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Network Structure and Proxy Network Measures of HIV, Drug and Incarceration Risks for Active Drug Users

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Recent work in the area of drug and HIV risk reduction has demonstrated that ethnographic, ego-centered, and full network analysis of drug using groups fills an important information gap for understanding the impact of both peers and culture on the risky conditions and practices which lead to HIV infection. This paper explores the relationships between individual risk taking behavior and overall network structure measures, specifically measures of density, transitivity, and centralization. These measures are compared with individual risk measures including frequency of drug use, use of common IV drugs, number of IDU sex partners, percent of use of condoms, lifetime number of STDs and time spent in jail. The results indicate there are significant associations between centralization and other network measures and the level of risky behavior of individuals in a network. Taking this finding one step further, the second part of the paper explores the relationships between three proxy measures of network structure and risky behavior. These three proxies are network type, single or multiple network membership, and project recruitment order. The public health implications of these network proxy measures are discussed.

Introduction

The utility of the network analysis paradigm for HIV prevention programs has been recently established (Friedman, 1989; Latkin *et al.*, 1994; Trotter *et al.* 1994). However, there is a clear need to create a bridge between the constraints placed on risk reduction efforts in public health programs and the types of intervention programs that are best suited to network approaches. This article explores the viability of using direct network measures to create a model of HIV and drug risk taking for active drug users. In addition, we investigate three proxy measures of network structure in an attempt to determine whether it is possible to identify conditions linked to individual risks which could subsequently be identified or predicted using relatively simple and non-threatening questions that could be asked about an individual's social relationships in a public health context. This article identifies variables which can be used in public health settings without having to complete a full network analysis on each individual drug network. Thus, HIV and drug prevention programs could take advantage of some of the positive impacts of network guided interventions, without the full time and labor intensive analysis of network structure.

This approach is being tested within the context of an HIV and drug prevention program directed at finding hidden populations of active (not-in-treatment) drug users from four cultural groups (Anglo, African American, Hispanic, and Native American). The project is being conducted in Strip Town, a town of approximately 45,000 people.[1,2] The town resembles other Southwestern U.S. towns which stretch along the interstate highways and the railroad tracks common in the region. Strip Town is slightly more than 100 years old and displays considerable cultural diversity. The largest population is the Anglo American community (29,647). The second largest population is the Hispanic community (6,972). The third group (4,210) is the Native American population. There are several federally recognized American Indian Reservations nearby. The fourth Strip Town cultural community is African American (1,135). The community residents feel that the town is relatively isolated, but at the same time, the community is linked to metropolitan areas by numerous tourists who travel through the town to see the local sights. Drug use is rarely visible on the streets of Strip Town. However, our ethnographic research has determined that the town is not exempt from any of the drugs found in urban centers in the United States (Trotter *et al.*, 1994). Heroin, cocaine, amphetamines, marijuana, hallucinogens, and a variety of prescription drugs are all readily available for illegal consumption. A few drugs are grown or manufactured within the community, but most drugs are obtained from metropolitan areas within three to five hours of driving time from Strip Town. The most commonly used injection drugs are heroin, cocaine, and amphetamines. At the present time, heroin and cocaine are very similar in price. Small drug networks often pool their money and send one of their members to an urban area to buy their drug supply. This generates a considerable need for trust on the part of group members, since the purchases tend to be infrequent and to involve large sums of money, in relation to the wealth of the group. These conditions create a number of positive conditions for the use of network approaches to HIV risk reduction (Trotter *et al.*, 1994).

The recent HIV infection surveillance report for the state in which Strip Town is located indicates a total of 1900 AIDS cases (52.19 per 100,000), and 3285 HIV infected individuals (121 per 100,000).[3] The AIDS infection rate for Strip Town's predominantly rural county is 10.35 per 100,000, and the HIV infection rate is 20.71 per 100,000. However, the local drug using population has an HIV prevalence rate of approximately 3 percent (3,000 per 100,000), based on the active local cocaine, heroin, and other injection drug users recruited by our project. This differential in HIV rates indicates that we are targeting many, if not most, of the highest risk individuals in the area.

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[1]The project is funded by the Community Research Branch of the National Institute on Drug Abuse (Grant # U01-DA07295), as part of NIDA's Cooperative Agreement Project. The primary orientation of the project is to combine ethnographic, psychosocial, epidemiological and network based approaches to create a model for preventing the spread of HIV in drug using populations in small towns.

[2] Following the general ethical guidelines for projects like ours, the names of the communities involved in the project have been replaced by pseudonyms or generic terms to meet privacy and confidentiality conditions.

[3]We have omitted the citation for this report, to protect the anonymity of the community.

TABLE 1. DEMOGRAPHIC CHARACTERISTICS OF PROJECT PARTICIPANTS

A. Gender

	Frequency	Percent
MALE	348	70.2
FEMALE	148	29.8
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Total	496	100.0

B. Racial-ethnic group

	Frequency	Percent
BLACK (NOT HISPANIC)	94	18.6
WHITE (NOT HISPANIC)	165	33.2
HISPANIC	163	32.9
ASIAN OR PACIFIC ISL.	2	0.4
NATIVE AMERICAN	64	12.9
OTHER	8	1.6
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Total	496	100.0

C. Frequency of drug use past 30 days

	Frequency	Percent
1-10 times	53	10.7
11-30 times	137	27.6
31-60 times	180	36.3
61-90 times	98	19.8
> 90 times	24	4.8
missing data	4	0.8
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Total	496	100.0

D. Ever been in drug treatment or detox?

	Frequency	Percent
NO TREATMENT OR DETOX	319	64.3
YES, DETOX OR TREAT	177	35.7
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Total	496	100.0

E. Times used injectable drugs past 30 days

	Frequency	Percent
No injection Use	273	55.0
1-4 times/month	69	13.9
5-8 times/month	30	6.0
9-16 times/month	29	5.8
17-30 times/month	39	7.9
31-60 times/month	27	5.4
61 thru highest	26	5.2
missing	3	0.6
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Total	496	100.0

Respondent Demographics

To date, we have recruited more than 550 active drug users into our HIV prevention project. We have a total of 496 individuals with sufficient longitudinal data collected to be analyzed for this paper. Each individual accepted by the project is screened for injection drug use (needle tracks and positive urine screen for heroin, cocaine, or amphetamines) or crack cocaine use (positive urine screen for cocaine) prior to acceptance in the project. Table 1 provides a demographic overview of the client population for the project.

The following sections describe the network structural relationships among these individuals and the HIV, drug and incarceration risks encountered by them.

Hypothetical Relationships of Aggregate Network Structure to Individual Risk Taking

The project uses an active outreach recruitment model, following targeted sampling procedures to identify and recruit active drug users into a HIV prevention program. The model includes a network based recruitment and intervention design (Trotter *et al.*, 1994). Recruitment is accomplished by outreach workers with extensive knowledge of the local drug culture. Individuals are recruited by network, and the intervention efforts are both individually psychosocially focused and network focused. Following informed consent, individuals are administered an extensive Risk Behavior Assessment instrument, offered HIV testing and counseling, and provided with one of two different HIV and drug risk reduction interventions which the project is testing for efficacy and impact.[4] Data relevant to the project goals are collected at each intervention session, and at a 6 month follow-up session. The network data collected includes ethnographic mapping of network connections, ego-centered network attributional characteristics, and full network relational data. The Risk Behavior Assessment (RBA) is conducted both at baseline and at six month follow up (Risk Behavior Follow-up Assessment, RBFA).

Our previous research (Trotter *et al.*, 1994) demonstrates that it is possible to use a network approach to identify individuals who may be the most effective at disseminating prevention information and skills in their networks, as part of an HIV or drug intervention program. In this article, we are exploring the next level of aggregation of that relational data. In addition to discovering the centrality, influence, or position of individuals in a network, it is

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[4]. The RBA (Risk Behavior Assessment) instrument, and companion RBFA (Risk Behavior Follow-up Assessment) administered at six month follow-up, were created for the National Institute on Drug Abuse's Community Research Branch as part of the Cooperative Agreement Program. The instruments are standardized and administered at 21 sites, including our own, testing HIV prevention and intervention programs for active drug users. The instruments contain over 300 self report variables on drug history, current drug use, sexual behavior and preferences, injection drug use information, and other risk variables. In addition to these instruments, we administer several project generated psycho-social, ethnographic, and network instruments to project participants. We only selected a small sample of the most common composite drug use, sexual, and incarceration history variables from the overall data available, in order to conduct an exploratory analysis of the utility of the approach identified in this paper

also possible to create overall network structural measures. These measures indicate the social equivalence of groups that are "loose" or "tight." The social bonds that hold some groups together can be either frequently or infrequently activated. The relationships can be densely packed, with everyone having a one to one relationship with everyone else, or they can all be bonded by a small number of relationships that need "go betweens" to get from one point in the network to other points. Our hypothesis is that the nature of these relationships (tight to loose, dense to dispersed, few to multiple connections among members) has an impact on the average level of risk that is encountered by a network member over time. The group can be strongly cohesive, or only weakly associated with one another. Therefore, measures of network structure should show a significant relationship to the HIV, drug, and incarceration risks of individuals when the network is characterized by standard measures, such as the amount of information that passes through a particular individual; the length of time it takes information to reach each person in the network; measures of differential influence in the group; and measures of the probability that someone can or cannot receive information that is moving through the network (cf. Doreian 1974; Ford and Fulkerson 1956; Katz 1953; Taylor 1969). Given these options, we chose three measures of network structure for the purposes of this analysis. These are network density, transitivity, and Bonacich eigenvector centrality. These measures represent three different approaches to understanding the elements of network structure that may have a significant impact on risk taking behavior (Borgatti 1993; Bonacich 1972).

Density is a measure of the number of connections that the average individual in a network maintains with other individuals, divided by the total number of possible connections. Perfect density means that everyone in a network is directly connected with everyone else. A high density network should have frequent and easy communication among all members. Theoretically these connections should lead to high consensus about social norms for risk taking, interpersonal interaction, and all of the characteristics of a "tightly knit" group. The range of behaviors (frequency of drug use, etc.) should cluster more tightly around the mean than in less dense groups.

Transitivity can be measured as the proportion of transitive triplets in a network. A transitive triplet is a set of three people who, if person *W* is connected to person *X*, and Person *X* is connected to person *Y*, then, theoretically, *W* should also be connected to *Y*. It can be thought of as a measure of the number of friends-of-friends who are linked back into a triadic relationship with the original friend. The measure determines the number of these triads in a network, compared to "broken" triangles. A highly transitive network should have a high degree of reciprocity, and it should show a strong agreement upon, and reinforcement of social norms, since the friendship networks would tend to move back in upon themselves rather than extending into other networks.

Finally, Bonacich's eigenvector centrality is a statistic which computes the relative centrality (Bonacich 1972) for each individual in a network, and provides an overall network centralization index for the network. Centralization may be seen as a measure of the variance of centrality among actors in a network: to the extent that centrality is concentrated in just one or two individuals, the network is highly centralized. Theoretically, in less centralized networks the actors are more independent of each other, and the less likely they are to influence each others' decisions about risk taking. Thus, a highly centralized network should show more uniformity of behavior than a decentralized network.

This paper is an exploratory venture that is intended to help us structure new prospective data collection and analysis tools and hypotheses, based on what we have learned from our current use of network analysis. Both our ethnographic data collection and much of our network data collection have evolved as we have identified new areas for exploration. Thus, many of our current analytical strategies are post hoc, rather than designed *a priori* for single variable hypothesis testing. Consequently, we are using conservative probability estimates for identifying significant relationships between variables, following the Bonferroni model (cf. Dunn 1961). Using the Bonferroni adjustment, relationships in the data were considered significant if $p < .008$. for the tests described below.

Results of Comparison of Network Structure Variables and Individual Risk Taking Behavior

To date, we have conducted full relational analysis on 10 drug using networks, out of the total of 29 networks identified for the project. Each network member was asked to define his or her relationship to all other network members on the basis of 12 questions. The questions explore four key relationships which we believe provide us a theoretical basis for exploring HIV and drug risk reduction interventions among active drug users. These relational areas include interactive drug relationships (Drug Relationship measures), social relationships (Social Relationship measures), measures of intimacy (Intimacy and AIDS communication measures), and measures of the level of reciprocal trust among network members (Trust measures). For the purpose of this paper, we analyzed the relationships between individual risks and composite network measures of the AIDS, social, and drug relationships questions only. The intimacy questions and the trust questions will be analyzed at a later date. The actual questions used to create the matrix of relationships used in our network analysis are presented in Table 2. The questions used in the analysis are indicated by bold lettering.

The data from the matrix questionnaires were analyzed using UCINET IV software (Borgatti, Everett and Freeman 1993). The reciprocal individual judgements about each relationship in the network were recorded as valued adjacency matrices. The relationships were then transformed into a composite measure for each of the three areas (AIDS relationships, Social relationships, and Drug relationships) using the WAVG routine. Each composite matrix was then analyzed for the common structural measures available in UCINET IV. These included density, transitivity, distance measures, influence measures,

TABLE 2. NETWORK RELATIONSHIP QUESTIONS FOR ACTIVE DRUG USING NETWORKS

DRUG Relationship measures
How often do you use drugs with____?
How often do you go to___ for drugs?
How comfortable would___ be to share works with you?

SOCIAL Relationship measures
How close a friend is____?
How much do you hang around with.

Intimacy and AIDS Communication measures
How comfortable would you feel discussing AIDS with.

If you had AIDS, how willing would you be to tell___?
How comfortable would you feel discussing an affair with_?
How comfortable would you feel discussing unwanted sex with_?

TRUST
How honest is_ with you?
How often does _ tell important things to you?

and both structural equivalence and clique analysis. The results allow us to identify the network qualities of both individual and group level relationships. Only the relationships between overall network measures and individual risks are reported in this paper. Significant relationships also exist between individual network structural conditions and risk taking behavior, which will be reported elsewhere.

Table 3 presents correlations between structural aspects of individuals' network environments, computed at the individual level, and measures of individual risk collected in our risk behavior assessment.

TABLE 3. SIGNIFICANT RELATIONSHIPS BETWEEN NETWORK STRUCTURAL MEASURES AND MEASURES OF INDIVIDUAL RISK TAKING

	Network Type	Network Density (N = 228)	Transitivity (N = 228)	Centralization (N = 228)
Frequency of Drug Use (30 days)	A	.29	.21	-.21
	D	.19	.21	-.22
	S	.ns	.27	-.17
Frequency of Injection Drug Use (30 days)	A	.29	.29	-.30
	D	.20	.ns	-.19
	S	.20	.18	-.27
Polydrug Use Past 48 Hours	A	.24	.25	-.22
	D	.25	.24	-.21
	S	.29	.30	-.27
Sex with IDU vs Non-IDU Partners	A	-.33	-.19	.26
	D	-.22	.ns	.ns
	S	-.25	-.22	.23
Number of STD Infections Lifetime	A	.ns	-.13	.ns
	D	-.23	-.20	.ns
	S	-.21	-.22	.ns

Legend: A = AIDS communication questions, D = Drug relationship questions, S = Social relationship questions. Unless marked "ns" all correlations are significant at the 0.007 level.

The data indicate that increased overall social "tightness" of networks (density and transitivity) is associated with increased risk taking by members of the group. In this case, the frequency of drug use, the use of injection drugs, and polydrug use all increase as density and transitivity increase. Drug related risk behaviors decrease with the dispersal of the Bonacich centrality within the network, indicating that they are lower where peer pressure is less effective. On the other hand, there is an inverse relationship between structural conditions and sexual risks. Both the percent of partners who are non-IDU partners, and the number of STD's reported by clients (lifetime) decrease as the networks become denser and have a higher degree of centralization (both measures of how well people know one another and have knowledge about each other). The centralization measures did not meet the Bonferroni criteria for significance for STD's, but there was a positive correlation between increasing numbers of IDU sex partners and the network centralization measure. The data suggest that knowing these measures for a significant portion of the network members provides a guide to the behavior of newly recruited members, which allows for a better targeting of HIV prevention strategies at both an individual and group basis.

In addition to the significant relationships identified in Table 3, there were several trends that surfaced during the exploratory data analysis. These included relationships between total time spent in jail and three network centralization measures: AIDS degree centrality [$r(226)$ = .18, p=.008], Drug Bonacich centralization [r (237) = .18, p=.007], and Social Bonacich Centralization [r (237) = .18, p=.007]. Our ethnographic data indicate that drug users are most at risk for being identified to law enforcement officials by members of their own networks, rather than others, in order to avoid jail time when they are caught. These centrality relationships appear to support that information. Other significant relationships between network structure and individual risk included times used injection drugs in past 30 days (Drug Closeness centralization, $r(252) = -.33$, p=.002), and level of condom use (Drug density measure, $r(239)$ = -.20, p=.002). There were also some trends for key risk variables including percent of condom use and social transitivity [$r(228) = -.16$, p= .012) as well as total jail time and all transitivity measures (social transitivity, $r(237) = -.16$, p.007; drug transitivity, $r(237) = -.18$, p = .007; social transitivity, $r(237) = -.18$, p = .006). Each of these relationships provides confirmation that overall network structural measures are an appropriate tool for exploring aggregate levels of risk taking in drug users networks. As a potential intervention tool, they suggest that drug networks can be segmented by structural type, and that interventions can be more tightly targeted, using aggregate network measures to suggest more tightly defined individual and groups interventions.

Theory, Procedures, and "Proxy Measures" of Network Structure Related to Individual Risk Taking

Given the success of linking full network structural measures with individual risk taking behavior, we felt it would be useful to explore possible links between broad (proxy) network structures and individual risky behavior. We chose three potential proxy measures that in some ways parallel the structural relationships described above. These are network type, project recruitment order, and single or multiple network membership.

Network Types and Their Relationship to Risks

Previous research has demonstrated that ethnographic typologies of drug networks are a useful tool for understanding and targeting differentials in risk taking behavior in hidden populations (Trotter *et al.*, 1994). These typologies advance our understanding of some of the important social relationships among drug users, and can be used to generate hypotheses about drug use and specific HIV risk conditions. They also help target outreach and prevention, depending on the characteristics of the network type. On a broad level, our network typology is a proxy for the network density measure described above, since the classification is based on how well network members know each other, how well connected they are with each other, and the types of social activities they engage in as a group.

Type A (mature injector networks) are closed systems in which members allow virtually no new recruitment. Group size ranges from approximately 5 to 10 individuals. Type A networks often include individuals from a variety of social, economic and ethnic backgrounds. The most commonly encountered drug use for this type of group is heroin, although other drug preferences were found in Type A groups. The primary purpose of the group is to pool resources for the acquisition of drugs. Joint drug use activities do not extend beyond scoring, for the most part. Type A drug use tends to be very secretive. Most of the members are married or in monogamous relationships. They are employed at various economic levels. They may use on a maintenance level during the week and get "loaded" on weekends or special occasions. The major area of risk for HIV transmission is the contact with persons outside their own group (weak ties), when they come in contact with outsiders whose HIV status is unknown. For the most part, this type of network does not include the exchange of sex for drugs.

Type B drug networks (kin based groups) are semi-closed and are predominantly kinship groups (family, in-laws, or fictive kinship such as compadrazgo relationships in the Hispanic community). One is either born into, marries into, or has a steady sexual partner in the group, with rare exceptions. The members have gone to school together and were often raised together. The groups tend to be homogeneous in socioeconomic status and ethnic identification. Drug use within these groups could be considered a family tradition. The individual has very strong pressures to conform to group norms. The non-user is considered to be sending a message condemning the group's behavior. The HIV risk areas for this type include sharing works between family and friends. For the most part, these networks involve individuals with long standing monogamous partnerships, and there is not a significant amount of exchange of sex for drugs, although there is co-use of sex and drugs in some of the partnerships. These groups can have any one of several drugs as the drug of choice for the group, with the most common being cocaine, crack, rock, crystal meth, marijuana, and alcohol.

Type C networks (friendship based networks) are semi-open systems whose members cop (buy drugs) together and are socially bonded by drug use. These networks are relatively homogeneous in terms of socioeconomic status and ethnicity, but they are more mixed than Type B groups. The predominant social bonds in the group are long term friendships, although some kinship relationships are normally present. Individuals in these networks involve one another in both drug use and in other types of social activities. The members are often connected through work, as well as socially. These groups are somewhat open to recruitment of new members, although it takes time. The groups also tend to include both injectors and non-injectors in the same network. The risk areas for this group include the sharing of works "among friends." Sexual activity may also be present within the group, with multiple sexual partners a possibility, and with some changing sexual relationships within the group over time. There appears to be some exchange of sex for drugs, although this seems to involve on-going social relationships rather than commercial transactions.

Type D (acquaintance) networks are the most open of the four types. They often include poly drug users who bridge or skip from group to group, The most common drug used is crack cocaine. The crack dealers operate more openly than most of the other suppliers, and profit is a major condition for establishing a relationship with recruits. Introduction into the group can be accelerated if an individual has become a known buyer. Individuals in these groups regularly exchange sex for drugs, and there is far more "impersonal" exchanges of this type than in the other groups, including a considerable power differential between the person giving the sex for the drug, and the person in control of the drug (and consequently in control of the sexual activity). These groups are normally heterogeneous in terms of ethnicity. The socioeconomic status of group members can also vary to a considerable degree. These networks tend to consist of users who are new in the area and are looking for contacts, people who have progressed to a drug use stage that makes them unattractive to members of the more closed groups, users in transition between groups, or young drug users who have not been recruited to a stable network. The Type D groups appear to be at the highest risk for HIV infection, due to a full range of sex for drug activities (commercial and non-commercial), and needle sharing with strangers. They also include a large proportion of individuals who are highly mobile and who are likely to move back and forth to nearby urban areas during the year, increasing local risks due to contact with higher HIV prevalence sites.

TABLE 4. IDENTIFICATION OF LOCAL NETWORKS BY NETWORK TYPE

Network Type	Frequency	Percentage
Type A	4	10.2
Type B	6	15.4
Type C	14	35.9
Type D	15	38.5
	39	100.0

Table 4 identifies the distribution of each type of network, out of a total of 39 networks identified to date and recruited into participation in our project. Individuals in our prevention project are assigned to a particular network based on six inclusion/exclusion criteria; four social criteria and two drug use criteria. If they cannot be assigned to a network, they are designated an isolate. The distribution of individuals recruited into our prevention project across each network type is presented in Table 5.

Given the differences in social activities, types of drug use, openness or restrictions of recruitment, and the knowledge that members do or do not have of one another, we would hypothesize that there will be significant differences in individual risk taking behavior associated with different network types. If true, then knowing the associations between type and risk would be a valuable public health tool, since it is far easier to assign a network type based on the criteria we use (it can be done by outsiders) than to collect the data necessary for full relational analysis.

TABLE 5. DISTRIBUTION OF INDIVIDUAL RESPONDENTS BY NETWORK TYPE OR ISOLATE STATUS

Network Type	Frequency	Percent
Isolates	22	4.3
A-Closed Injector	40	7.9
B-Kinship	48	9.5
C-Friendship	158	31.2
D-Open access	239	47.1
	507	100.0

Recruitment Order and its Relationship to Risks

The second relationship we felt should be explored is the rank order of recruitment into the project. We assumed that risk taking is a generalized, rather than a specific activity. Therefore, the individuals who are most likely to accept early recruitment into our program are more likely to be higher risk takers than the individuals recruited from the same network later in the process. In this case, we felt that this relationship might be a proxy measure for individual centrality, based on the assumption that the individuals most willing to try out a new program were also those most likely to take the lead in other social undertakings, or in risky behavior.

Multiple Network Membership and its Relationship to Risks

Finally, we hypothesized that participation in two or more networks involved more potential risk and risk taking than membership in a single network. This is a very general proxy for network structure relating to connectivity, and perhaps to role and position in the network. In some ways it is the reverse of transitivity. It is a measure of ties outside, rather than within a group, especially those that tend to be dyadic, rather than triadic. We used both ethnographic data (direct observation by project ethnographers and outreach workers) and self report to project personnel to identify individuals with single or multiple network participation. The criteria used was that an individual had to be actively using drugs with both networks and had to meet at least one of the social criteria for network membership (described above) to be assigned to the multiple network membership category. Table 6 summarizes the multiple network assignment category.

TABLE 6. SINGLE OR MULTIPLE NETWORK MEMBERSHIP

	Frequency	Percent
Single group members	321	66.5
Member of multiple groups	162	33.5
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Total	483	100.0

Comparison of Proxy Structural Variables and Individual Risk Taking Behavior

We found significant relationships between each of the three proxy measures of network structure and individual risk taking behavior.

Network Type and Individual Risk Taking Behavior

We tested whether or not there were significant relationships between the network structural measures taken for each of 10 networks and the network type assigned to that network. This process was intended to provide a cross validation for the typology system. In this case, every relationship tested between network type and overall measure of network structure (density, betweeness, closeness, degree, flow betweeness and power) was significant for each set of network relationships tested (AIDS communication measures, social relationships, and drug relationships), based on oneway ANOVA analysis, utilizing a Bonferroni adjustment for establishing level of significance, and based on the most conservative measures of significant relationships.[5]

[5]The F ratios calculated for these tests ranged from the lowest [$F = 4.20$, $p=.006$] for the AIDS questions network density measure, to the highest [$F = 70.03$, $p = .000$] for the drug questions related to network betweeness centralization. The actual measures for each structural network measure

The next step was to compare network type with individual reports of risk taking behavior. This allowed us to identify the significant differences between network types which act as a proxy for understanding the context of drug and HIV risk for active drug users. Significant relationships were identified, by network type, for the number of times individuals used injectable drugs [χ^2 (20, *N*=492) = 50.66, p<.000], frequency of use of common IV drugs in the past 30 days [χ^2 (20, *N*=493)= 50.82, p<.000], and percentage of IDU sex partners [χ^2 (8, *N*= 493) = 20.34, p<.008]. Another relationship which showed a tendency toward significance was times individuals used non-injection drugs in the past 30 days [χ^2 (20, *N*=484) = 30.74, p=.016). The amount of times individuals were arrested and the total amount of time they have spent in jail did not vary significantly across the different types of networks.

The primary differences in individual risks by network type, for the number of times individuals used injectable drugs, were the differences between the Type A (injector) and the Type D (open access) networks, compared with each other and the other two types. The highest percentage of non-injectors (77.3%) occurred among the isolates recruited by the project. These are individuals for whom there is no known connection with a drug network, based on the criteria described above. The Open Access, Type D, networks also contain a much higher number of non-injectors (60.8%) than the Type A (42.1%), Type C (47.4%), and Type B, kinship based networks (54.2%). At the other end of the usage spectrum, those individuals who inject more than 31 times per month comprised only 9 percent of the isolates, but 18.6 percent of the Type A network members, 14.6 percent of the Type D networks, and only 6 percent of the Type C, friendship networks. No one in any of the kinship networks, Type B (*N*=48), reported injecting drugs more than 30 times per month. The frequency of use of common IV drugs followed very similar patterns.

The network types provided evidence for significant differences in whether or not our respondents had sex with injection drug using partners. The majority of the isolates (75.0%) reported having no IDU sex partners, while 18.98 percent of the isolates claimed to have all of their sexual partners be injection drug users. The kinship networks, Type B, had the lowest percentage of respondents who stated that all of their sexual partners were IDU's (11.6%). The Type B respondents stated almost three times as often as all of the other three groups that some, but not all, of their sex partners were injection drug users. This group appears to include a more heterogeneous mix of injection and non-injection users compared with the other groups. This can be contrasted with the Type D, open access networks, where the number of respondents with only IDU sex partners is about the same (13.0 percent), but a much higher percentage (78.1%) state that they have no known IDU sex partners. It is interesting that the injection networks, Type A, and the friendship networks, Type B, fall between these reported conditions with 64.5 percent and 63.3 percent, respectively, reporting that all of their sex partners are injection drug users.

It should be briefly noted that several other key characteristics vary significantly by network type in our sample of small town drug users. The gender ratios of the networks varies significantly [χ^2 (4, *N*=493) = 39.34, p<.000) from the overall 70 percent male, 30 percent female ratio. Females are found in the highest percentage (64.6%) in the Type B, kinship networks, and in the lowest percent in the open access, Type D, networks (20.6%). Males are

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are available upon request. In particular, the three measures reported above (Density, Transitivity, and Bonacich Centralization) were all significantly associated with network type.

found less frequently among the isolates (59.1 percent) than would be expected. The male to female ratios of the other network types are Type A (male = 74.4%, female = 25.6%) and Type C, friendship (male = 67.3%, female 32.7%). Ethnicity varies significantly across network types as well [χ^2 (20, *N*=492) = 65.90, p<.000). The highest percentage of African American respondents are found in open access (Type D) networks (74.5%), and the least as isolates (1.1%). Anglo respondents are found in the highest percentages in both the open access (43.6%) and the friendship networks (38.2%). The lowest percentage of the total Anglos is found in the kinship networks (4.2%). Hispanics, in contrast, are found most frequently in the kinship networks (52.1% of all individuals associated with kinship networks), although the highest percentages of Hispanics, compared with all other Hispanics, are found in the Type C (33.7%) and Type D networks (33.1%).The Native American respondents follow a similar pattern, compared with the Hispanics. They constituted a higher percentage of the individuals in kinship networks (20.8%) than the Anglos and African American respondents, although the within group comparison indicated that they were most frequently associated with open access (46.0% of all Native Americans) and friendship networks (33.3%).

The variability in risk profiles combined with the sociocultural configurations of the network types clearly indicates that this is a powerful proxy measure for network structure. This finding provides strong support for targeting elements of drug and HIV risk reduction programs by identifying the network type for individual respondents, taking into account the different cultural parameters of the network types.

Project Recruitment Order and Individual Risk Taking Behavior

We were able to show that the overall program recruitment order data (the rank order in which each individual was recruited into the project as a whole) did correlate with several network structure measures that either met our conservative significance test (Drug Density, *r*(239) = -.20, p = .003; Social Flow Betweeness, *r*(228)= .18, p=.005) or showed trends toward significance (Social Betweeness, *r* (239) = .15, p=.026; Drug Closeness, *r* (228) = .17, p=.011; Social Closeness, *r* (228) = .14, p=.028; Drug Degree Centralization, *r* (228) = .15 p=.023; Social Degree Centralization, *r* (228) = .16, p=.013). However, we feel there are a number of intervening conditions that make the overall rank order of recruitment for a project a less-than-ideal proxy measure for network structure. At the very least, it mixes individuals from distinct networks, and obscures the recruitment order in those smaller units. Consequently, we do not feel that the overall recruitment measure is precise enough to use as a public health proxy measure. In fact, only one significant relationship emerged from the exploratory analysis, the number of times that an individual had attempted drug treatment. This was inversely and mildly correlated with recruitment order [*r*(496) = -.18, p=.001]. This finding supports our ethnographic data which indicates that we are systematically moving into networks that are more resistant to both drug and HIV intervention, as we saturate the drug using networks in town. However, overall recruitment order appears to have little significance to HIV risk reduction efforts.

Subsequently, we calculated the within network recruitment order for each network, using the RBA administration date to create a rank order of recruitment within each network. We compared that ranking with individual risk taking variables. Two conditions were significantly correlated with the measures of within network recruitment order. These were a positive correlation between recruitment order and having an non-IDU sex partner, i.e., later arrivals were more likely to have no injection drug user sex partners, [*r*(496)= .14, p= .003], and a negative correlation between having been in treatment or detoxification programs and recruitment order [$r(496) = .18$, $p=.000$). Early arrivals in each network were more likely to have tried treatment than the later recruits in the same network. These findings provide some support for using order of recruitment as a proxy measure of network structure. It appears that it would be worthwhile to develop more precise measures of both recruitment order and of risk variables that are associated with it. However, as an overall proxy measure, it was less useful than the ones described above.

Multiple Network Membership and Individual Risk Taking Behavior

We calculated the relationship between single versus multiple network membership among our population of active drug users, compared to network structural measures and to individual risk. We used general ethnographic data to identify the existence or absence of multiple network membership. However, this may be a case in which the definition of membership and the criteria for inclusion or exclusion from a network need to be more carefully defined. We would recommend further exploration of the process for identifying multiple membership. Nevertheless, there were two suggestive relationships between multiple network membership and network structural variables for the networks where we had full network data. One relationship was between the drug relationship questions and multiple network membership measured for betweenness centralization, using a oneway ANOVA with membership (F=12.4519 p=.008), and the other was a significant relationship between drug "flowbetweenness" and multiple network membership ($F = 9.36$, p=.033). Therefore we proceeded to compare this membership variable with individual risk taking.

Several conditions showed a significant relationship between individual risk taking and multiple network membership. These included the number of times individuals used injection drugs in the past 30 days ($F = 9.36$, p=.002), their frequency of use of common (cocaine, heroin, amphetamines) injection drugs ($F = 12.4519$, p=.001), and times injected drugs in the last 30 days ($F = 6.52$, p=.007). Several other relationships showed a trend toward significance. These included ever having been in drug treatment ($F = 4.18$, p=.041), having tried to get treatment but unable to do so ($F = 4.44$, p=.036), and the total time individuals have spent in jail (F=5.36, p=.020). Each of these relationships indicates that individuals with known multiple network memberships are more likely to be taking higher levels of risk than those confined to a single network. They use more drugs, use drugs more frequently, are more likely to be injectors, and are more likely to have done more jail time. On the positive side, they are also more likely to want to try treatment, and to have already been in treatment programs. They may be very good bridges between single network members and the outside world. There are enough interesting results from this test to suggest that this condition be explored more thoroughly in a prospective study with a methodological design more suited to this variable.

Conclusions

This analysis was intended as an exploratory venture, using both theoretical definitions of network structure and empirical data that could be used to conduct post hoc tests of connections between network structure and HIV risk. It was assumed that both classic and proxy measures of network structural or environmental conditions would be directly related to drug, HIV, and incarceration risks for members of active drug using networks. The results of the study are very promising on two levels. First, it is clear that the overall measures of network structure, which can be computed from network relational data, are clearly associated with differentials in individual risk taking behavior. This condition shows a great deal of promise for both research and intervention work being conducted with drug users. Wherever network structural data can be collected, these data can provide important guidelines for targeting both general (social diffusion style) and specific (individual psychosocial) prevention messages, behavioral training, and assessment strategies.

On the second level, it appears that it is feasible to move from actual network analysis to proxy measures of network structure. The proxy measures we tested all showed evidence of being correlated with individual risk taking behavior for drug network members. This is a promising for risk reduction efforts that must be embedded in public health programs, or must be conducted using public health or other community based approaches. Although the actual measures need a great deal of refinement, even these preliminary findings could be used to improve the targeting of some programs. For example, simply asking individuals to self identify as members of either single or multiple networks, assuming a valid question to determine this condition, provides a direct indication of both the types and the levels of risks that the individual is most likely engaged in, allowing for improved specificity of the intervention messages directed at that individual. Full network approaches may be more effective, but they are also more expensive and time consuming. A mild drop in efficacy, accompanied by a significant reduction in the time and cost of targeting messages correctly to individuals, appears to be a worthwhile trade off for this process. Further exploration of these types of direct and proxy measures of network structure, and their relationship to risk taking and the improvement of HIV and drug intervention efforts appear to be extremely valuable directors for prevention research.

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