An Experiment on Network Density and Sequential Learning

Krishna Dasaratha
Kevin He

July 15, 2020
Main Question

Q: do people learn better from their peers when there are more social connections?
Sequential Social Learning: people take turns guessing an unknown state, after observing a private signal and some predecessors’ guesses

This paper: an experiment comparing learning outcomes when people have many social observations (dense network) and few social observations (sparse network)

Results:

- Social learning is worse with more social observations
- Accuracy gain from social learning twice as large on sparse network vs. dense network
- Matches predictions of a naive learning model but not rational learning model
Basic setup

- Binary state of the world $\omega \in \{L, R\}$, equally likely
- Sequence of 40 agents indexed by $i = 1, 2, 3, \ldots$, move in turn

On agent $i$’s turn

- Observe private signal $s_i$
- Observe actions of some previous agents (next slide)
- Choose action $a_i \in \{L, R\}$ to match state
Setup

Gaussian private signals

- $s_i \sim \mathcal{N}(1, \sigma^2)$ when $\omega = 1$
- $s_i \sim \mathcal{N}(-1, \sigma^2)$ when $\omega = 0$
- Signals conditionally i.i.d. given $\omega$

Network observation

- Agent $i$ observes each predecessor with probability $q$
- Each network either sparse ($q = \frac{1}{4}$) or dense ($q = \frac{3}{4}$)
- Compare average guess accuracy on sparse and dense networks
Logistics

**Subjects**

- Experiment done on *Amazon Mechanical Turk*, 1040 subjects
- Must pass a three-question comprehension check
- Each plays 10 games with same density in same position
- Subjects know network-generating process
- $0.25 per correct guess, plus $0.25 completion fee. Average: $2.08 for less than 10 min
Logistics

Signals and accuracy

- Private signal $\sim \mathcal{N}(-1, 4)$ in state $L$, and $\sim \mathcal{N}(1, 4)$ in state $R$
- Can have accuracy 69% from using private signal alone
- $\tilde{y}_j$ — fraction of last 8 agents who guess correctly in game $j$

Dataset: 260 games, half with each density. Regress across games

$$\tilde{y}_j = \beta_0 + \beta_1 q_j + \epsilon_j$$

The experiment — including sample size, measure of long run accuracy, and statistical analysis — was pre-registered prior to data collection on the AsPredicted registry.
Results

Accuracy gain from social learning:

- In dense networks, last 8 agents guess correctly 5.7% more often than if they had no social observations.
- This accuracy gain is 12.6% in sparse networks, more than twice as large ($p$-value 0.0239).
- This comparative static is consistent with our naive-learning model (in 3 slides) but not with the rational-learning model.
## Results

**Dependent variable:**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetworkDensity</td>
<td>-0.092**</td>
<td>0.041</td>
<td><strong>p &lt; 0.05</strong></td>
</tr>
<tr>
<td>Constant</td>
<td>0.802***</td>
<td>0.022</td>
<td><strong>p &lt; 0.01</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary Statistics</th>
<th>Value</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Residual Std. Error</td>
<td>0.164 (df = 258)</td>
<td></td>
</tr>
<tr>
<td>F Statistic</td>
<td>5.166** (df = 1; 258)</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* *p < 0.1; **p < 0.05; ***p < 0.01
Results

Source of this difference in accuracy:

- Agent *goes against signal* if guess L with a positive signal or guess R with a negative signal
- Among agents in the last 8 positions, 138 instances of this in sparse networks, 136 instances in dense networks
- Accuracy conditional on going against signal:
  - 82% in sparse networks
  - 71% in dense networks
- So difference in accuracy driven by *differential effectiveness* of social learning on networks of different densities
Proposed Mechanism: Inferential Naiveté

Inferential naiveté

- Agents wrongly believe predecessors’ actions only reflect their private info, not their observations of still others (Eyster and Rabin, 2010)
- $i$ observes $(a_j)_{j \in N_i}$ and thinks $a_j = \mathbb{P}[\omega = 1 | s_j]$ for each $j \in N_i$
- Agents are Bayesians except for this mistake
Overcounting

- Under inferential naiveté, early agents’ private signals are overcounted
- This overcounting is more severe on denser networks
- So later agents’ guesses will be less accurate in denser networks (shown theoretically in Dasaratha and He, 2020)
Predictions under Inferential Naiveté

Learning on Erdos–Rényi Networks with Naive Agents

Probability of correct action

Agent

q = 0.25
q = 0.75
Predictions for Rational Agents

Rational Agents

- Results of Acemoglu, Dahleh, Lobel, and Ozdaglar (2011) imply asymptotic learning of state regardless of $q$
- Is 40 agents enough for this limit?
- Using technique similar to Lobel and Sadler (2015)’s neighborhood choice function, can compute explicit lower bound on the accuracy of rational agents
- This lower bound is 97% for 33rd agent on dense network — so sparse network cannot improve accuracy much, if at all
Conclusion

- Conducted an experiment testing how network density affects social learning outcomes
- Found social learning is more effective on sparser networks
- Provides evidence for a naive model of updating

Thank you!