Neuroeconomics :

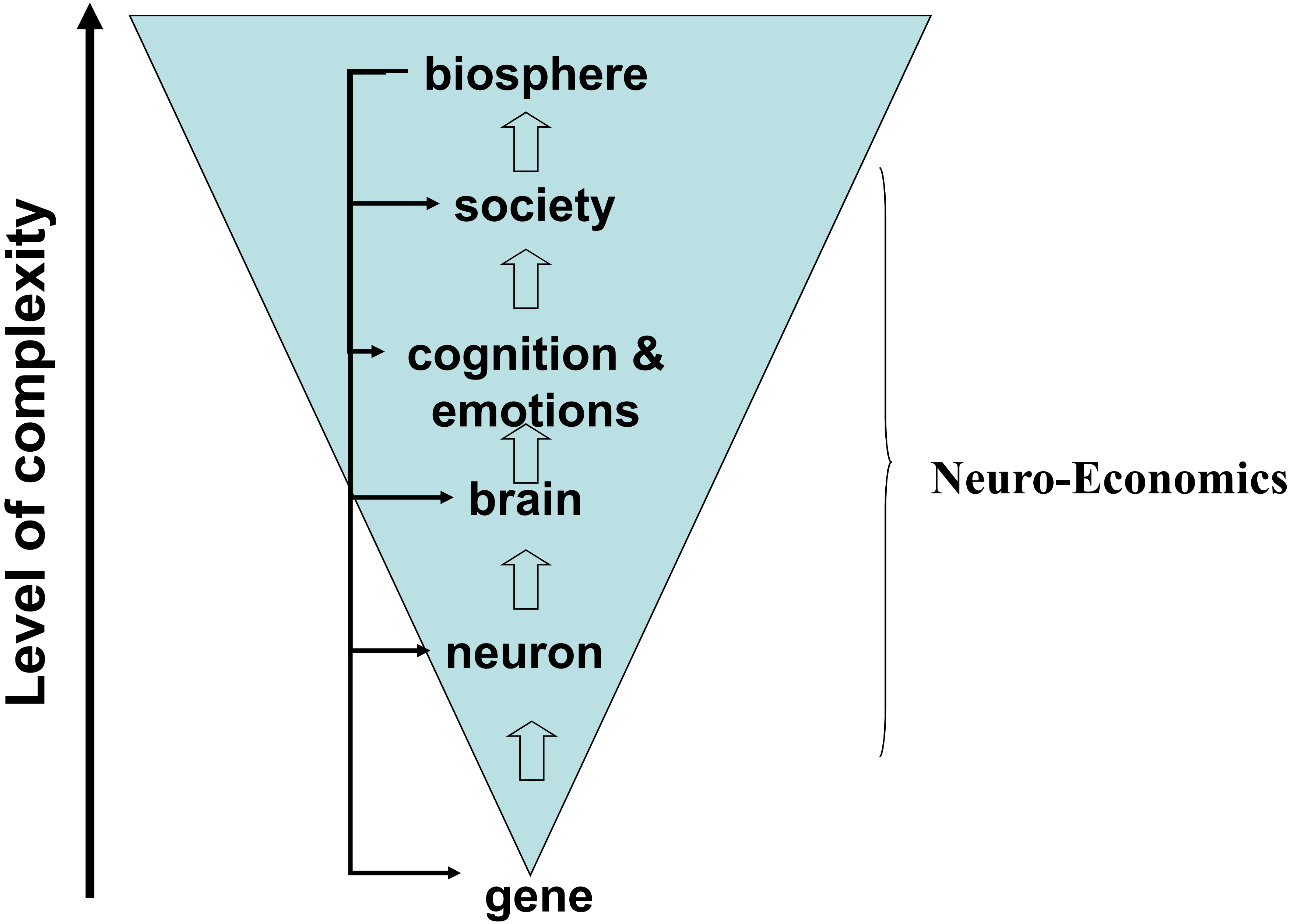
Neuroscience of decision making

Lecture N8

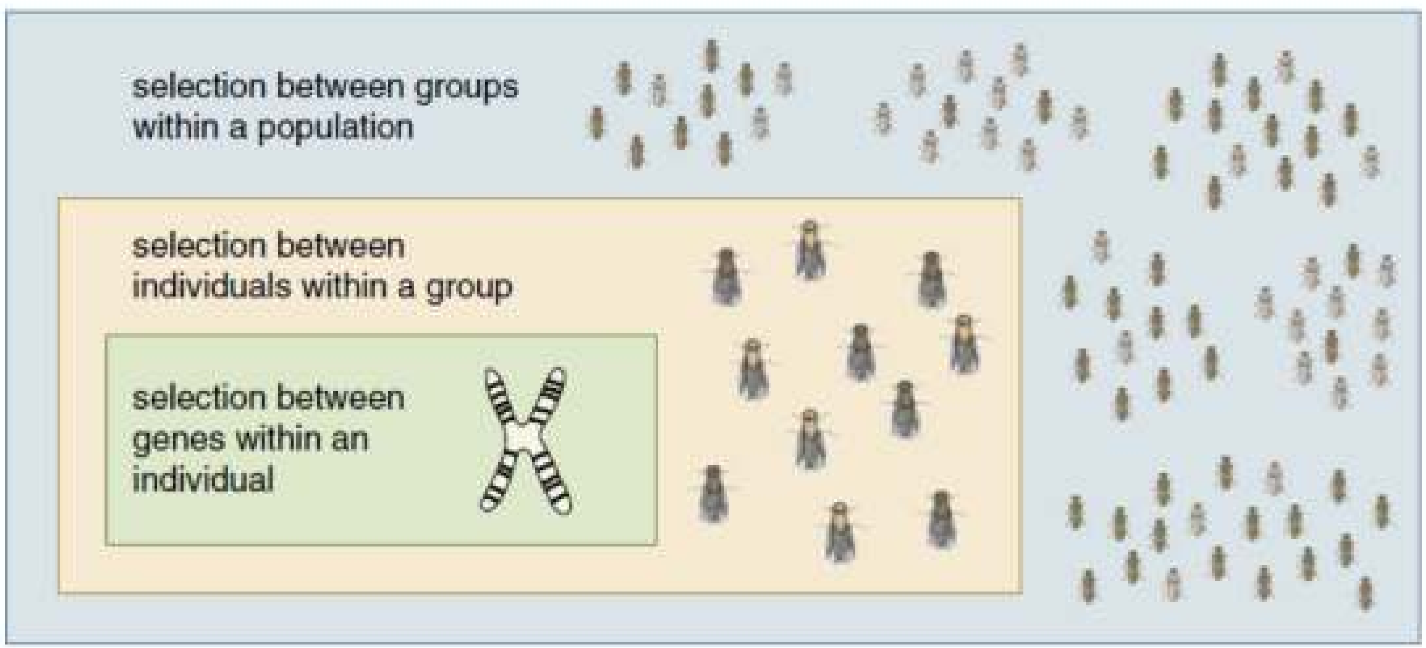
The social brain: Games in the brain.

Vasily Klucharev

-Higher School of Economics


Level of complexity
biosphere
society
cognition &
emotions
brain
neuron
gene
Neuro-Economics

Group (multilevel) selection theory - natural selection takes place at multiple levels: genes, individuals, group of individuals.

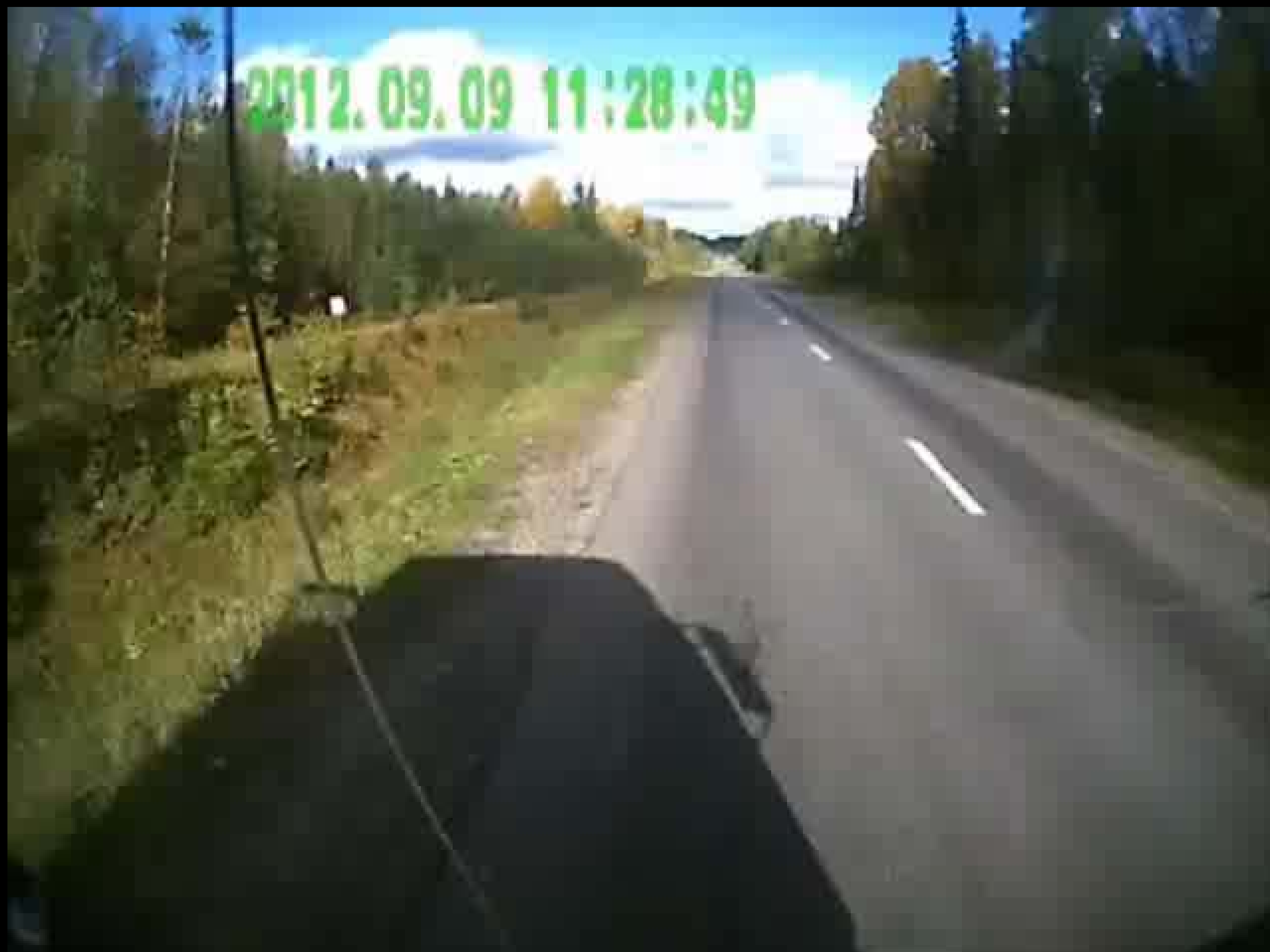


Group (multilevel) selection theory

- Selection between individuals within groups **favors cheating behaviors**, even at the expense of the group as a whole.

- Selection between groups within the total population **favors behaviors that increase the relative fitness of the whole group**.

David Sloan Wilson and Edward O. Wilson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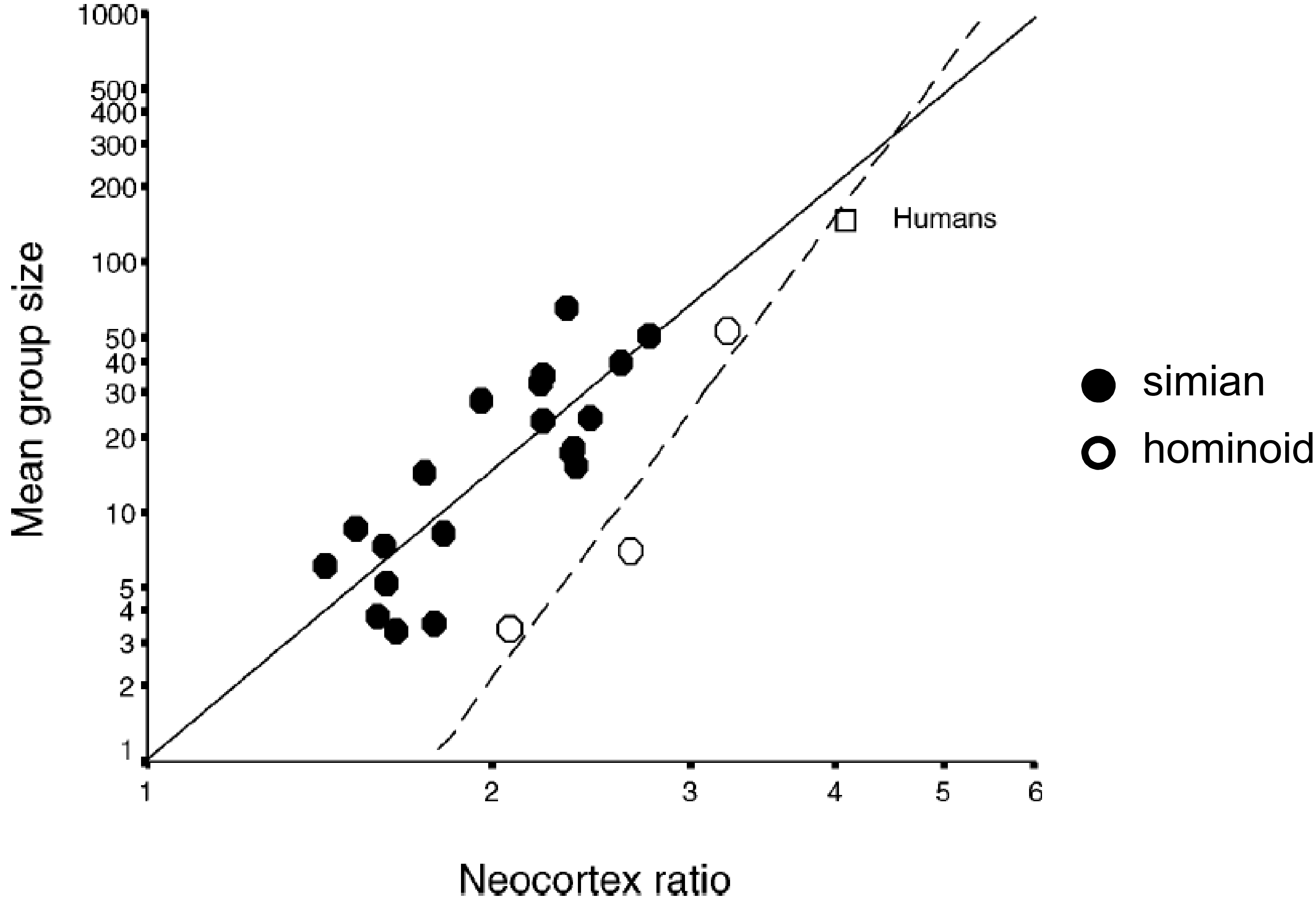
Mechanisms of cooperation *(Bowles S, Gintis H):*

- Cooperation is advantageous at the group level.
- Society protects altruists from exploitation by the self-interested, e.g. weapons lower costs of the coordinated punishment of norm violators.
- Long socialization leads to internalized norms.
- Between-group competition for resources stimulates within-group cooperation.

Various indices of social complexity or skill have been correlated against neocortex volume in primates:

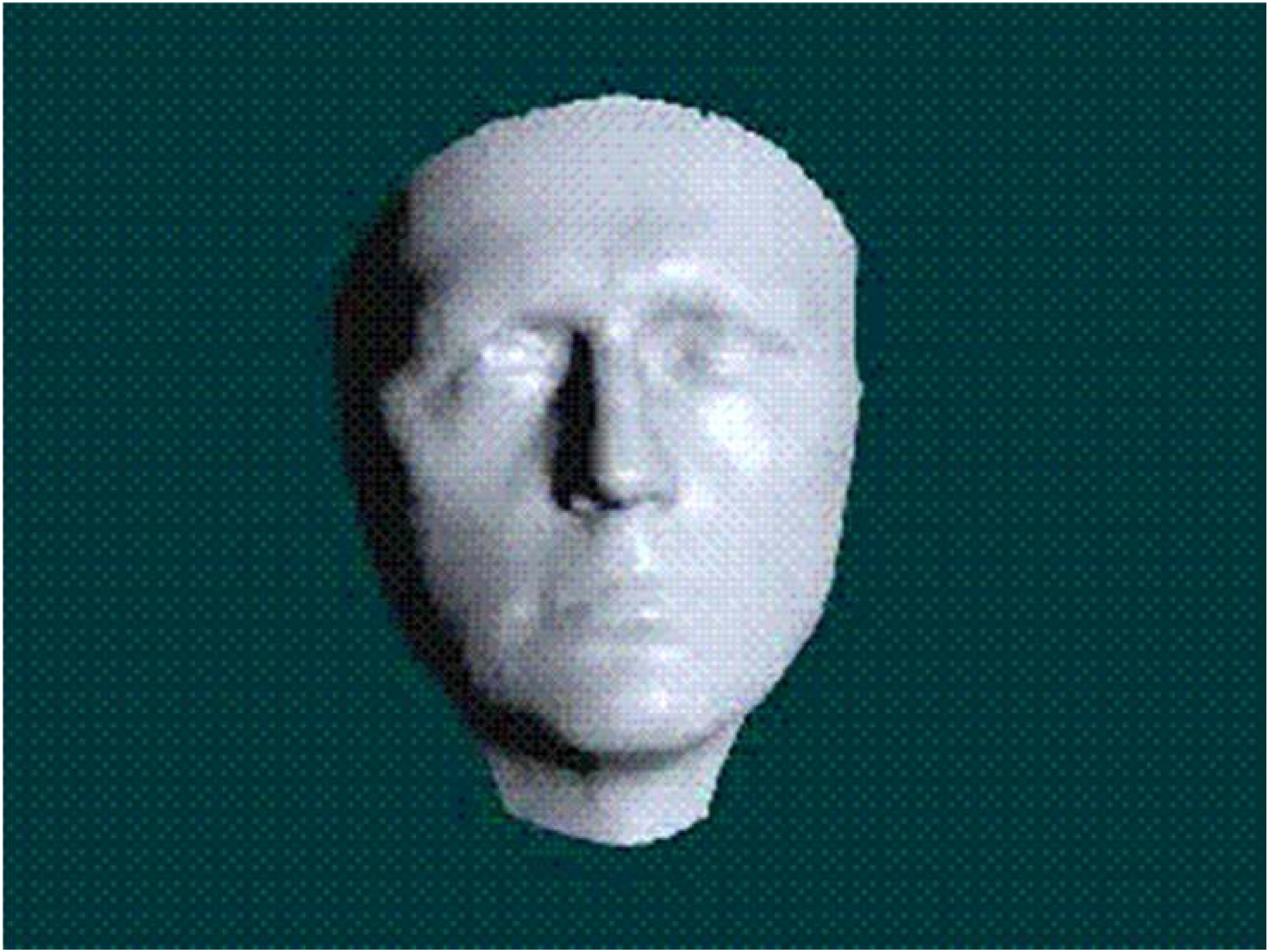
- social group size (Sawaguchi &Kudo 1990; Dunbar 1992, 1998; Barton 1996; Barton&Dunbar 1997),
- grooming clique size (Kudo & Dunbar 2001),
- the extent to which social skills are used in male mating strategies (Pawlowski et al. 1997),
- the frequency of tactical deception (Byrne 1995, 1996)
- the frequency of social play (Lewis 2001).



Mean social group size for individual primate species plotted against relative neocortex volume (indexed as neocortex volume divided by the volume of the rest of the brain). Simian (*solid symbols*) and hominoid (*open symbols*) taxa are shown separately. The datapoint for humans is that obtained by Dunbar (1992a). Barrett et al. (2002).

R.I.M. Dunbar ***THE SOCIAL BRAIN:*** *Mind, Language, and Society in Evolutionary Perspective Annu. Rev. Anthropol. 2003. 32:163–81*

Evolutionary adaptation in perception: innate recognition.




Prosopagnosia

- (face blindness) – a disorder of face perception where the ability to recognize faces is impaired, while the ability to recognize other objects can be relatively intact.
- The term originally referred to a condition following acute brain damage, but recently a congenital form of the disorder has been identified, which is inherited by about 2.5% of the population
- The specific brain area usually associated with prosopagnosia is the *fusiform gyrus*.

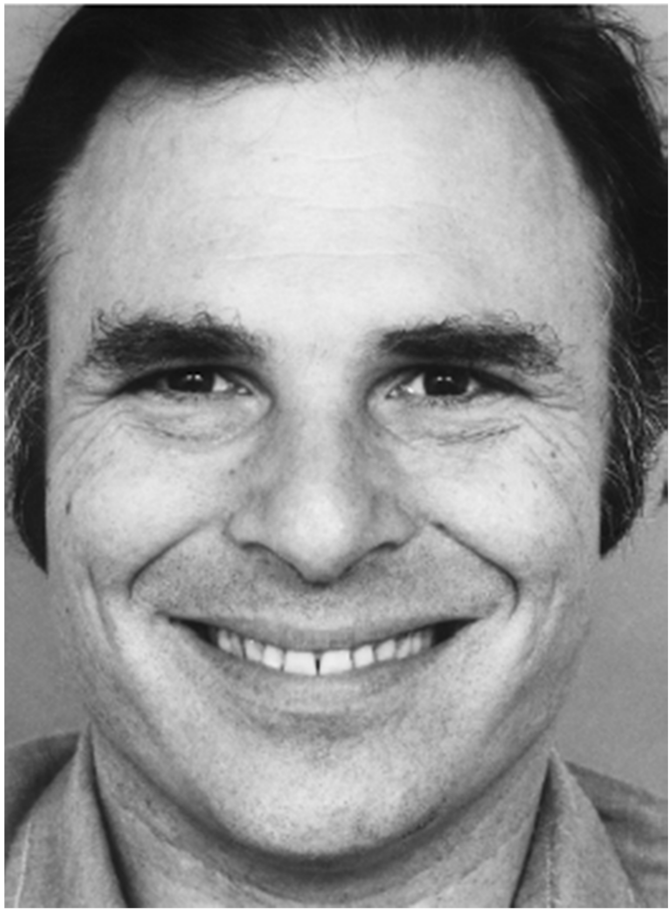
This is Hans, my husband

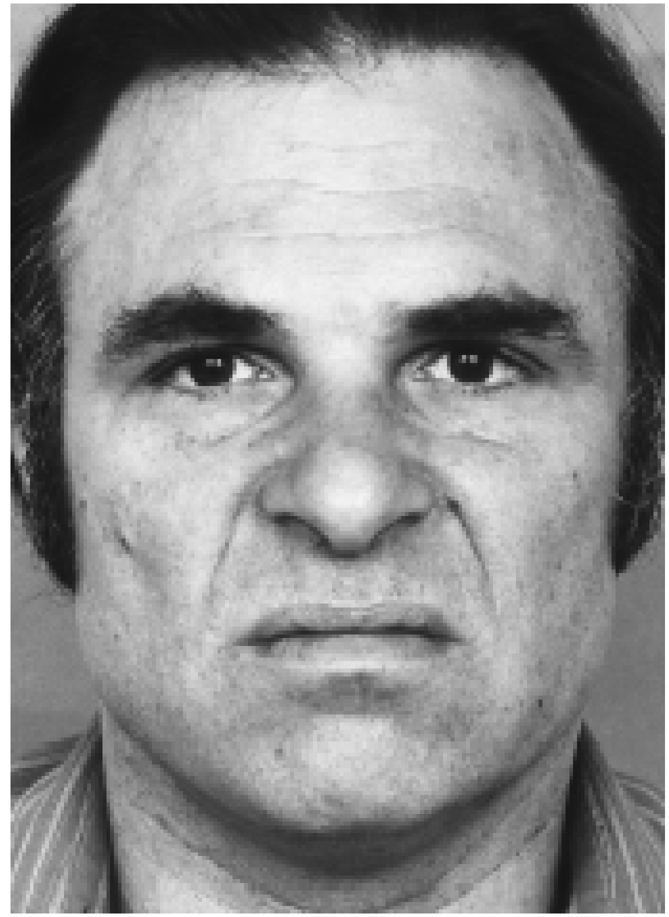
When it is someone I know really well, such as my husband, I often have a less good image for some reason. What I have is mainly the feeling that the person invokes in me.

Whether I visualize someone straight in front of me or look beside the image does not seem to make much of a difference for the result when it is someone I know really well.

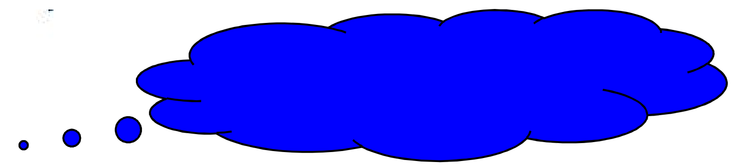
YES
I don't need to see his face to know who it is. As most people with their loved ones, I can see a part of his neck over a shelf 50 meters away and know it is him. Seing his face makes me even more sure, but that is probably largely because I can see in his face how well he knows me. Of course I also knows how he usally moves and acts, so seeing that helps too.

http://www.prosopagnosia.com/main/faces/





	It rains	It does not rain
Umbrella	15	15
No umbrella	0	18



	Shoot	Not Shoot
Umbrella	15 -15	15 0
No umbrella	0 15	18 0

Game Theory

- **Game Theory** aims to help us understand situations in which decision-makers interact.

- A **game** - a competitive activity in which players contend with each other according to a set of rules.

A standard Game has two components:

- a **Set of all actions** that are available to the decision-maker.
- and a specification of the decision-maker's preferences **-** a **payoff function** (u = utility function), which associates a number with each action in such a way that actions with higher numbers are preferred.

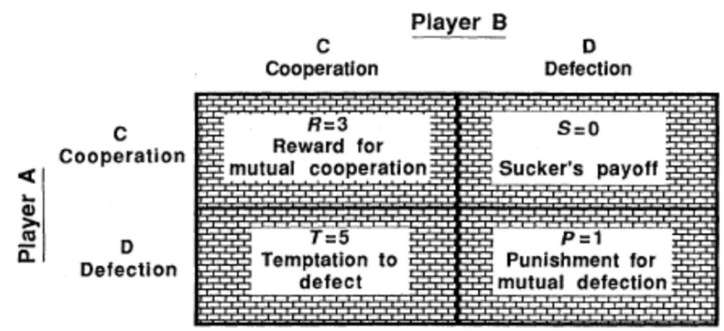


Fig. 1. The Prisoner's Dilemma game. The payoff to player A is shown with illustrative numerical values. The game is defined by $T > R > P > S$ and $R > (S + T)/2$.

The payoff function **u** represents a decision-maker's preferences for any actions *a* and *b*
u(a) > u(b) if the decision-maker prefers a to b.

The theory of rational choice

The theory of rational choice :

- the action chosen by a decision-maker is at least as good, according to her preferences, as every other available action.

= The rule of maximization

Choose the alternative with the highest utility. If more than one alternative has the highest utility, pick one of them (no matter which).

Strategic games

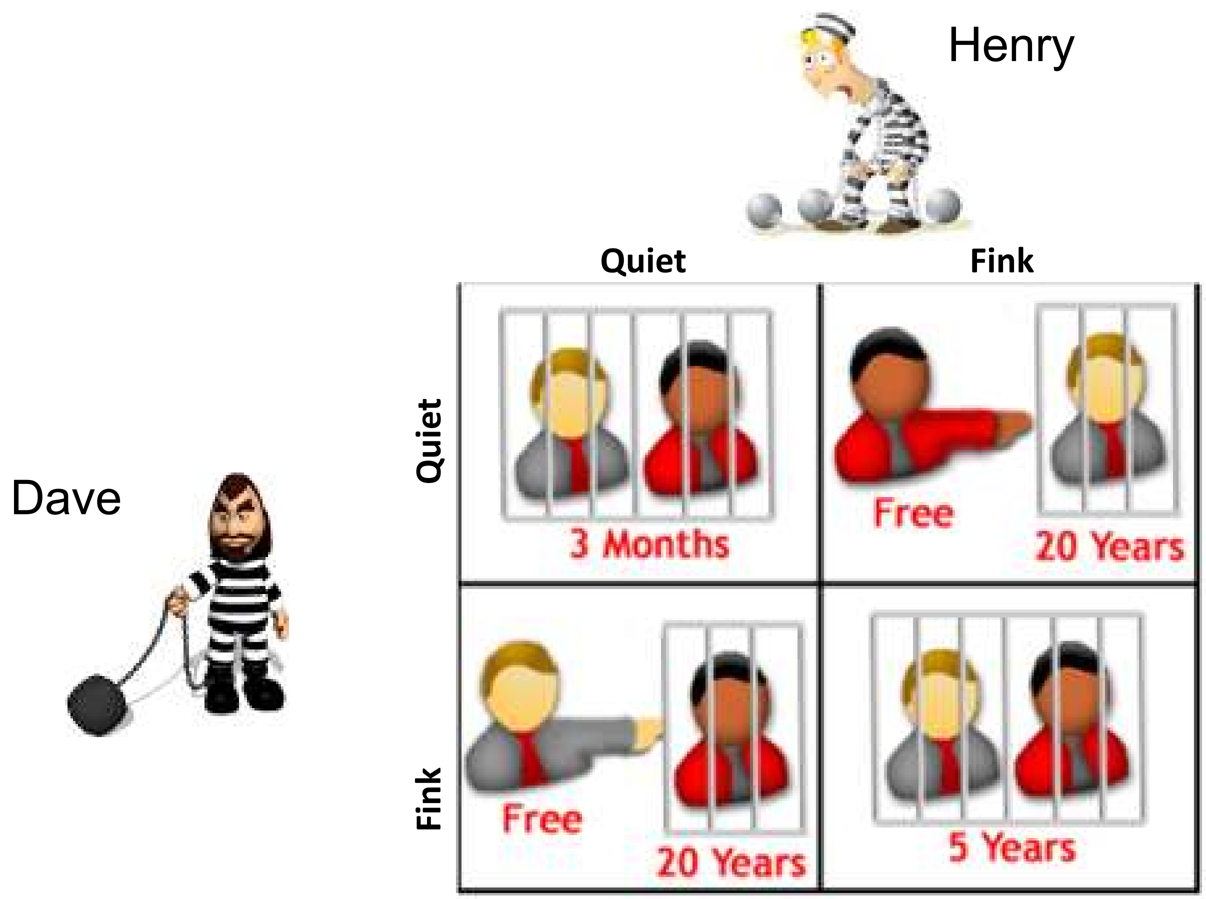
Thus, a **Strategic game** (with ordinal preferences) consists of:

- a set of **players** (decision-makers)
- for each player, a set of **actions**
- for each player, **preferences** over the set of action profiles.

Prisoner's Dilemma

- Two suspects in a major crime are held in separate cells.
- There is enough evidence to convict each of them of a minor offense, but not enough evidence to convict either of them of the major crime unless one of them acts as an informer against the other (finks).
- If they both stay quiet, each will be convicted of the minor offense and spend 3 months year in prison.
- If one and only one of them finks, she will be freed and used as a witness against the other, who will spend 20 years in prison.
- If they both fink, each will spend 5 years in prison.

Prisoner's Dilemma



Strategic game:

Players: The two suspects.

Actions: Each player's set of actions is (Quiet, Fink).

Preferences:

u_1(Fink, Quiet) > u_1 (Quiet, Quiet) > u_1 (Fink, Fink) > u_1 (Quiet, Fink).

Specification

Suspect 1:

u_1(Fink, Quiet) = 3, u_1(Quiet, Quiet) = 2, u_1(Fink, Fink) = 1, and u_1(Quiet, Fink) = 0.

Suspect 2:

u_2(Fink, Quiet) = 3, u_2(Quiet, Quiet) = 2, u_2(Fink, Fink) = 1, and u_2 (Quiet, Fink) = 0.

The Prisoner's Dilemma models a situation in which there are gains from cooperation but each player has an incentive to free ride.

“Renting” Dilemma

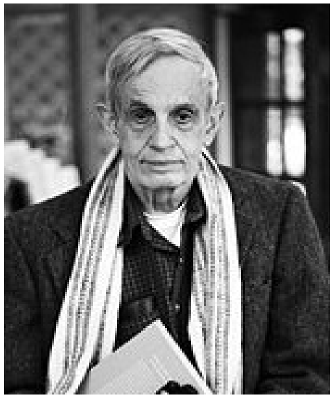
Henry (customer)

Dave (landlord)

	Cooperate	Defect
Cooperate	 U = 250$	 X U = -250$
Defect	X  U = 500$	X X U = 0$

Nash equilibrium

Informally, a set of strategies is a **Nash equilibrium** if no player can do better by unilaterally changing his or her strategy



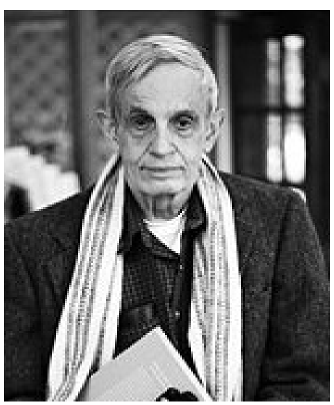
John Forbes Nash

Player 2

		Cooperate	Defect
Player 1	Cooperate	250$/250$	-250$/500$
	Defect	500$/-250$	0$/0$

Nash equilibrium

Informally, a set of strategies is a **Nash equilibrium** if no player can do better by unilaterally changing his or her strategy



John Forbes Nash

Player 2

Player 1		Cooperate	Defect
	Cooperate	250$/250$	-250$/500$
	Defect	500$/-250$	0$/0$

	Column Player Cooperate	Defect
Cooperate	3,3	0,5
Defect	5,0	1,1

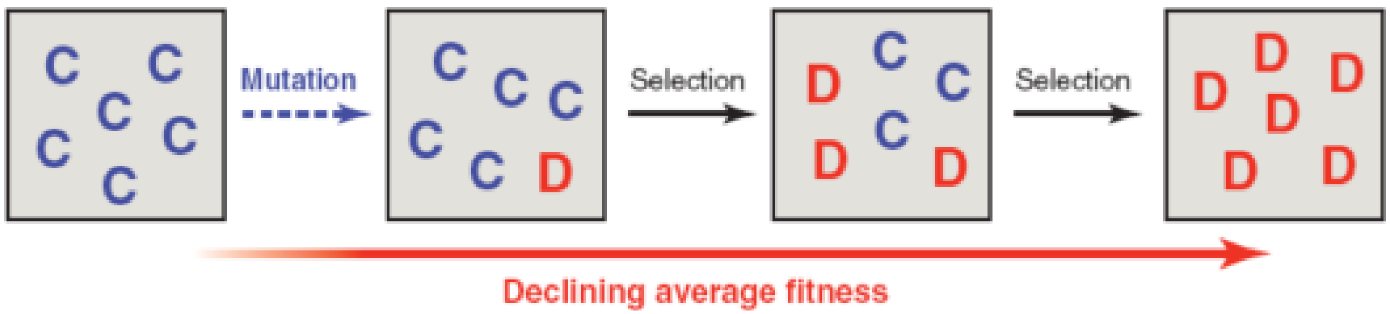
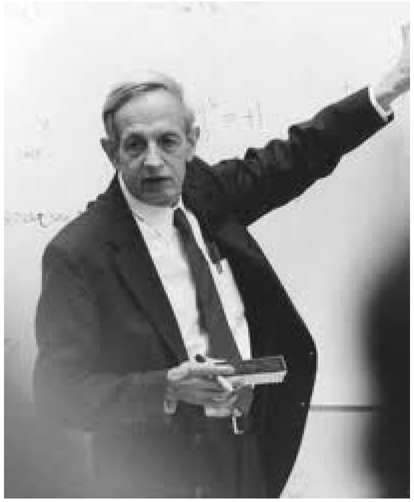


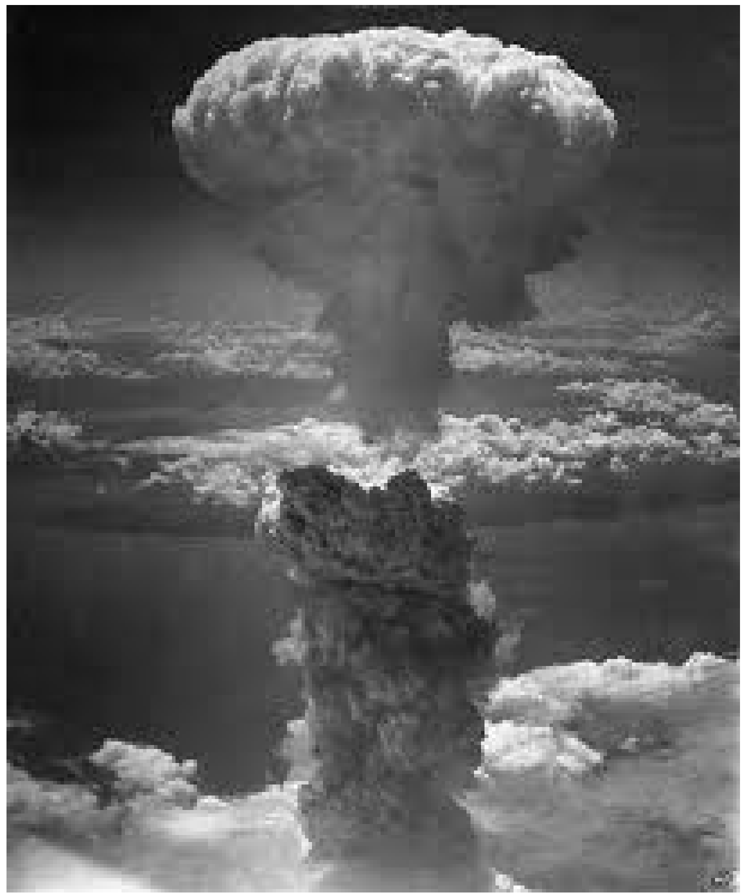
Fig. 1. Without any mechanism for the evolution of cooperation, natural selection favors defectors. In a mixed population, defectors, *D*, have a higher payoff (= fitness) than cooperators, *C*. Therefore, natural selection continuously reduces the abundance, *i*, of cooperators until they are extinct. The average fitness of the population also declines under natural selection. The total population size is given by *N*. If there are *i* cooperators and $N - i$ defectors, then the fitness of cooperators and defectors, respectively, is given by $f_C = [b(i-1)/(N-1)] - c$ and $f_D = bi/(N-1)$. The average fitness of the population is given by $\bar{f} = (b-c)i/N$.



	Cooperate	Defect
	3,3	0,5
	5,0	1,1

John Forbes Nash, Jr.
(born June 13, 1928)

John von Neumann
(1903 – 1957)



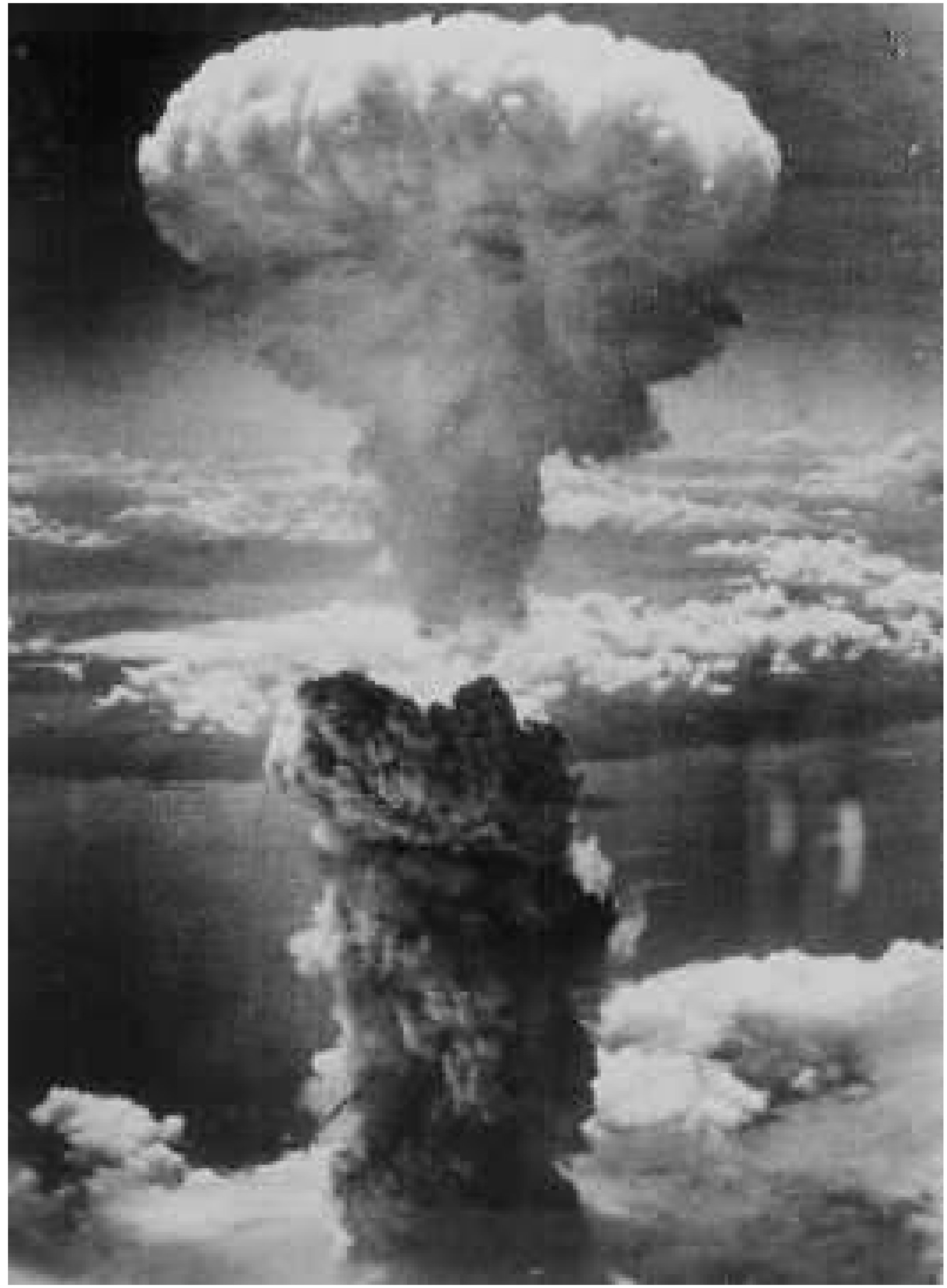
RAND
CORPORATION

"If you say why not bomb them tomorrow, I say why not today? If you say today at 5
o'clock, I say why not at 1
o'clock?"

John von Neumann

"Because Russia did not acquiesce in the Baruch Plan for the international control of atomic energy, the West should wage preventive war."

Bertrand Russell



Any reason for an individual to cooperate?

ω [omega] - the probability that the players will meet again, the discount parameter or, poetically, the *shadow of the future*.

When ω is low – that is, the players have a negligible chance of meeting again – each interaction is effectively a *single-shot Prisoner's Dilemma* game, and one might as well defect in all cases (a strategy called "ALL D"), because even if one cooperates there is no way to keep the other player from exploiting that.

A question…

- A **lame duck** is an elected official who is approaching the end of his or her tenure, and especially an official whose successor has already been elected.

Axioms

- if the game is only played once, then each player gets a higher payoff from defecting than from cooperating, regardless of what the other player does.
- if the game is played repeatedly (the iterated Prisoner's Dilemma, or IPD), there is greater room for cooperation.

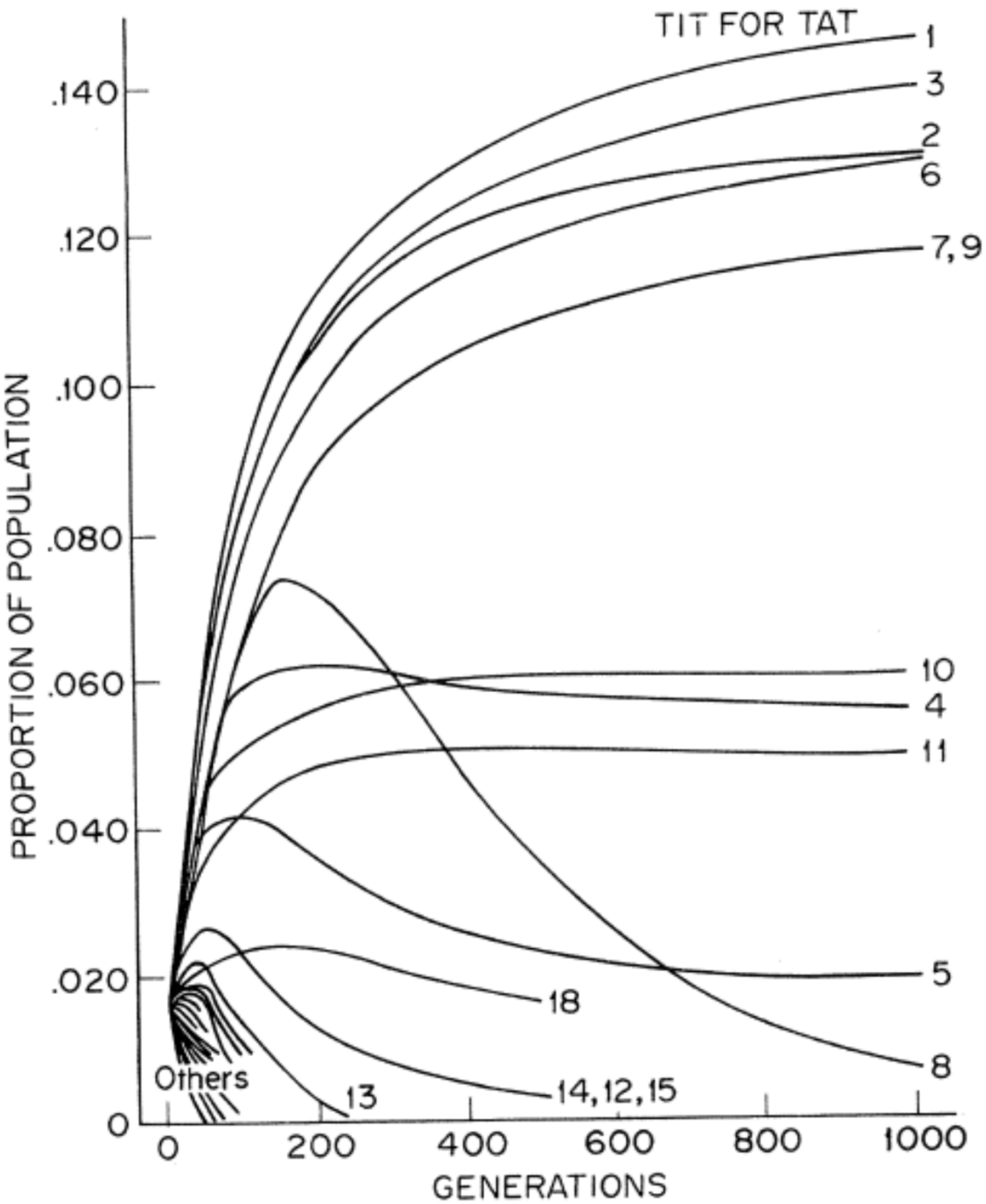


Figure 1: Simulated Ecological Success of the Decision Rules

TFT uses cooperation on the first move of the game and then plays whatever the other player chose on the previous move.

The Further Evolution of Cooperation

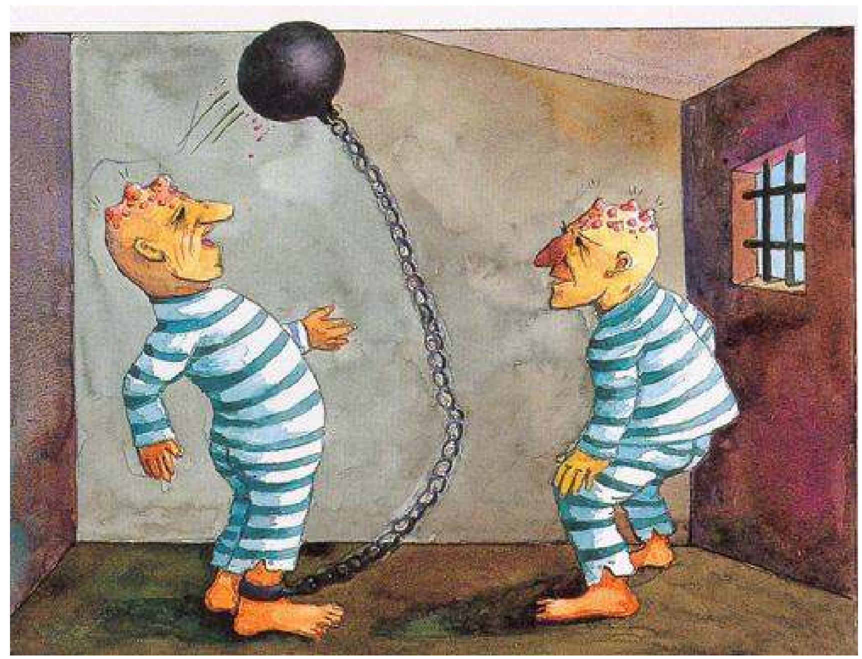
Robert Axelrod and Douglas Dion

Success in an evolutionary "game" correlated with the following characteristics – **TIT FOR TAT** :

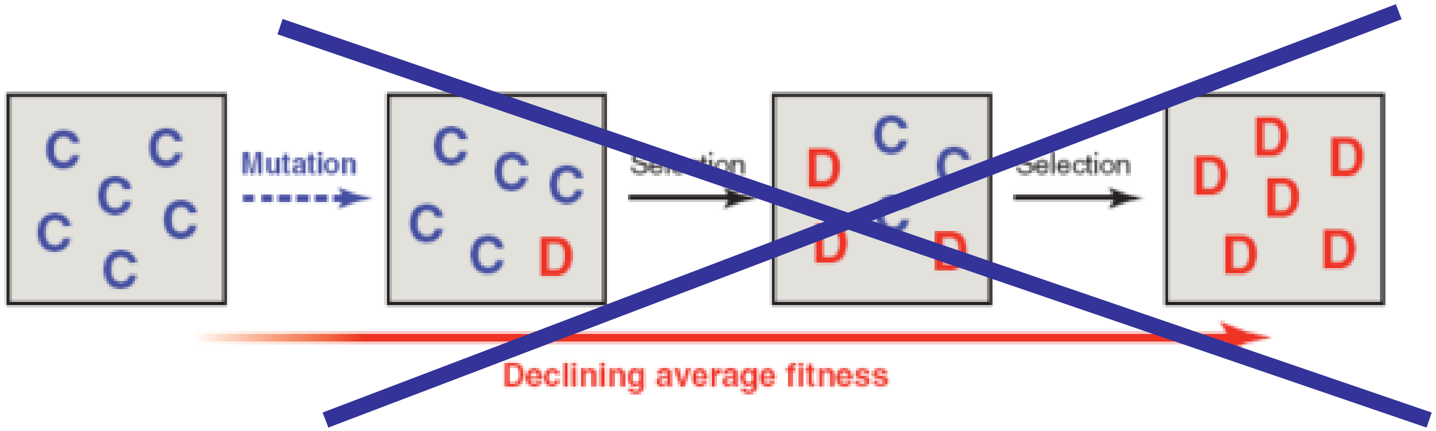
- **Be nice:** cooperate, never be the first to defect.
- **Be provocable:** return defection for defection, cooperation for cooperation.
- **Don't be envious:** be fair with your partner.
- **Don't be too clever:** or, don't try to be tricky.

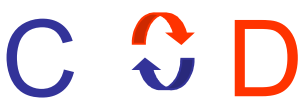
TFT is stable

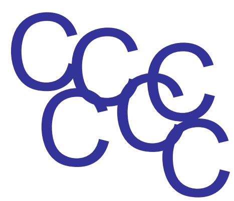
- A strategy is collectively stable if no strategy can invade it.
- In ecological simulation, TFT quickly became the most common strategy – everyone using TFT is a Nash equilibrium when the shadow of the future ω [omega] is sufficiently high.
- When there is a credible threat of future retaliation (ω), it overcomes defection and supports cooperation.



	Column Player	
	Cooperate	Defect
Cooperate	3,3	0,5
Defect	5,0	1,1







Stimulate cooperation:

- Direct reciprocity - if I cooperate now, you may cooperate later
- Clusters – cooperate within groups
- Punishment - punish non-cooperators

A Neural Basis for Social Cooperation

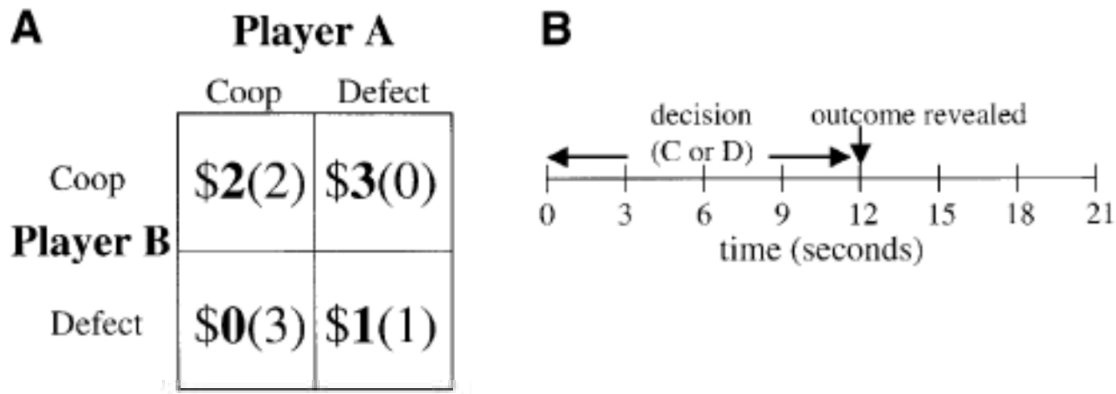


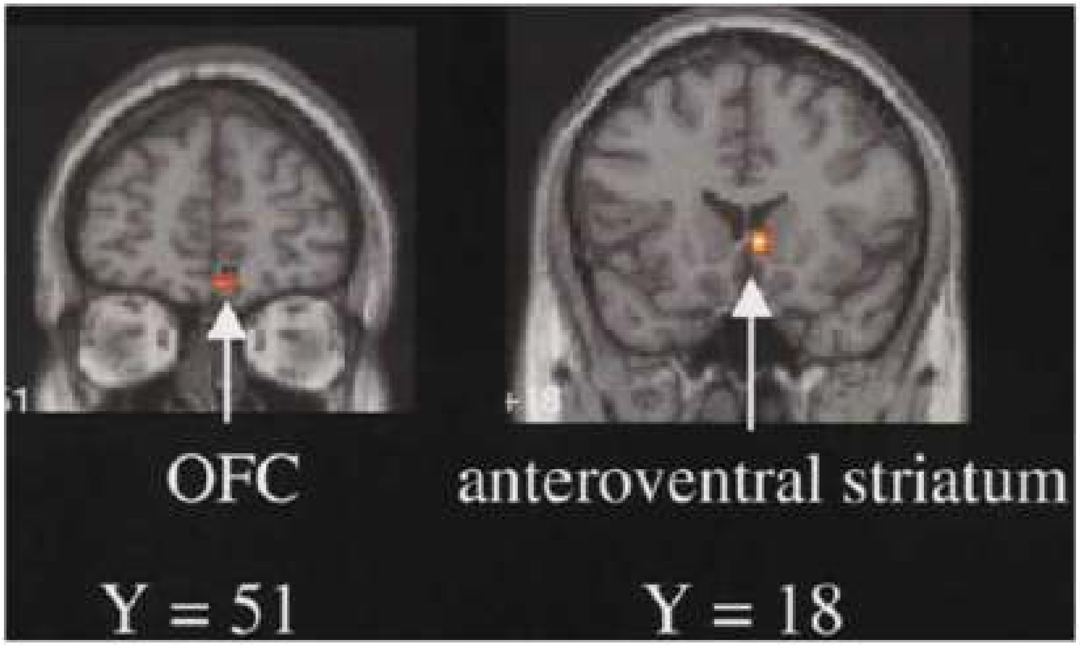
Figure 1. Study Design

(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.
(B) Time course of a single round of the Prisoner's Dilemma Game.

In the iterated Prisoner's dilemma two players simultaneously and independently choose to either cooperate with each other or not and receive a payoff that depends upon the interaction of their two choices.

Rilling et al 2002

nucleus accumbens



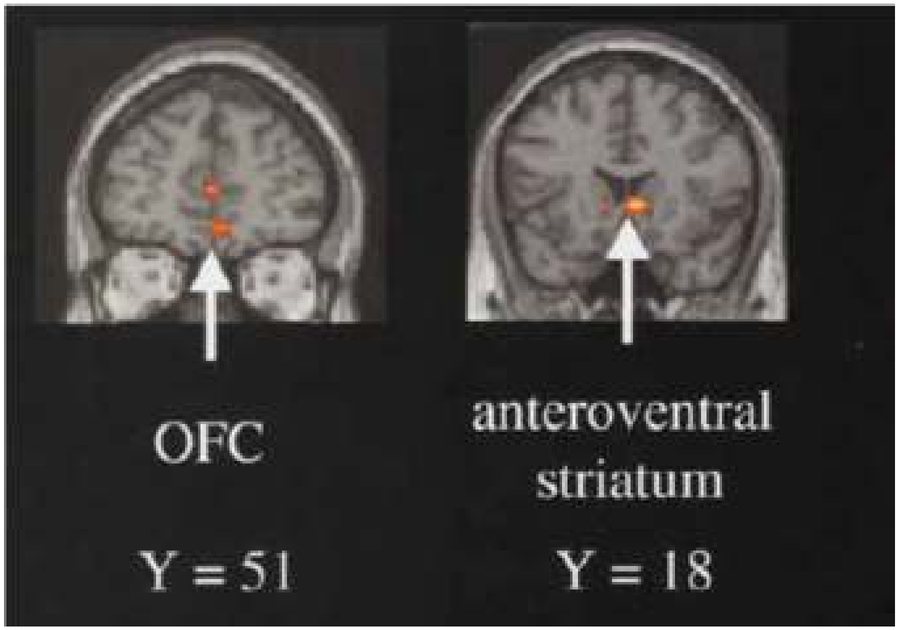
Reaction (outcome) Epoch
Activation in player A. Voxels activated for the interaction of player A and player B's choices (CC - CD) - (DC - DD)

C – cooperation
D – defection

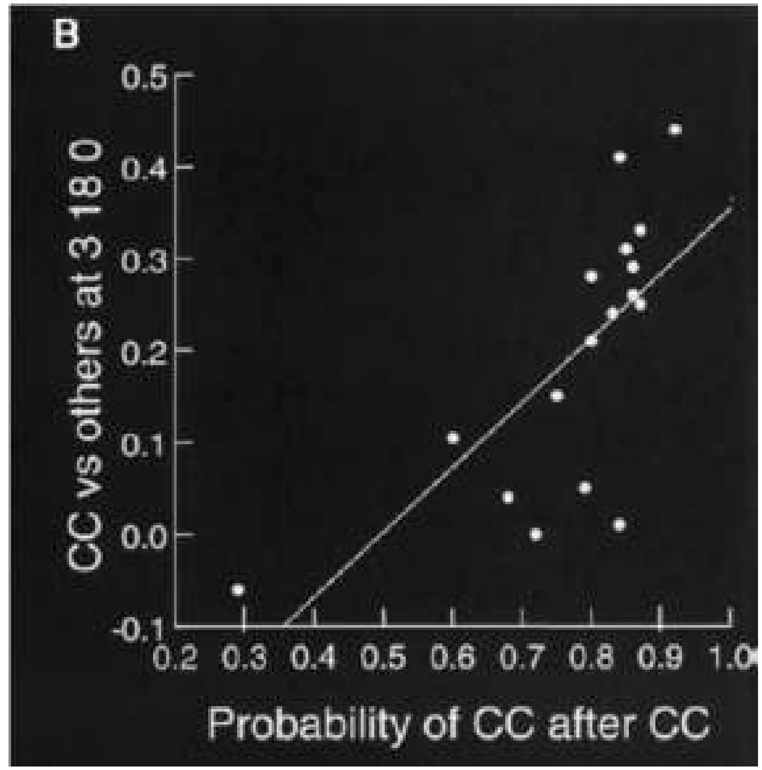
OFC – orbitofrontal cortex
Anterovetral striatum – nucleus accumbens

Rilling et al 2002

nucleus accumbens



nucleus accumbens



Reaction (outcome) Epoch:

Activation in Player A in Response to CC Outcomes.

(A) Voxels activated more by mutual cooperation (CC) than the mean of the other three outcomes

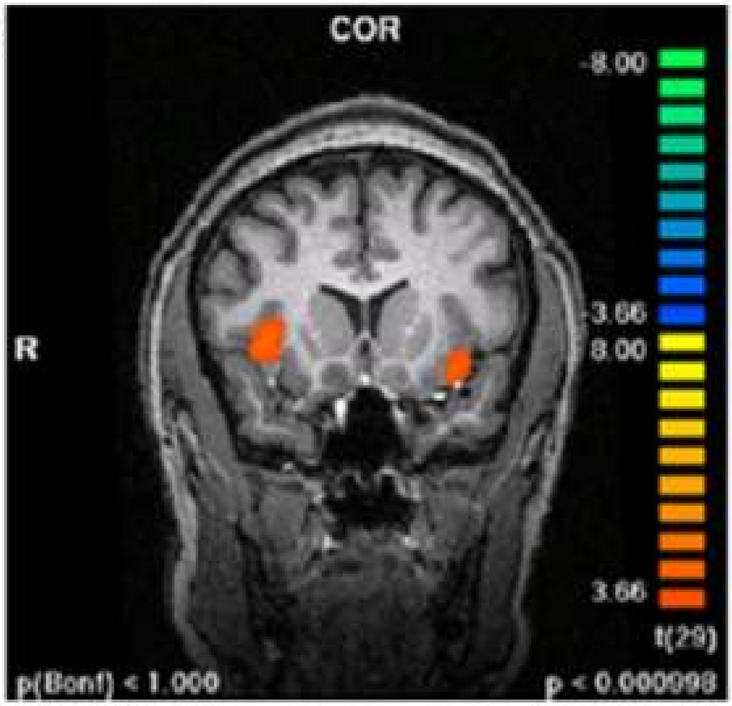
(B) Plot of contrast value for CC versus others in the peak voxel of the anteroventral striatal (nucleus accumbens) against the probability of CC repeating in consecutive rounds

Rilling et al 2002

Summary

- Mutual cooperation is associated with consistent activation in brain areas that have been linked with subjective values: e.g. ventral striatum (nucleus accumbens) and orbitofrontal cortex.
- Perhaps activation of this neural network positively reinforces reciprocal altruism – to reciprocate favors.

The neural response to unreciprocated cooperation

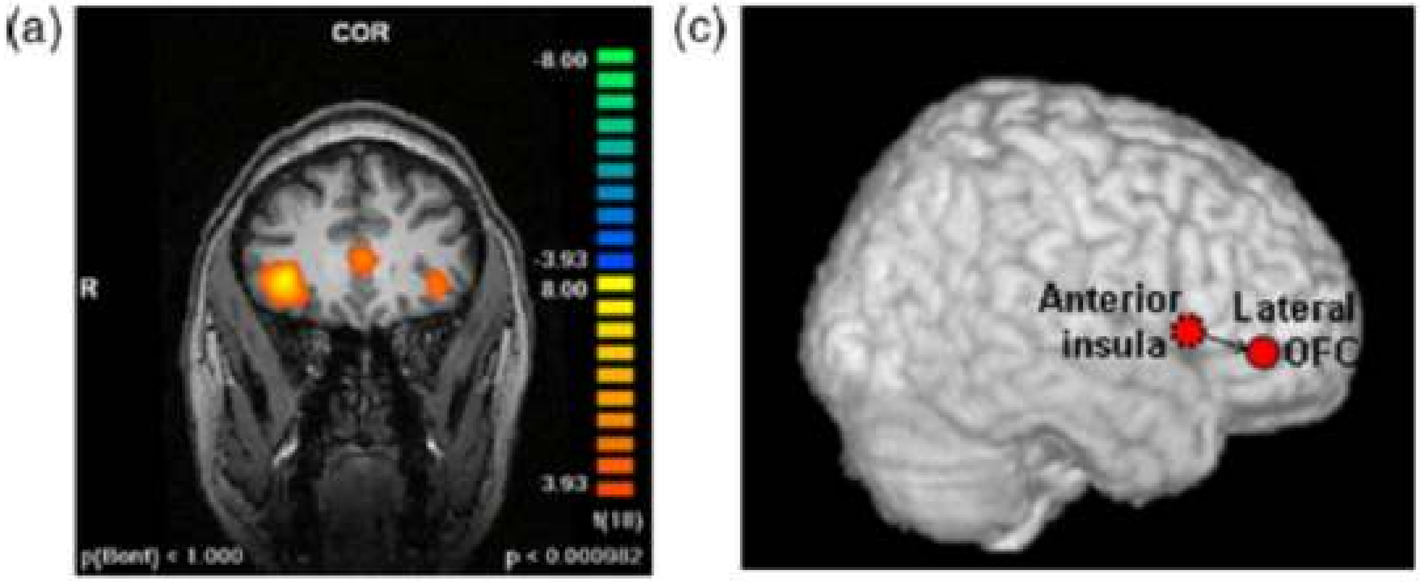
(a)


		YOU	
		Cooperate	Defect
PARTNER	Cooperate	**$2** ($2)	**$3** ($0)
	Defect	**$0** ($3)	**$1** ($1)

Fig. 1. Payoff matrix used in PD game. Scanned player's choices are atop columns and non-scanned partner's choices are beside rows. Payoff to scanned player ("You") is in bold. Payoff to non-scanned partner is in parentheses.

Anterior insula activation in response to unreciprocated vs. reciprocated cooperation (CD-CC)

Rilling et al 2008



(a) regions showing functional connectivity with the right anterior insula (from the contrast CD-CC) during CD outcomes

(c) schematic illustration of connectivity results that predict defection in rounds following CD outcomes.

Rilling et al 2008

Summary

- Unreciprocated cooperation is associated with greater activity in anterior insula compared with reciprocated cooperation.
- Functional connectivity between anterior insula and lateral orbitofrontal cortex (OFC) in response to unreciprocated cooperation predicted subsequent defection.

Most popular Games in Neuroeconomics

- Prisoner Dilemma
- Ultimatum Game
- Dictator Game
- Public Goods Game
- Matching Pennies Game
- Trust Game
- etc…

Trust Game

In the Trust Game (a version of a sequential Prisoner's Dilemma game), two subjects interacting anonymously play either the role of an investor or a trustee.

The investor is caught in a dilemma: if he trusts and the trustee shares, the investor increases his payoff, but he is also subject to the risk that the trustee will abuse this trust.

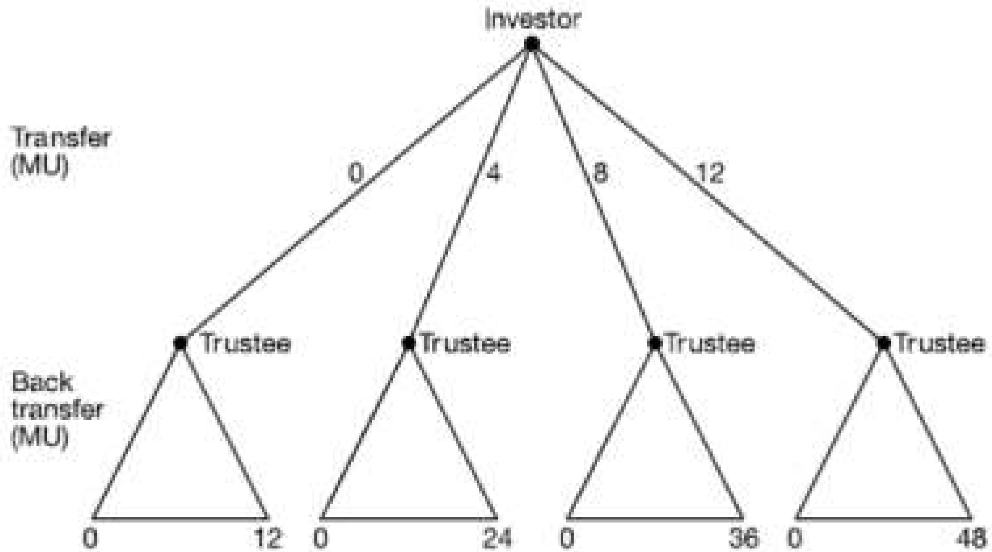
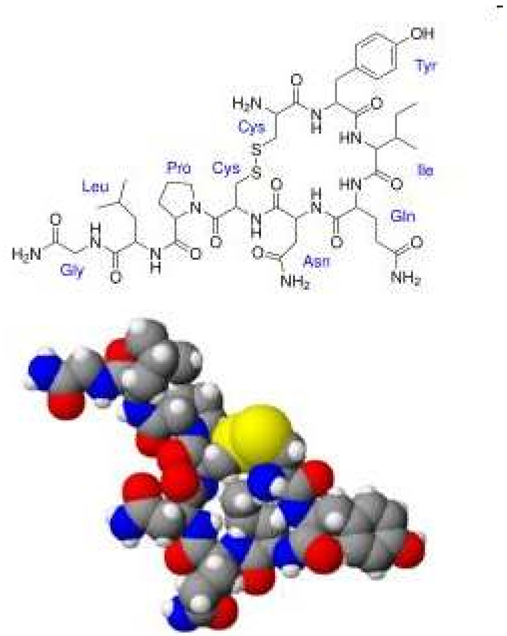


Figure 1 | The trust game. Both subjects receive an initial endowment of 12 monetary units (MU). The investor can send 0, 4, 8 or 12 MU to the trustee. The experimenter triples each MU the investor transfers. After the investor's decision is made, the trustee is informed about the investor's transfer. Then the trustee has the option of sending any amount between zero and his total amount available back to the investor. For example, if the investor has sent 12 MU, the trustee possesses 48 MU (12 MU own endowment + 36 MU tripled transfer) and can, therefore choose any back transfer from 0 to 48 MUs. The experimenter does not triple the back transfer. The investor's final payoff corresponds to the initial endowment minus the transfer to the trustee, plus the back transfer from the trustee. The trustee's final payoff is given by his initial endowment plus the tripled transfer of the investor, minus the back transfer to the investor. At the end of the experiment, the earned MU are exchanged into real money according to a publicly announced exchange rate (see Methods). Each subject made four decisions in the same player role while paired with four different, randomly selected interaction partners.

Kosfeld et al 2005



Oxytocin

Trust - the willingness of one party (trustor) to be vulnerable to the actions of another party (trustee)

In nonhuman mammals the neuropeptide oxytocin (OT) plays a central role in the ability to form social attachments and affiliations, including parental care, pair bonding, and social memory.

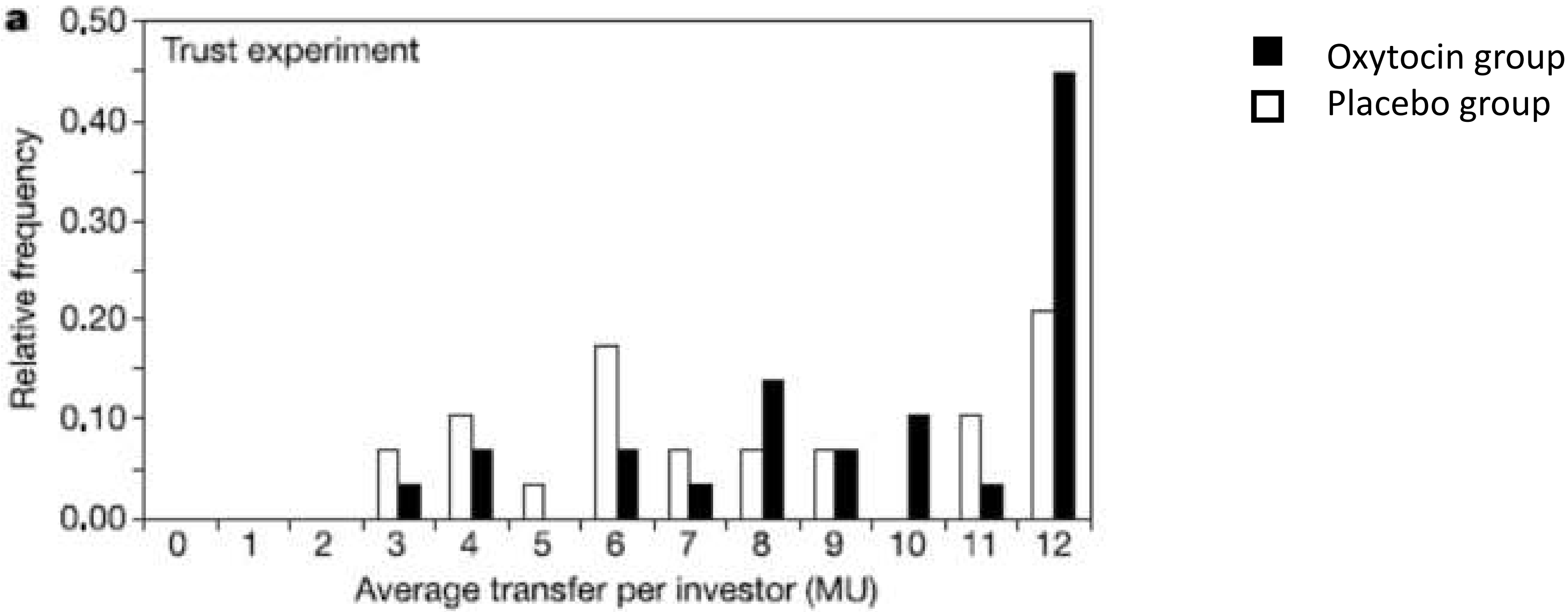


Table 1 | Median and average transfer behaviour of investors

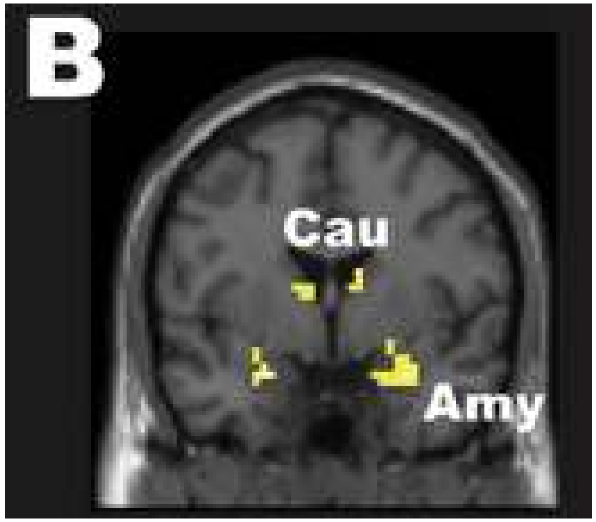
	Trust experiment	
	Oxytocin group	Placebo group
Mean average transfer (MU)	9.6	8.1
Median average transfer (MU)	10	8
Standard deviation of transfers (MU)	2.8	3.1
Number of observations	29	29

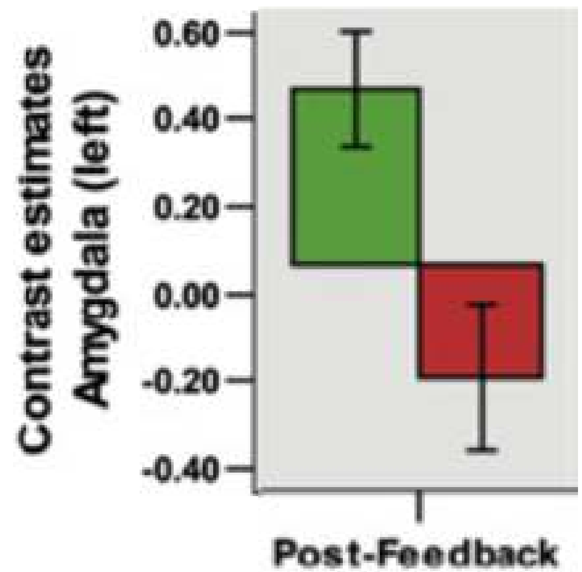
Kosfeld et al 2005

Summary

- Oxytocin specifically affects an individual's willingness to accept social risks arising through interpersonal interactions.
- These results concur with animal research suggesting an essential role for oxytocin as a biological basis of prosocial approach behaviour.

Postfeedback activity

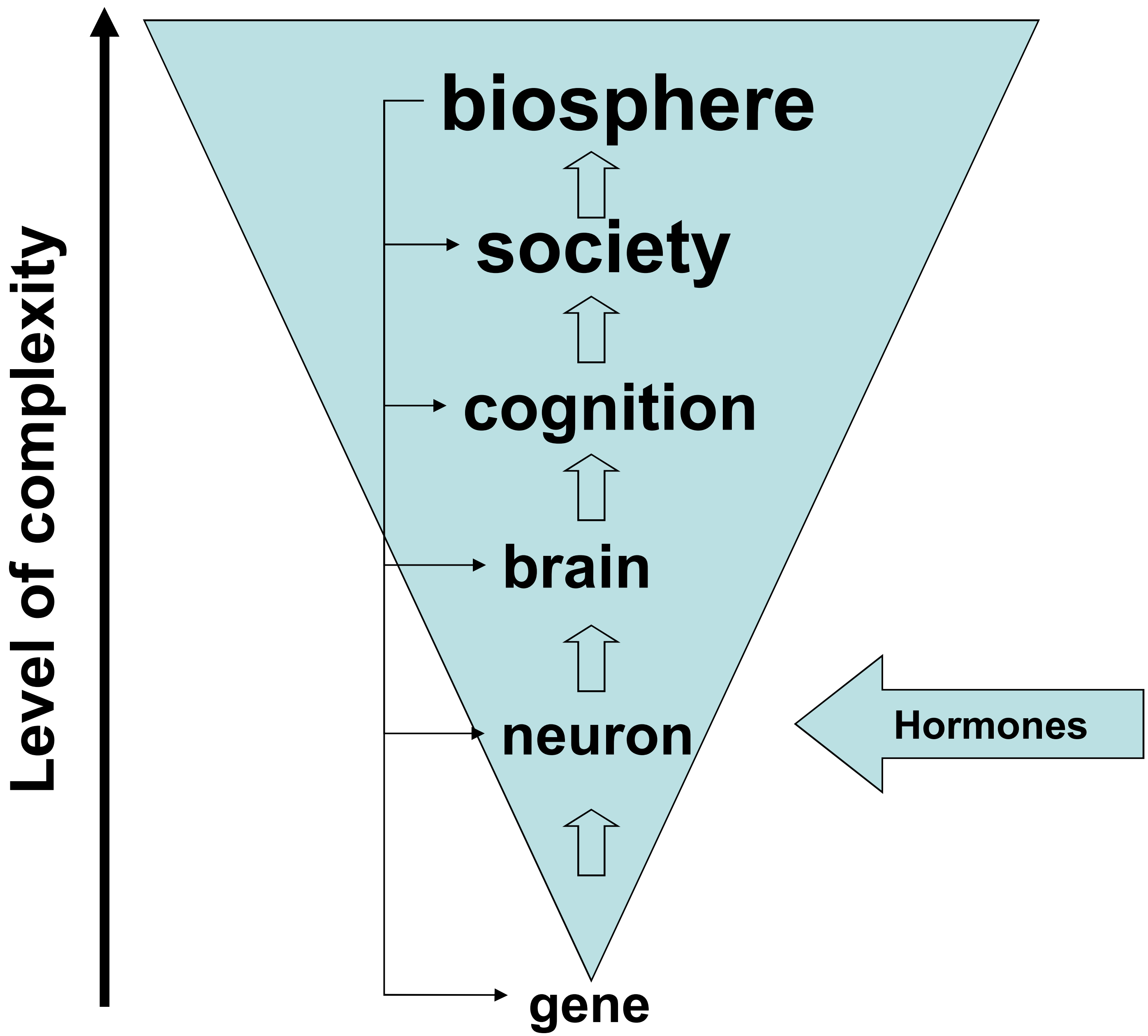




Subjects in the oxytocin group show no change in their trusting behavior after they learned that their trust had been breached several times while subjects receiving placebo decrease their trust.

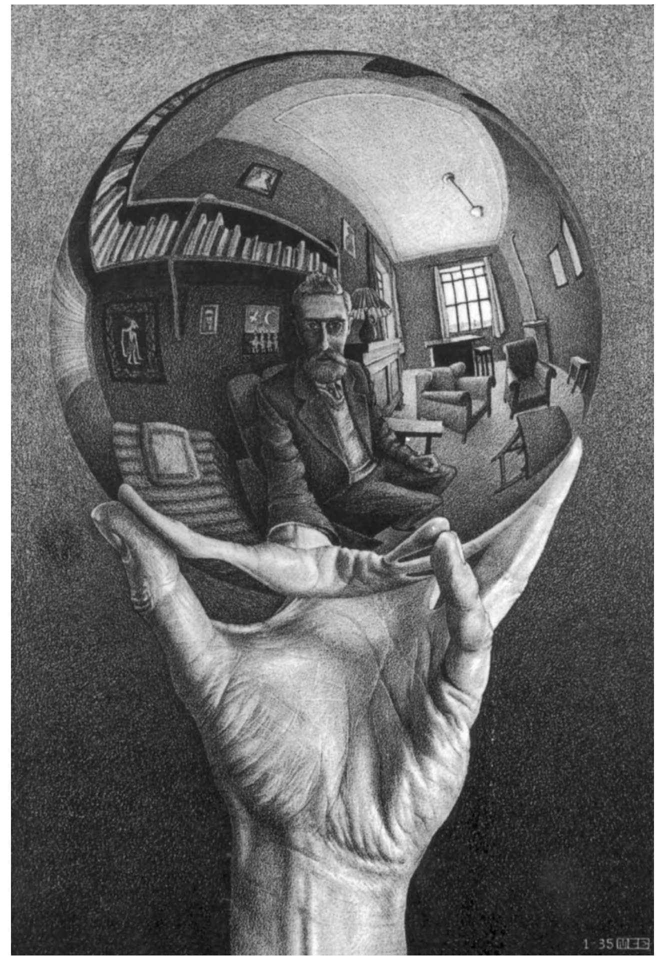
This difference in trust adaptation is associated with a specific reduction in activation in the amygdala, suggesting that neural system mediating fear processing (amygdala) modulate oxytocin's effect on trust.

Baumgartner, 2008


Level of complexity
biosphere
society
cognition
brain
neuron
gene
Hormones

Mirror neurons mechanism of social interaction

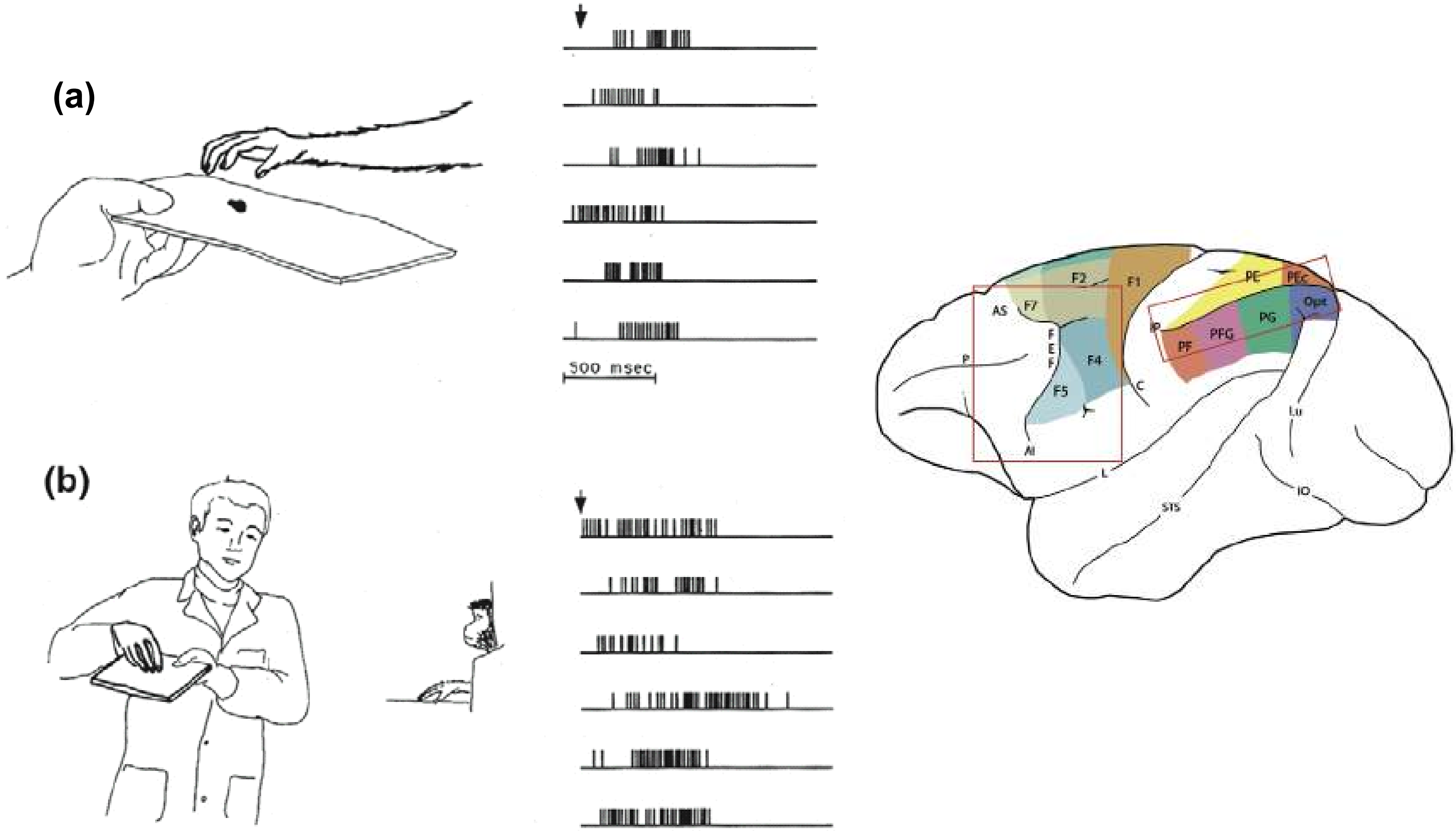
- A fundamental aspect of social interaction – capacity to understand what others are doing, their intention and their feelings.
- How do we understand each other?
- Perhaps by simulation…



Mirror neurons (Rizzolatti, G.)

Hypothesis:

- “Mirror neurons” transforms sensory information describing actions of others into a motor format similar to that the observers internally generate when they imagine themselves doing that action or when they actually perform it.



Example of a mirror neuron and anatomy of frontal and posterior parietal cortex of the macaque monkey. F5 mirror neuron. The neuron discharges when the monkey grasps an object (a) and when it observes the experimenter grasping it (b).

Mirroring others…

- Mirror neurons: understanding of goals via a simulation.
- Empathy…   perhaps also via simulation?!

"…we often derive sorrow from the sorrow of others, is a matter of fact too obvious to require any instances to prove it."

Adam Smith (1759)

Introduction to *The Theory of Moral Sentiments*

Mirror mechanisms of processing of emotional information (insular cortex is activated both by experienced and perceived disgust)

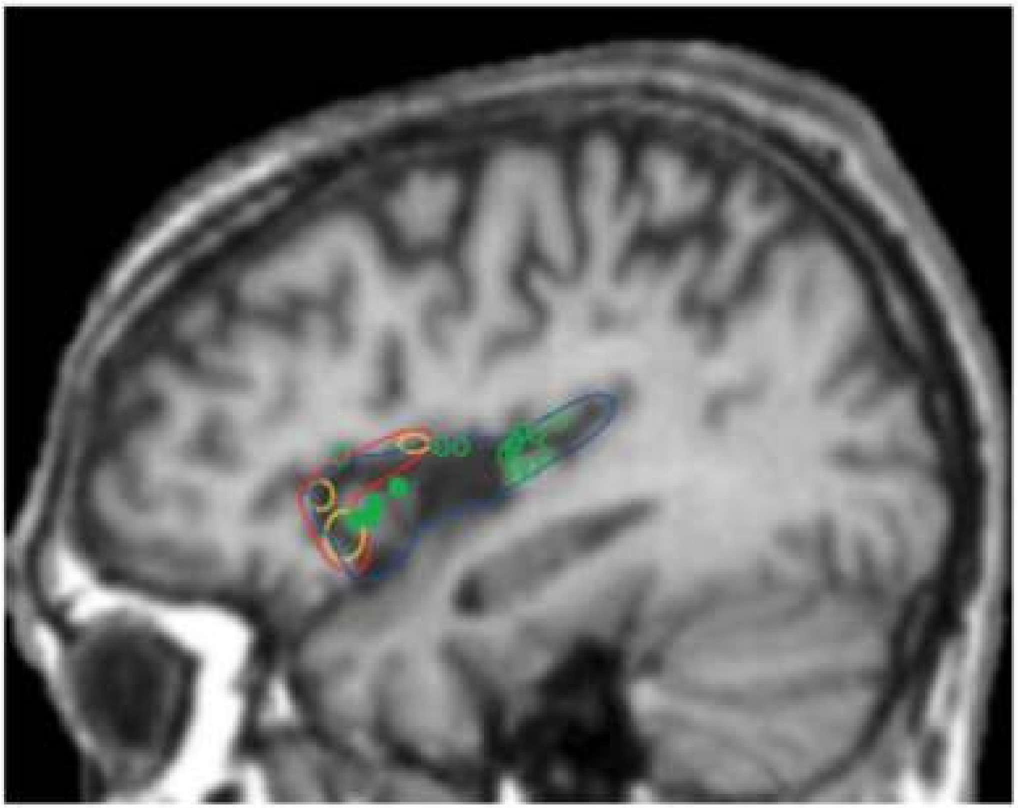


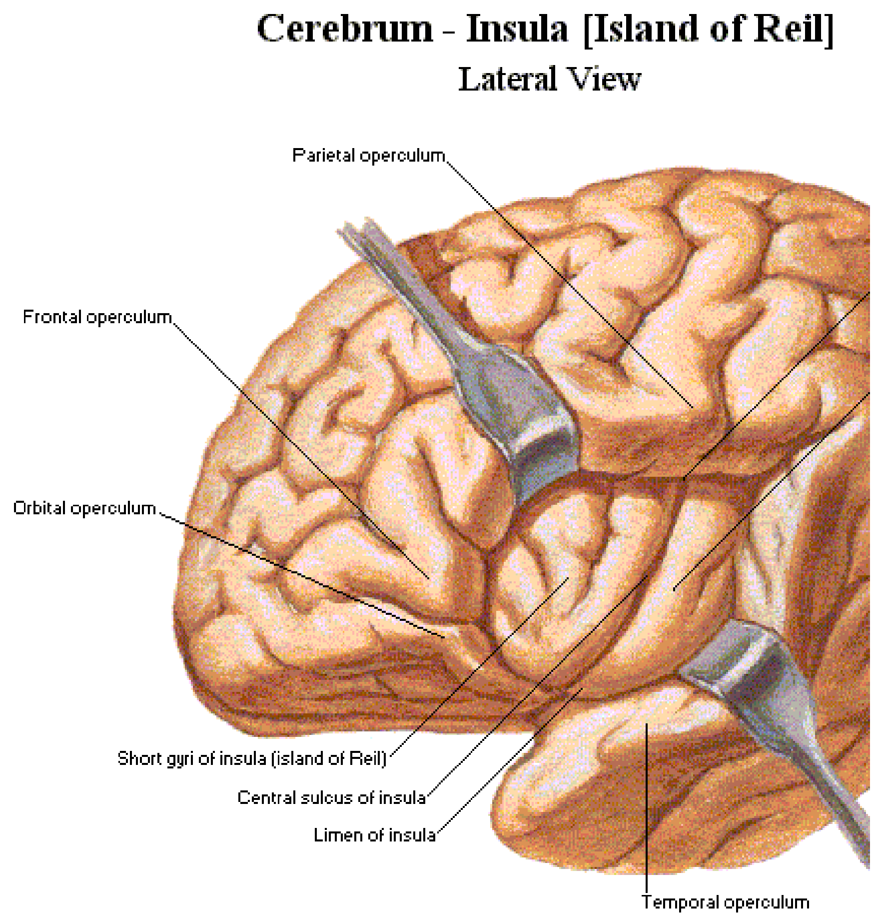
Figure 3. Sagittal T1-weighted anatomical MRI (x = −36) of patient NK [53] normalized to MNI space. The blue outline marks the zone of the left insular infarction. The red outline shows the zone we found to be activated during the experience of disgust; the yellow outline indicates those zones found to be common to this experience and the observation of someone else's facial expression of disgust [55]. The approximate location of the depth-electrodes of Krolak-Salmon *et al.* [51] are shown in green. Filled circles mark electrodes that showed selective responses to the sight of disgusted facial expressions.

Yellow line indicates areas activated both by experience of disgust and by the others' facial expressions of disgust

Gallese et al 2004

Insular cortex: disgust, pain, risk-avoidance….

Insular cortex connects to decision-making networks: OFC, nucleus accumbens, anterior cingulate, dorsolateral prefrontal cortex and other prefrontal areas.



Empathy for pain

- T. Singer et al. (2004), showed that the same structures (anterior *insula* and *cinglulate cortex*) that are involved in the experience and perception of disgust, also mediate empathy for pain.

- It is likely that empathy for pain is mediated by a “mirror” mechanism similar to that postulated for disgust.

- Singer et al. (2004) measured empathic brain responses elicited by the knowledge that your partner suffered pain.

- Painful stimulation was applied either to a female own or to her partner’s right hand who was sitting next to her in the MRI room.

- Parts of the so-called ‘pain matrix’, predominantly bilateral anterior **insula** (AI) and the anterior **cingulate cortex**, were activated when subjects experienced pain themselves as well as when they saw a signal indicating that a loved one had experienced pain.

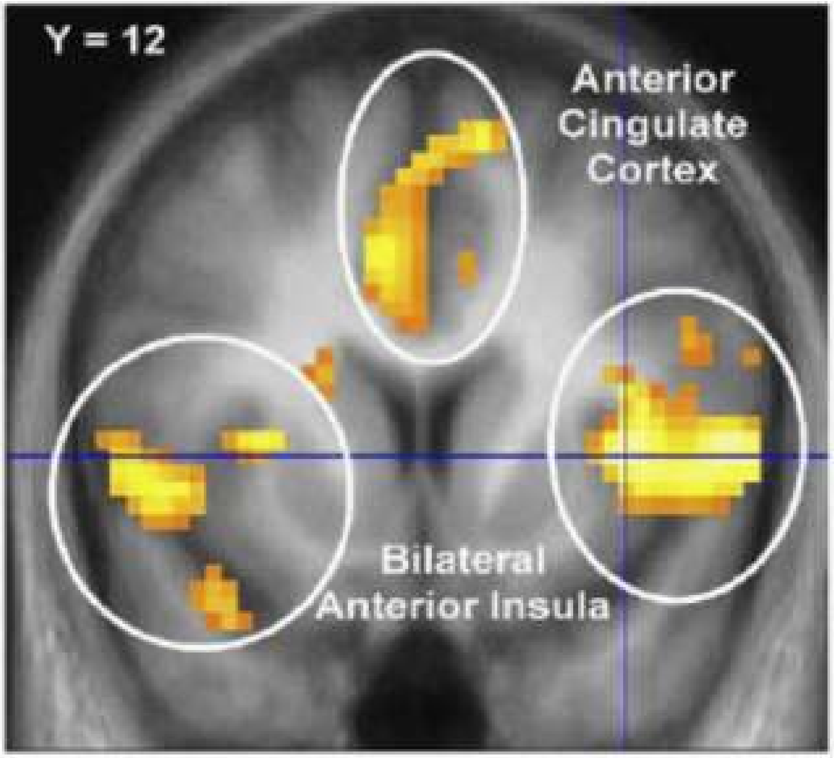
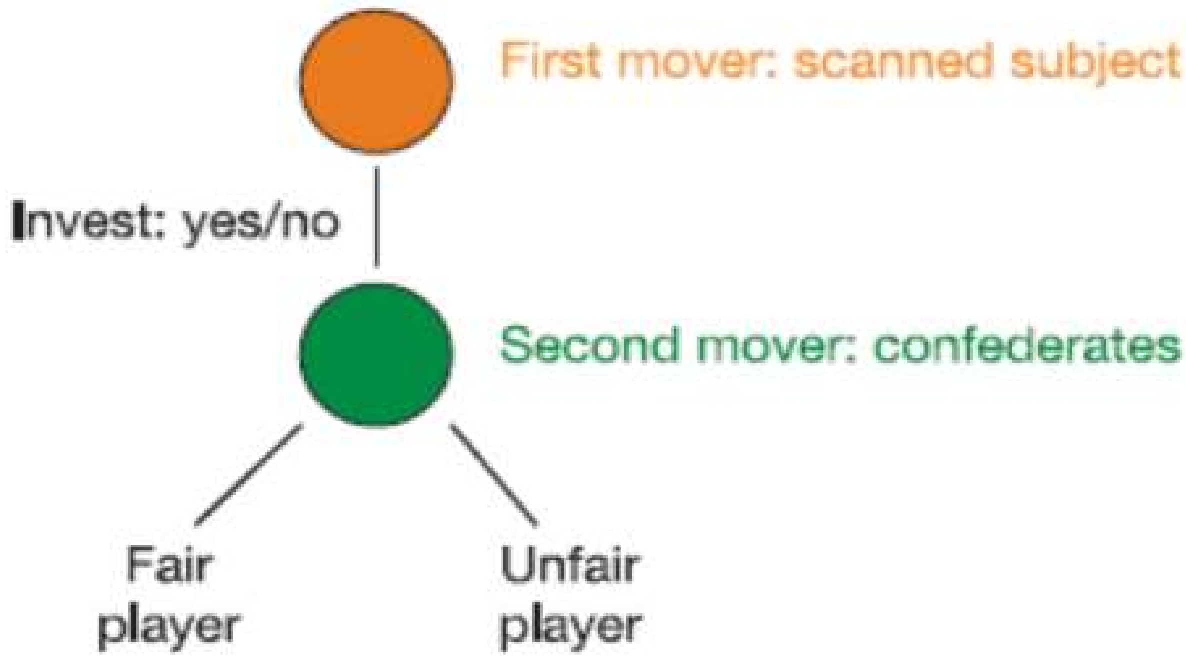


Fig. 2. Shared pain- and empathy-related networks observed when pain was applied to self or partner. The female volunteers activated anterior cingulated cortex (ACC) and bilateral anterior insula—the affective component of their own pain experience—when they observed their loved one receiving painful stimulation to his right hand. The figure illustrates results of a conjunction analysis between the contrasts pain–no pain in the context of self and other at $P<0.001$ (adapted from Singer et al., 2004b).

Singer et al.,2004

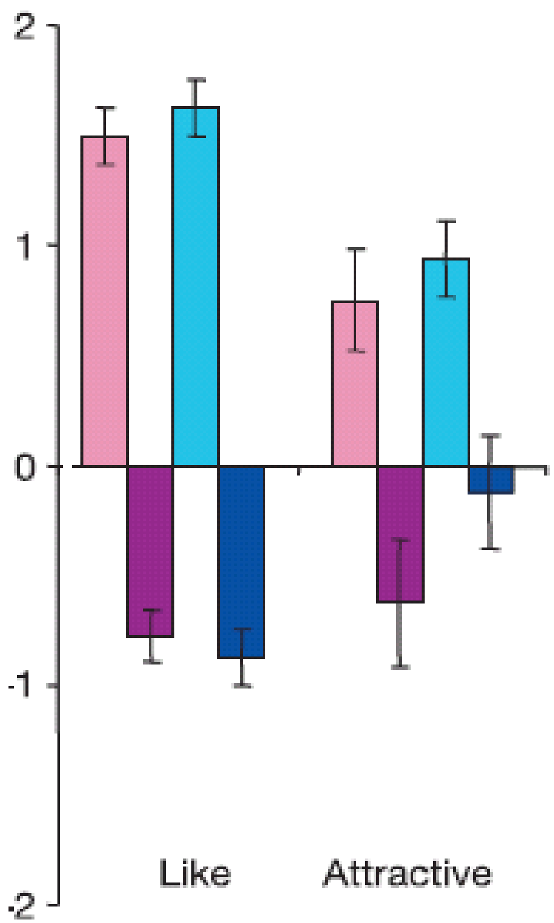
Pain of our enemy?

- The confederates played fair or unfair strategies in a Trust Game with the subjects.
- The confederates were always ‘second mover’ and could choose between a fair or an unfair response by returning high or low amounts of money
- Subjects liked fair players and dislike unfair players.



Game tree used to induce liking and disliking of opponent players. First movers (subjects) chose between keeping and sending money to the second mover. One of the confederates sent fair (large) amounts of money back, the other unfair (small) amounts.

Singer et al.,2004



Ratings showing that both sexes rated the fair confederates as being more reasonable/fair, their personality as being more agreeable/pleasant, as being more likeable and more attractive than unfair players.

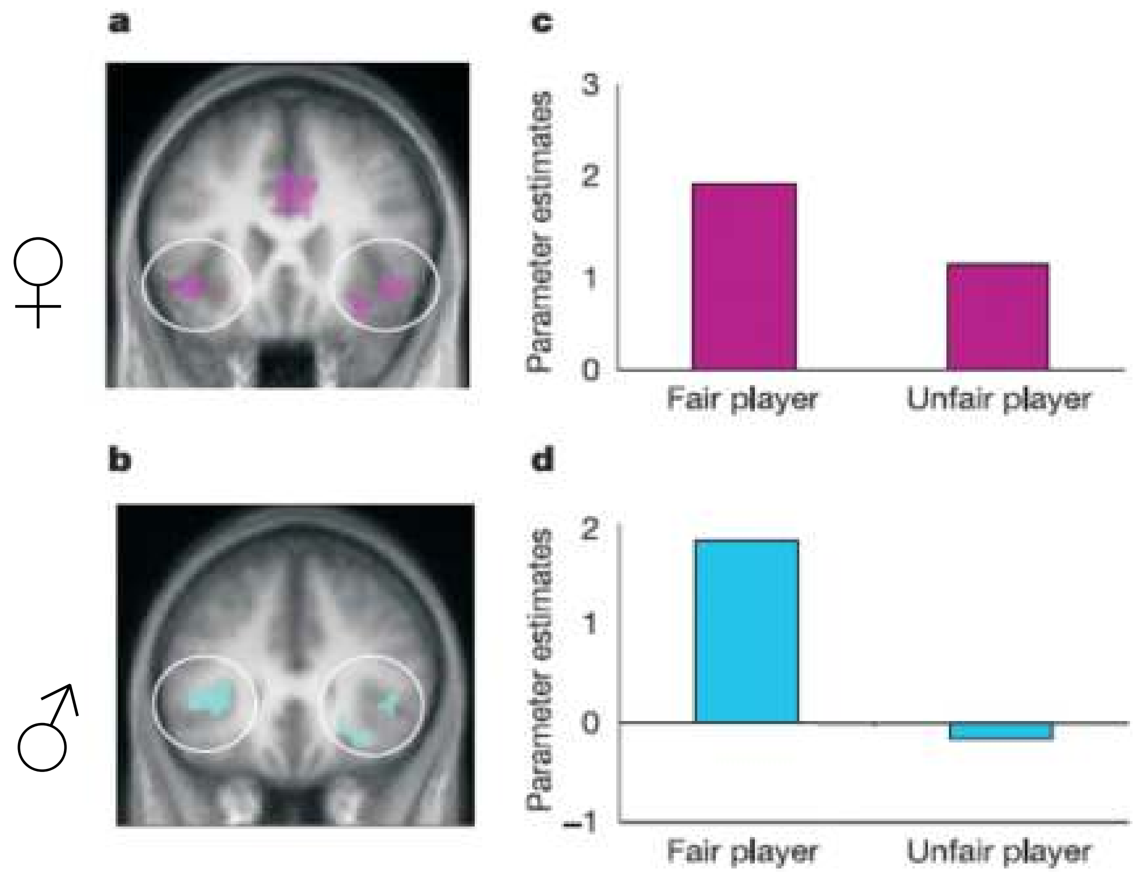
Pink bars, women subjects rating the fair player;

Purple bars, women subjects rating the unfair player;

cyan bars, men subjects rating the fair player;

blue bars, men subjects rating the unfair player.

Singer et al.,2004

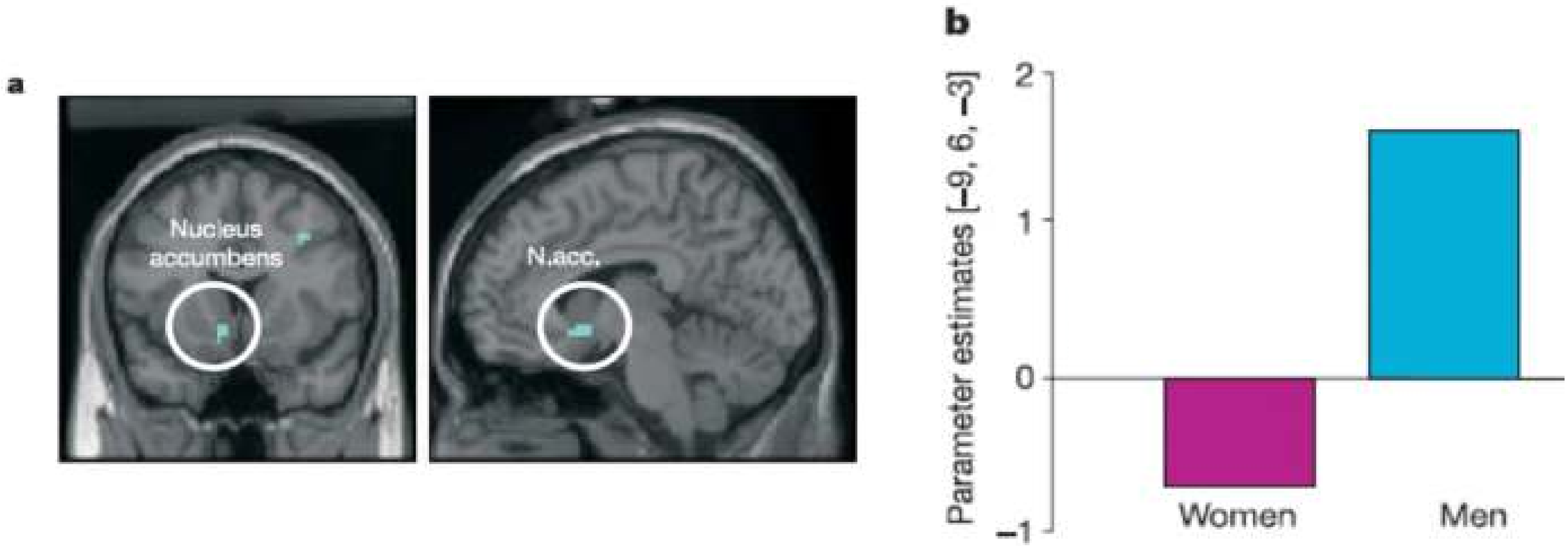


Pain-sensitive activation networks to the sight of fair and unfair players in pain.

a, b, Conjunction analysis between the contrasts pain–no pain in the context of self and the fair condition , for women (pink, a) and men (blue, b).

c, d, Average activation (parameter estimates) in peak voxels of left insula for the painful–non painful trials in fair and unfair conditions for women (c) and men (d).

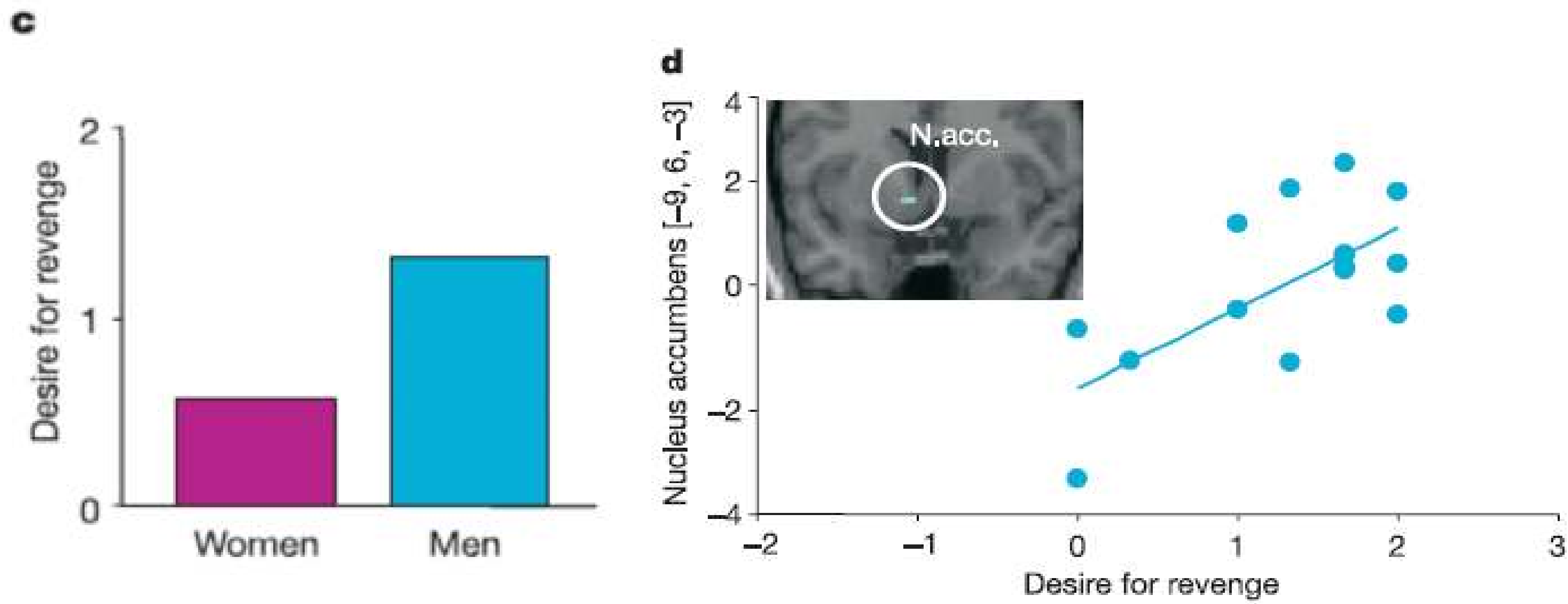
Singer et al.,2004



Gender differences in brain activity in nucleus accumbens specific to the perception of an unfair compared to fair player in pain.

a, Increased activity in nucleus accumbens for painful trials in the unfair–fair condition for men but not for women.

b, Average activation (parameter estimates) for women (pink) and men in left nucleus accumbens



- c, Men (blue) indicate stronger feelings of desire for revenge than women (pink)
- d, Correlation of parameter estimates at peak of nucleus accumbens activation for the (pain in unfair–pain in fair) contrast in men with expressed desire for revenge in men. There was no correlation for women.

Summary

- Both sexes exhibited empathy-related activation in pain-related brain areas (insular and anterior cingulate cortices) towards fair players.
- However, these empathy-related responses were significantly reduced in males when observing an unfair person receiving pain.
- This effect was accompanied by increased activation in reward-related areas (N.Acc), correlated with an expressed desire for revenge.
- Men (at least) empathize with fair opponents while favouring the physical punishment of unfair opponents.

T. Singer

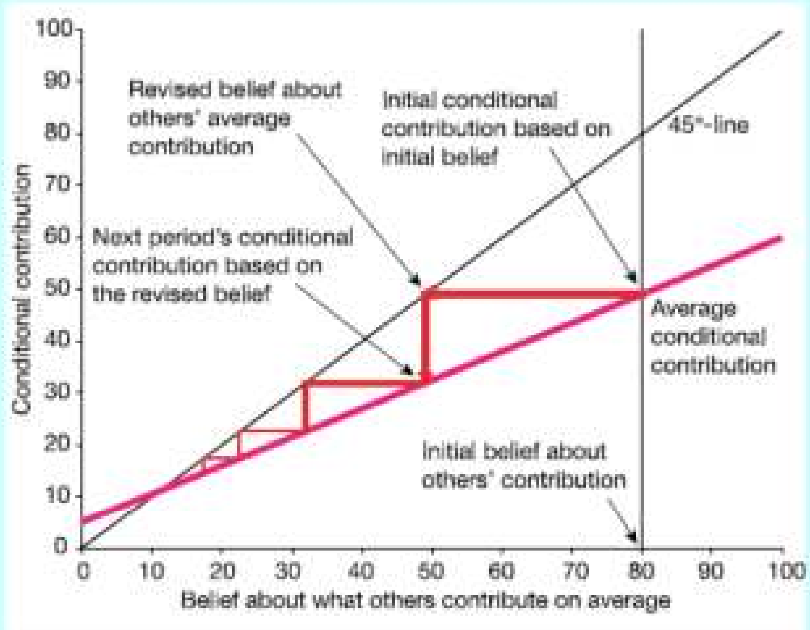


Figure 2 The decay of cooperation over time. Subjects are heterogeneous with regard to their willingness to reward altruistically. This results in the relationship between the expected average contribution of other group members to the public good and the contribution of a representative individual (the average conditional contribution indicated by the purple line). Initially, individuals expect high average contribution rates, say 80% of the endowment. On average, this induces them to contribute 50%. Therefore, expectations are disappointed which leads to a downwards revision of expectations to say, 50% of the endowment. Yet, if individuals expect 50% they will in fact only contribute roughly 30%, causing a further downwards revision of expectations. The process stops at the intersection point with the 45° line, which determines the equilibrium level of altruistic cooperation in this setting.

- Despite the fact that there are a large number of strong reciprocators, they cannot prevent the decay of cooperation.
- In a population with a clear majority of strong reciprocators, a small minority of selfish individuals suffices to render zero cooperation.

More players…

- Interactions could involve more than two players, e.g. n-player PD (NPD)
- Theorists have shown that increasing the number of individuals in the NPD makes cooperation more difficult.

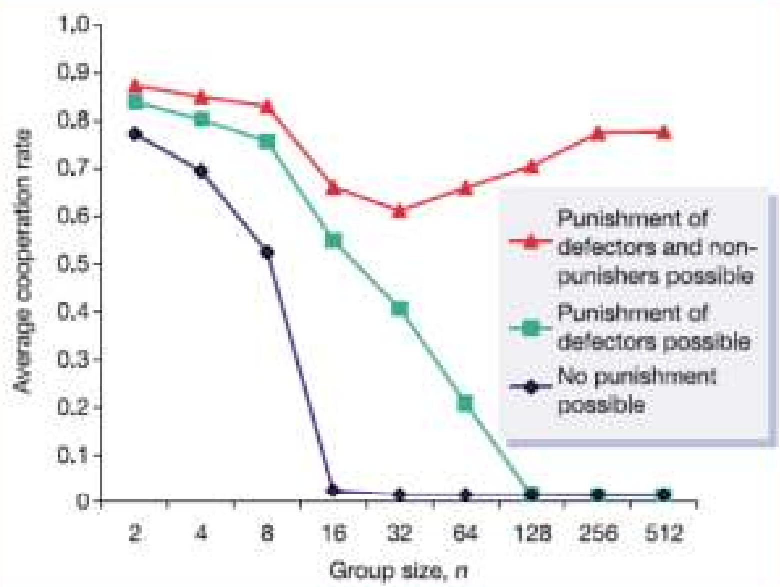


Figure 4 Simulations of the evolution of cooperation in multi-person prisoners' dilemmas with group conflicts and different degrees of altruistic punishment. The simulations are based on the model of ref. 73 but we added the possibility of punishing the non-punishers. There are 64 groups of fixed size *n* with *n* ranging from 2 to 512. The figure shows the average cooperation rate in 100 independent simulations over the last 1,000 of 2,000 generations. If the altruistic punishment of defectors is ruled out, cooperation already breaks down for groups of size 16 and larger. If altruistic punishment of defectors is possible, groups of size 32 can still maintain a cooperation rate of 40%. However, the biggest impact from altruistic punishment prevails if non-punishers can also be punished. In this case, even groups of several hundred individuals can establish cooperation rates of between 70 and 80%.

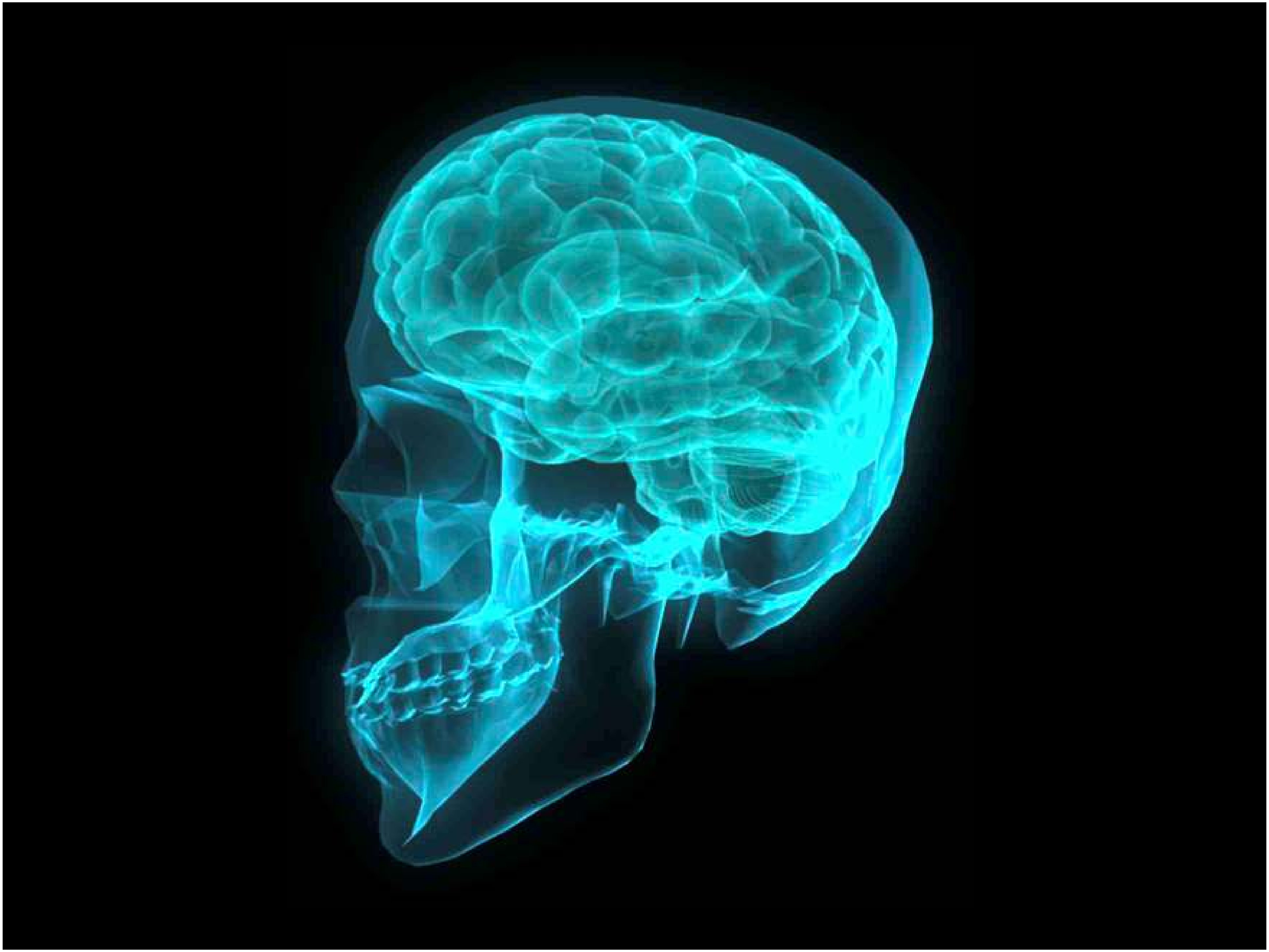
• Altruistic punishment means that individuals punish, although the punishment is costly for them and yields no material gain.

•A minority of strong reciprocators – altruistic punishers - suffices to discipline a majority of selfish individuals when direct punishment is possible.

The nature of human altruism

Take home message

- Cooperation has an evolutionary basis.
- Mutual cooperation is associated with consistent activation of the ventral striatum (nucleus accumbens) and orbitofrontal cortex.
- Perhaps during social interactions our nervous system emulates feelings of others (“mirror neurons mechanism”).
- Fairness of social/financial transactions modulates empathy-related “mirroring” activation of the insular cortex and ventral striatum (nucleus accumbens).
- People empathize with fair opponents while favouring the punishment of unfair opponents.



Thank you for your attention!