

Network Analysis:

The Hidden Structures behind the Webs We Weave

17-213 / 17-668

Social Capital 1: Benefits of Network Diversity

Tuesday, November 12, 2024

Patrick Park & Bogdan Vasilescu

2-min Quiz, on Canvas



Social Capital

Network social capital

The resources that individuals or groups can draw from the structure of social networks

Individual level

- Individual's position in a network can confer opportunities to benefit
- Example: degree centrality

Subgroup level

- Teams composed of members in certain network positions can benefit
- Himalaya expedition teams with diverse member composition more likely to succeed (reaching the top and fewer member deaths)

Network level

- Structure of the entire network can benefit everyone in the network
- Example: small-world networks and musical performance

Categories of network social capital

Bridging social capital (Today)

- Advantages of diversity
- Information advantage, divide and conquer

Bonding social capital (Next lecture)

- Advantages of cohesion
- Norms, trust, support

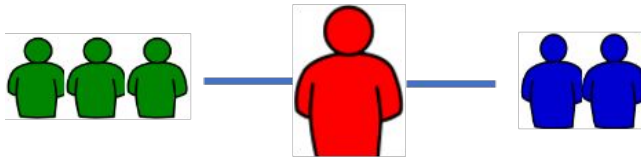
When the tie is the bridge

Bridging social capital



Tie is the bridge: Network Bridging

- A shortcut that connects otherwise separated social contexts.
- Bridging ties are the conduits through which non-redundant information can flow through.



Node is the bridge: Network Brokerage

- The separation among one's alters
- Alters likely come from different social groups

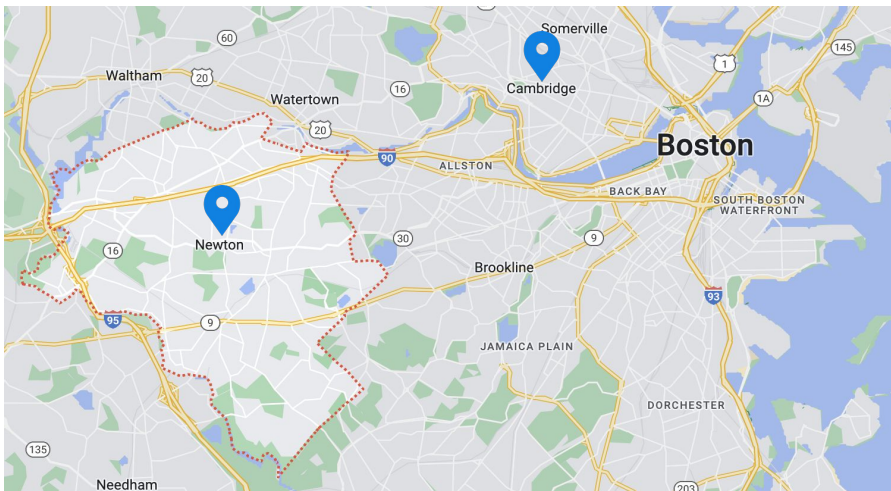
Network Bridging



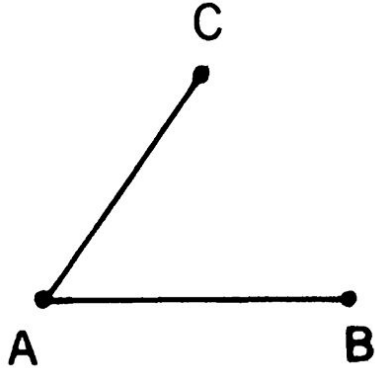
Sociologist, Mark Granovetter's PhD dissertation (1970's)

Counter-intuitive discovery: 55% of professionals who got their jobs through network ties found out about the new job opportunities through **acquaintances** (meet less than twice a week)

Q: Why?



The forbidden triad



Remember **structural balance** theory?

A-B is a “strong” tie
A-C is a “strong” tie

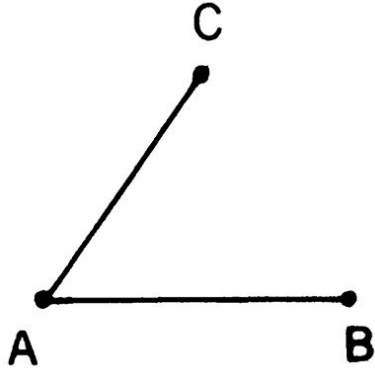
Then, to reduce cognitive dissonance, A may try to introduce B and C

Similarly, B and C may try to become friends to reduce their own cognitive dissonance.

Hence, a triad with only two “strong” ties are less likely to exist

Tie strength: interaction frequency, reciprocity, emotional intensity

Tie strength and clustering



A strong tie:

- Usually embedded in dense clusters
- Closed triangles

A weak tie:

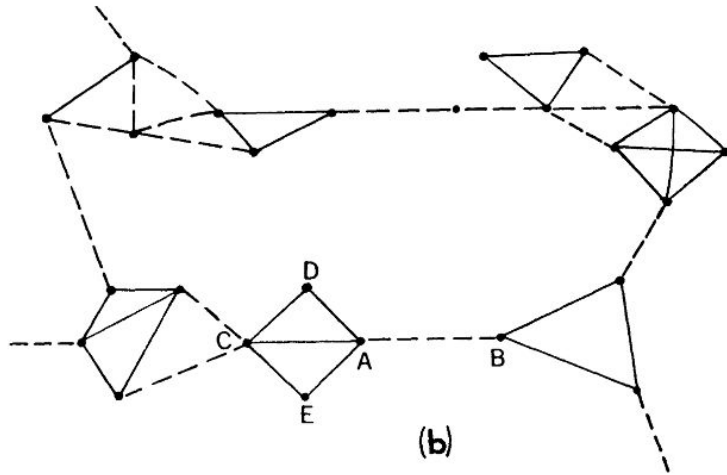
- Less likely to introduce each other's friends
- Less likely to be embedded in dense clusters

Key assumption:

Strong ties are embedded in clusters

Ties that **bridge** clusters are likely to be **weak ties**

Tie strength and clustering

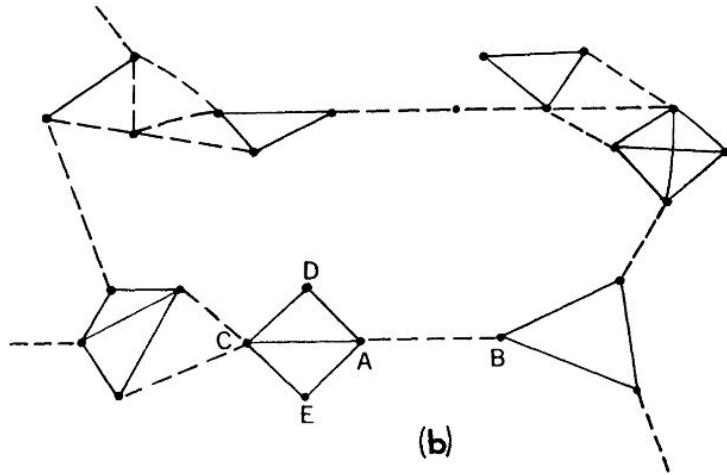


Granovetter created a measure of bridge length → “Local bridge of degree n ”

Bridge length of the A-B tie:

- second shortest path length

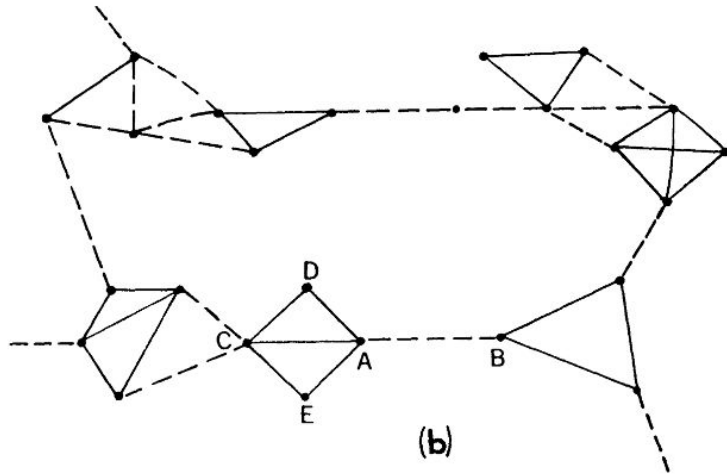
Tie strength and clustering



This measure requires global network information → unmeasurable with small-scale network data

Weakness of ties was a **good proxy** for the structural bridging

Tie strength and clustering



Strong ties transmit redundant information circulating in the local cluster

Weak ties have higher probability of transmitting novel information circulating in a distant cluster

News about new job openings are more likely to come through weak ties
→ Hence, the **strength of weak relational ties**

SWT: 50 years of empirical research

The Strength of Weak Ties

35785 citations (2.3 per day) ← Citation count in 2016

social sciences
management,
biology
computer science
statistical physics
...

Wealth of Nations: 35744 citations

SWT: 50 years of observational (correlational) research

The Strength of Weak Ties

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The strength of weak ties

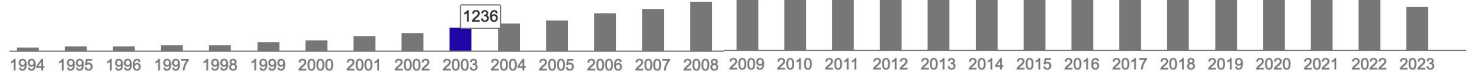
Authors Mark S Granovetter
Publication date 1973/5/1
Journal American journal of sociology
Pages 1360-1380
Publisher University of Chicago Press

Description Analysis of social networks is suggested as a tool for linking micro and macro levels of sociological theory. The procedure is illustrated by elaboration of the macro implications of one aspect of small-scale interaction: the strength of dyadic ties. It is argued that the degree of overlap of two individuals' friendship networks varies directly with the strength of their tie to one another. The impact of this principle on diffusion of influence and information, mobility opportunity, and community organization is explored. Stress is laid on the cohesive power of weak ties. Most network models deal, implicitly, with strong ties, thus confining their applicability to small, well-defined groups. Emphasis on weak ties lends itself to discussion of relations between groups and to analysis of segments of social structure not easily defined in terms of primary groups.

Citation count in 2023

Total citations Cited by 71117

Wealth of Nations: 35744 citations



Continuing debates: The diversity-bandwidth tradeoff

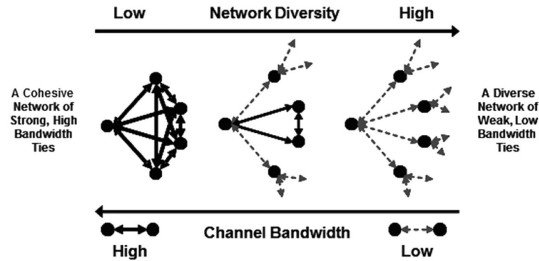


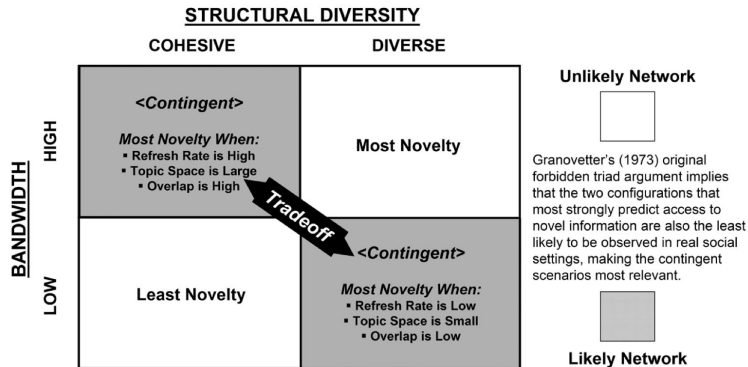
FIG. 1.—The diversity-bandwidth trade-off. As structural diversity increases, channel bandwidth decreases.

Bandwidth: Interaction strength of tie

- Volume of information: high
- Novelty of information: low

Diversity: ties to non-overlapping groups

- Volume of information: low
- Novelty of information: high

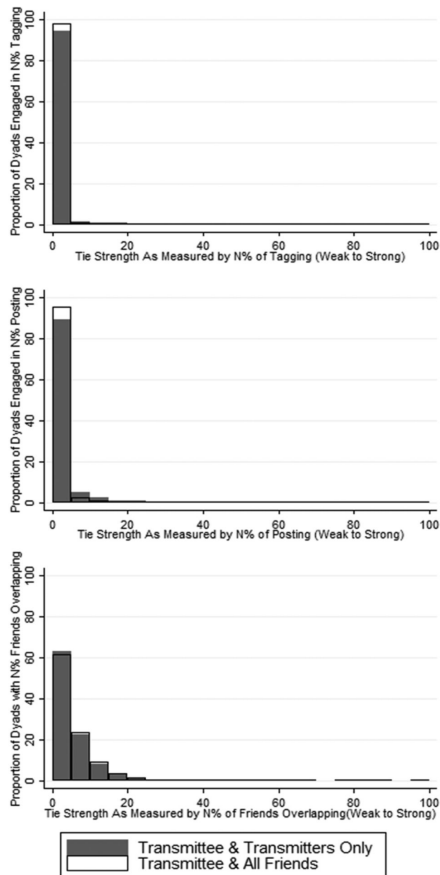


Having diverse ties means volume of information transmission is low, but novelty is high

Having ties with high bandwidth lowers the proportion of novel information, but you get higher volume, so the volume of novel information can be substantial

Continuing debates: Getting a job with weak ties

Tie strength distribution



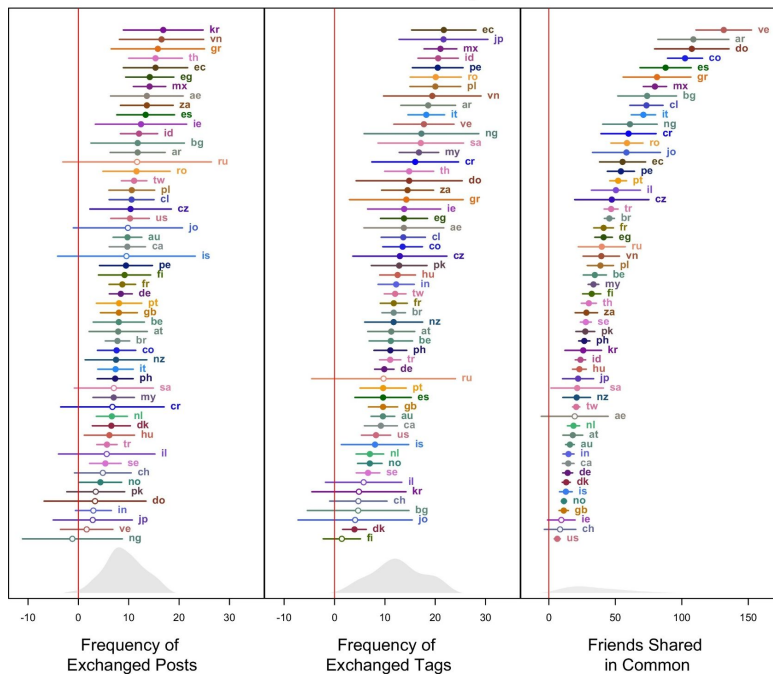
Strength of strong ties in job mobility:

- Facebook users' subsequent jobs were at a place where a weak tie worked
- Because most FB friends were composed of weak ties
- However, **strong ties were more "effective"**

(Gee et al. 2017)

Continuing debates: Getting a job with weak ties

Relationship Between Sequential Job and Measures of Tie Strength



Country Key

ae	United Arab Emirates
ar	Argentina
at	Austria
au	Australia
be	Belgium
bg	Bulgaria
br	Brazil
ca	Canada
ch	Switzerland
cl	Chile
co	Colombia
cr	Costa Rica
cz	Czech Republic
de	Germany
dk	Denmark
do	Dominican Republic
ec	Ecuador
eg	Egypt
es	Spain
fi	Finland
fr	France
gb	United Kingdom
gr	Greece
hu	Hungary
id	Indonesia
ie	Ireland
il	Israel
in	India
is	Iceland
it	Italy
jo	Jordan
jp	Japan
kr	South Korea
mx	Mexico
my	Malaysia
ng	Nigeria
nl	Netherlands
no	Norway
nz	New Zealand
pe	Peru
ph	Philippines
pk	Pakistan
pl	Poland
pt	Portugal
ro	Romania
ru	Russian Federation
sa	Saudi Arabia
se	Sweden
th	Thailand
tr	Turkey
tw	Taiwan
us	United States
ve	Venezuela
vn	VietNam
za	South Africa

Similar story across 55 countries

Shortcoming:

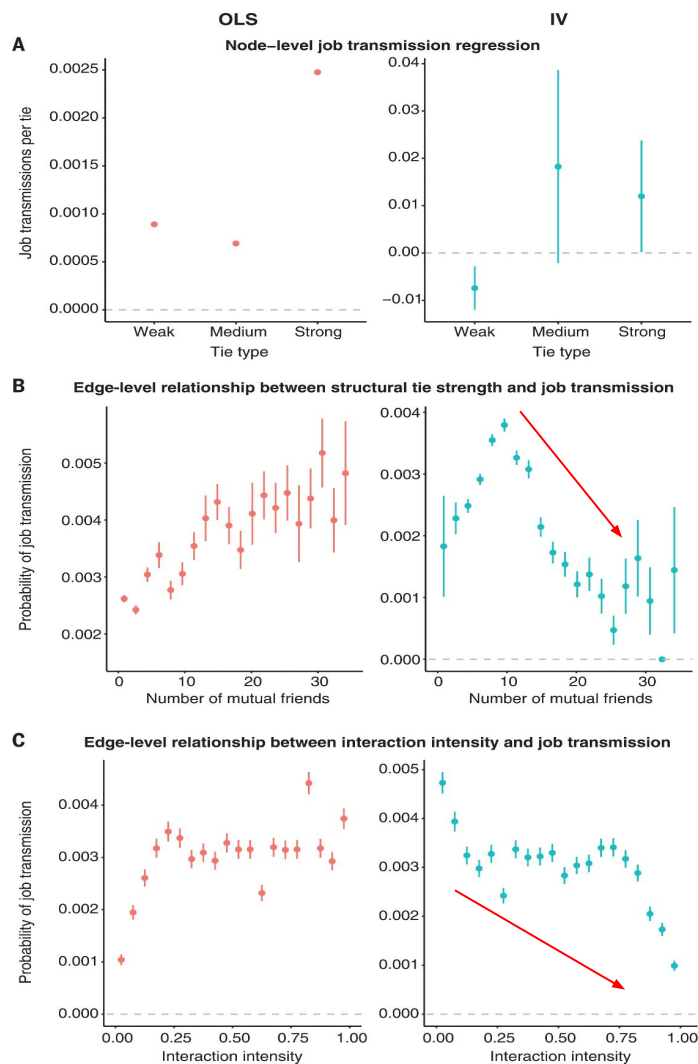
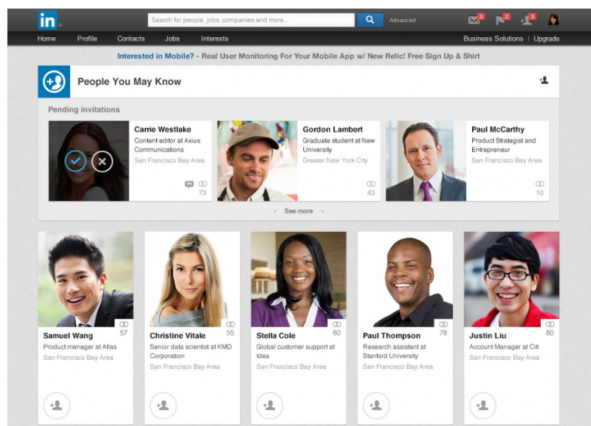
- Correlational evidence (inconclusive)
- Job information transmission was not directly measured:
 - First, user A reports working at company c at date $D1$. Second, user B reports working at that same company c at a later date $D2$, with $D2$ and $D1$ being at least one year apart. Third, user A and user B were friends on the social network at least one full year before $D2$. In the weak tie literature, when these three criteria are met, a tie is considered a “**sequential job**” tie, which represents the state of the art in measuring relational job mobility.

Continuing debates

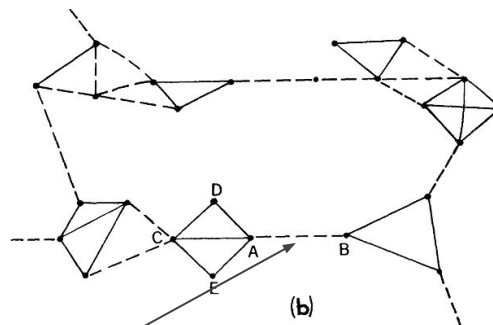
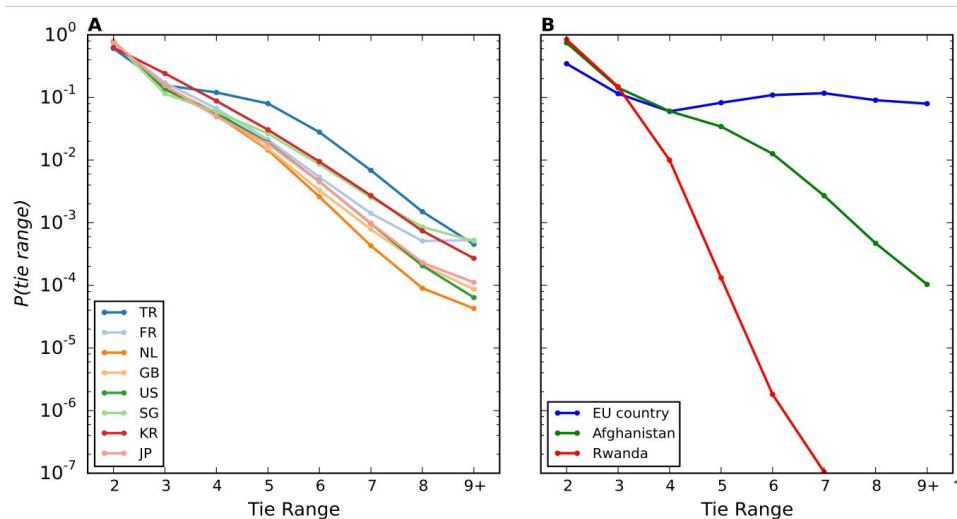
A LinkedIn study finds experimental evidence that **weak ties are effective** ([Rajkumar et al. 2022](#))

First study with causal evidence

- Experimentally manipulated recommendation algorithm (PYMK)



Continuing debates: Are bridging ties really weak?



With population-scale communication network data, we can finally observe the long bridging ties that Granovetter envisioned

However, these long-range bridges are rare → Unobservable in the small-scale network data in the 1970s

Continuing debates: Are bridging ties really weak?



Source: Meryl Ye (2024)

The strength of long-range ties in population-scale social networks

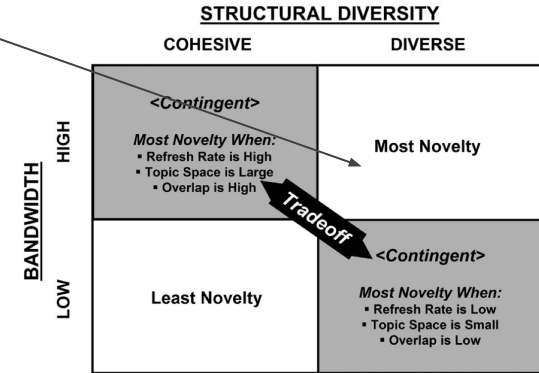
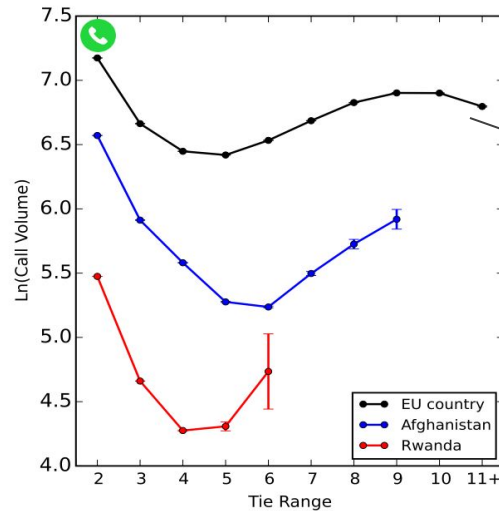
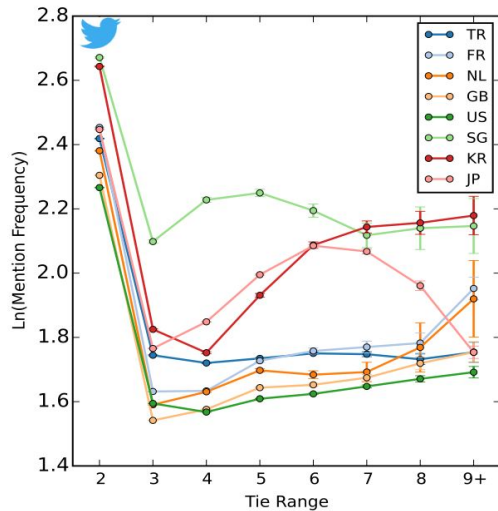
PATRICK S. PARK , JOSHUA E. BLUMENSTOCK , AND MICHAEL W. MACY  [Authors Info & Affiliations](#)

SCIENCE · 21 Dec 2018 · Vol 362, Issue 6421 · pp. 1410-1413 · [DOI: 10.1126/science.aau9735](https://doi.org/10.1126/science.aau9735)

Long bridges are rare,...

but not necessarily weak

Continuing debates: Are bridging ties really weak?

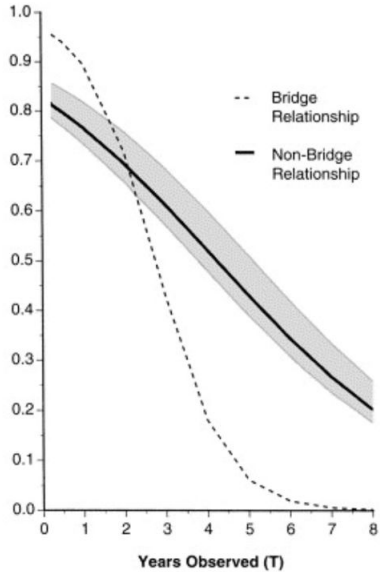


Population-scale communication data reveal the strength of long bridging ties
 There can be exceptions to the diversity-bandwidth tradeoff

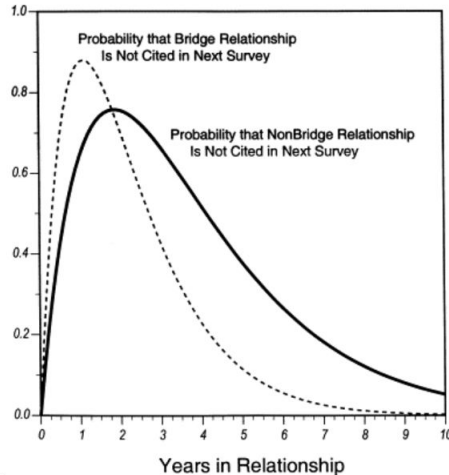
But recall the “forbidden triad”
 How can the bridging ties be so strong?

How do bridging ties form?

Predicted Probability of Relationship Not Being Cited Next Year



B. Kinked Decay Projected for Banker Relationships (cf. Figure 2)



The strength of long-range ties raises the question of how they come about

Q: How do strong, long-range ties form?

Strong ties lead to triadic closure (forbidden triad)
→ Strong ties are not likely to be bridges

Bridges tend to decay quickly → So how can they be strong?

How do bridging ties form?

Hypothesis 1: Intimate Strangers



How do bridging ties form?

Hypothesis 1: Intimate Strangers

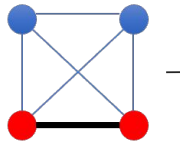


How do bridging ties form?

Hypothesis 2: The strongest ties survive to become bridges



Time 0



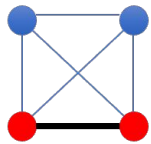
Range = 2

How do bridging ties form?

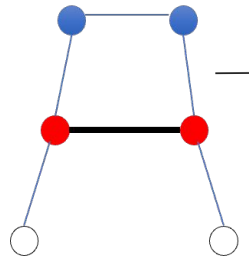
Hypothesis 2: The strongest ties survive to become bridges



Time 0



Time 1



Range = 2

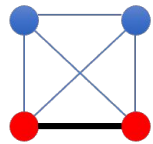
Range = 3

How do bridging ties form?

Hypothesis 2: The strongest ties survive to become bridges

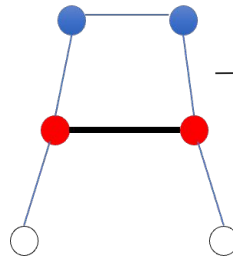


Time 0



Range = 2

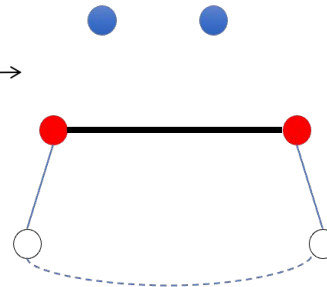
Time 1



Range = 3



Time 2



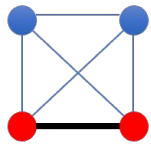
Range > 3

How do bridging ties form?

Hypothesis 2: The strongest ties survive to become bridges

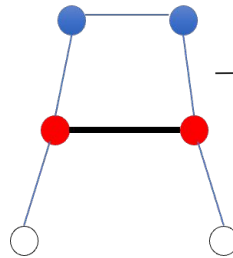


Time 0



Range = 2

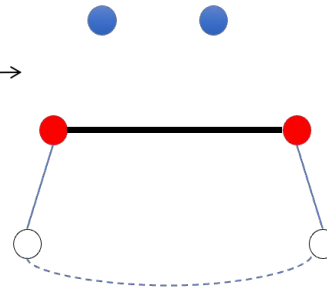
Time 1



Range = 3



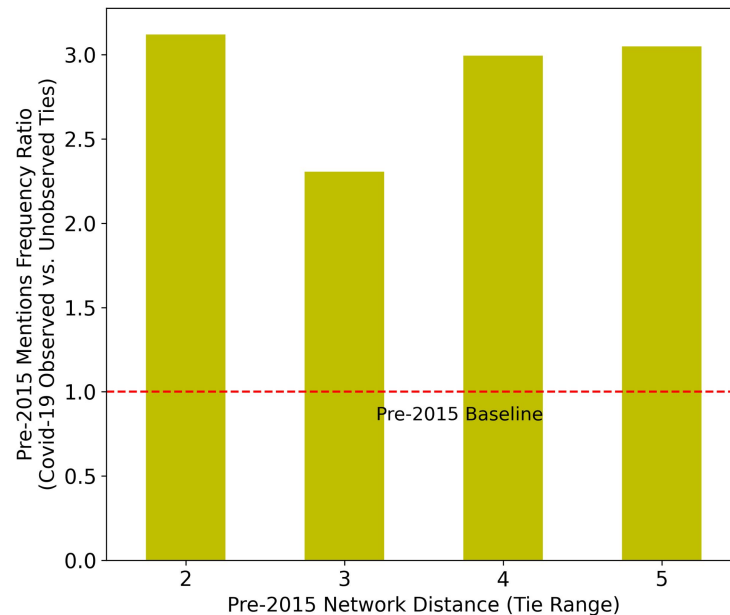
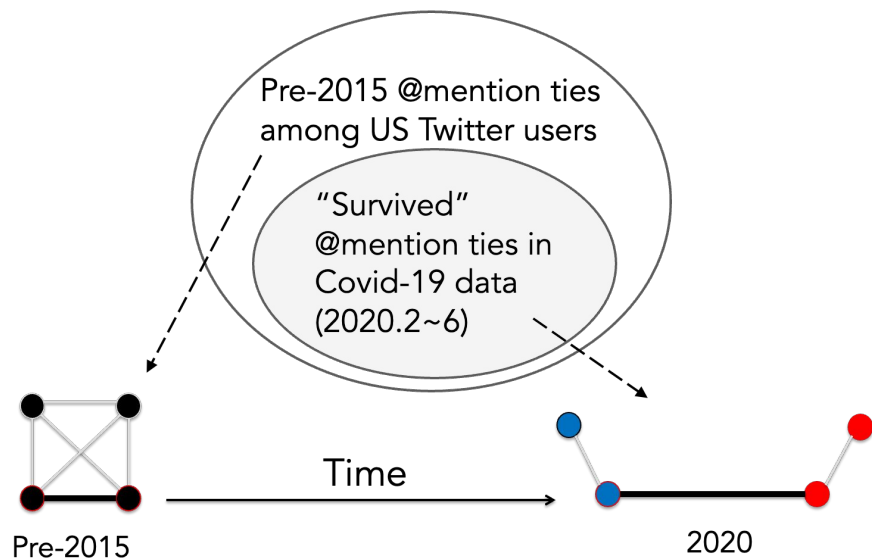
Time 2



Range > 3

How do bridging ties form?

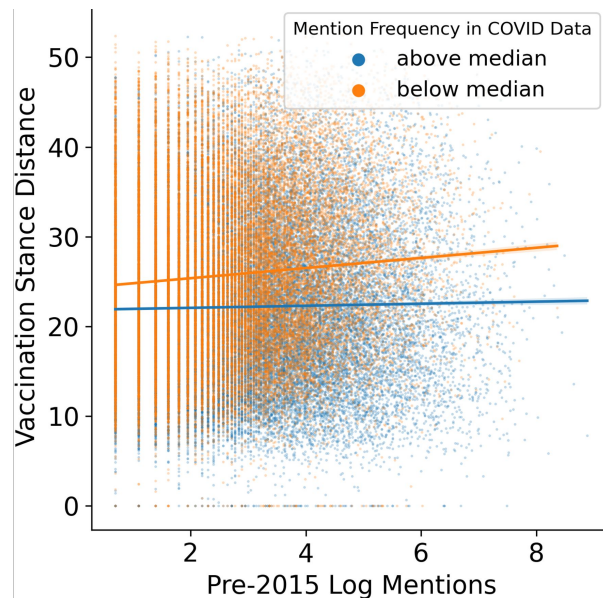
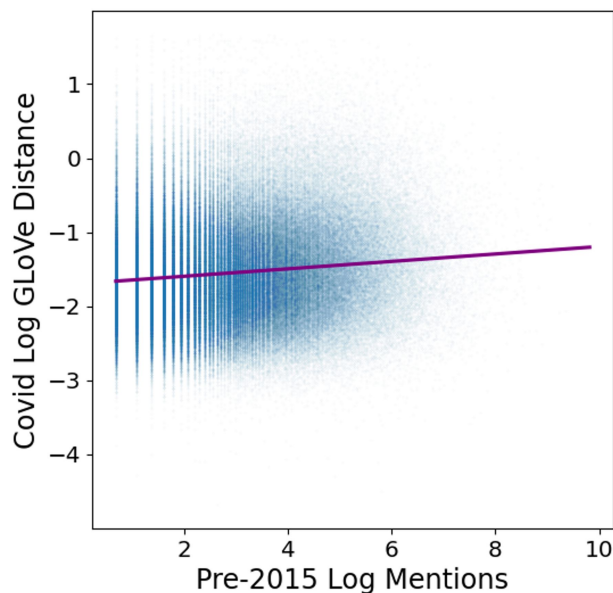
Hypothesis 2: The strongest ties survive to become bridges



How do bridging ties form?

The survived ties that used to be stronger show:

- larger cognitive distance on COVID-related topics (e.g., school reopening vs. depression)
- larger disagreements about vaccination (pro- vs. anti-vaccination)



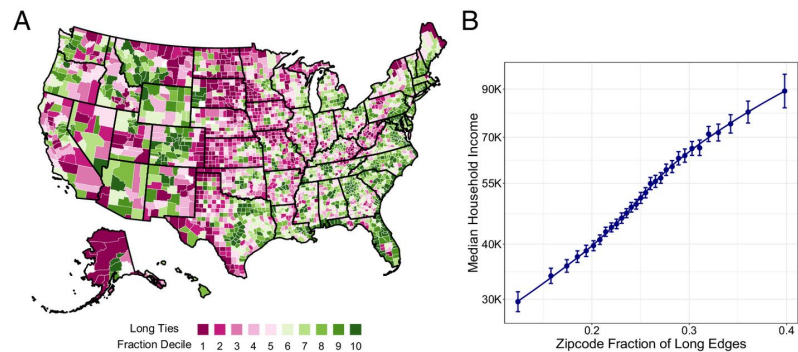
How do bridging ties form?

Hypothesis 3: People learn to **adapt** through disruptive events

- Befriend strangers
- Flexibly adjust to local norms of interaction

social networks are rebuilt after **disruptive life events**

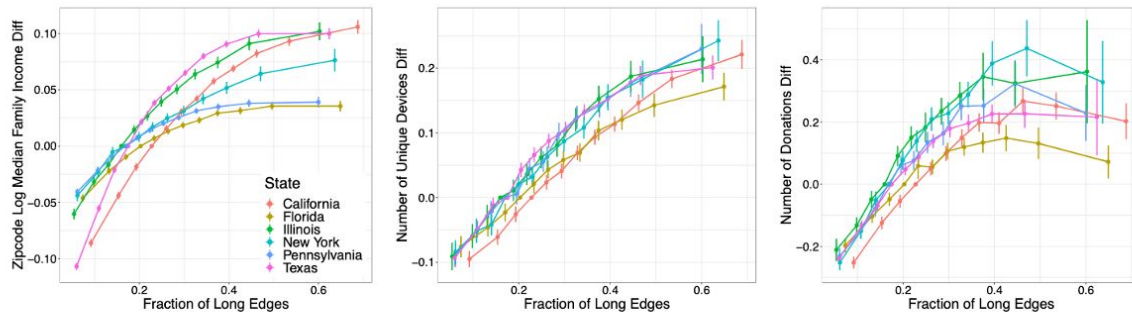
- Interstate migration
- College attendance in different state
- High school transfer



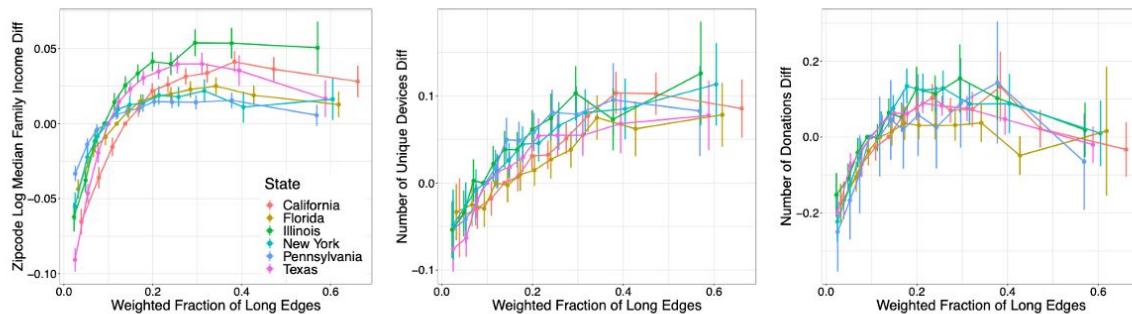
Source: Jahani et al. ([2022](#))

Result: People with these experiences can form and maintain higher proportion of bridging ties

How do bridging ties form?



(A)



(B)

The strength of weak ties

Not just for jobs, but owning expensive devices and higher donations

How do bridging ties form?

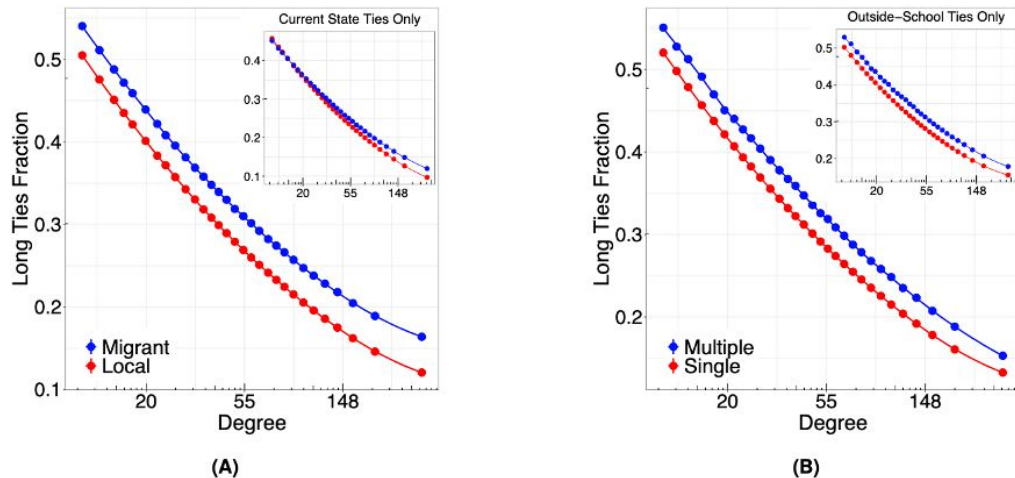
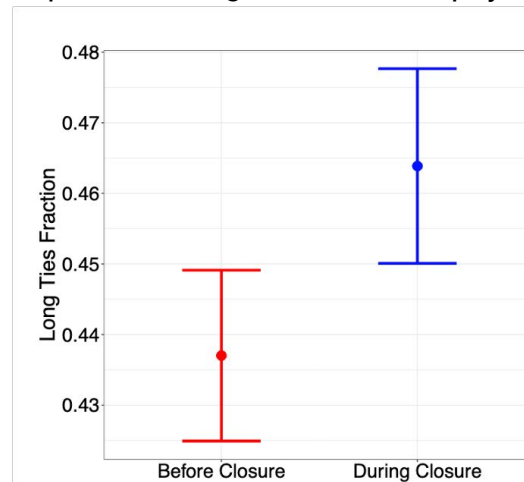


Fig. 4. Conditional on degree, people who (A) are interstate migrants or (B) attended multiple high schools have more long ties than matched controls. Qualitatively similar relationships hold when restricting the analysis to less-directly implicated ties — those within the current state (A inset) and those outside of high school (B inset). All estimates are post-stratified by gender, age, and hometown county income bins.

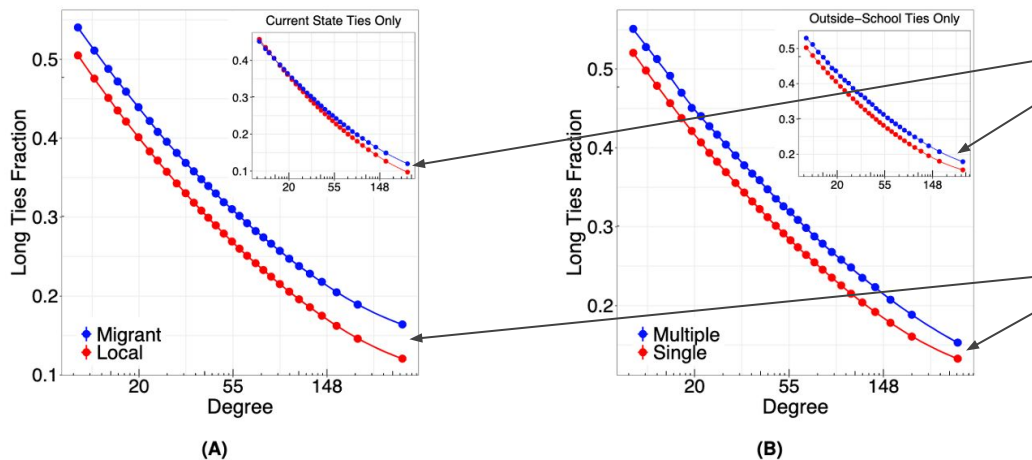
People whose high schools abruptly closed



How do bridging ties form?

So, do people adapt/learn to form and maintain bridging ties? (individual-level explanation)

Or do strong relationships survive over time and become bridging ties? (tie-level explanation)



Supporting evidence for individual adaptation
(smaller percentage difference)

Supporting evidence for strong-tie
survival (larger percentage difference)

Fig. 4. Conditional on degree, people who (A) are interstate migrants or (B) attended multiple high schools have more long ties than matched controls. Qualitatively similar relationships hold when restricting the analysis to less-directly implicated ties — those within the current state (A inset) and those outside of high school (B inset). All estimates are post-stratified by gender, age, and hometown county income bins.

When the node is the bridge

Structural holes



Ronald Burt

Extended the idea of bridging ties

- From ties to nodes
- The node is the bridge
- Emphasis on individual's agency
- Benefits that accrue to individual

Structural holes

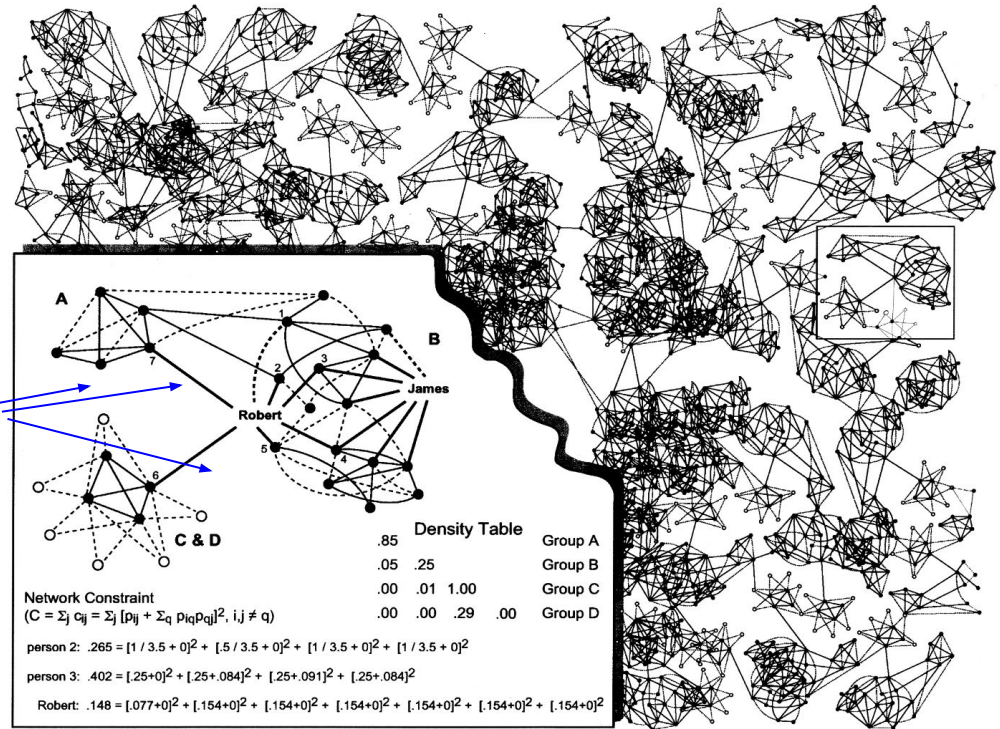


Ronald Burt

Extended the idea of bridging ties

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- Benefits that accrue to individual

Structural holes



James vs. Robert

How are their positions different?

Who spans more structural holes?

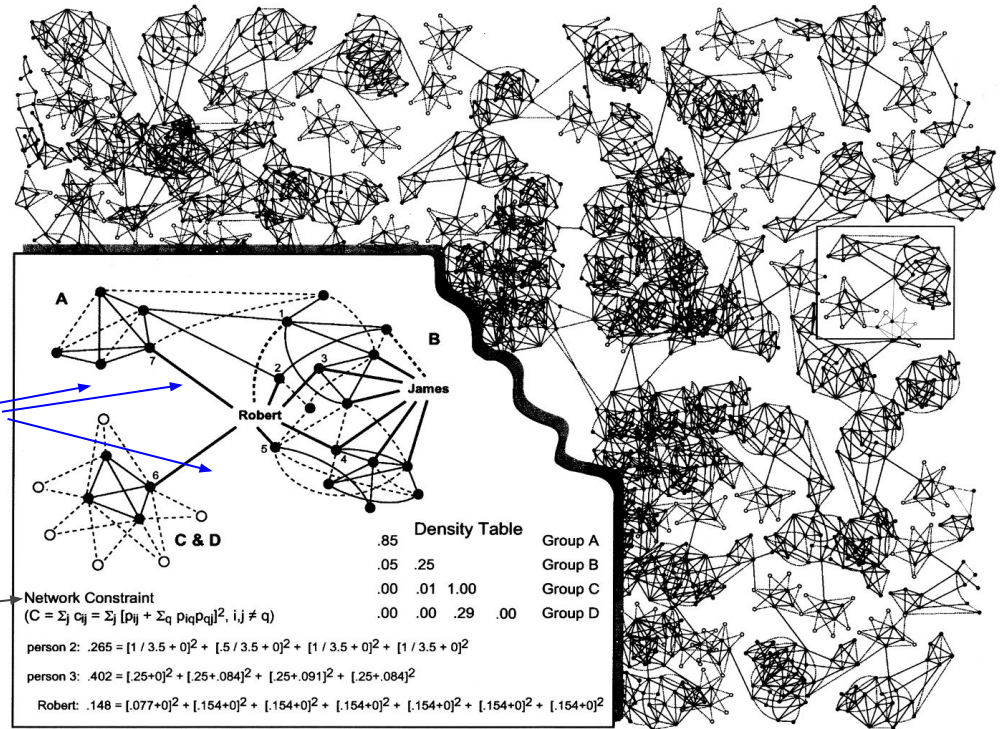
Structural holes

Structural holes create
arbitrage opportunities

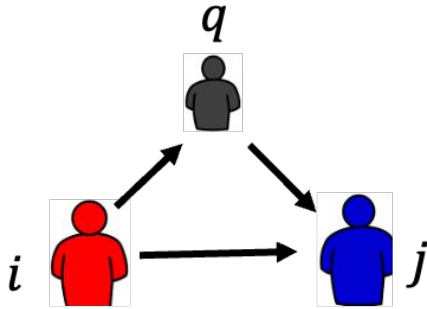
People who bridge more
structural holes have
advantages

Network Constraint quantifies
the amount of structural holes,
hence arbitrage potential

Structural holes



Measuring Brokerage: Network Constraint



$$c_{ij} = \left(p_{ij} + \sum_q p_{iq} p_{qj} \right)^2$$

i's dependence on *j*: Proportion of direct communication with *j* and the sum of the indirect communications with *j* through common neighbors, *q*

$$p_{ij} = \frac{z_{ij}}{\sum_q z_{iq}}$$

communication with *j* relative to the sum of *i*'s total communications

$$C_i = \sum_j c_{ij}$$

i's total constraint is the sum of *i*'s pairwise constraints

Measuring Brokerage: Network Constraint

Network constraint can be interpreted as a composite measure consisting of [size](#), [density](#), and [hierarchy](#).

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Measuring Brokerage: Network Constraint

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$$c_{ij} = p_{ij}^2 + 2(p_{ij} p_{iq_1} p_{q_1j} + p_{ij} p_{iq_2} p_{q_2j} + \dots) + (p_{iq_1} p_{q_1j} + p_{iq_2} p_{q_2j} \dots)$$

Measuring Brokerage: Network Constraint

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size

$$p_{ij} = \frac{z_{ij}}{\sum_q z_{iq}}$$

Larger size, less constrained

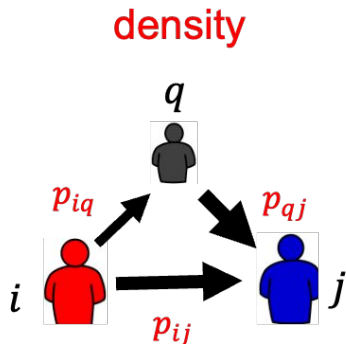
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size

$$p_{ij} = \frac{z_{ij}}{\sum_q z_{iq}}$$



Larger size, less constrained High density, more constrained

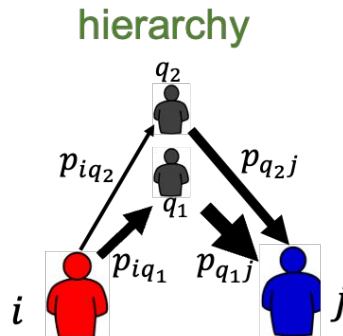
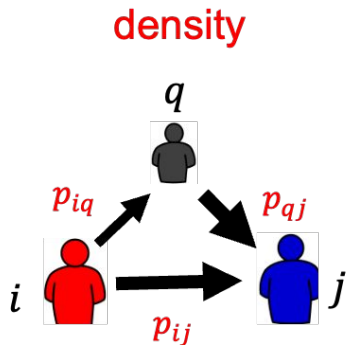
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size

$$p_{ij} = \frac{z_{ij}}{\sum_q z_{iq}}$$



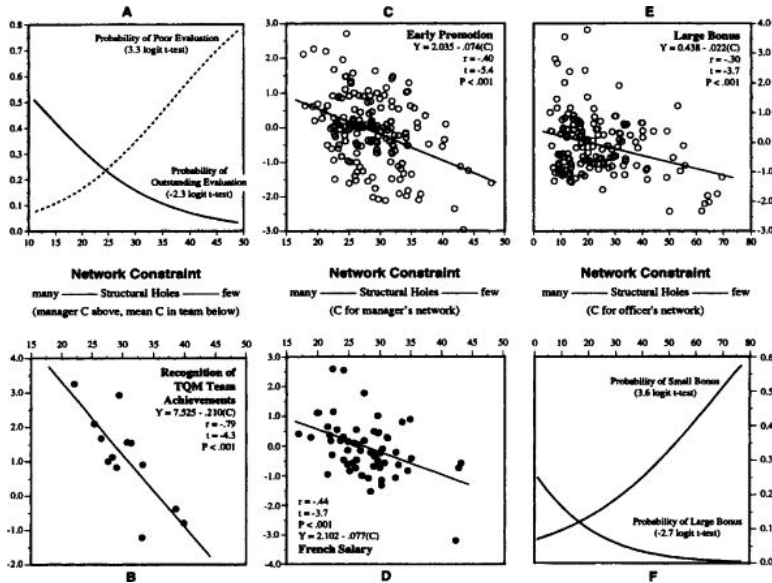
Larger size, less constrained

High density, more constrained

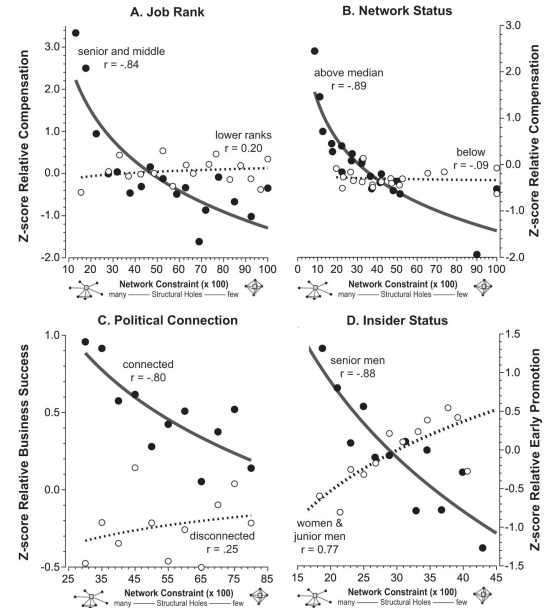
Strong hierarchy, more constrained

Brokerage Benefits

Study after study shows correlation of network diversity and success/performance



Source: Burt 2000

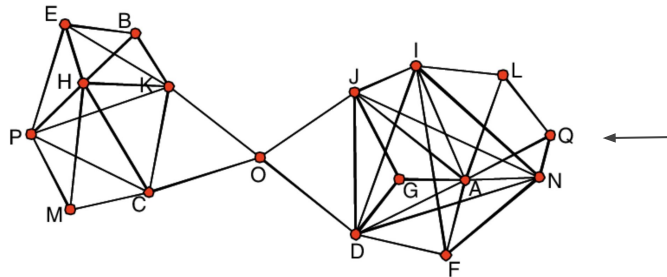


Source: Burt 2021

Conditions for Brokerage Benefits



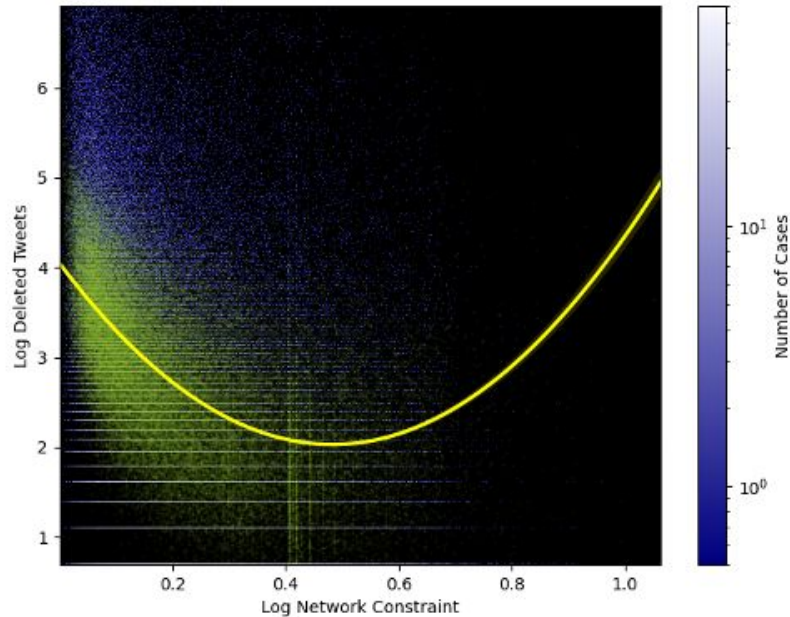
A critical condition for brokerage benefits is the separation of context



Imagine two groups of strangers brokered by node O gathered into the same room

Q: How might node O's behaviors change?

Conditions for Brokerage Benefits



Self-censorship: Twitter users with low network constraint (higher brokerage) tend to delete more tweets

Source: Park (unpublished)

Summary

Random Networks

Social capital originates from relationships

Social ties that bridge communities are a source of social capital

Individuals who broker communities are a source of social capital

New data confirm these insights, but also challenge them