# Finding Causality Link Between Mental Health and Substance Abuse

Ankith C Kowshik, Ayush Gupta, Gagan Giri, Gautam Kushwah
akowsh2@uic.edu, agupt69@uic.edu, ggiri3@uic.edu, gkushw2@uic.edu

## 1 ABSTRACT

Causal relationships have helped scientists across disciplines to understand the effects of one thing on another thus helping them to design better solutions and policies. One such setting in our society is the usage of drugs and mental health illness. Current research approach in this area focuses on one particular drug on one particular mental illness.

In this paper we aim to establish a causality link between drug usage and mental health illness or vice-versa in general. We try to provide a more birds-eye perspective of the whole problems rather than a focused view on one particular drug. We look at data from the year 2020 which captures the status of drug usage and mental health and analyze it using contemporary algorithms to discover underlying causal mechanisms. We hope that our work will reduce the stigma attached with substance abuse disorder and mental health thus helping people understand the relationship between the two. Our major contributions are towards applying causal discovery algorithms such PC, FCI, GES, and NO TEARS to generate causal models to determine how mental illness and substance use are related. Further we apply refutation methods to verify our results to show substance abuse has an effect on mental illness in general.

## 2 INTRODUCTION

Over the last few years mental health has been seeing increased awareness around it. More and more people are understanding the role mental health plays in professional as well as in personal life. Mental health includes our emotional, psychological, and social well-being. It affects how we think, feel, and act. It also helps determine how we handle stress, relate to others, and make healthy choices. Although the terms are often used interchangeably, poor mental health and mental illness are not the same. A person can experience poor mental health and not be diagnosed with a mental illness. Likewise, a person diagnosed with a mental illness can experience periods of physical, mental, and social well-being.[5]
Mental health just like our physical health can change over time. There is not just one one cause of mental health illness. There are several factors affecting it. The most common ones according to the Center for Disease Control include

- Early adverse life experiences, such as trauma or a history of abuse (for example, child abuse, sexual assault, witnessing violence, etc.)
- Experiences related to other ongoing (chronic) medical conditions, such as cancer or diabetes
- Biological factors or chemical imbalances in the brain
- Use of alcohol or drugs
- Having feelings of loneliness or isolation[5]

Substance use disorder (SUD) is a complex condition in which there is uncontrolled use of a substance despite harmful consequences. People with SUD have an intense focus on using a certain substance(s) such as alcohol, tobacco, or illicit drugs, to the point where the person's ability to function in day-to-day life becomes impaired. People keep using the substance even when they know it is causing or will cause problems. The most severe SUDs are sometimes called addictions.[1]

According to the World Health Organisation there has been a 13% rise in mental health conditions and substance use disorders in the last decade (to 2017).[17] Mental health conditions now cause 1 in 5 years lived with disability.[17] Around 20% of the world's children and adolescents have a mental health condition. Many individuals who develop substance use disorders are also diagnosed with mental disorders, and vice versa. [17]

Mental health illness and SUDs can affect people from all ages and walks of life. Both of these topics are subjects of ongoing research worldwide as researchers are trying to identify and pin point the causes and effects of these disorders. Understanding these topics in depth can help prevent loss of productivity and resources by identifying the markers of these conditions in early stages. Mental health conditions can have a substantial effect on all areas of life, such as school or work performance, relationships with family and friends and ability to participate in the community. Two of the most common mental health conditions, depression and anxiety, cost the global economy US$ 1 trillion each year.[17] The annual economic impact of substance misuse is estimated to be $249 billion for alcohol misuse and $193 billion for illicit drug use.[15]

According to Mental Health foundation 74% of mental health issues are faced by the age group of 24 years and below.[6] It was studied by the UN that the most substance abuse disorder if found are amongst the age group of 18 - 25 years.[16] If we had a better understanding of relationship between the both, mechanisms could be placed in order to prevent such disorders. Additionally, it could aid in developing policies and avenues to help individuals currently facing these disorders.

Although there are fewer studies on comorbidity among youth, research suggests that adolescents with substance use disorders also have high rates of co-occurring mental illness; over 60 percent of adolescents in community-based substance use disorder treatment programs also meet diagnostic criteria for another mental illness.[8] The effect of a specific substance on mental health or the relationship between a specific substance abuse and a specific mental illness has been studied in depth over the years but there has not been a study to generalise the relationship between any substance abuse and any form of a mental illness.[4, 9, 12, 18, 20]

In this research we are trying to find a causality between mental health illness and substance use disorder regardless of the type of the substance

The rest of the paper is as follows, in section 3 we discuss related works in this research area. Section 4 gives a formal description of the problem which is being addressed. In section 5 we talk about the data that we have used and how we processed it. Section 6 talks about the algorithms we have used to find and establish causality and in section 7 we talk about the results we derived from our work.

## 3 RELATED WORK

Many people who have substance use disorders (SUD) also have mental problems identified, and the opposite is also true[10]. According to research by Hser, Grella and Hubbard (2001)[19], co-occurring mental illnesses among teenagers with substance use disorders are common. More than 60 percent of adolescents in community-based substance use disorder treatment programs fulfill diagnostic criteria for another mental illness[23]. Data indicates significant incidence of co-occurring substance use disorders and anxiety disorders, such as post-traumatic stress disorder, panic disorder, and generalized anxiety disorder. Additionally, mental diseases including depression, bipolar disorder, ADHD, psychotic illness, borderline personality disorder, and antisocial personality disorder co-occur with substance use disorders at a significant rate[18]. Compared to the general population, patients with schizophrenia have greater rates of alcohol, cigarette, and drug use issues[3].

The impact of substance addiction on physical health is well supported by study and data[12]. Alcohol, cocaine, and prescription stimulants used are often linked to an increased risk of heart disease and cardiovascular illness[4]. Physical health improves by 0.707 standard deviations for every standard deviation rise in mental health.

Although the high comorbidity of substance use disorders and mental illnesses may imply a causal link between the two, it is challenging to prove this even in situations when one of the two problems first developed. Most empirical data appear to point toward three primary pathways that lead to the comorbidity between the two[22]. The three pathways are:

- Common parent pathway: Assumes that both are linked to an independent, third factor that contributes to the development of both disorders.
- Primary personality disorder pathway: Pathological personality traits contribute to the development of a substance use disorder.
- Primary substance-use disorder pathway: Substance abuse contributes to the development of personality pathology.

In supporting evidence, interviews with general practitioners and substance users express their belief that substance use usually has a combined biological, psychological, and sociological origin[7]. Despite this, studies exist that are able to establish the causality between substance use and mental illness. Researchers have found that the presence of abnormalities in specific brain circuits may predispose individuals to schizophrenia and enhance the pleasurable effects of drugs like nicotine. Making the process of quitting smoking all the more difficult. The mechanism is consistent with other drugs that act on the same receptors[14]. Similarly, study on the causality between substance use disorder and ADHD was able to conclude that a common genetic background was the source of the comorbidity. The study used the GWAS-MA summary statistics data and performed a bidirectional two sample Mendelian Randomization (MR) to get the treatment and control groups. Inversed-variance weighted (IVW) was used as the main method to obtain the average effect across genetic variants[11]. The work by Gage, Jones and Taylor[20], was able to identify 59 single nucleotide polymorphisms in association with risk of schizophrenia and cannabis initiation. When studying the causal relationship between substance use and insomnia, it has been shown that there is strong causal evidence for the causal effects of liability to insomnia on alcohol dependence and cannabis initiation. However the study also established bidirectional effects between liability to insomnia and smoking measures[9].

The majority of studies to date appears to have been on establishing the causation of particular mental illness due to a single drug or vice versa. The researches are more focused on the mechanism by which the causality is established and thus has a very narrow focus. We intend to conduct a more broader investigation and establish a causal relationship between substance usage and mental health in general.

## 4 PROBLEM DESCRIPTION

There is stigma associated with both substance abuse issues and mental health issues. The question of whether mental illness causes substance abuse problems or vice versa emerges in light of the correlation between the two conditions. Let $Y_i$ denote the mental illness of an individual $i$. $X_i$ denote the individual's drug abuse and $Z_i$ is a vector that represents other factors such as age, income level, employment status, etc that could affect $Y_i$. We would like to find the causality between mental illness ($Y_i$) and drug abuse ($X_i$). Hopefully, this should perhaps reduce the stigma associated with the issue and raise people's awareness of the issue. Thus benefiting both the individual going through it and those around them.

The project's objective is to identify the relationship between mental illness and substance abuse and the causal mechanism that underlies it. This is accomplished through the process of causal discovery. Following that, we seek to determine the robustness of the causal model by measuring the estimand.

## 5 DATA DESCRIPTION AND CLEANING

The National Survey on Drug Use and Health (NSDUH) is the leading source of statistical information on substance abuse and mental health issues in the United States. The NSDUH conducts an annual survey in the form of a face-to-face interview on a population of 12 years or older across a large geographical area across the USA. The survey is publicly available on the NSDUH website[13] in multiple formats, out of which we opted for the delimited format. The website also provides an elaborate documentation of the questions asked in the survey along with the list of opt-able answers for each question. The survey captures an individual's demographic background, prior substance use, dependence on illicit substances, abuse of illicit substances, and their mental health conditions. The survey is available from the 1979 to 2020, and for our research we

primarily focus on the most recent data that is of the year 2020. The survey was answered by close to 33,000 individuals. The data spans to approximately 2600 attributes generated out of all the questions asked to an individual in the survey.

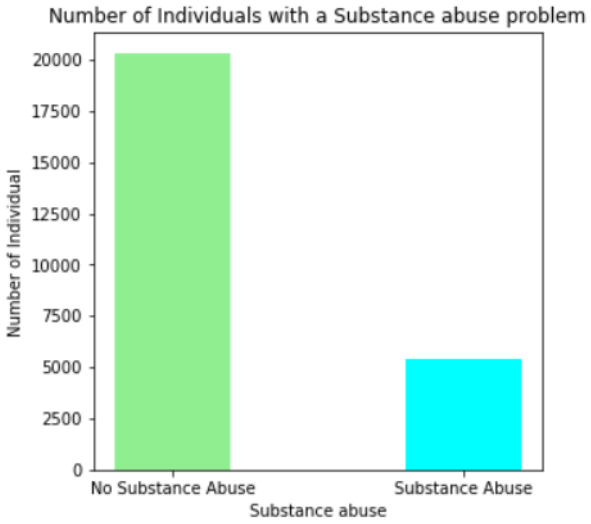


**Figure 1: Substance Abuse among individual's**

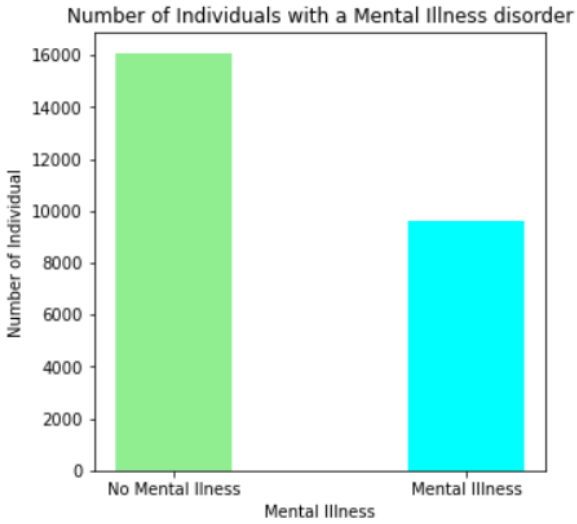


**Figure 2: Mental Illness among individual's**

We broke the data down into three area of concentration for our area of focus. The first is the drug use of an individual, where we aim to find if an individual has dependency or abuses any form of drug. The survey focuses on various substances that individual's can develop a dependency on substances such as nicotine, alcohol, sedatives, opioids, hallucinogens, and many more. The survey captured all aspects of drug use of an individual to compute their substance abuse/dependency, number of days since last used, frequency of use, any form of treatment received for the substance control. The data is additionally consolidated with time, for instance the frequency of use of nicotine is captured across weeks, days, months, and year. These collected attributes are further extended to determine an Individual's dependency on a particular substance, in the case of nicotine, the NDSS scale was used to determine whether an individual is dependent on nicotine, and similarly for other substances. We extracted this information from the survey, however, the question of our research isn't focused on what kind of drug abuse could impact mental health, rather it is about whether any kind of drug usage has an impact on mental health or vice-versa. In our case, the use of any form of drug should be considered, hence we collated all the columns on substance abuse to a single attribute, "drug use", that represents that an individual is dependent on some kind of substance.

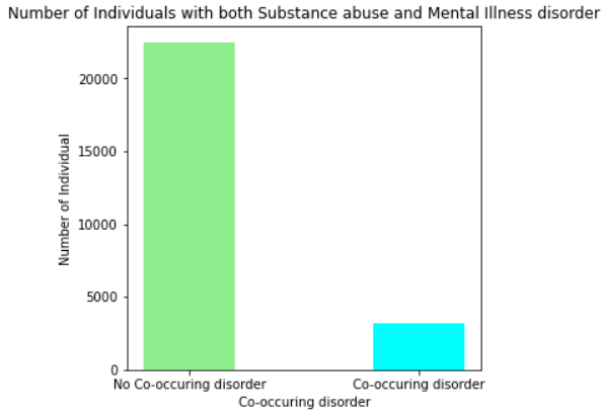


**Figure 3: Individual's facing both mental illness and substance abuse disorders**

The second area focuses on the mental health of the individual.The survey data captures the current state of the individual along with their diagnosed disorders and whether the individual has taken professional help with their condition. These attributes aim to capture the mental health of an individual in terms to feeling hopeless, restless, or occurrence of any major depressive disorders. These attributes were considered in computing the mental illness column that represents if an individual is affected by any form of mental illness.

The third area is focused on our external factors of the individual that includes the demographic information such as their social environment that is whether they live in an urban or rural area, employment status, individual's income, sex, highest education completed, and age.

The survey questions had a multiple options in forms of answers, which included binary yes or no questions, continuous values, and the individual also had the option to refuse answering any question. For the cleaning process, first we drop individuals that have not clearly established their drug abuse status or the state of their mental health as we realized that an individual who hasn't shared

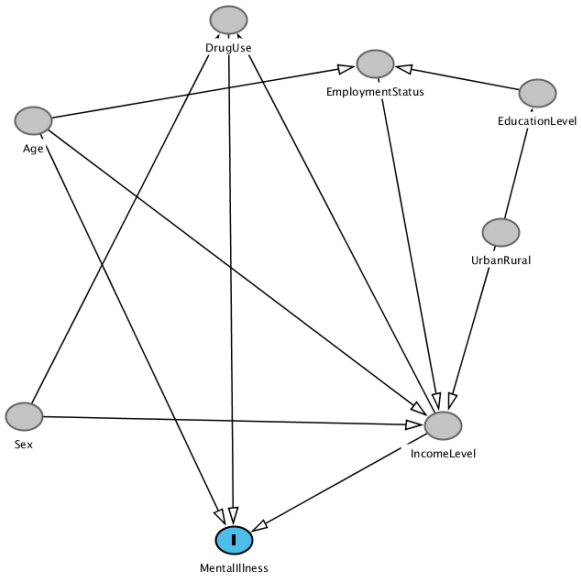


**Figure 4: Baseline causal model Drug Use to Mental Illness**

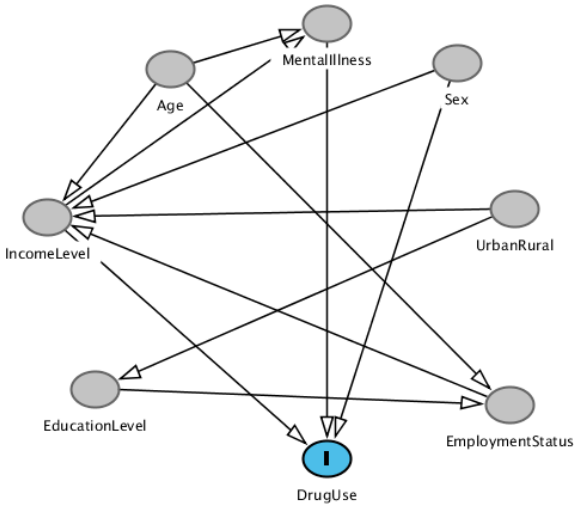


**Figure 5: Baseline causal model Mental Illness to Drug Use**

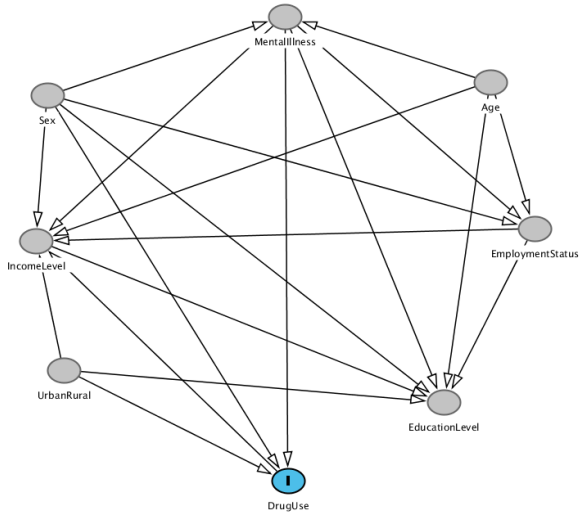


**Figure 6: PC causal model Mental Illness to Drug Use**

this information would either try to hide their condition or would feel uncomfortable to answer such questions which would result in misleading insights. The second step was to break down the attributes with continuous values into binary value columns such as the income level, age, education status, for our algorithms to generate the causal models.
Exploratory data analysis was done on both the raw and cleaned data to derive insights to better understand the data.
It was discovered that about 12.75% of the individuals were categorized as individuals with substance abuse issues, 32% of the individuals faced mental health issues, and 7% of the individuals faced both drug abuse and mental health problems.

After cleaning and feature selection from our data, below listed were the features/attributes that were selected for answering the causal questions.

- **Age**: The age of an individual, this attribute was re-coded to be a binary attribute from a continuous value attribute, where individuals between 18 to 50 are encoded to 1 as our related work and article research shows that there is a significant drop in mental health disorders post the age of 50 and a significant increase in drug abuse post the age of 18, whereas all other age group individuals are encoded to 0.
- **Sex**: This captures the gender of an individual, where Male's are encoded as 0 and Female's are encoded as 1.
- **Urban/Rural**: This attribute looks into what kind of county an individual lives in, Large and Small Metro county's are encoded as Urban or 1, and Non Metro county's are encoded as Rural or 0.
- **Income**: This data was available as a categorical data in which income levels were divided into 8 groups ranging from $10,000 per annum to above $80,000 per annum. We used to the USA median salary to determine the binary threshold here, that is if the annual income is above $54,000 then the income of an individual is encoded as 1, whereas the other are encoded as 0
- **Education Level**: This data was captured as a categorical data groups as well, where the lowest level of education was "less than high school" and highest was "Graduate degree and above". The individual's who had not completed high school had their education level encoded to 0 whereas all others were encoded to 1.
- **Employment Status**: This attribute was again a categorical column where an individual's employment was broken down into full-time, part-time and No job. The employment

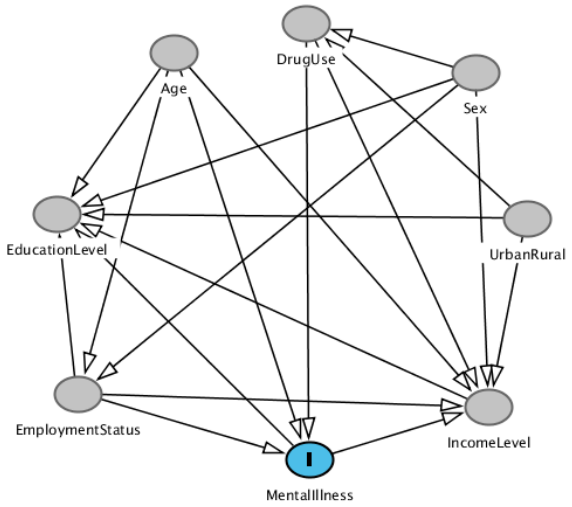


**Figure 7: FCI causal model Drug Use to Mental Illness**

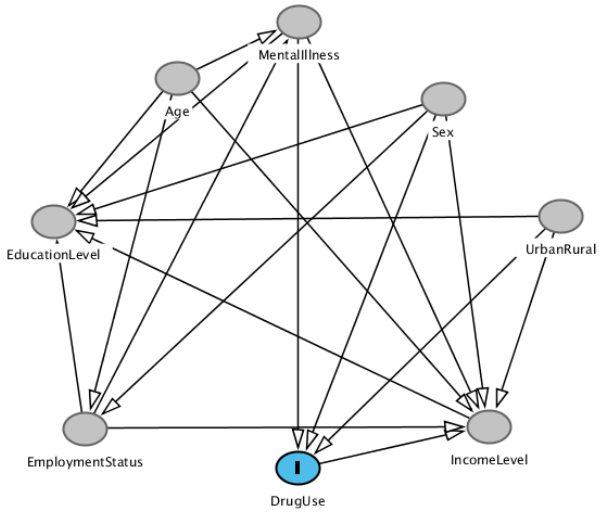


**Figure 8: FCI causal model Mental Illness to Drug Use**

status of an individual with a part-time or full-time job was encoded to 1, the rest were encoded to 0.

- **Mental Illness**: This was a consolidated attribute that was generated based on the various attributes that the data captured through the survey questions, such as feeling of hopelessness, restlessness, anxiety, major depressive disorder episode, treatment for any mental disorder, and many other attribute. These attributes had a time constraint ranging from a within the past month to within the past year, these were further extended to determine whether an individual currently faces any form of mental illness disorder. Since we are not focusing on any kind of particular mental illness disorder, if an individual has either one of them or multiple, the individual's mental illness is encoded as 1, whereas for individual's with none are encoded as 0.
- **Drug Use**: This attribute was generated similarly as the Mental illness attribute. Instead of including the dependency of various substances, or whether an individual seeks out help for the same, we have consolidated it all to single attribute were if an individual faces a substance abuse problem for one or more substances, then their drug use is encoded to 1, the rest are encoded as 0.

It is important to note here that while the data offered a large number of attributes in terms of mental illness and Substance abuse, our goal here is to determine if any form of substance abuse causes mental illness or vice-versa, hence, all the related columns were consolidated into a single attribute for each of them. As for other data available related to an individual or their demographic, such as their insurance information, population density, or number of individual's living in a house with them, such attributes were eliminated based on domain knowledge, which left us to focus on the above mentioned 8 attributes.

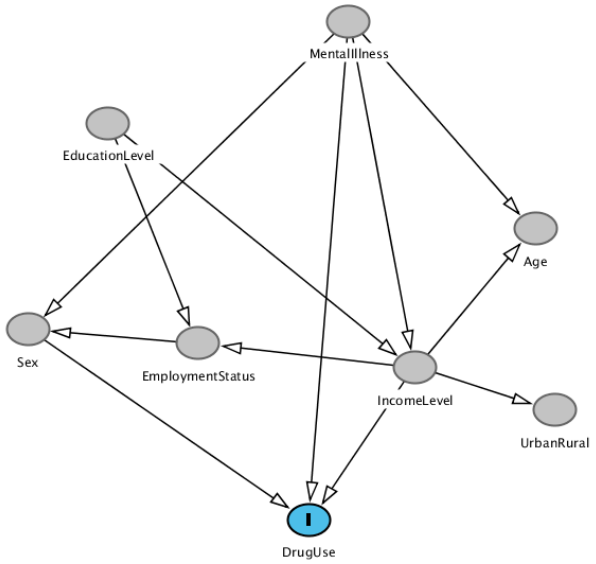


**Figure 9: GES causal model Mental Illness to Drug Use**

## 6 SOLUTION

The constraints we took into consideration when constructing our baseline causal model based on the domain knowledge were the fact that no other factors could affect an individual's age and sex. We constructed two baseline causal model based on the above constraints. The first baseline causal model was constructed to examine the effect of drug use on mental illness use as shown in Fig.1, and the other was constructed to examine the impact of mental Illness on drug use as shown in Fig.2.

While we built our baseline model using the domain knowledge. We utilized causal discovery algorithms like PC, FCI, GES, and NO TEARS to uncover further instances of causal model on the

data. There are many assumptions made across causal discovery algorithms. Some of the assumptions which are generally made are:

- **Acyclicity**: The causal graph G is assumed to be a Directed Acyclic Graph (DAG).
- **Causal Markov Assumption** : All variables in G are independent of their non-effects (non-descendants in the causal graph) conditionally to their direct causes (parents).
- **Faithfulness Assumption**: The joint density $p(x)$ is assumed to be faithful to graph G, that is, every conditional independence relation that holds true according to $p$ is entailed by G.
- Causal sufficiency: Any pair of nodes in G has no common external cause.

We notice that our model will most likely not meet the assumption of causal sufficiency based on what we know about the relevant study. This is due to the fact that we think there may be a single external cause for both mental illness and substance abuse. We make the assumptions of acyclicity, CMA and faithfulness for the causal discovery step.

FCI and NO TEARS would best meet our demands based on the aforementioned hypotheses. However, we also carry out causal discovery utilizing the PC and GES technique in order to verify our hypotheses. The two later algorithms assume causal sufficiency. The constraints we took into consideration when constructing causal model from these causal discovery algorithm were the fact that no other factors could affect an individual's age and sex and also an individual's age and sex cannot affect urban or rural attribute

**NO TEARS Algorithm:**
The NO TEARS algorithm is an optimised structure learning algorithm. NO TEARS determines if a slight rise in the value of one node will cause an increase in the value of another node. NO TEARS will be able to identify this and claim that there is a causal relationship if there is.

**Fast Causal Inference Algorithm:**
Different causal structures imply various independence connections, which is the main idea underlying constraint-based causal discovery algorithm. For instance, the causal relationship A $\rightarrow$ B $\rightarrow$ C, implies that variable A is independent of C given B. However, when A $\rightarrow$ C $\leftarrow$ B, A and B are independent (unconditionally), but become dependent conditional on C. The latter structure is called collider which is one the primitives that constraint-based algorithms like FCI seek out.
A feature specific to FCI is its ability to discover latent (unobserved) confounders. When FCI finds a "Y" structure in the graph i.e. $A_1$ $\rightarrow$ B $\leftarrow$ $A_2$ and B $\rightarrow$ C, the causal relationship from B to C is guaranteed to be unconfounded; otherwise, FCI assumes that possibly unobserved confounders exist. FCI constructs a causal graph starting with a fully connected undirected graph and removes edges that connect conditionally independent variables. In the second phase, it orients edges by identifying the "V" and "Y" structures, and tries to orient the remaining edges based on a set of rules which have been explained in detail[2].

**PC Algorithm:**
The PC algorithm has two main steps. In the first step, it learns from data a skeleton graph, which contains only undirected edges. In the second step, it orients the undirected edges to form an equivalence class of DAGs.The theoretical foundation of the PC algorithm is that if there is no link (edge) between nodes x and Y , then there is a set of vertices Z that either are neighbours of X or Y such that X and Y are independent conditioning on Z.

**Greedy Equivalence Search Algorithm:**
GES is a Bayesian algorithm that heuristically searches the space of CBNs and returns the model with highest score it finds. In particular, GES starts its search with the empty graph. It then performs a forward stepping search in which edges are added between nodes in order to increase the Bayesian score. This process continues until no single edge addition increases the score. Finally, it performs a backward stepping search that removes edges until no single edge removal can increase the score.

As part of our experimentation, we ran the PC, GES, FCI and NOTEARS algorithm on our dataset. The Fisher's Z, Chi-Squared and G-Squared conditional independence tests were used to check for independence between variables in the PC and FCI algorithm. Similarly, the BIC score and BDeu score functions were used in the implementation of the GES algorithm.

The causal model we obtained using the PC algorithm is depicted in Figure 3. The causal model discovered using the FCI algorithm had a bidirectional edge between drug abuse and mental illness. Two graphs, seen in Figures 4 and 5, were obtained after splitting the bidirectional edge. Figures 6 and 7 show the causal models derived from the GES and NOTEARS algorithms, respectively.

## 7 RESULTS

As a starting point for assessing our findings, we contrast the outcomes of causal discovery and causal estimation with those from the model we developed using domain expertise which we shall refer to as the baseline. Figure 1 and Figure 2 show the baseline causal model. We used Average Treatment Effect (ATE) which is a metric used to compare treatments in clinical trials, policy intervention evaluations, and randomized experiments. The ATE calculates the difference in mean (average) results between the treatment and control groups of units.

The Average Treatment Effect for the baseline model in Figure 1 was 0.295 with age and income level as the treatment variables when measuring the effect of mental illness due to drug use. Similarly, for the model in Figure 2 we got an average treatment effect of 0.197 with the variables income level and age as treatment when measuring the effect of drug use on mental health. This seems to suggest that drug usage has a greater effect on mental illness when compared the other way round.

To evaluate the robustness of the models we used Random Common Cause and Placebo Test refutation methods as the metrics. The Random Common Cause test strives to answer the question, when a common cause is added to the dataset using an independent random variable, does the estimation method's estimate change? If the causality is correctly established, we should not see any change

in the estimate. Similarly the Placebo Test answers the question, what happens to the estimated causal effect when an independent random variable is used in place of the real treatment variable? An effect with a value tending to zero supports the correctness of the model.

We see that in the baseline model depicted by Figure 1, the Placebo Test gives us a value tending to 0 with a p-Value of 0.38 and Random Common Cause value tending to zero as well with a p-Value of 0.38. We see similar results as tabulated in Table 4 for the baseline depicted in Figure 4.

In addition to the baseline model, we generated multiple causal models using the causal discovery algorithms FCI, PC, GES, and NO TEARS. In the case of estimating the effect of drug use on mental health, the models generated by PC and GES algorithms were unable to give provide and estimand as the effect was direct with no backdoor or front door paths. When estimating the effect on mental health on drug use, the model generated by the NO TEARS algorithm failed to provide and estimand for the same reason. All the models generated by these algorithms are documented below. In instances where the estimand could not be derived, refutation methods cannot be used to test the robustness of the model.

As it can be observed from the tables of the ATE for the various models generated and the refutation table establishing the robustness of the results, we can see here that the causal model indicating an effect from drug use on mental illness is higher when compared to the effect from mental illness on drug use with the highest ATE for the baseline and FCI causal models, additionally these are supported through the refutation methods that were applied on the models.

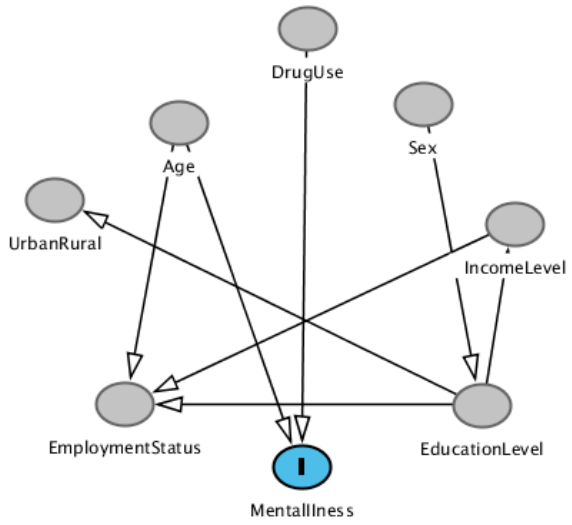


**Figure 10: NOTEARS causal model Drug Use to Mental Illness**

## 8 CONCLUSION

In this article, we looked at the existing research in the field of mental health and substance use disorders which establish comorbidity between the two. The statistics obtained from WHO and UN[16, 17] helped us understand a correlation between substance use and mental health illness. We also examined the economic and social burden faced around the world due to these conditions. We also looked at previous research work on establishing a causal link between substance abuse and mental health illness and found that majority of research focuses on the effects of a particular substance.

With the aim to take a more general approach we obtained data from Substance Abuse and Mental Health Services Administration (SAMHSA)[21] and consolidated and cleaned it. Based on domain knowledge[5] we identified the relevant attributes and used causal discovery algorithms such as PC, FCI, GES and NOTEARS to generate causal models and additionally generated a baseline causal model through our domain knowledge.

We then validated the robustness of the generated causal models using Placebo Test and Random Common Cause test and were able to observe that substance abuse has a higher impact on mental illness when compared to the impact of mental illness on substance abuse.

| Algorithm | Treatment | ATE |
|---|---|---|
| **Baseline** | Income Level, Sex | 0.295 |
| **PC** | N/A | N/A |
| **FCI** | Age | 0.2864 |
| **GES** | N/A | N/A |
| **NO TEARS** | Age | 0.2755 |

**Table 1: ATE on Drug Use to Mental Illness**

| Algorithm | Placebo Test | Random Common Cause |
|---|---|---|
| **Baseline** | 0.0028 | -0.0023 |
| **PC** | N/A | N/A |
| **FCI** | -0.0003 | 0.2864 |
| **GES** | N/A | N/A |
| **NO TEARS** | 0.00018 | 0.2755 |

**Table 2: Refutation Methods Drug Use to Mental Illness**

| Algorithm | Treatment | ATE |
|---|---|---|
| **Baseline** | Age, Income Level | 0.197 |
| **PC** | Sex | 0.2105 |
| **FCI** | Sex | 0.2105 |
| **GES** | Education Level | 0.2 |
| **NO TEARS** | N/A | N/A |

**Table 3: ATE on Mental Illness to Drug Use**

| Algorithm | Placebo Test | Random Common Cause |
|---|---|---|
| **Baseline** | -0.00092 | 0.11 |
| **PC** | 0.00054 | 0.2005 |
| **FCI** | 0.0013 | 0.2105 |
| **GES** | 0.0021 | 0.20 |
| **NO TEARS** | N/A | N/A |

**Table 4: Refutation Methods Mental Illness to Drug Use**

This article could be further extended by factoring in a much more comprehensive data source to identify individuals with mental illness disorder and substance abuse problems along with data related to genetics that show patterns of substance abuse problem among generations of an individual. Additionally we can try defining new constraints as done above in regards to age, sex, and county of an individual to further encourage investigating and establishing other possible scenarios where substance abuse may cause mental illness disorders or vice-versa,

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