AIDS AND SOCIAL NETWORKS: HIV PREVENTION THROUGH NETWORK MOBILIZATION*

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Whereas many infectious diseases are spread through casual contact and contagion, HIV transmission results from risk behaviors that involve close and often intimate contact. As a result, the transmission of HIV is structured by the social relationships within which these contacts are embedded. Hence, social network analysis is especially suitable for understanding the AIDS epidemic. This paper reports the results of a field experiment that compares a network-based HIV prevention intervention, termed a "Peer-Driven Intervention" (PDI), with the standard form of street-based outreach intervention. The results suggest that the network intervention outperforms the standard approach with respect to number of people accessed, reductions in self-reported levels of HIV risk behavior and cost. Finally, the analysis focuses on the network structure of drug injectors and discusses the implications of these structures for understanding both the spread of HIV through social networks and the design of HIV-prevention interventions. The results show that certain network features, including geographically extensive networks and an abundance of ties across ethnic boundaries, genders, ages and drug preferences, can further the spread of HIV. Ironically, these are also the network features that increase the effectiveness of network-based HIV-prevention interventions. Thus, we show that network interventions work best precisely when they are most needed, that is, when network structures facilitate the spread of HIV.

INTRODUCTION

The rationale for employing social network analysis to understand the AIDS epidemic is strong. Whereas many infectious diseases are spread through casual contact and contagion, HIV transmission results from risk behaviors that involve close and often intimate contact. Hence, the transmission of HIV is structured by the social relationships within which these contacts are embedded (Neaigus 1998; Klovdahl et al. 1994; Morris and Kretzschmar 1995; Laumann et al. 1993). An implication is that efforts to prevent the spread of HIV must take social networks into account. Social networks can play a dual role in the HIV epidemic. They serve as both the route of transmission for the virus, and, potentially, the route of transmission for HIV-prevention information and services. This recognition has led to the development of a

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number of interventions that operate at the social network level (Grund et al. 1992; Broadhead et al. 1995; Jose et al. 1996; Valente et al. 1998). This paper analyzes and empirically evaluates a field experiment comparing two types of HIV-prevention interventions for injection drug users, a social network-based HIV-prevention intervention termed a "Peer-Driven Intervention" (PDI) and "street-based outreach" (Brown and Beschner 1993; National Institute on Drug Abuse (NIDA] 1992; Wiebel 1992), a more individualistically based form of intervention. Because the latter has become the most standard form of intervention, we refer to it as the "traditional outreach intervention."

Section one briefly summarizes research on HIV transmission among injection drug users and their reactions to HIV-prevention interventions. Section two presents a network-based theory of social influence. Whereas many theories view social influence as a dyadic relationship between the source and target of control, the theory of network-mediated control views influence relations as embedded in networks that can serve either to amplify or weaken influence relations. Section three shows how the theory was used to design the PDI. Section four presents the results of a field experiment comparing the PDI with the traditional intervention. The results suggest that the network intervention outperforms the standard approach in several respects. The network intervention accesses a larger number of people, it reduces their self-reported levels of HIV risk behavior more effectively and it does so at less cost. Section five draws on the recruitment records from the network intervention to analyze the network structure of drug injectors. Finally, the conclusion discusses the implications of these results for understanding both the spread of HIV through social networks and the design of HIV-prevention interventions. The analysis shows that certain network features, including geographically extensive networks with abundant ties across ethnicity, gender, age and drug preference, can further the spread of HIV. However, these network features also can increase the effectiveness of network-based HIV-prevention interventions. *Thus, we show that network interventions work best precisely when they are most needed, that is, when network structures facilitate the spread of HIV.*

I. REACTIONS BY INJECTION DRUG USERS TO THE HIV EPIDEMIC

Drug injectors did not react passively to the HIV epidemic. Even before governmentally sponsored outreach efforts began in 1988, injectors began taking steps to protect themselves from the spread of HIV. For example, Des Jarlais et al. (1985) found in 1983 that injectors in New York City reacted to reports about the risk of AIDS by reducing syringe sharing and increasing the demand for clean syringes. By 1984, injectors' demand for clean syringes was so great that it spawned a new market ripe for exploitation: syringe dealers began repackaging used syringes and selling them as new (Des Jarlais et al. 1985; Friedman et al. 1987).

In 1988 the federal government, through the National Institute on Drug Abuse (NIDA), began funding HIV-prevention projects in over sixty inner-city areas throughout the country. These projects were based on the model that continues to dominate health and social service delivery, the provider/client model, in which indigenous outreach workers perform four core tasks:

(1) access injectors in the community;
(2) educate them about drug and sex-related HIV risk behaviors;
(3) distribute prevention materials including bleach and condoms; and finally,
(4) provide referrals to facilities where additional HIV-prevention services are available, including HIV testing and counseling, more extensive HIV-prevention education and drug treatment.

The injector response to these interventions was impressive. Researchers reported that injectors began to disinfect their syringes with bleach and to reduce syringe sharing. Injectors also increased their use of condoms, though less successfully (Brown and Beschner 1993).

Injectors' responsiveness went beyond risk reduction in HIV-associated behaviors. In projects throughout the country, outreach workers found, and ethnographers documented, that injectors volunteered and helped outreach workers carry out AIDS prevention efforts (Broadhead and Fox 1990; Grund et al. 1992; Rivera-Beckman 1992; Johnson, Williams and Kotarba 1990). Injectors frequently introduced outreach workers to other users, vouched for outreach workers in -new communities, helped outreach workers fill and prepare bleach bottles and helped outreach workers distribute bleach, condoms and prevention information. Outreach workers also utilized injectors to locate users to be interviewed and to find users who needed to return for follow-up interviews.

The AIDS prevention efforts that injectors engaged in on behalf of one another, and in helping outreach workers, can be seen as important extensions of the sharing patterns and norms of reciprocity that underlie and sustain user networks. One can describe the injector subculture as a "culture of survival," organized around the procurement of drugs (Grund 1993). Due to their illegal status, drugs such as heroin and cocaine cannot be purchased in ordinary outlets. Hence, drug users must turn to alternative, illegal distribution networks that are at the bottom of the drug trafficking pyramid. Drugs are often sold by users to users, and the difference between dealer and the client is ambiguous because a dealer one day may become a customer the next. Drugs may also be sold by non-using street dealers. In both cases, dealers are distrustful of strangers and conceal' their activities. Ritual interaction plays an important role in these networks to distinguish users from non-risers and to prevent police detection (Carlson 1977). As a result of entrepreneurial and law enforcement forces, drug using and dealing networks are generally unstable, both geographically and in time. Hence, the individual user needs up-to-date information on where drug dealing is most active and on the prevailing codes for overcoming distrust. This requires active and enduring participation in drug use-defined networks. Active participation is further enhanced by a need to generate considerable amounts of money to pay black market drug prices.

While early descriptions of drug users conveyed a stereotypical predatory image, recent research shows that a more prevalent interactional pattern evidences cooperation and sharing (Grund 1993). Habitual drug users are often organized in small friendship groups. These networks provide injectors with opportunities for partnerships aimed at garnering resources, through various hustles, to buy drugs. These friendship networks are linked to larger networks through exchanges and the sharing of information, money, drugs and other necessities (Des Jarlais et al. 1988; Preble and Casey 1969). While the satisfaction of individual craving is an important objective of these interactions, they are also an expression of community solidarity aimed at the maintenance of an interdependency network.

Syringe sharing and its associated patterns of reciprocity provide a practical and emotional counter to the daily hardship of addict life (Grund 1993; Grund et al. 1991). Before AIDS, syringe sharing fitted firmly into this pattern and was considered an expression of the almost universal subcultural code of "share what you have" (Wieder 1974). Changing this hazardous practice has proven most successful when the changes do not contradict subcultural norms. The introduction of bleach is a good example of an intervention that builds appropriately upon existing practices. Changes can also be initiated by group members themselves, as was witnessed at a Dutch syringe exchangeloutreach program. After requests from participating injectors, the program started exchanging syringes in bulk, allowing injectors to give unused syringes to their peers and thereby conforming to the subcultural norm that encourages sharing, yet in a safe way (Grund et al. 1992).

Given injectors' aforementioned capabilities and responsiveness, new approaches to AIDS prevention that rely on, and work to strengthen, the capabilities of drug users to collaborate in promoting risk reduction among their peers have been developed (Carlson and Needle, 1991; Chitwood et al. 1990; Des Jarlais and Friedman 1990; Feldman and Biernacki 1988; Wiebel 1988). Such prevention models draw upon and strengthen the sharing rituals and reciprocity norms integral to user networks. In other words, they mobilize networks of injectors on behalf of HIV prevention.

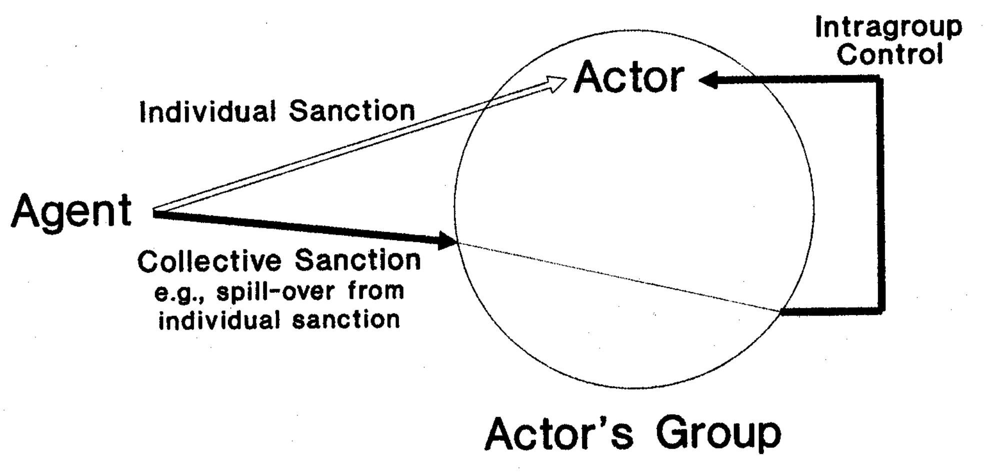
II. THE NETWORK EMBEDDEDNESS OF SOCIAL INFLUENCE

According to a network theory of collective action (Heckathorn 1990, 1993, 1996), interpersonal relationships cannot be validly analyzed as though they consist of a set of isolated dyads, for each dyadic relationship is embedded within social networks that structure the relationship. These networks include family members, friends, neighbors, co-workers and others with whom an individual interacts regularly. To the extent that networks of actors are interdependent, events that impact on any individual have consequences that extend to other network members. For example, when one person is promoted on the job or fired, the sanction spills over and affects family members and friends. Except in the limited case of social isolates, almost all social sanctions targeted at an individual generate collective rewards or punishments that impinge on his or her primary group. Imprisonment is an example of a punishment that spills over to others. It is not merely a personal calamity, it frequently drives whole families into poverty. Similarly, rewards spill over when a family's major breadwinner earns an important promotion because it improves the entire family's circumstances. Due to the network embeddedness of rewards and punishments from individuals to others, social sanctions are virtually never individualized. Instead, they give rise to collective rewards or punishments that impact not merely the target of influence, but also members of the target's social network.

Given that most social sanctioning includes both an individual and a collective component, social influence can arise from either of two theoretically distinguishable sources (Heckathorn 1990). First, it can arise from *individual-sanction-based control* directed at an actor by an agent such as a teacher, parent, neighbor or AIDS prevention counselor. For example, an agent may target an actor with the promise of a reward or a threat of punishment. The result is a dyadic relation of the sort presumed in most analyses of influence relations. (See figure 1.) Second, compliance can arise from *network-mediated control,* as when students obey teachers because punishment administered by the school would be augmented by parents; or when workers hold onto disagreeable jobs because unemployment would inflict hardship on their families. In these cases, control occurs through a two-step process. First, members of the actor's first-order network recognize that, based on whether the actor complies, they will either receive a collective reward or suffer a collective punishment. Second, the network mobilizes to exert influence over the actor based on that potential benefit or loss. For example, parents augment the authority of teachers, or awareness of the financial needs of one's family has the effect of increasing the power of one's boss. In this way, the agent's influence is amplified through the network in which the target of control is embedded. Network embeddedness can also have the opposite effect, by serving to weaken or nullify the influence of an actor upon a target. For example, during periods of political unrest, those who are arrested may thereby become local heroes, so informal sanctions serve to counter or even nullify official sanctions (Heckathorn 1988).

FIGURE 1

INDIVIDUAL VERSUS GROUP-MEDIATED SOCIAL CONTROL



The solid arrows depict group-mediated social control.
The hollow arrow depicts indiviual sanction-based control.

Influence based on individual sanctions works by altering people's *inclinations,* that is, their preferences regarding their own personal behavior. It does this by using what may be termed *primary incentives,* such as performance-specific rewards or punishments. In contrast, network-mediated control works by altering people's *regulatory interests,* that is, their preferences regarding how others behave. Network-mediated control does this by using what may be termed *secondary incentives,* such as rewards or punishments based on the performance of peers.

A central conclusion from the theory is that secondary incentives can be both more efficient and more effective than primary incentives (Heckathorn 1990). This occurs when the means for intragroup control are both inexpensive and effective, as in cohesive networks where peer approval is an important sanction. In the case of primary sanctions, compliance costs are internal. The targeted actor either complies or refuses to comply with the directive, and thereby bears whatever costs are involved. In contrast, in the case of secondary incentives, compliance costs are external. The targeted actor either succeeds or fails in inducing another actor to comply so the costs of compliance are borne by the other actor, and the targeted actor bears merely the cost of exercising social influence. It is usually easier to tell others to comply than to do it oneself. In extreme cases, one might urge others to endure great suffering to avoid minor inconvenience or embarrassment to oneself.

A second reason for the potential effectiveness of secondary incentives concerns monitoring. Monitoring for primary incentives is undertaken by the agent controlling the sanctions. Police, teachers and supervisors typically can observe only a small portion of behavior, so monitoring is difficult when activities cannot be geographically confined. In contrast, secondary incentives operate through network mobilization, and peers tend to be far more effective monitors of members' behavior (Heckathorn 1990).

A third reason for the potential effectiveness of secondary incentives concerns what is termed the "hidden cost of reward." Material rewards may undermine intrinsic motivation when they are framed as "pay" rather than as "recognition" for achievement (Deci and Ryan 1985). This creates a dilemma for organizations that rely on primary incentives, because if their ability to reward symbolically is limited, they must rely on material rewards. In contrast, secondary incentives harness peer pressure, so they rely on non-material rewards such as peer approval to secure compliance. Thus, whatever intrinsic motivation exists will be preserved and even strengthened because of peer support. Secondary incentives do, however, present a potential problem. If the secondary incentives employ material rewards, might they undermine intrinsic motivations to engage in network mobilization? That is, might they weaken pre-existing peer norms? This appears not to occur, because when members mobilize other network members, that entails *a commitment.* When a person urges peers to act in a certain way, that person publicly affirms the special value of that behavior. If that person then attempts to retreat from the behavior, he or she risks appearing opportunistic or hypocritical. Thus when individuals induce peers to affirm publicly the value of certain acts, it serves as a means to strengthen their commitments to them. Indeed, public affirmations of commitment to particular ways of behaving are a fundamental and powerful social mechanism for creating and maintaining social cohesion.

Norms within a network can be altered by using secondary incentives in any one of several ways. First, these incentives can be used to create new regulatory interests, and thereby create wholly new norms (e.g., see Heckathorn 1988). Second, they can be used to counter previously existing regulatory interests, and thereby weaken or dissolve the norms based on those interests. Finally, secondary incentives can be used to amplify previously existing regulatory interests, thereby allowing a latent or near-group to become normatively regulated. This is the use of secondary incentives on which the AIDS prevention intervention is based. In essence, it works as follows: a collection of individuals who purchase and use drugs together may possess some regulatory interests, in the form of concerns about HIV infection. Yet they may also be too loosely knit to create effective AIDS prevention norms. If their regulatory interests are then amplified through secondary incentives, they can become capable of creating and enforcing AIDS prevention norms that work to reduce high-risk behavior. By increasing the extent to which behavior is normatively regulated, the secondary sanctions thereby increase the group's solidarity.

III. THE DESIGN FOR A NETWORK-BASED INTERVENTION: THE PEER-DRIVEN INTERVENTION

Traditional outreach is based on a "provider-client" model. The model involves hiring a small number of community members, usually ex-addicts or people with street credentials, to contact and work with members of their own community as clients. They do this by going into neighborhoods as outreach workers to distribute AIDS prevention materials and information and to recruit injectors to various programs and services, including research interviews conducted by social scientists.

Research has shown that outreach projects operate under conditions that cause hierarchy and supervision to break down. First, moral hazard problems abound because of the opportunities to gain illicitly from working in active drug scenes. For example, Broadhead and Fox (1990) reported cases where outreach workers used their jobs as a cover for drug dealing and fencing stolen goods. Second, adverse selection problems are severe. Being streetwise is an essential qualification for an outreach worker. Such individuals are generally accomplished hustlers, so distinguishing those with a sincere desire to work to prevent AIDS from those who simply wish to hustle a project is virtually impossible; projects can only find out they have been conned *ex post.* Finally, monitoring outreach worker performance is necessarily limited because AIDS prevention efforts occur on the street, in single-room-occupancy hotels, public housing projects, public parks and so on. In sum, moral hazard and adverse selection problems are unusually severe, and the monitoring of outreach workers' performance is limited. The result is an array of organizational problems that invite and allow the poor performance by outreach workers to go on virtually unnoticed and that push outreach projects toward stagnation (Broadhead and Heckathorn 1994).

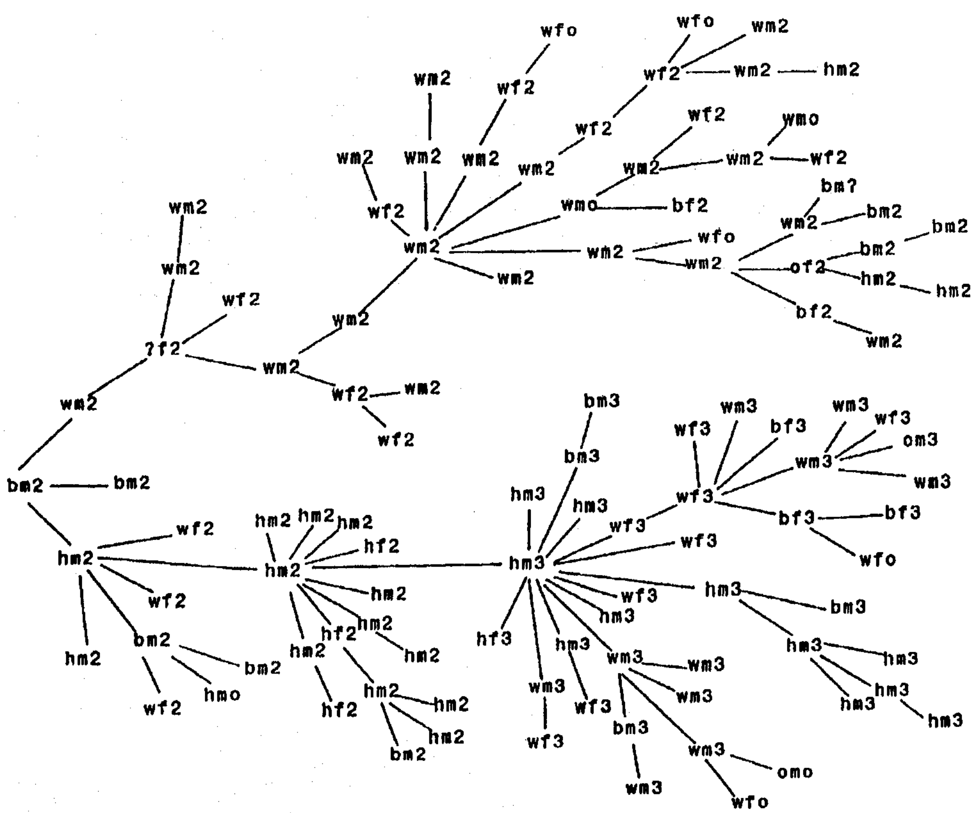
Paradoxically, as noted above, research has also documented that injectors responded impressively to the outreach services they received; injectors adopted many risk-reduction measures at high rates, and they volunteered and substantially augmented the efforts of outreach workers. Put simply, injectors went well beyond the role of being mere clients; their response to traditional outreach was far more robust and far-reaching than were the efforts of outreach projects themselves.

Based on the theory of network-mediated control, we designed the "Peer-Driven Intervention" model to draw on injectors' demonstrated capacity to become active participants in HIV prevention. The intervention began operating in March 1994 in eastern Connecticut. It was compared to a traditional outreach intervention operating in a separate but demographically similar community. (For a detailed account of the implementation of this intervention, its operating procedures and the sites in which it and traditional intervention were implemented, see Broadhead et al. 1995.)

The PDI used secondary incentives to harness the potentially enormous power of peer-pressure as a means for altering behavior. The PDI design employed a two-step process. First, the essential activities of traditional outreach were identified. Second, a structure of secondary incentives was implemented that offered injectors recognition and modest material rewards for encouraging their drug-using peers to carry out prevention activities in their own community.

FIGURE 2

PEER RECRUITMENT NETWORK BEGINNING FROM A SINGLE SEED



KEY: B = Black; H = Hispanic; W = White; F = Female; M = Male; 2 = Middletwon; 3 = Meriden; 0 = Other; 7 = Missing

The first task of traditional outreach is recruiting injectors into prevention programs. As in traditional programs, the nexus of the PDI is a storefront facility within which HIV testing and counseling services are offered, as well as risk reduction education and materials such as bleach kits and condoms. In the PDI, injectors are motivated to recruit other users for the above services via a coupon system: for each injector recruited bearing a coupon, the user who recruited him or her receives a monetary reward. Only modest rewards are required, because the cost involved in exercising influence over peers is small, and there now exists widespread concern about AIDS within the injection community - which is to say that *regulatory interests among injectors concerning AIDS prevention already exist.* Furthermore, recruiting and educating peers involves a public commitment to AIDS prevention that reinforces those regulatory interests. Each recruit, in turn, is also given a small number of coupons to recruit still other injectors within their drug-using network. Thus, the mechanism coopts user networks to serve as a medium to recruit further subjects.

Starting with a single seed, successive waves of peer recruitment can produce hundreds of recruits over dozens of waves (see Figure 1). A recent paper (Heckathorn 1997) showed that this recruitment mechanism - which we call "Respondent-Driven Sampling" (RDS) - has several features that make it well suited as a mechanism for accessing populations at risk of HIV infection, including injectors. The paper contains three theorems. The first shows that the sample drawn by RDS reaches an equilibrium that is independent of the seed or seeds from which it began; e.g., it does not matter whether the initial recruiters were drawn from the same or different ethnic groups, the sample composition remains wholly unaffected. A second theorem shows that this equilibrium is attained rather quickly, e.g., by four to six waves in our current studies. A third theorem specifies the condition under which the RDS sample is exactly representative of the underlying population; that is, all groups must have the same degree of homophily (preference for ingroup ties) or heterophily (preference for out-group ties). Finally, a sensitivity analysis shows that even when the third theorem's condition is not met, RDS nonetheless draws a broadly representative sample. The implication is that the PDI's recruitment mechanism, RDS, can be expected to access a representative set of injectors, irrespective of the network structure of the injector community.

The PDI's recruitment mechanism has several advantages over approaches that rely on outreach workers. First, the former puts the burden of identifying recruits on those with the best current information: active users. Second, the PDI's pay-for-performance design recognizes and rewards the most productive recruiters. As a result, subjects are rewarded in direct proportion to the success of their recruitment efforts, with those who recruit no one receiving no reward. Third, a PDI offers a built-in accommodation to the cultural diversity in the user population. With injectors accessing their peers, the recruitment effort is always couched in culturally appropriate terms for each user subgroup. Thus, a performance-based reward system is built into a PDI that continuously adapts to cultural and other subgroup differences.

Based on the above discussions, we hypothesize that a PDI has three potential advantages over traditional outreach:

Hypothesis one
Because the PDI relies on active user networks for recruitment, its coverage of the target population may be more extensive than traditional outreach projects.

Hypothesis two
Because the PDI relies on persuasion and influence from peers rather than from professional staff, it may be more effective at securing users' compliance with risk reduction efforts.

Hypothesis three
Because of reduced reliance on professional staff, a PDI may be substantially less expensive to operate than traditional outreach.

IV. RESULTS

We began operations in March 1994, with the experimental (PDI) site located in New London, Connecticut, and the control (traditional outreach) site in Windham, Connecticut. As of July 1, 1995, there were 288 initial interviews and 122 follow-up interviews, for a total of 410 interviews. Initial interviews ended at the experimental site on February 28, 1995, when a zoning problem compelled us to cease operations. A limited number of follow-up interviews continued in alternative locations at that site until July 1. Analyses of subject characteristics are based on initial interviews, and analyses of the behavioral impact of the interventions are based on comparisons of the initial and the follow-up interviews.

RECRUITMENT AND SUBJECT CHARACTERISTICS

The clearest indicator of the relative robustness of recruitment by each outreach effort is the number of recruits. The PDI recruited 50 percent more injectors than the traditional outreach intervention, 159 to 106 subjects respectively (see Table 1). One reason why the PDI outperformed the traditional outreach intervention may be that it drew subjects from a broader geographic area. These results provide support for hypothesis one.

TABLE 1

SUBJECTS' CHARACTERISTICS

	Peer-Driven Intervention	Traditional Outreach Intervention
Gender		
Female	30.2%	31.1%
Male	69.8%	68.9%
Total	100%	100%
(n)	(*n* = 159)	(*n* = 106)
Race /Ethnicity		
Non-Hispanic Black	24.7%	12.4%
Non-Hispanic White	52:6%	36.2%
Hispanic	18.2%	47.6%
Other	4.5%	3.9%
Total	100%	100%
(n)	(*n* = 154)	(*n* = 105)
Age		
Mean	39.1	35.6
Standard Deviation	7.42	8.34
Total (n)	(*n* = 156)	(*n* = 102)
Residence		
Within Town	71.7%	83.0%
Within Surrounding Area	10.7%	6.6%
Outside of Area	17.6%	10.4%
Total	100%	100%
(n)	(*n* = 159)	(*n* = 106)

TABLE 1 ***(Continued)***

	Peer-Driven Intervention	Traditional Outreach Intervention
Drug Preference		
Alcohol	2.0%	0%
Cannabis	6.6%	2.9%
Heroin/Other Opiate	75.0%	85.3%
Methadone	2.0%	0%
Cocaine	7.9%	7.8%
Crack/Free Base	5.3%	1.0%
Speed Ball	1.3%	2.9%
Total	100%	100%
(n)	(n = 152)	(n = 102)

The racial and ethnic breakdown of subjects reflects the over-representation of minorities in populations of injectors. Similarly, the results reflect the male-dominated character of injector populations. At both sites, male subjects predominate over female subjects by slightly more than two to one. In this respect, the two interventions are remarkably similar. Both sites also draw subjects with similar ages. Finally, drug preferences at both sites reflect a preference for heroin among most injectors.

BEHAVIORAL IMPACT OF THE INTERVENTIONS

FREQUENCY OF INJECTION

Drug-related HIV risk is a function of the frequency of injection, and sharing of syringes, cookers, filters and rinse water. Table 2 depicts changes in the frequency of injection of all drugs during the last 30 days for each intervention.

TABLE 2

FREQUENCY OF INJECTION BY SITE

Frequency of Injection: Mean Number of Incidents by Site	Peer-Driven Intervention	Traditional Outreach Intervention
Initial Interview: last 30 days	42.57	78.99
(SD)	(54.43)	(107.13)
Six-Month Follow-up Interview: last 30 days	18.80	71.60
(SD)	(42.0)	(128.88)
Percent Reduction in HIV Risk Behavior between Follow-up and Initial Interviews (exponential model)	77%	47%
2-tail significance (exponential model)	.000	.039
N	67	53
T-ratio of difference between sites=-2.12, p = .036		

The means are strongly affected by a few people with very high rates of injection. For example, among the 120 subjects from whom we have complete information, 42 reported not injecting at all in the month before the follow-up interview and a majority reported ten or fewer incidents. However, 13 reported over 100 incidents, including one subject who reported 614 injections during the last 30 days. Thus the data is strongly skewed in a positive direction. As a result, mean injection frequencies provide an unreliable measure of central tendency; for example, note that in Table 2, the standard deviation exceeds the mean injection frequency for both interviews at both sites (e.g., for the follow-up at the traditional outreach site, the injection frequency is 71.60 ± 128.88). Hence, ordinary statistical tests, which assume normally distributed variables, are not very powerful for these data. Therefore, the significance levels shown are from an exponential model for the frequency of injections.[1] We also show the estimated effects of each treatment under the exponential model, which can be understood as multiplicative changes in the predicted rate of injection in a given period of time. More precisely, estimated effects are measured by the percent change in the geometric means of the follow-up as compared to the initial injection rates.[2] As is apparent from Table 2, there is a large and statistically significant reduction in the rates of injection in both sites. The estimated reduction is larger at the PDI site (i.e., 77 percent at the PDI site compared to 47 percent in the traditional outreach site), and the difference between the two interventions is statistically significant. There is a high degree of consistency in this data, with statistically significant reductions occurring in heroin, cocaine and speedball injections.

SHARING SYRINGES

The baseline rate of syringe sharing during the last 30 days at the two sites was low, with less than one in seven at the PDI site, and only one in six at the traditional outreach intervention. Again, the means are strongly influenced by a few cases with exceptionally high numbers of incidents, so we use the exponential model of frequency (see Table 3). Both interventions appear to reduce the frequency of syringe sharing, but the PDI clearly outperforms the TOI on significantly reducing this form of high-risk behavior. The reduction in syringe sharing at the PDI site is statistically significant but not at the TOI site. The difference between sites does not attain statistical significance.

TABLE 3

SYRINGE SHARING BY SITE

Syringe Sharing: Mean Number of Incidents by Site	**Peer-Driven Intervention**	**Traditional Outreach Intervention**
Initial Interview: last 30 days	.750	2.41
(SD)	(2.82)	(12.14)
Six-Month Follow-up Interview: last 30 days	.260	.111
(SD)	(1.49)	(.38)
Percent Reduction in HIV Risk Behavior between Follow-up and Initial Interviews (exponential model)	82%	64%
2-tail significance (exponential model)	.007	**.139**
N	68	53
T-ratio of difference between sites=-.758, p =.449		

SHARING COOKERS

Table 4 depicts the change in the mean number of cooker sharings during the last 30 days for each intervention. Both interventions produce a significant reduction in this form of high-risk behavior, but the difference between the two programs is not statistically significant.

TABLE 4

COOKER SHARING BY SITE

Cooker Sharing: Mean Number of Incidents by Site	Peer-Driven Intervention	Traditional Outreach Intervention
Initial Interview: last 30 days	5.61	16.60
(SD)	(21.38)	(52.61)
Six-Month Follow-up Interview: last 30 days	1.12	9.56
(SD)	(3.43)	(43.90)
Percent Reduction in HIV Risk Behavior between Follow-up and Initial Interviews (exponential model)	62%	63%
2-tail significance (exponential model)	.036	.038
N	67	52
T-ratio of difference between sites= .042, p = .967		

SHARING RINSE WATER

Table 5 depicts the change in incidents of sharing rinse water. Both interventions dramatically reduce water sharing, but the reduction is significant only in the control site. The difference between the treatments does not approach statistical significance.

TABLE 5

RINSE WATER SHARING BY SITE

Rinse Water Sharing. Mean Number of Incidents by Site	Peer-Driven Intervention	Traditional Outreach Intervention
Initial Interview: last 30 days	3.89	16.42
(SD)	(18.75)	(61.79)
Six-Month Follow-up Interview: last 30 days	.34	1.26
(SD)	(1.42)	(3.56)
Percent Reduction in HIV Risk Behavior between Follow-up and Initial Interviews (exponential model)	71%	82%
2-tail significance (exponential model)	.056	.001
N	67	53
T-ratio of difference between sites=.596, p = .552		

In sum, the impact results provide support for hypothesis two, the PDI is generally more effective at reducing HIV-associated behavior than is the traditional intervention. However, when compared to previously published results (Broadhead et al. 1998), these results also point to the need for additional research on the PDI's impact on HIV risk behavior. A recent report on a PDI site located in Middletown, Connecticut, that also used Windham's traditional outreach intervention as a control, revealed a more complex pattern of results (Broadhead et al. 1998). This site showed the ability of a PDI to draw subjects from a broad geographic area. About one half the subjects came from Middletown and immediately surrounding areas. The other half came from Meriden, a town about eight miles away with a large and vigorous drug scene, and traveling to the Middletown site required a 20-minute bus ride and a one-mile walk. These two sets of subjects reacted differentially to the intervention. Whereas the PDI tended to outperform the traditional intervention in the PDI's core area, Middletown and the immediately surrounding area, the PDI's impact was weaker for the subjects from Meriden. This difference was attributed (Broadhead et al. 1998) to a "proximity effect," in which subjects closer to the intervention's office benefited by stopping in for additional prevention materials, including bleach and condoms, and this provided an opportunity for prevention messages to be reinforced. In addition, the hurdles involved in traveling from Meriden to Middletown had the effect of drawing a special subset of subjects from the former town. In general, subjects traveled from Meriden to Middletown only to participate in the intervention.

In contrast this study reveals no significant proximity effects. That is, subjects from within New London, from the surrounding area, and from outside of town, did not respond differentially to the intervention. This may be because of the greater geographic compactness of the site. New London was a regional drug distribution center, the only such center within the study area, so even subjects who were categorized as being from outside of the area visited it frequently. Furthermore, the intervention office was centrally located, near the town's drug scene, so when subjects came to buy drugs that also brought them close to the intervention's office. This may explain why the intervention did not appear to lose effectiveness for more geographically distant subjects.

RELATIVE COST

The difference in the cost of the two interventions is striking. The secondary incentives paid to injectors in the peer-driven intervention, of $10 for recruiting a peer, and up to $10 for educating him/her in the community, resulted in an average cost of approximately $14 per recruit. The cost of recruiting 227 subjects for initial and follow-up interviews in the PDI over fourteen months was about $3,178. In contrast, the traditional outreach project cost $113,400 for the fourteen months involved, consisting primarily of each outreach worker's salary of approximately $2,700 per month including fringe benefits, and the cost for the 182 initial and follow-up interviews. This resulted in a cost per interviewee recruited of $623. Thus, the cost per recruit in the PDI is more than forty times lower than in the traditional outreach intervention. These results support hypothesis three, the PDI is less costly than the traditional intervention.

Our approach to AIDS prevention was supported in a report from the *Institute of Medicine* (1995) of the *National Academy of Sciences.* The report's aim was "assessing the social and behavioral science base for HIV/AIDS prevention and intervention," and it was "targeted primarily to policy-makers who will be making decisions for the

HIV/AIDS research agenda in the next decade." The PDI was described as "the state of the art of preventive intervention."

V. THE STRUCTURE OF INJECTOR NETWORKS

A benefit of our use of a network recruitment strategy in the peer-driven intervention is that, as a byproduct of recruitment, it yields information about the structure of recruiter networks. Here, we follow "biased network theory" (Rapoport 1979; Fararo and Skvoretz 1984; Heckathorn 1997) in defining network structure in terms of departures from strictly random patterns of association. Some structures result from homophily, as when friendships are disproportionately drawn from within one's ethnic group. As conceptualized in biased network theory, homophily reflects "bias events" in which an actor forms a tie because the target is an in-group member. If the "homophily bias event" does not occur, the actor forms ties without regard to group affiliation. Degree of homophily is defined formally as the probability of the bias event. As thus defined homophily produces an excess of in-group ties, above that which would have resulted from a random pattern of association. Heterophily is defined similarly, except that it reflects a "heterophily bias event" in which the actor forms a tie because the target is *not* an in-group member, and if that event does not occur, ties are formed independent of group affiliation. Based on this conceptualization, a homophily index can be defined as follows:

$$H = \frac{S-P}{1-P}, \text{ if } S > P \qquad (1)$$

$$H = \frac{S-P}{P}, \text{ if } P > S \qquad (2)$$

where H is homophily (if $H > 0$) or heterophily (if $H < 0$), S is the proportion of in-group ties and P is the proportion of in-group members in the system. As thus defined, the index can vary from ±1, reflecting perfect homophily in which all ties are with in-group members (i.e., the probability of the homophily bias event is one, so S = P), to -1, reflecting perfect heterophily in which all ties are with outgroup members (i.e., the probability of the heterophily bias event is 1, so S = 0). The index is zero, reflecting an unstructured system, if the proportion of in-group ties equals the proportion of in-group members in the system (i.e., the probability of a bias event is zero, so S = P).

Network information in the PDI is generated via the peer-recruitment process. Recall that when subjects in the PDI recruit one another, they do so using a coupon system. That is, the recruiter gives a coupon to the recruit, and the recruit brings it to the project's storefront for a session that includes a research interview, HIV-prevention education and the opportunity for HIV testing and counseling. Recruitments are tracked using a serial number on each coupon. Thus, each act of recruitment is documented, by recording, the serial number as the coupon is given to the peer recruiter, and then as it is returned by the recruit. The result is information regarding network linkages that is based, not on self-reports, but on behavior. Figure 1 summarizes the network structure of injectors with respect to five factors - race/ethnicity, gender, age, area of residence and drug preference.

FIGURE 3

NETWORK STRUCTURES OF DRUG INJECTORS
PATTERNS OF ASSOCIATION SHOW VARYING DEGREES OF HOMOPHILY
NEW LONDON, CT (N = 128)

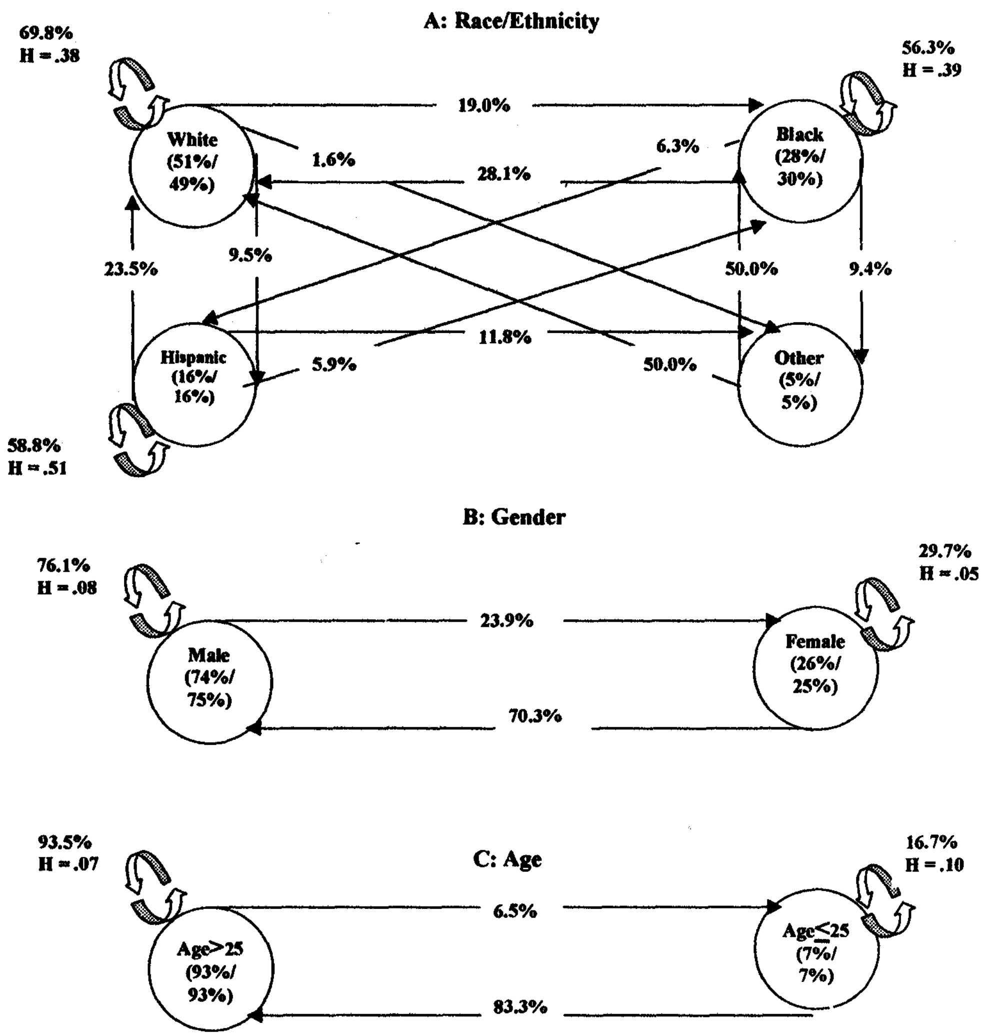
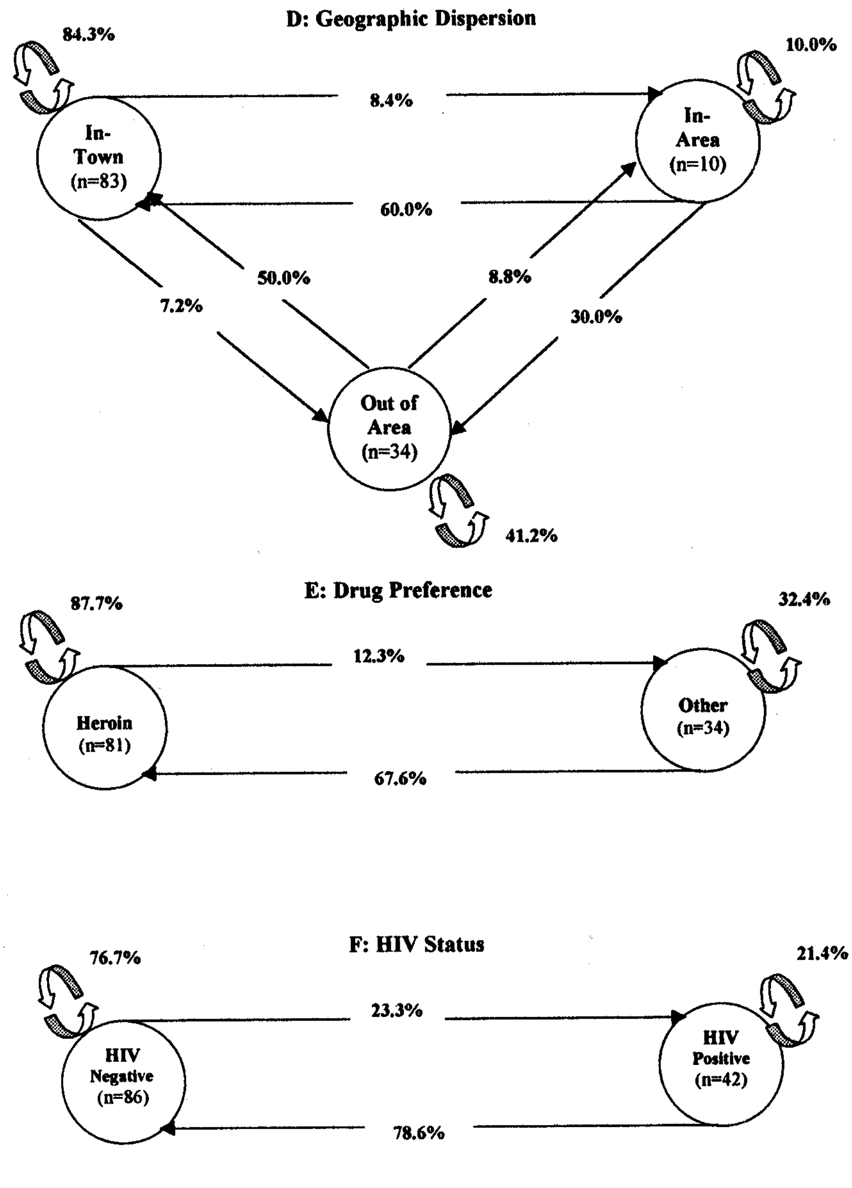


FIGURE 3 ***(Continued)***



(H = Homophily, and the numbers under each category are percent in sample and percent in equilibrium).

The race/ethnicity network reflects the presence of substantial homophily. (See Figure 3A.) For example, non-Hispanic white persons recruited coethnics 70 percent of the time, even though they made up only 51 percent of the persons in the sample. This corresponds to a homophily index of H = (.698 - .51)/(1 - .51) = .38. Non-Hispanic blacks also exhibit homophily, recruiting coethnics 56 percent of the time although they made up only 28 percent of the sample, for a homophily index of .39. Finally, Hispanics also exhibited homophily, recruiting coethnics 59 percent of the time, though they made up only 16 percent of the sample, for a homophily index of .51. Thus all three groups were homophilous, with the smaller groups exhibiting greater homophily. In contrast, subjects in the "other" category, a combination of Native Americans and Asian Indians, exhibited heterophily, $H = -1$, because they *never* recruited others like themselves. This reflects their very small number both in the sample (n = 6) and in the population from which the sample was drawn. They were too small in number to form their own autonomous network.

In contrast with race/ethnicity, the network structure of gender relations reflects neither strong homophily nor heterophily, i.e., the heterophily index is .08 and .05 for males and females respectively. (See Figure 3B.) For example, both women and men recruit about the same percentage of women, i.e., 30 percent and 24 percent, respectively.

The network structure of age relationships (Figure 3C) reveals slight homophily. For example, whereas "older" injectors, those 26 years of age or older, recruited only 7 percent younger injectors, the younger injectors recruited 17 percent younger injectors. Thus the younger injectors recruited' more than two and one half times more of their age-peers than did the older injectors. Homophily among younger injectors was slightly higher ($H = .10$) than among older injectors ($H = .07$). This failure of younger injectors to form exclusive networks may reflect their small numbers at this site. A different network structure was observed in Meriden, Connecticut, where younger injectors recruited their peers 65.5 percent of the time, though they made up only 23.7 percent of peer recruits, for a homophily index of .55. Thus the age structure of injectors appears to be a term that is highly variable.

Figure 3D depicts the geographic structure of injector networks. Subjects were divided into three categories based on their place of residence. We differentiated among those who resided within the town in which the intervention was located (i.e., "within town"), those who lived in adjacent towns (i.e., "within the area") and those who lived in more distant locations (i.e., "outside of area"). This network reflects varying degrees of homophily. Some homophile is demonstrated by subjects living in town. They recruited one another 84 percent of the time though they made up only 78 percent of the sample. In contrast, subjects residing "within the area" demonstrate almost no homophily ($H = .01$), because they recruited from within the area ten percent of the time and made up nine percent of the sample. This may reflect both the close geographic proximity of the town and its immediately surrounding area, and also the area's proximity to the more remote areas categorized as "outside of area." Finally, subjects from outside the area exhibit the greatest homophily ($H = .32$), recruiting themselves 41 percent of the time, though they made up only 14 percent of the sample. This reflects the geographic rootedness of social networks in which many relationships are based on propinquity. Finally, the substantial amount of inter-area recruitment is notable, varying from 16 percent for those in town, to 90 percent for those in the area and 59 percent for those outside the area. Given that some out-of-area respondents lived dozens or more miles from the research site, this shows that some injector networks are quite geographically extensive.

Figure 3E depicts the network structure of drug preference. Subjects were divided into two groups, those who most preferred heroin, and those with a different preference. The results reveal modest homophily, i.e., .18 for the heroin group, and .2 for the other group. Nonetheless, cross-linking ties are very abundant.

Finally, Figure 3F depicts the network structure by HIV status. Recruitment patterns for both HIV-positive and HIV-negative subjects were remarkably free of homophily. For example, whereas HIV-positive subjects recruited 21 percent HIV-positives, HIV-negatives recruited 23 percent HIV-positives. This suggests that HIV-positives do not form a socially distinct group.

CONCLUSION

Studies of the network structure of injectors are important because social networks play two opposite roles in the HIV epidemic. First, they serve as the conduits through which infection is transmitted. Second, in the new generation of network-based interventions, these networks are harnessed on behalf of HIV prevention. This creates a set of apparent paradoxes. First, consider the geographic extenseven's of networks. The more extensive these networks, the greater is the ease with which HIV infection can spread from an initial point of infection outward in ever expanding circles. Hence, geographically extensive networks accelerate the epidemic. Yet, geographically extensive networks can also further HIV prevention. For when networks are extensive, a network-based intervention can provide services to a correspondingly broad area. Hence, a factor that can aggravate the epidemic, geographically extensive networks, can also increase the effectiveness of HIV prevention efforts.

Other network features play an equally ambivalent role. For example, an abundance of cross-ethnic ties can facilitate the spread of the epidemic across group boundaries. Yet, cross-ethnic ties also increase the effectiveness of network-based interventions, by ensuring that even if the initial subjects from whom network recruitment began were not representative of injectors, cross-ethnic recruitment will quickly spread into other groups. Extensive ties across gender, age, drug preference and especially HIV status have a similarly ambivalent status, because they facilitate the spread across these boundaries of both the HIV epidemic and the provision of network-mediated HIV prevention services. This suggests an important benefit of network-based interventions. *Network interventions work best precisely when they are most needed, that is, when network structures are facilitating the spread of HIV*.

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