Simple Models of Social Learning

Dan Hruschka
Santa Fe Institute
dhrusch@santafe.edu

Recap from Lecture 1

- Human communities show a great deal of variation in social organization, behaviors, and knowledge
- Several theories attempt to explain why such variation exists
  - Biological differences
  - Rational behavior in context
  - Darwinian processes
  - Neutral theory

Social Learning

- Social learning plays a key role in the last two theories, which depend on the transmission of ideas and behaviors
- *Backtracking:* I'm going to focus on social learning--that is reproduction of behaviors and ideas from "mind to mind" or "body to body"

Questions

- When does it make sense to learn from others?
- When are variants under selection? And how can we detect this?
- How do different learning rules affect the distribution of behaviors and ideas in a population?
- How do people choose individuals to learn from?
- What can explain the human capacity for cumulative social learning?

Tools

- *Population genetics models*—people are people, genes are ideas or behaviors
- *Modeling comparison*—Predicting distributions of cultural variants under different kinds of imitation
- *Experiments*—how do people choose when to learn socially? And from whom?

Overview of Lecture 2

- Introducing Social Learning
- Simple models to assess claims about social learning
- Comparing the fit of learning models to distributions of cultural variants
- Experiments in social learning

Part 1: Introduction to Social Learning

- *Definition:* Change in ideas or behaviors as a result of monitoring other's behaviors
- This often involves an imitation of others' behaviors, but can also involve strategic deviation.
  - If you see someone die after eating a strange mushroom, you choose not to eat such mushrooms
- Contrast with individual trial-and-error learning

Context biases in social learning

Problem: You enter a room and must decide whether to sit down or stay standing

- *Just do something*
- *Random learning*: pick someone at random and imitate her
- *Conformist learning*: choose the majority behavior
- *Contrarian learning:* choose the minority behavior
- *Success-biased learning*: choose a successful individual and imitate
- *Similarity-biased learning:* choose someone like you and imitate

Social learning in non-human animals

- Choosing prey in novel contexts
- Choosing mates
- Flee-response
- *For a good review:* Danchin et al. (2004). From Nosy Neighbors to Cultural Evolution. Science

Part 2: Using simple models to assess claims about social learning

- By 20,000 years ago humans occupied a much wider geographical and ecological range than any other vertebrate species
- Dramatic range of subsistence systems and social arrangements
- Social learning commonly cited as reason for this success in expansion

Proposed explanation

- Individual trial-and-error learning is costly, and social learning permits one to avoid this cost (Boyd and Richerson 1985)
- Sometimes no explanation is given

Assessing the premises of this claim

- One simple model:
  - Varying environment
  - Fitness consequences of behavior depend on environment
  - Individual learning is costly
  - Social learning costs less, but if the environment changes the information may be wrong

“Snerdwumps” Model

- “Snerdwumps” live in variable environment (w/ 2 states)
- Each environmental state has an optimal behavior with associated fitness increase of *b*
- Fitness increase for other behaviors is 0
- The probability that environments change is *u*
- After environment changes, no existing behaviors are optimal

McElreath and Boyd (2006), based on Rogers (1988)

There are two kinds of learners

- Two genotypes with the following behavioral phenotypes:
  - *Individual learners:* discover locally optimal behavior but pay cost=*c*
  - *Social learners:* imitate a randomly chosen individual from previous generation

Fitness

- Individual Learner: $W(I) = w + b - c$
- Social Learner: $W(S) = w + b(1-u)((1-p) + pq)$

q = freq. of optimal behavior among social learners in prior generation
p = freq. of social learners
u = probability of environmental change

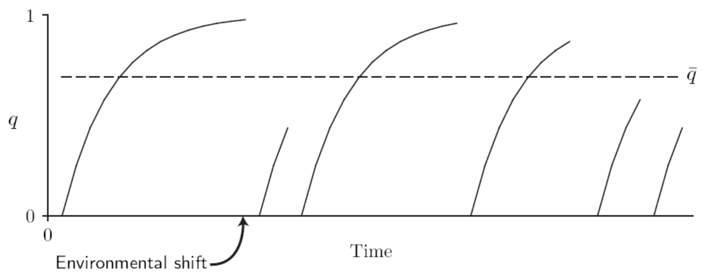
Recursion for q

$$q' = (1-u)((1-p) + pq) + u0$$

Substituting q’ into earlier equation for fitness of social learners, we get:

$$W(S) = w + bq'$$

Changes in q over time



Over the long-term we have a *stationary distribution* of *q* with expected value = *q bar*

A moving target

- Natural selection acts on frequency of social learners
- Learning processes govern the frequency of adaptive behavior
- And each of these frequencies depends on the other
- We get out of this by assuming that genetic evolution occurs much more slowly than social learning dynamics

Assuming gene frequencies are constant

- We find the expected value of the steady state distribution of q

$$\bar{q} = (1-u)E[(1-p+pq]$$
$$= (1-u)(1-p+p\bar{q}) = \frac{(1-p)(1-u)}{1-p(1-u)}$$

Now we can calculate the fitness of social learners in terms of p

$$\hat{W}(S) = w + b\bar{q}$$
$$= w + b\frac{(1-p)(1-u)}{1-p(1-u)}$$

When can social learners invade?

$$\hat{W}(S) > W(I)$$

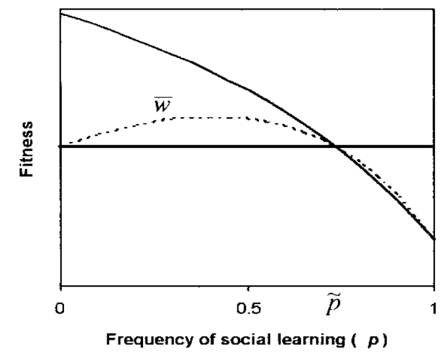
$$b\frac{(1-p)(1-u)}{1-p(1-u)} > b-c$$

$$b(1-u) > b-c$$

$$\frac{c}{b} > u$$

When the c of individual learning divided by the benefit of the optimal behavior is greater than the probability of environmental change

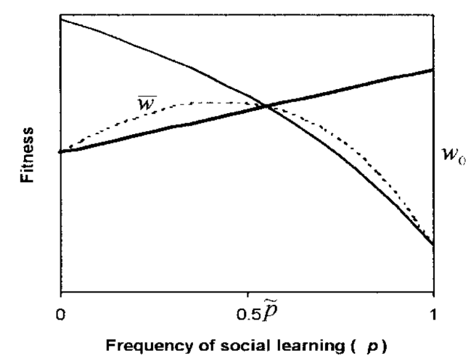
But does social learning convey an fitness advantage in the long-run?



Conclusions from this Simple Model

- Under certain conditions, it pays individuals to imitate
- Thus, imitation will increase in a population
- BUT, this may not improve the average fitness of social learners
- Thus we may need more to understand how social learning played a role in the expansion of humans

But if more social learners makes individual learning less costly….



Changing the Game

- Increase in proportion of social learners increases accuracy of individual learning
- Increase in proportion of social learners decreases the cost of individual learning (Boyd and Richerson 2005)
- Social learners “pay” prestigious individual learners (deference, gifts, labor) for knowledge (Henrich and Gil-White, 2001).

Broader Lessons

- Explicitly modeling a proposition can lead to count-intuitive implications
- It can also point to assumptions necessary for original expectations to hold

Further Reading

- Aoki et al. (2005). The emergence of social learning in a temporally changing environment: a theoretical model. Current Anthropology; 46, 2

Part 3. Neutral Model

- N individuals
- Each has a behavioral or cultural variant
- At each time step each person randomly copies from someone from previous time step
- With probability, μ, a variant changes to a novel variant

Kimura and Crow 1965, Crow and Kimura 1970

Implications under the Neutral Model

- The equilibrium frequency distribution of variants at one point in time is:

$$P(v) = 2N\mu^{-1}(1-v)^{2N\mu-1}$$

Where P(v) is the proportion of variants with frequency v.

Using with cultural data

- Cultural and archeological data is rarely available from one point in time
- Bentley, Hahn and Shennan (2004) use simulations to estimate distribution for data accumulated over time.
- They compare with distributions of:
  - First names
  - Pottery motifs
  - Patent Citations

First Names

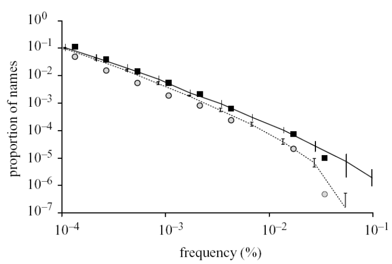
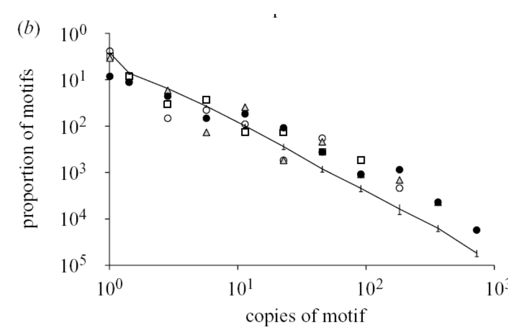
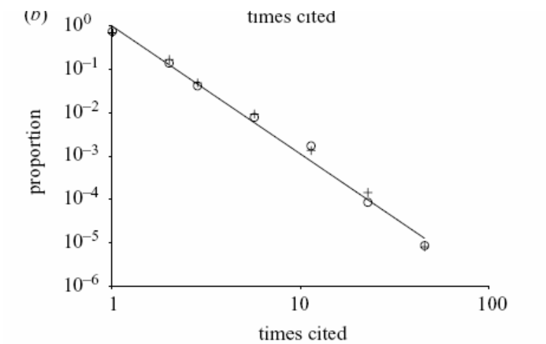


Figure 4. Frequency distribution of first names, from 1990 US Census data. The popularity of a name is measured as a fraction of the US population. The exponent α for male names (squares) is 1.73 ($r^2 = 0.990$) and for female names (circles) is 1.93 ($r^2 = 0.968$). Dotted line, $N\mu = 16$ model (100 time steps); solid line, $N\mu = 8$ model (100 time steps).

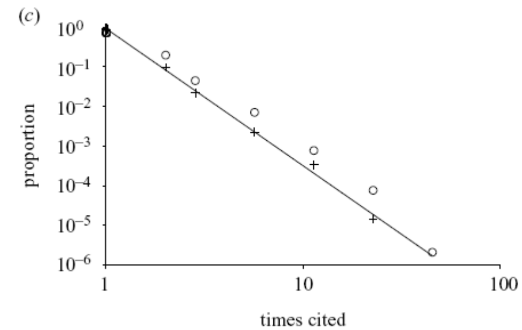
Pottery Motifs from Merzbach, Germany



Patent Citations for ‘CD’ patents



Patent Citations for ‘automobile



Other models

- Bentley and Shennan (2003, Am. Antiquity) describe the frequency distributions expected for other models:
  - Independent decisions
  - Conformist transmission

Conclusion

- Probably not all cultural phenomenon fit the neutral model, but it is a good null model to test against

Further readings on testing theories of social learning against observational data

- Peyton Young: Spread of Innovations by Social Learning
- Simkin & Roychowdhury (2005): Stochastic modeling of citation slips. Scientometrics.
- Roychowdhury & Simkin (200): Nature.
- Neiman (1995). American Antiquity. 60, 7

Part 4. Experimental Studies

- Intended to identify the context and content effects on social learning
- Salganik et al. (2006). Science.
- Efferson et al. (2007). Evolution and Human Behavior.
- Baum et al. (2004). Evolution and Human Behavior.

Testing theories about differential success of stories

- Heath et al. (2001). The differential success of urban legends is influenced by both their judged plausibility and their emotional evocativeness (principally disgustingness)
- Norenzayan et al. (2006). Comparison of successful and unsuccessful Grimm's fairy tales, widely known fairy tales had 2 or 3 counterintuitive violations

Heath et al. (2001). Journal of Personality and Social Psychology.

The Value of Good Case Studies

- The Extinction of Ants in Madeira

Modeling challenges

- Data quantity and quality
- Closer link between known processes of change and mathematical models
- We have thus ignored innovations
  - are their general principles that guide cultural innovation?
  - What are the conditions under which cultural innovation arises?

41

Overview

- Social Learning
- Neutral models of imitation processes
- Experiments in social learning

42

Next Steps

- Lecture 3—Cultural evolution at the group level

43