# Network Mechanisms and Network Structures

## The Principle of Homophily

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# Outline

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# Network Theories across the Various Weeks of SMM638



| **Network theory** | **2** | **3** | **4** | **5** | **6** | **7** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|
| Value creation | | • | • | | | | | |
| Coordination | | | | • | | | | |
| Network change | | | | | • | • | • | • |
| Contagion | | | | | | • | | • |

# Groups of Network Theories



| **Underlying model** | **Social capital** | **Social homogeneity** |
|---|---|---|
| **Network flow** | Capitalization (value creation) | Contagion |
| **Network architecture** | Coordination | Adaptation (network change) |

Source is [7, page 47]

# Why do Network Mechanisms Matter?



1. Network mechanisms can explain why networks look how they look!
2. If we know the network mechanisms, we can predict the evolution of a network. E.g.,
   - Who will pay attention to which market offers
   - Who will date whom
   - Who will adopt or reject whom's opinion

# What Are We Trying to Achieve in Sessions 6 and 7?



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- In session 6, we tried to discover the mixture of network mechanisms accounting for Soundcloud's network structure

# What Are We Trying to Achieve in Sessions 6 and 7?



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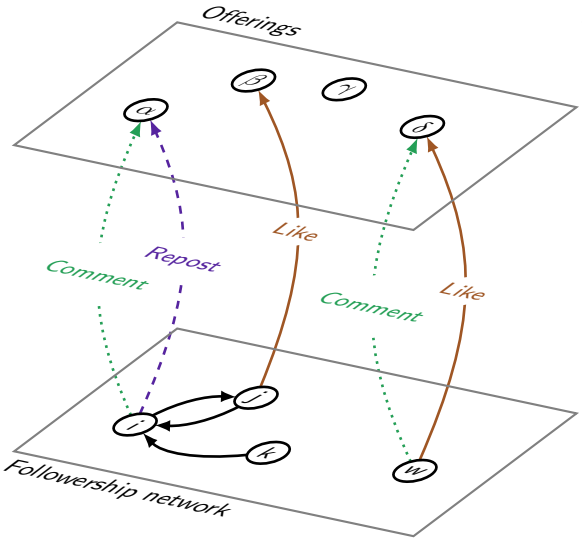
- In session 6, we tried to discover the mixture of network mechanisms accounting for Soundcloud's network structure
- In session 7, we learned how to quantify a key network mechanism and will connect it to the problem of contagion (critically important to explain offering popularity in markets)

# A Real-World Example: The Soundcloud Networks





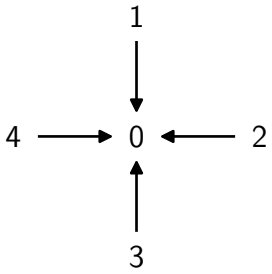

Some key general points emerging from the analysis of the Soundcloud example:

- The same pair of nodes can be connected because of multiple relationships (i.e., 'like,' 'repost,' 'comment')
- The nodes of a network may have the same type (e.g., 'following') or different types (e.g., 'like')
- Analytically separated networks may be correlated (e.g., one tends to like her/his followings' likes)

# Network Mechanisms in the Followership Network

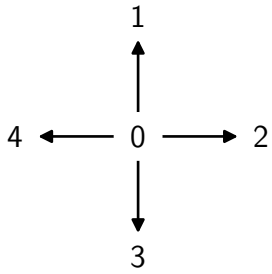
## Popularity effects

**Indegree popularity**




*Synopsis:* certain nodes may develop a cumulative advantage — a so-called rich-get-richer effect

**Outdegree popularity**




*Synopsis:* certain nodes may develop a tendency to connect with many others

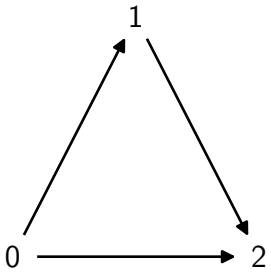
# Network Mechanisms in the Followership Network

## Reciprocity effect


*Synopsis:* pairs of nodes may show a tendency to follow each other — that is, to reciprocate each other's following choice

# Network Mechanisms in the Followership Network

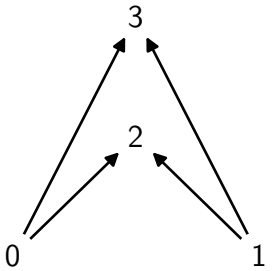
## Triadic closure




*Synopsis:* "My following's following is my following"

# Network Mechanisms in the Followership Network

## Balance

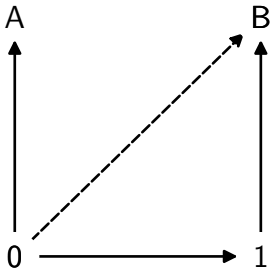



*Synopsis:* Pairs of (connected or disconnected) nodes may show the tendency to share 'followings'

# Cross-Level Effects: From Following to Taste and Back

## Membership closure

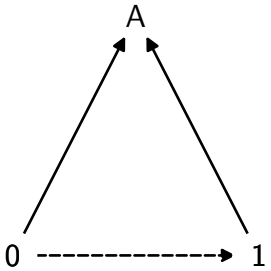





*Synopsis:* 1 introduces 0 to music style $B$; $\{A, B\}$ is the set of music styles; $\{0, 1\}$ is the set of users; 'vertical' ties can be intended as a bipartite graph linking users and music styles via 'likes,' 'comments,' or 'reposts' (mainly, user preferences); dashed arrows denote ties at risk of emerging based on membership closure

# Cross-Level Effects: From Following to Preferences and Back

## Focal closure




*Synopsis:* 0 follows 1 because of shared taste/preferences; $\{A, B\}$ is the set of music styles; $\{0, 1\}$ is the set of users; 'vertical' ties can be intended as a bipartite graph linking users and music styles via 'likes,' 'comments,' or 'reposts'; dashed arrows denote ties at risk of emerging based on focal closure

# Let Us Get Back to the Fundamental Question

Why do networks look how they look?

# A Possible Answer: Homophily

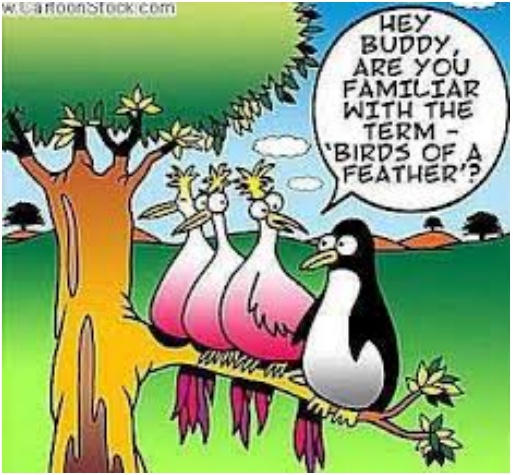


- According to the homophily principle, similarity breeds connection

# A Possible Answer: Homophily



- According to the homophily principle, similarity breeds connection
- Hence, networks are homogeneous concerning:
  - Sociodemographic variables (e.g., age)
  - Reference social categories (e.g., being a knowledge worker)
  - Behaviors (e.g., purchasing choices)



# Theoretical Background

## BIRDS OF A FEATHER: Homophily in Social Networks

Miller McPherson[1], Lynn Smith-Lovin[1], and James M Cook[2]

[1]*Department of Sociology, University of Arizona, Tucson, Arizona 85721; e-mail: mcpherson@u.arizona.edu; smithlov@u.arizona.edu*

[2]*Department of Sociology, Duke University, Durham, North Carolina 27708; e-mail: jcook@soc.duke.edu*

**Key Words** human ecology, voluntary associations, organizations

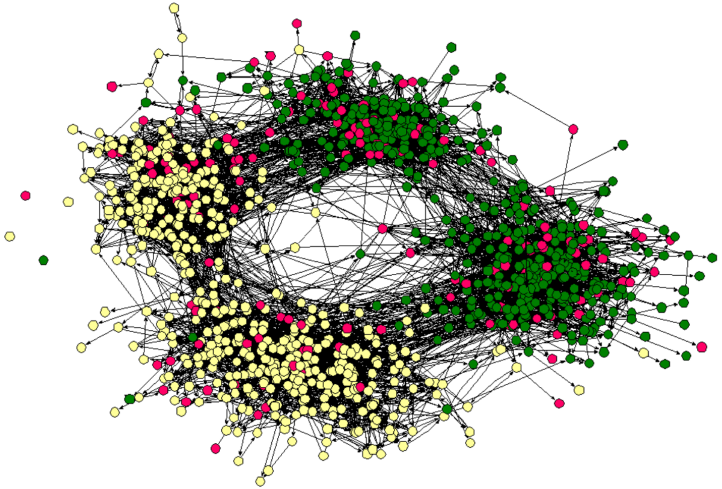
■ **Abstract** Similarity breeds connection. This principle—the homophily principle—structures network ties of every type, including marriage, friendship, work, advice, support, information transfer, exchange, comembership, and other types of relationship. The result is that people's personal networks are homogeneous with regard to many sociodemographic, behavioral, and intrapersonal characteristics. Homophily limits people's social worlds in a way that has powerful implications for the information they receive, the attitudes they form, and the interactions they experience. Homophily in race and ethnicity creates the strongest divides in our personal environments, with age, religion, education, occupation, and gender following in roughly that order. Geographic propinquity, families, organizations, and isomorphic positions in social systems all create contexts in which homophilous relations form. Ties between nonsimilar individuals also dissolve at a higher rate, which sets the stage for the formation of niches (localized positions) within social space. We argue for more research on: (*a*) the basic ecological processes that link organizations, associations, cultural communities, social movements, and many other social forms; (*b*) the impact of multiplex ties on the patterns of homophily; and (*c*) the dynamics of network change over time through which networks and other social entities co-evolve.

Source is [5]

# Homophily in Practice: Example 1

## Friendship and racial segregation in an American high-school





Source is [6]; nodes are color-coded to reflect student racial background; ties denote friendship between pairs of nodes

# Homophily in Practice: Example 2

## Discovering cultural similarity is key for tie formation in speed dating



**Making the Connection: Social Bonding in Courtship Situations**[1]

Daniel A. McFarland and Dan Jurafsky
*Stanford University*

Craig Rawlings
*University of California, Santa Barbara*

Sociologists have long argued that the force of a social bond resides in a sense of interpersonal connection. This is especially true for initial courtship encounters when pairs report a sense of interpersonal chemistry. The authors explore the process of romantic bonding by applying interaction ritual theory, extended and integrated with methods from computational linguistics, to the study of courtship encounters and, specifically, heterosexual speed dating. The authors find that the assortment of interpersonal moves associated with a sense of connection characterizes a conventionalized form of initial courtship activity. The game is successfully played when females are the point of focus and engaged in the conversation and males demonstrate alignment with and understanding of the female. In short, initial heterosexual courtship encounters are associated with a sense of bonding when they reflect a reciprocal asymmetrical performance in which differentiated roles are mutually coordinated.

INTRODUCTION

Social bonds are a central topic of sociology because they are the social glue of society. What renders social bonds distinct from other forms of inter-

[1] This article was prepared for presentation at the American Sociological Association meeting in Las Vegas, Nevada, August 21, 2011. Special thanks to Rajesh Ranganath, Sonal Nalkur, and Tanzeem Choudhury for assistance and advice on data collection and Sandy Pentland for a helpful discussion about feature extraction. This work received


0002-9602/2013/11806-0004$10.00



Source is [4]

# Homophily in Practice: Example 3

## Executives ask for advice from similar others in difficult times



Getting by with the Advice of Their Friends: CEOs' Advice Networks and Firms' Strategic Responses to Poor Performance

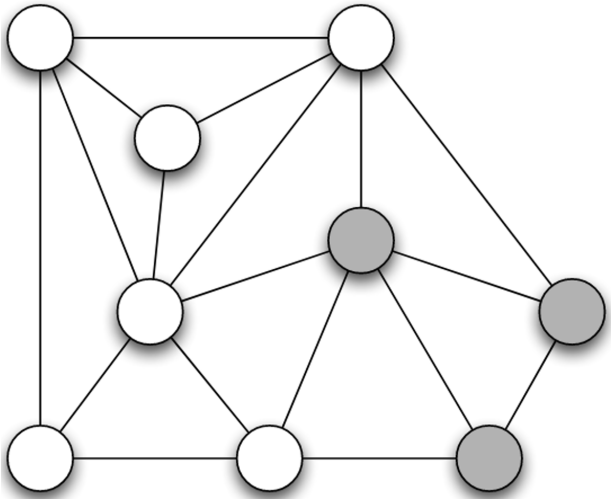
**Michael L. McDonald**
**James D. Westphal**
*University of Texas at Austin*

This paper theorizes that relatively poor firm performance can prompt chief executive officers (CEOs) to seek more advice from executives of other firms who are their friends or similar to them and less advice from acquaintances or dissimilar others and suggests how and why this pattern of advice seeking could reduce firms' propensity to change corporate strategy in response to poor performance. We test our hypotheses with large-sample survey data on the identities of CEOs' advice contacts and archival data on firm performance and corporate strategy. The results confirm our hypotheses and show that executives' social network ties can influence firms' responses to economic adversity, in particular by inhibiting strategic change in response to relatively poor firm performance. Additional findings indicate that CEOs' advice seeking in response to low performance may ultimately have negative consequences for subsequent performance, suggesting how CEOs' social network ties could play an indirect role in organizational decline and downward spirals in firm performance.●

Source is [3]

# When Does a Network Exhibit Homophily?





*Notes:* — Nodes are color-coded concerning a key relevant attribute (e.g., gender)

# A Simple Homophily Measure Based on Frequencies

## Intuition

Let us consider 'gender' as the key feature of nodes: what would it mean for a network not to exhibit homophily?

- The proportion of male and female friends that a person has resembles the underlying male/female distribution in the full population

# A Simple Homophily Measure Based on Frequencies

## Intuition

Let us consider 'gender' as the key feature of nodes: what would it mean for a network not to exhibit homophily?

- The proportion of male and female friends that a person has resembles the underlying male/female distribution in the full population
- In other words, "if we were to randomly assign each node a gender according to the gender balance in the real network, then the number of cross-gender edges should not change significantly relatively to what is seen in the real network"

Source is

# A Simple Homophily Measure Based on Frequencies

## The formal representation

Let's consider a network containing a fraction $p$ of male nodes ($m$) and a fraction $q$ of female nodes ($f$), and denote the link between nodes $i$ and $j$ as $e_{i,j}$.

The no-homophily hypothesis implies what follows:

1. $pr(e_{ij} \mid i = m,\ j = m) = p * p$
2. $pr(e_{ij} \mid i = f,\ j = f) = q * q$
3. $pr(e_{ij} \mid i = m,\ j = f) = p * q$
4. $pr(e_{ij} \mid i = f,\ j = m) = q * p$

If the proportion of male-female ties deviates from $2 * (p * q)$, then there is evidence of homophily in the network.

# Mechanisms Underlying the Homophily Principle

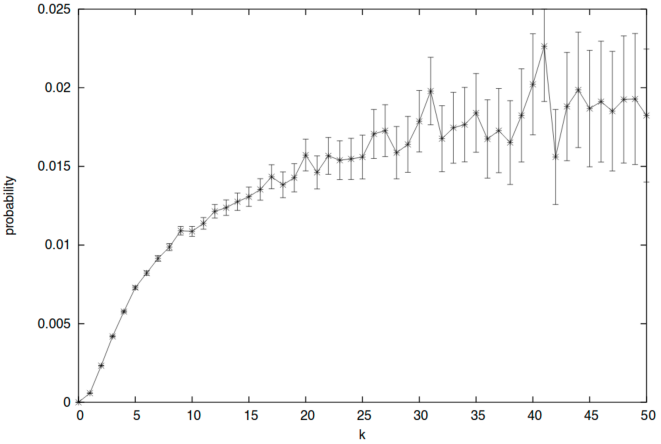


There are two mechanisms through which homophily affects tie formation:

- **Selection:** individual bond with others they perceive 'similar' on salient dimensions
- **Socialization:** individuals that directly, closely, frequently interact with each other become more and more 'similar'

*Note:* The relative strength of 'selection' and 'socialization' largely depends on the attributes individuals use to assess interpersonal similarity. Socialization does not operate for fixed demographic factors, whereas it plays a central role when attitudes or behavior are used as a basis for similarity

Probability to become a member of a community $i$ when $k$ friends are already part

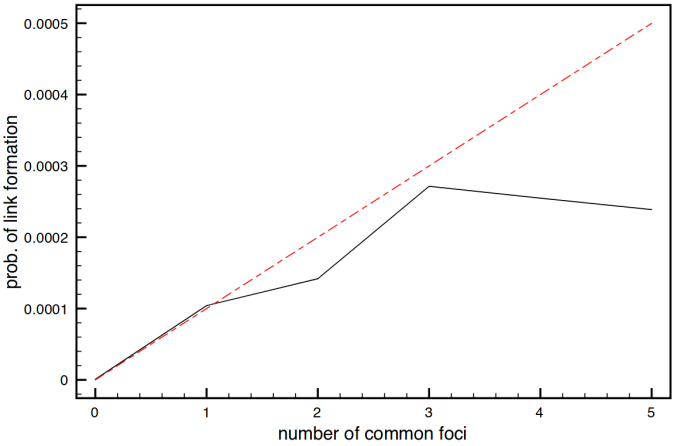



Source is [2]

# Mechanisms Underlying the Homophily Principle

## The selection mechanism

Probability of inter-personal link formation when two members share $k$ classes

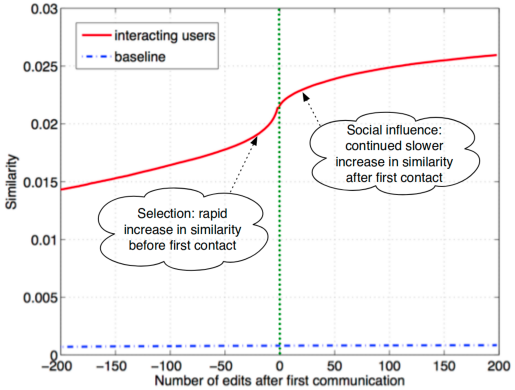



Source is [2]

# Mechanisms Underlying the Homophily Principle

## The interaction between selection and socialization

Similarity of two Wikipedia contributors' edits before and after the formation of an inter-personal link




Source is [1]

# Outline

- **Scope:** SAOMs are a family of models that express empirically observed changes in network ties and inmany cases, changes in individual attributes as time-aggregated outcomes of a series of individual decisions [8]
- **The role of actors:** SAOMs model network change over time from the perspective of each actor, under the assumption that each actor has the option to adjust the structure of his or her network (by "deciding" whom to start, continue, or stop communicating with) or the level of a specific attribute (whether to increase or decrease the extent to which he or she perceives the team's climate as being positive).

# Stochastic Actor Oriented Models

## The 'how' aspects



- SAOMS enable researchers to use data from a first measured timepoint to test whether a given set of hypothesized effects can produce the network structures and attribute levels measured at later timepoints
- Central to these models is the idea that changes in network ties and actors' attributes occur continuously even though data on the state of the network and its actors are collected at discrete timepoints
- These models also assume that the difference between observed timepoints can be broken down into probabilistic, sequential small steps, called ministeps
  - At each ministep, a focal actor is randomly selected and has the opportunity to make a single decision
  - In a network ministep, the actor has the opportunity to modify one of his or her outgoing ties by creating a tie to a new actor, terminating an existing tie, or maintaining current ties
  - In an attribute (or behavioral) ministep, the actor can modify (increase, decrease, or maintain) his or her level of a given attribute

# Modeling Network and Behavioral Change with Rules



- To model these changes, the researcher constructs, on the basis of theoretical and empirical considerations, a set of "rules" that might drive an actor's decision to change a network tie or adjust the level of one of his or her attributes
- Rules are grouped into four categories:
  - Network evolution rules
  - Attribute evolution rules
  - Social selection rules
  - Social influence rules

- These rules determine **how ties develop given the structure of ties in the previous timepoints**
- An example might be that individuals prefer to communicate with those who communicated with them in previous timepoints or that individuals prefer to communicate with those with whom many others communicated in previous timepoints

- These rules determine how attributes evolve over time
- An example might be that there is a general tendency for the attribute (negative affectivity, turnover intention, identification with a program) to increase over time

- These rules describe how ties develop in response to actors' attributes (and ties) in the previous timepoint
- For these rules, actors' attributes are considered to be the drivers of network ties
- An example might be that people who have higher levels of negative affectivity talk to fewer others over time or that people prefer to communicate with others whose levels of turnover intentions resemble their own

# Modeling Network and Behavioral Change with Rules

## Social influence rules

- These rules describe how actors' attributes change in response to ties (and attributes) in the previous timepoint
- For these rules, the network is considered to drive actors' attributes
- For example, communicating with fewer others over time may increase a person's turn-over intentions, or people may catch their network partners' levels of negative affectivity over time (emotional contagion)

# Empirical Estimation Aspects

## Decision frequency and rules

- SAOMs assume that whereas network and attribute data are collected at discrete timepoints, underlying time is continuous
- At discrete, unobservable timepoints, a randomly selected actor gets an opportunity to change his or her outgoing ties (a network ministep) or level of the attribute (a behavioral ministep)
- This implies two separate subprocesses that need to be modeled:
  - The first subprocess involves modeling the frequency of change: how often a ministep occurs
  - The second subprocess models how change occurs: what changes occur once an actor is given an opportunity to change his or her network or attribute (in a network or behavioral ministep, respectively)

# From Subprocesses to Objective Functions



The above mentiond subprocesses are modeled as two interdependent mathematical functions termed objective functions:

$$f_i^{net}(x, y) = \sum_k \beta_k nets_{ik}^{net} \tag{1}$$

$$f_i^{beh}(x, y) = \sum_k \beta_k behs_{ik}^{beh} \tag{2}$$

where equation 1 denotes the objective function that actor $i$ seeks to optimize in a network ministep, while equation 2 represents the objective function that actor $i$ seeks to optimize in an attribute (behavioral) ministep.
Notes: i) in each equation, $f_i(x, z)$ denotes the value of the objective function for actor $i$ for a given network state $x$ and $i$'s level of the attribute $z$; ii) The value of $f$ is dependent on a series of parameter values $b_k$, each of which is coupled to an effect, denoted $s_{ik}$; iii) n effect represents a subgraph count in the network neighborhood of the focal actor in a given ministep

Let us model the co-evolution of a friendship network and intention to quit.

# References

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