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Drug Abuse and HIV Prevention Research: Expanding Paradigms and Network Contributions to Risk Reduction

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This paper identifies an important paradigm shift in social research on HIV transmission, drug abuse, and risk reduction research. The article describes the key research trends and the institutional support for social network analysis in the HIV and drug risk field for the past decade. Key hypotheses and recommended areas for future research are identified.

Introduction

The current paradigm for HIV and drug prevention research is going through a rapid expansion that includes the use of social network theory, methods, and practical implications. Most epidemiologic and prevention research on HIV/AIDS transmission, substance abuse, and high risk behaviors has been conducted in urban settings targeting injection drug users (Castro, Valdiserri, & Curran, 1992), gay/bisexual groups, the sexual partners of injection drug users, or other high risk individuals. In the recent past, some attention has also been given to HIV infection moving into smaller towns and rural areas (Gardner *et al.* 1989, Conway *et al.*, 1992, Woods *et al.*, 1992, Trotter *et al.*, 1994). These studies emphasize that HIV infection is most commonly spread through multiple person use of contaminated injection equipment and through unprotected sexual relationships.

The majority of the research on HIV risk reduction or HIV prevention has concentrated on changing individual risk-taking behavior and understanding the theoretical underpinnings of the individual's likelihood to modify risky behavior. It was clear from the outset that studies based on individual behavior had a positive effect on risk reduction (Holtgrave *et al.*, 1993). Unfortunately they were not as successful as hoped. This paper, and the companion articles in this issue of the journal, constitute an expansion of the existing paradigm, providing evidence for the need to move both the theoretical understanding of HIV intervention efforts and empirical studies of risk taking behavior to a more complex and contextualized level of analysis. This does not negate the importance of individual level studies, but it does point out the need to include other forms of analysis. The assumption that the individual is the primary focus for change is restrictive, and fails to bring into the equation the micro and macro social

environment. This article provides an environmental-epidemiological rationale for the use of network analysis to explore the facilitating factors or barriers to the transmission of HIV infection in drug using populations. And, it presents a brief overview of the theoretical, empirical, and practical conditions that have led to the current paradigm expansion illustrated in this journal issue.

Recent Network Research in HIV High Risk Populations

In its broadest sense, a social network involves both a set of people and the sum of the linkages among them. Large social networks contain smaller webs of individuals involved in personal transactions. Among these smaller webs are "HIV risk contact" networks whose members are at high risk of HIV infection due to the extent and nature of their connections with infected people in the same or connecting webs. Members of drug injector networks, for example, are at elevated risk for HIV transmission because of the plentiful opportunity for multiple person events such as sharing needles and other drug paraphernalia or having unprotected sex with an HIV infected person (Wallace, 1991; Friedman, DesJarlais *et al.*, 1987; Klovdahl, 1985). Conceptually, then, studies of drug injector networks have a critically important role to play in explaining the spread of HIV.

The traditional focus of HIV related social research has been on determinants of individual risk behaviors. It derives from the psychological literature and corresponding methodologies. It tends to analyze on the basis of aggregated personal data, and it interprets the probability of HIV transmission on the basis of individual self-reports. In contrast, the network paradigm focuses on behavioral dynamics or transactions of network members. It is derived from the sociological, epidemiological, biological, and anthropological literatures. It analyzes network characteristics and membership, and it interprets HIV transmission probabilities from network features. The social network research paradigm explores the influence of partners, peer groups, community norms, and structural contexts of risky behavior. Recognition of the interplay between personal behavior and social structure permits an explicit distinction between viral transmission (an interpersonal event) and epidemic propagation (a social event).

The merger of the social network paradigm with epidemiologic concepts of infectious disease transmission has resulted in the confluence of several lines of investigation. The primary lines include incorporating ethnographic data into the sampling and evaluation of networks, combining network techniques and epidemiologic approaches to study groups at risk, and using mathematical modeling to describe disease transmission in high risk groups.

Ethnographic Approaches

Network analysis, mathematical modeling, and epidemiologic approaches to disease transmission have all benefited from the role ethnography has played in understanding networks of drug users or other risk taking groups. The sociocultural information developed from ethnographic research in hard-to-reach settings has helped to avoid at-risk populations being de-contextualized, de-socialized, and de-humanized. We know that HIV infection in a population does not occur randomly; rather, HIV is endemic in sex partner and drug user contact networks. Not all individuals in the drug injector risk category are at equal risk of infection, however, nor are injectors from the same area at equal risk, despite having similar rates of risk behaviors (Robles *et al.*, 1992; Williams, 1990). In fact, one of the striking findings of the present

epidemiology is the great variation in HIV spread and cumulative seroprevalence rates among IDUs in different geographic locations (regions, states, cities, and neighborhoods) and across different racial/ethnic and gender groups. This condition strongly recommends the use of ethnographic network mapping techniques to complement other social network approaches.

Combining ethnographic approaches with the collection of egocentric data and full relational network information has proven to be a fruitful method of inquiry. For example, in Flagstaff AZ, a five year project (NIDA Grant # U01-DA07295; part of NIDA's Community Research Branch Cooperative Agreement program) combines network and individually based interventions for four cultural groups: African Americans, Anglo Americans, Hispanics, and Native Americans (Trotter *et al.*, 1994). The project has enrolled close to 600 active, not-in-treatment, injection drug and crack cocaine users (Trotter, *et al.* 1994), in three small towns. These individuals are members of 48 drug networks, plus some isolates. The networks range in size from 2 to 45 people, and the serostatus of the networks ranges from 0% to 50% HIV positive. The combined approach of these investigators has permitted the delineation of a typology of drug using networks that provides important contextual information for assessing or reducing risky behavior (Trotter *et al.* 1994, Trotter *et al.* 1995 in press). The networks differ with regard to the patterns of drug use, the sharing of needles, and the frequency of unprotected sexual encounters. These and related data are useful for targeting intervention and education activities for the highest risk groups based on multiple risk criteria. They also contain important information about the sub-epidemics that are likely to be part of HIV transmission and drug use. These findings have led to the creation of intervention models that expand the current psycho-social paradigms for HIV risk reduction.

Two articles presented in this volume, Johnson *et al.*'s "Truth or Dare..." and Elwood's "Lipstick, Needle and Company...", are strong examples of work in the parallel area of ethnographic network research on sexual risks and HIV, while Rothenberg's "Sampling in Social Networks" complements these pieces by presenting the rationale for using ethnographic information as an ongoing tool for validating the representativeness of a network sample chosen by non-random methods.

Network Techniques and Epidemiologic Approaches

The current explanations for variability in seroprevalence and seroincidence include asynchronous viral introduction, the size of susceptible populations, differences in prevalence of high risk drug use, needle sharing, needle hygiene and sexual behaviors. But these factors alone are not sufficient to explain the variation. Individually based cohort studies of drug user histories and practices have not provided the additional answers necessary to fully understand the epidemic, especially where they fail to account for the structure and dynamics of drug injector risk networks or the transactional nature of risk behaviors (e.g., behavioral sequences in multi-person drug using, needle sharing, and needle disinfecting events) and the HIV serostatus of participants in drug using events. By approaching behavior from a less micro, more intermediate level perspective, network analysis has the potential to more fully illuminate the pattern of spread and prevention of HIV infection. While there are undoubtedly many explanations for the phenomenon of variable seroconversion rates, work to date suggests that patterns of HIV seroprevalence might be better understood using models that focus on dyadic, triadic, or larger group behavior interactions related to needle sharing and/or sexual practices.

Following this lead, lines of inquiry began emerging during the mid-1980s which used network concepts to focus on the transmission of HIV. Using an early group of persons who became ill with the constellation of symptoms now attributed to infection with HIV, Auerbach and colleagues (1984) used network diagrams to demonstrate the interconnections discovered through contact tracing. Grimson and Darrow (1984) showed that the probability that such connections could have occurred by chance was extremely small. Anderson and May began a series of publications that modeled the spread of HIV based on the interaction of subgroups (compartments) at varying risk (May and Anderson 1987; Anderson and May 1988). A small number of recent studies have investigated the social networks, norms and interactions with AIDS related behavior in homosexual men (Ostrow *et al.* 1988). More recently, an important extension of this research was contributed by Morris (1994), incorporating egocentric information on frequency of partner change, use of preventive practices, and age-mixing patterns (assortative versus disassortative age mixing) to model the epidemic curve for gay men in New York City. A number of investigators have also examined alternative assumptions and parameters (Anderson and May, 1988b; Anderson, Blythe, Gupta *et al.* 1989; Anderson, May, Boily *et al.* 1991; Hyman and Stanley 1988; Jacquez, Simon and Koopman 1988; Peterson, Williard, Altmann *et al.* 1990; Allard 1990). In addition, understanding the importance of commercial networks (for the spread of drugs) and personal networks (for the spread of behaviors and infections such as Hepatitis B) led to the application of network concepts and methods (Alperin and Needle 1989) in risk reduction programs.

Other studies have assessed the relationship of social interaction measures with AIDS protective behaviors among IDUs (cf. Friedman 1993, 1994; Hadden, Gilbert, & Muska, 1991; Ouellett *et al.*, 1991, Trotter *et al.*, 1994, Tross *et al.* 1991). Several studies of HIV spread within drug using networks have provided some important insights. For example, investigators have described the phenomenon that the seroprevalence for HIV is higher among African American than among white IDUs (Allen 1989; DesJarlais and Friedman 1989) and that race remains a significant predictor even when behavior is controlled for (D'Aquila 1989; Friedman *et al.* 1989; Lewis 1989). The isolation of networks of drug users that has been observed may account for the failure of transmission between types of networks. Similarly, Friedman *et al.* (1992) have hypothesized that the network interactions of gay women who inject drugs may be the source of their higher prevalence compared to other women who inject drugs. Social network processes also affect risk behaviors and potential interventions. Latkin and colleagues (1994) have provided evidence that social network based intervention may have greater efficacy than standard interventions (i.e., individually directed) in reducing needle sharing, and shooting gallery use. In a study of clients in a short term detoxification program, decrease in drug-related risk behavior was related to reducing the number of drug using friends in the subject's social network. A report on two large networks (Neaigus 1993) demonstrates that risk and social networks converge, and that relationships within them are commonly long-standing and multiplex, often based on kinship, friendship, and economic activity. The importance of social context, both in terms of mixing within and between social networks, has been stressed by Wallace and his colleagues in a series of more than 20 publications (see Wallace 1988 and Wallace 1990). They demonstrate the relationship between urban destruction, dissolution of community networks, the metastasis of risk behaviors and the spread of HIV in the South Bronx. In an extension of this work, eventual spread of HIV to more affluent suburban populations is hypothesized to be based on network mixing (Wallace and Wallace 1993). In this view, the appropriate network-based interventions involve large scale social and economic intervention, because the control of HIV is linked directly to larger social structure rather than to individual behavior change.

In further pursuit of these issues, investigators in Colorado Springs performed a social network investigation involving 595 primary respondents (see Klovdahl 1994 for Methods). Study participants were prostitutes, their paying and nonpaying partners, IDUs, and the sexual partners of IDUs. Each interview elicited information on demographics, past medical history, current risk practices, knowledge about HIV and current perceptions and attitudes about personal risk, as well as persons in their network. The resulting data identified a network (5864 contacts) consisting of a large single connected component and numerous smaller components (Woodhouse 1994). HIV positive persons within the network were for the most part located in the smaller connected components, whichever type of personal connection was used in the analysis (Woodhouse 1994; Rothenberg 1994). This suggested HIV positives were marginalized, and not part of the larger connected group of persons. HIV positive persons who were within a larger connected component — primarily IDUs — occupied a noncentral position in the connected component. These observations indicate that network structure and its particular effect on HIV positive persons may play an important role in inhibiting the transmission of HIV, based on an earlier report that there was little endogenous HIV transmission in Colorado Springs [Woodhouse 1993].

Two articles in this issue represent two different approaches to the network-epidemiology connection. Williams, *et al.*, report on the relationships between epidemiological characteristics of drug abuse, HIV risks and ego-centered network characteristics of active drug users, while Trotter *et al.* provide evidence for correlations between overall network structure (density, transitivity, and centralization measures) or proxies for network roles and structure (network type, recruitment order, and multiple network membership) and profiles of drug, sexual and incarceration risks for active drug users.

Mathematical Modeling

Successful and stimulating mathematical modeling of HIV transmission is currently being pursued from two complementary directions: a network based approach and a population biology approach. These models are derived, in part, from mathematical biology and population ecology (Anderson 1982; Anderson and May 1982). The investigations provide a mathematical framework for incorporating clinical epidemiology (transmissibility, latent period, disease duration) with contact frequency to explore the reproductive rate (R_0, the number of new cases of disease generated by a case), as well as barriers to transmission. By specifying the interaction of groups with varying characteristics, researchers construct models for predicting the epidemic trends of diseases. Hethcote and Yorke developed a model for the spread of gonorrhea in the population based on the interaction of groups with varying characteristics and differing risks (Yorke *et al.* 1978; Hethcote and Yorke 1984). Their models, based on solving a set of differential equations, provide theoretical confirmation of the existence of core transmission groups (networks). Furthering this approach, Rothenberg and Potterat (1988) provided empirical validation of the core concept, and added the discovery of the importance of duration of infectiousness and selection patterns. They calculated the number of days that an infected person's contacts remained untreated in the community, and called this measure "the force of infectivity" (not to be confused with the force of infection, a hazard rate developed by Anderson and others). This measure is a convenient way of describing the potential importance of various group conditions. One important finding was that those who have low self-selectivity generate a force of infectivity more than four times greater than those who do self-select. In modern parlance, geographic disassortative mixing appears to have greater potential for propagation of an epidemic. In a more mathematical approach, these data and those from New York

(Rothenberg ,1983) were used by Garnett and Anderson (1993) to explain the observed epidemiologic patterns of gonorrhea transmission. Turning to HIV transmission, other mathematical modeling approaches are being successfully used by Blower and colleagues (Blower *et al.* 1991, Blower and McLean 1994) to provide very important transmission models of HIV infection in various mixing matrices (networks in our terminology), which can be tested and refined using both qualitative and quantitative network approaches. One of the most important findings from this research is a "behavioral target" that shows the level of behavior change (risk reduction) that must be accomplished in a population (with or without the presence of an HIV vaccine) to reduce the HIV seroprevalence rate below epidemic proportions.

Network Sampling Issues

The paradigm expansion that we are supporting carries with it several very interesting methodological issues, which have critical implications for grant review and funding at the federal level. The individually centered social research paradigm is focused primarily on survey and quasi-experimental research designs. These designs demand a probabilistic approach to identifying epidemiological conditions and to the analysis of key relationships among the variables under study. Both of these approaches necessitate using probabilistic sampling frameworks, and metrically based power analysis of required sample sizes. Some of these assumptions cannot be directly applied to social network analysis, as the following demonstrates, but the assumptions behind these issues can be accommodated using network, rather than individually based analytical processes.

The methodological issues surrounding network based sampling have generated considerable discussion and need future exploration in relation to drug use, HIV risks and the new intervention paradigms. Granovetter (1976) provides the classic discussion of the issues in network sampling. Network sampling is complex and includes both the critical issue of how to sample individuals within networks in order to provide a full description of network relationships, and the issues associated with choosing a sample of networks from all of the networks that might be potentially available for data collection. Klovdahl (1989) provides a concise review of current network sampling issues, including a discussion of his own contribution on the random walk method. Burt and Ronchi (1994) identify a contemporary model for sampling large networks where there is difficulty in reaching all participants. They provide a mechanism for estimating uncaptured relationships, as well as the reliability of captured data. Johnson *et al.* (1989) provide a new model for increasing the analytical power of snowball samples, and Doreian and Woodard (1994) provide an improved method for defining cores and boundaries of social networks, an issue critical to sampling justification. Finally, Marsden (1990) provides an excellent review of survey based (egocentered) network measurement issues. Based on a review of these resources, it is clear that nonprobability samples cannot be avoided in parts of network research, but this condition does not destroy their analytic power. This is an important consideration if network grants are to be competitive for funding from research funding programs that are predominantly based on probabilistic statistical research paradigms. The same condition applies for power calculations in network analysis. In line with this reasoning, presenting a convincing power calculation for at least some of the analysis anticipated in a research proposal has become an automatic necessity for gaining funding from programs such as the National Institute on Drug Abuse. However, power calculations fall prey to the same statistical demons that plague sampling strategies and sample size calculations for networks. This places network researchers in the bind of doing spurious calculations, in order to meet "normative" standards for grant writing. Rothenberg's article in

this issue,"Sampling in Social Networks," presents the rationale for using ethnographic methods as a part of the overall approach to network sampling issues. Further explorations of network based sampling and power issues will be needed to support competitive funding requests from network researchers.

Institutional Support for Network Approaches to HIV and Drug Research

The institutional history of support for network research on HIV transmission and drug related research is fairly recent, but is clearly on a positive curve for increasing support. All but one of the articles in this issue report on research projects directly supported by the National Institute on Drug Abuse (NIDA). This support is the result of a steady effort by NIDA's Community Research Branch and particularly its chief, Richard H. Needle, to expand the existing HIV, drug abuse and sexual risk paradigms. The following table identifies a selected but representative chronology of key institutional events that have supported the development of the network paradigm expansion in drug related research. The majority of projects listed were funded by NIDA, but federal support has also been provided by the National Science Foundation (NSF), the National Institute on Child Health and Human Development (NICHD), the Centers for Disease Control and Prevention (CDC), and the National Institute of Mental Health (NIMH).

TABLE 1. CHRONOLOGY OF INSTITUTIONAL SUPPORT AND SELECTED PUBLICATION EVENTS FOR SOCIAL NETWORK ANALYSIS, DRUG USE, AND HIV TRANSMISSION

1985	Klovdahl, 1985, Social Science and Medicine. First "think-piece" on the usefulness of social network analysis for evaluating the infectious agent hypothesis to study the outbreak of HIV and to develop strategies that limit the spread for infectious disease transmitted through personal relationships. Data Provided by CDC.
1988	CDC funds a cooperative agreement (U64) project in which the government research team collaborates with investigators in Colorado Springs to study the transmission of HIV and other pathogens in a population of prostitutes, IDUs and their personal associates.
1988	Wiebel, NIDA monograph 80, Needle Sharing Among Intravenous Drug Abusers. NIDA-funded (R18) author discusses how ethnographic and epidemiologic methods might be combined to target HIV risk reduction interventions to cohorts of drug users. Drug user networks are viewed in terms of their normative influence on behavior and the prospect of using networks to diffuse information about HIV.
1989	Laumann *et al.*, Science. Authors describe the utility of network research perspective to analyze data from the General Social Survey to track distribution of AIDS. Through network techniques, authors identify proportionately more cases than are reported to the CDC. Partial funding provided by NICHD.
1990	Wiebel (U Illinois-Chicago) receives R01-DA6589 to conduct an "AIDS/IVDU Social Network Panel Study," and Friedman (NDRI-New York) receives R01-DA-6723 to study "Social Factors and HIV Risk." These are the first research grants provided by NIDA to support research in the network paradigm.
1991	Wallace, Social Science and Medicine. In view of AIDS spread in selected U.S. populations, author hypothesizes HIV infection travels in waves along a "socio-geographic network" and proposes that researchers examine the network contexts of behavioral transactions that risk HIV infection. No institutional support.

1991	Blower *et al.*, Phil. Trans. R. Soc. Lond. B. Mathematical model presented on the epidemiological consequences of heterosexual IDU and perinatal transmission of HIV. Results show a significance of interaction model. Predictions for the epidemic were limited insofar as data values for key IDU network variables were uncertain. Partially supported by NIDA and NIMH.
1991	NIDA technical review holds single session on social network analysis to stimulate researchers to use network analysis paradigm/research techniques to explore HIV-related behavioral transactions.
1992	Five of NIDA's U01 grantees from the Cooperative Agreement for Community-Based AIDS Research Program conduct multi-site ego-centered study of drug injector risk networks in their communities (Dayton/Columbus, OH. , Flagstaff, AZ. Houston, TX, New Orleans, LA, and San Juan, PR)
1993	Laumann *et al.*, Journal of Health and Social Behavior. A theoretical piece from the University of Chicago which again highlights the utility of a network approach to monitoring rare health events such as AIDS. Partially supported by NICHD and NSF.
1993	Morris, Sociological Methods and Research. The author draws attention to selective mixing patterns involved in social networks and epidemiological use of network analysis to model structured diffusion of the HIV epidemic. Partially supported by NSF.
1993	NIDA technical review meeting on Social Networks, Drug Abuse, and HIV Transmission The review covered: theory and methods of social network analysis; ethics, the law and other challenges to network research implementation; findings from basic studies on social networks and IDUs; and empirical findings from applied studies on HIV interventions directed to networks of drug users.
1994	Klovdahl *et al.*, Social Science and Medicine. CDC and its U64 funded investigators report on their Colorado Springs study.
1994	Neaigus *et al.*, Social Science and Medicine. NIDA-funded (R18) investigators report on the relevance of drug injectors' social and risk networks for understanding and preventing HIV infection.
1994	NIDA issues monograph 143 ("The Context of HIV Risk Among Drug Users and Their Sexual Partners"). Needle suggests that understanding the HIV epidemic will improve dramatically if researchers shift from examining risk behaviors from an individual perspective to examining risk behaviors as behavioral transactions within networks and focus on the social context in which the behaviors occur.
1994	Institute of Medicine publishes AIDS and Behavior, which recommends that NIDA, NIMH, and NIAAA expand the research effort examining social and structural factors to take into account the social context and relationships (e.g., dyads, families, communities) that increase risk for AIDS and that provide points of intervention.
1994	Laumann *et al.*, publish The Social Organization of Sexuality, a network-based study of how sexual partnerships are formed and its implication for HIV transmission.
1995	Scheduled release date for NIDA's Research Monograph, Network Analysis, Drug Abuse, and HIV Transmission, publishing 11 of the papers presented at the 8/93 technical review meeting.

These events, and the research findings reported in the previous section, not only support the viability of network based approaches to HIV transmission in special populations, they also suggest the following areas for future studies.

Key Areas for Future Research

The articles in this issue and those reviewed above provide good evidence that the network paradigm contributes to understanding of HIV transmission and drug use. They also suggest several important new directions which could be taken in pushing the current boundaries of this type of research. These directions are summarized in the following sections.

Ethnographic Approaches to Network Studies

There is a need for both quantitative and ethnographic studies of network boundaries, typologies, embedded behaviors, and cross-group differences based on cultural orientation and demographic conditions. Network theory suggests thinking of each type of relationship within a group of individuals as defining a separate network, while it also notes that people commonly engage in highly multiplex relationships with overlapping groups of individuals. This tension between splitting and lumping relationships creates a need for trained observations of both drug and sexual networks that would help define HIV risk reduction conditions by finding the types of multiplex relationships that naturally occur together, as well as the ones that truly distinguish between key (network defining) relationships and less important types of relationships that correspond with risky behavior. This exploratory research should cover the following topics.

Boundaries and Bridges. The issue of boundaries and bridges is central to any understanding of both small and large group approaches to risk reduction. Ethnographic techniques, including direct long term observation of behavior and relationships, could provide important clues to the formation, change, and dissolution of drug using and sexual networks. The mechanisms that permit group formation, group identification, maintenance of identity even with changes in membership, and ultimate group dissolution must be explored. These mechanisms should be examined in the context of other environmental conditions such as population density, gender differences and cultural processes.

Once bounded groups have been identified, it will be essential to develop a better understanding of how connections are created between networks, and to understand the strength of those connections. Bridges can be individuals or small subunits of networks that have multiple network memberships, or act as intermediaries between networks (with or without being actual members of either network). Strong qualitative descriptions of the behavior and function of these bridges could provide very important information in modeling the vulnerability of different types of networks to HIV, drug, and sexual risks. The ethnography of bridges and boundaries — from cognitive models and role analysis to indigenous understandings of the conditions that produce and maintain boundaries (however fuzzy) at the edges of networks - would be invaluable for both modeling research and for targeting public health interventions.

Network Typologies. Ethnographic typologies of drug networks are a useful tool for understanding and targeting differentials in risk taking behavior in hidden populations. To date, this type of research has only been conducted for small towns (Trotter *et al.*, 1994). It needs to be replicated in other sociocultural environments (urban and suburban, other cultural communities). It also needs to be expanded to investigate other types of relationships, beyond drug users, such as sexual networks, macro-level drug distribution networks, self help networks, and others. These typologies would advance our understanding of some of the important social relationships among groups at risk for HIV infection, and can be used to generate hypotheses

about drug use and specific HIV risk conditions. They would also help target outreach and prevention, depending on the characteristics of the network type.

Outreach and Follow-up Efforts. Additional ethnographic network studies would be valuable in supporting continuing efforts to develop effective outreach systems for high risk individuals. Ethnographic network approaches can provide useful information on how individuals can be recruited into programs within the context of the same unit that will reinforce or act as a barrier to achieving program objectives. Keeping track of network members is a natural ongoing function of the gatekeepers of the network, and can be understood through ethnographic research. This condition can greatly assist the follow-up phase of any project. If the core or most influential members of the network can be identified and tracked, then they can act as primary links to the other members of the group six months, twelve months, or even longer into the future, reducing the disadvantages of follow-up that must track every single individual.

Interaction and "Embedded Behaviors". In the history of prevention research, much has been learned about individual behavior, motivations, readiness to change, self efficacy and other psychological conditions that have an impact on behavioral change. However, only a handful of these issues has been studied within the context where the change is supposed to take place. And even fewer have been analyzed at a network, rather than individual level of measurement. Many risky behaviors (such as using drugs in a shooting gallery, or exchanging sex for crack) are not individual activities; their outcomes are dependent on more than the psychological state of the individual. Many are the result of interactions, not simply reactions. The more that can be learned about how these behaviors are embedded in a network context, the more likely significant strides will be taken in prevention research.

Cross-Group Differences. Network research needs to be conducted that compares and contrasts differences in network dynamics and risk taking across cultural, social, age and gender based configurations. This research will shed light on whether membership in heterogeneous groups is any more risky than in groups that are homogeneous (in terms of age, ethnicity, gender, sexual orientation, and the like). Additionally, comparative network research can identify different types of risk or differing proportions of risk in certain behavioral areas. Each of these issues should be thoroughly explored.

Ego-Centered Network Efforts

Ego-centered data collection provides a mechanism to quickly establish some of the salient attributes of "average" networks in a given location, such as the homogeneity of membership, closeness of relationships, duration of relationships, and peer norms. The questions that identify these parameters can be piggy-backed on a general questionnaire and can provide the basis for both modeling the context of risk taking behavior and for directing questions about influence and social support for risk reduction. There is a significant need to systematically add ego-centered network data collection and analysis elements to existing surveys and outcome measurement instruments for existing, large scale, HIV risk and epidemiological studies. There is also a need to explore proxy measures of network structure. These proxies are attributes of individuals that represent or are parallel to structural conditions (or positions) within networks, which can be used in a public health context to focus interventions based on differentials in risk profiles for individuals with that particular characteristic (such as multiple network membership).

Rapid Network Ascertainment. There is a bridge area (between ego-centered and full network structural measures) that needs to be effectively explored in the near future. Public health programs can obviously benefit from network approaches to outreach, information diffusion, and intervention efforts directed at both individuals and groups. Trotter, *et al.*'s article in this issue is a starting point for this type of bridging research. However, a great deal of new research in this area is called for, in order to find the best network measures (ego-centered and full relational) to inform public health programs, to discover how to elicit those measures from simple (and non-threatening) questions that could be asked in a public health context, and to find new measures that are specifically targeted at understanding disease transmission in social networks.

There are also several methodological issues that should be explored in this context. Ego-centered data may quickly provide important information about the structure of networks, but the extent to which we can depend on such data deserves testing with the simultaneous collection of ego-centered and full relational information. In addition, other methods of rapid ascertainment should be explored. For example, we have hypothesized that those recruited earlier into a network are central figures in that network. Should that observation be generalizable, considerable efficiency can be introduced into the ascertainment of network structures. In addition, some sampling procedures, such as the random walk design (Klovdahl 1989) afford an excellent opportunity for rapid and efficient ascertainment. Future research could focus on the validity of such approaches.

Full Relational Network Analysis

Data on the reciprocal relationships within drug networks, sexual networks, or other forms of high risk groups have a great deal of promise to further prevention and intervention research goals. Reciprocal relationships suggest that HIV risk prevention efforts can be evaluated at a level beyond that of the individual who directly receives education and counseling services, and indeed an array of measures are available to evaluate cumulative network effects of an intervention. For example, it can be expected that the impact and effectiveness of HIV risk interventions will be moderated by such network variables as communication flow, within-group norms and peer influences, factions within networks, and the types of networks to which people belong (e.g., open versus closed, small versus large). There are a series of hypotheses about reciprocal network relationships which could be effectively tested using network techniques.

Communication Flow. The effectiveness of interventions that require increased communication can be assessed by measuring the presence or absence of increased information flow within the network (Hubbell 1965; Taylor 1969). Network data can be collected to identify the presence or absence of communication between individuals, and between sets of individuals, on particular topics. The patterns of information flow within networks, sometimes called connectivity (Doreian 1974), can be characterized by several measures, including the amount of information that passes through a particular individual; the length of time it takes information to reach each person in the network; identification of the people who are gatekeepers of the information flow; measures of differential influence in the group; and measures of the probability that someone can or cannot receive information that is introduced into the network (Ford and Fulkerson 1956; Katz 1953; Taylor 1969). Each of these measures would be valuable for assessing the impact of information based interventions.

Distance and Segmentation. Intervention effects are also measurable in terms of reduced geodesic distances among all network members or among some portions of the network (Doreian 1974; Burt 1976). It should be possible to identify risk reduction in the network between time 1 and time 2 if high risk elements of the network have been segmented off, and if the interactions with those cliques are reduced or eliminated (Glover 1989, 1990). Factions within the network should show either risk reduction or risk concentration with increased distance to the risky parts of the network. Knowledge of clients' network memberships should allow for the measurement of peer influence on desired behavioral effects, such as entry into drug treatment. An individual's potential for treatment success may be directly related to splits in the group or within-group associations that can then be converted to a group "willingness to change" measure.

Positions and Roles of Network Members. Centralization is a measure of the way that information is controlled by individuals (Stephenson and Zelen 1991), and for some networks, a reduction of centralization should correlate with risk reduction through the creation of more communication linkages between non-central individuals. Careful observation should be able to detect changes in influence, both in drug and socially related issues, where individuals take on new roles within the group to reinforce protective behaviors and reduce risks (Bonacich 1987). Ethnographic studies should also be able to detect changes in influence, both for drug taking and sexual issues, as individuals take on new roles within the group to reinforce protective behaviors and reduce risks.

Network Types. The reduction of risky conditions should also be linked to network types. For example, the presence of HIV infection (or percentage of infected individuals) should vary among the various network types. There should be lower arrest levels and jail time in the most closed networks and higher levels in the wide open networks, thus varying the probability of viral transmission among network members. In addition, the size of the network should have some impact on the ease or the difficulty of changing norms that will protect members from risks in the community. Again, it should be possible to measure differential effects on HIV risk and drug use, holding the type of network constant. When these network data are correlated with qualitative and attributional data sets, we have an important set of tools to measure HIV risk reduction in a high risk population.

Testing Network Informed Intervention Modalities

One of the primary purposes for supporting an expanded paradigm is to further our ability to intervene in the transmission of HIV and other illnesses. In our case, the primary effort is directed at drug related networks, but can be easily moved into other social and cultural contexts as well. Network analysis provides some new approaches to designing, conducting and analyzing the efficacy of intervention programs, but there will need to be considerable innovation in this area. Since network programs are targeted at a group level, their effectiveness will also have to be assessed at that level, rather than using individual behavior change assessment formats in some aggregate form.

It may be possible to introduce considerable efficiency into programs by using a network approach. We have hypothesized that network analysis can identify some of the individuals who should become key players in network level intervention and outreach. Once identified, these individuals can be recruited specifically for intervention related roles in their

own social context. Central individuals from different groups could also be assembled into a grass roots organization, to assist in forming a drug community effort to confront the spread of HIV infection. Since these leaders are already backed by social groups, they could form the nucleus for "street level" community development efforts. For example, educational modalities need to take into account the potential for diffusion of information and the influence of network members as role models for the adoption of safer behavior patterns. In combination with others, such persons can constitute grass roots community organizations or can form the nucleus of Public Advisory Committees. This type of intervention provides an opportunity to create a self help infrastructure that will last beyond formal funding cycles, since they will have a local base that has continuity beyond the present circumstance.

Summary and Conclusions

Network analysis in its various forms appears to be a highly desirable and productive tool for the reduction of HIV hazards in hard to reach populations. Ego centered data collection, especially early in the program cycle, provides excellent baseline data for understanding the general network characteristics in a population. Ethnographic network data collection, combined with relational data, can provide critical information throughout the project by identifying the most effective recipients of prevention and intervention actions, and can act as an effective evaluation tool to determine the impact of interventions at a level above individual measures of change. Once a program is in operation, network data collection can provide both qualitative and quantitative measures of success.

One advantage of the network approach is that network data collection can act as an effective evaluation tool to determine the impacts that transcend individual behavior alterations. Network aggregated data can provide both qualitative and quantitative measures of program success. Many of the variables collected on individuals are useful in their network aggregate to determine the impact of a program: the changing level of HIV infection; the types; levels, and frequency of drugs used; treatment attempts; risk taking behaviors; readiness to change; knowledge of HIV causes and symptoms. Tracking changes in these variables over time, ascertained through repeated sampling of networks, adds a previously untapped dimension to the evaluation of risk reduction programs.

Changes in network configurations that occur over time may have considerable influence on epidemic propagation. Therefore, the network paradigm appears very useful for understanding trends in HIV seroprevalence (Klovdahl, 1985; Laumann, Gagnon *et al.*, 1989, 1993; Morris, 1993; Williams and Johnson, 1993). It has been hypothesized that the structure of networks linking people in drug use or sexual practices (e.g. direct, indirect and cross linked), together with the amount of HIV infection prevalent in the network, determines the rate and extent of HIV spread among IDUs (Wallace, 1991); additionally, their larger social networks and risk settings influence the spread of HIV (Neaigus, Friedman *et al.*, 1994).

Network analysis will also be useful for forecasting the future trajectory of the epidemic based on local environmental conditions (Klovdahl, 1985; Laumann, Gagnon *et al.* 1989, 1993; Morris, 1993, Williams and Johnson, 1993). One positive aspect of the network approach is that this type of prediction will probably be most salient on the local level, where the majority of preventative action takes place. The summation of national data can be highly misleading for local conditions, and that data is often exquisitely sensitive to its assumptions. Since

intervention is a local affair, a local understanding of the disease transmission process is far more important than national data for those who try to intervene, and it is in this arena that social network analysis has its greatest strength. Network change may be a harbinger of both intervention impact and changes in seroconversion rates for a particular locale.

As the articles in this issue illustrate, the network paradigm adds to our optimism about understanding the patterns of HIV transmission, for scouting out individual versus group contributions to risk taking behavior and risk reduction, for estimating the future course of HIV events, and for evaluating our impact on those events. It also appears to be highly valuable when extended to other epidemiological conditions, such as drug risk taking behavior, that are not directly associated with HIV transmission. The success of the venture depends on a judicious combination of research and actions: testing what we think and using what we know in the foreseeable future.

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