The Sexual Network of HIV in Botswana

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What is HIV?

- Human Immunodeficiency Virus
- A lentivirus that causes HIV and AIDS
- HIV-1 and HIV-2 both originated in nonhuman primates in West Africa.
- It is believed that HIV is the result of a mutation of SIV. That it jumped the species barrier and was transmitted from person to person.
How is HIV Transmitted?

- Exchange of bodily fluids through sexual activities
- Sharing of syringes and needles
- Mother to child
How Can Transmission be Prevented?

• Condom use
• Male circumcision
• Antiretroviral therapy (ART)
• Microbicides
• Pre-exposure prophylaxis (PrEP)
Victor’s and Rui’s Research

• Model the sexual network of communities in Botswana.
• Believed to be transmitted heterosexually
• Compare the effects of standard treatments of HIV to combination treatments.
• Simulate the effects of treatments on the sexual networks.
• Do combined efforts achieve community level control?
Goals of HIV Research

• The goal of this research is to investigate the effects that monogamy has on a sexual network.
• Because there is no cure for HIV, research is aimed at optimizing the prevention of new cases.
Project Outline

• Network Basics
• Small World Properties
• Setup
• Assumptions
• Methods
• Method Comparison
• Further Investigation
Networks Basics

• An undirected network $G = (N, E)$
• $N =$ the set of nodes within the network
  – In this case $N =$ number of couples in the network
• $E =$ the set of edges that connect the nodes
  – These are always unordered pairs of the elements of $N$
• $K =$ number of neighbors each node has
Small World Properties

• Clustering coefficient
  – measure of the degree to which nodes in a graph tend to cluster together

• Rewiring Probability
  – $0 < \beta < 1$
  – As $\beta \to 1$ the clustering coefficient decreases

• Hubs
  – High degree nodes
Small World Properties
Network Setup

- Nodes $n = 200$ couples
- Rewiring Probability $\beta = .5$
- Trials = 200
- Degree $d = 2$
- Mean degree $k = 4$
- Period = 1 year
- Simulated over 10 years
- Undirected network
Network Assumptions

- HIV is transmitted only heterosexually
- Behavioral Change is set to .1 probability/year
- Monogamy occurs 30% of the time
- Edges represent the non-monogamous relationship between nodes.
Methods: No Edge Replacement

• As monogamy takes over the network nodes become isolated.
• No edge replacement or reassignment
• Changing mean degree
Methods: Random Assignment with Fixed Edge

- If node A becomes isolated, the neighbor node B maintains their end of the edge, but the side previously belonging to the now monogamous node A is reassigned to some living node C, iff node C is not already connected to node B.
- If node A and node B become isolated in the same year a pure random assignment rule is applied to the link and it’s reassigned randomly to preserve the mean degree.
Mean Degree

- Mean Degree vs Time (k=4, beta = 0.5, No Edge Replacement)
- Mean Degree vs Time (k=4, beta = 0.5, Random Fixed Replacement)
Number of Components

- **No Edge Replacement**: The number of components increases over time, starting from a low value and gradually growing as time progresses.
- **Random-Fixed Replacement**: The number of components decreases over time, starting from a higher value and steadily declining as time progresses.
Clustering Coefficients

![Graph 1: Clustering Coefficient vs Time (k=4, beta = 0.5, No Edge Replacement)](image1)

![Graph 2: Clustering Coefficient vs Time (k=4, beta = 0.5, Random-Fixed Replacement)](image2)
Network Graphs
Network Graphs
Results

• The mean degree in the base case drops from 4 to just over 2 over the course of 10 years.
• Mean degree of Random-Fixed case remains constant.
• In the case of no edge replacement the number of components increases.
• Components maintain about 1 in the case of random-fixed assignment.
Results Continued

- The clustering coefficient in the case of no replacement has a general trend upward.
- The case of random-fixed edge reassignment shows an initial dip in the clustering coefficient indicating that triples are being broken up faster than they can be replaced.
Further Investigation

- Determining survival rate based on viral load
- Instead of nodes being couples, gender assignment could be done for nodes to compare sexual contact networks for male and female.
- Also, contact tracing for an infected node’s network can be done to determine the epidemic stage other nodes are in.
- Expanding on the contact tracing further, when an infected person is identified, and contact tracing is done, apply the different treatment regimens to compare the benefits of each.
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