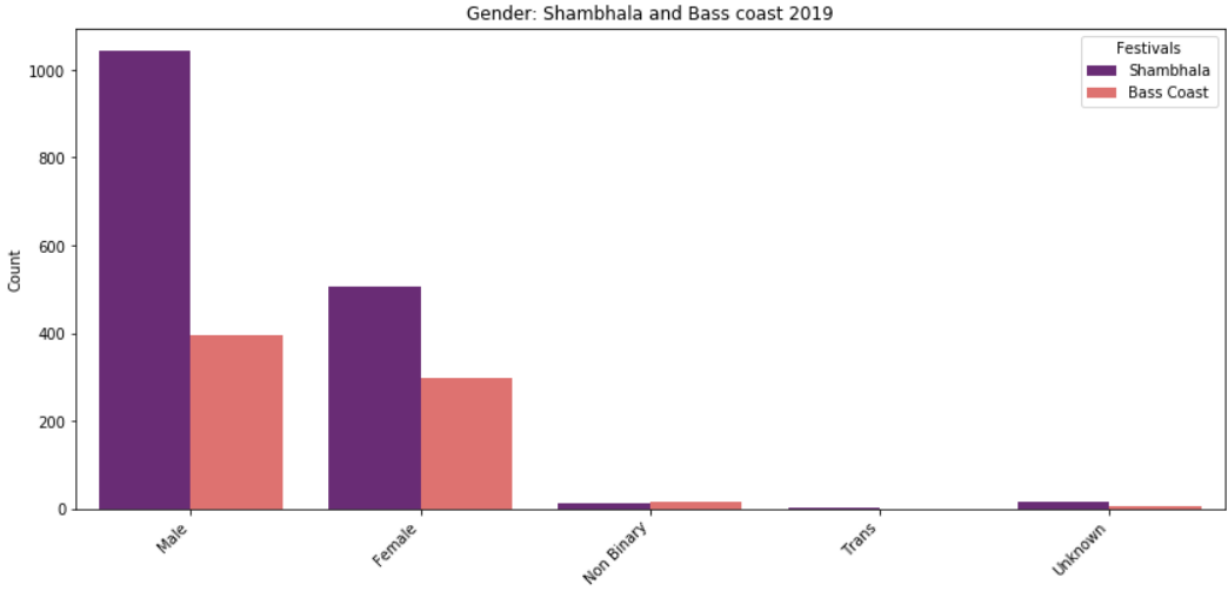

Figure 5. Demographics at Shambhala and Bass Coast

This gender imbalance is unexpected: dance culture is understood to be equally gendered (Measham, 2002). Admittedly, the organizers of the Shambhala music festival report that their attendance is slightly male-dominated, with 55% of attendees being male and 45% being female (C. Sage, personal communication, June 8, 2020), but this does not quite account for our gendered lopsidedness in drug checks. Possibly contributing to the imbalance is the fact that, in so many drug cultures, females occupy marginal positions, while men retain positions of control over drug access: the best-known example being the fact that drug dealers are more commonly males rather than females (Maher & Hudson, 2007; McNeil et al., 2014; Pinkham et al., 2014). Perhaps more males than females bringing the drug in for drug checking - doing quality control with the drug - is more evidence of this pervasive power imbalance.

Location of drug obtained by service users

At music festivals it is likely that drug samples can be obtained through multiple sources. In case of Shambhala and Bass Coast, there were five sources where the service user could have obtained the sample, they were getting checked at the drug checking service. The source of obtaining drug samples at both of these festivals differed. 60% of Bass Coast service users get

their drugs *offsite*, while 60% of Shambhala service users get them *onsite* (Figure 6). Statistical tests were performed and it was observed that there is a difference in where the service users obtain the sample from at Shambhala and Bass Coast.

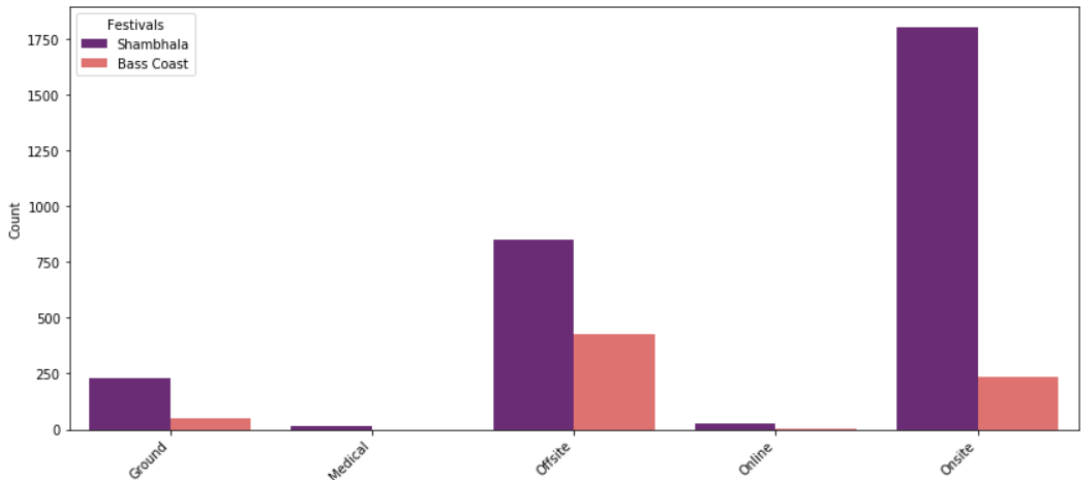

Figure 6. Drug Obtained at Shambhala and Bass Coast

Seemingly the festival attendees at Bass Coast tend to be more local than attendees at Shambhala festival who are more international. International travelers are heavily penalized for taking drugs over the border, which could explain why they end up getting them at the festival. At both festivals, a small but important portion of drugs have been found on the ground and are then taken to the harm reduction tent. It is understandable that someone would want a "ground find" checked before using it. This is an example of the importance of drug checking services at festivals.

<u>Who Service Users are Checking For</u>

In Figure 7. It's observed that service users are most likely to test for themselves or their friends at both of the music festivals.

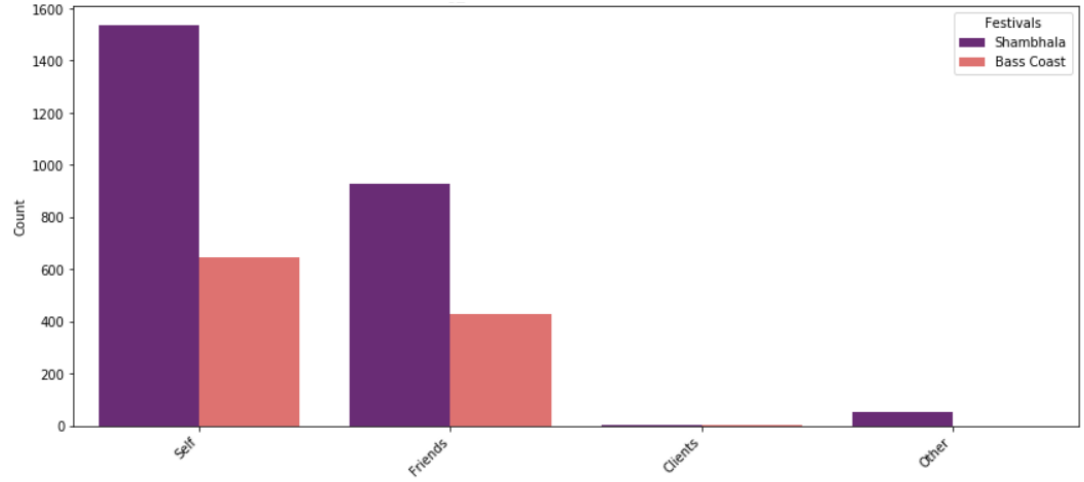

Figure 7. Testing sample for at Shambhala and Bass Coast

8.3) Substances

Number of Samples Brought During a Testing Episode

It was of interest to find out how many samples service users are bringing to get checked at the drug checking service. Figure 8. shows the majority of service users bring just one or two samples, and the number of samples that a service user brings drops off rapidly, forming a significantly right-skewed distribution. There is one outlier in the distribution, where the service user brought 18 samples to get tested.

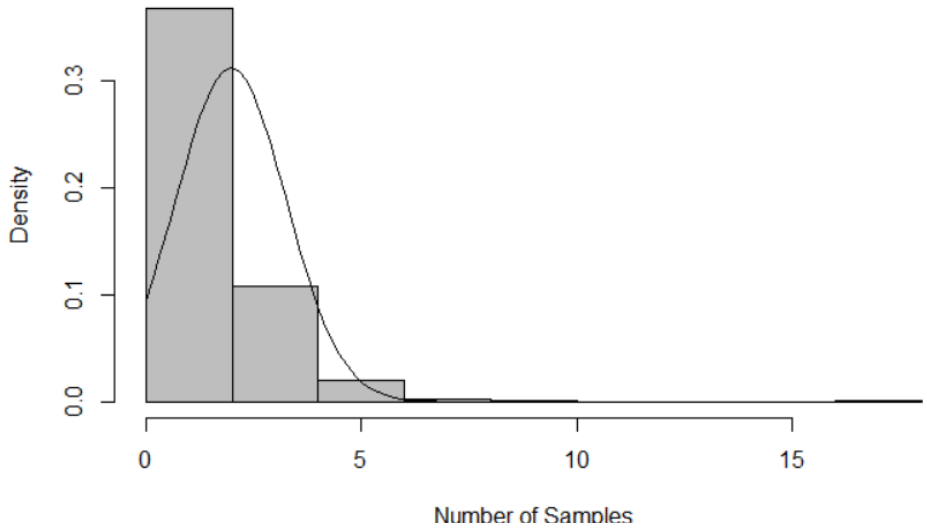

Figure 8. Distribution of sample brought by service users

As has been mentioned before, at Shambhala 2019, when a service user brought more than one item to be checked, those items were linked, so we can see which items were brought during the same testing episode. Table 2. shows how often a service user brought just one drug (696 times) but on 67 occasions, 4 drugs were brought. It should be noted that at one point in this festival, service users were instructed that they could only bring a maximum of 6 drugs, explaining the sudden decrease in the number of episodes at 7 or more drugs.

Number of Samples per episode	Number of Episode
1	696
2	418
3	261
4	67
5	36
6	24
7	4
8	2
9	2
18	1

Table 2: Shambhala 2019 Number of drugs checked by service user

Concordance Between Service Users' Expectation and Point of Care Results

Service users at Bass Coast experience slightly more concordance between their expectations and point of care results. At Bass Coast, 58% percent of the time, a drug contained what service users believed it did, including any secondary, tertiary or quaternary substances present. For Shambhala, this number is 48%.

The calculations above do *not* include instances where service users thought they had, say, cocaine, and it did contain cocaine, but it also contained something else. However, when we consider the number of times a service user knew the *primary* substance in their drug, we see that concordance is improved: 77% of the time, Bass Coast attendees' expectation concorded, or "matched" results, and 69% of the time, Shambhala attendees' expectation matched.

Items That Are Brought During the Same Testing Episode

During each service user's visit there are possibilities that more than one sample were brought together. To better understand what drugs are the most popular. There are 305 different combinations of drugs that people may bring to check in one visit. Figure 9. shows the top 10 combinations of multiple substances that were brought in one visit being tested for either self, friends or both, the most common samples are MDMA (sample 1) and LSD (sample 2)

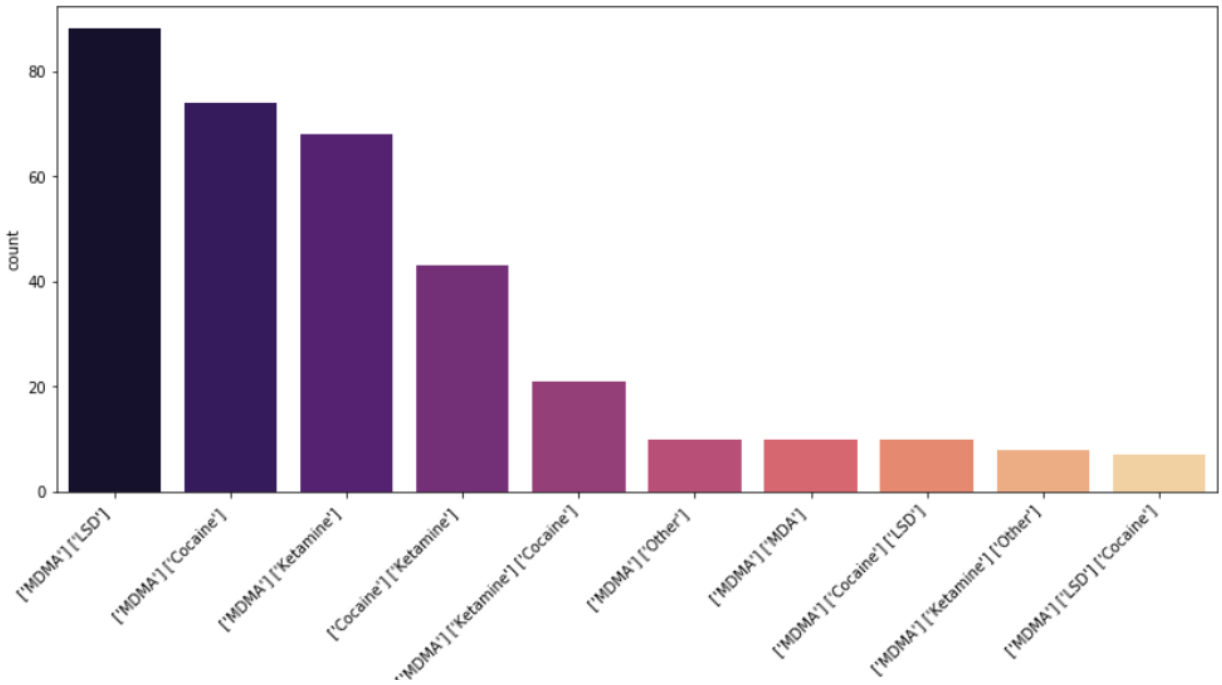

Figure 9. Most common multi samples tested at Shambhala 2019

8.4 Substance Prediction

Matches for Each Drug and Substance Prediction

It would be of researchers at ANKOR or Interior Health interest to learn if the service user's prior belief of the drug they are getting checked matches with the spectroscopy analysis, so they can be better informed about the drug(s) they are consuming (Figure 10,11). Only drugs that were believed to be MDMA *and then turned out to be MDMA* as primary FTIR analysis are counted in the "MDMA Actual". It was observed that most of the time service users are aware of the substance(s) present in their samples. The most common sample at both music festivals is MDMA:

Two proportion Z-tests were run to check if there is a difference between the proportion of belief and actual for each substance at Bass Coast and Shambhala. Methamphetamine is the only substance where the difference between belief and actual is not statistically significant at a 95% confidence interval. All other substances had a statistically significant difference.

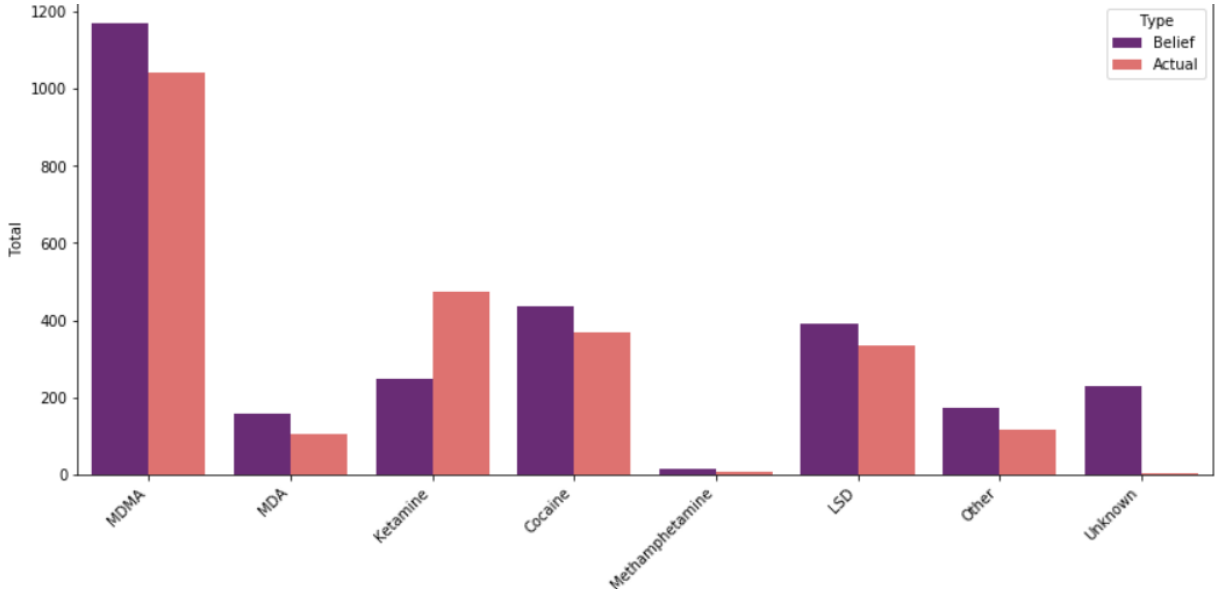

Figure 10. Service user's belief and FTIR primary result at Shambhala 2019

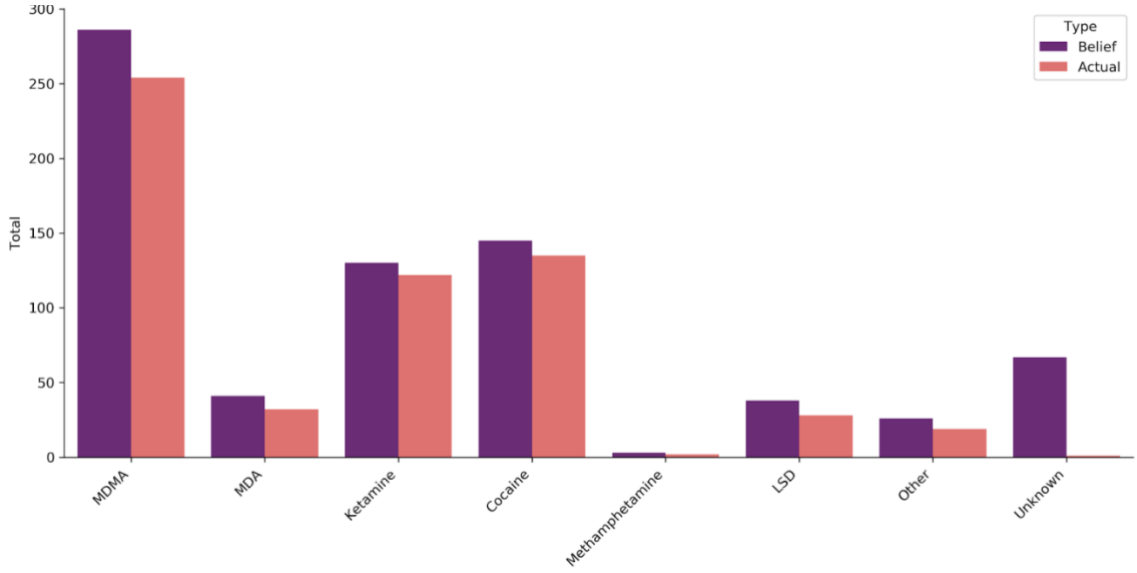

Figure 11. Service user's belief and FTIR primary result at Bass Coast 2019

Items That Are Within The Samples

There are possibilities that some service user's drug samples have been adulterated by a dangerous substance that the service user wasn't expecting. Hence, using the drug checking service to get the drugs checked prior to consuming would be considered a safer option and with the information of which adulterants are the most common can be beneficial to promote harm reduction. Figure 12. shows the most common adulterant is 'Unknown', which means that the FTIR analysis couldn't identify the adulterant. The second most common adulterant was 'Other', the FTIR analysis identified the substance(s), but it was neither of the following: MDMA, MDA, cocaine, ketamine, LSD, nor methamphetamine.

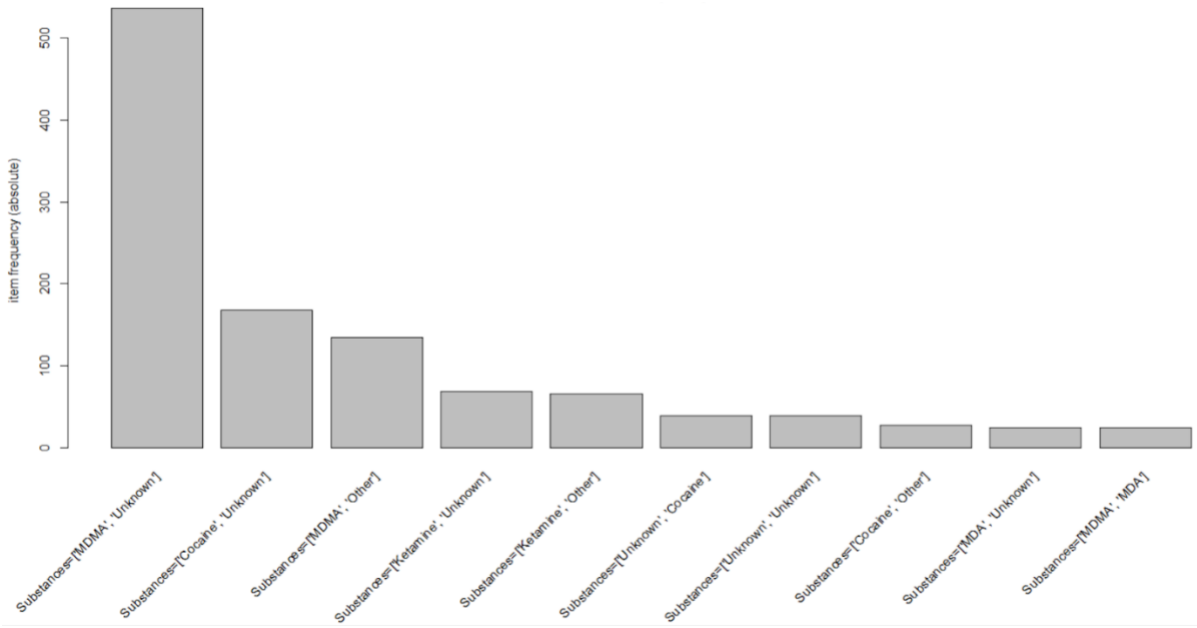

Figure 12. Most frequent adulterant in service user's sample

Since the 'Other' substances are found to be one of the most common adulterants some analysis was performed to classify them into few categorize (Table 3).

Non-Standard Substances

Naturally, we wanted to know more about what these "other" substances were. Table 3 shows the 15 most common non-standard substances and the total number of times they were identified in FTIR results at Shambhala 2019, as well as a comment about the substance's role.

Total	Item	Role
278	sugars	Filler
63	phenacetin	Psychoactive
57	caffeine	Psychoactive
62	cellulose	Filler
46	2c-b	Psychoactive
44	base tryptamines	Psychoactive
39	dimethyl sulfone	Filler
27	water	Filler
23	creatine	Filler
22	carbohydrate	Filler
14	4-HO sub tryptamine	Psychoactive
14	benzocaine	Psychoactive
12	gamma hydroxybutyrate	Psychoactive
12	lactose	Filler
12	parazetamol	Psychoactive

Table 3. Non-Standard/"other" Substances Categorized in roles

Discarding in the Presence of a Volunteer

An interesting insight would be to find if a service user will discard the drug after using the drug checking services. Volunteer/technician observed the service user to see if the substance the service users were hoping the test would reveal to be present or absent and if they would discard it after finding out the testing results. At Shambhala, 41 of the service users discarded their drug in front of a volunteer, and 1558 did not, creating a 2.56% discard rate overall.

Unexpectedly, this was less likely to happen if they were surprised at their results: Only 0.75% (12) of surprised service users discarded their drugs but 1.81% (29) unsurprised people did. This is not a large difference, and could be just due to random variations in the data. However, it is important to note that the situation is muddied by the fact that while a DCF for Shambhala 2019 was designed record information regarding up to three drugs, the question, "Did the participant discard the substance?" was posed last. There were simply three boxes to check: "Yes," No," and "Unknown." An entry on this line could have been referring to between one and three substances. In the event that some substances recorded on the sheet were discarded, the Harm Reduction Volunteer would have had to make a decision regarding what to check.

8.5) Change in Behaviour

A more interesting question was what people would do with their substance given the test result they got. In Figure 13, it is observed that most of the service users will not change their intention after getting the drug checked at both music festivals.

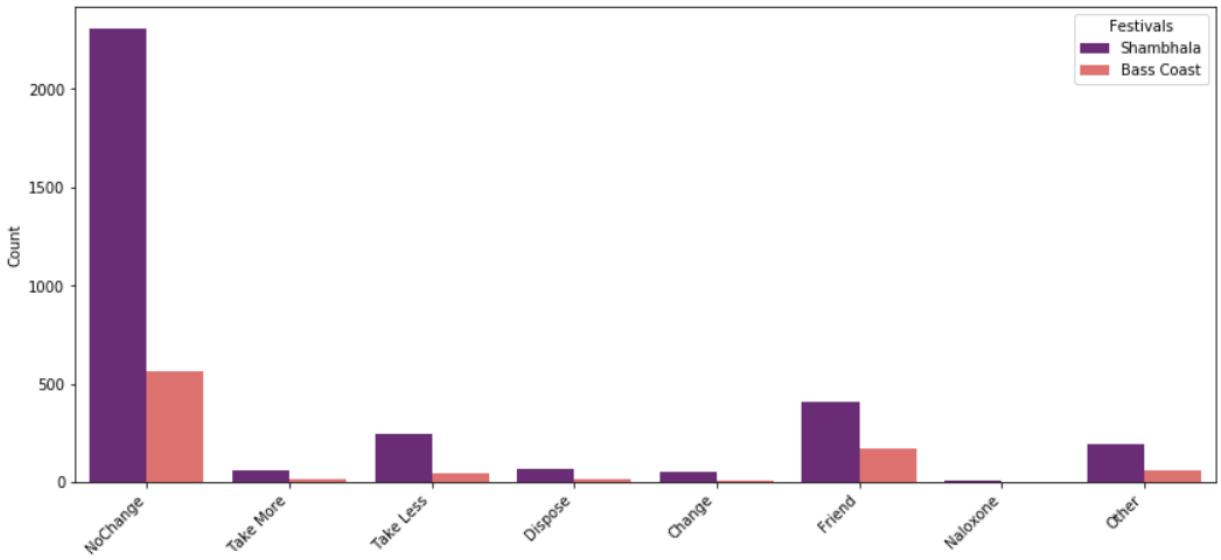

Figure 13. Service user's intentions at Shambhala and Bass Coast 2019

If someone said they intended to take the drug with a friend, take less of it, dispose of it, or take naloxone training, such services users are described below as having followed, "harm reduction advice."

At Bass Coast, after having checks done, the following can be said about their intentions:

- 29% said they would take their drug in a way that followed harm reduction advice
- 22% said they would not take the drug as intended
- 10% said they would not take the drug as intended *and* they would take it in a way that follows harm reduction advice

The following can be said about those who were surprised by their results:

- 26% said they were surprised
- 47% said they would not take they drug as they intended
- 33% said they would take it in a way that followed harm reduction advice
- 20% said they would not take the drug as intended, *and* they would take it in a way that followed harm reduction advice

At Shambhala, after having checks done,

- 14% said they would take their drug in a way that followed harm reduction advice
- 55% said they would not take their drug as intended
- 8% said they would not take as intended *and* they would take it in a way that followed harm reduction advice

The following can be said about those who were surprised by their results:

- 13% said were surprised

- 40% said they will not take their drug as intended
- 33% said they would take it in a way that followed harm reduction advice
- 23% said they would not take the drug as intended, *and* they would take it in a way that followed harm reduction advice

To understand if the presence of certain substances will cause the service user to be surprised or change their behaviour. It was observed that 73% percent of people who had cocaine were not surprised while 27% were surprised (Figure 14). 72% of people with Cocaine will not change their behaviour, while 28% will change (Figure 15). If service users intend to do the following: Take more/less substances, take it with friends, take naloxone training, dispose of the sample, then the service user's behaviour will change. However, if they don't intend to make any changes then their behaviour will not change.

	FALSE	TRUE
['Cocaine']	0.7378641	0.2621359
['Ketamine']	0.7967914	0.2032086
['LSD']	1.0000000	0.0000000
['MDA']	0.6913580	0.3086420
['MDMA']	0.7796610	0.2203390
['Methamphetamine']	0.6666667	0.3333333
['Other']	0.6666667	0.3333333
['Unknown']	0.6711712	0.3288288

Figure 14. Proportion of service users who report being surprised after their drug is checked, Shambhala 2019

	FALSE	TRUE
['Cocaine']	0.7205543	0.2794457
['Ketamine']	0.7777778	0.2222222
['LSD']	0.6666667	0.3333333
['MDA']	0.6918605	0.3081395
['MDMA']	0.8405923	0.1594077
['Methamphetamine']	0.6666667	0.3333333
['Other']	0.2173913	0.7826087
['Unknown']	0.5411255	0.4588745

Figure 15. Proportion of service user's behaviour change for each substance, Shambhala 2019

8.6) Machine Learning Techniques

This section contains the application of machine learning techniques on the dataset. Those who are unfamiliar with such approaches to data, or who wish to read a simple explanation of them, are referred to Appendix B: Machine Learning Techniques.

Unsupervised Learning

Looking for Patterns in the Bass Coast 2019 Data

Unsupervised learning allows researchers to see if patterns can be discovered in the drug checks. For this research, the Bass Coast data was probed, looking for patterns in the following variables:

1. Intention: No change, take more, take less, dispose of the drug, use with a friend, change how you take the drug or take naloxone training
2. Type: Type of drug (powder, crystal, liquid, blotter, or press tab)
3. Match2: Whether what the service user's belief about the primary composition of the drug concurred with the FTIR result regarding the drug's largest ingredient
4. Combo_name: The complete FTIR results, considering primary, secondary, tertiary and quaternary FTIR output
5. Gender: Male, Female, Non-binary, Gender Unknown

2) K-Means

K-Means Clustering: Eight Groups

The researchers attempted to create meaningful groups using k-means. Eight clusters were assigned to get meaningful separate groups. Due to the seemingly good spread of groups on this plot, we considered the groups in more detail focusing on what their characteristics are Some preliminary analyses were performed and it was determined that the use of eight groups seemed to split the data well. Applying k-means with eight groups produced Figure 17.

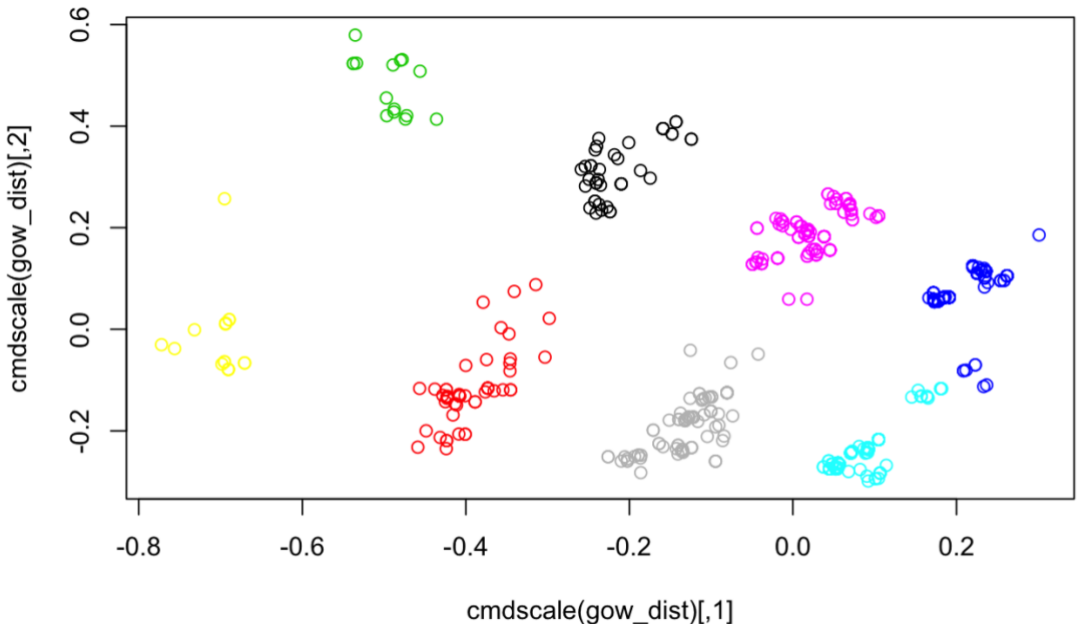

Figure 17. K-Means Model for Bass Coast Festival's Characteristics

These groups represent the characteristics of Bass Coast data. The information is summarized in Figure 18. The groups are visually separated by colour. A colour (any colour) indicates a positive value in that column for that group. The table can be interpreted as follows: Cluster 1 (Row 1) - Males who said they will take the sample (MDMA or Unknown or Both) in a safer manner. Cluster 2 (Row 2) - Females will take the sample (Cocaine or Ketamine or Both) in a safer manner.

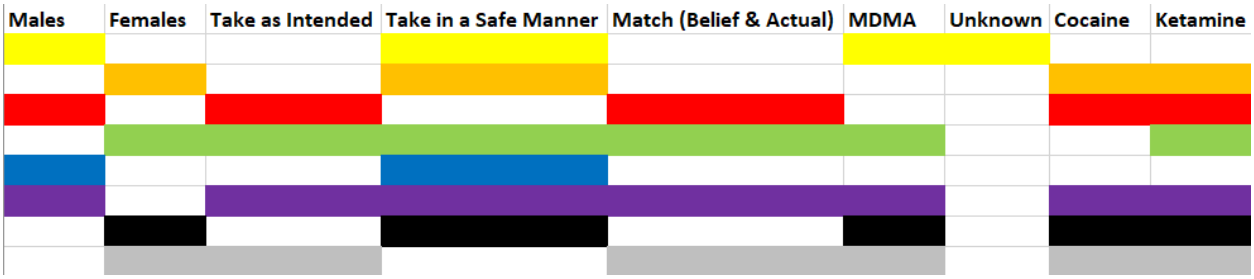

Figure 18. K-Means Model's Interpretation By Clusters

Supervised Learning

Looking for Predictors of Discarding at Bass Coast 2019

a) Random Forests

The researchers attempted to probe the data for variables to understand which ones predict whether or not a drug will be discarded. We chose random forests because it is an accurate classifier that can handle missing values in the data, while providing results that can be generalized to other situations reliably (Anurag, n. d.).

Table 4 is the confusion matrix for the random forest output. This confusion matrix illustrates the number of times the model was able to correctly classify Discarded and Not Discarded in correct and incorrect groups:

	Prediction: Discarded	**Prediction**: Not Discarded
Actually: Discarded	6	10
Actually: Not Discarded	2	656

Table 4. Confusion Matrix for Discarded Number of Samples

Rows represent the actual values while columns represent predictions. From the table above it can be noted that the number of service users who actually discard the substance is miniscule (16) when compared to those who have not (658). This suggests that the data is highly imbalanced. Due to this imbalance, the number of times the model correctly predicts Discard is quite low. However, the researchers believe that this is a significant result.

The following are the top 8 Variables that associates with service users discarding the sample:

1) Drug- the sextets
2) Where the drug was obtained
3) Gender
4) Whether or not they said they would change their behaviour and use the drug in a way that follows harm reduction advice.
5) Whether or not they said they would change their behaviour.
6) Whether or not the results matched their beliefs about the drug
7) Whether or not they were surprised
8) The type of drug (Powder, crystal, blotter, liquid, gummy)

Looking for Predictors of Intention:

b) Categorical Boosting

The approach the researchers took, however, was to choose a target variable that had more instances of interest. While few drugs were discarded, many intentions are expressed). For example, in the cleaned Bass Coast dataset of 722 drugs, we considered 812 intentions (service users could express more than one intention). Figure 21. shows intentions expressed

Intention:	No change	Take More	Take less	Dispose of the drug	Use with a friend	Change how you take this drug	Take naloxone training
	564	**14**	**40**	**14**	**170**	**6**	**1**

Figure 21. Intentions After Drug Check, Bass Coast 2019

Figure 22. shows the output of CatBoosting. Importance" is a percentage that represents the degree to which a variable predicts intention. It appears as though gender, where they obtained the drug, and the type of drug equally make up almost ¾ of the prediction. Thus, they could all be reasonable predictors of what a service users' intention will be after the check. However, the documentation on this new method says very little about how these numbers should be interpreted ("Feature Importance," n. d.

	Feature	Importance
2	Gender	24.096463
3	Obtained	23.556772
4	Type	23.250742
5	match2	11.396559
1	Surprised1	8.277156
0	PreviousDC	7.294464
6	combo_name	2.127843

Figure 22. Most correlated variable with Intentions, Bass Coast 2019

Limitations of CatBoosting Results:

Of greater concern, however, is the implication of CatBoost's "Best Accuracy Score". This score is 58%. That might sound sufficient, but it actually represents quite a concern: It is exactly the same percentage as the percentage of people who say they will take the drug as intended (58%). Although we do not know for sure, this implies that because

such a large proportion will take the drug as intended, the CatBoost algorithms, after looking at all the variables, develop an overly simple rule: service users will always take the drug as intended. That is why the algorithm was accurate exactly 58% of the time. The researchers have to sadly conclude that it's likely that the CatBoosting algorithms do not tell us anything other than the fact that what we know, is that drugs are usually taken the way they were intended to be taken.

9) Future Work

The report surfaces a variety of suggestions for data collection in the future:

Timing of testing:

- If the time of a test was recorded, researchers could map the effects of certain announcements about with-in drug polysubstance at the festival.
- The committee has suggested that by going over the initials of the tester (indicated in the dataset already) and combining that information with the volunteer's schedule, we might be able to get a rough idea about what time of day tests were done. However, there's a limitation:
    - Shifts would be several hours long, and therefore, only a general sense of the time would be achievable

It's worthy of note that the committee already seems agreeable to the plan of recording testing times in the future. They have also suggested volunteers are kept track of in a clearer way.

Medical data:

Shambhala has 24-hour medical services with a team of doctors, nurses, and volunteers to assist from emergency contraceptives to a drug overdose. One way to increase the usefulness of drug checking data is to integrate them with medical data. If this were the case, some of the following questions could be considered:

- How frequently do people need medical attention? As far as the medical staff can tell, how often is this drug-related?
- What is the interaction between what the drug checking services discover about substances on the site and substances that seem to be of medical concern? When the drug checking service releases warnings about drugs, does that mitigate resulting medical concerns?
- When people bring drugs to be tested at the same time that are dangerous when taken together, do we seem to see a related medical pattern?

10) Resources

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Appendix A: Substance Testing Methods

Many harm reduction agencies are exploring techniques to test illicit drugs to identify and, where possible, quantify their constituents allowing their users to make informed decisions.

Raman Spectroscopy

Raman Spectroscopy is a non-destructive chemical analysis technique which provides detailed information about chemical structure, phase and polymorphy, crystallinity and molecular interactions. It is based upon the interaction of light with the chemical bonds within a material. Raman spectroscopy probes the chemical structure of a material and provides information about:

- Chemical structure and identity
- Phase and polymorphism
- Intrinsic stress/strain
- Contamination and impurity

Typically, a Raman spectrum is a distinct chemical fingerprint for a particular molecule or material, and can be used to very quickly identify the material, or distinguish it from others. The general spectrum profile (peak position and relative peak intensity) provides a unique chemical fingerprint which can be used to identify a material, and distinguish it from others (What Is Raman Spectroscopy, 2020)

Colorimetric

Colorimetric analysis is the technique normally used to determine the concentration of analyte through comparing the color changes of the solution (H.N. Wilson, 1966). Colorimetric tests are considered presumptive, in that they can only identify presence or non-presence of a particular substance based on the test administered. A single test/reagent will only test for the presence or absence of a drug or class of drugs (Harper, 2017).

Fourier Transform Raman Spectroscopy (FTIR)

FTIR is an analytical technique used to identify organic, polymeric, and, in some cases, inorganic materials. The FTIR analysis method uses infrared light to scan test samples and observe chemical properties (FTIR Analysis, 2020).

Infrared spectroscopy (FTIR) is ideal for identifying unknown substances. The technique is fast, easy and versatile, and can analyze solids, liquids, pastes and gases. Unknown samples can even be identified from mixtures, which is vital when sampling drugs that may have impurities, fillers or cutting agents (Bruker Optics, 2017).

The FTIR was able to identify the top 4 substances per sample, the most evident substances to the least (Primary, Secondary, Tertiary, and Quaternary). For most of the analysis the primary result was used.

Appendix B: Machine Learning Techniques

Machine learning is an important application of Data Science. Using machine learning techniques one can train models to learn on its own through experience. Within the field of machine learning, there are two categories: supervised, and unsupervised (Soni, 2018).

Unsupervised Learning

Unsupervised learning, on the other hand, does not have labeled outputs, so its goal is to infer the natural structure present within a set of data points (Soni, 2018). The idea behind these techniques is to identify natural clusters/groupings within the data based on how similar/dissimilar observations are.

These complex variables need to be understood in some cohesive way, so their Gower's distance from each other is calculated. Gower's distance is an overall measure of how similar two data points are when their dissimilarity or similarities are averaged. To be more specific, each data point is compared to the others on every variable, so that it receives a score on each variable, and all the scores are summed up and divided by the total number of comparisons, creating a measure of Gower's distance for each point. They can then be plotted, as can be seen in Figure 23.

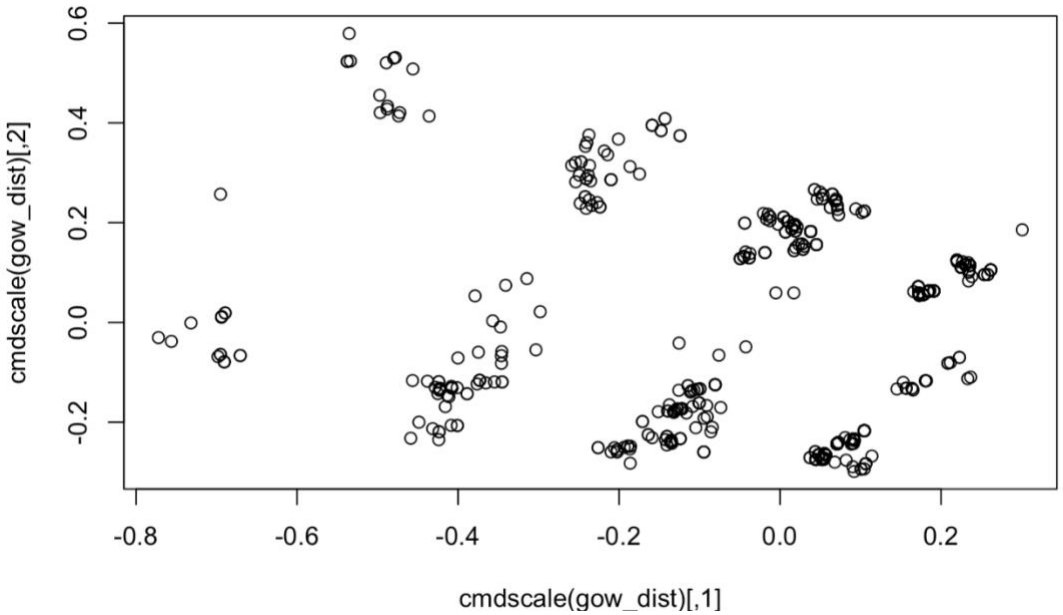


Figure 23. Mixture Model

There appear to be clusters in this array of data, and the researchers wanted to know if they could be divided into meaningful groups. Mixture Model and K-Means Clustering methods were used to identify meaningful clusters.

Mixture Model

A mixture model tries to separate data into meaningful groupings by assuming that underneath the data are underlying subgroups. Each data point is assigned a probability that it is each group. A major strength of mixture models is they allow researchers to infer the properties of each group (such as the mean of each group and the standard deviation). However, it is also true that groups overlap, making unclear what group some data belong to, and this can be a weakness in mixture models, as it was in this situation

K-Means

K-means is a long-standing model that can often be easier to fit onto data than mixture models. It is similar to mixture models in that it attempts to divide data into groups, but it is different in that it partitions the data, making choices about what values belong in which group, resulting in no values that are in more than one group. In doing so, it tries to maximize the differences between clusters, creating clusters that are distinct as it can. In k-means clustering, the k stands for the number of groups, which can be any amount. The number of clusters 'k' is chosen empirically. In our first attempt three clusters were used, producing the following plot. Since eight clusters are visible, k=8 was used to differentiate the clusters for our final analysis.

Supervised Learning

Supervised learning is done using a ground truth, or in other words, we have prior knowledge of what the output values for our samples should be (Soni, 2018).

Random Forest

A classification method called random forests was used to output key influencers/ variables for what we are trying to predict. The "forests" part of random forests comes from the fact that random forests are made up of many decision trees.

To create a random forest model, first, the data is bootstrapped, i.e. data is sampled with replacement (As a result, usually 66% of the original data is contained in the bootstrapped data. The remaining 34% are duplicates. This has been proved mathematically). Next, using this data, a decision tree is created. The tree is then split by input variables at each step. Each variable is tested to be a split and the variable that has the most "purity" i.e. has the best separation is the variable that is selected to be the split at that step. This process is repeated until the tree finds the best split for Discarded and Not Discarded. In this way, multiple trees are created to form a Random Forest algorithm. The number of trees to be created can be specified by the modeler.

When a new row of information is passed through the random forest model, it is passed through all the decision trees in the model and the results from each tree are aggregated. For instance, if the random forest is made up of 500 trees and of those 500, 300 resulted in the drug being Not Discarded while 200 resulted in the drug being Discarded, then the result from the random forest model will be Not Discarded since the majority of the trees suggested that the drug will not be discarded

Random forests provide a reliable way to decrease the likelihood of overfitting. Overfitting is the case when our model doesn't generalize well from our data to unseen data. Briefly, random forests are made of decision trees that are all a little different from each other, reducing the problem of overfitting and creating more robust models. Statisticians can create these slightly-different trees by using only a portion of the data, and even the variables for each tree. They do this, again and again, creating a "forest" of trees, and average the results.

Categorical Boosting

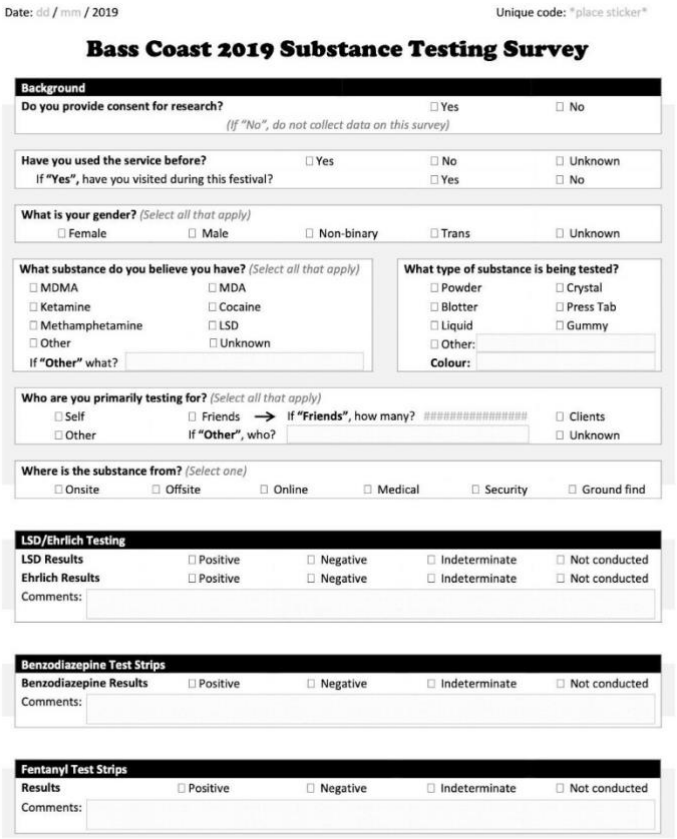
A random forest technique works when predicting a binary response such as, "Did they discard or not?" but when using such a multifaceted target variable like intention, another technique is required. Accordingly, we attempted categorical boosting, or "CatBoosting" because CatBoosting is a technique that can work with a more complex categorical target variable. CatBoosting is a gradient boosting machine learning library that uses the variables supplied to create an algorithm that predicts the data multiple times, then makes a generalization about the algorithms, thus creating a new, more generalizable algorithm ("Ensemble Learning," n. d.; "Gradient Boosting," n.d.). CatBoosting has received considerable attention in recent years not only because it can predict a multifaceted target variable, but also because of its accuracy, its ability to compensate for overfitting, its deal with missing values, and the fact that it can handle inputs that are not comparable (Peretz, 2019). As was mentioned in the discussion of mixture

models, there is no quantitative comparison that can be made between many of our inputs, such as gender and previous drug checking experience

Appendix C: Data Collection Forms

Bass Coast 2019

The following images are the DCFs, that were used to collect data at the music festivals, beginning with the Bass Coast 2019 DCF form:



Date: dd / mm / 2019 Unique code: *place sticker*

Bass Coast 2019 Substance Testing Survey

Background

Do you provide consent for research? ☐ Yes ☐ No
(If "No", do not collect data on this survey)

Have you used the service before? ☐ Yes ☐ No ☐ Unknown
If **"Yes"**, have you visited during this festival? ☐ Yes ☐ No

What is your gender? *(Select all that apply)*
☐ Female ☐ Male ☐ Non-binary ☐ Trans ☐ Unknown

What substance do you believe you have? *(Select all that apply)*
☐ MDMA ☐ MDA
☐ Ketamine ☐ Cocaine
☐ Methamphetamine ☐ LSD
☐ Other ☐ Unknown
If **"Other"** what?

What type of substance is being tested?
☐ Powder ☐ Crystal
☐ Blotter ☐ Press Tab
☐ Liquid ☐ Gummy
☐ Other:
Colour:

Who are you primarily testing for? *(Select all that apply)*
☐ Self ☐ Friends → If **"Friends"**, how many? ☐ Clients
☐ Other If **"Other"**, who? ☐ Unknown

Where is the substance from? *(Select one)*
☐ Onsite ☐ Offsite ☐ Online ☐ Medical ☐ Security ☐ Ground find

LSD/Ehrlich Testing

LSD Results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Ehrlich Results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

Comments:

Benzodiazepine Test Strips

Benzodiazepine Results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

Comments:

Fentanyl Test Strips

Results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

Comments:

Spectroscopy

Was FTIR testing completed? ☐ Yes ☐ No **Technician initials** xxx

FTIR results:
1st ## If **"7"** what is it?
2nd ## If **"7"** what is it?
3rd ## If **"7"** what is it?
4th ## If **"7"** what is it?

Comments:

FTIR Key Please use the below key for all FTIR results

1. MDMA	2. MDA	3. Ketamine	4. Cocaine
5. Methamphetamine	6. LSD	7. Other	8. No match

Post Test Questions

Were you surprised by the result? ☐ Yes ☐ No
If you were surprised, what was surprising about the results?

Are you satisfied with the drug checking process? ☐ Yes ☐ No
How would you improve this service?

Based on the result, what will you do with your drug? *(Select all that apply)*
☐ Take as intended ☐ Take more
☐ Take less ☐ Change how you take this drug (i.e. IV to inhalation)
☐ Dispose of the drug ☐ Use with a friend
☐ Take naloxone training ☐ Other:

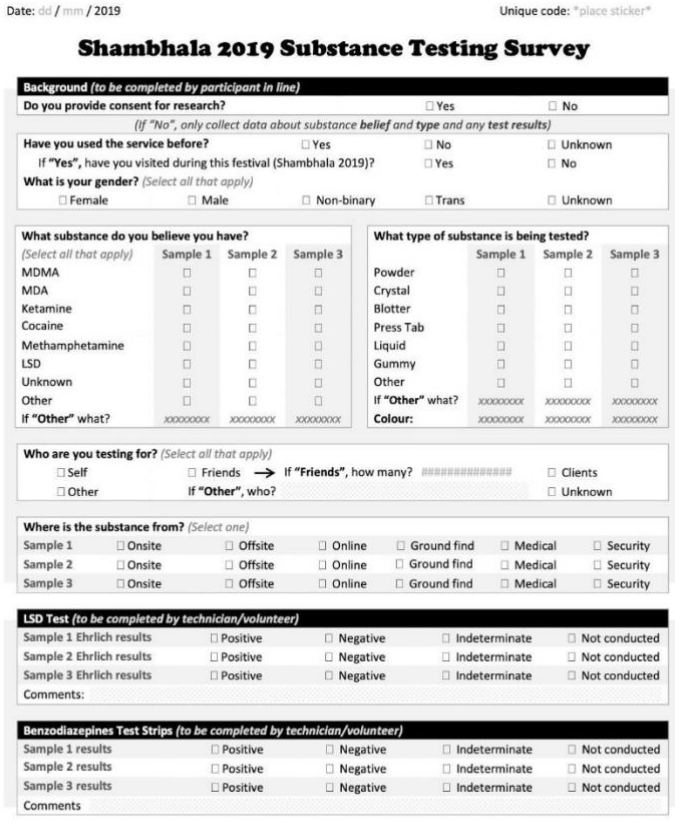
For Completion By Harm Reduction Volunteer

Did the participant discard the substance? ☐ Yes ☐ No ☐ Unknown
Please review form and make sure all fields are as completed as possible **Initials:**
Comments:

0

Shambhala 2019

The following images are the DCFs, that were used to collect data at the music festivals, beginning with the Shambhala 2019 DCF form:



Date: dd / mm / 2019 Unique code: *place sticker*

Shambhala 2019 Substance Testing Survey

Background *(to be completed by participant in line)*

Do you provide consent for research? ☐ Yes ☐ No

*(If "No", only collect data about substance **belief** and **type** and any test results)*

Have you used the service before? ☐ Yes ☐ No ☐ Unknown

If **"Yes"**, have you visited during this festival (Shambhala 2019)? ☐ Yes ☐ No

What is your gender? *(Select all that apply)*

☐ Female ☐ Male ☐ Non-binary ☐ Trans ☐ Unknown

What substance do you believe you have? *(Select all that apply)*	Sample 1	Sample 2	Sample 3
MDMA	☐	☐	☐
MDA	☐	☐	☐
Ketamine	☐	☐	☐
Cocaine	☐	☐	☐
Methamphetamine	☐	☐	☐
LSD	☐	☐	☐
Unknown	☐	☐	☐
Other	☐	☐	☐
If **"Other"** what?	xxxxxxxx	xxxxxxxx	xxxxxxxx

What type of substance is being tested?	Sample 1	Sample 2	Sample 3
Powder	☐	☐	☐
Crystal	☐	☐	☐
Blotter	☐	☐	☐
Press Tab	☐	☐	☐
Liquid	☐	☐	☐
Gummy	☐	☐	☐
Other	☐	☐	☐
If **"Other"** what?	xxxxxxxx	xxxxxxxx	xxxxxxxx
Colour:	xxxxxxxx	xxxxxxxx	xxxxxxxx

Who are you testing for? *(Select all that apply)*

☐ Self ☐ Friends → If **"Friends"**, how many? ########## ☐ Clients

☐ Other If **"Other"**, who? ☐ Unknown

Where is the substance from? *(Select one)*

Sample 1	☐ Onsite	☐ Offsite	☐ Online	☐ Ground find	☐ Medical	☐ Security
Sample 2	☐ Onsite	☐ Offsite	☐ Online	☐ Ground find	☐ Medical	☐ Security
Sample 3	☐ Onsite	☐ Offsite	☐ Online	☐ Ground find	☐ Medical	☐ Security

LSD Test *(to be completed by technician/volunteer)*

Sample 1 Ehrlich results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 2 Ehrlich results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 3 Ehrlich results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

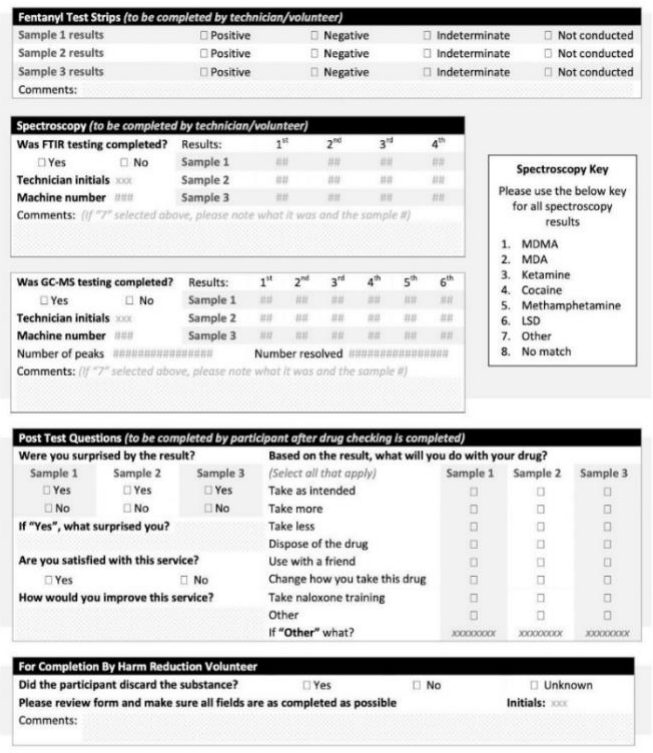
Comments:

Benzodiazepines Test Strips *(to be completed by technician/volunteer)*

Sample 1 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 2 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 3 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

Comments

Note: Dot shading, multiple x's or multiple #'s indicate areas where you can write answers.



Fentanyl Test Strips *(to be completed by technician/volunteer)*

Sample 1 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 2 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted
Sample 3 results	☐ Positive	☐ Negative	☐ Indeterminate	☐ Not conducted

Comments:

Spectroscopy *(to be completed by technician/volunteer)*

Was FTIR testing completed? ☐ Yes ☐ No

Technician initials xxx

Machine number ###

Results:	1st	2nd	3rd	4th
Sample 1	##	##	##	##
Sample 2	##	##	##	##
Sample 3	##	##	##	##

Comments: *(If "?" selected above, please note what it was and the sample #)*

Was GC-MS testing completed? ☐ Yes ☐ No

Technician initials xxx

Machine number ###

Results:	1st	2nd	3rd	4th	5th	6th
Sample 1	##	##	##	##	##	##
Sample 2	##	##	##	##	##	##
Sample 3	##	##	##	##	##	##

Number of peaks ########## Number resolved ##########

Comments: *(If "?" selected above, please note what it was and the sample #)*

Spectroscopy Key

Please use the below key for all spectroscopy results

1. MDMA
2. MDA
3. Ketamine
4. Cocaine
5. Methamphetamine
6. LSD
7. Other
8. No match

Post Test Questions *(to be completed by participant after drug checking is completed)*

Were you surprised by the result?

Sample 1	Sample 2	Sample 3
☐ Yes	☐ Yes	☐ Yes
☐ No	☐ No	☐ No

If "Yes", what surprised you?

Are you satisfied with this service? ☐ Yes ☐ No

How would you improve this service?

Based on the result, what will you do with your drug?

(Select all that apply)	Sample 1	Sample 2	Sample 3
Take as intended	☐	☐	☐
Take more	☐	☐	☐
Take less	☐	☐	☐
Dispose of the drug	☐	☐	☐
Use with a friend	☐	☐	☐
Change how you take this drug	☐	☐	☐
Take naloxone training	☐	☐	☐
Other	☐	☐	☐
If **"Other"** what?	xxxxxxxx	xxxxxxxx	xxxxxxxx

For Completion By Harm Reduction Volunteer

Did the participant discard the substance? ☐ Yes ☐ No ☐ Unknown

Please review form and make sure all fields are as completed as possible **Initials:** xxx

Comments:

Note: Dot shading, multiple x's or multiple #'s indicate areas where you can write answers.