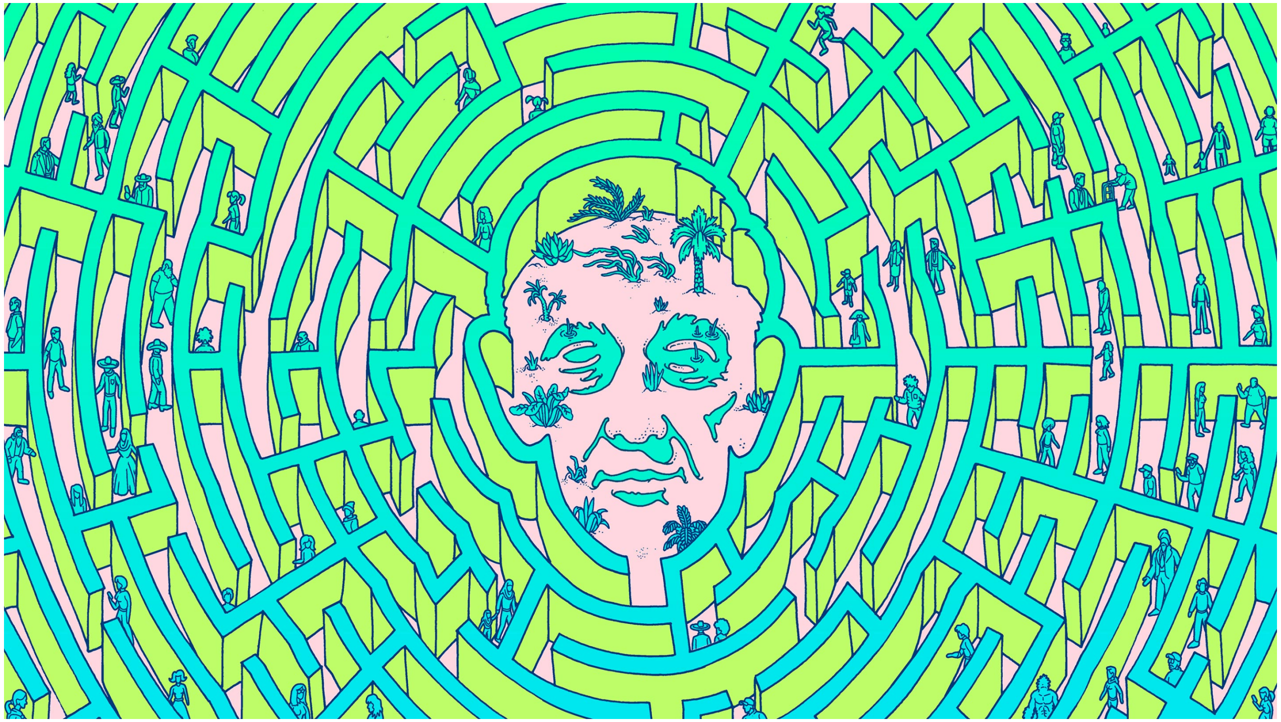
Today's question

To cooperate or not to cooperate?

Game Theory



Lecture 4

Today's docket

1. Challenge of cooperation
   Prisoner's dilemma, Nash equilibrium
2. Mechanisms for cooperation
   Reciprocity, reputation, networks, group and kin selection
3. Neural basis for cooperation
   Brain, problem of asymmetry

Social dilemma, a game-theoretic definition

Other

You

	C	D
C	R	S
D	T	P

Incentive to cooperate if:
R > P

Incentive to defect if:
T > R (against a C)
P > S (against a D)
T > S (against a D)

If two cooperators obtain a higher payoff yet there is incentive to defect

Challenge of cooperation

DARTMOUTH

Prisoner's dilemma

		Other	
		stay silent	betray
You	stay silent	-1 / -1	0 / -3
	betray	-3 / 0	-2 / -2

no jail time

Natural selection ought to favor defectors over cooperators

Nash equilibrium

- A Nash Equilibrium is a profile of strategies such that each player's strategy is an optimal response to the other players strategies
- If all players play according to the NE, no player has any incentive to change their action unilaterally
- Therefore, NE is the most likely, stable outcome (e.g., mutual defection in PD). Any form of choice deviating from NE is *irrational*

If no player can do better by unilaterally changing their strategy

Challenge of cooperation

DARTMOUTH

Nash equilibrium

EQUILIBRIUM POINTS IN N-PERSON GAMES

BY JOHN F. NASH, JR.*

PRINCETON UNIVERSITY

Communicated by S. Lefschetz, November 16, 1949

One may define a concept of an n-person game in which each player has a finite set of pure strategies and in which a definite set of payments to the n players corresponds to each n-tuple of pure strategies, one strategy being taken for each player. For mixed strategies, which are probability

distributions over the pure strategies, the pay-off functions are the expectations of the players, thus becoming polylinear forms in the probabilities with which the various players play their various pure strategies.

Any n-tuple of strategies, one for each player, may be regarded as a point in the product space obtained by multiplying the n strategy spaces of the players. One such n-tuple counters another if the strategy of each player in the countering n-tuple yields the highest obtainable expectation for its player against the $n - 1$ strategies of the other players in the countered n-tuple. A self-countering n-tuple is called an equilibrium point.

The correspondence of each n-tuple with its set of countering n-tuples gives a one-to-many mapping of the product space into itself. From the definition of countering we see that the set of countering points of a point is convex. By using the continuity of the pay-off functions we see that the graph of the mapping is closed. The closedness is equivalent to saying: if $P_1, P_2, \ldots$ and $Q_1, Q_2, \ldots, Q_n, \ldots$ are sequences of points in the product space where $Q_n \to Q$, $P_n \to P$ and Q_n counters P_n then Q counters P.

Since the graph is closed and since the image of each point under the mapping is convex, we infer from Kakutani's theorem[1] that the mapping has a fixed point (i.e., point contained in its image). Hence there is an equilibrium point.

In the two-person zero-sum case the "main theorem"[2] and the existence of an equilibrium point are equivalent. In this case any two equilibrium points lead to the same expectations for the players, but this need not occur in general.

* The author is indebted to Dr. David Gale for suggesting the use of Kakutani's theorem to simplify the proof and to the A. E. C. for financial support.

[1] Kakutani, S., *Duke Math. J.*, 8, 457–459 (1941).

[2] Von Neumann, J., and Morgenstern, O., *The Theory of Games and Economic Behaviour*, Chap. 3, Princeton University Press, Princeton, 1947.

Prisoner's dilemma

- Superpowers engaged in arms race
- Performance enhancing drugs in sports
- Two (or more) competitors battling for market share

Real-world examples

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Yet, humans intuitively cooperate

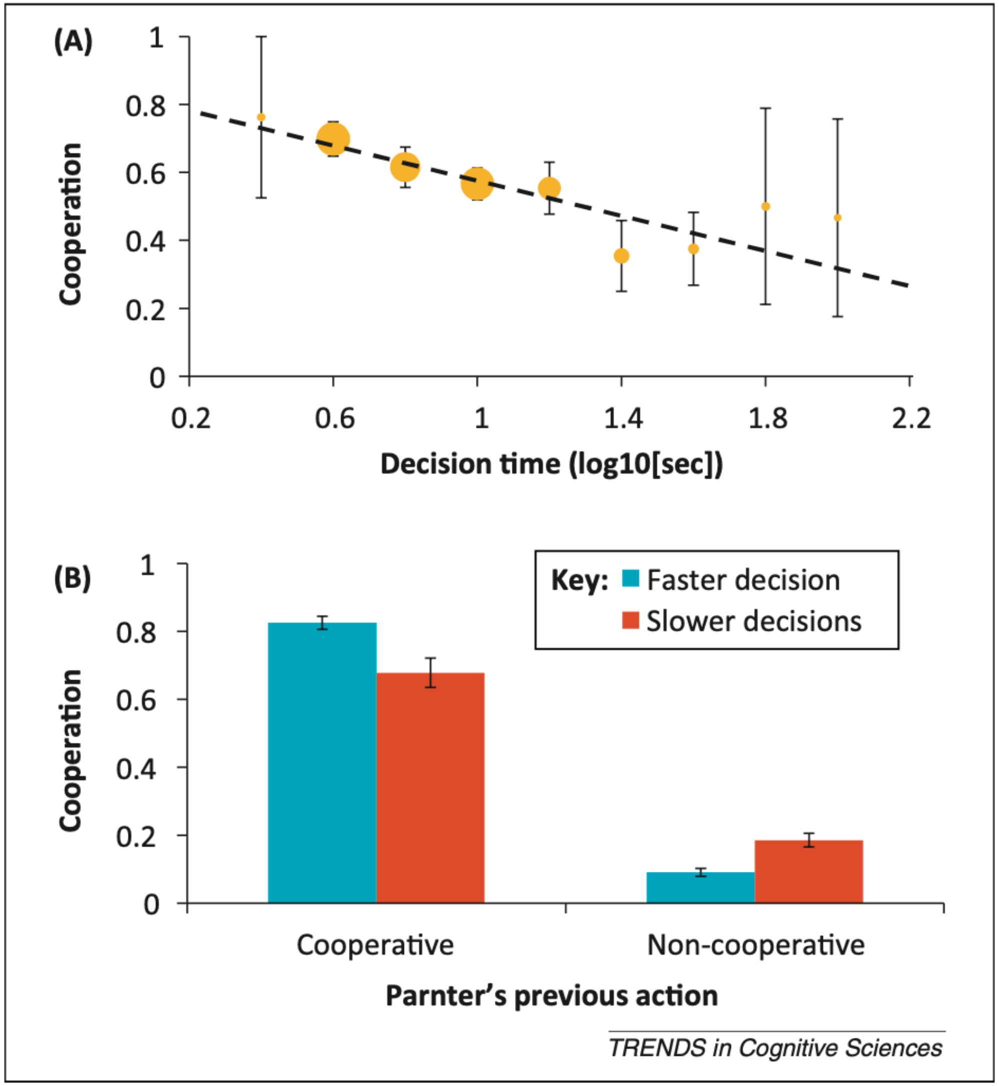


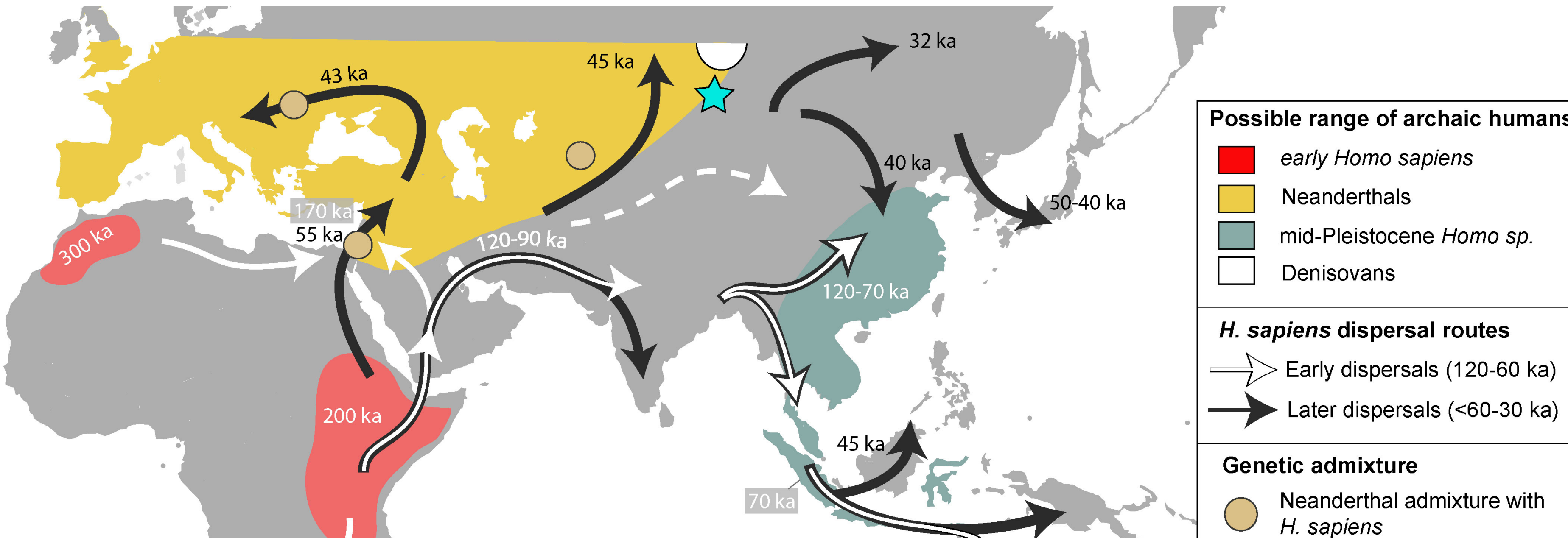
Figure 5. Automatic, intuitive responses involve reciprocal cooperation strategies.

Human cooperation

David G. Rand[1] and Martin A. Nowak[2]

Mechanisms for cooperation

Natural selection promoted cooperation



Humans beat Neanderthals at attrition warfare

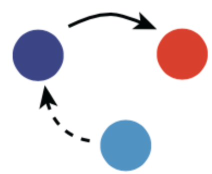
Natural selection promoted cooperation

Chimp war is not dissimilar from human war

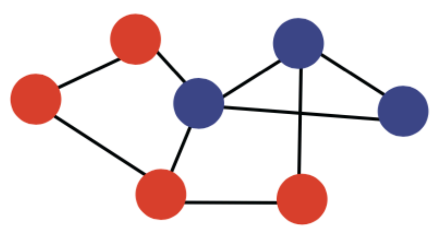
Evolutionary mechanisms

Direct reciprocity

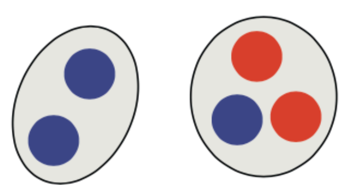
Indirect reciprocity



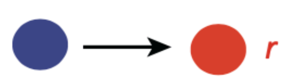
Spatial selection



Multi-level selection

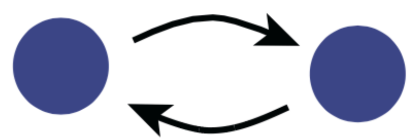


Kin selection

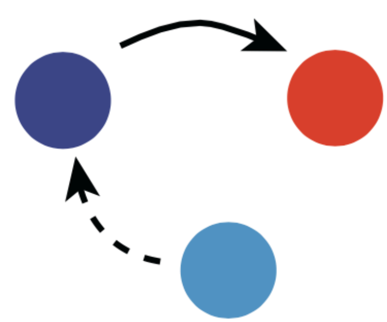


Reciprocity and reputation

Direct reciprocity



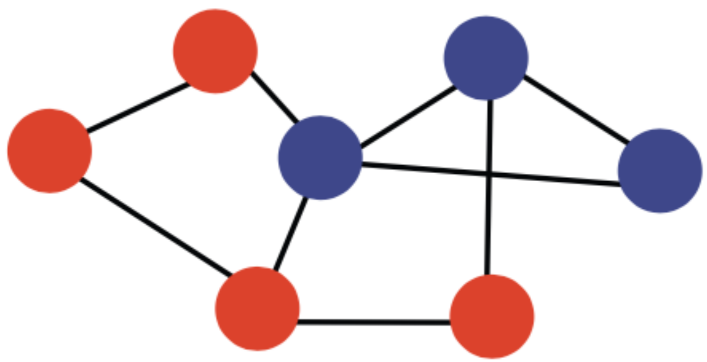
Indirect reciprocity



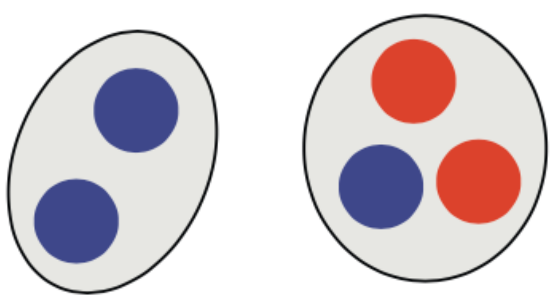
Strategic behaviors depend on previous outcomes and reputation

Networks, group and kin selection

Spatial selection



Multi-level selection



Kin selection

Clusters of cooperators prevail because of higher payoffs

Selection favored flexible group bias

Infants prefer those who harm dissimilar others

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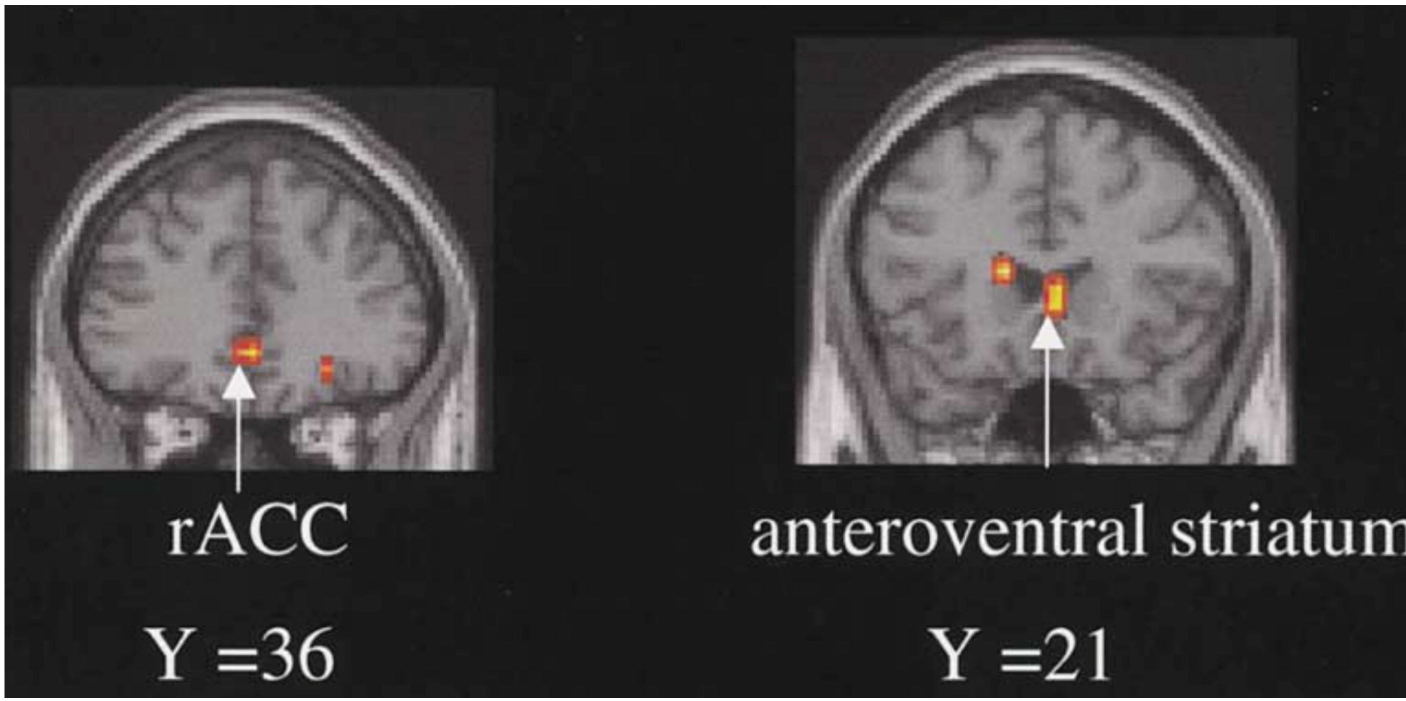
Neural basis for cooperation

DARTMOUTH

Iterated prisoner’s dilemma

Figure 7. Decision-Making Epoch: Activation Related to the Decision-Making Epoch

(A) Voxels activated more when player A chose cooperation following a cooperative choice by her partner in the previous round



A

		Player A	
		Coop	Defect
Player B	Coop	**$2**(2)	**$3**(0)
	Defect	**$0**(3)	**$1**(1)

Figure 1. Study Design

(A) Payoff matrix used for the four outcomes in the Prisoner’s Dilemma Game. Scanned subject’s choices (C or D; player A) are listed atop columns and nonscanned subject’s choices (C or D; player B) are listed aside rows. Dollar amounts in bold are awarded to player A. Amounts in parentheses are awarded to player B.

Neuron, Vol. 35, 395–405, July 18, 2002, Copyright ©2002 by Cell Press

A Neural Basis for Social Cooperation

James K. Rilling,[1,2] David A. Gutman, Thorsten R. Zeh, Giuseppe Pagnoni, Gregory S. Berns, and Clinton D. Kilts

Neural activation of sustaining cooperative social relationships

The problem of knowledge asymmetry

Strategic reasoning presupposes full knowledge of payoff outcomes

Take-home concepts

- Natural selection favors strategic defection in rational selfish maximizers

- Paradoxically, the human species developed a predisposition towards cooperation, likely benefitting competition with other species (e.g., Neanderthals)

- Strategic reasoning presupposes full knowledge including other agents' options, which might not be realistic

Next up

- Agent-based Modeling