Evolution of Prosociality via Preferential Detachment

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What is Evolution?

- A process by which variation in individuals' features determines the prevelance of the associated features through reproduction and elimination of individuals.

- Fitness is the relative degree to which a feature, or a set of features, changes the prevalence of individuals exhibiting the feature(s).

What is Prosociality?

- A system of behaviors (and indirectly: attitudes, beliefs, norms, interactions, institutions, etc.) is prosocial if maintaining that system confers greater fitness to the individuals maintaining it than alternative systems.
- Purported examples include altruism, reciprocity, trust, honesty, promise-keeping, cooperation, coordination, contribution, parental care, fairness, punishment, justice, …
- To be prosocial a system must be sustainable through changing environments, endogenous shifts, invasive behaviors, group competition, etc. Depends on scope.

What is Preferential Detachment?

- The behaviors of agents classify them into types.
- They interact with a limited number of agents every period.
- The benefit from interactions depends only on the type of the focal agent and the types of its interaction partners.
- Individuals stop interacting with a partner if and only if it yields less benefit than another current partner.
- Individuals with fewer than the maximum capacity of interaction partners randomly pick another partner.

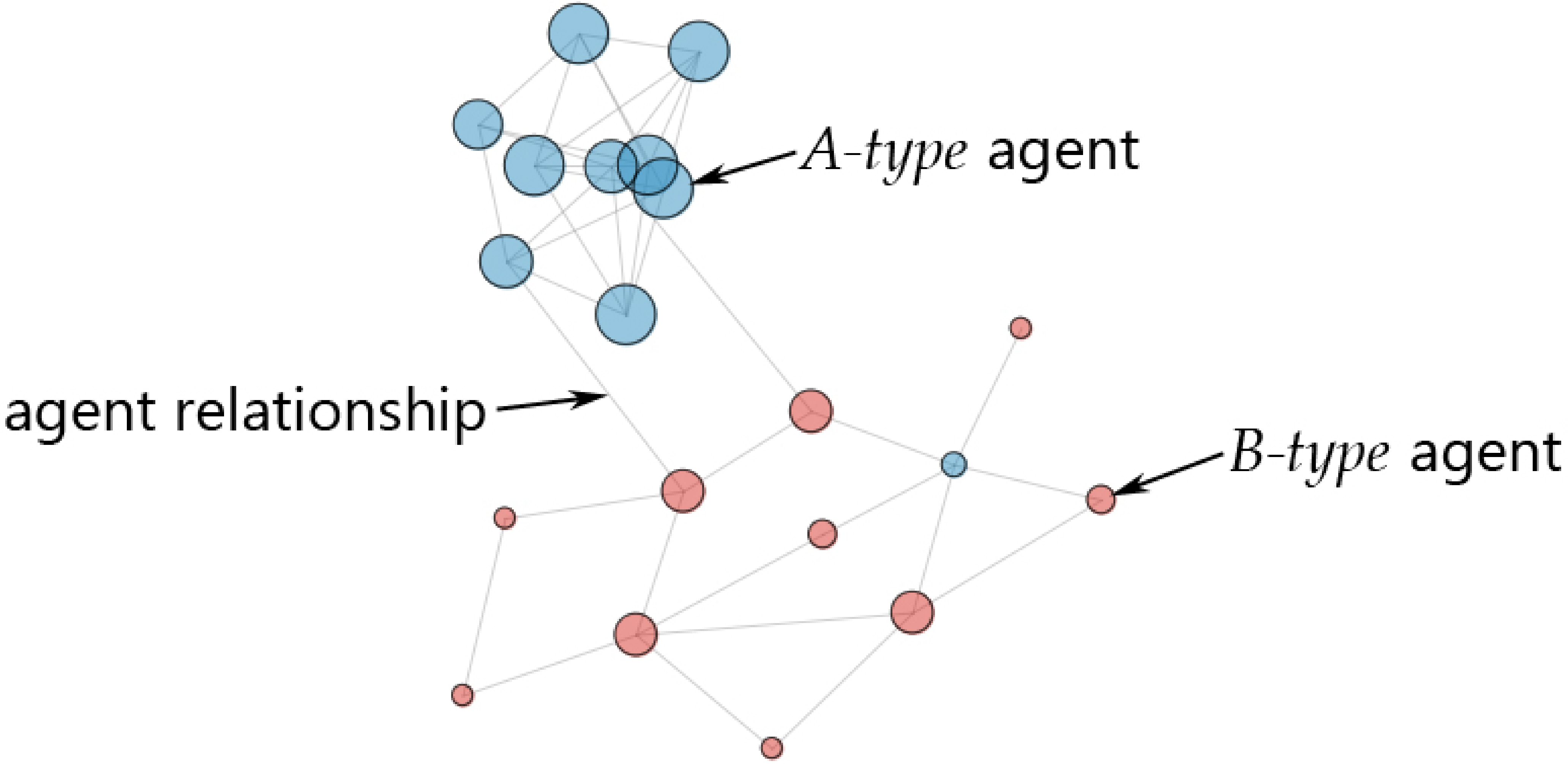
What is the Theory?

- Individuals utilizing preferential detachment sort themselves into social arrangements such that the agents who benefit the members of their group more than others also do better for themselves in the long run.
- Furthermore, the groups consisting of agents whose behavior benefits (is preferred by) the other members of the group also perform collectively better.
- Even furthermore, agents can do this with minimal information about their environment, the other agents, the future, and with minimal cognitive/computational ability.

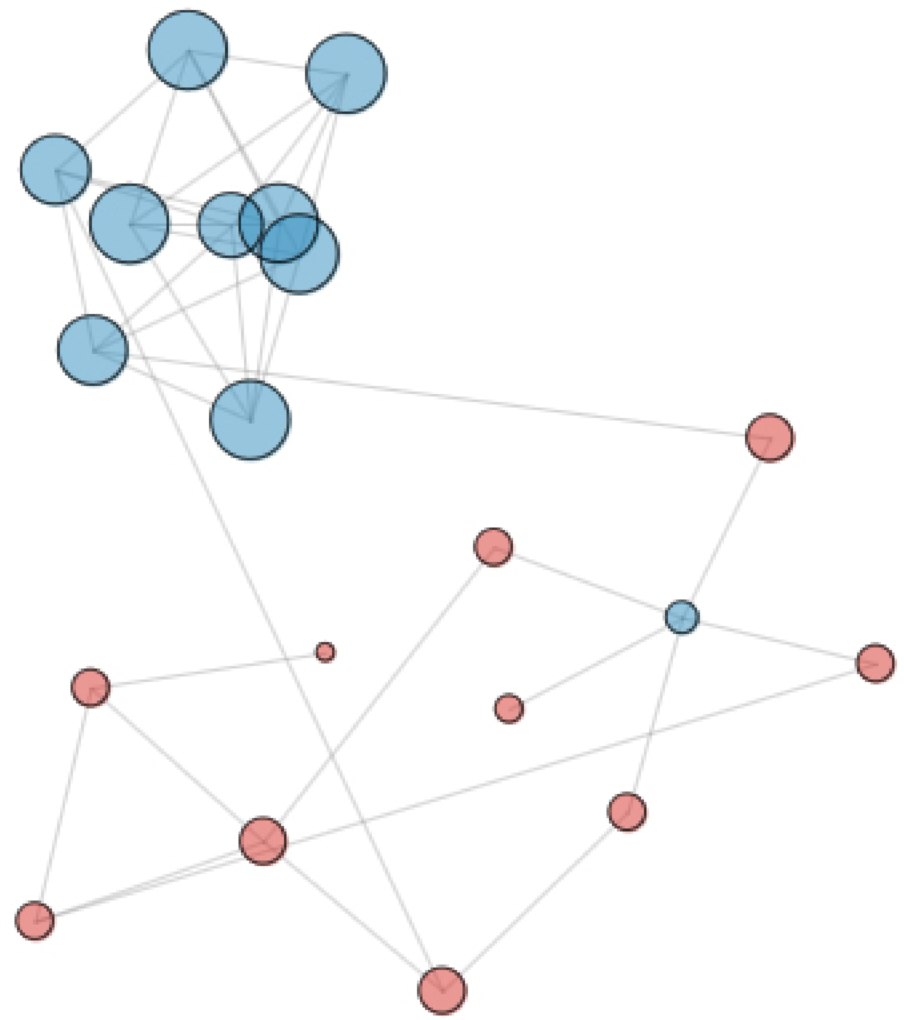
Assumptions: Agents

- There are agents that can be sorted exhaustively into types that capture all features upon which agent behavior may be contingent.
- Agents interact with other agents over time in a way that is symmetric, that they can unilaterally form and break, and that transmits information about partner types.
- It will be convenient for us to represent the relationship structure as a network, but it could be geographic location, transaction patterns, discussant interactions, etc.

Assumptions: Agents



Assumptions: Agents



Assumptions: Behavior

- Agents' behavior is contingent upon:
  [C1] their own type,
  [C2] the number of their current interaction partners, and
  [C3] the types of their current interaction partners.

- Depending on the values of C1, C2, and C3 agents will:
  [B1] End the relationship/interaction with certain partners.
  [B2] Connect to new partners.
  [B3] Do nothing.

- Applying the theory consists in determining/deciding the appropriate map from C1-3 to B1-3 for each situation.

Assumptions: Complete

- The assumptions for the base preferential detachment theory can be summarized in the following list:
  - [A1] There exist agents partitioned into types.
  - [A2] Agent can assess C1-3 every period.
  - [A3] Agents perform an action among B1-3 depending on C1-3 every period.
  - [A4] There are multiple periods in succession.

- Types categorize agents by their contingent behavior -- how those agents behave vis-a-vis other agents. Thus each agent of the same type has the same mapping of C1-3 to B1-3 and treats other agents of identical type identically.

Population Size

- Based on the neocortical size of human brains compared to other primates, the largest group that an anatomically modern human should be able to maintain is between 100 and 230 (Dunbar 1993, 1998). Actual population sizes for hunter-gatherer groups, neolithic villages, and Hutterite settlements agree with these figures.

- I use a population of N = 200 agents in the Markov model examples, and provide analysis for any value of N.
  I sweep N = 20 to 2000 in the agent-based models.

Direct Social Connections

- The number of people in a person's "core" social network is typically 5 or 6 with as many 12 to 16 people who qualify as "close friends" (Dunbar 1998).
- Each agent has the same maximum degree, K, an upper limit on the number of interaction partners it can maintain (there is no minimum number of connections).
- The Markov model examples are calculated with $K = 4$, and I analyze the effects of increasing K to infinity.
- The ABM sweeps $K = 3$ to 20.

Strategic Contexts

- The dependency of the outcome on the collective actions is what makes a situation strategic rather than just a decision.
- When using heuristics, agents do not "game" the situation to achieve maximum individual benefit, even though the agents receive utility according to the collective outcome achieved in the situation.
- Because behavior is based on a rule that does not explicitly consider the expected actions of the other agents, the theory is no longer game theoretic, though it continues to share many features with game theory.

Strategic Contexts

- Because the rewards for each agent depend on all involved agents, the context in which the agents behave is still strategic; even though the agents are not strategic in their action.

- The rewards received by each agent for each potential set of collective behaviors is what I refer to as the strategic context.

- Hence strategic contexts contain all the same information as game payoff matrices; and types correspond to game actions.

Strategic Contexts

- First, consider 2x2 games: strategic contexts with two types.

		Player2	
		A	*B*
Player1	*A*	*a,w*	*b,x*
	B	*c,y*	*d,z*

- There are 726 possible 2x2 games of this form (Kilgour 1986).

Strategic Contexts

- Since agents here are fixed in their type, they are only comparing the order of two figures. What this means is that every payoff matrix corresponds to one of these nine patterns:

Pattern1	$A : A \prec B$	$B : A \prec B$
Pattern2	$A : A \prec B$	$B : B \prec A$
Pattern3	$A : A \prec B$	$B : A \approx B$
Pattern4	$A : B \prec A$	$B : B \prec A$
Pattern5	$A : B \prec A$	$B : A \prec B$
Pattern6	$A : B \prec A$	$B : B \approx A$
Pattern7	$A : A \approx B$	$B : B \prec A$
Pattern8	$A : A \approx B$	$B : A \prec B$
Pattern9	$A : A \approx B$	$B : A \approx B$

Strategic Contexts

- Any game created by switching both the rows and columns of a symmetric game is isomorphic to the original game. Thus Pattern1 and Pattern4 are isomorphic.
- Appreciating such isomorphisms further condenses the nine patterns into the six forms presented in this table:

Form	Patterns		Relationship		Category
Form1	Pattern1	Pattern4	$A : B \prec A$	$B : B \prec A$	Cooperative
Form2	Pattern2		$A : B \prec A$	$B : A \prec B$	Coordinative
Form3	Pattern5		$A : A \prec B$	$B : B \prec A$	Specialized
Form4	Pattern6	Pattern8	$A : B \prec A$	$B : A \approx B$	Contributive
Form5	Pattern3	Pattern7	$A : A \prec B$	$B : A \approx B$	Commensal
Form6	Pattern9		$A : A \approx B$	$B : A \approx B$	Undifferentiated

Game Library

Prisoners' Dilemma

player2

player1	A	B
A	3,3	1,4
B	4,1	2,2

Hawk and Dove

player2

player1	A	B
A	3,3	2,4
B	4,2	1,1

Stag Hunt

player2

player1	A	B
A	4,4	1,2
B	2,1	2,2

Battle of the Sexes

player2

player1	A	B
A	4,3	2,1
B	1,2	3,4

Coordination Game

player2

player1	A	B
A	4,4	2,2
B	2,2	4,4

Matching Pennies

player2

player1	A	B
A	3,1	1,3
B	1,3	3,1

Lichen

player2

player1	A	B
A	1,1	3,3
B	3,3	1,1

Commensal

player2

player1	A	B
A	1,1	4,2
B	2,4	2,2

Prosocial Outcomes

- The categories also identify what the prosocial outcome is for all games in it:
- In the Cooperative games the agents have to sacrifice utility (defy temptation) in order to achieve the prosocial outcome.
- In Coordinative games the agents must agree on an outcome, and though both alternatives are acceptable they may not be equally valuable.
- Specialized games require that distinct types connect.

Prosocial Outcomes

- Contributive games require agents to risk a guaranteed modest payoff to contribute to a project that would yield better payoffs.
- In a Commensal game agents attempt to exploit safe players at the risk of meeting another unproductive exploiter.
- Agents always do the best they can in Undifferentiated games.
- Prosociality is the unifying concept, but each form of strategic context presents a distinct social problem and the criterion for prosociality changes.

Prosocial Outcomes

- We can also see a pattern in the social arrangements required:
- Cooperative, Coordinative, and Contributive games all reach the prosocial outcome when agents are mixed assortatively.
- Specialized and parasitic games are solved for the social optimum when agents mix disassortatively.
- Undifferentiated games always achieve the same outcome.

Markov Model of Preferential Detachment

- The first approach to formally representing the preferential detachment mechanism is with a time-homogeneous Markov model.
- This approach assumes that the agent characteristics at time t+1 can be determined using information contained in the agent characteristics at time t.
- Rather than modeling each agent explicitly, I collect the agents into bins by configuration.

Agent Configurations

- The configuration includes the agent's type and how many of each type of neighbor it has.
- The configuration thus captures all the information that agent behavior is contingent upon (C1-3 of assumptions).
- The schema used here if there are two types of agents (A and B) is that an A-type agent connected to one A-type agent and two B-type agents as $A12$. A B-type agent with the same link neighbors would be written $B12$.

Agent Configurations

- K is the maximum degree; k is the agent actual degree. The number of possible configurations for each focal type equals the number of possible combinations of T types of neighbors satisfying

$$\sum_{i=1}^{T} k_i \leq K$$

- For any K>0 and T>0 we can calculate the number of configurations by

$$\mathbb{C} = \sum_{i=0}^{K} \binom{T-1+i}{T-1} = \binom{T+K}{T} = \frac{(T+K)!}{T!(K!)}$$

Agent Configurations

- Starting with K=4 and T=2, there are 15 configurations:

$\theta 00, \theta 01, \theta 02, \theta 03, \theta 04, \theta 10, \theta 11, \theta 12, \theta 13, \theta 20, \theta 21, \theta 22, \theta 30, \theta 31, \theta 40$

- Because there are only three possible preference relations, we can list all three possible preferences over all configurations:

$\phi_1 : B \prec A :$	$\theta 00 \prec \theta 01 \prec \theta 02 \prec \theta 03 \prec \theta 04 \prec \theta 13 \prec \theta 12 \prec \theta 11 \prec \theta 10 \prec \theta 22 \prec \theta 21 \prec \theta 20 \prec \theta 31 \prec \theta 30 \prec \theta 40$
$\phi_2 : A \prec B :$	$\theta 00 \prec \theta 10 \prec \theta 20 \prec \theta 30 \prec \theta 40 \prec \theta 31 \prec \theta 21 \prec \theta 11 \prec \theta 01 \prec \theta 22 \prec \theta 12 \prec \theta 02 \prec \theta 13 \prec \theta 03 \prec \theta 04$
$\phi_3 : B \approx A :$	$\theta 00 \prec \theta 10 \approx \theta 01 \prec \theta 20 \approx \theta 11 \approx \theta 02 \prec \theta 30 \approx \theta 21 \approx \theta 12 \approx \theta 03 \prec \theta 40 \approx \theta 31 \approx \theta 22 \approx \theta 13 \approx \theta 04$

- That indicates which behavior happens given an opportunity set. It fails to specify what the opportunity set from each configuration is. It also fails to include what other agents are likely to do to it.

Transition Matrices

- I have separated the transitions into three independent behaviors:
  1) attachment and detachment in matrix **X,**
  2) being randomly connected to in matrix **R**, and
  3) being detached from in matrix **Y**.

- All together the resulting transition probabilities include both the action taken by the agents in each configuration and the actions taken by other agents with respect to them.

- Those behaviors are not actually independent, but the approximation facilitates representation as a Markov model.

Transition Matrices: Random Connection

- The probability for a focal agent that other agents will randomly connect to it is like a Bernoulli trial:

$$\rho(a,b) = \binom{\eta_A}{a}\left(\frac{1}{N-1}\right)^{a}\left(1-\frac{1}{N-1}\right)^{\eta_A-a}\cdot\binom{\eta_B}{b}\left(\frac{1}{N-1}\right)^{b}\left(1-\frac{1}{N-1}\right)^{\eta_B-b}$$

- The probilities fall in a particular pattern.

	$\theta 00$	$\theta 01$	$\theta 02$	$\theta 03$	$\theta 04$	$\theta 10$	$\theta 11$	$\theta 12$	$\theta 13$	$\theta 20$	$\theta 21$	$\theta 22$	$\theta 30$	$\theta 31$	$\theta 40$
$\theta 00$	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	$\rho(0,3)$	$\rho(0,4)$	$\rho(1,0)$	$\rho(1,1)$	$\rho(1,2)$	$\rho(1,3)$	$\rho(2,0)$	$\rho(2,1)$	$\rho(2,2)$	$\rho(3,0)$	$\rho(3,1)$	$\rho(4,0)$
$\theta 01$	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	$\rho(0,3)$	0	$\rho(1,0)$	$\rho(1,1)$	$\rho(1,2)$	0	$\rho(2,0)$	$\rho(2,1)$	0	$\rho(3,0)$	0
$\theta 02$	0	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	0	0	$\rho(1,0)$	$\rho(1,1)$	0	0	$\rho(2,0)$	0	0	0
$\theta 03$	0	0	0	$\rho(0,0)$	$\rho(0,1)$	0	0	0	$\rho(1,0)$	0	0	0	0	0	0
$\theta 04$	0	0	0	0	$\rho(0,0)$	0	0	0	0	0	0	0	0	0	0
$\theta 10$	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	$\rho(0,3)$	$\rho(1,0)$	$\rho(1,1)$	$\rho(1,2)$	$\rho(2,0)$	$\rho(2,1)$	$\rho(3,0)$
$\theta 11$	0	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	0	$\rho(1,0)$	$\rho(1,1)$	0	$\rho(2,0)$	0
$\theta 12$	0	0	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	0	0	$\rho(1,0)$	0	0	0
$\theta 13$	0	0	0	0	0	0	0	0	$\rho(0,0)$	0	0	0	0	0	0
$\theta 20$	0	0	0	0	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(0,2)$	$\rho(1,0)$	$\rho(1,1)$	$\rho(2,0)$
$\theta 21$	0	0	0	0	0	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	0	$\rho(1,0)$	0
$\theta 22$	0	0	0	0	0	0	0	0	0	0	0	$\rho(0,0)$	0	0	0
$\theta 30$	0	0	0	0	0	0	0	0	0	0	0	0	$\rho(0,0)$	$\rho(0,1)$	$\rho(1,0)$
$\theta 31$	0	0	0	0	0	0	0	0	0	0	0	0	0	$\rho(0,0)$	0
$\theta 40$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$\rho(0,0)$

Transition Matrices: Random Connection

- Because more than K-k agents may attempt to connect, these probabilities do not sum to 1. To account for this, the leftover probability mass is added to the $a+b=K$ cases.
- The random connection probabilities do not depend on the strategic context.

Transition Matrices: Detachment by Others

- Recall that preferential detachment theory states that when an agent has interaction partners of differing types, and one type is less preferred, a least preferred agent will be detached.

- In this Markov model we do not have access to who else an agent's neighbors are connected to (i.e., a focal agent's neighbors' neighbors), so a uniform approximation is used.

- Though there are six forms, there are only four different **Y**:
  1) both types detach the focal types,
  2) only same-type agents detach,
  3) only other-type agents detach,
  4) or neither type of agent detaches.

Transition Matrices: Detachment by Others

- Example matrix when A-types detach:

	$\theta 00$	$\theta 01$	$\theta 02$	$\theta 03$	$\theta 04$	$\theta 10$	$\theta 11$	$\theta 12$	$\theta 13$	$\theta 20$	$\theta 21$	$\theta 22$	$\theta 30$	$\theta 31$	$\theta 40$
$\theta 00$	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 01$	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 02$	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 03$	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0
$\theta 04$	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0
$\theta 10$	$\frac{3}{5}$	0	0	0	0	$\frac{2}{5}$	0	0	0	0	0	0	0	0	0
$\theta 11$	0	$\frac{3}{5}$	0	0	0	0	$\frac{2}{5}$	0	0	0	0	0	0	0	0
$\theta 12$	0	0	$\frac{3}{5}$	0	0	0	0	$\frac{2}{5}$	0	0	0	0	0	0	0
$\theta 13$	0	0	0	$\frac{3}{5}$	0	0	0	0	$\frac{2}{5}$	0	0	0	0	0	0
$\theta 20$	$\frac{9}{25}$	0	0	0	0	$\frac{12}{25}$	0	0	0	$\frac{4}{25}$	0	0	0	0	0
$\theta 21$	0	$\frac{9}{25}$	0	0	0	0	$\frac{12}{25}$	0	0	0	$\frac{4}{25}$	0	0	0	0
$\theta 22$	0	0	$\frac{9}{25}$	0	0	0	0	$\frac{12}{25}$	0	0	0	$\frac{4}{25}$	0	0	0
$\theta 30$	$\frac{27}{125}$	0	0	0	0	$\frac{54}{125}$	0	0	0	$\frac{36}{125}$	0	0	$\frac{8}{125}$	0	0
$\theta 31$	0	$\frac{27}{125}$	0	0	0	0	$\frac{54}{125}$	0	0	0	$\frac{36}{125}$	0	0	$\frac{8}{125}$	0
$\theta 40$	$\frac{81}{625}$	0	0	0	0	$\frac{216}{625}$	0	0	0	$\frac{216}{625}$	0	0	$\frac{96}{625}$	0	$\frac{16}{625}$

Transition Matrices: Detachment by Others

- Example matrix when B-types detach:

	$\theta00$	$\theta01$	$\theta02$	$\theta03$	$\theta04$	$\theta10$	$\theta11$	$\theta12$	$\theta13$	$\theta20$	$\theta21$	$\theta22$	$\theta30$	$\theta31$	$\theta40$
$\theta00$	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta01$	$\frac{3}{5}$	$\frac{2}{5}$	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta02$	$\frac{9}{25}$	$\frac{12}{25}$	$\frac{4}{25}$	0	0	0	0	0	0	0	0	0	0	0	0
$\theta03$	$\frac{27}{125}$	$\frac{54}{125}$	$\frac{36}{125}$	$\frac{8}{125}$	0	0	0	0	0	0	0	0	0	0	0
$\theta04$	$\frac{81}{625}$	$\frac{216}{625}$	$\frac{216}{625}$	$\frac{96}{625}$	$\frac{16}{625}$	0	0	0	0	0	0	0	0	0	0
$\theta10$	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0
$\theta11$	0	0	0	0	0	$\frac{3}{5}$	$\frac{2}{5}$	0	0	0	0	0	0	0	0
$\theta12$	0	0	0	0	0	$\frac{9}{25}$	$\frac{12}{25}$	$\frac{4}{25}$	0	0	0	0	0	0	0
$\theta13$	0	0	0	0	0	$\frac{27}{125}$	$\frac{54}{125}$	$\frac{36}{125}$	$\frac{8}{125}$	0	0	0	0	0	0
$\theta20$	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0
$\theta21$	0	0	0	0	0	0	0	0	0	$\frac{3}{5}$	$\frac{2}{5}$	0	0	0	0
$\theta22$	0	0	0	0	0	0	0	0	0	$\frac{9}{25}$	$\frac{12}{25}$	$\frac{4}{25}$	0	0	0
$\theta30$	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0
$\theta31$	0	0	0	0	0	0	0	0	0	0	0	0	$\frac{3}{5}$	$\frac{2}{5}$	0
$\theta40$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0

Transition Matrices: Detachment by Others

- Example matrix when both types detach:

	$\theta 00$	$\theta 01$	$\theta 02$	$\theta 03$	$\theta 04$	$\theta 10$	$\theta 11$	$\theta 12$	$\theta 13$	$\theta 20$	$\theta 21$	$\theta 22$	$\theta 30$	$\theta 31$	$\theta 40$
$\theta 00$	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 01$	$\frac{3}{5}$	$\frac{2}{5}$	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 02$	$\frac{9}{25}$	$\frac{12}{25}$	$\frac{4}{25}$	0	0	0	0	0	0	0	0	0	0	0	0
$\theta 03$	$\frac{27}{125}$	$\frac{54}{125}$	$\frac{36}{125}$	$\frac{8}{125}$	0	0	0	0	0	0	0	0	0	0	0
$\theta 04$	$\frac{81}{625}$	$\frac{216}{625}$	$\frac{216}{625}$	$\frac{96}{625}$	$\frac{16}{625}$	0	0	0	0	0	0	0	0	0	0
$\theta 10$	$\frac{3}{5}$	0	0	0	0	$\frac{2}{5}$	0	0	0	0	0	0	0	0	0
$\theta 11$	$\frac{9}{25}$	$\frac{6}{25}$	0	0	0	$\frac{6}{25}$	$\frac{4}{25}$	0	0	0	0	0	0	0	0
$\theta 12$	$\frac{27}{125}$	$\frac{36}{125}$	$\frac{12}{125}$	0	0	$\frac{18}{125}$	$\frac{24}{125}$	$\frac{8}{125}$	0	0	0	0	0	0	0
$\theta 13$	$\frac{81}{625}$	$\frac{162}{625}$	$\frac{108}{625}$	$\frac{24}{625}$	0	$\frac{54}{625}$	$\frac{108}{625}$	$\frac{72}{625}$	$\frac{16}{625}$	0	0	0	0	0	0
$\theta 20$	$\frac{9}{25}$	0	0	0	0	$\frac{12}{25}$	0	0	0	$\frac{4}{25}$	0	0	0	0	0
$\theta 21$	$\frac{27}{125}$	$\frac{18}{125}$	0	0	0	$\frac{36}{125}$	$\frac{24}{125}$	0	0	$\frac{12}{125}$	$\frac{8}{125}$	0	0	0	0
$\theta 22$	$\frac{81}{625}$	$\frac{108}{625}$	$\frac{36}{625}$	0	0	$\frac{108}{625}$	$\frac{144}{625}$	$\frac{48}{625}$	0	$\frac{36}{625}$	$\frac{48}{625}$	$\frac{16}{625}$	0	0	0
$\theta 30$	$\frac{27}{125}$	0	0	0	0	$\frac{54}{125}$	0	0	0	$\frac{36}{125}$	0	0	$\frac{8}{125}$	0	0
$\theta 31$	$\frac{81}{625}$	$\frac{108}{625}$	0	0	0	$\frac{108}{625}$	$\frac{108}{625}$	0	0	$\frac{108}{625}$	$\frac{72}{625}$	0	$\frac{24}{625}$	$\frac{16}{625}$	0
$\theta 40$	$\frac{81}{625}$	0	0	0	0	$\frac{216}{625}$	0	0	0	$\frac{216}{625}$	0	0	$\frac{96}{625}$	0	$\frac{16}{625}$

Transition Matrices: Agent Action

- The preferential detachment mechanism is that an agent disconnects from any one less preferred neighbor if one exists, and connects to a new agent at random if one does not.
- Agents can only add or remove one connection per iteration.
- Only agents with mixed configurations will detach, and they will do so with probability 1.0 if either type is preferred.
- Agents with the maximum number cannot connect to any more.
- Agents that will add a random connection have a uniform probability of doing so over the whole population.

Transition Matrices: Agent Action

- Example probabilities if *A-types* are preferred to *B-types*

	$\theta00$	$\theta01$	$\theta02$	$\theta03$	$\theta04$	$\theta10$	$\theta11$	$\theta12$	$\theta13$	$\theta20$	$\theta21$	$\theta22$	$\theta30$	$\theta31$	$\theta40$
$\theta00$	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0	0
$\theta01$	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0
$\theta02$	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0
$\theta03$	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0
$\theta04$	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0
$\theta10$	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0
$\theta11$	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0
$\theta12$	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0
$\theta13$	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0
$\theta20$	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	$\frac{\eta_A}{N-1}$	0	0
$\theta21$	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0
$\theta22$	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0
$\theta30$	0	0	0	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	$\frac{\eta_A}{N-1}$
$\theta31$	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0
$\theta40$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0

Transition Matrices: Agent Action

- Example probabilities if *B-types* are preferred to *A-types*

	$\theta00$	$\theta01$	$\theta02$	$\theta03$	$\theta04$	$\theta10$	$\theta11$	$\theta12$	$\theta13$	$\theta20$	$\theta21$	$\theta22$	$\theta30$	$\theta31$	$\theta40$
$\theta00$	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0	0
$\theta01$	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0
$\theta02$	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0
$\theta03$	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0
$\theta04$	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0
$\theta10$	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0
$\theta11$	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta12$	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0
$\theta13$	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0
$\theta20$	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	$\frac{\eta_A}{N-1}$	0	0
$\theta21$	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0
$\theta22$	0	0	0	0	0	0	0	1.0	0	0	1.0	0	0	0	0
$\theta30$	0	0	0	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	$\frac{\eta_A}{N-1}$
$\theta31$	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0
$\theta40$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0

Transition Matrices: Agent Action

- Example probabilities if indifferent between *A-types* and *B-types*

	$\theta00$	$\theta01$	$\theta02$	$\theta03$	$\theta04$	$\theta10$	$\theta11$	$\theta12$	$\theta13$	$\theta20$	$\theta21$	$\theta22$	$\theta30$	$\theta31$	$\theta40$
$\theta00$	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0	0
$\theta01$	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0	0
$\theta02$	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0	0
$\theta03$	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0	0
$\theta04$	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0
$\theta10$	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0	0
$\theta11$	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	$\frac{\eta_A}{N-1}$	0	0	0	0
$\theta12$	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	0	$\frac{\eta_A}{N-1}$	0	0	0
$\theta13$	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0
$\theta20$	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	$\frac{\eta_A}{N-1}$	0	0
$\theta21$	0	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	0	$\frac{\eta_A}{N-1}$	0
$\theta22$	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0
$\theta30$	0	0	0	0	0	0	0	0	0	0	0	0	0	$\frac{\eta_B}{N-1}$	$\frac{\eta_A}{N-1}$
$\theta31$	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0
$\theta40$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0

Transition Matrices: Combined Probabilities

- The complete transition probability is the product of the independent component matrices...order matters.
- The strategic context preferences determine the mapping from conditions to actions, and hence the transition matrix used.

Category	Relationship		A-type	B-type
Cooperative	$A : B \prec A$	$B : B \prec A$	$\mathcal{A} = \mathcal{X}_{\phi_1}\mathcal{Y}0\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_1}\mathcal{Y}\delta\mathcal{R}_B$
Coordinative	$A : B \prec A$	$B : A \prec B$	$\mathcal{A} = \mathcal{X}_{\phi_1}\mathcal{Y}\beta\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_2}\mathcal{Y}\alpha\mathcal{R}_B$
Specialized	$A : A \prec B$	$B : B \prec A$	$\mathcal{A} = \mathcal{X}_{\phi_2}\mathcal{Y}\alpha\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_1}\mathcal{Y}\beta\mathcal{R}_B$
Contributive	$A : B \prec A$	$B : A \approx B$	$\mathcal{A} = \mathcal{X}_{\phi_1}\mathcal{Y}0\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_3}\mathcal{Y}\alpha\mathcal{R}_B$
Parasitic	$A : A \prec B$	$B : A \approx B$	$\mathcal{A} = \mathcal{X}_{\phi_2}\mathcal{Y}\alpha\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_3}\mathcal{Y}0\mathcal{R}_B$
Undifferentiated	$A : A \approx B$	$B : A \approx B$	$\mathcal{A} = \mathcal{X}_{\phi_3}\mathcal{Y}0\mathcal{R}_A$	$\mathcal{B} = \mathcal{X}_{\phi_3}\mathcal{Y}0\mathcal{R}_B$

Stationary Distributions

Cooperative Games

$A00$	0	$B00$	13.8330
$A01$	0	$B01$	12.4963
$A02$	0	$B02$	5.5655
$A03$	0	$B03$	1.6606
$A04$	6.5338	$B04$	0.6268
$A10$	0	$B10$	17.4611
$A11$	0	$B11$	13.7988
$A12$	0	$B12$	5.3802
$A13$	0	$B13$	2.0060
$A20$	0	$B20$	9.5330
$A21$	0	$B21$	6.8630
$A22$	0	$B22$	3.2347
$A30$	0	$B30$	3.2424
$A31$	0	$B31$	2.9927
A40	**93.4662**	$B40$	1.3058

Coordinative Games

$A00$	0	$B00$	0
$A01$	0	$B01$	0
$A02$	0	$B02$	0
$A03$	0	$B03$	0
$A04$	0	**B04**	**100**
$A10$	0	$B10$	0
$A11$	0	$B11$	0
$A12$	0	$B12$	0
$A13$	0	$B13$	0
$A20$	0	$B20$	0
$A21$	0	$B21$	0
$A22$	0	$B22$	0
$A30$	0	$B30$	0
$A31$	0	$B31$	0
A40	**100**	$B40$	0

Stationary Distributions

Specialized Games

$A00$	0	$B00$	0
$A01$	0	$B01$	0
$A02$	0	$B02$	0
$A03$	0	$B03$	0
A04	**100**	$B04$	0
$A10$	0	$B10$	0
$A11$	0	$B11$	0
$A12$	0	$B12$	0
$A13$	0	$B13$	0
$A20$	0	$B20$	0
$A21$	0	$B21$	0
$A22$	0	$B22$	0
$A30$	0	$B30$	0
$A31$	0	$B31$	0
$A40$	0	**B40**	**100**

Contributive Games

$A00$	0	$B00$	0
$A01$	0	$B01$	0
$A02$	0	$B02$	0
$A03$	0	$B03$	0
$A04$	6.5338	$B04$	100
$A10$	0	$B10$	0
$A11$	0	$B11$	0
$A12$	0	$B12$	0
$A13$	0	$B13$	0
$A20$	0	$B20$	0
$A21$	0	$B21$	0
$A22$	0	$B22$	0
$A30$	0	$B30$	0
$A31$	0	$B31$	0
A40	**93.4662**	$B40$	0

Stationary Distributions

Parasitic Games

$A00$	0	$B00$	0
$A01$	0	$B01$	0
$A02$	0	$B02$	0
$A03$	0	$B03$	0
A04	**100**	$B04$	6.2960
$A10$	0	$B10$	0
$A11$	0	$B11$	0
$A12$	0	$B12$	0
$A13$	0	$B13$	24.7664
$A20$	0	$B20$	0
$A21$	0	$B21$	0
$A22$	0	$B22$	37.1703
$A30$	0	$B30$	0
$A31$	0	$B31$	25.2336
$A40$	0	$B40$	6.5338

Undifferentiated Games

$A00$	0	$B00$	0
$A01$	0	$B01$	0
$A02$	0	$B02$	0
$A03$	0	$B03$	0
$A04$	6.5338	$B04$	6.2960
$A10$	0	$B10$	0
$A11$	0	$B11$	0
$A12$	0	$B12$	0
$A13$	25.2336	$B13$	24.7664
$A20$	0	$B20$	0
$A21$	0	$B21$	0
$A22$	37.1703	$B22$	37.1703
$A30$	0	$B30$	0
$A31$	24.7664	$B31$	25.2336
$A40$	6.2960	$B40$	6.5338

Markov Model Conclusions

- Increasing K or $N_A = N_B$ improves the prosociality of the outcomes across all strategic contexts. Varying proportions of the types has the intuitive effects.

- These results demonstrate the consistently high level of prosociality that the preferential detachment mechanism achieves across the full range of strategic contexts.

- They also reveal the degree to which system-level approximations of agent arrangements affect the interpretations of the results.

Evaluation of Markov Model

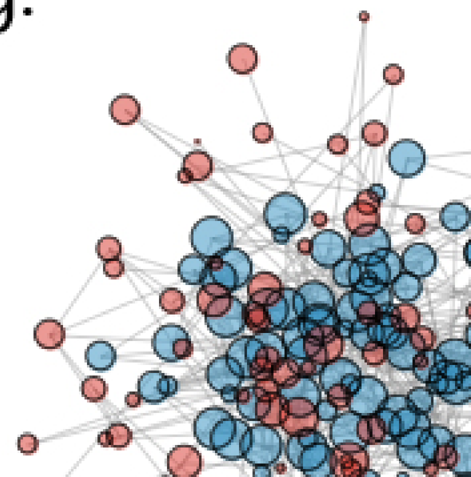
- The Markov model is not tracking any system-wide features directly, just the distribution of configurations.
- There are some system-level assumptions that are known to be false in general, but are still reasonable approximations.
- These are necessary because the Markov model is time-homogeneous, yet the actual probabilities **do** change in response to the numbers of agents in each configuration.
- The simplicity and clarity of the mathematical representation has other benefits that make it still useful.

Agent-based Model of Preferential Detachment

- Includes system-level arrangements of agents.
- Encodes theory as contingent agent behavior rules.
- Requires fewer assumptions and approximations.
- Fosters inclusion of learning and population dynamics.
- Fosters structural analysis, detection and sensitivity to rare events, greater modularity, intuitive uptake, and spiffy graphics.

ABM Procedure

- Initialized with N unconnected agents equally divided into types.
- All agents assess the payoffs received from each neighbor.
  If any pays less than others, detach a lowest paying neighbor.
- If all neighbors pay the same, and $k < K$, randomly connect to a new agent with $k < K$.
- If learning and/or population dynamics are activated, do that.
- Collect measures, update visuals, and check for halting.



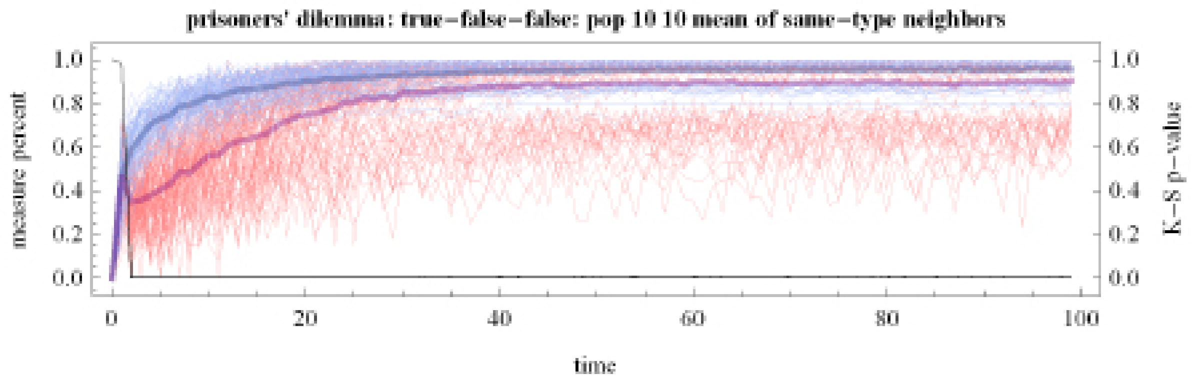
Branch One: Sweeping Population Size in PD

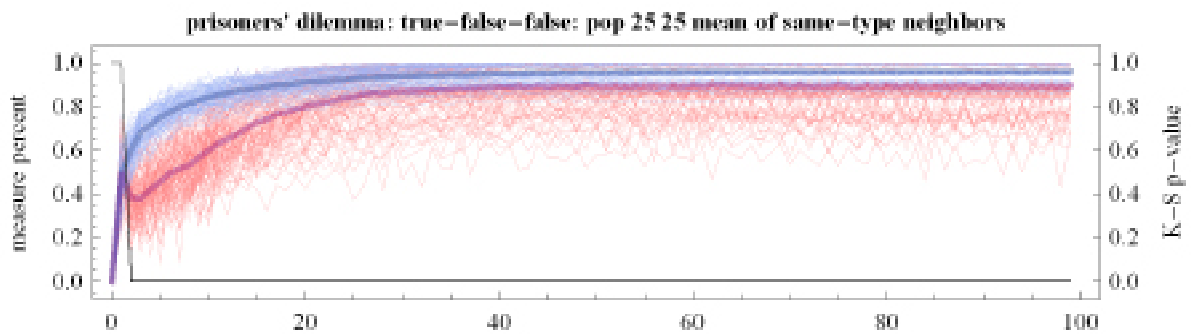
- These experiments seek to determine whether the success of the mechanism scales well with population size, and whether there is a minimum population size required for the preferential detachment mechanism to achieve the prosocial outcome.

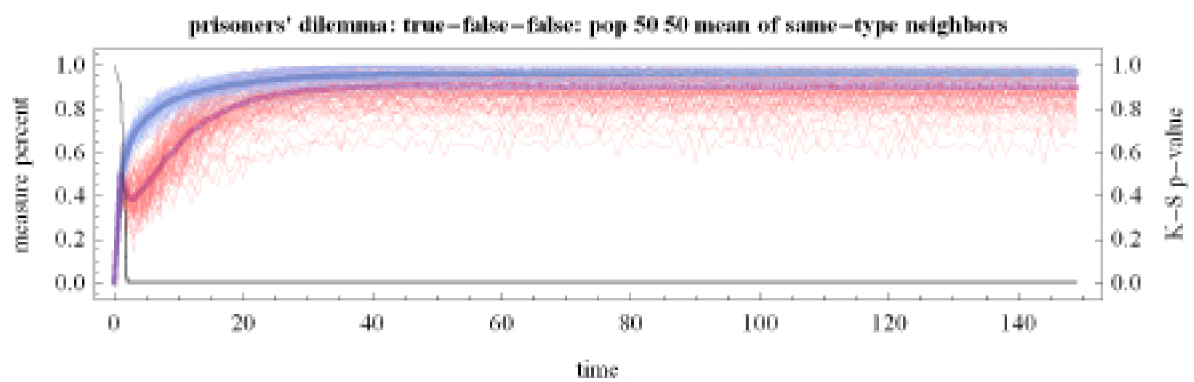
num-typeA	*num-typeB*
10	10
25	25
50	50
100	100
250	250
500	500
1000	1000

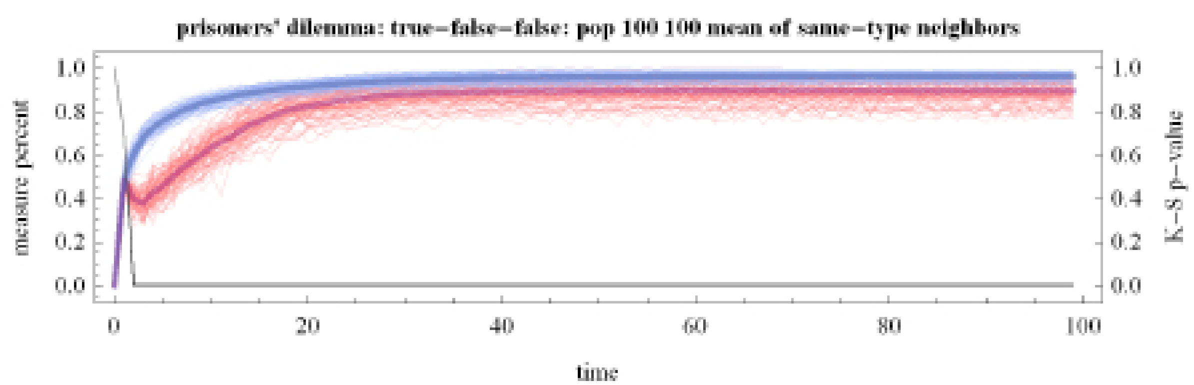
Evolution of Prosociality via Preferential Detachment

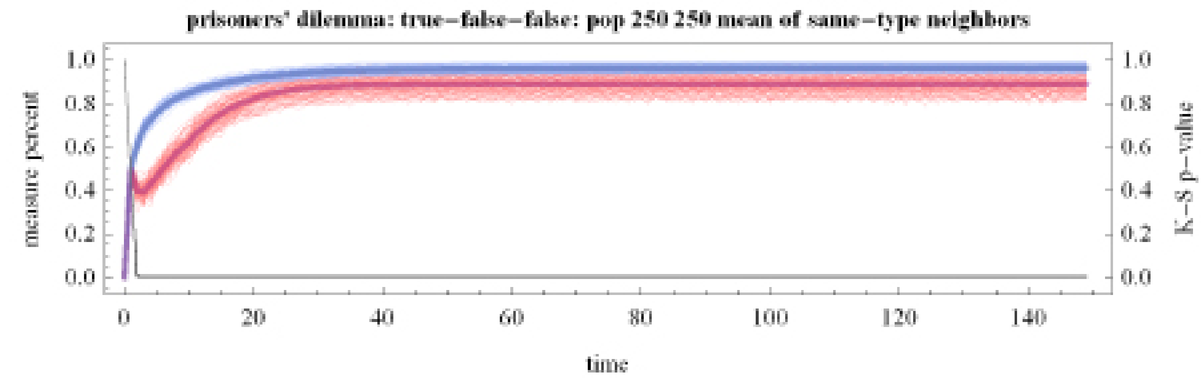
Aaron L Bramson

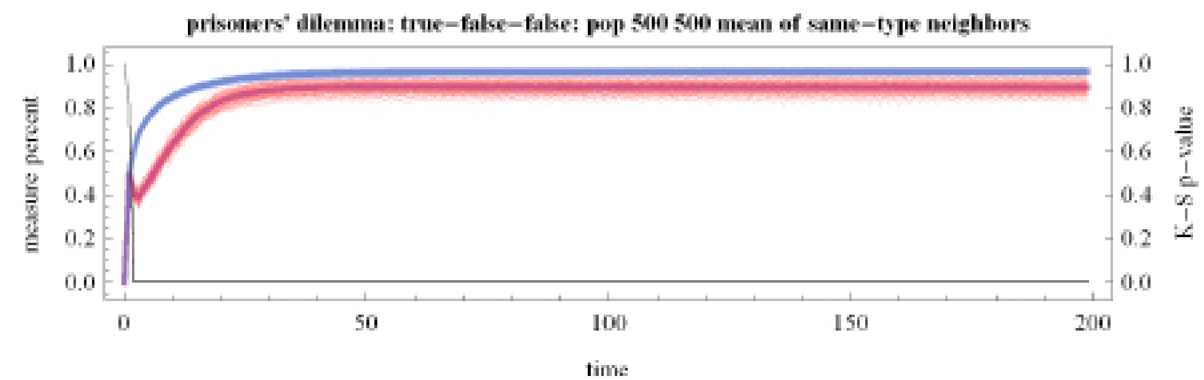


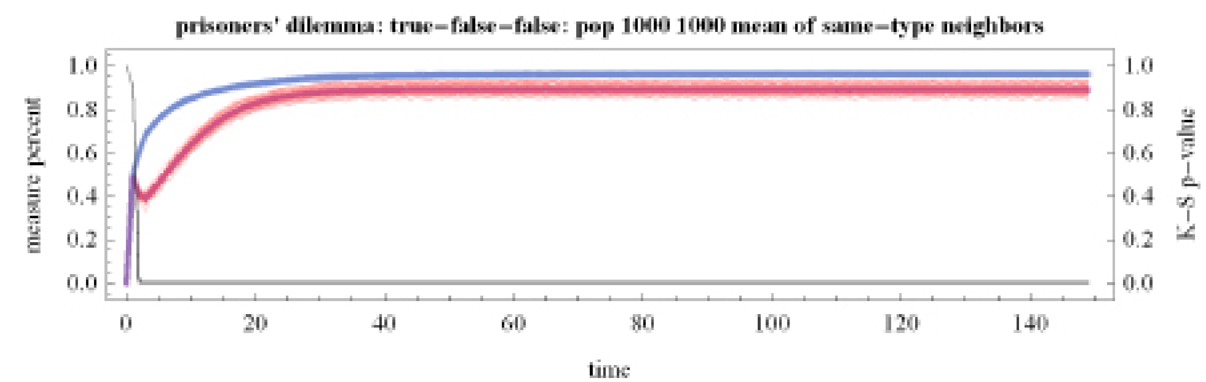












Evolution of Prosociality via Preferential Detachment

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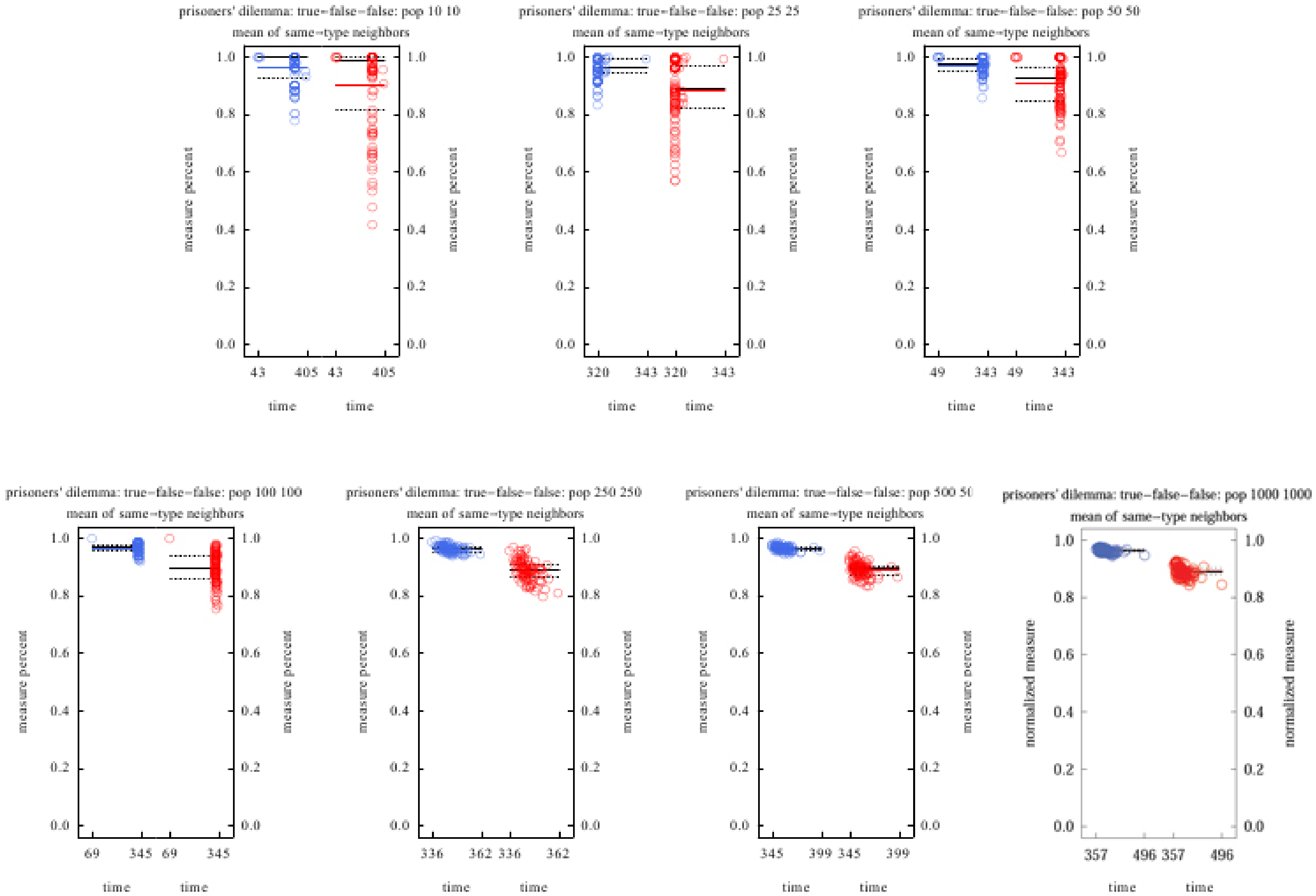
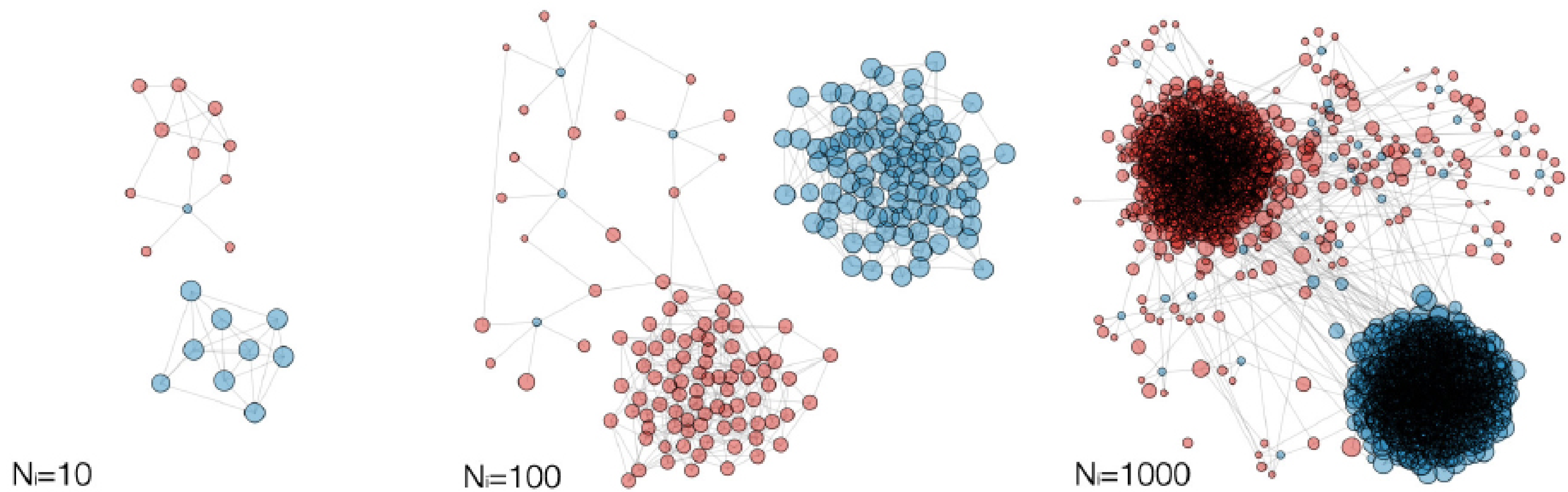


Stable Heterogeneous Groups



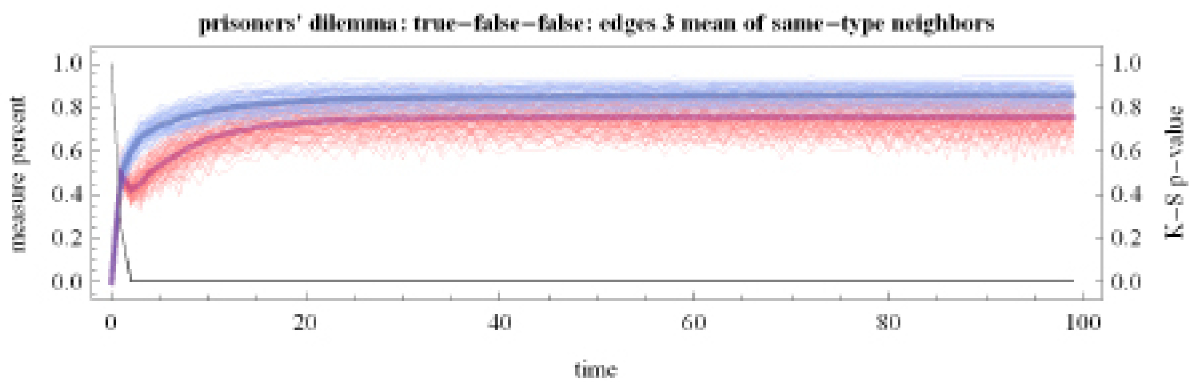
Branch Two: Sweeping Maximum Degree in PD

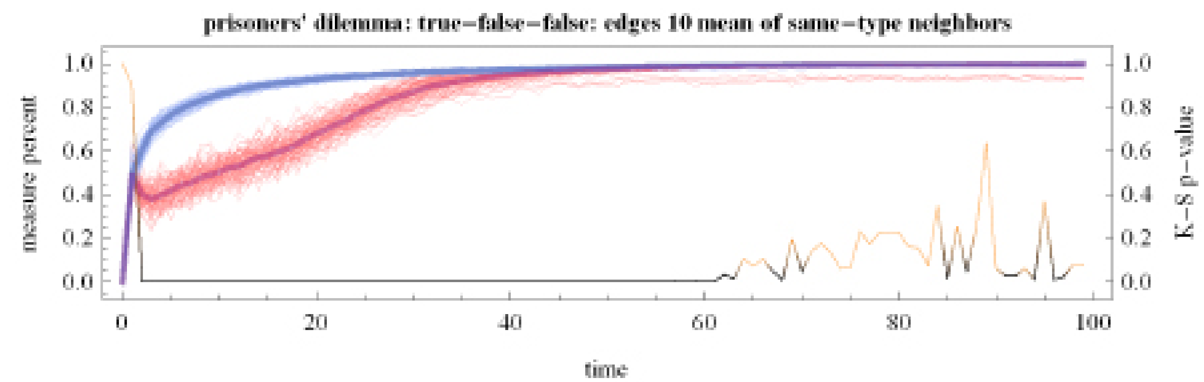
- Recall that the default value for maximum degree ($K{=}5$) was based on neurological and anthropological research regarding primates' abilities to keep track of social relationships.

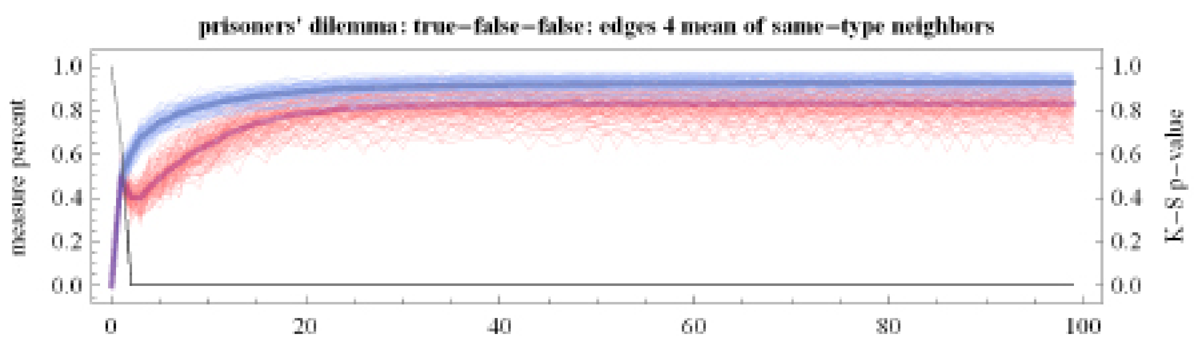
- To extrapolating these results to modern humans, and to expand the range of applicability of the model, I sweep the maximum degree from 3 to 20.

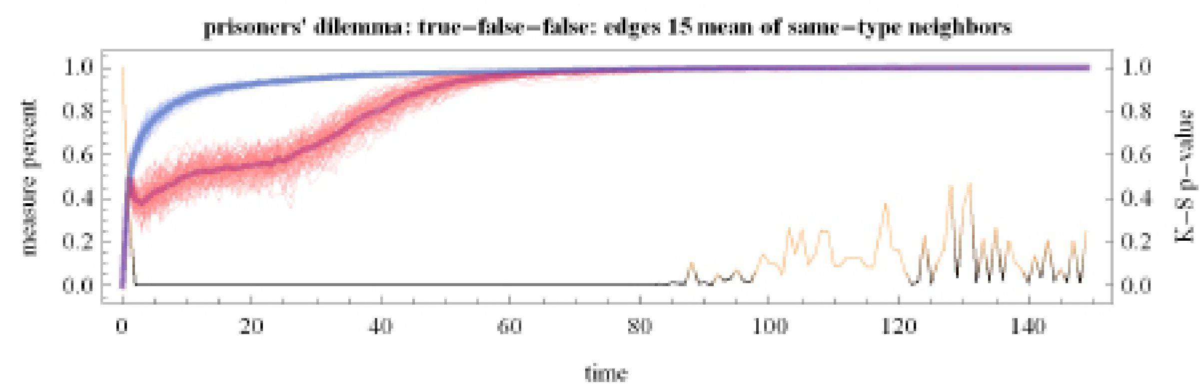
max-degree
3
4
5
10
15
20

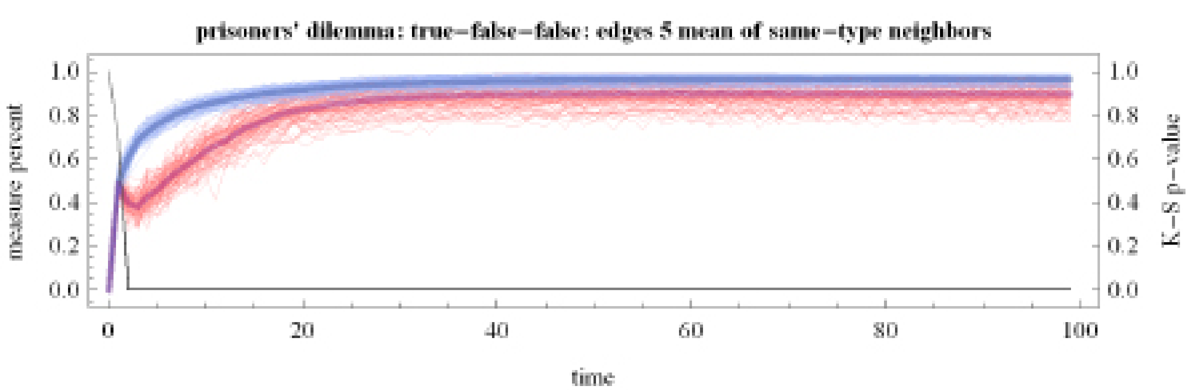
Branch Two: Sweeping Maximum Degree in PD

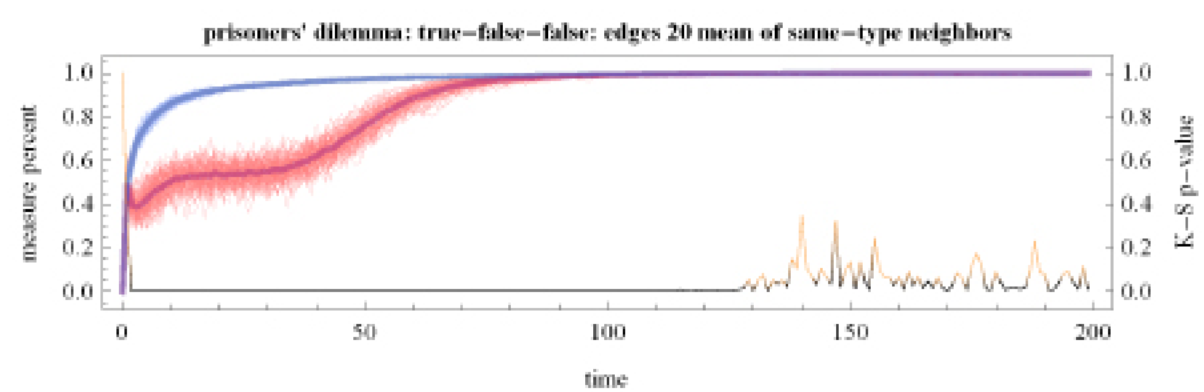




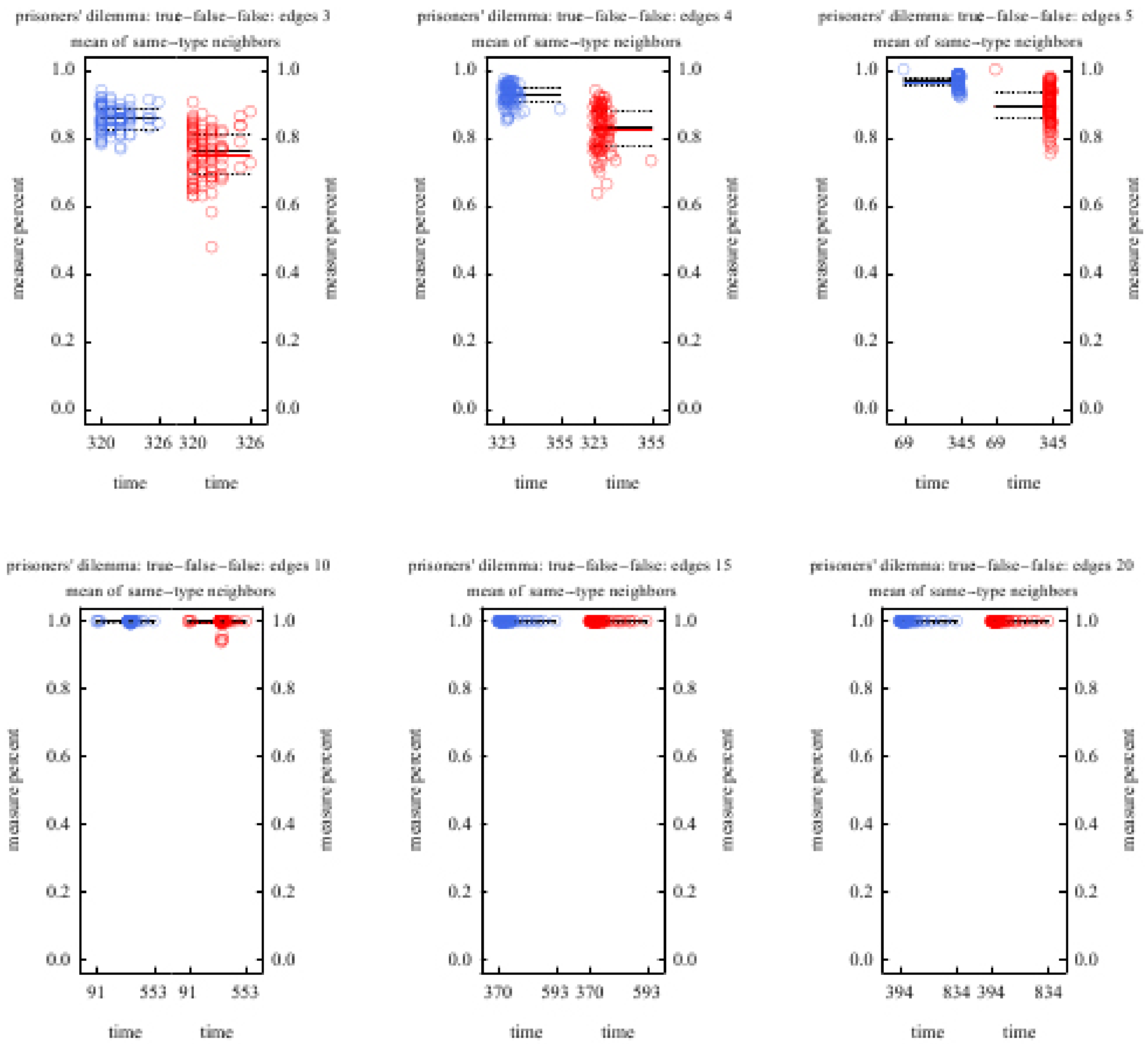








Branch Two: Sweeping Maximum Degree in PD



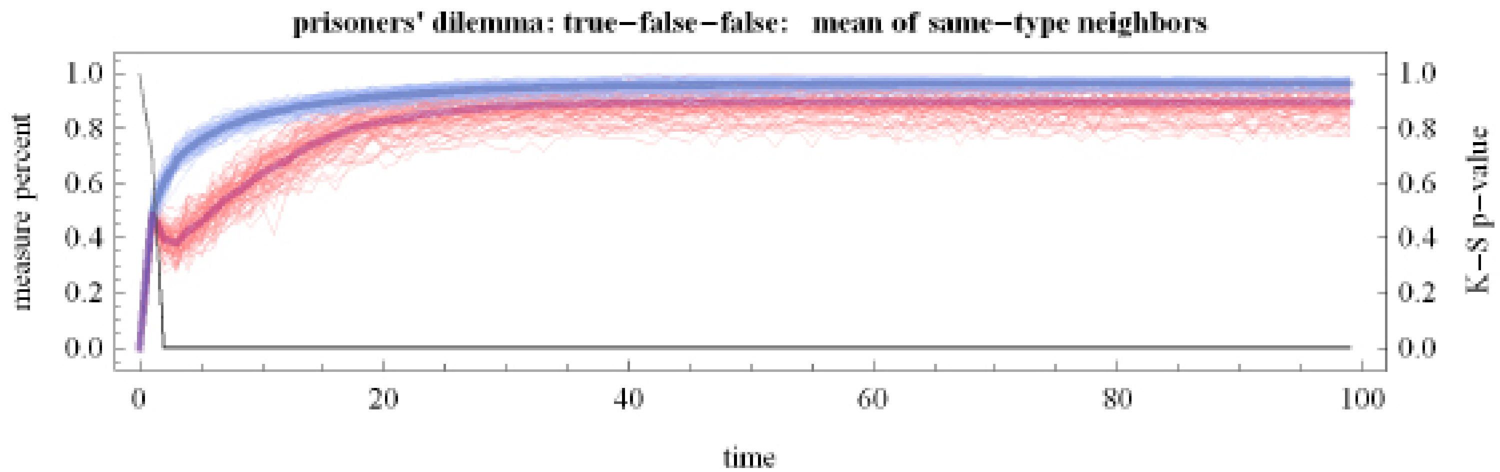
Branch Two: Sweeping Maximum Degree in PD

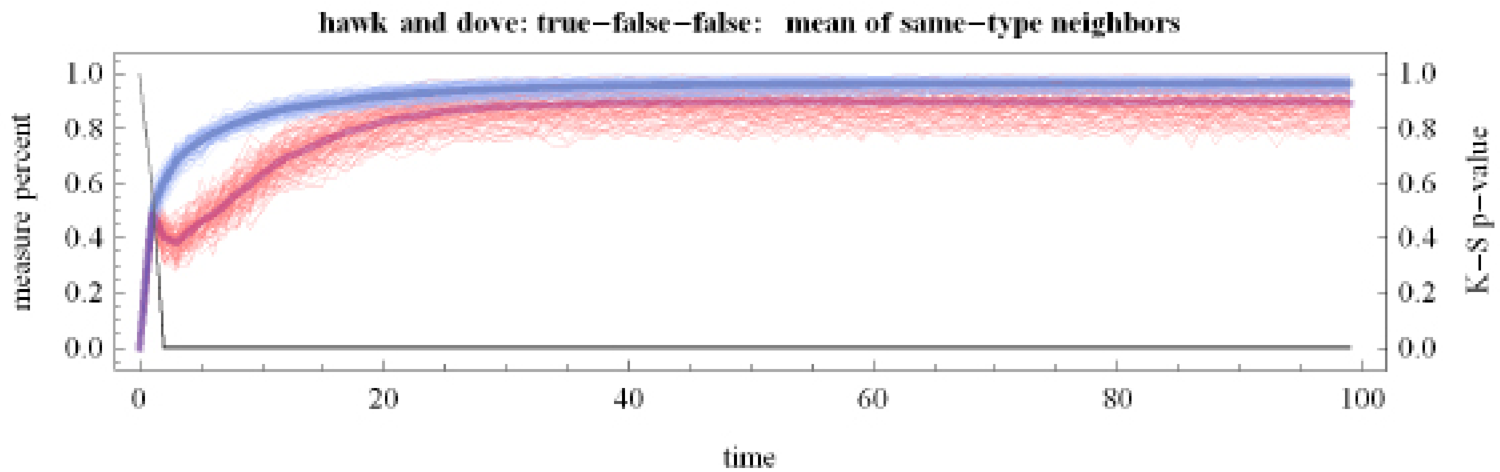
- During the transition period, increasing values of K decrease variability of the cooperators, but not the defectors.
- Defectors experience longer transition periods with increasing K through which they have lower overall degree and a few connections to cooperators.
- Stable heterogeneous groups are common at smaller values of K, but disappear before K=15.
- The success of preferential detachment in achieving prosociality across ranges of maximum degree is clear from these results.

Branch Three: Sweeping the Strategic Context

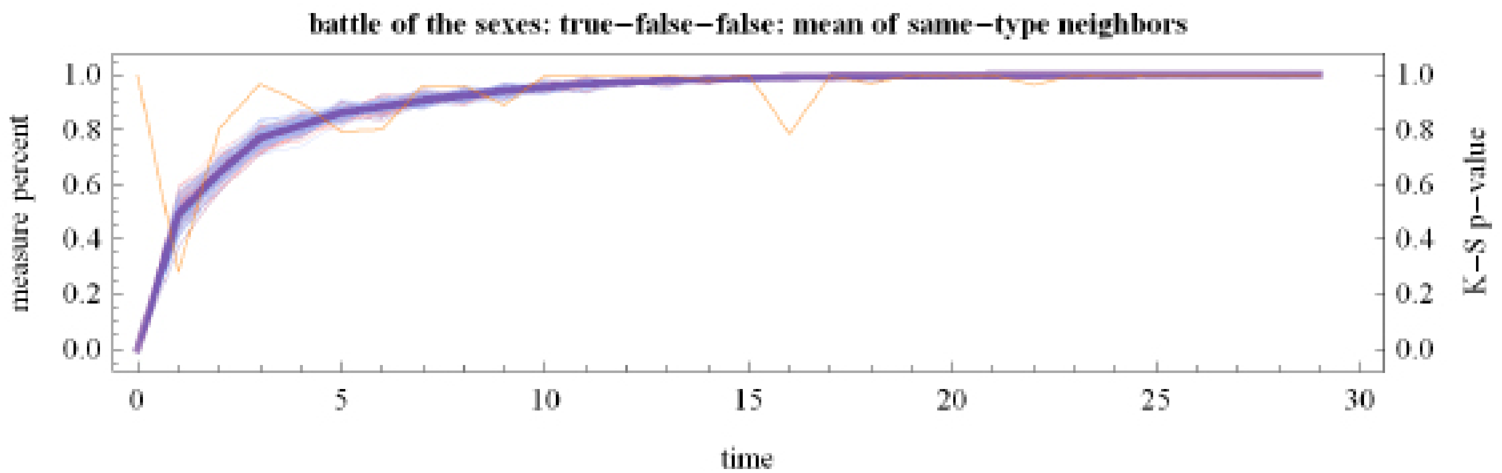
- We now explore the results for each strategic context in the game library.
- One hundred simulations for each payoff matrix are performed with an initial population of two hundred total agents, and a maximum degree of five.
- Recall that, though the preference relations differ for each category of game, the same mechanism is used in each.

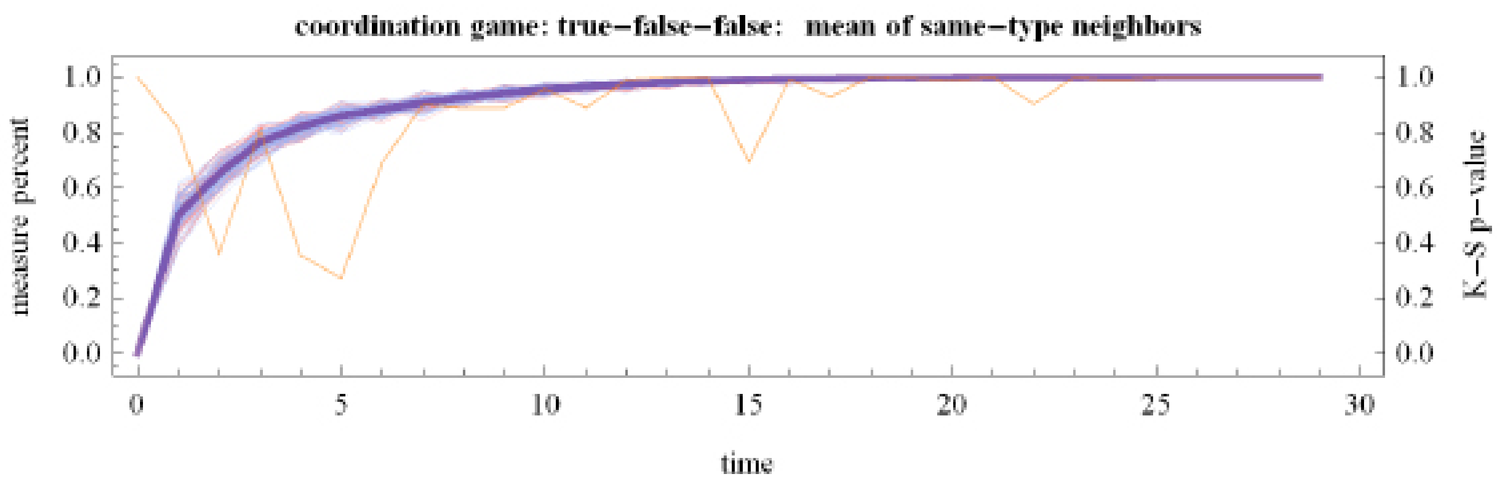
Prisoners' Dilemma and Hawk and Dove



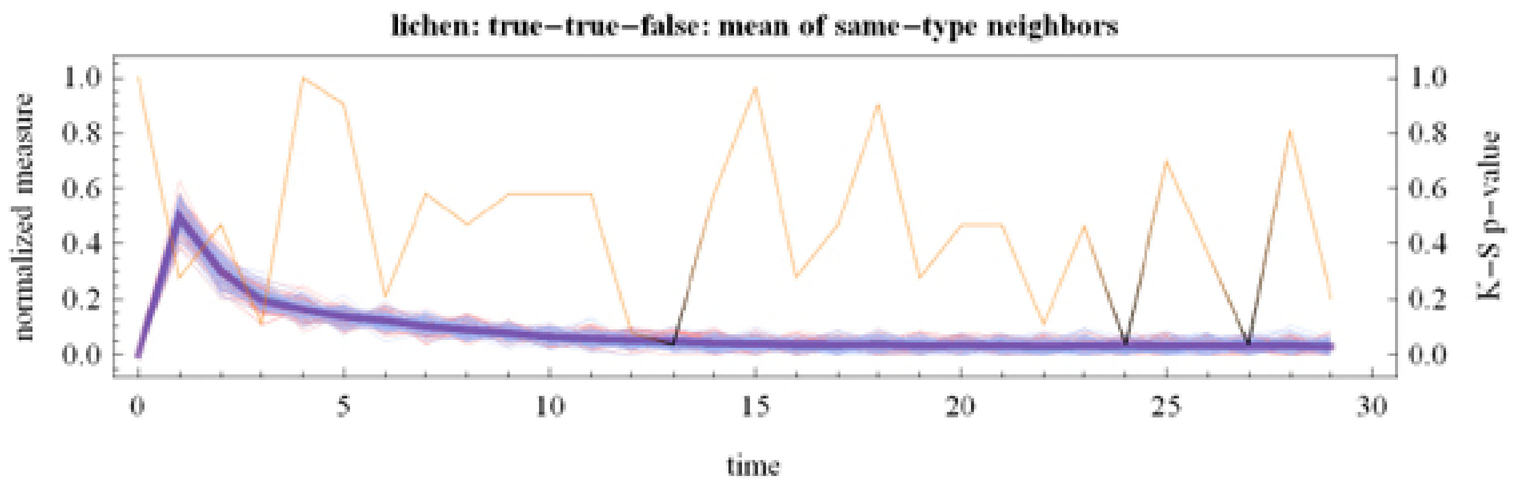


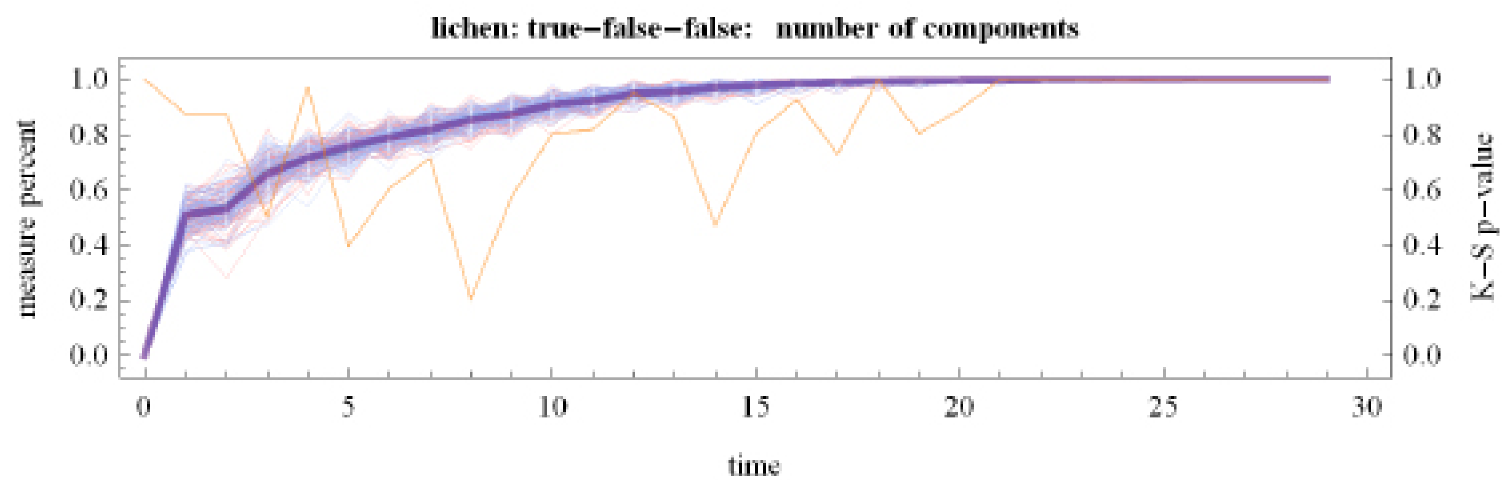
Battle of the Sexes and Coordination Game



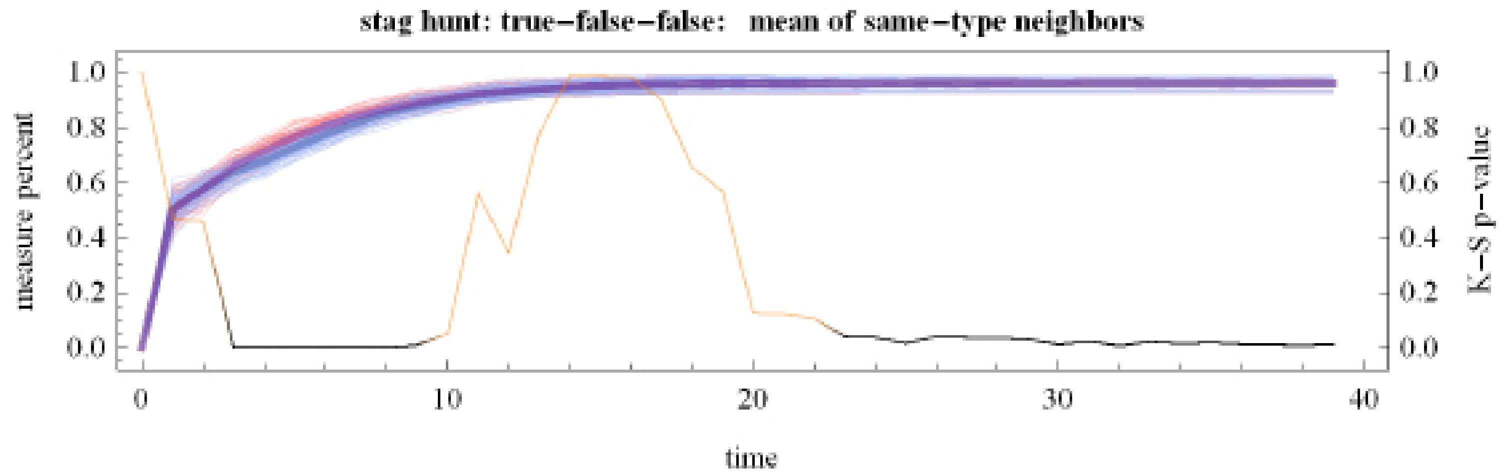


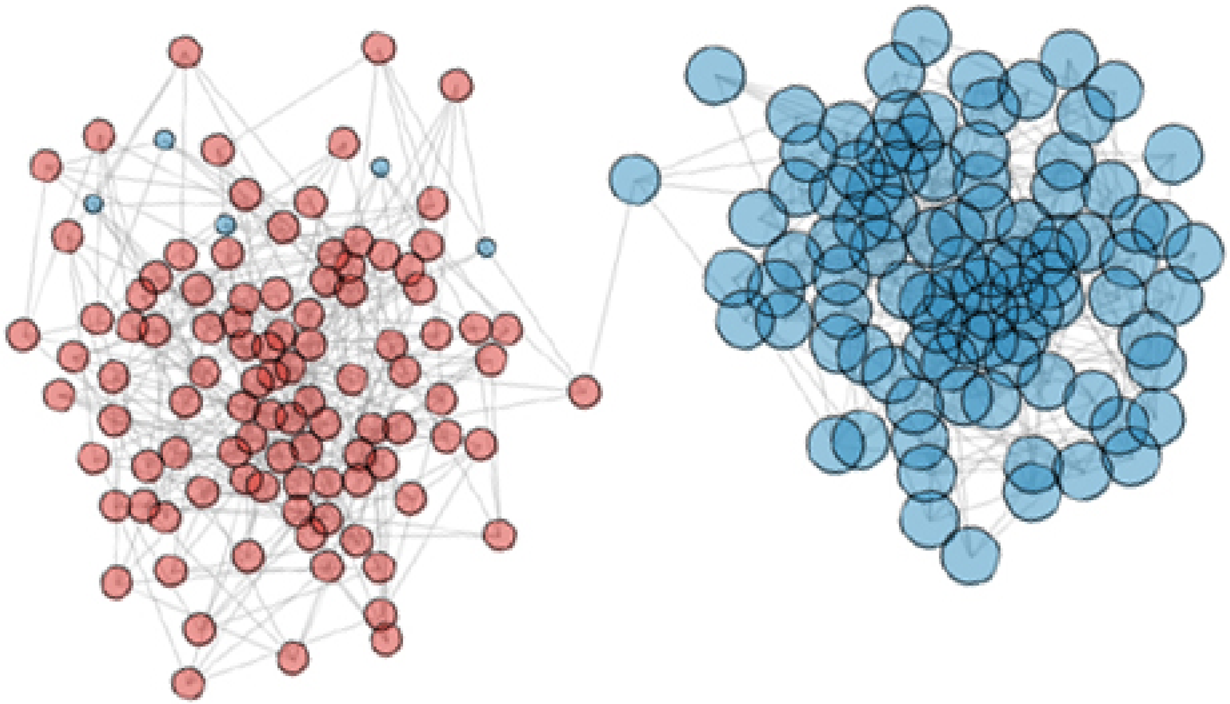
Lichen (Miscoordination Game)



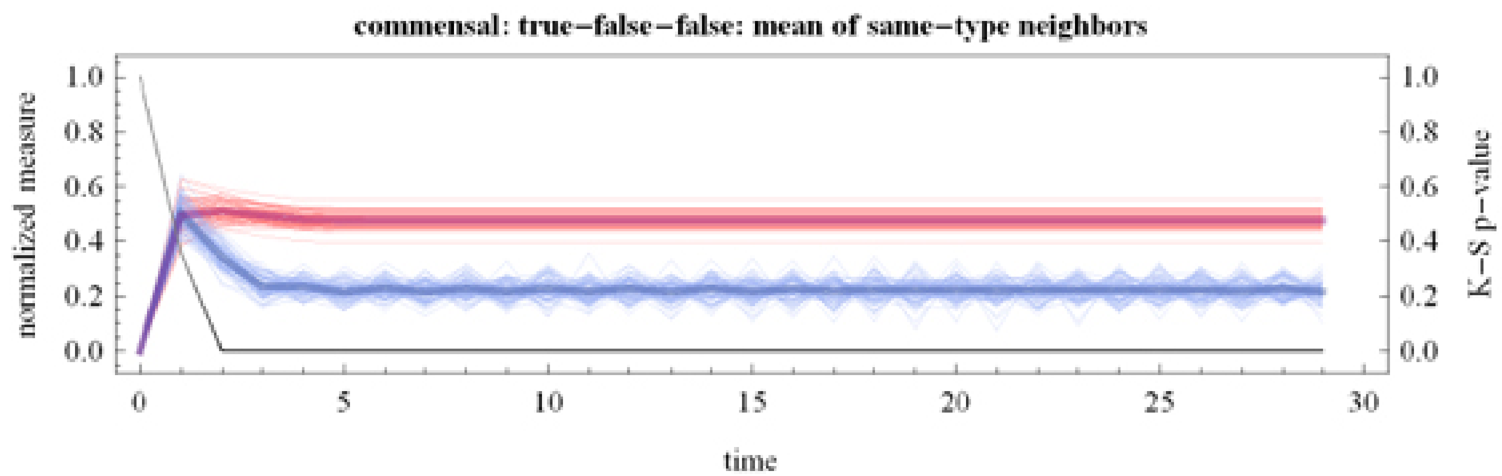


Stag Hunt

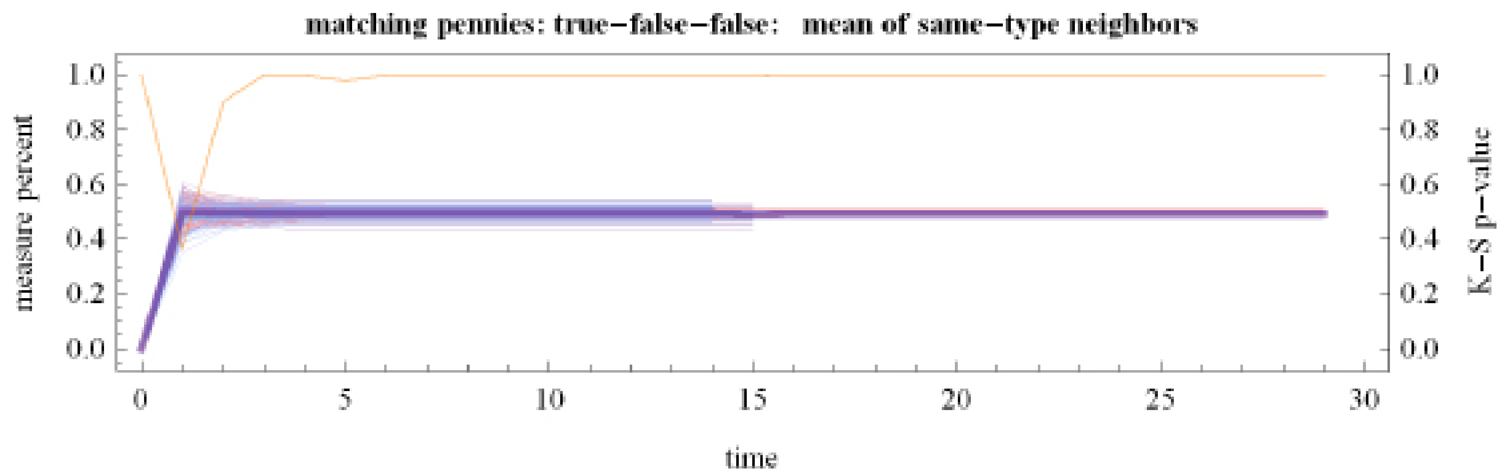

stag hunt: true–false–false: mean of same–type neighbors
measure percent
K–S p–value
time
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40



Commensal


commensal: true−false−false: mean of same−type neighbors
normalized measure
K−S p−value
time
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30

Matching Pennies



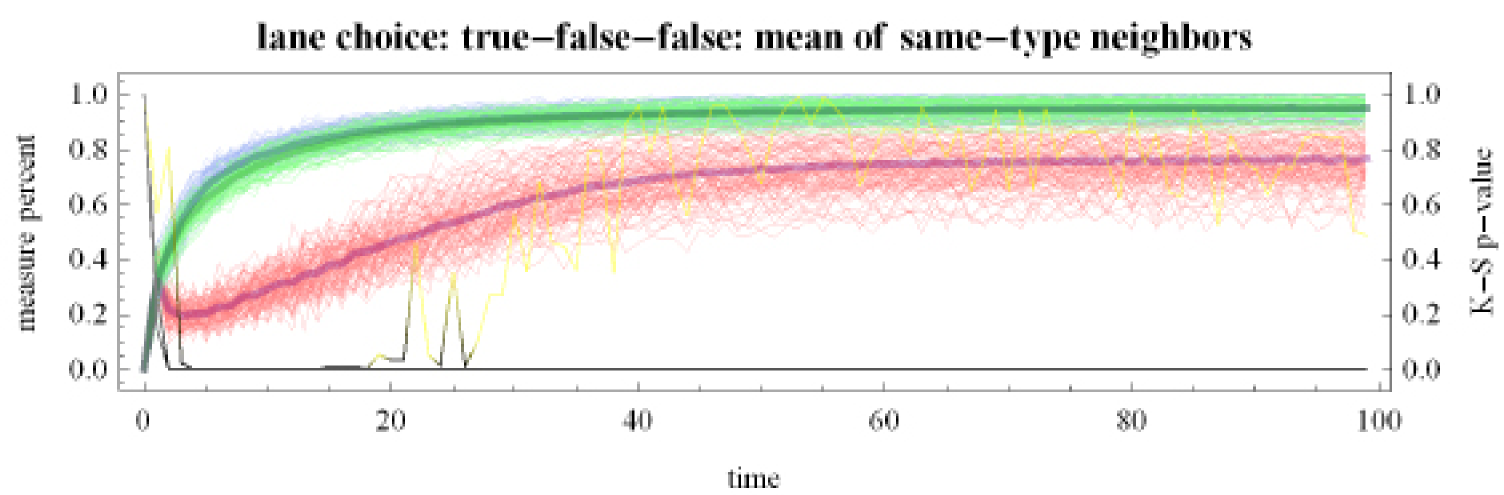
Lane Choice Game

- Also successful in a 3x3 Collaborative Game that is a combination of Prisoners' Dilemma and Coordination Game.

Lane Choice

player2 (columns) / player1 (rows)

	A	B	C
A	3,3	1,4	1,1
B	4,1	2,2	4,1
C	1,1	1,4	3,3



Branch Three Summary

- Preferential detachment is highly successful in achieving the prosocial outcome in all possible strategic contexts.

	Preferential Detachment					
Parameter Value	A % pop	A %-sim	B %-pop	B %-sim	C %-pop	C %-sim
Prisoners' Dilemma	0.500	0.965	0.500	0.896		
Hawk and Dove	0.500	0.965	0.500	0.899		
Battle of the Sexes	0.500	1.000	0.500	0.999		
Coordination Game	0.500	1.000	0.500	1.000		
Lichen	0.500	0.000	0.500	0.000		
Stag Hunt	0.500	0.961	0.500	0.961		
Parasite	0.500	0.220	0.500	0.475		
Matching Pennies	0.500	0.496	0.500	0.496		
Lane Choice	0.333	0.954	0.333	0.763	0.333	0.954
Biased Lane Choice	0.333	0.955	0.333	0.766	0.333	0.952

Imitative Learning and Population Dynamics

- Agents must compare cardinal utility, so preference ranking is no longer sufficient; greatly expands dimensionality.
- In learning, agents imitate the type of the most successful network neighbor.
- In population dynamics, the bottom 5% of agents are removed and the top 5% are replicated.
- Preliminary results reveal that learning is only benefitial in some strategic contexts, but population dynamics improves prosociality across them all.

Evolutionary Approach

- To more fully understand the evolution of prosociality with formal models, the models must include the spectrum of features of evolutionary processes: endogenously generated communities, intercommunity competition, intracommunity structural changes, and individual selection pressures.
- Creating such a model is the aim of this project, and the results demonstrate a preliminary success in fulfilling these desiderata.
- Deeper analysis using population dynamics, heterogeneity, measures of network structure, and more complicated strategic contexts are then next steps.

Conclusions from Formal Models

- The primary contribution of this research is that a single, simple mechanism operating in different contexts generates the conceptually distinct prosocial behaviors achieved by other models, and in a manner that is more amenable to evolutionary explanations.
- The conclusion is that self-organizing into groups that maintain prosocial behaviors may be simpler and more robust than previously thought.

Implications for Moral Experience

- I build a bridge from the evolution of prosocial behaviors to various psychological and sociological phenomena associated with morality.

- Moral attitudes, which admit to a variety of forms and expressions, are experiences with a particular characteristic: these attitudes correlate with behaviors which are necessary for sustaining a population of individuals who similarly behave appropriately for the perpetuation of that arrangement.

Evolutionary Approach

- Behaviors are directly selected, not the generating mechanisms.
- Moral attitudes are thus only contingently and coincidently adaptive: they happen to correlate with adaptive behaviors.
- However, because evolution operates by tweaking biological structures, there is a near continuity in mechanisms.
- Conservatism in mechanisms implies that similar problems are adapted to with similar mechanisms.
- Social problems are shared across the animal kingdom.

Primacy of Behavior

- Behavior is what an individual does. It includes the action taken in a game, the interactions engaged in, the imitation of another individual, and all the things it actually does.
- Individuals' behaviors may be contingent upon interaction structure, environmental features, the behaviors of others, performance, memory, signals, etc.
- A mechanism that would do better in a situation that never actually arises, but is equivalent to all other mechanisms in all realized situations, does not increase in prevalence vis-a-vis the other mechanisms.

Individual Interest

- Fitness is a placeholder for a relative change in prevalence: this can occur through biological reproduction, imitation, group growth and splitting, etc.
- An individual's interest is determined by what is in line with that individual's behavioral tendencies.
- Behavioral tendencies capture motivations, preferences, urges, reactions, and whatever other social, psychological, biological, chemical, or physical, process is considered the driving mechanism.

Individual Selection

- Individuals behave according to their interest; however, it is the fitness of an individual's behavior that determines whether that behavior persists.

- Individuals whose interests align with those behaviors that, in the prevailing context, foster a higher rate of replication are the ones adapted to that context.

- Behaviors are actually selected for, but it is typically the behavior-generating mechanism that gets passed on (either in whole are a part thereof).

Prosociality in Collectives

- Groups are composed of individuals, the social arrangement of a group is the set of individuals' behaviors and interactions, and a group's behavior is an aggregate of individuals' behavior.
- Fitness of the group is not just an aggregate of the members.
- The behaviors of a group of individuals considered together is called a behavioral repertoire.
- The degree to which a behavioral repertoire results in greater group fitness is its prosociality.

Prosociality in Collectives

- It is only the set of collectively adapted behaviors that bear prosociality properties.
- The individual behaviors (actions and interactions) involved in this repertoire are only derivatively prosocial.
- Studies that only examine contexts in which prosociality is achieved through the domination of one type of behavior (such as in the Prisoners' Dilemma, Stag Hunt, or Ultimatum Game) will likely miss this nuance of prosociality.

Intergroup Competition

- Intergroup competition is any process through which groups become more or less prevalent with respect to other groups.
- The simplest form is comparative replication rate.
- When a group grows beyond a threshold it may schism to produce two or more groups - group reproduction.
- We have an general description of groups that can survive longer, grow faster, and split into new groups with the same or similar features; i.e. be considered analogous to individuals.

Implications of Evolved Prosociality

- The behaviors enacted by individuals as part of a repertoire will match the behavioral tendencies of the individuals (aka interests) in the current context.
- Prosociality evolves because behaviors that are conducive to sustaining a group of practicing individuals succeed in maintaining and spreading that behavioral repertoire.
- The most fit actual arrangement in the current context will not be the all-things-considered best social arrangement.
- In some cases there may not be a prosocial repertoire because none of them are sustainable.

Evolution of the Moral Experience

- If the way we experience morality evolved, then it too depends on the presence and/or absence of specific behaviors rather than depending on any specific underlying mechanisms.
- The drivers of behavior are merely contingent; however, the restrictions of biology allow us to expand the domain of moral experiences beyond humans and human societies.
- Moral intuitions are a particular flavor of attitude that correlates with the mechanism that enacts those behaviors which are contingently necessary to achieve and sustain a population of individuals who behave in that way.

Whence the Moral Attitudes

- The demands of prosociality, combined with the constraints of behavioral mechanisms in evolved biological creatures, imply that a narrow range of experiences would be expected to correlate with behaviors producing prosocial and antisocial behavior.

- The character, force, and ubiquity of these attitudes reveals, and results from, their import for group sustenance, cohesion, growth, and replications (aka fitness and prosociality).

Moral Attitudes

- Attitudes are the broadest, most inclusive class of phenomena captured under the moral experience.
- An attitude isn't moral because it is coincident with and/or generates prosocial behavior.
- It is a non-linguistic, stimulus-responsive, behavior-inductive, emotionally loaded mental state.
- It can experienced simultaneously (and perhaps mixed) with other emotions, urges, moods, motivations, feelings, etc.

Neurological Evidence for Morality's Flavor

- Jorge Moll et al have uncovered that particular regions of the brain become activated when a social situation involves moral judgments but not when it is emotionally evocative in general.
- They had shown previously that different regions are activated for tasks of moral versus factual discrimination.
- The evidence is helpful in supporting my argument that the critical importance of solving social problems over long enough time spans selected for a distinctive experience with regard to the appropriate behaviors in those social contexts.

The Moral/Conventional Distinction

- Conventional norms are sets of behaviors that are varyingly appropriate in specific contexts, and the appropriateness shows the same contextual contingency as moral norms.

- Behaviors essential to sustainable arrangements attach to moral experiences over evolutionary time, those that are important yet not essential gain weaker moral force, and those that are inessential gain an attitude that is similar in operation but phenomenologically distinct.

- The strongest attitudes, therefore, can be expected to solve problems that have faced groups of individuals the longest.

Universality of Social Problems

- Because
  1) the environments across the globe and across time have been largely similar,
  2) the demands of keeping living things living rather uniform,
  3) the behavioral repertoires that are prosocial and antisocial are similar,

  the key features of behavior-generating mechanisms directed toward prosociality (i.e., moral attitudes) are also similar.

- Prosocial behaviors have been widely observed in diverse animal species and, given the explanations for the attachment of moral attitudes to critically prosocial and antisocial behaviors, the explanation for human moral attitudes run parallel for other species.

Continuity in Nature

- We must consider both variation and similarity across living organisms and the history of organisms across time.
- 1) The descent from a common ancestor, or 2) independent adaptation to similar contexts can explain the evolution of certain socially related emotions shared across species.
- Social behavior among non-human animals, and the cues and contingencies they respond to, are also complex in the same ways that we say human behavior is complex.
- They are quantitatively less complicated, but qualitatively similar to fulfill the same role in the prosociality.

Concluding Remarks

- This represents a broad-stroke investigation into what features we would expect of moral experience given that it has evolved.
- System-level thinking about the origins of moral experiences leads us to consider which behavioral features are essential for prosociality, and what mechanisms may set those behaviors apart from other, less critical, behaviors.
- Animals share similar mechanisms to produce similar behavior, and this implies that there likely exists a great deal of commonality in our moral (and other) experiences.

Implications

- Seeing moral experiences as a natural feature of any evolutionarily successful group has potentially deep and important ramifications for moral theory.
- So does conceiving of moral experiences as universally shared contingent cognitive adaptations to foster prosociality.
- Shifts from (1) explaining the evolutionary role of a psychological phenomenon that we accept as moral, to (2) identifying which behaviors we would expect to be morally linked given the demands of survival and reproduction.

THANK YOU ALL

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