



How Behavior Spreads

The Science of Complex Contagions

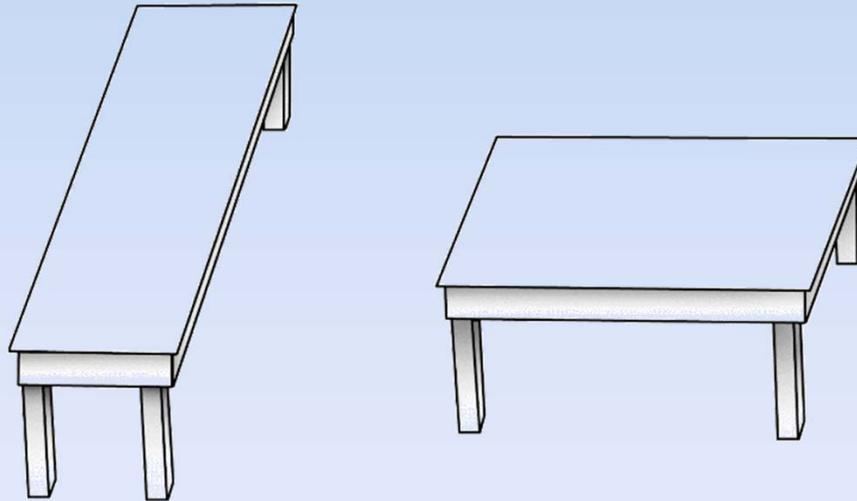
Damon Centola

Financial Disclosures

2017 served as a consultant for CIGNA

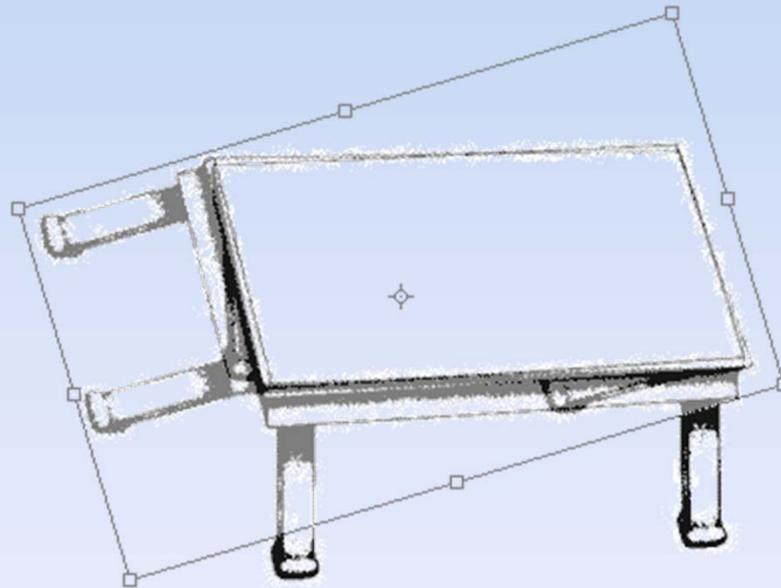
Intuitions

Which table is longer?



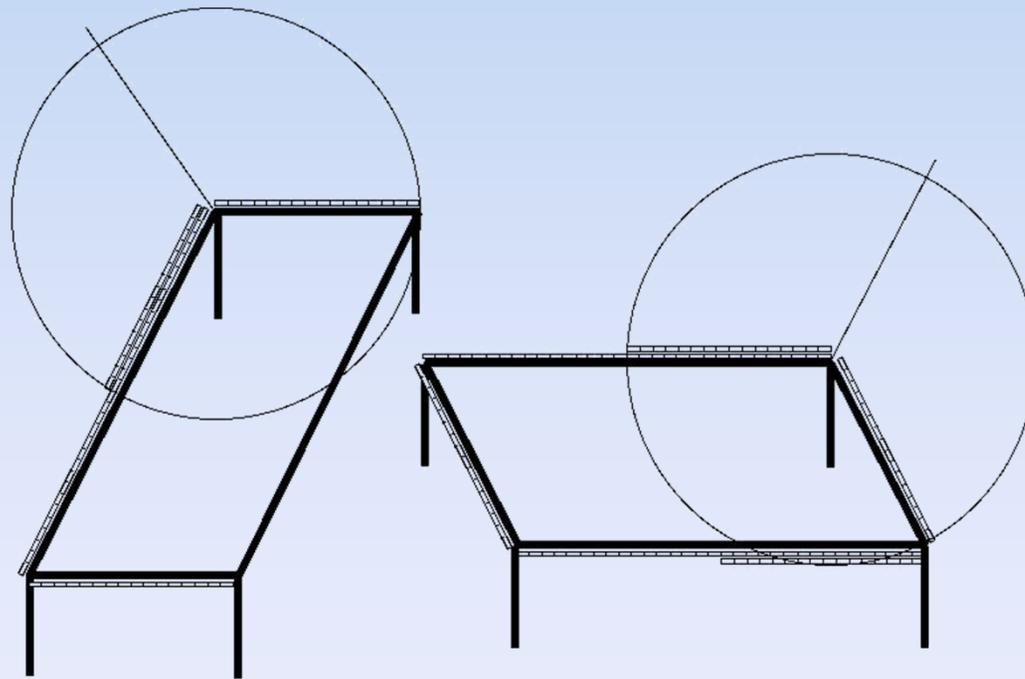
Intuitions

It's a trick question



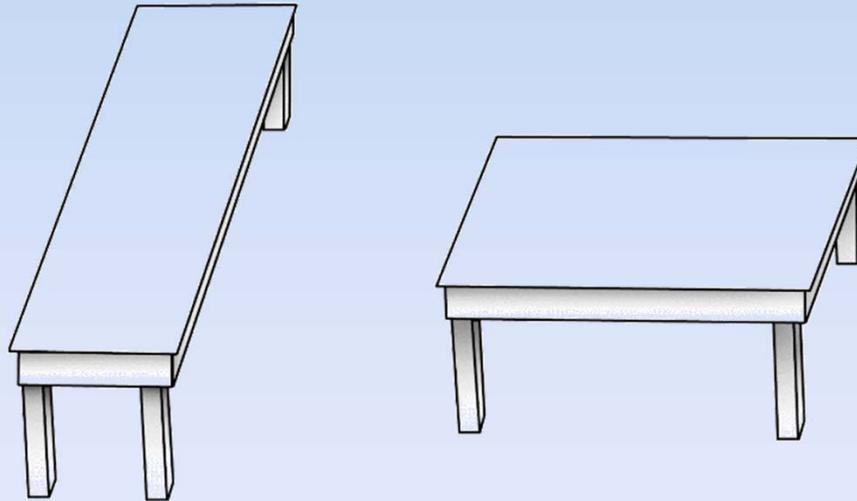
Intuitions

It's a trick question



Intuitions

Which table is longer?



Weak Ties

What kinds of social networks facilitate social diffusion?

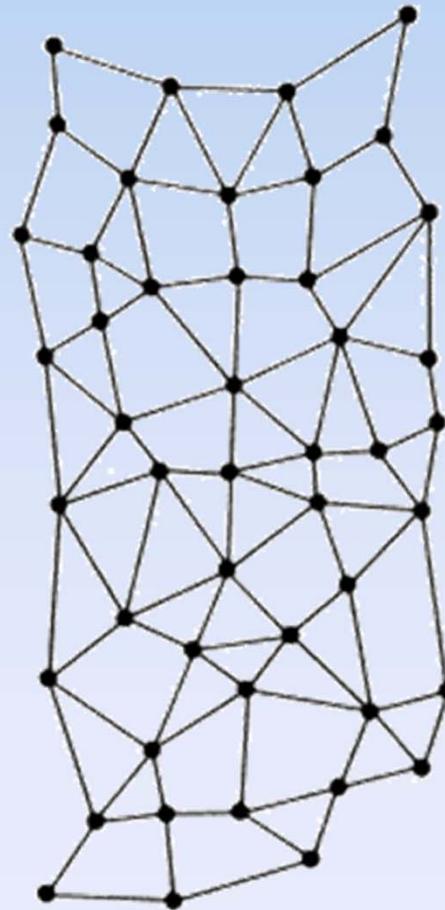
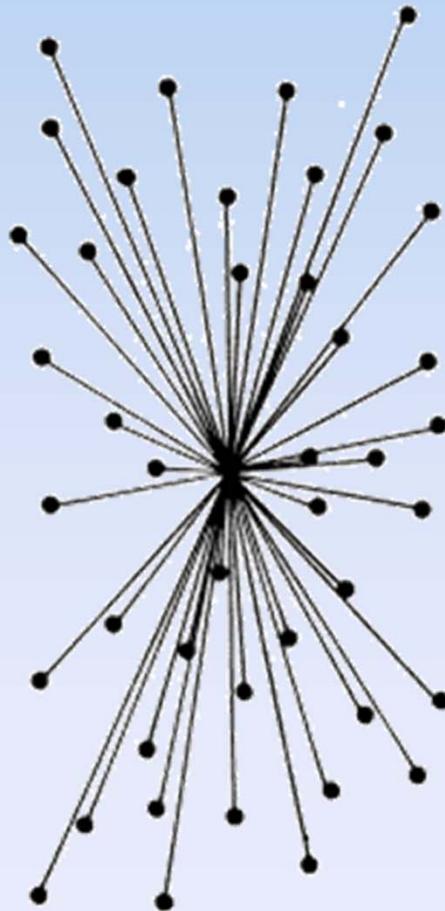
- Weak ties facilitate the spread of collective action
Granovetter (1973)
- ‘Small worlds’ allow cooperation to emerge more easily than ‘large worlds’ (Watts 1999)

“Whatever is to be diffused can reach a larger number of people, and traverse a greater social distance, when passed through weak ties rather than strong.”

- Granovetter 1973

Intuitions

Which network will spread behavior better?



What Goes Wrong?

Epidemiological thinking:

Exposure leads to spreading

Social thinking:

Social context and peer feedback
drive behavior change

Ideas of Diffusion

“I’m convinced that ideas and behaviors and new products move through a population very much like a disease does. This isn’t just a metaphor, in other words. I’m talking about a very literal analogy. ... Ideas can be contagious in exactly the same way that a virus is.”

Gladwell Q& A (2010)

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Gladwell Q& A (2010)

“Even revolutionary actions that look spontaneous, like the demonstrations in East Germany that led to the fall of the Berlin Wall, are, at core, strong-tie phenomena...The primary determinant of who showed up was “critical friends”—the more friends you had who were critical of the regime the more likely you were to join the protest.

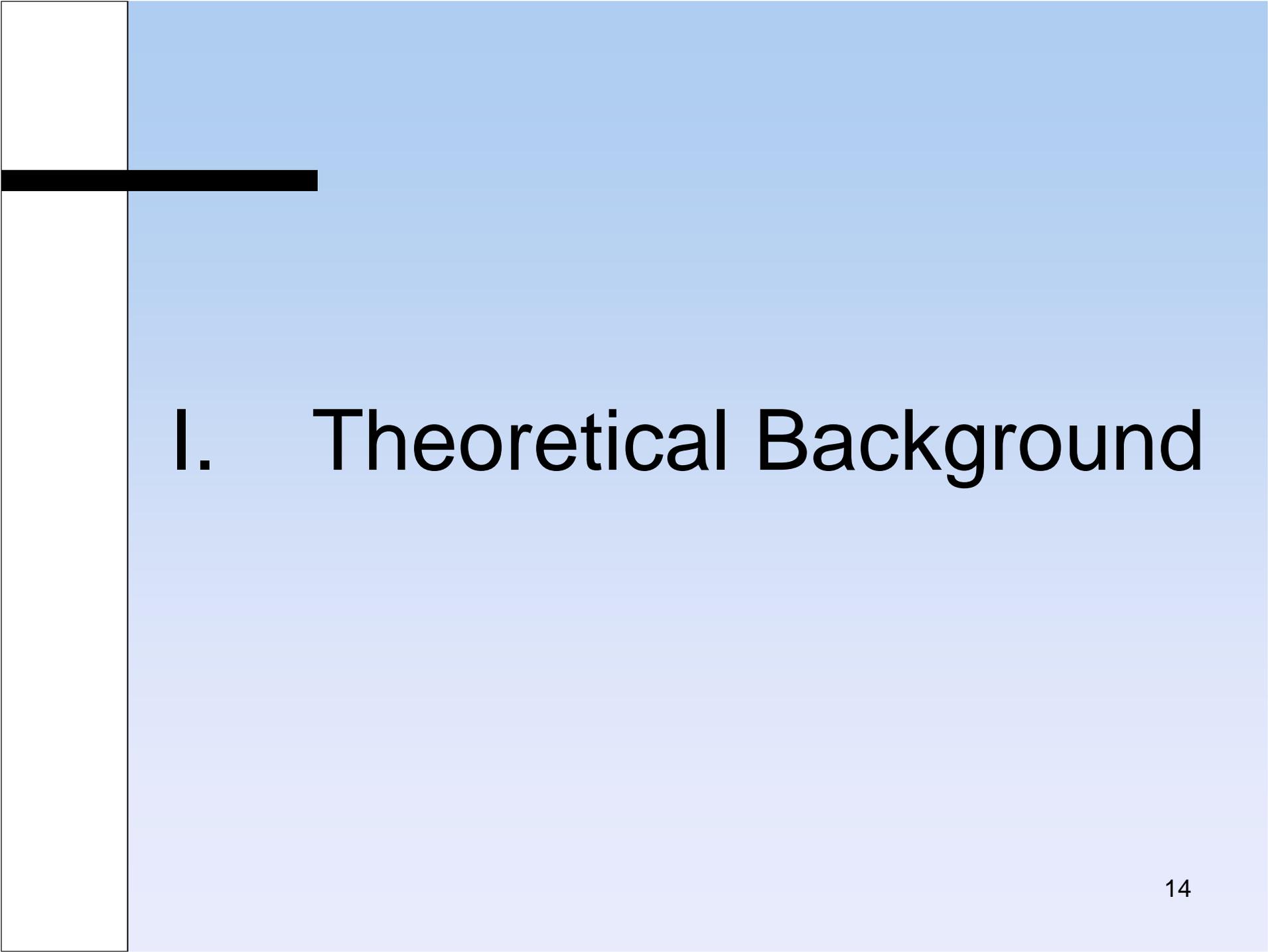
Gladwell *Small Change* (2010)

Summary

- Weak ties help the spread of ‘whatever is to be diffused’
- Closely knit residential and spatial networks facilitate collective action and innovation diffusion (Gould 1996, Hedstrom 1994)
- When social reinforcement is needed, behaviors spread farther and faster across clustered, spatial networks than across ‘small world’ networks
- A new kind of “network experiment” to study how social diffusion processes work
- Much like “choice architecture” in behavioral economics, we can design “social architectures” to improve the adoption of social innovations

Overview

- I. Theoretical Background
- II. Theoretical Results
- III. Experimental Study
- IV. Social Design

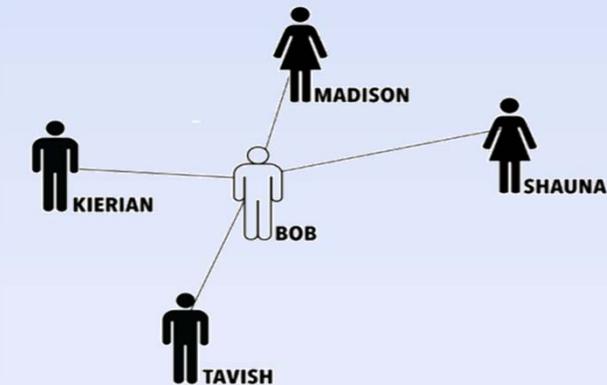


I. Theoretical Background

Social Networks

What are networks?

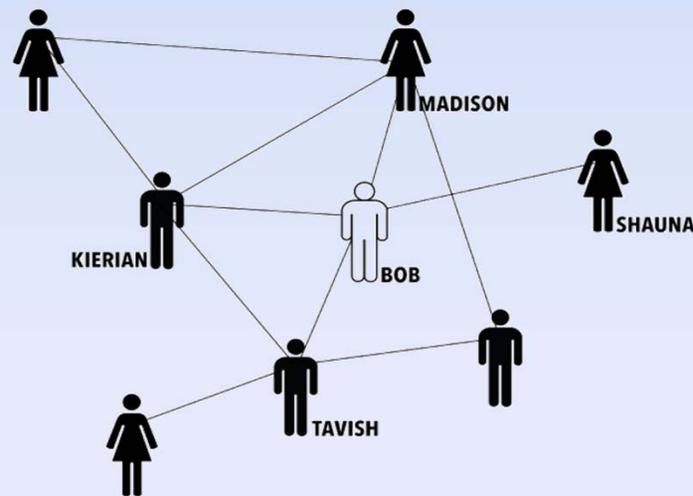
- An individual's "ego network" is the set of people that he or she is connected to – patterns of association



Social Networks

What are networks?

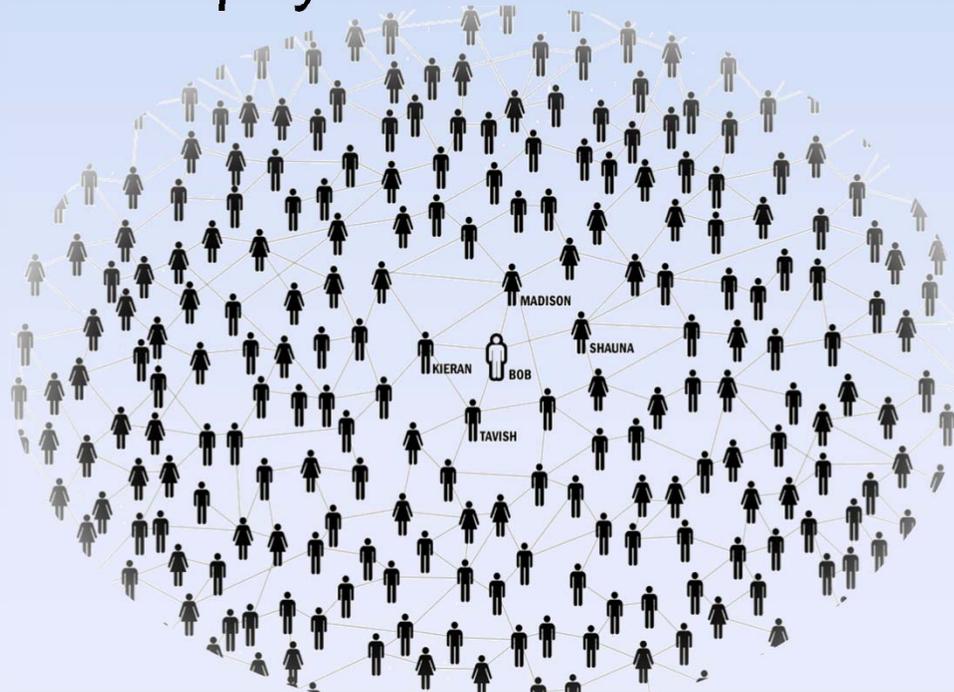
- Theorists connected these insights with micro/macro dynamics of social life (Granovetter 1973, Blau and Schwartz 1984)



Social Networks

What are networks?

- Contemporary sociological network theory builds on classical insights (Simmel 1908) with new methods from physics and mathematics



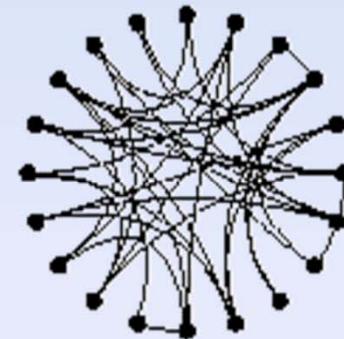
Small World Model

More “long ties” reduce local structure, and increase diffusion rates

Strong Ties



Weak Ties

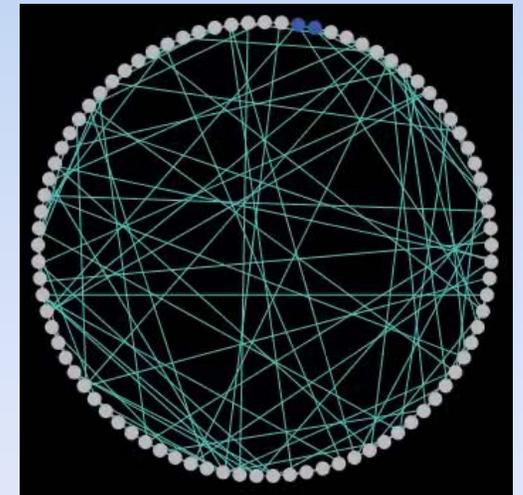
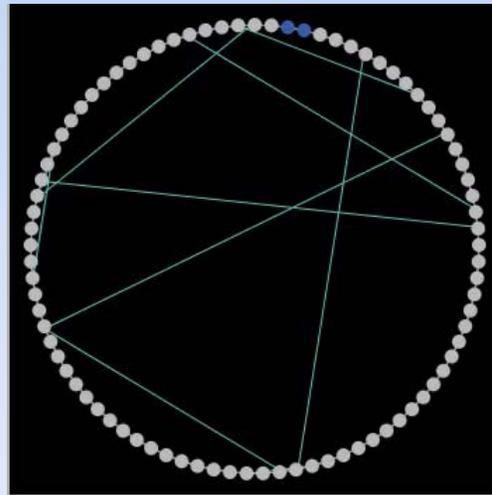
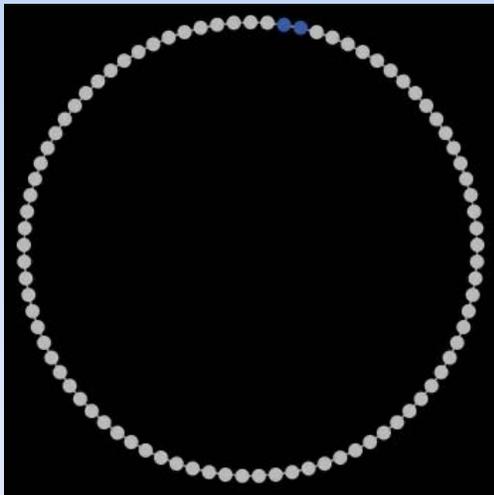


Small World Model

Strong Ties



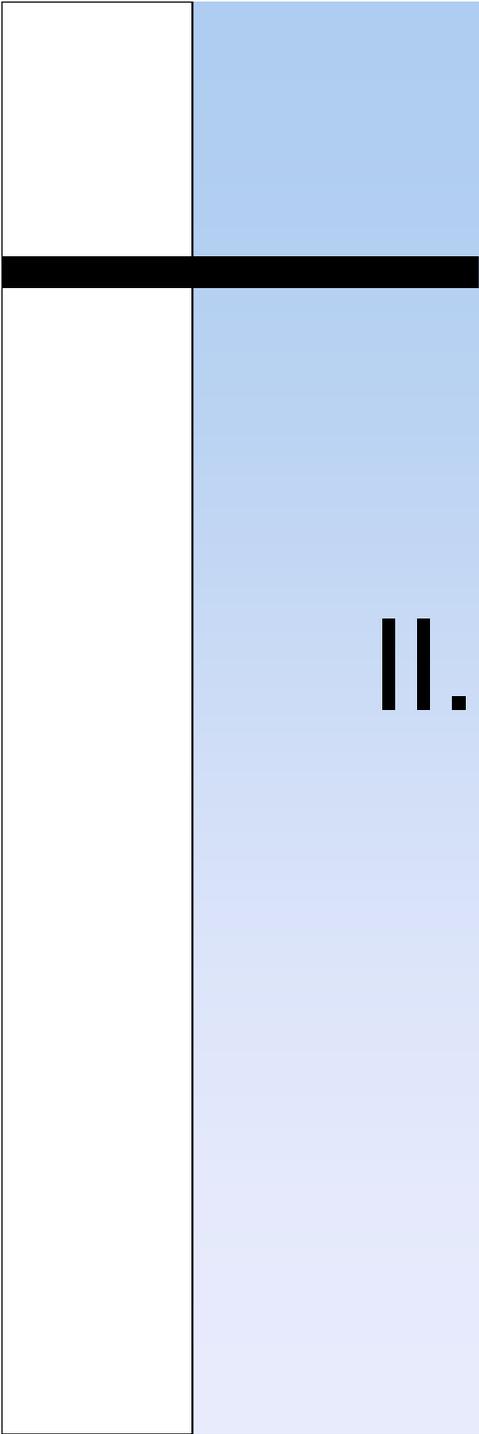
Weak Ties



Diffusion in Networks

Take home from network theory:

- Weak ties facilitate diffusion
- Random networks are better for diffusion than clustered networks



II. Theoretical Findings

Social Reinforcement

“The fact that we are embedded in many relationships means that any major decision we are contemplating will likely be mediated by a significant subset of those relationships.”

McAdam and Paulsen 1993

Simple Contagions: Single Contact is Sufficient

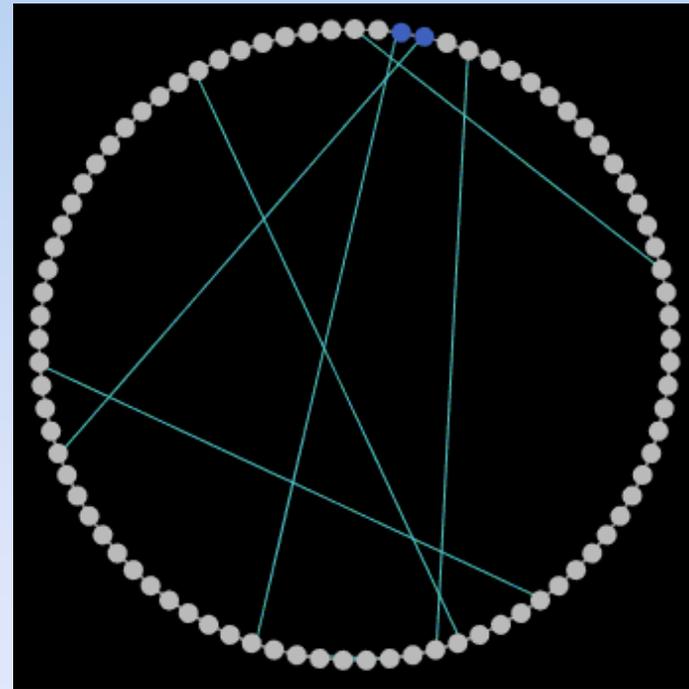
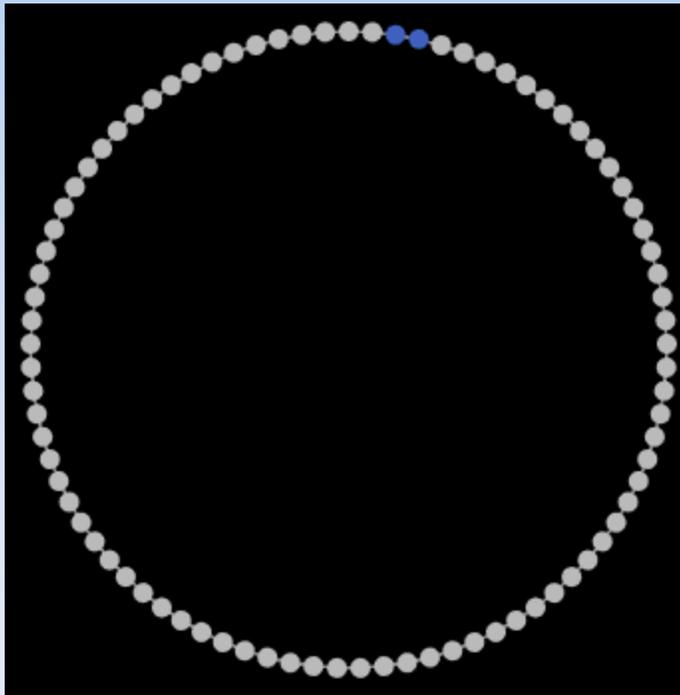
Complex Contagions: Multiple Contacts are Required

Collective Behaviors

Many collective behaviors require social reinforcement

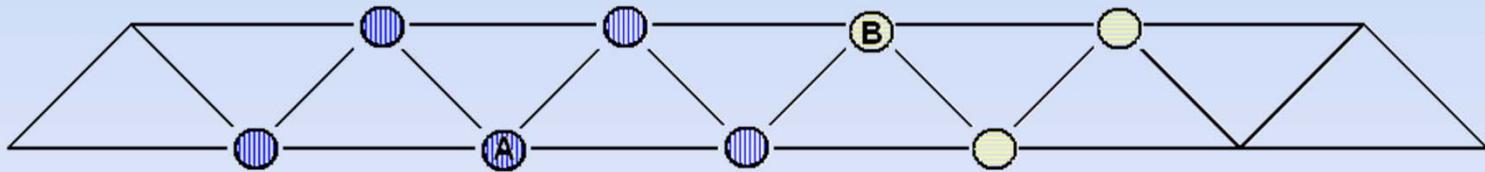
- **Credibility:** Adoption of new technologies, participation in risky behaviors, vaccinations
- **Legitimacy:** Appeal of *avant-garde* fashion, social norms, screenings, dieting, weight gain
- **Complementarity:** mobilizing strikes, recruitment to social movements, complementary technologies

Complex Contagions



Neighborhood Structure

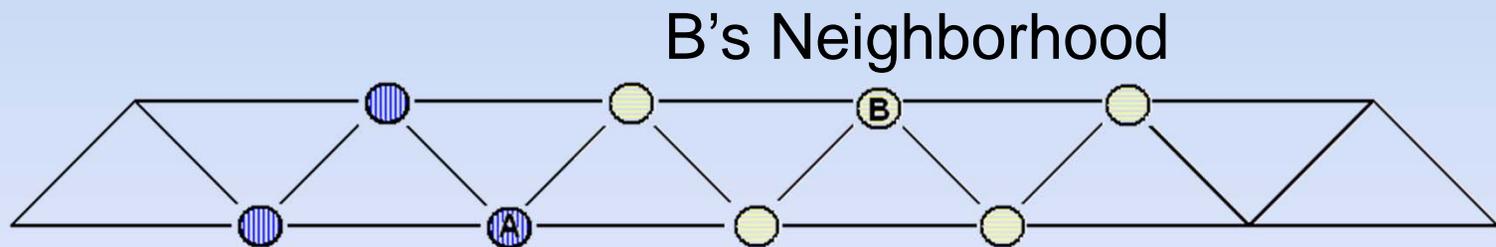
Neighborhoods on a lattice



A's Neighborhood

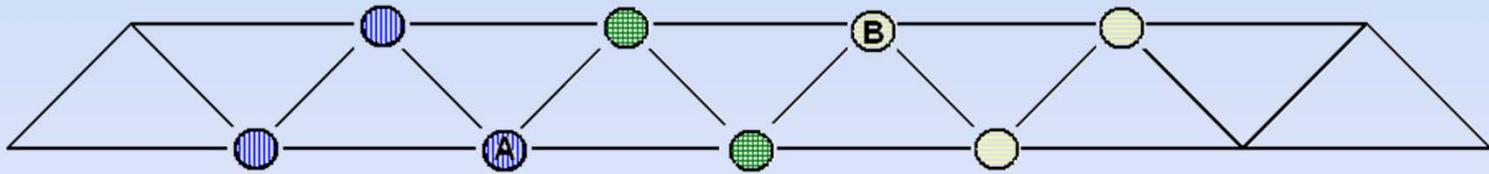
Neighborhood Structure

Neighborhoods on a lattice



Neighborhood Structure

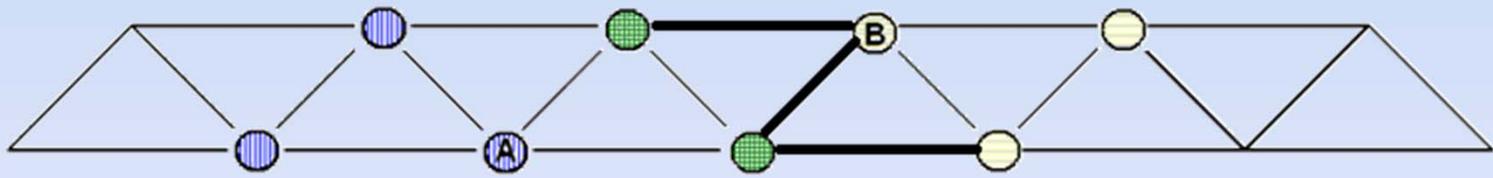
Overlap between neighborhoods



Common Neighbors

Neighborhood Structure

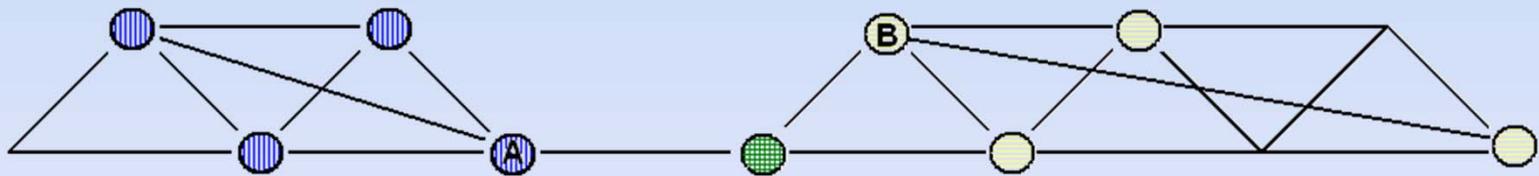
“Wide bridges” between neighborhoods



Common Neighbors

Neighborhood Structure

When local structure is disrupted,
bridges become too narrow



Common Neighbors

Findings

Different kinds of networks help the spread of different kinds of behaviors

If multiple social contacts needed for adoption:

- Weak ties may inhibit diffusion
- Clustered networks may be better for diffusion than random networks

Centola and Macy 2007 American Journal of Sociology.

Centola et al 2007 Physica A.

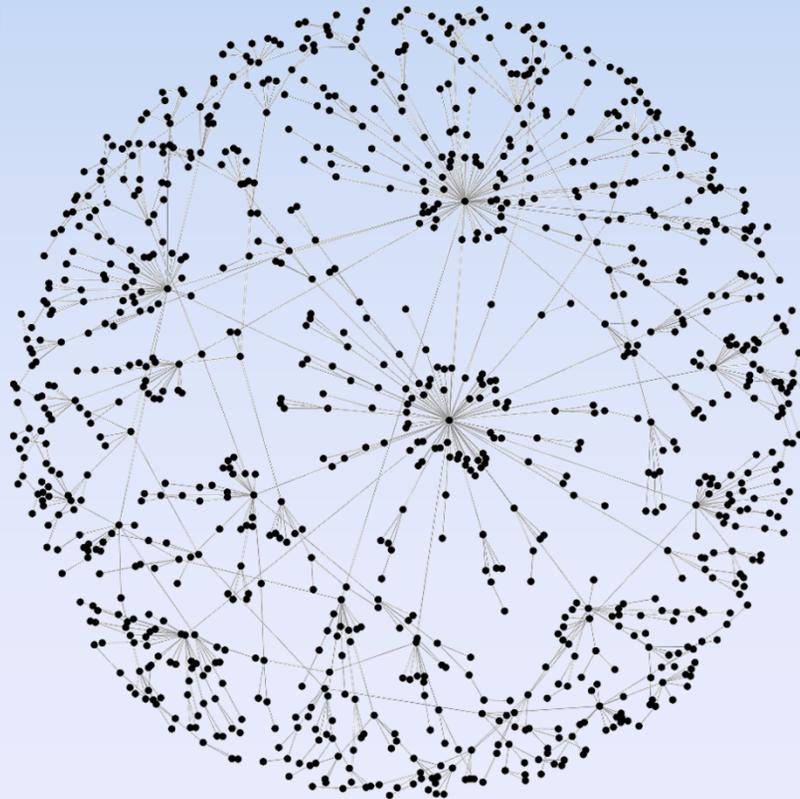
Centola 2008 Journal of Mathematical Sociology

Centola 2010 Science

Centola 2015 American Journal of Sociology

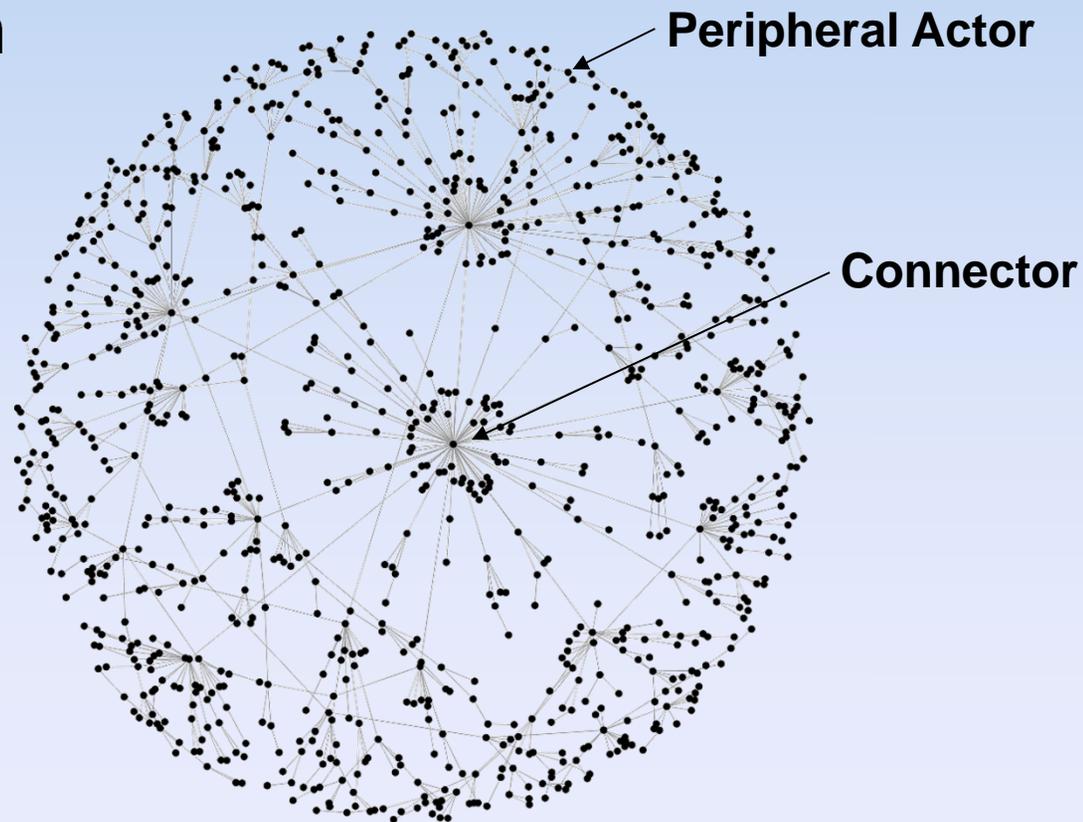
Implications

- Hubs (Barabasi 1999) are susceptible to countervailing influences that can impede diffusion



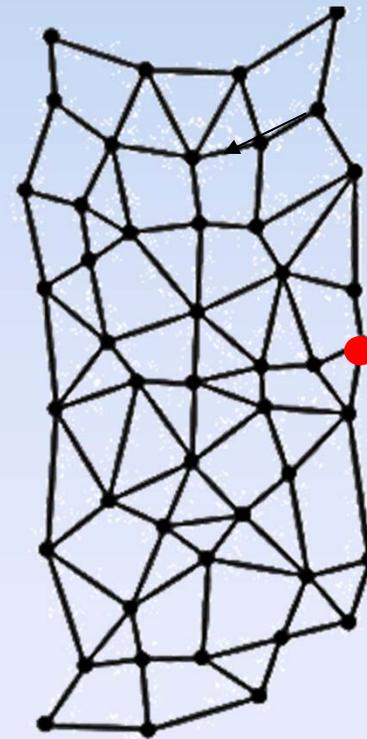
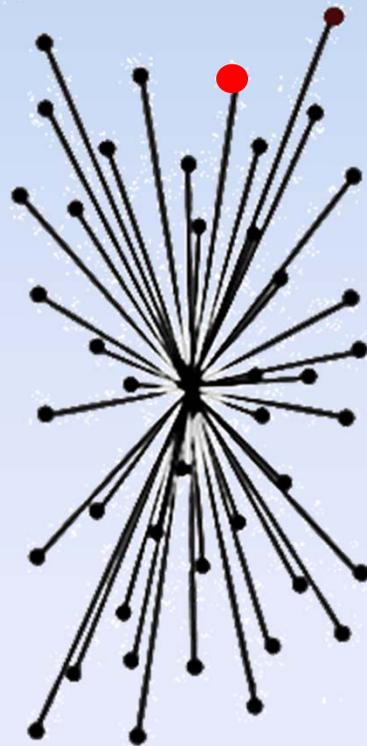
Network Hubs

- Hubs (Barabasi 1999) are susceptible to countervailing influences that can impede diffusion



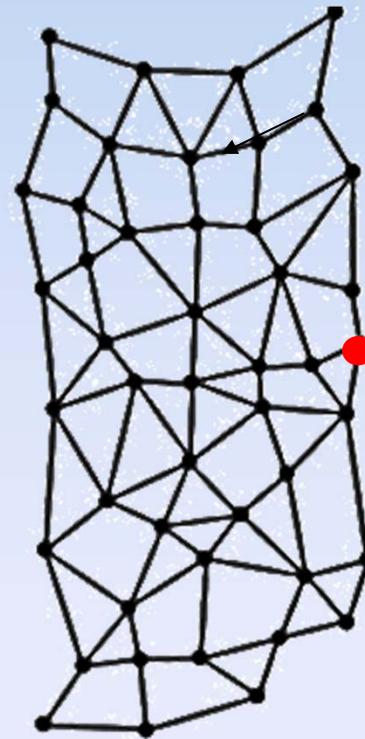
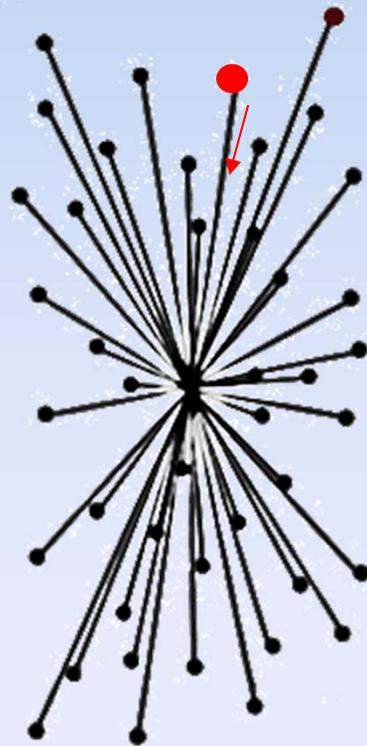
Network Hubs

Simple Contagion



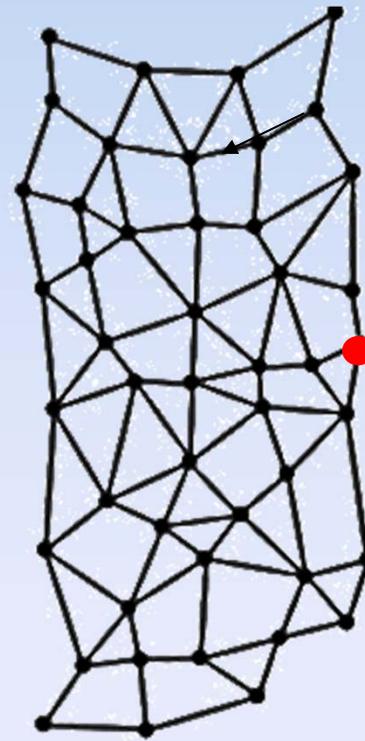
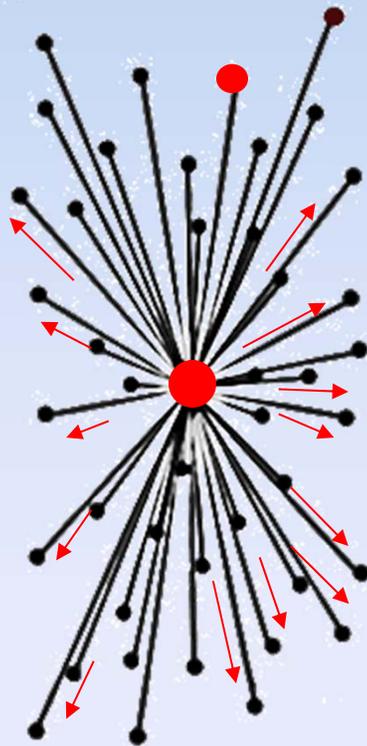
Network Hubs

Simple Contagion



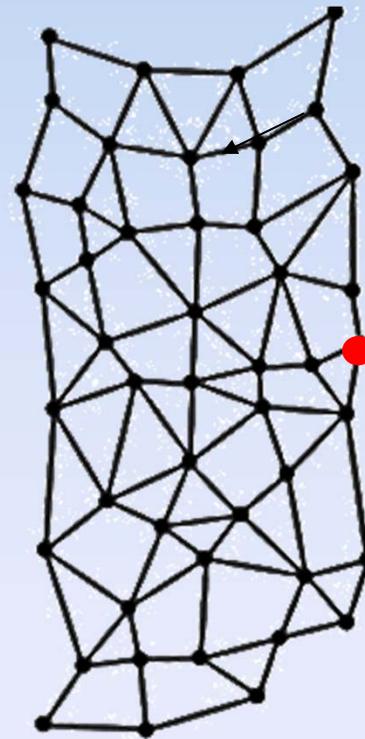
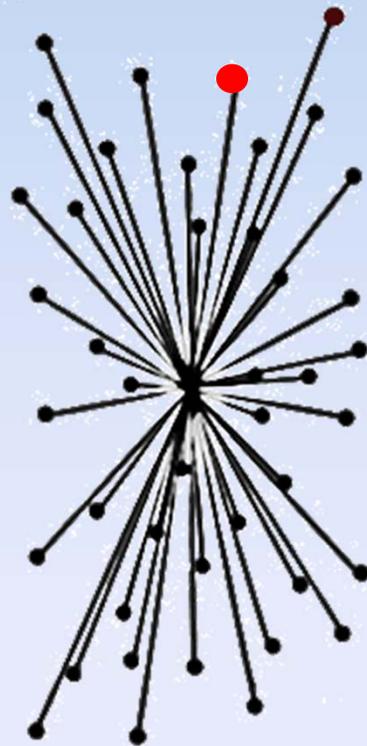
Network Hubs

Simple Contagion



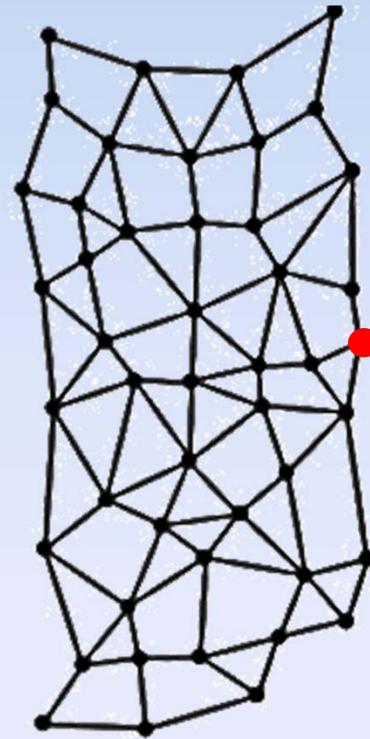
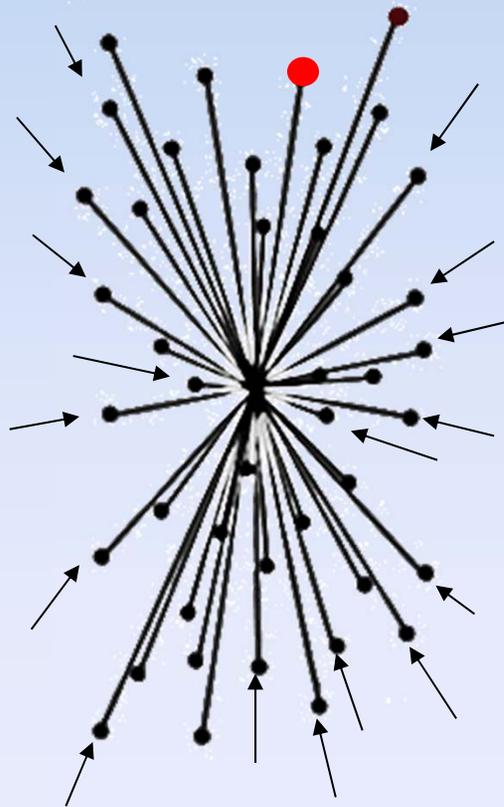
Network Hubs

Complex Contagion



Network Hubs

Complex Contagion



Network Hubs

- Hubs (Barabasi 1999) are susceptible to countervailing influences that can impede diffusion

- | | |
|------------------------------------|-------------------------------------|
| • School interventions | Paluck (2011) |
| • Adoption of Twitter, Facebook | Toole et al., Ugander et al. (2012) |
| • Social mobilization on Twitter | Harrigan et al. (2012) |
| • Innovation diffusion on Facebook | State and Adamic (2015) |
| • Arab Spring | Steinert-Threlkeld (2017) |

Empirical Research

- Spatial networks (and strong ties) in diffusion of collective action provide some support for our results:
 - Health Innovations, Berkman and Kawachi (2014)
 - Paris Commune Revolts, Gould (1996)
 - Freedom Summer, McAdam & Paulsen (1993)
- Spatial structure may play a role, but so do physical proximity and affective strength
- How can we isolate network topology (a la the small world model) to test the role of social structure in these diffusion dynamics?



III. Experimental Study of Health Behavior

Experimental Study

Parameters for developing empirical tests of social change processes

- Time series of adoption
- Network of diffusion (even non-adopters)
- Size matters
- Replication of diffusion

Populations are Actors



Experimental Sociology

Growing “cultures”

- Use on-line communities to create a “social petri dish” in which we can observe how social structure shapes collective behavior



Experimental Behavior

Health Information vs. Health Behavior

- Health screening provides new information
- Social reinforcement for changing behavior after screening can rely on having multiple contacts who encourage new behavior

Internet Experiment

Build an online health community and recruit people to join it

- Subjects enroll through taking an on-line health screening
- Subjects are randomly assigned to membership in different pre-existing network structures
- Subjects receive messages when their network “neighbors” adopt the follow-up behavior

The Healthy Lifestyle Network

Arrive at “Landing Page”

 HARVARD CENTER FOR CANCER PREVENTION
HARVARD SCHOOL OF PUBLIC HEALTH

The Healthy Lifestyle Network

Join us for a healthier lifestyle!

- * Weight loss
- * Nutrition
- * Smoking cessation
- * And more...

and a chance to win a **Wii Fit**.

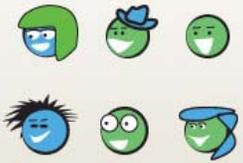


It's easy to get started:

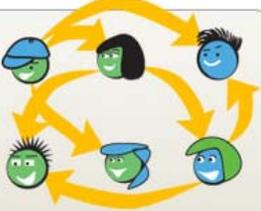


Yaz 234

- Pick a screen name and avatar to represent you.
- Choose your health interests and concerns.



- We find people who share your health interests and concerns and match them to you.



- You and your “Health Buddies” find, rate and share health resources.

Get started

Join the Experiment

Enter E-mail and Agree to Consent Form

The screenshot shows a web form for joining an experiment. At the top, there is a header for the Harvard Center for Cancer Prevention, Harvard School of Public Health. Below this is a dark blue bar with the text 'The Healthy Lifestyle Network'. The main content area has a yellow heading 'Welcome to the Healthy Lifestyle Network'. The text below explains that the network is a study of how people find and share online health resources. It asks the user to enter their email address, with 'dcentola@mit.edu' shown in a yellow box. Below this is a 'Consent form:' section. It states that Harvard requires formal consent and asks the user to read the information and click a button to indicate their choice. A scrollable text box contains the following text: 'Investigators: Damon M. Centola, Ph.D. We are asking you to participate in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether or not to take part in this online study. The purpose of this study is to understand how people find health resources. You will'. At the bottom, there are two radio buttons: 'I accept' (checked) and 'I do not accept'. A green 'Join' button is located at the bottom center.

HARVARD CENTER FOR CANCER PREVENTION
HARVARD SCHOOL OF PUBLIC HEALTH

The Healthy Lifestyle Network

Welcome to the Healthy Lifestyle Network

The Healthy Lifestyle Network is a study of how people find and share online health resources. It provides an opportunity for users to anonymously share advice and information on improving their health.

To get started, just fill in your email address below:

dcentola@mit.edu

Consent form:

In order to participate in The Healthy Lifestyle Network, Harvard requires that we obtain your formal consent. Please read the information below and then click on the appropriate button to indicate your choice.

Investigators:
Damon M. Centola, Ph.D.

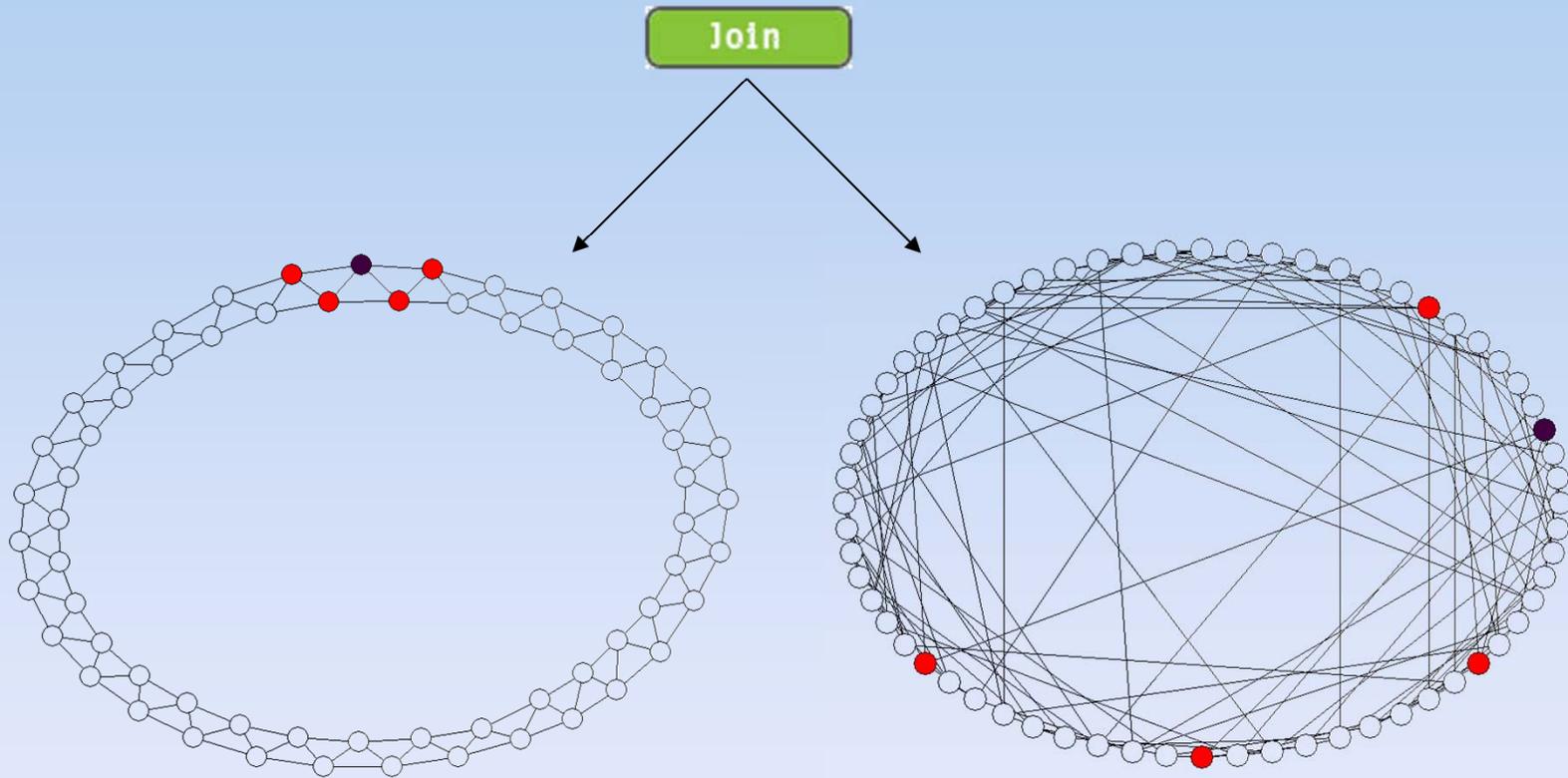
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The purpose of this study is to understand how people find health resources. You will

I accept I do not accept

Join

Randomization to Networks



Clustered Network
(Large World)

$N = 400$

$Z = 4$

Randomized Network
(Small World)

$N = 400$

$Z = 4$

Create On-Line Identity

Choose screen name and “avatar”

The screenshot shows a web interface for creating an online identity. At the top, there is a blue header with the Harvard Center for Cancer Prevention logo and text: "HARVARD CENTER FOR CANCER PREVENTION" and "HARVARD SCHOOL OF PUBLIC HEALTH". Below this is a dark grey banner with the text "The Healthy Lifestyle Network". The main content area is white and contains the following text: "Choose your screen name and the symbol that you'd like to represent you:". Below this text is a text input field with the name "Damon" entered. A note below the input field reads: "*Note: Please do not use the back button during the sign-up process, as it may result in you being assigned to multiple groups." Below the note is a grid of 26 cartoon avatars, each with a "pick me" button underneath. The avatars are arranged in five rows: the first four rows have six avatars each, and the fifth row has four avatars. Each avatar is a simple, colorful character with various features like different hair colors, styles, and accessories.

Select Health Interests



HARVARD CENTER FOR CANCER PREVENTION
HARVARD SCHOOL OF PUBLIC HEALTH

The **Healthy Lifestyle Network**

Complete Your Profile

Screen Name: **Damon**

ID Number: **601**

Symbol: 

Email: **dcentola@mit.edu**

Gender: **Male**

To help us match you up with other members of the network, please indicate your current health interests from the list below. Please select at least two.

- Tobacco quitting and preventing relapse
- Weight awareness and control
- Choosing a healthy diet
- Avoiding environmental pollutants
- Exercise programs and routines
- Alcohol moderation and stress factors
- Using vitamin supplements
- Prophylactic use and counseling
- Finding where and how to get screenings
- Limiting sun exposure
- Attention to cholesterol
- Stress reduction and relaxation

Continue

Health Buddies



HARVARD CENTER FOR CANCER PREVENTION
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The Healthy Lifestyle Network

Here's how it works:

People like you find and review online resources for developing and maintaining a healthy lifestyle. When someone finds something that they think you'll like they will send you an email to let you know. You can look at their recommendation and see other recommendations by other network members, and you can rank selections yourself.

You are: Damon-601 

Your health interests:

- * Weight awareness and control
- * Choosing a healthy diet
- * Exercise programs and routines
- * Stress reduction and relaxation

These are your health buddies:



David-430

Health interests:

- * Choosing a healthy diet
- * Stress reduction and relaxation
- * Prophylactic use and counseling
- * Finding where and how to get screenings



Geoff-523

Health interests:

- * Weight awareness and control
- * Choosing a healthy diet
- * Using vitamin supplements
- * Prophylactic use and counseling



Jake-152

Health interests:

- * Stress reduction and relaxation
- * Weight awareness and control
- * Using vitamin supplements



Theo-234

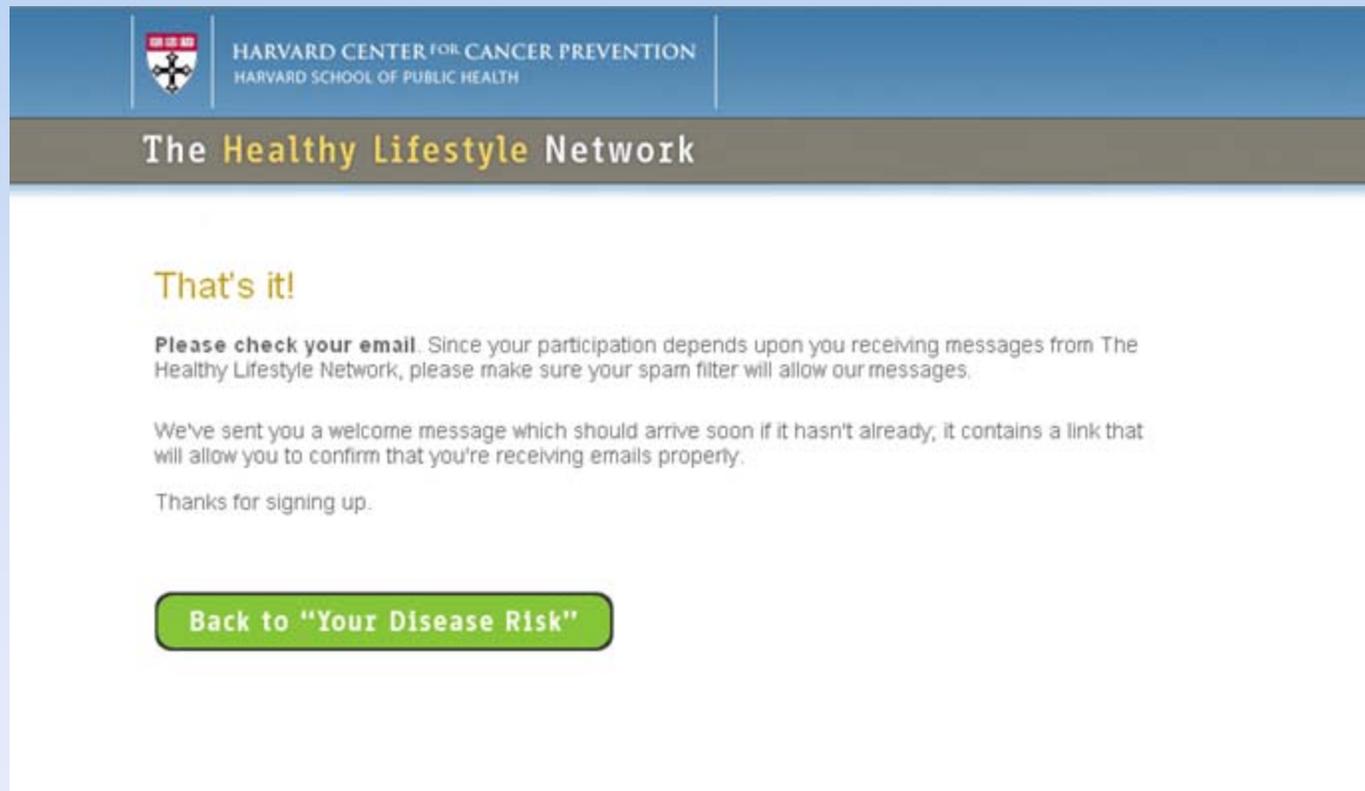
Health interests:

- * Choosing a healthy diet
- * Stress reduction and relaxation
- * Limiting sun exposure

Finish

Finish Registration

Subjects are told to expect email contact from us



The screenshot shows an email header with the Harvard Center for Cancer Prevention logo and name. Below the header is a dark blue bar with the text "The Healthy Lifestyle Network". The main body of the email contains the following text:

That's it!

Please check your email. Since your participation depends upon you receiving messages from The Healthy Lifestyle Network, please make sure your spam filter will allow our messages.

We've sent you a welcome message which should arrive soon if it hasn't already, it contains a link that will allow you to confirm that you're receiving emails properly.

Thanks for signing up.

[Back to "Your Disease Risk"](#)

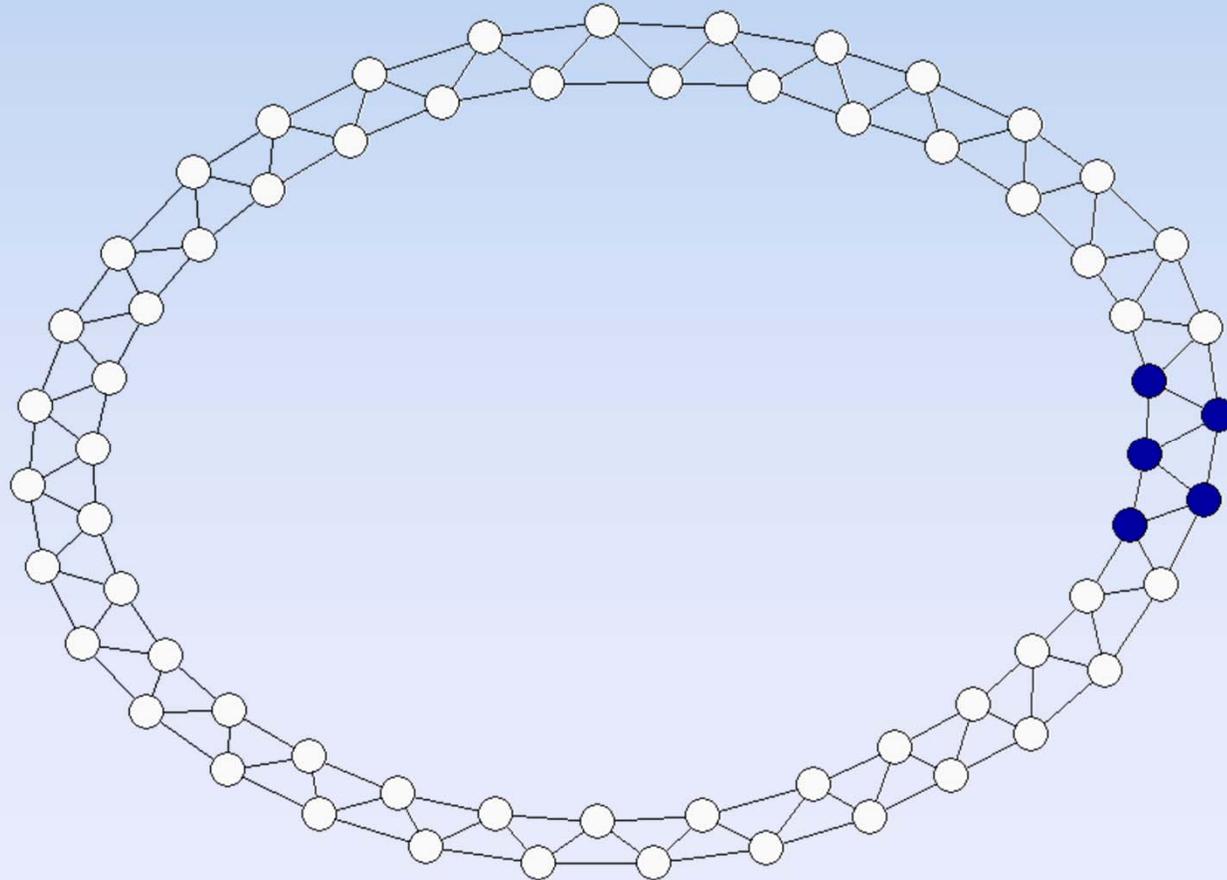
Follow-up Behavior

On-line tool for rating health resources

The screenshot displays the 'The Healthy Lifestyle Network' website. At the top, the Harvard Center for Cancer Prevention logo is visible. The main heading is 'Community Forum' with a user profile for 'Damon-601'. A navigation bar includes links for Home, Healthy Lifestyle, Fitness, Nutrition, Smoking Cessation, and Weight Loss. The page is divided into several sections: 'New Recommendations' featuring 'Free and Clear' (4.2/25 votes), 'TryToStop.org' (4.4/24 votes), and 'Real Age' (1.8/13 votes); 'Health Buddies Recommend' featuring 'Spark People' (3.0/3 votes) by users Jake-152 and Theo-234; and 'Recommended Resources' featuring 'TryToStop.org' (4.4/24 votes), 'Harvard Vanguard' (4.4/15 votes), 'Free and Clear' (4.2/25 votes), 'Nutrition Source' (4.2/24 votes), 'Intelhealth' (3.9/21 votes), 'Harvard Medical School' (3.8/17 votes), and 'Weight Watchers'. On the right side, there is a 'Site Rated' section showing a 5-star rating (4.2/25 votes) and a sidebar with 'Organizational Tools' including 'Free & Clear Videos' and 'Tobacco Cessation Research Library'. A 'TO QUIT?' section is also visible, along with a 'T HERE' button.

Initiating Behavior

Target group is selected to go to a (previously unknown) follow-up site.

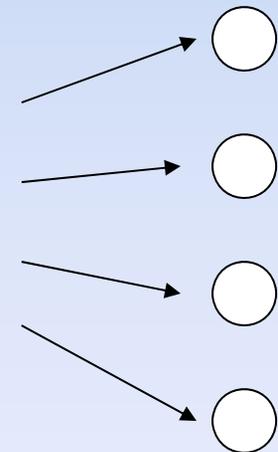


Social Signal

Registration for the community forum sends signals to all neighbors who have not yet registered

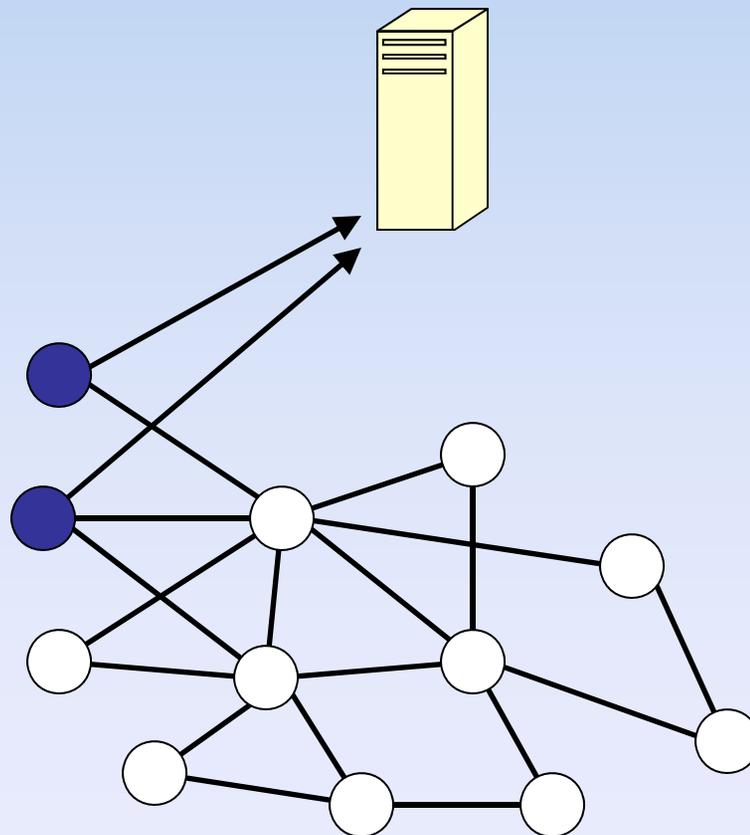


The screenshot shows the 'Community Forum' registration page. At the top, it features the Harvard Center for Cancer Prevention logo and the text 'The Healthy Lifestyle Network'. The main heading is 'Please Register to join the Community Forum'. Below this, there is a welcome message and a 'New Recommendations' section with a 'TryToStop.org' link. A registration form is visible, asking questions like 'Why did you come to the Forum?' and 'How did you hear about the Forum?'. The form includes a 'Register' button. To the right of the form, there is a 'Recommended Resources' section with links to 'Real Age', 'Nutrition Source', and 'Health Buddy'.



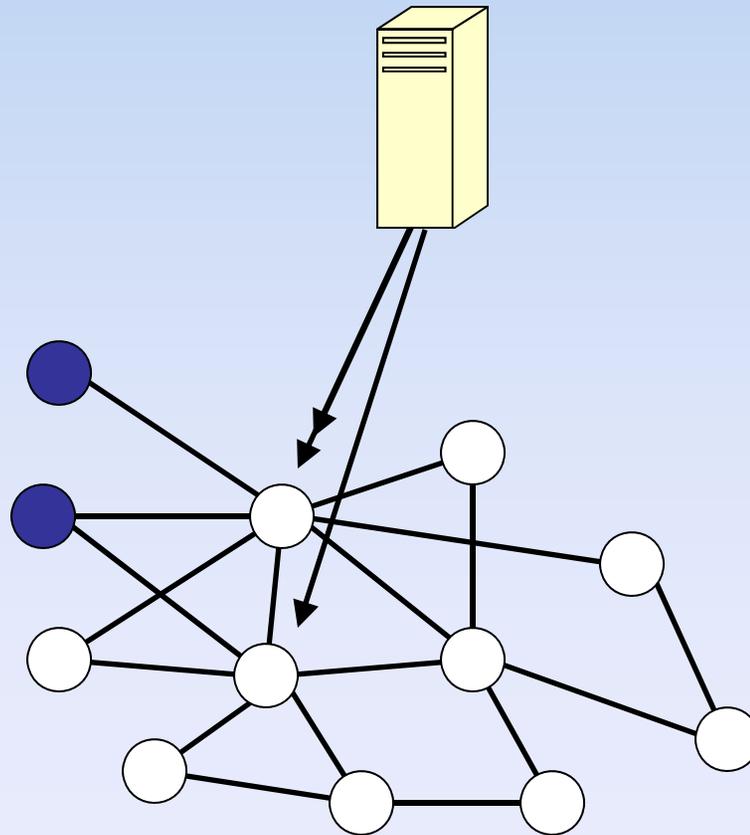
Feedback Dynamics

Members of Seed Group Follow-up



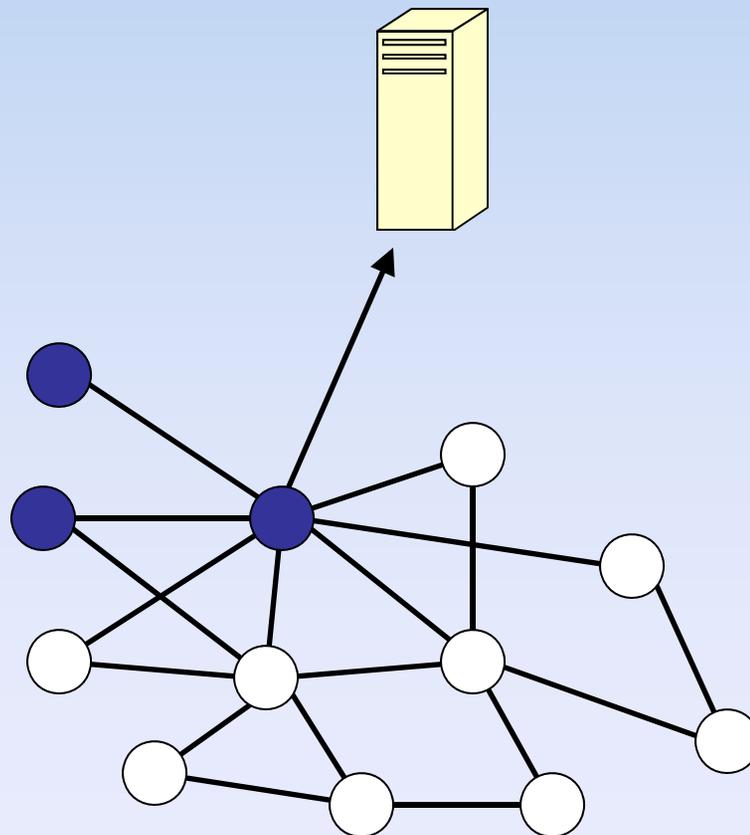
Feedback Dynamics

Follow-up Signal Sent to Neighbors



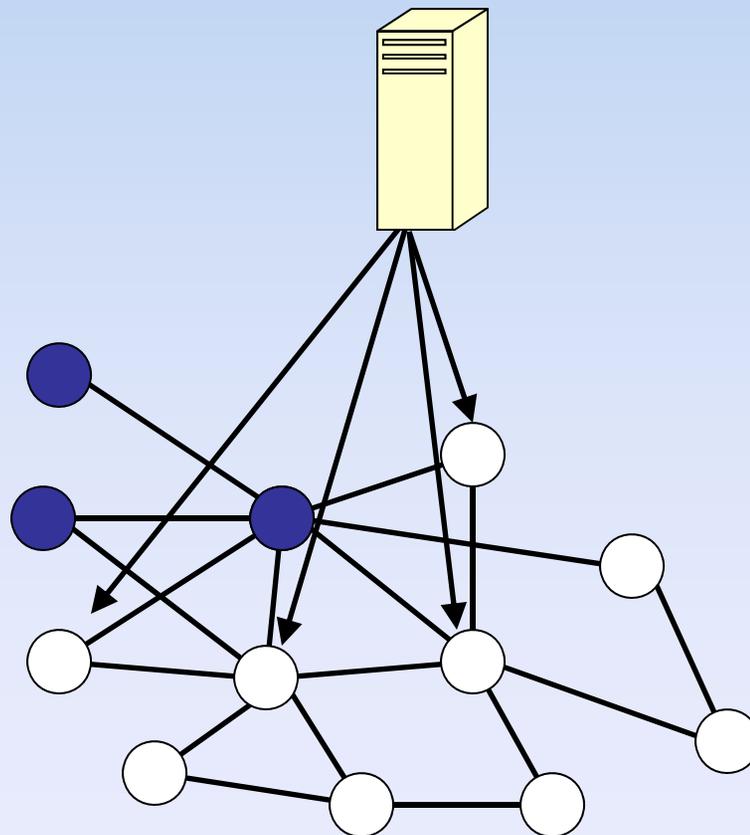
Feedback Dynamics

Neighbor with Multiple Signals Follows Up



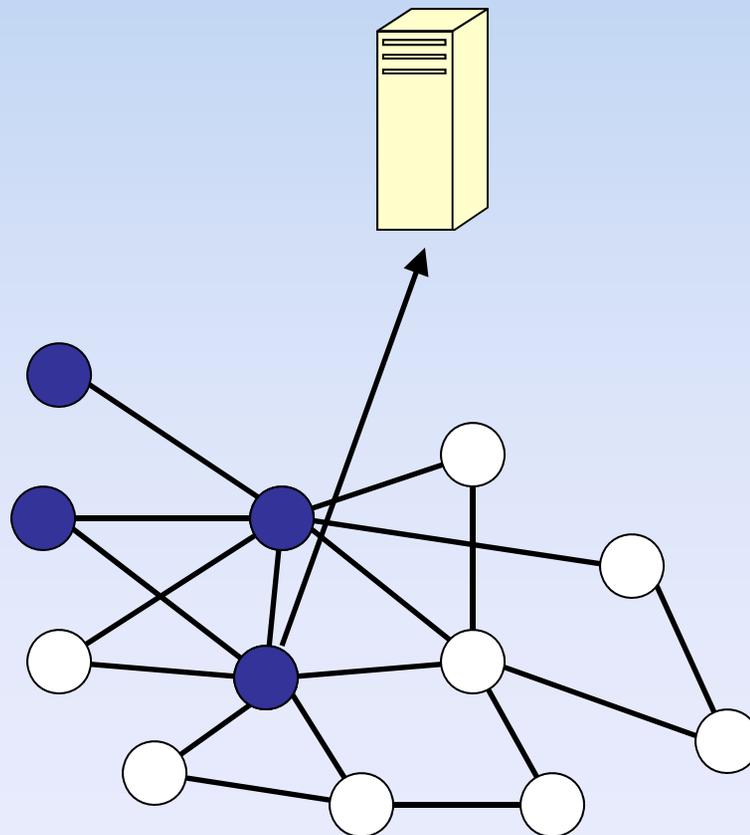
Feedback Dynamics

Follow-up Signals Sent to Her Neighbors



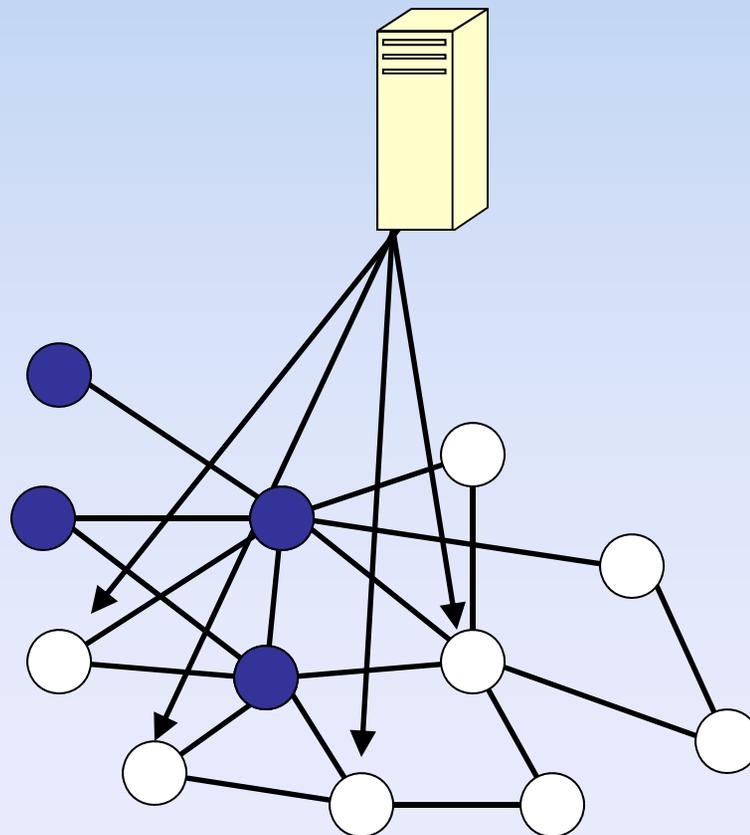
Feedback Dynamics

Neighbor with Multiple Signals Follows Up



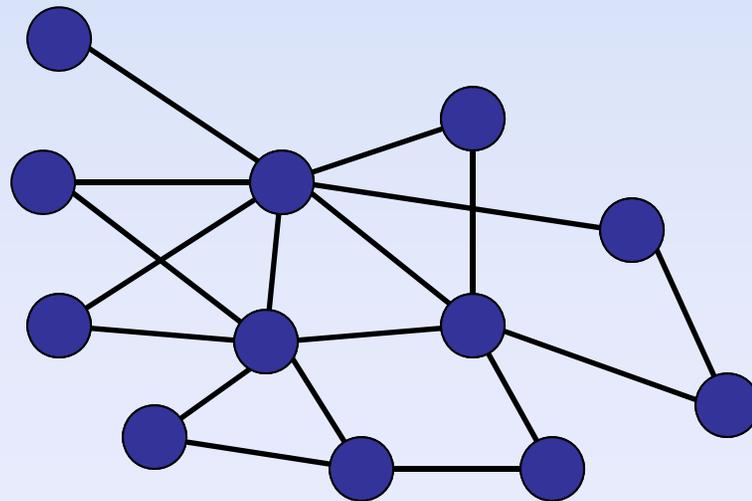
Feedback Dynamics

Reinforcing Signals Sent to Her Neighbors...



Feedback Dynamics

**Reinforcing Dynamic Continues until
Behavior Saturates Network**



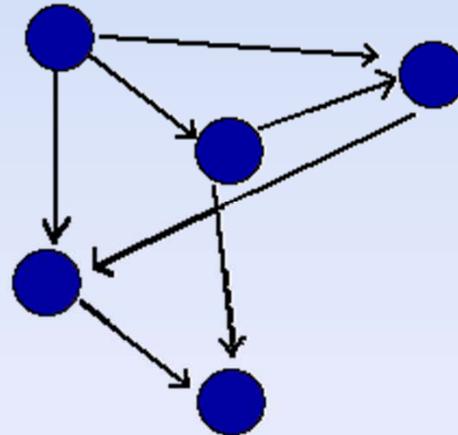
Network Dynamics

How does social structure affect diffusion?

Simple



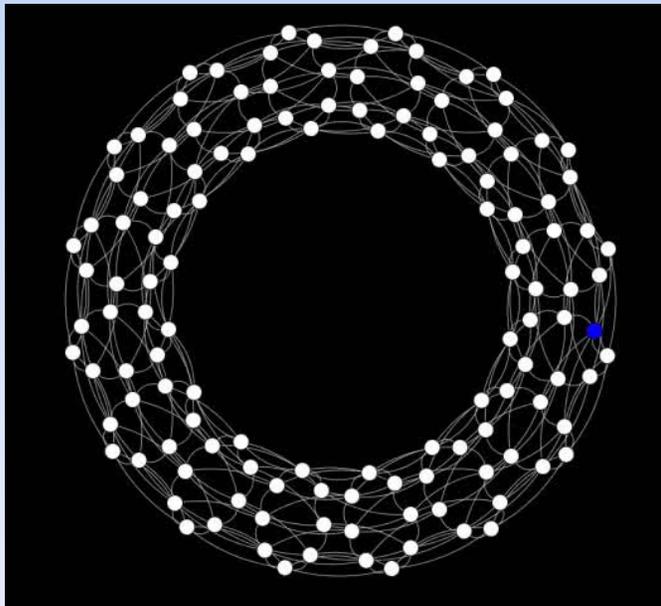
Complex



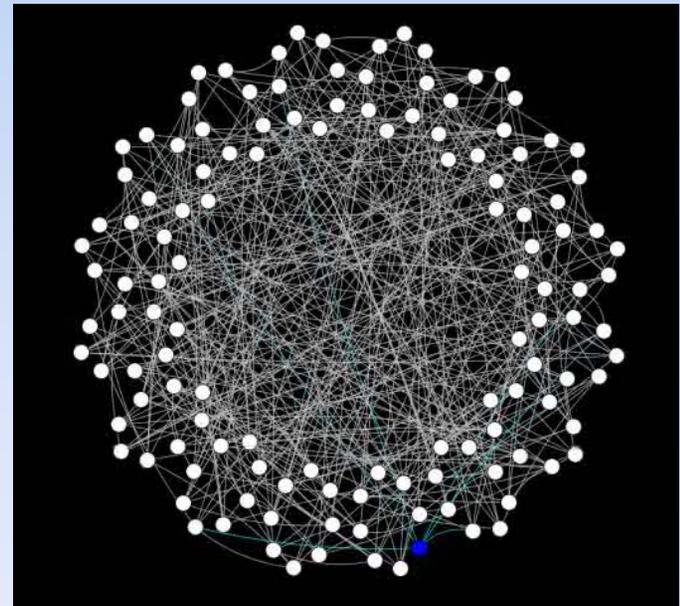
IV. Watching Behavior Spread

Diffusion of Behavior

Clustered Network



Random Network

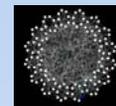
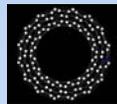


Replication

Clustered

Random

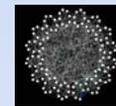
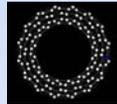
Trial 1



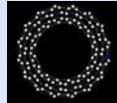
Trial 2



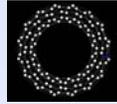
Trial 3



Trial 4



Trial 5



Trial 6



Results

Dynamics of behavior

Across six independent trials of the experiment

Network diffusion:

More people adopted in clustered networks ($p < 0.01$)

Faster diffusion in clustered networks ($p < 0.01$)

Results

Dynamics of behavior

Across six independent trials of the experiment

Network diffusion:

More people adopted in clustered networks ($p < 0.01$)

Faster diffusion in clustered networks ($p < 0.01$)

Individual-level mechanism:

Social reinforcement from second source significantly increased likelihood of adoption ($p < 0.001$)

Reinforcement from third source also increased adoption ($p < 0.05$)

Commitment

Are there any effects of social reinforcement on commitment to the behavior?

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Return visits grouped by signals received

- 1 signal
- 2 signals
- 3 signals
- 4 signals
- 5 signals

Commitment

Are there any effects of social reinforcement on commitment to the behavior?

Return visits grouped by signals received

- 1 signal: 12% returned
- 2 signals
- 3 signals
- 4 signals
- 5 signals

Commitment

Are there any effects of social reinforcement on commitment to the behavior?

Return visits grouped by signals received

- 1 signal: 12% returned
- 2 signals: 35% returned ($p < .001$)
- 3 signals: 40% returned ($p < .001$)
- 4 signals: 41% returned ($p < .01$)
- 5 signals: 45% returned ($p < .01$)

Diffusion and Commitment

Correlational finding

- Clustered spatial networks can accelerate social dynamics of diffusion
- Reinforcement can lead to greater commitment even in anonymous online networks
- Reasons for adoption become reasons for commitment



V. Social Design

HPV Vaccination

Cervical Cancer Prevention with Twitter



- 4,220 annual deaths from cervical cancer:
 - 17% women do not receive appropriate Pap smear screening
 - Only 35% of girls 13 to 17 fully receive HPV vaccine
 - Disproportionate burden on minority communities
- Physician recommendations miss many women who:
 - do not attend medical visits
 - do not have a regular source of care
 - lack trust in health care system
 - associated with stigma
 - evolving guidelines are confusing to patients
- Younger individuals and parents use social media to discuss health

Social Design

- **Social reinforcement:**
 - increases the credibility and legitimacy of a new health behavior (e.g., vaccination)
- **Anonymity:**
 - reputation effects do not follow you through rest of your social life
 - offering a conversational space for behavioral influence where difficult topics can be discussed without judgment or fear of long term consequences

Designing Patient Centered Precision Prevention

- **Social relevance:**
 - relevant peers whose advice is trusted
- **Empathy:**
 - offering a conversational space for behavioral influence where difficult medical topics can be discussed without judgment or fear of long term consequences
- **Protection:**
 - reputation effects do not follow you through rest of our social life
- **Influence:**
 - advice that impacts healthcare choices (like vaccination).

HPV Vaccination



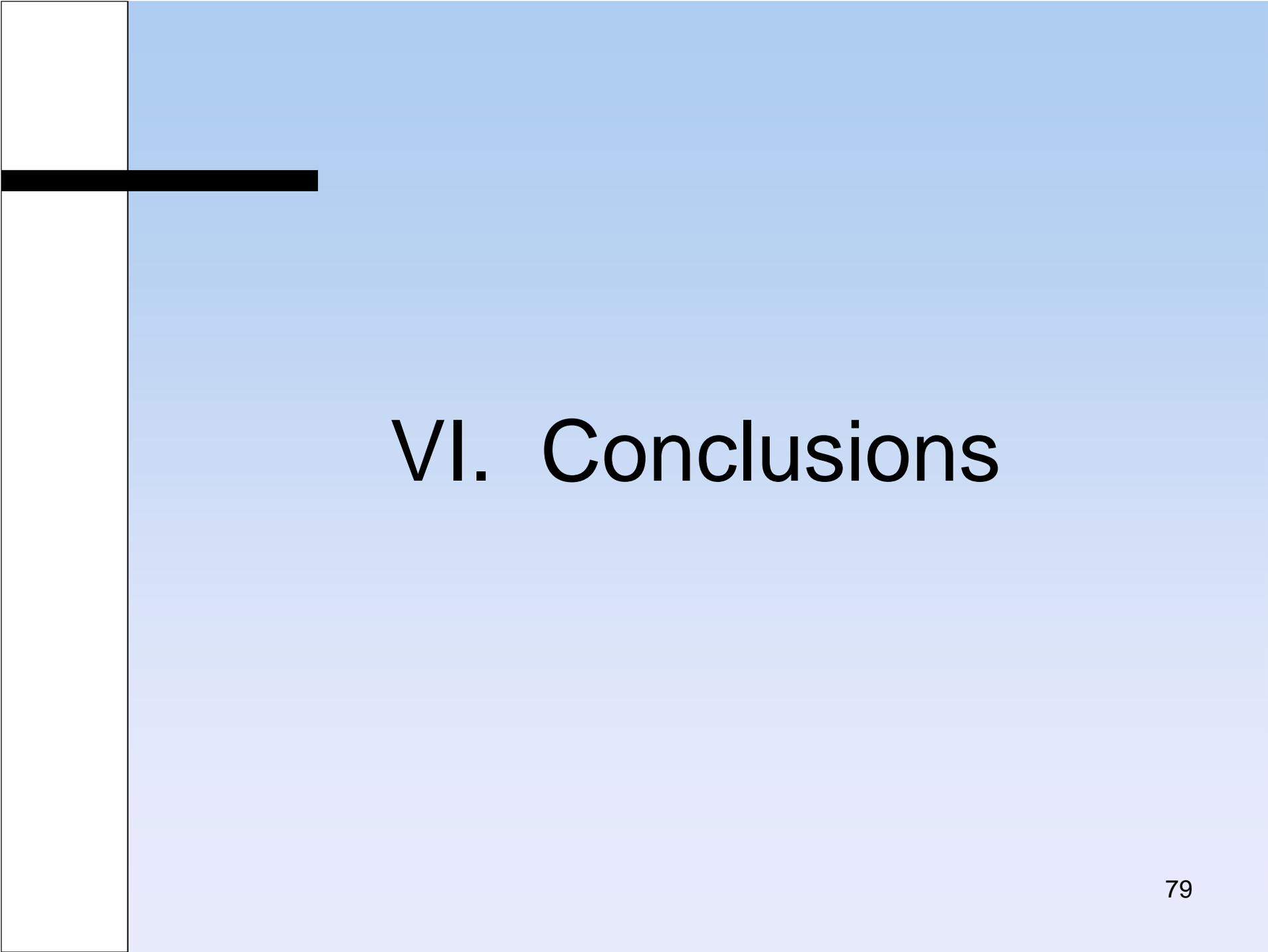
Centola 2011 Science

Centola 2013 Circulation

Zhang et al. 2015 Preventive Medicine

Zhang et al. 2016 Preventive Medicine

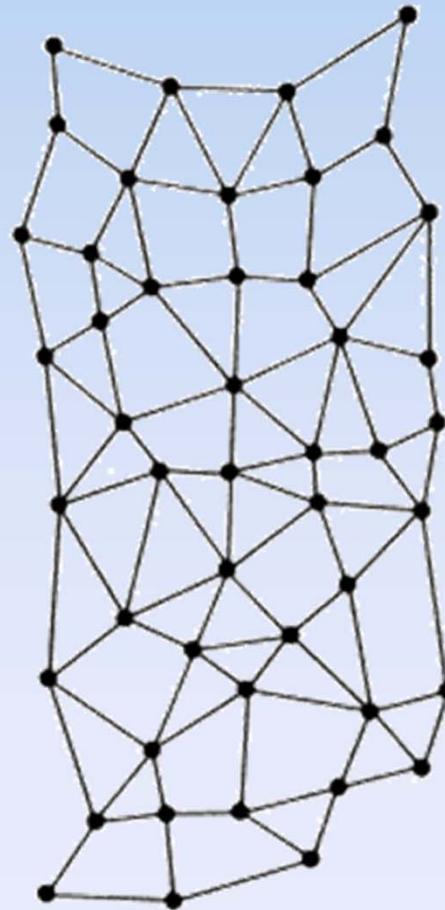
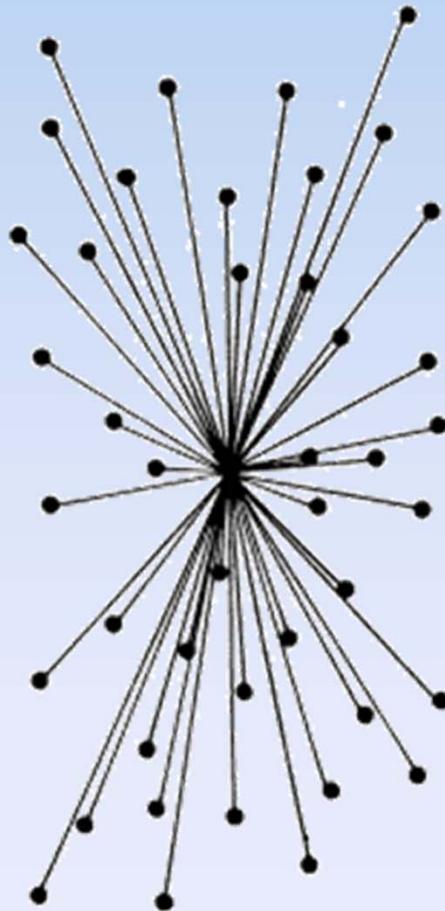
Lyson et al American Journal of Public Health (Forthcoming)



VI. Conclusions

Intuitions

Which network will spread behavior better?



Designing Social Change

- When new behaviors are costly, unfamiliar, or require complementarity, social reinforcement will typically improve the spread of behavior change
- Like “choice architecture” in behavioral economics, “social architectures” can be designed to improve the diffusion and maintenance of challenging behaviors
- Social capital, like financial capital or human capital, is a resource that we can provide for the people who need it the most