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A Case Study of a Network Analysis of Drug Use and Emergency Department Visits in St. Louis: Supporting a Quicker Rehabilitation

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Abstract

Substance abuse is a long-standing problem, particularly in the St. Louis, Missouri area. Recently, 350,000 individuals reported using illicit drugs with more than half living with a substance abuse disorder in the St. Louis Metropolitan area. Among the illicit drugs, heroin, cocaine, marijuana, methamphetamine and LSD (lysergic acid diethylamide) are considered the most prevalent, with heroin/opioids being particularly linked to increased rates of death, violence, and arrests. Because drug prevalence and popularity change over time, it is important to explore how and why the drug landscape changes and how this impacts illicit drug use. With a changing healthcare system, it will be imperative to examine the causes and risks of poly use of illicit drugs to inform prevention and treatment approaches for individuals who may end up in the emergency department (ED), which may be a first step in treatment for many. This study applies findings from a social network analysis utilizing a St. Louis subset of 1997 Drug Abuse Warning Network (DAWN) data compared to recent national emergency department statistics. By examining an example of a changing drug landscape, rehabilitation professionals can learn to best serve individuals leaving the emergency department to facilitate quicker, more efficient, rehabilitation.

Background

Nationally, there are almost 8,000 new drug users a day (National Institute on Drug Abuse, 2015). Most of these new users will try illicit drugs before their 18th birthday (NIDA, 2015). An estimated 27 million individuals ages 12 and older used an illicit substance on any given month in 2014, which was largely driven by marijuana and nonmedical use of prescription pain killers (Substance Abuse and Mental Health Services Administration [SAMHSA], 2014). This number in 2014 approached 140 million when factoring in the number of individuals ages 12 and older who drank alcohol within any given month (SAMHSA, 2014).

Of the individuals ages 12 and older using either alcohol or an illicit substance within a 30-day period during 2014, nearly 22 million were diagnosed with a substance use disorder. A substance use disorder is diagnosable per the guidelines set by the *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition* (DSM V; American Psychiatric Association, 2018) and is characterized as mild, moderate or severe depending on the level of impairment and use (SAMHSA, 2015). Recent statistics suggest that almost 9% of individuals report they need or want substance use treatment, but less than 1% receive it (NIDA, 2015). This discrepancy may explain why, at a national level, 4.6 million emergency department visits were drug-related (National Institutes of Health [NIH], 2011). Since 2004, the total number of drug-related ED visits has increased over 80% since 2004 (NIH, 2011).

The increase in national drug-related ED visits calls for a closer examination of what is going on within our individual states. In 2015, the Drug Enforcement Agency (DEA) found the prevalence of illicit drug use in the State of Missouri to exceed national statistics. Among the illicit drugs, heroin is considered an epidemic in the St. Louis area and is linked to increased rates of death, violence, and arrests (DEA, 2015). There are 350,000 individuals ages 12 and older who reported using illicit substances, with close to 220,000 individuals reported living with a substance use disorder in the St. Louis area (SAMHSA, 2012).

The Missouri Department of Mental Health (2016) Status Report on Substance Abuse and Mental Health describe the disparities in the number of substance use disorders and the treatment admission rate; while disorder rates are most prevalent among the Northeastern part of the State throughout central Missouri, the highest treatment admission rates are not necessarily seen in the areas with the highest concentration of substance use disorders. The city of St. Louis appears to be one of the treatment hubs for substance use disorders in the State of Missouri. This study sought to explore the drug-related ED visits given the understudied nature of this despite the prevalence of illicit

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drug use in the St. Louis area. The following research questions were asked of St. Louis network data: 1) which drug(s) were associated with the highest number of ED episodes and 2) does illegal versus legal drugs relate to the number of ED episodes.

Methods

This study conducted a social network analysis using the 1997 Drug Abuse Warning Network (DAWN) data using the R studio software where Statnet and Ergm packages were utilized for further analysis. The 1997 DAWN is a publicly available dataset designed to capture data on emergency department (ED) episodes that are related to the illegal or nonmedical use of an illicit or prescription drugs. A drug episode is an ED visit in patients six years and old that was induced by or related to the use of an illegal drug or the nonmedical use of a legal drug.

There are 164,057 observed ED episodes associated with drugs in the 1997 DAWN data. The St. Louis DAWN subset was created from the original 164,057 episodes by randomly selecting 400 of 2,956 episodes in St. Louis. The sample size of 400 is feasible yet robust to conduct network analysis. The two types of nodes in this network are drugs and episodes. Ties are non-directed and connect the two types of nodes when the episode is associated with the drug. An association refers to the *drug mention* during the ED visit, which can be understood as the possible cause of the episode.

The study examined an affiliation two-mode network where ED episodes were connected to drugs and a one-mode projection drug network where different drugs were connected if they shared at least one ED episode. The drug network showed how drugs were connected by sharing the same episode. Performing a social network analysis of the drug network allowed the authors to examine the research question of what drugs were more likely to be used together and, thus, became the possible cause for shared ED episodes.

Information about each drug's recent popularity, category and legal status were also used in the analysis (See Table 1 for the complete description of drug attributes). In this study, 'popular' is defined as the substances that were most used. Both network descriptive analysis and exponential random graph models (ERGM) were performed.

See Table 1. Drug Attributes *next page*

Results

Descriptive Analysis

Two-mode affiliation network.

According to Luke (2015), an affiliation network is made up of a node for the actors (e.g., drugs in this study) and a node for the groups or events to which the actor belongs (e.g., ED episode in this study). Figure 1 reflects the bipartite graph representative of the DAWN data; drugs are connected by sharing the same ED episodes and episodes were connected by the same *drug mention*, which suggests possible cause of the episode.

The bipartite network (i.e., two-mode affiliation network) has 445 vertices and 494 edges with a density of 0.005. The results of the network analysis indicated the average number of *drug mentions* per episode was 1.24, suggesting overall an average of 1.24 drugs caused one ED episode. In total, 81% of episodes (N=323) were associated with only one drug, suggesting most episodes in 1997 were caused by only one drug. There were 19 % of episodes (N=77) associated with two drugs and above; specifically, 15.5% of episodes (N=62) involved two drugs, 3.25% of episodes (N=13) involved three drugs, and 0.5% of episodes (N=2) involved four drugs.

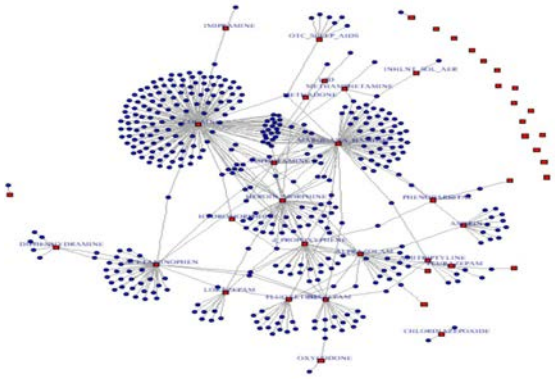

Figure 1. Two-mode Affiliation Network.

Analysis on top 4 prevalent drugs in 1997.

To the researchers' knowledge, there is no known list documenting the most prevalent drugs or substances available in St. Louis Area. However, according to the Department of Mental Health's (DMH; 2016) *Status Report on Missouri's Substance Use and Mental Health*, the top four most prevalent drugs in Missouri are marijuana/hashish, methamphetamine, heroin and cocaine. The study investigated how these four drugs performed in 1997 (Figure 2). It was found that the most current and prevalent drugs, cocaine, heroin/morphine and marijuana/hashish, was

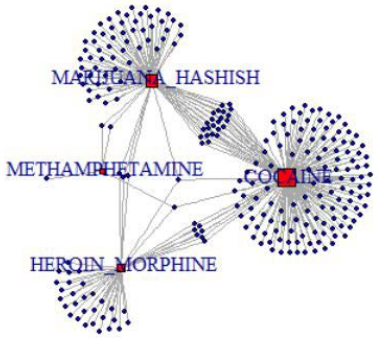

Figure 2. Top 4 currently-prevalent drugs in 1997

Table 1. Drug Attributes

Drug Category	**Drug Name** *N=45*	**Legal Status**	**Recent Popularity** (nationally, as of 2011)
1: Psychotherapeutic Agents *N=15*	ALPRAZOLAM	Legal	Not popular
	AMITRIPTYLINE	Legal	Not popular
	CHLORDIAZEPOXIDE	Legal	Not popular
	CHLORPROMAZINE	Legal	Not popular
	CLORAZEPATE	Legal	Not popular
	DESIPRAMINE	Legal	Not popular
	DIAZEPAM	Legal	Not popular
	DOXEPIN	Legal	Not popular
	FLUOXETINE	Legal	Not popular
	HALOPERIDOL	Legal	Not popular
	IMIPRAMINE	Legal	Not popular
	LORAZEPAM	Legal	Not popular
	MEPROBAMATE	Legal	Not popular
	THIORIDAZINE	Legal	Not popular
	TRIFLUOPERAZINE	Legal	Not popular
2: Depressant *N=11*	CHLORAL/HYDRATE	Legal	Not popular
	DIPHENYLHYDANTOIN SODIUM	Legal	Not popular
	ETHCHLORVYNOL	Legal	Not popular
	FLURAZEPAM	Legal	Not popular
	GLUTETHIMIDE	Legal	Not popular
	MARIJUANA/HASHISH	Illegal	Popular currently
	METHAQUALONE	Legal	Not popular
	PENTOBARBITAL	Legal	Not popular
	PHENOBARBITAL	Legal	Not popular
	SECOBARBITAL	Legal	Not popular
	SECOBARBTL/AMOBARBITAL	Legal	Not popular
3: Hallucinogen *N=1*	LSD	Illegal	Popular currently
4: Opioid *N=8*	CODEINE	Legal	Popular currently
	d-PROPOXYPHENE	Legal	Not popular
	HEROIN/MORPHINE	Illegal	Popular currently
	HYDROMORPHONE	Legal	Popular currently
	MEPERIDINE/HCL	Legal	Popular currently
	METHADONE	Legal	Popular currently
	OXYCODONE	Legal	Popular currently
	PENTAZOCINE	Legal	Popular currently
5: Stimulant *N=5*	AMPHETAMINE	Illegal	Popular currently
	COCAINE	Illegal	Popular currently
	INHLNT SOL AER	Legal	Not popular
	METHAMPHETAMINE	Illegal	Popular currently
	METHYLPHENIDATE	Legal	Not popular
6: Other *N=5*	ACETAMINOPHEN	Legal	Popular currently
	ASPIRIN	Legal	Popular currently
	DIPHENHYDRAMINE	Legal	Not popular
	OTC DIET AIDS	Legal	Not popular
	OTC_SLEEP_AIDS	Legal	Not popular

prevalent in 1997 as well since each of them were associated with 40% of episodes (N=160), 21.5% of episodes (N=86) and 10.25% of episodes (N=41), respectively. However, it was discovered methamphetamine was not prevalent in 1997; methamphetamine was only associated with 1% of episodes (N=4) in 1997, suggesting only 4 out of 400 episodes were probably caused by methamphetamine.

To further investigate the number of shared episodes among these four drugs, it was found that marijuana/hashish and cocaine shared the most episodes; 24 episodes were associated with both marijuana/hashish and cocaine. The number of episodes shared by other drugs (i.e., cocaine, methamphetamine, and heroin/morphine) ranged from one to nine

One-mode Affiliation Network: Episode network and drug network.

The DAWN network can be projected as two one-mode networks: the episode network and the drug network (see Figures 6 and 7 below). The drug network was plotted so that the thickness of the tie represents the number of shared episodes between two drugs; visually, it makes sense to see greyer or thicker ties in the center as the outliers or less connected clusters would not have as many shared episodes. The size of the drug nodes in the drug network represented the degree of the nodes; the bigger the nodes, the more each drug was connected by shared episodes.

The drug network has 45 vertices and 59 edges with a density of 0.06. The episode network has 400 vertices and 18,612 edges with a density of 0.23. In the episode network, episodes were connected by sharing the same drugs. Similarly, in the drug network, drugs were connected by sharing the same episodes. As mentioned previously, analyzing this network allows the authors to examine the research question *'what drugs were more likely to be used together and thus became the possible cause of the shared ED episode?'*.

The most well-connected drugs.

Examining the one-mode drug network allows the authors to answer the research question *what drugs are more likely to be used together?* However, the entire drug network had 19 components, which caused difficulty during examination. Thus, two sub-networks were created to alleviate analysis difficulties; this allowed one network to only include nodes in the greatest component of the drug network (see Figure 3), and the other to only include nodes in the greatest component that showed degrees equal to five or above (degree ≥ 5) (see Figure 4).

Figure 3 indicates that the most well-connected drugs (i.e. most frequently mentioned together) during an ED episode included methamphetamine, heroin/morphine, hydromorphone, cocaine, marijuana/hashish, alprazolam, d-propoxyphene, diazepam, acetaminophen, and fluoxetine (N=10). Each drug was linked to at least five other drugs by sharing the same episode and constituted the greatest component among the 45 drugs.

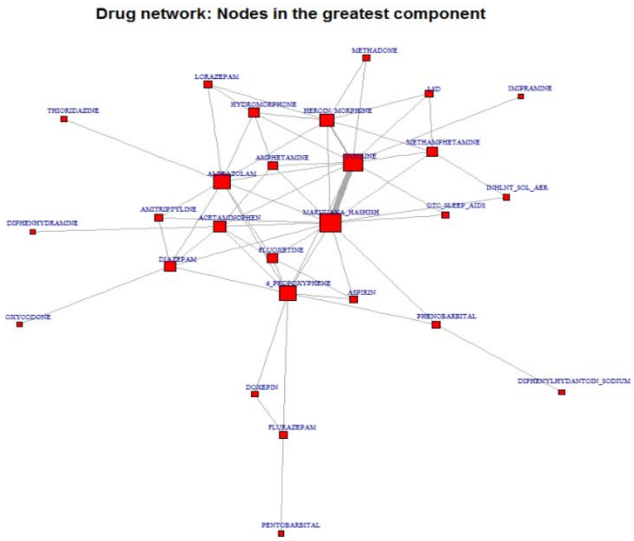

Figure 3. Drugs in the Greatest Component.

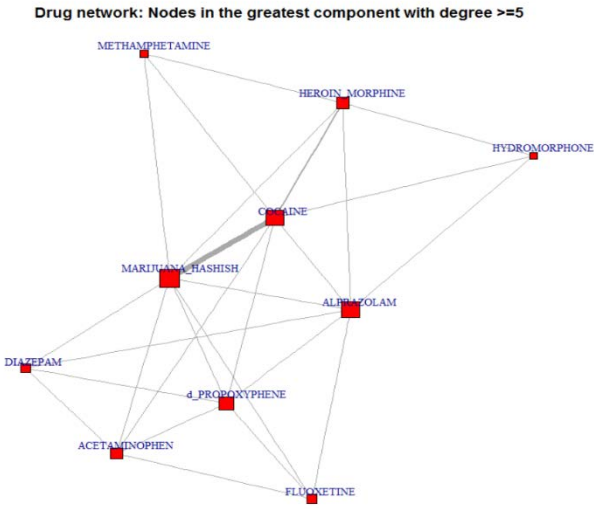

Figure 4. Drugs in the Greatest Component with Degree ≥ 5.

Exponential Random Graph Models (ERGM) Interpretations of statistical results.

The ERGM was conducted to examine the drug network, a one-mode projection network where different drugs were connected if they shared at least one ED episode. The complete results of ERGM are documented in Table 2. The study conducted four models (Model 0-3) using predictors including edge, drug category, current popularity, current legal status, and local structure predictor based on edgewise

shared partners (GWESP). The AIC statistics showed that the best-fit model was Model 3 *(AIC=328)*.

Model 3 used drug category, current legal status (mix ematch function) and GWESP as predictors. The major findings from the results of Model 3 included: 1) The likelihood of *two illicit drugs being used together* as the possible cause of an ED episode is 70.86 times higher than when it is *two legal drugs being used together (p<.001)*; 2) the likelihood of *one illicit and one legal drug being used together* as the possible cause of an ED episode is 2.18 times higher than when it is *two legal drugs being used together (p<.05); 3)* the likelihood of using LSD as the possible cause of an ED episode is smaller than the likelihood of using drugs categorized as *"Psychotherapeutic Agents"* as the possible cause of an ED episode by 85.4% *(p<.05),* and 4) the GWESP term captured the effects of clustering in the drug network *(p<.001)*.

Goodness of fit.

The study also examined the goodness-of-fit for the final model *(Model 3, AIC=328)*. The goodness-of-fit statistic was computed by comparing the results of the simulated network of the final and the observed drug network. Thus, non-significant p-values shows the simulated network based on the final model did a good job capturing the network structure of the observed drug network; in other words, the difference between the simulated network based on the final model and the observed network drug was not significant. Among the 47 goodness-of-fit statistics, only one statistic was significant (i.e., poor fit) *(p<.05)*, showing the final model did an accurate job capturing the structure of the observed network although only two predictors (legal status and drug category) and the local structure predictor GWESP were used.

Simulated network based on the final model.

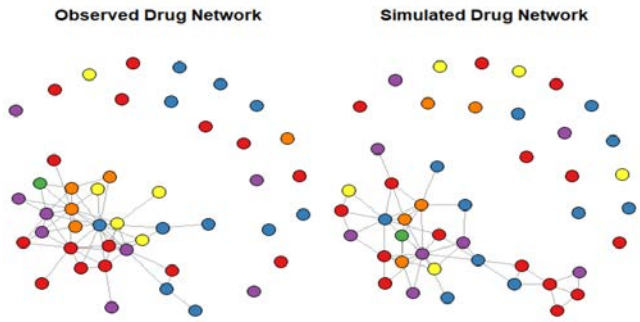

Figure 5: The Simulated and the Observed

Lastly, the study compared the simulated network based on the final model (Model 3) and the observed drug network found the final model did a good job capturing/representing the structures of the observed drug network because of the similarity of the basic statistics and the visual plots of between the simulated network and observed network (see Figure 5).

Table 2. ERGM Model Comparison (Model 0-3)

Variable	Model 0			Model 1			Model 2			Model 3		
	β	OR	p-value	β	OR	p-value	β	OR	p-value	β	OR	p-value
Edge	-2.76	0.0634	<0.0001***	-3.156	0.043	<0.001***	-3.155	0.043	<0.001***	-5.056	0.006	<0.001***
nodefactor.Pop.1				0.161	1.175	0.6929						
nodefactor.DrugCat.2				-0.552	0.576	0.0933	-0.532	0.587	0.1001	-0.254	0.776	0.274
nodefactor.DrugCat.3				-2.848	0.058	0.0041**	-2.786	0.062	0.0045**	-1.857	0.156	0.034*
nodefactor.DrugCat.4				-0.166	0.847	0.7001	-0.052	0.950	0.8707	-0.026	0.974	0.905
nodefactor.DrugCat.5				-1.097	0.334	0.0210*	-1.039	0.354	0.0208*	-0.543	0.581	0.112
nodefactor.DrugCat.6				0.190	1.209	0.6290	0.257	1.293	0.4642	0.123	1.131	0.621
mix.ematch.Illegal.0.1				1.873	6.510	<0.001***	1.968	7.153	<0.001***	0.779	2.178	0.014*
mix.ematch.Illegal.1.1				6.367	582.190	<0.001***	6.569	712.436	<0.001***	4.261	70.861	<0.001***
GWESP										2.342	10.402	<0.001***
AIC	449			384			382			328		

***<.001 **<.01 *<.05

Discussion

Limitations

The current study has several limitations. First, drugs reported to DAWN come from many possible sources, including laboratory (toxicology) testing, the clinical assessment and diagnoses, as well as reports by patients, their friends, or their families. Thus, a particular drug mention may or may not be the *confirmed cause* of the episode.

Second, "combo drugs", or drugs that were used in combination with each other, were excluded from the analysis. Unfortunately, this meant the exclusion of a legal, accessible, and highly addictive substance was excluded, alcohol, because it was not a category defined by itself; the only categories for alcohol were listed in combination with another drug (e.g. alcohol-in-combo). Alcohol was excluded because it was important to the research question to examine which single drugs were used and then used together and the existing category already defined alcohol as being used in combination with another substance. This is a rather large limitation as alcohol use disorder is the leading substance driving substance-use disorders (SAMHSA, 2014).

Third, since the DAWN data stopped collecting data from the St. Louis area from 1998, the top four recent-prevalent drugs compared to the 1997 network were drawn from DMH's (2016) *Status Report on Missouri's Substance Use and Mental Health*. In this report, prevalence was operationalized as frequencies of individuals admitted to the Department of Behavioral Health's certified substance use treatment programs. By reviewing the report, the study defined the top four currently prevalent drugs in Missouri as marijuana/hashish, methamphetamine, heroin, and cocaine and compared the top four currently-prevalent drugs with the 1997 St. Louis drug network. This is the best publicly available data to compare with the 1997 St. Louis drug network. However, it should be noted that the scope and methodologies of data collection differed between the Status Report in Missouri and the DAWN data in St. Louis.

Implications

While the results of this analysis are specific to one metropolitan city in the United States, the implications of sustained heroin and polydrug use are far reaching. Nationally, over half of all drug users use more than one drug (Addiction Center, 2017; SAMHSA CBSQ, 2012). For heroin users, 90% also use at least one other drug as of 2015; close to half of individuals who use heroin are also addicted to opioid painkillers (CDC, 2015). Further, polydrug users are more likely to be seen in the emergency department (Addiction Center, 2017).

While ED visits often indicate the physical impact substance abuse can have on the body, brain imaging, such as the Single Photon Emission Computed Tomography (SPECT) Scan, are helpful in showing the brain damage that can occur from recreational or long-term use (Amen Clinics, 2017). For example, a healthy brain appears smooth, however, a brain that has experienced substance abuse shows visible holes that indicate areas of diminished blood flow and brain activity (Amen Clinic, 2017). While the SPECT scan images can show the damage that occurs from substance abuse, they also show the brain's ability to heal itself during periods of abstinence. Ultimately, these images are used to evaluate brain activity and assist in determining courses of treatment (Amen Clinic, 2017).

The passage of the Affordable Care Act (2010) jumpstarted the integration of substance abuse treatment into primary health, also known as behavioral health (Banerjee, 2016). For individuals with substance use disorders visiting the ED, visits are often associated with lack of insurance and unmet substance abuse treatment needs, which is why they are often a primary point of entry into substance abuse treatment (Banerjee, 2016). Individuals leaving the ED with substance use disorders are more likely to readmit within 30 days because of their substance use (Walley, Paasche-Orlow, Lee, Forsythe, Chetty, 2012) or other medical issues (Becker, Boaz, Andel, & Hafner, 2017).

Most treatment modalities for substance use occur in a hospital and/or community- based service setting. For example, inpatient services may occur within a hospital for detoxification and/or starting medication management programs and community-based settings may deliver behavioral therapies in an outpatient setting where participants can access group and individual counseling (SAMHSA, 2016). There are 13 principles of effective treatment outlined by NIDA (2018) which speak to the importance of treating the entire person (i.e. considering a person in their environments), not treating people in isolation (i.e. including family and support persons in their treatment), and utilization of medication, as needed, in combination with behavioral therapies. These treatment principles are important for medical providers to consider when providing and recommending appropriate courses of treatment once an individual is preparing for discharge from a hospital inpatient or ED setting.

As rehabilitation professionals in medical settings work with the patient and their care team to transition out of more inpatient medical settings to more community-based referrals, a helpful and effective evidence-based practice that can be used across disciplines is Screening, Brief Intervention, and Referral to Treatment (SBIRT). The SBIRT treatment model allows rehabilitation professionals to intervene and/or prevent further development of disorders by identifying risk levels in patients and tailoring course of treatment and referral in collaboration with the patient and their individual resources (Powers, Benningfield, & Clinton, 2016). The three major components of SBIRT include screening, brief intervention, and referral to treatment. The first phase, screening, helps to identify risky use (Center for Substance Abuse Treatment, 1997; BSAS MASBIRT, 2012); standardized screening tools are utilized in this process- to see a list please see SBIRT (1997). For patients who screen

positive for risky use, brief intervention would include in a conversation where results of the screening are shared, along with advice on how to navigate future behavior change (CSAT, 1997; BSAS BASBIRT, 2012). The third phase, referral to treatment, is needed for the patients that screen high risk or need additional substance abuse services (CSAT, 1997; BSAS MASBIRT, 2012).

Conclusion

The results of the case study revealed that the prevalence of heroin has remained consistent overtime. Cocaine, marijuana/hashish, heroin/morphine, acetaminophen, and d-Propoxyphene were the top five drugs that caused the most ED episodes in 1997, as they were associated with 87% of episodes. Cocaine, marijuana/hashish, heroin/morphine, and acetaminophen remained popular through most recent data as of 2011. D-Propoxyphene was no longer epidemic as of 2011. Episodes related to methamphetamine and LSD were only 1% and 0.5% in 1997 but were the most popular drugs related to ED visits as of 2011.

With respect to the polydrug (multiple drug) use, 81% of episodes were associated with only one drug and 19% of episodes were associated with two drugs or more in 1997. This percentage of polydrug use looks quite different from more recent data. The results reinforce that overtime, drug prevalence and popularity changes; it is important to further explore how and why the drug landscape changes and how this impacts illicit drug use. With a changing healthcare system, it will be imperative to examine the causes and risks of poly use of illicit drugs to inform prevention and treatment approaches for individuals that may end up in the ED, which may be a first step in treatment for many (Banerjee, 2017).

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