Social Learning and Cumulative Mutual Improvement in a Networked Group

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2010 International Conference on Social Computing, Behavioral Modeling, and Prediction
How do you learn about…

Shoes, books, restaurants, movies, cars, new cities to move to, job candidates, or political candidates?

In general, it's difficult to think of many tasks we engage in that do not depend in some way on knowledge from others.
Social Learning

In general, social learning can be defined as "the acquisition of behavior by observation or teaching from other conspecifics" (Boyd & Richerson, 2005)

Humans’ direct and flexible imitation: "no-trial learning" (Bandura, 1965)
Social Learning Strategies
(Laland, 2004)

*When* to copy

- Often uses the relative *cost* or *risk* of asocial learning as criteria (*copy when uncertain*)
- When cost or risk are high, imitation can yield a cheaper or more reliable solution.
Social Learning Strategies 
(Laland, 2004)

*Who* to copy

- This decision often relies on the **performance** of candidate solutions.
  - absolute (*copy* the **best**)
  - relative (*copy* if **better**)

- These require **relative evaluations** of others' solutions and one's own – but this info is **not always available**.
Social Learning Strategies (Laland, 2004)

*Who* to copy (cont’d.)

- Relative **popularity** of solutions is often easier to estimate than quality (e.g. *copy the majority*)
- There is also **similarity** bias (*copy if similar*) – e.g. "backwards compatibility" (Rogers, 2003)
Social Learning as a Social Dilemma

Conflict between **Self-interest of imitators**

- **Avoid learning costs**, get cheap solutions

and **Common interest of group**

- **Explore broadly**, find better solutions

Assumption:

- *Imitation only benefits imitators.*

→ **Self-interested behavior (Imitation) will be rare** in high-performing groups.
Group Consequences of Social Learning

• In a simple, temporally unstable environment, adding random social learners to a population of asocial learners does not improve the overall fitness of the population.

• Learning costs saved by imitators are offset by costs resulting from the use of outdated and inaccurate information.

(Rogers, 1988)
Group Consequences of Social Learning

However, if social learners can imitate selectively (i.e. imitating when individual learning is more uncertain) the fitness of the population can increase, because both social and individual learning can become more accurate.

(Boyd & Richerson, 1995; Kameda & Nakanishi, 2003)
More Realistic Tasks?

What kind of results should we expect?

• Complex multi-dimensional problem
  (e.g. car design, cooking, cancer treatment)

• Intrinsic motivations
  (e.g. novelty-seeking, risk-aversion)

& capabilities
  (e.g. partial imitation)
Experimental Questions

1. Is imitation only good for imitators, or does it have broader group benefits?
2. How does making imitation more difficult affect indiv. strategies & performance?
3. How do these individual-level decisions interact to create group-level outcomes?
   → Tragedy of the information commons?
Task: Creature Tournament

• Sort of a fantasy sports league crossed with virtual pets, but much simpler.

• Object of the game: maximize score earned by one’s own subset ("team") chosen from a set ("league") of creature icons over a series of rounds.
  – Scores depend on point values associated with individual icons as well as interactions between icons.
Point Distribution

The League
Point Distribution

Each **icon** has a (hidden, randomly assigned) **point value**
Point Distribution

Certain pairs of icons will give bonuses or penalties if both are present on a team.
Task details

• 10 seconds per round, 24 rounds per game, 6 games per session

= 3 repetitions x 2 conditions
(Visible / Invisible peer scores)

• Display position and point values of icons are re-shuffled randomly after each game.

• No info is given about the point distribution or maximum score.
Experiment Details

• **234 participants** recruited from IU Psychology subject pool, distributed across group sizes from 1 to 9 persons.

• Instructions include a summary of the game mechanics and a hands-on demo.

• It was emphasized that the game was not intended to be cooperative or competitive -- one should simply maximize one’s own score over the course of all 24 rounds.
Simplifying Assumptions

- Fully-connected social network
- No-cost imitation
- Unambiguous performance information
- No complex social interactions
Dependent variables

For each player in each round:

- **Score**: total of linear & interaction terms
- **Choice**: icons on present “team”
  - **Source** of each icon:
    - Retain, Retrieve, Innovate, Imitate
      - (including unique ID of copied player)
Retain: unchanged from previous round
**Retrieve**: recovered from one’s best-scoring team so far
Innovate: chosen from the League display
Imitate:
copied from another player’s team
Imitate:
copied from another player’s team
Predictions: Strategy

**Imitation** will be biased toward:

- **High scores**, when visible.
- **Similar solutions** to the imitator's own solutions
- **Popular elements** among others' solutions
- The latter two strategies will be accentuated when scores are invisible.
Predictions

- **Visible-scores**: easy imitation, thus limited exploration.
  - **Lower** average group performance?

- **Invisible-scores**: no easy imitation, thus broader exploration.
  - **Higher** average group performance?
Result 1: Score & Exploration

- **Visible-scores**: limited exploration, but *better performance* (mean & max) through more efficient search of good (enough) regions of the problem space.

- **Invisible-scores**: broader exploration, but divergent, less efficient search led to *worse performance*!
Result 1: Score & Exploration
Results: Individual Performance

- Higher mean and max. scores
- Over 80% of players did better when scores are visible.
Results: Sharing the Load of Innovation

*Improvement*: a guess with a better score than those in all previous rounds within a game

*Improvement share*: an individual’s normalized proportion of all improvements achieved by their group

– “Fair share” == 1 (e.g. achieving 1/3 of all improvements in a 3-person group)
Result 2: (In)equality of Improvement Share

- **Invisible**
  - Unequal skew
  - Modal share: 0

- **Visible:**
  - Less skew
  - Peak near “fair share” of 1
Results: Strategy/Performance

We found some rather intuitive correlations for *individuals*:

- More *Imitation* $\rightarrow$ *higher* scores  
  *(Visible condition)*
- More *Innovation* $\rightarrow$ *lower* scores  
  *(both conditions)*
Result 3: Non-Conflicts of Interest

But, these were also true for group means e.g. high group imitation $\rightarrow$ better group scores

...as well as individuals’ scores with the behavior of others in their group!

e.g. the more others in your group innovate $\rightarrow$ the worse your score
Results: Strategy (when to copy)

Mean proportions of each choice source by condition and improvement:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Improvement?</th>
<th>Imitate</th>
<th>Innovate</th>
<th>Retain</th>
<th>Retrieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invisible</td>
<td>No</td>
<td>.100</td>
<td>.133</td>
<td>.712</td>
<td>.044</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>.039</td>
<td>.216</td>
<td>.705</td>
<td>.035</td>
</tr>
<tr>
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<td>No</td>
<td>.091</td>
<td>.114</td>
<td>.763</td>
<td>.022</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>.082</td>
<td>.194</td>
<td>.695</td>
<td>.021</td>
</tr>
</tbody>
</table>

[Signif. Diffs: **boldface:** within / *italics:* between]
Results: Strategy
( who to copy )

Copy the best?

- **Visible**: *yes*. 90% of imitations were of the 1\textsuperscript{st} or 2\textsuperscript{nd} highest-scoring guess.
- **Invisible**: *no*. Imitation was essentially random with respect to score, as expected.
Results: Strategy

(who to copy)

Copy similar solutions?

- **Visible**: yes. Imitation was slightly biased toward similar guesses
- **Invisible**: no. Imitation was slightly biased toward dissimilar guesses
  - Novelty bias / divergent search
  - Lower avg. Retention overall
Results: Strategy
(who to copy)

Copy popular solutions?

- **Visible:** *yes.* Participants imitated higher-frequency icons at a rate greater than expected by chance.
- **Invisible:** *no.* Participants imitated higher-frequency icons less often than chance.
  - Further evidence for divergent tendency
Results: Benefit of Imitation

Does imitation only help imitators to avoid learning costs?

→ If so, there is no benefit to being copied.

However, we found that a large majority of improvements that included Imitation involved players imitating a peer who had previously imitated them.
Result 4: Cumulative Mutual Improvement

i.e., copying directly benefited those who were copied!

→ Changes made by the imitator were often incorporated into later improvements by the originator.
Conclusion A: Benefits of Imitation

Imitation can make innovation cheaper & more efficient (and allow costs to be more equally shared).

- A twist on earlier research:
  Rather than increasing average success by just reducing the number of risky attempts, participants in this task also increased average success by reducing the risk itself, and improving the efficiency of search.
Conclusion B: Comedy of the Commons

A situation which (in theory) resembles a **social dilemma** can be solved **without explicit communication or coordination**.

The tendency to **learn from others** instead of only exploring for oneself has been shown to be **adaptive** in uncertain environments – “**Conformity bias**”

(Boyd & Richerson, 1985)
Overall Conclusions

**Imitation** is not necessarily idle scrounging.

Even in this simplified domain, effective **innovation** in groups is a deeply dynamic, interactive process, not merely the sum of individuals’ efforts.
Future Directions

A certain resemblance has been noted between these results and case studies of open-source software projects, in that the monetary rewards of all participants is the same (zero).

What happens when participants are paid according to their performance?
Future Directions

Both high- and low-achievers got about the same relative rewards in the Visible condition – relative rewards were only greater for high achievers in the Invisible condition.

When competitive / relative rewards are more salient, the above outcome may not be satisfactory for high achievers, and thus varying incentives may be required.
“Where’s the model?”
(or, “How did you get in here?”)

None yet: relatively little guiding theory or data so far around group exploration in realistically complex domains.

(Please tell me if I’m wrong!)

But now that we have results, a model can:

• **Establish performance baselines** for simple / random strategies

• **Help explain differences** in performance across group size and other results
Future Directions

A new experiment (in progress) uses cash payment according to performance to explore the effect of monetary rewards, and a simple intellectual property system to explore the effects of varying incentives.
Thanks!

Xianfeng Song
Drew Hendrickson
Bennis Pavisian

Zoran Rilak
Michael Roberts
Frances Kidwell

The Percepts & Concepts Lab
NSF IGERT traineeship program
Questions?