Sex, Drugs and STIs:
Decomposing Network Contributions of Different Risk Behaviors

jimi adams
Today’s Roadmap

- **Background**
  - My research
  - Networks & STIs

- **The question(s)**
  - How do different risk behaviors contribute to network predictors of STI?
  - Could those differences help understand racial differences in STI?

- **Method**
  - Simulation-based network counterfactual approach

- **Results**
  - Sex-ties fundamentally different
  - (& most likely to be cross-race)

- **Discussion**
  - Intervention implications
My primary projects

- **IDEAS – Interdisciplinary Dynamics in Emerging Areas of Science Project**
  - w/ Ryan Light, University of Oregon
  - Coauthorship, Cocitation & Topic Model networks in problem-based science (HIV & environmental science) examining catalysts and barriers to effective multi-disciplinary science

- **“Capturing Context” – Integrating network and spatial analytic strategies**
  - w/ Gina Lovasi, Columbia University
  - Forthcoming special issue of *Social Networks*, late 2011

- **Modeling HIV/STI Epidemics**
  - Simulation & empirical-based epidemic surveillance, modeling and decomposition
  - Partner-Based Interventions Modeling Project
    - w/ Georges Reniers, Princeton University
What predicts disease risk?
What predicts disease risk?
What predicts disease risk?

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What predicts disease risk?

degree: number of partners for an individual (node)

Who is at greatest risk? Least?
Why / how does “degree” matter?

"Epidemics arise and propagate much faster in scale free networks" (Liljeros et al 2001:907)
"To stop AIDS, find hub, scientists say" (Bay Area Reporter 2001)

Figure 1: Distribution of the number of sex partners during one year men and women in the Gotland data.
Is degree enough?

A Network Simulation of Epidemic Potential - Description

- Simulate networks
  - 10,000 nodes
- Same total # of partners - 2 degree distributions
  - “Scale free”
  - Low-degree \((1 < x < 3)\)
- Compare measures of epidemic potential
  - Component size
  - Bicomponent size
Is degree enough?
A Network Simulation of Epidemic Potential

Simulated Low-Degree Networks
Is degree enough?
A Network Simulation of Epidemic Potential

Simulated Low-Degree Networks
Is degree enough?
A Network Simulation of Epidemic Potential

Simulated Low-Degree Networks

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<td>Largest bicomponent: 0</td>
<td>Largest bicomponent: 91</td>
<td>Largest bicomponent: 538</td>
<td>Largest bicomponent: 1,458</td>
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Histograms of Number of Sexual Partners:
- Average: 1.68
- Average: 1.74
- Average: 1.80
- Average: 1.87
Is degree enough?
A Network Simulation of Epidemic Potential
Comparing Low-Degree and Scale-Free Networks

“Epidemics arise and propagate much faster in scale-free networks”
(Liljeros et al 2001:907)
Is degree enough?
A Network Simulation of Epidemic Potential

“To stop AIDS, find hub, scientists say” (Liljeros et al 1999)
Target everyone for “risk reduction” strategies (Moody et al 2007)
Do Scale-Free Networks “Fit”? (Source: Handcock and Jones 2005)
Adults and Children Estimated to Be Living with HIV/AIDS as of End 2005

Total: 38.6 million people [33.4 - 46.0 million]

(Source: USAID 2006)
Is degree enough?
A Network Simulation of Epidemic Potential - comparison to observed data

(Source: Helleringer and Kohler 2006)
Is Degree Enough? (No)

- Conditions necessary for disease epidemics are (more) possible in networks without high-degree actors ("hubs").
- Interventions should target everyone
  - (with respect to ABCs):
- Strategic interventions should focus also on patterns of network structure.

Today’s Questions
- What are the relevant patterns of network structure?
- How do different “risky” behaviors contribute to those patterns?
Examining Racial Differences in Sexually Transmitted Infections
The Differential Importance of Sex & Drug Ties in a High Risk Population

(w/ James Moody, Duke University)

Acknowledgements:
NIDA (Martina Morris, PI)
John Potterat, Stephen Q. Muth (project directors)
Peter Bearman & RWJ H&SS Program, Columbia University
Social Networks & Health Working Group, Columbia University
Structural Dynamics Working Group, SSFD, Arizona State University
Proportions of AIDS Cases among Adults and Adolescents, by Race/Ethnicity and Year of Diagnosis 1985–2005—United States and Dependent Areas

- White, not Hispanic
- Black, not Hispanic
- Hispanic
- Asian/Pacific Islander
- American Indian/Alaska Native

Note: Data have been adjusted for reporting delays.

Revised June 2007
Racial Discrepancies in STD Prevalence
Existing Explanations

- Individual Risk Factors:
  - Poverty, healthcare access and use and community prevalence rates (e.g., Aral 1996; CDC 1995) and drug use (Kottiri et al 2002)
  - Number of sexual partnerships (Santelli et al 1998)
  - Concurrency (Morris and Kretzchmar 1995)
    - Higher for blacks than whites (Adimora et al. 2002; Billy et al. 1993; Manhart et al. 2002; Ford and Norris 1997)
Existing Explanations for Racial Discrepancies in STD Prevalence

Reported Number of Sexual Partners

Odds ratios, controlling for age, residence, marital status, alcohol and drug use, and age at first intercourse (Source Santelli et al 1998)

(*’s – difference significant for p<0.05)
Racial Discrepancies in STD Prevalence

Existing Explanations

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□ Sexual network structure can explain differences not observed through individual level modeling, such as:
  ▪ Network bridges (Morris et al. 1996)
    ■ More frequently among blacks than whites (Laumann and Youm 1999)
  ▪ “Sexual segregation” can isolate an STI in a particular population
Racial Discrepancies in STD Prevalence
Existing Explanations

Table 2  Characteristics of persons by component size membership

<table>
<thead>
<tr>
<th>Component size (n)</th>
<th>Sex</th>
<th>M</th>
<th>F</th>
<th>M/F ratio</th>
<th>Ethnicity</th>
<th>Accepts (W)</th>
<th>AA (%)</th>
<th>Other (%)</th>
<th>Ethnicity</th>
<th>Accepts (W)</th>
<th>AA (%)</th>
<th>Other (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large (n=10)</td>
<td></td>
<td>120</td>
<td>155</td>
<td>0.77</td>
<td>Male</td>
<td>16 (13.3)</td>
<td>98 (81.7)</td>
<td>6 (5.0)</td>
<td>Female</td>
<td>59 (38.1)</td>
<td>68 (43.9)</td>
<td>28 (18.0)</td>
</tr>
<tr>
<td>Medium (n=66)</td>
<td></td>
<td>639</td>
<td>822</td>
<td>0.78</td>
<td>Male</td>
<td>185 (29.0)</td>
<td>324 (50.7)</td>
<td>130 (20.3)</td>
<td>Female</td>
<td>360 (43.8)</td>
<td>258 (31.4)</td>
<td>204 (24.8)</td>
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<tr>
<td>Small (n=2625)</td>
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<td>1013</td>
<td>1610</td>
<td>0.63</td>
<td>Male</td>
<td>356 (35.1)</td>
<td>430 (42.4)</td>
<td>227 (22.4)</td>
<td>Female</td>
<td>766 (47.6)</td>
<td>440 (27.3)</td>
<td>404 (25.1)</td>
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<tr>
<td>Total (n=2701)</td>
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<td>1772</td>
<td>2587</td>
<td>0.68</td>
<td>Male</td>
<td>557 (31.4)</td>
<td>852 (48.1)</td>
<td>363 (20.5)</td>
<td>Female</td>
<td>1185 (45.8)</td>
<td>766 (29.6)</td>
<td>636 (24.6)</td>
</tr>
</tbody>
</table>

AA, African American; other, other ethnicity (76.6% Hispanic); W, white.
Racial Discrepancies in STD Prevalence
Existing Explanations

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  - Network bridges (Morris et al. 1996)
    - More frequently among blacks than whites (Laumann and Youm 1999)
  - “Sexual segregation” can isolate an STI in a particular population

Net of all this, **LARGE disparities remain**
Wide gap in HIV and other STD prevalence remains between blacks and whites in the US

Even controlling for all of the explanations mentioned above.

So…Let’s examine:

Do different types of relations (sex, drugs, both) differentially connect a “high-risk” population?

Can those differences help explain race differences in STI rates?
Data – Colorado Springs, Project 90

- CDC Funded (1988-1992)
- To assess the size, structure and epidemic potential of a high-risk partnership network
- HIV-transmission risk in population of:
  - Prostitutes
  - Their sex partners (heterosexual)
  - IDU
- 595 respondents
  - Face-to-face interviews
  - 5 year open cohort design
  - Link tracing design
- Sexual, drug sharing & social contact network data
Data – Colorado Springs, Project 90
# Data – Colorado Springs, Project 90

Node Level Mixing, by Tie-Type

<table>
<thead>
<tr>
<th></th>
<th>Sex Only</th>
<th>Drug Only</th>
<th>Both Only</th>
<th>Bridge Only</th>
<th>Both &amp; Bridge</th>
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<td>1022</td>
<td>42</td>
<td>944</td>
<td>353</td>
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<td>(35.2)</td>
<td>(28.1)</td>
<td>(1.2)</td>
<td>(25.9)</td>
<td>(9.7)</td>
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<tr>
<td>Black</td>
<td>418</td>
<td>365</td>
<td>12</td>
<td>305</td>
<td>108</td>
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<td>(34.6)</td>
<td>(30.2)</td>
<td>(1.0)</td>
<td>(25.3)</td>
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<td>Total</td>
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<td>1717</td>
<td>68</td>
<td>1503</td>
<td>530</td>
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<td></td>
<td>(34.5)</td>
<td>(29.5)</td>
<td>(1.2)</td>
<td>(25.8)</td>
<td>(9.1)</td>
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Modeling Group Differences in HIV Risk

Contour Overlay - by Race
Modeling Group Differences in HIV Risk

Note the distribution of edge types. The large “eastern” cluster is where most of the sex is happening in this network.
Method

We can assess the *connectivity contributions* of each type of tie by *selectively removing* ties from a network and assessing the change in connectivity-relevant measures.

- That is:
  - Select at random $n$ ties of type $k$
  - Calculate the connectivity measures on the resulting network
  - Repeat this many times (here 500 at each setting).
  - Plot observed (mean) changes by tie type

- We remove between 1% and 12% of the total ties observed in the network, separately for:
  - Sex ties
  - Drug Ties
  - Sex & Drug Ties
  - Random Ties
Connectivity Measures

- **Size of the largest component**
  - The maximum number of people connected by a path of any length
  - Captures the ultimate potential extent of STI diffusion
Full-Network Measures - Range
Component – maximal set on a single connected path
Connectivity Measures

- **Size of the largest component**
  - Captures the ultimate potential extent of STI diffusion

- **Relative size of the largest bi-component**
  - The maximum number of people connected by *at least two* node-independent paths (of any length)
  - A measure of the extent of a more robust portion of the network
Full-Network Measures - Connectivity

Bi-Component – subset of a graph connected by \textit{at least} two node-independent paths
Connectivity Measures

- **Size of the largest component**
  - Captures the ultimate potential extent of STI diffusion

- **Relative size of the largest bi-component**
  - A measure of the extent of a more robust portion of the network

- **Relative average distance among pairs in the networks**
  - The number of links between two people (in-/directly) connected in a network
  - Transmission likelihood is higher if there are many shortcuts in the network. We measure this relative to the largest component.
Individual Measures - Distance

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Graph representation: 1-2-3-4-5-6
Connectivity Measures

- **Size of the largest component**
  - Captures the ultimate potential extent of STI diffusion

- **Relative size of the largest bi-component**
  - A measure of the extent of a more robust portion of the network

- **Relative average distance among pairs in the networks**
  - Transmission likelihood is higher if there are many shortcuts in the network. We measure this relative to the largest component.

- **Transitivity Ratio**
  - Given ties between $i-k$ and $j-k$, the proportion of times a tie is also observed between $i-j$
  - As ties revert back on themselves (“recursion”) transmission is reinforced, but not spread as widely.
Social Balance & Transitivity

We determine balance based on the product of the edges:

$\text{++} \quad \text{++} \quad \text{++} = \text{++} \quad \text{Balanced} \quad \text{"A friend of a friend is a friend"}$

$\text{--} \quad \text{+-} \quad \text{-} = \text{-} \quad \text{Balanced} \quad \text{"An enemy of my enemy is a friend"}$

$\text{-} \quad \text{-} \quad \text{-} = \text{-} \quad \text{Unbalanced} \quad \text{"An enemy of my enemy is an enemy"}$

$\text{-} \quad \text{-} \quad \text{-} = \text{-} \quad \text{Unbalanced} \quad \text{"A Friend of a Friend is an enemy"}$
Effect of edge removal on size of largest component

Effect of edge removal on relative size of largest bicomponent

Effect of edge removal on relative average distance

Effect of edge removal on transitivity ratio

Remember – decreases from deletions means increasing importance
Findings - Overall

- Across all measures, *sex ties* provide the most reach; removing them:
  - Quickly decreases the size of the largest component
  - Leaves the network with a relatively larger biconnected core
  - Decreases the average (relative) distance faster than drug or random ties
  - Increases the transitivity (redundancy) of the network

- This suggests that, sex ties:
  - Create “tendrils” that reach out into the wider population
  - But do so in a relatively sparse way
  - With (comparatively) fewer re-connections to the strongest core(s) of the network
  - While drug ties create more redundancies in the network, or provide shortcuts between otherwise connected sections
Connectivity Measures

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- **Racial Segregation index**
  - Freeman’s segregation index. Extent of cross race ties compared to random (1 = completely segregated, 0 = random mixing).
Segregation Index – Freeman (1972) asked how we could identify segregation in a social network. Theoretically, he argues, if a given attribute (group label) does not matter for social relations, then relations should be distributed randomly with respect to the attribute. Thus, the difference between the number of cross-group ties expected by chance and the number observed measures segregation.

\[ E(X) = \frac{R \times C}{T} \]

\[ X = (17+17) \]

\[ E(X) = (13.55+13.55) \]

\[ Seg = \frac{E(X) - X}{E(X)} \]

\[ Seg = \frac{27.1 - 34}{27.1} \]

\[ = -0.25 \]

Range: 1 = Perfect In-Group Preference
0 = Random
-1 = Perfect Out-Group Preference
Effect of edge removal on racial segregation

Network Racial Segregation

Proportion of all edges removed
Findings – Racial Segregation

- Again, sex ties have the most different effect:
- Removing them increases the overall racial segregation in the network faster than other tie-types, meaning:
  - In this population, sex-ties are more cross-race than are drug ties or sex & drug ties
  - Thus are potential (hidden) bridges
So What?

- Epidemiologically –
  - Traditional approach (network studies of sex OR drugs) would substantially mis-estimate epidemic potential:
    - For the population at large
    - AND the potential contribution of sex/drug ties alone
  - Basing interventions on one could lead to unexpected results
    - *In this population:*
      - Drug only interventions would be most likely to influence “core group” infections (epidemic **duration**)
      - Sex only interventions would be most likely to influence non-core group infections (epidemic **breadth**)
    - Unless network contributions are well known, condom promotion & needle exchange simultaneously for maximal effect
Thank You!

- Questions?
- Contact – jim.adams@asu.edu
Project 90: Respondent only Contact Network

Figure 1. Drug & Sex Network, Respondents only, by race
Results I

Effect of edge removal on *Racial Segregation Index*

Segregation is Freeman's (1972) Segregation Index using a 4 category race variable.
Findings – Comparison

- Sex Ties still the most different
  - Distance effect reverses
- “Both” ties important for RR redundancy

A few notes:
- The *base level* of segregation is higher across the full network than the RR-only network, suggesting:
  - Respondents were more likely to have cross race ties than non-Rs
- The racial segregation sex- *sampling* effect is lower in the full network than the RR network