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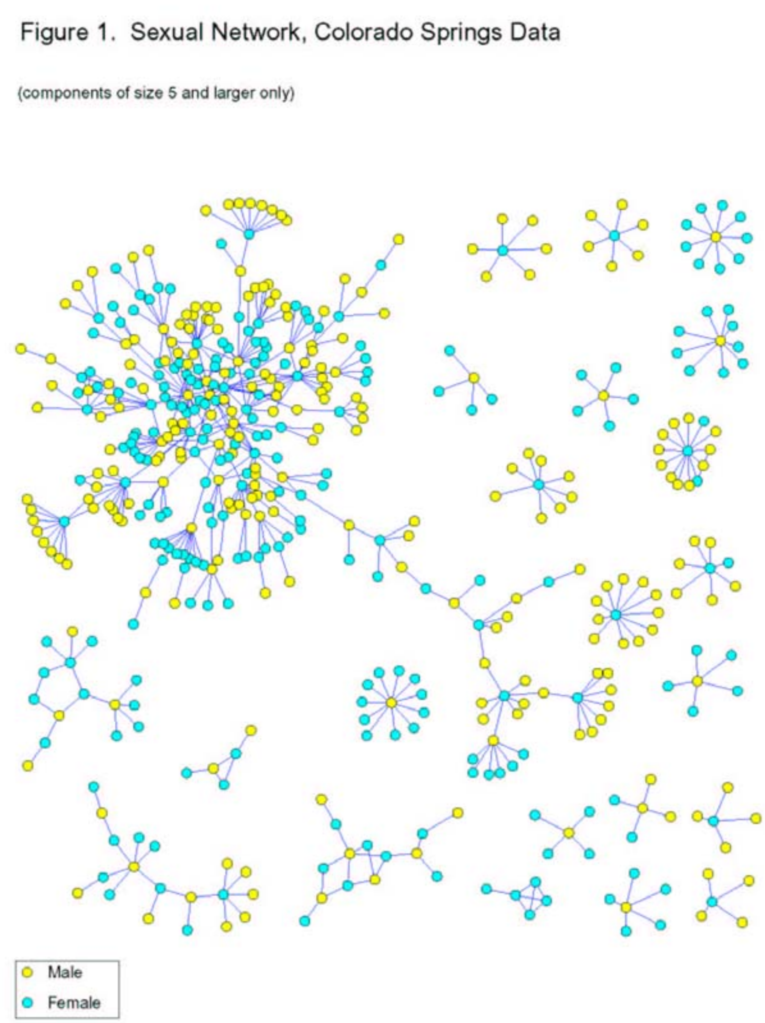
By Martina Morris, PhD; Ruth O. Levine, MA; and Marcia Weaver, PhD

Introduction

Sexual Network Analysis: Changing the Face of HIV Program Design

Social network analysis is changing the way HIV prevention strategies are designed and, ultimately, how HIV transmission is viewed in epidemiological circles. What began as research on kinship structures in the field of anthropology and small group studies in social psychology has evolved into a powerful body of research on sexual networks that is particularly pertinent to HIV prevention efforts. This new knowledge broadens the focus from individuals to the web of relationships that encompass the individual. These romantic and sexual partnerships form the dynamic network along which disease travels. The implications of this conceptual shift are profound, reshaping how and for whom interventions are designed.

For the last three decades, the core group concept has guided intervention strategies for sexually transmitted infections (STIs) (Yorke, Hethcote, and Nold 1978). STI prevention and treatment strategies targeted the few active individuals who repeatedly became infected and were responsible for a disproportionate share of the caseload. This strategy became less useful within the context of HIV, an incurable infection and chronic disease.



Source: Moody and Morris (2000), unpublished.

The spread of HIV, particularly in settings with generalized epidemics, depends on the extent to which a network is connected. To evaluate this requires empirical research on sexual network structures, examining the patterns of sexual relationships in a locale and how they link together to make the pathways that shape the epidemic (see Figure 1). Some network structures facilitate spread, whereas other structures impede it. For example, HIV program planners are becoming increasingly interested in methods for mapping “bridge populations,” those people who have sex with both high- and low-risk partners, thereby creating a pathway for the virus to spread. Until recently, the theory existed for looking at sexual network structures, but not the prerequisite statistical and mathematical models to identify and quantify transmission pathways and prevention targets. However, the pervasive spread of HIV in sub-Saharan African countries has galvanized researchers to narrow the gap between theory and methodology.

In the early 1990s, local researchers in Uganda had begun to suspect that concurrency (when an individual has multiple partnerships at the same time) was amplifying the local HIV epidemic. No models existed at that time for projecting the impact of concurrency on HIV transmission, nor were there data on how often or widely concurrency occurred. The work of Watts and May (1992) and Morris and Kretzschmar (1997) bridged that gap, providing both the theory and tools for understanding sexual network structures and a simple methodology for collecting sexual network data.

These approaches represent a movement away from the core group theory, revitalized recently by Liljeros et al. (2001), a group of physicists who argue that HIV prevention efforts should be directed at individuals who have the largest number of partners, as based on a theoretical model of the distribution of sexual contacts. Jones and Handcock (2003) challenged their statistical approach and the conclusion that HIV prevention efforts should target promiscuous individuals.

Network approaches provide a more solid methodology for mapping risk and projecting HIV transmission and for orienting behavioral prevention interventions. The fact that HIV risk behavior occurs in the context of a partnership means that individual knowledge, attitudes, and beliefs do not determine behavior and are mediated by the relationship between partners. All the attendant characteristics of relations—gender dynamics, age and power differentials, cultural mores, and socioeconomic inequalities—become the context in which behavior change must be negotiated. For example, a literature review by Luke and Kurz (2002) highlighted cross-generational sexual relationships between adolescent girls and older men in sub-Saharan Africa, specifically because these partnerships are so important to the context of HIV transmission but were not receiving nearly enough focus from HIV prevention programs.

In sum, network position determines both the level of exposure to HIV and the interactional context that constrains behavioral change. This is what makes network research so essential to HIV prevention research. In this article, we review recent research on two characteristics of sexual networks: concurrency and assortative mixing.

Current State of Research

Concurrency

Concurrency is of key interest to HIV/AIDS researchers who study sexual networks. Over a period of time, sexual partnerships link together to form larger sexual networks. These networks or roadways exist regardless of whether or not disease is present. In a network characterized by serial monogamy, with time gaps occurring between relationships, HIV becomes temporarily locked in partnerships. As a result, it travels much more slowly through the sexual network, and earlier partners are not indirectly exposed by later partners. In a sexual network characterized by concurrency, in which all current partners are potentially at risk, being among the first of these partners is no longer protective. Concurrency helps explain the rationale for shifting the focus of HIV prevention efforts from the individual to the individual and his or her sexual partners (Morris 2001).

Using simulation models, Morris and Kretzschmar (1997) found that concurrency exponentially increases the number of individuals infected as well as the rate of HIV spread within a population. The researchers established a mean number of partnerships and tracked the spread of HIV through ten hypothetical structures of sexual networks, beginning with serial monogamy, and moving toward increasing increments of concurrency. In a direct application of these methods, and using survey data from Uganda, Morris et al. (2004) identified high rates of concurrency. Based on these findings, the researchers concluded that concurrency may play a critical role in the generalized HIV spread in some sub-Saharan African countries and called for further modeling efforts and an HIV prevention message of one partner at one time. More recent empirical studies have verified that persons with concurrent partners are three times more likely to transmit an infection (Potterat et al. 1999; Koumans et al. 2001).

The diversity and richness of concurrency in sexual networks are described by Gorbach et al. (2002). Based on interviews with 140 STI patients and a non-representative sample of 120 individuals from high- and low-STI prevalence communities in an urban setting in the United States, six common types of concurrent partnership patterns were identified, each carrying its own level of social acceptability, STI risk, and condom use practices. Given the nuances of these varied patterns, a range of prevention interventions, rather than one standard approach, is most likely needed. Table 1 (below) describes these different types of concurrency.

Assortative mixing

Assortative mixing is another sexual network characteristic that influences epidemic spread. Assortative mixing simply means the extent to which individuals choose sexual partners who are similar in age, race, sexual orientation, marital status, socioeconomic status, religion, or locale. When these groups are distinct and stable, HIV may remain isolated in well-defined pockets of the general population (Morris 1991). Through mathematical modeling, Morris (1991) demonstrated that in a setting with strong assortative sexual networks, a small bridge population connecting the two groups may not be powerful enough to counter the effect of the assortative mixing patterns in terms of HIV transmission rates. Assortative mixing tends to create several, unlinked smaller epidemics within a population, as compared to patterns more indicative of concurrency, where ever-increasing numbers of people are linked together, thereby amplifying the rate of HIV transmission (Morris 1997).

Table 1. Six types of concurrency in relationships.

Experimental	• multiple exploratory relationships and no primary partner, i.e., dating • condom use common with all partners
Separational	• relationships that occur when an individual's primary partner works in another location or is in school, the military, or jail • condom use low or nonexistent with primary partner and variable with other partners
Transitional	• multiple relationships that occur as a partnership ends or as an individual moves out of dating and toward having a primary partner • condom use low with former and new partners
Reactive	• relationships galvanized by a partner's not being monogamous • condom use low or nonexistent with primary partner and variable with other partners
Reciprocal	• open relationship or mutual nonmonogamy within a primary relationship • condom use low or nonexistent with primary partner and variable with other partners
Compensatory	• multiple short relationships or one-night flings outside of primary relationship • condom use low or nonexistent with primary partner and variable with other partners

Source: Gorbach et al. (2002)

In Thailand, Morris et al. (1996) used sexual network data to determine who was at highest risk for HIV transmission from a bridge population of men who had relations with both commercial sex partners (CSPs) and non-CSPs. The non-intuitive answer was that young, unmarried women in the general population were the group most likely to be exposed to potential transmission across this bridge. The analysis was based on a 1992 behavioral study that gathered information on sexual behavior from low-income men and long-haul truck drivers. Morris et al. (1996) were able to calculate that for every 100 sexually active men, 30 women in the general population were potentially exposed to HIV in the past year, based on condom use, the number of men with concurrent CSPs and non-CSPs, and the rate of partner acquisition. Sexual network analysis of age- and group-specific patterns indicated that younger men who engaged in commercial sex had a higher number of non-CSPs than older men, and that more of their non-CSPs were non-spousal female partners. Without such analysis, researchers might have assumed that spouses, rather than young unmarried women, were the primary group placed at risk. These types of findings inform program intervention design and ensure that all at-risk groups are identified.

Morris and Dean (1994) looked at the impact of age-mixing patterns on HIV transmission rates in homosexual men and found that assortative mixing initially amplified the spread of infection within the most active group (those aged 25–35 years). Therefore, the usual protective effect that assortative mixing provided to the other groups was overwhelmed by the higher levels of HIV prevalence. However, as contact rates declined and HIV mortality increased within the older age groups, the net protective effect of assortative mixing for all age groups grew, particularly for the youngest group of enrollees (aged 18–24 years). The network analysis was based on data from the decade-long Longitudinal AIDS Impact Project in New York City (LAIP), a seven-year behavior study of gay men in New York City.

The Turning Point: Data Collection and Analysis

Traditional methods of STI partner notification and contact tracing do not transfer easily to the behavioral survey setting, where issues of privacy, confidentiality, and limited access to HIV testing are paramount. These roadblocks have stimulated researchers to develop more “user friendly” ways to study sexual networks and broaden the way that network concepts can be used at many levels of STI programming. For example, in a review of partner notification studies from several countries, Rothenberg (2002) discovered that case finding in some instances went beyond simply identifying sexual partners to tracing a broader social network of at-risk friends and acquaintances.

In order to undertake sexual network analysis, researchers are developing new tools to support this crossover research between epidemiology and social network theory (see handbook on network epidemiology, Morris 2004). One of the greatest challenges is the collection and analysis of network data. In the ideal situation, researchers would collect data on all individuals within a given network. This “complete network data” would be used to definitively map an entire set of partnerships. The first wave of the National Longitudinal Survey of Adolescent Health (Udry and Bearman 1998; Bearman and Jones 1997), conducted in the United States in 1995, gathered one of the few existing examples of complete network data in a national survey setting. Researchers were able to construct a comprehensive map of the romantic and non-romantic sexual relationships in one high school, by gathering data from each student on a total of 535 romantic relationships (Moody 2002). Moody calculates the sequence and timing of relations to show all possible pathways a disease can travel through this romantic network.

However, as comprehensive network data are almost unheard of in the developing world, partial or “local” network data are often collected. Partial networks are typically surveyed through some kind of snowball sampling. An example is shown in Figure 1. This sexual network from Colorado Springs was sampled using a combination of multisite enrollment and contact tracing from 1990 to 1995. The figure, based on data reported in the first year of the study, shows all sexual partnerships that had occurred during the previous six months. In a “local network” study, a representative sample of a population is asked to report information on their immediate partners, but the partners are not traced or enrolled. These local network data are rich enough to examine for concurrency and assortative mixing patterns, although researchers question how much information is lost by using this less comprehensive approach (Morris 1997).

The Future

Research on sexual networks benefits from a new synergy of improved tools, better data, and a clear need for this type of analysis on the part of HIV program planners in the field.

Researchers are actively investigating ways to improve the quality and breadth of information obtained from local network data. Morris (2003) is exploring sophisticated statistical approaches that will form the basis of a hybrid approach to local and complete network data. Sexual network theorists have traditionally used linear algebra tools to describe clustering and connectivity, and standard statistical methods for estimation and inference. Morris' recent work, drawing on exponential random graph models, represents a leap forward, providing sexual network theorists with intermediate statistical tools for modeling dependent data and a methodology for extrapolating from local network information. For the first time, researchers will be able to plug in sexual network data directly from the field into simulation models.

Moody (2002) broaches an area of modeling that is still at the stage of theory. However, by comparing various sexual network structures from concurrency to monogamy, Moody is able to demonstrate that the timing of relationships is critical for determining the diffusion of disease. While sexual network theorists understand the practical implications, statistical methods do not yet exist that can map the spread of disease and simultaneously account for the sequence or timing of relationships.

Recommendations for Practice: Research Implications for HIV/AIDS Programming

Local network data can be collected with a simple module that probes for key information on current and previous partners of the respondents. This module is easily integrated into a standard questionnaire, and is extremely flexible in terms of length and content. The data are invaluable for designing HIV prevention interventions that hone in on the most vulnerable links of HIV transmission. The module may start with a question as simple as, "I'd like to ask you some questions about the person you had sex with most recently." Essential information includes the dates of first and last sexual encounters, in order to establish partnership intervals, and partner attributes (e.g., age, race, geographic local, education, occupation), relationship attributes (e.g., nature of the partnership, if they have children, how they met), sexual behavior, and risk factors (Morris 1997). These same questions should be asked in regard to the respondent's two previous partners, at a minimum.

Two local network studies from Thailand and Uganda conducted in the early 1990s demonstrate how to collect sexual network data in the field (Morris et al. 2004). The cross-sectional study in Thailand collected survey information from 678 brothel-based prostitutes, 330 long-distance truck drivers, and 1,075 low-income men from the general population. Respondents were asked 32 questions about each of their three most recent sexual partners, covering partner attributes and the nature of their relationships, sexual behavior, and condom use. In Uganda, a cross-sectional survey of individuals from 90 communities in the Rakai district included 77 questions about each of the respondent's most recent three partners. The extensive number of questions, while not feasible in every situation, provided data rich in detail. In both cases, findings from the data helped identify sexual network characteristics that hastened the spread of HIV and therefore had implications for intervention design.

Conclusion

Sexual network analysis is changing the face of HIV prevention strategies by moving the focus of prevention efforts from isolated individuals to sexual partnerships. Network analysis can be used to identify those most at risk of HIV infection, the relational context of the risk behavior, and the means to tailor prevention strategies accordingly. Only within the past few years have specific sexual network characteristics been identified as critical to understanding HIV transmission patterns and spread of disease. Assortative mixing creates two effects: slowing disease spread between groups and increasing disease spread within groups. Concurrency amplifies the spread of HIV through multiple partnerships. In the future, other network characteristics may emerge that are just as important to track and understand. New modeling and statistical tools are advancing the field rapidly and will soon allow researchers to accurately forecast the spread of disease through particular sexual networks and to predict the effects of interventions that alter the characteristics of networks.

References

Armendáriz de Aghion, B., and J. Moruch. 2000. Microfinance beyond group lending. *The Economics of Transition*, 8(2):401–420.

Bearman, P.S. and J. Jones. 1997. The National Longitudinal Study of Adolescent Health: Research Design [www document]. Accessed at http://www.cpc.unc.edu/projects/addhealth/

Gorbach, P.M., B.P. Stoner, S.O. Aral, W.L.H. Whittington, and K.K. Holmes. 2002. "It Takes a Village": Understanding concurrent sexual partnerships in Seattle, Washington. *Sexually Transmitted Diseases*, 29(8):453–462.

Jones, J.H., and M.S. Handcock. 2003. Sexual contacts and epidemic thresholds. *Nature*, 423(6940):605–606.

Koumans, E.H., T.A. Farley, and J.J. Gibson, C. Langley, M.W. Ross, M. McFarlane, and J. Braxton. 2001. Characteristics of persons with syphilis in areas of persisting syphilis in the United States: Sustained transmission associated with concurrent partnerships. *Sexually Transmitted Diseases*, 28(9):497–503.

Liljeros, F., C.R. Edling, L.A. Nunes Amaral, H.E. Stanley, and Y. Åberg. 2001. The web of human sexual contacts: Promiscuous individuals are the vulnerable nodes to target in safe-sex campaigns. *Nature*, 411(6840):907–908.

Luke, N., and K.M. Kurz. 2002. *Cross-generational and transactional sexual relations in sub-Saharan Africa: Prevalence of behavior and implications for negotiating safer sexual practices*. International Center for Research on Women: Washington, D.C.

Moody, J. 2002. The importance of relationship timing for diffusion. *Social Forces*, 81(1):25–56.

Moody, J., and M. Morris. 2000. Sexual network (personal communication). Colorado Springs, Colo.

Morris, M. (ed.). 2004. *Network epidemiology: A handbook for survey design and data collection*. International Studies in Demography Series. Oxford: Oxford University Press.

Morris, M. 2003. "Local rules and global properties: Modeling the emergence of network structure" (National Academy of Sciences workshop), in *Dynamic social network modeling and analysis*. R. Breiger, K. Carley, and P. Pattison (eds.). Washington, D.C.: The National Academies Press. pp. 174–186.

Morris, M. 2001. Concurrent partnerships and syphilis persistence: New thoughts on an old puzzle. *Sexually Transmitted Diseases*, 28(9):504–507.

Morris, M. 1997. Sexual networks and HIV. *AIDS*, 11(Suppl A): S209–S216.

Morris, M. 1991. A log-linear modeling framework for selective mixing. *Mathematical Biosciences*, 107(2):349–377.

Morris, M., and L. Dean. 1994. Effect of sexual behavior change on long-term human immunodeficiency virus prevalence among homosexual men. *American Journal of Epidemiology*, 140(3):217–232.

Morris, M., and M. Kretzschmar. 1997. Concurrent partnerships and the spread of HIV. *AIDS*, 11(5):641–648.

Morris, M., C. Podhisita, M.J. Wawer, and M.S. Handcock. 1996. Bridge populations in the spread of HIV/AIDS in Thailand. *AIDS*, 10(11):1265–1271.

Morris, M., M.J. Wawer, C. Podhisita, T. Pramualratana, N. Sewankambo, and D. Serwadda. 2004. "The Thailand and Ugandan Sexual Network Studies," in M. Morris (ed.), *Network epidemiology: A handbook for survey design and data collection*. Oxford: Oxford University Press. pp. 42–57.

Potterat, J.J., H. Zimmerman-Rogers, S.Q. Muth, R.B. Rothenberg, D.L. Green, J.E. Taylor, M.S. Bonney, and H.A. White. 1999. Chlamydia transmission: Concurrency, reproduction number, and the epidemic trajectory. *American Journal of Epidemiology*, 150(12):1331–1339.

Rothenberg, R. 2002. The transformation of partner notification. *Clinical Infectious Diseases*, 35(Suppl 2): S138–S145.

Udry, J.R., and P.S. Bearman. 1998. "New methods for new research on adolescent sexual behavior," in R. Jessor (ed.), *New perspectives on adolescent risk behavior*. Cambridge: Cambridge University Press. pp. 241–269.

Watts, C.H., and R.M. May. 1992. The influence of concurrent partnerships on the dynamics of HIV/AIDS. *Mathematical Biosciences*, 108(1):89–104.

Yorke, J.A., H.W. Hethcote, and A. Nold. 1978. Dynamics and control of the transmission of gonorrhea. *Sexually Transmitted Diseases*, 5(2):51–56.

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The Expert

Martina Morris, PhD, is the Blumstein-Jordan professor in the Department of Sociology and professor in the Department of Statistics at the University of Washington, and director of the Center for Studies in Demography and Ecology. She is principal investigator on four grants funded by the National Institute of Child Health and Human Development: "Quantifying HIV transmission risk in sex/drug networks," "Modeling HIV and STD in drug user and social networks," "HIV and STIs in young adults: A network approach," and "Sexual networks and HIV: Data, models, and intervention." Dr. Morris has published extensively on the issues of concurrent partnerships and sexual networks specific to HIV/AIDS. She is deputy editor of the journal *Sociological Methodology*.

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