Information Aggregation on Networks: an Experimental Study

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Introduction

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  - by collecting noisy private info
  - by observing choices of others (family, friends, ...)

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  - a group of agents are tied together by a social network
  - each observes noisy but informative signal about true state
  - all agents want to match the state
  - in every round, guess the state and observe neighbor's guesses

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- The architecture of social network and one's position in it determines info set available to the agent

Introduction, cont...

- Theoretical literature
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  - mild conditions are sufficient for full convergence to the truth in connected societies

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- THIS PAPER:
  - explore effects of network architectures on dynamics of belief formation over large networks
  - characterize architecture features that prevent info aggregation

Related Literature

1. Theoretical literature
    - Bayesian model
        - Gale and Kariv (2003), Acemoglu et al ('11), Muller-Frank ('13), Mossel, Sly and Tamuz ('15)
    - Naive Model
        - de Groot ('74), deMarzo et al. ('03), Golub and Jackson ('10, 2012), Acemoglu and Ozdaglar ('11)
    - Other theories
        - Bala and Goyal ('98), Jackson and Watts ('03), Goyal and Vega Redondo ('05)
2. Empirical studies
    - lab experiments focus on relatively small networks
        - Choi et al ('05, '12), Corrazzini et al ('12), Mueller-Frank and Neri ('14), Grimm and Mengel ('20), Chandrasekhar et al. ('20)
    - field studies
        - Chandrasekhar et al. ('20), Banerjee et al ('19), Breza et al ('19)

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  - Round 1:
    - each player gets private signal about the state (iid, 70% correct)
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  - Rounds 2 onwards:
    - observe guesses of neighbors and guess the state
  - Game ends: if no one changes her guess in three consecutive rounds or with prob 50% after round 50

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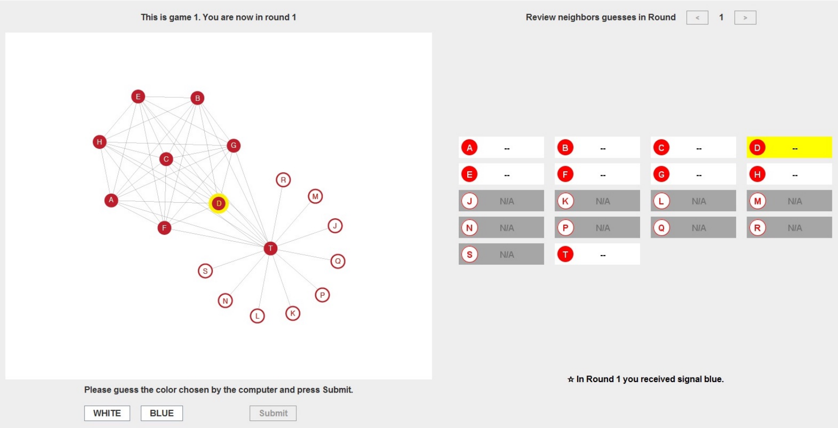
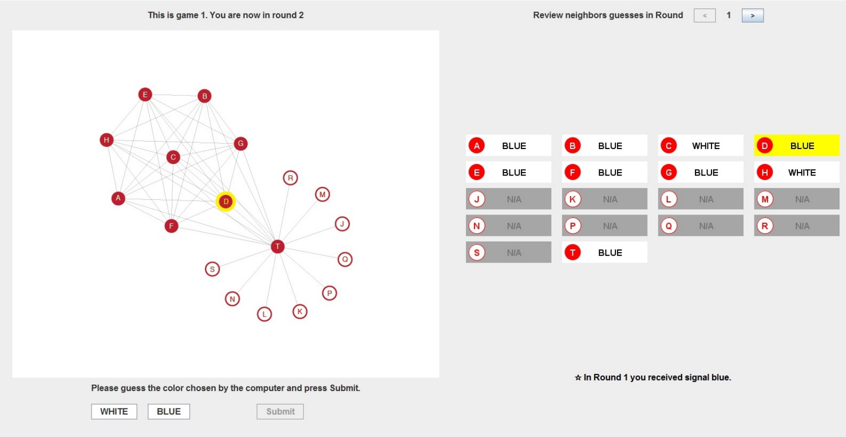
- Incentives:
  - $20 for correct guess in random round of random game, $5 o/w
  - show-up fee $10

Screenshot 1



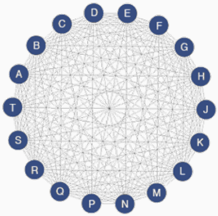
Screenshot 2



Observers

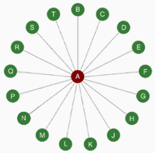
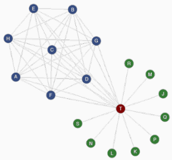
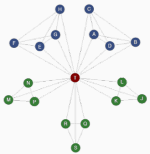
- Most sessions had more then 18 subjects
- 18 are placed in the network, others are observers (random)
- Observers' task
  - observe network structure
  - pick a position in the network whose payoff you will get if this game is selected for payment
- Measure *perceived* centrality (payoffs)
- How does perceived centrality match centrality indices?

Complete



- What do we expect in this network?
- Fast convergence to the right guess
  - Round 1: report own signal
  - Rounds 2 - 4: observe all r1 guesses (signals), report majority one

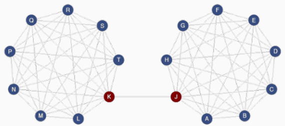
Networks, cont...

Star	One Gatekeeper	Single Mediator
		

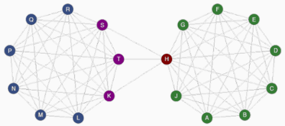
- What do we expect in these networks?
- Fast convergence to the right guess
    - Round 1: report own signal
    - Round 2: hub observes all signals, reports majority one
    - Round 3 - 5: all members imitate the hub

Networks, cont...

Two Cores One Link



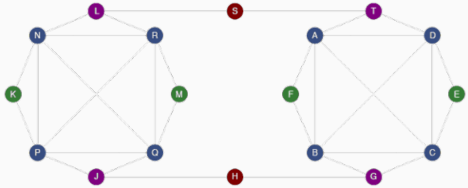
Two Cores with Three Links



- What do we expect in these networks?
    - Depends on the distribution of signals in each cluster
    - Fast convergence to the right guess
    - Fast convergence to the wrong guess
        - One Link: 10-8, 4 wrong in each cluster, red nodes wrong signals
    - Slow convergence (more than 7 rounds) to the right guess

Networks, cont...

Complex Network



- What do we expect in this network?
    - Depends on the distribution of signals in each cluster
    - Fast/slow convergence to the right/wrong guess
- Separation of centrality indices at the node level

Collected Data So Far

	UCI	UCSD	TAU	total # sessions	total # subjects
Complete 18	2	2	1	5 sessions	106 subjects
Star 18	2	2	3	7 sessions	141 subjects
One Gatekeeper	2	2	2	6 sessions	122 subjects
Single Mediator	2	2	0	4 sessions	82 subjects
Two Cores One Link	2	2	1	5 sessions	100 subjects
Two Cores Three Links	1	2	0	3 sessions	60 subjects
Complex	2	2	0	4 sessions	80 subjects
				34 sessions	691 subjects

First look at the data

- Identify structural features of networks
- Does network architecture affect long-run outcomes?
- Empirical strategy
  - last 5 games in each session
  - regression analysis with clustering at the session level

Outcomes

1. Game length
2. Frac correct last round guesses
    - Consensus in last round
        - 0.5 = fully polarized, 1 = full consensus
    - How often last round majority is correct
3. Agree-to-disagree state in last round
    - 7-11 or 8-10 or 9-9
4. Evolution of frac of correct guesses
5. Evolution of consensus

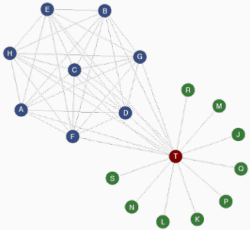
Structural features of networks

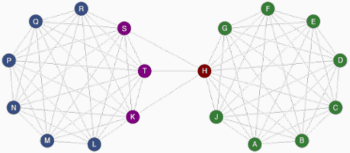
1. Big Brother: one observes everyone
    - Star, One Gatekeeper, Single Mediator
2. One Cluster: one large group of highly connected nodes
    - One Gatekeeper, Complete
3. Two Clusters
    - Two Cores One Link, Two Cores Three Links, Complex

Examples of Structural Features

One Gatekeeper

Two Cores Three Links





Big Brother
One Cluster

No Big Brother
Two Clusters

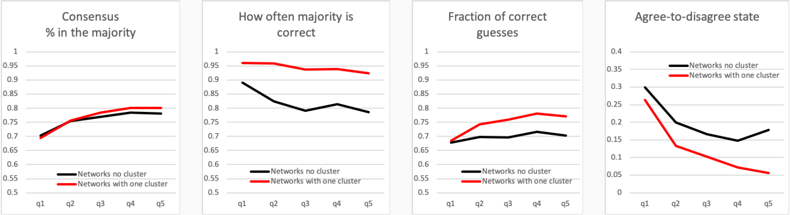
Results

$$\text{Outcome}_{n_m} = \beta_0 + \beta_1 \cdot \text{Architecture Feature}_n + \epsilon_{n_m}$$

Results

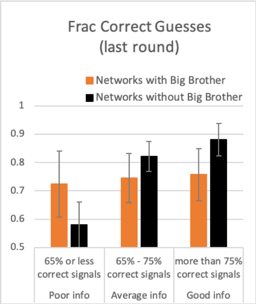
- Networks with Big Brother
  - games last longer ($p = 0.066$)
- Networks with One Cluster
  - higher frac of correct last round guesses ($p = 0.074$)
  - higher chance that majority is correct ($p = 0.026$)
  - lower chance of agree-to-disagree ($p = 0.009$)
  - 7% in One Gatekeeper
- Networks with Two Clusters
  - marginally lower consensus ($p = 0.097$)
  - higher chance of agree-to-disagree ($p = 0.021$)
  - 24% in Two Cores One Link

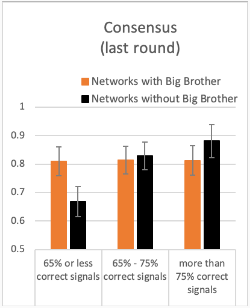
Evolution of Outcomes over Time: Effect of One Cluster



- Similar consensus rates
- Decrease in how often majority is correct over time
- Networks w/ a cluster aggregate info better than those w/out
- Agree-to-disagree state declines sharply with a cluster

Response to Information Quality

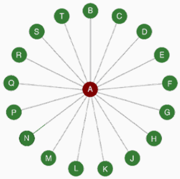




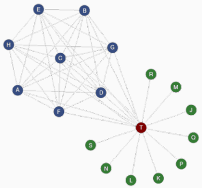
- Networks with Big Brother do not respond to info quality
- But they are sensitive to Big Brother info
  - frac of correct last round guesses: 66% $\rightarrow$ 79%
  - consensus rates: 78% $\rightarrow$ 83%

Adding Links (oversight)

Star



One Gatekeeper



- Star → One Gatekeeper
  - frac of correct guesses increases
  - consensus rates stays same, but majority is correct more often
  - agree-to-disagree state is less frequent

Local information matters

- Two Cores One Link
  - distribution of signals 12-6, both hubs have correct signal
- Session 6, Game 7
  - left cluster: signals 6/9 correct, last guesses all correct
  - right cluster: signals 6/9 correct, last guesses 6/9 correct
  - frac of correct last round guesses is 83% and consensus is 83%
- Session 6, Game 10
  - left cluster: signals 8/9 correct, last guesses 7/9 correct
  - right cluster: signals 4/9 correct, last guesses all wrong
  - frac of correct last round guesses is 39% and consensus is 61%

Aggregate Network Measures

$$\text{Outcome}_{n_m} = \beta_0 + \beta_1 \cdot \text{Info}_{n_m} + \beta_2 \cdot \text{Measure}_n + \epsilon_{n_m}$$

- n - network type, m - match in a session
- cluster by session
- Info is % correct signals minus 0.7 (av quality info)
- Measures
  - Diameter
  - Density

Aggregate Network Measures: Results

- Frac Correct Guesses
  - positively corr with Density ($p = 0.02$)
  - negatively corr with Diameter ($p = 0.004$)
- Consensus
  - negatively corr with Diameter ($p = 0.002$)
- Majority correct
  - positively corr with Density ($p = 0.007$)
- Agree-to-Disagree
  - positively corr with Diameter ($p = 0.02$)

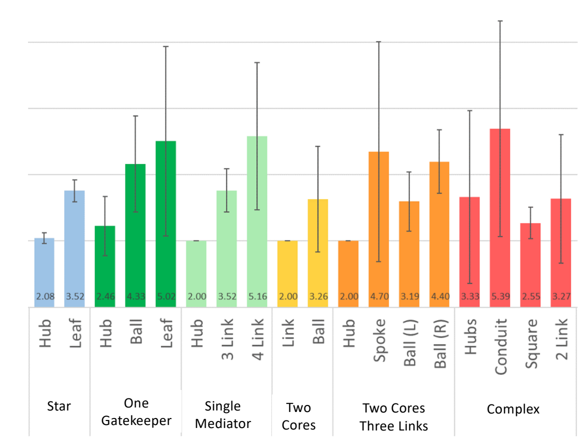
What we learned so far...

- Network architectures matters
  - for long-run outcomes
  - evolution of outcomes over time
- Local information plays an important role
  - distribution of signals in networks with clusters
  - signal of Big Brother
  - oversight (‘unnecessary links’)
- Standard measures pick up some of these patterns

Network position matters

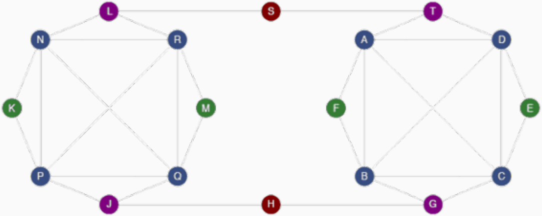
- How fast different nodes make up their minds?
- Do subjects change their mind (last guess $\neq$ first guess)?
- Do you learn directly from your local connections (second guess $\neq$ first guess)?
- Do subjects learn correctly (signal $\neq$ last guess $=$ state)?
- Which nodes are correct more often? (payoffs)

Speed of Making One's Mind



- Networks w/ Big Brother: hubs converge faster than others
- Networks w/ Two Cores: clusters take longer than 'connectors'

Complex Network



- Differentiation of centrality measures at the node level
  - Degree centrality: blue > purple > red = green
  - Betweenness: red = purple > blue > green
  - Eigenvalue centrality: blue > purple > green> red

Individual outcomes and node centrality

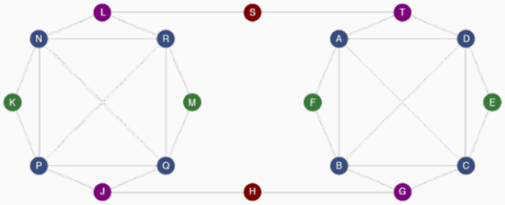
$$\text{Outcome}_{i_m} = \beta_0 + \beta_1 \cdot \text{Degree}_i + \beta_2 \cdot \text{Betweenness}_i + \beta_3 \cdot \text{Eigenvalue}_i + \\ + \beta_4 \cdot \text{My Info}_{i_m} + \beta_5 \cdot \text{Network Info}_{i_m} + \epsilon_{i_m}$$

Results

	Freq Correct (all rounds)	Correct (last round)	Changed Mind last − first	Learned Correctly
Degree	**0.09****	**0.12****	0.05	**0.07***
Betweenness	-0.02	-0.03	0.01	-0.02
Eigenvalue	0.04	0.03	**-0.24****	-0.09

significant at ** 5%, at * 10%

Perceived Centrality: Observers



	Observers' Choice		Theory			Performance	
	raw %	rescaled	degree	betw.	eigenv.	last guess	all
Blue	0.67	0.43	0.29	0.10	0.31	0.67	0.67
Red	0.10	0.27	0.12	0.24	0.09	0.65	0.63
Purple	0.15	0.19	0.18	0.24	0.17	0.60	0.62
Green	0.08	0.11	0.12	0.00	0.15	0.58	0.56

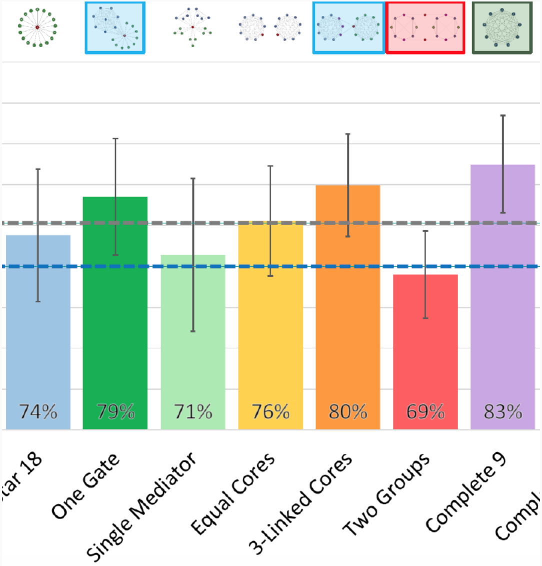
- Most choose nodes with highest degree and best performance
- Some pick nodes with high betweenness

Conclusions and Next Steps

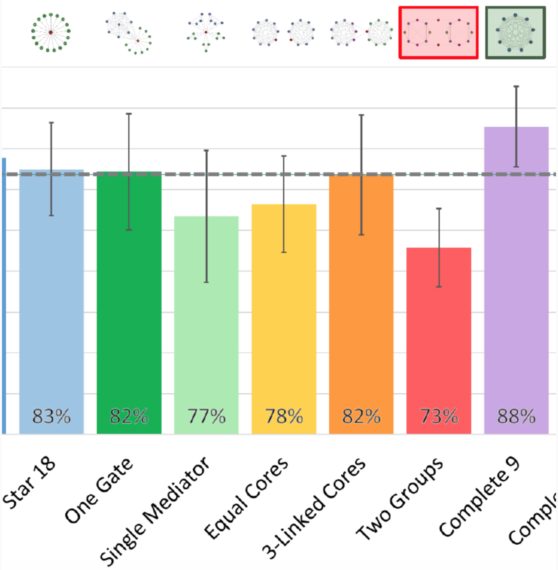
- Variation in network-level outcomes is related to structure features of networks
  - networks w/ well connected group aggregate info better and have lower chance of agree-to-disagree state
  - networks w/ Big Brother do not respond to info quality but instead to Big Brother's info
- Information aggregation does occur, but imperfectly
- Local information plays an important role
- Network position affects individual outcomes
  - hubs form their opinion faster than other members
  - nodes w/ higher degree are more likely to learn true state
  - nodes w/ higher eigenvalue are less likely to change their mind
- Observers' choices (perceived centrality)
  - heterogeneity, matches actual nodes' performance
- NEXT STEP: structural estimation of learning strategies

Additional Materials

Frequency of Correct Last Guesses



Consensus in the Last Round



How Often Majority is Correct?