

# Beyond Homo Oeconomicus, moderately

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- 2 – Deviations from Nash equilibrium in human games
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# 1 - Games

- **Game theory:** Study of multi-person decision problems influencing one another's welfare
- Economics, Biology, Social Sciences, Communication
- **Mechanism:**  
Cooperation or competition to reach a best goal state (from the cooperative or individual point of view)

# 1 - Games - Nash equilibrium

- $(s_1, s_2, \dots, s_k, \dots, s_n)$  is Nash equilibrium if  $P(s_1, s_2, \dots, s_k, \dots, s_n) > P(s_1, s_2, \dots, s_k', \dots, s_n)$  for all  $s_k'$
- No player can improve his payoff by changing his strategy, when the strategies of the other players are fixed
- **Theor:** (Nash) *Every N-player game, with finite strategies, has at least one equilibrium, in pure or mixed strategies*
- In economy, Nash equilibrium  $\Leftrightarrow$  Self-interested rational decisions (Homo Oeconomicus)
- Provides a sound basis for (almost) the whole of (rigorous) economic theory

# 1 - Games - Nash equilibrium

- Example :
- *Theor:* Consider the class of abstract economies with
  - (i) strategy sets convex and compact,
  - (ii) payoff functions continuous and quasi-concave,
  - (iii) the feasibility correspondences are continuous and have nonempty convex values.Then, the Nash correspondence is the unique solution that satisfies nonemptiness, rationality in one-person games and consistency

*(B. Peleg; Games and Economic Behavior 18 (1997) 277-285)*

# 1 - Games - Nash equilibrium

- Note :
- *“Feasibility correspondences”*  
The feasible strategies of each agent may depend on the other agents strategies
- *Social equilibrium (Debreu)* ,  
a generalization of Nash equilibrium

# However

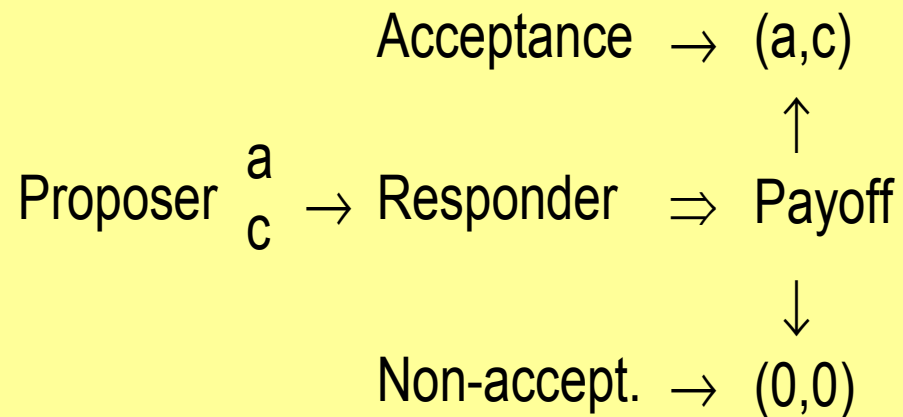
- *When played by humans, most games do not converge to the Nash equilibrium, consistently*
- *But, in some cases they do !*
- *What shall we do ?*
  - *To continue developing and applying classical economic theory, recognizing that it does not apply to humans (or not yet – see evolutionary refs.)*
  - *To abandon rationality (even bounded rationality) in economics and introduce a large contribution of randomness in economic decisions*
  - *To modify game theory to account for the experimental results and still use the solid Nash equilibrium framework. Is it possible ?*

## 2 - Deviations from Nash equilibrium in experimental games

- ◆ The ultimatum game
- ◆ The public goods game (with and without punishment)
- ◆ Dictator game
- ◆ Gift exchange game
- ◆ Third party punishment game
- ◆ The trust game



# The ultimatum game



$a+c=2b$  ,  $a \gg c$ ,  
(Example:  $a=99$ ,  $c=1$ ,  
 $b=50$ )

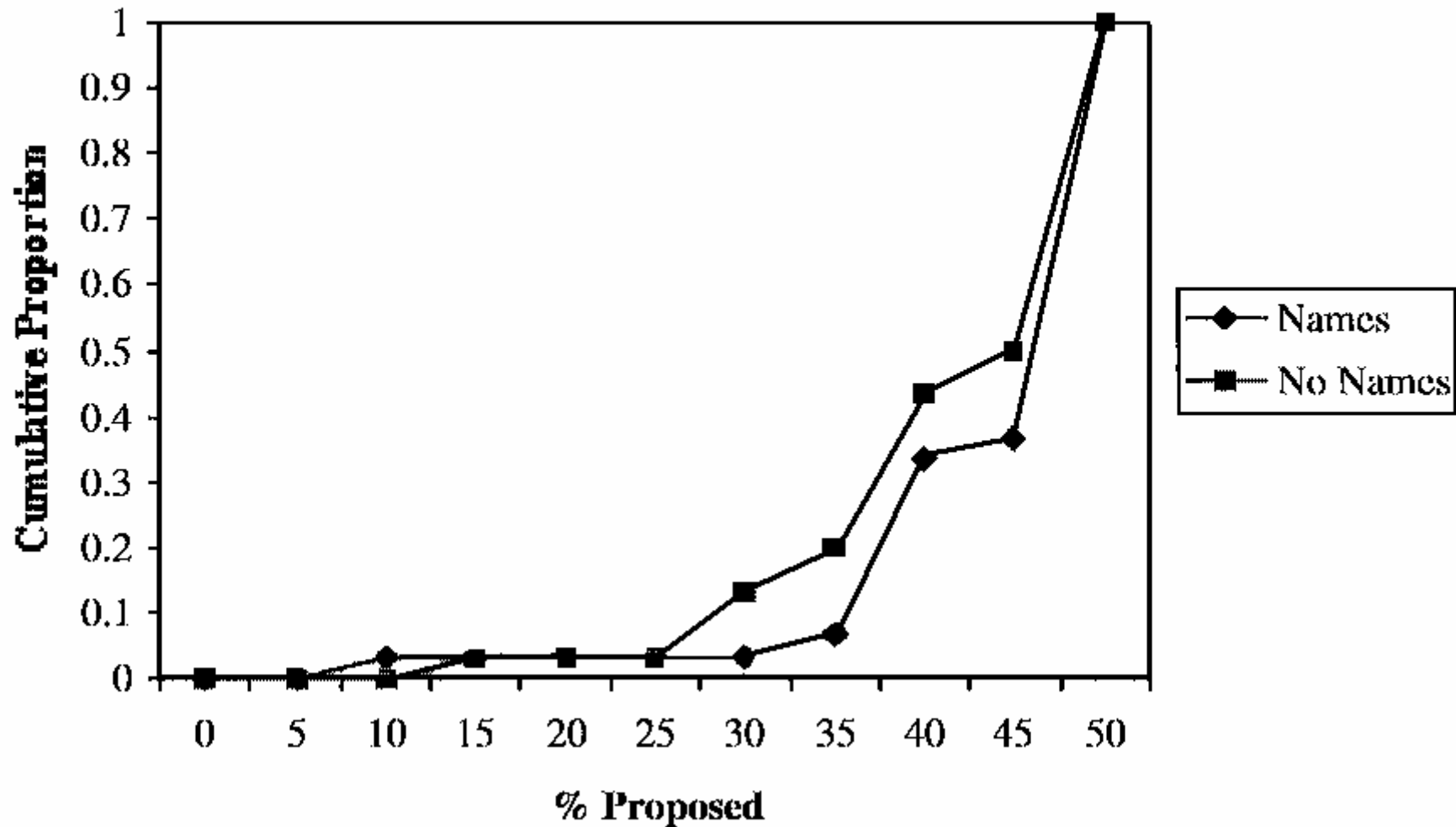
	R0	R1
P0	(a,c)	0,0
P1	b,b	0,0

Monopoly pricing of  
a perishable good



# The ultimatum game

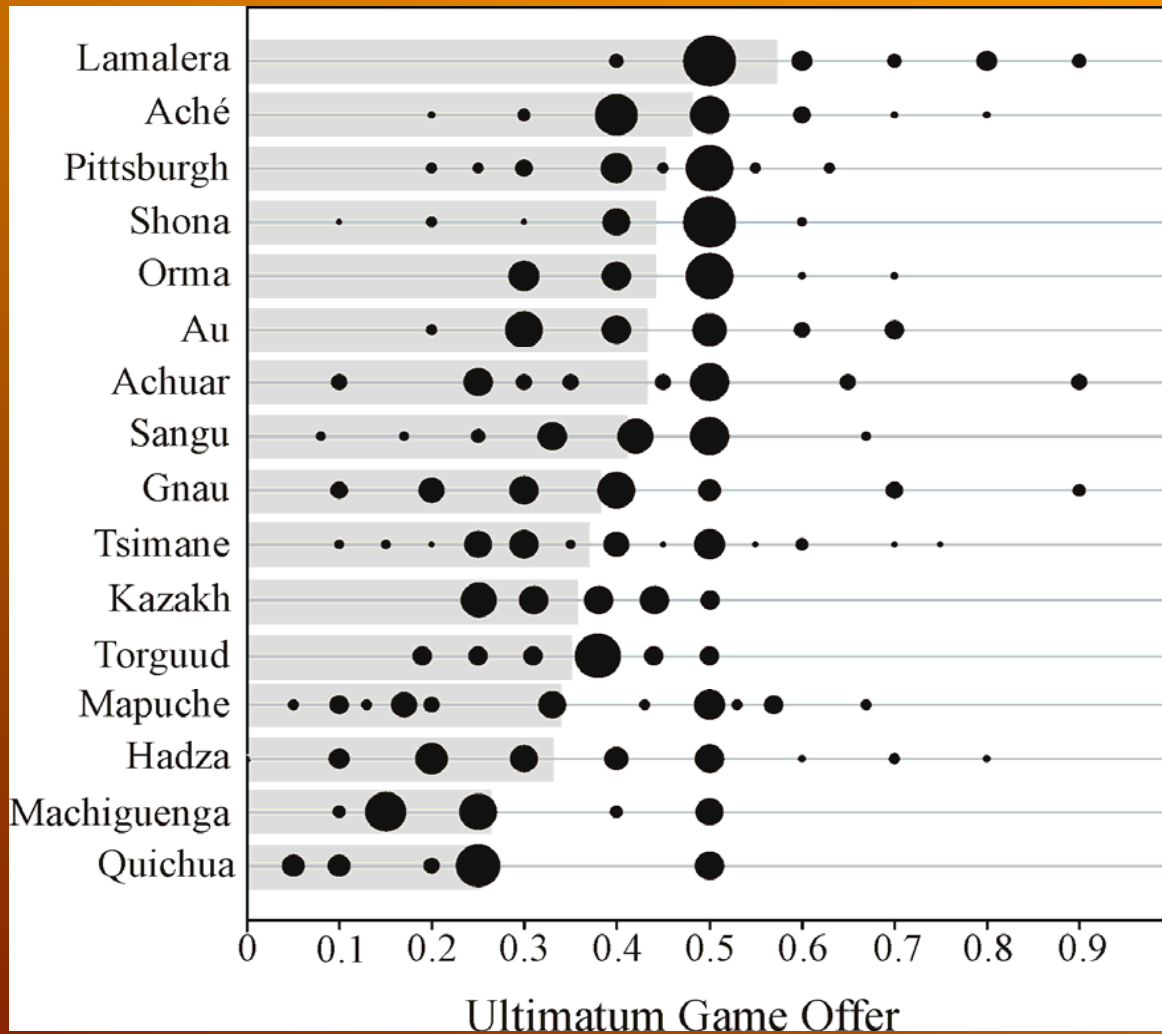
Figure 2 - Cumulative Ultimatum Proposals



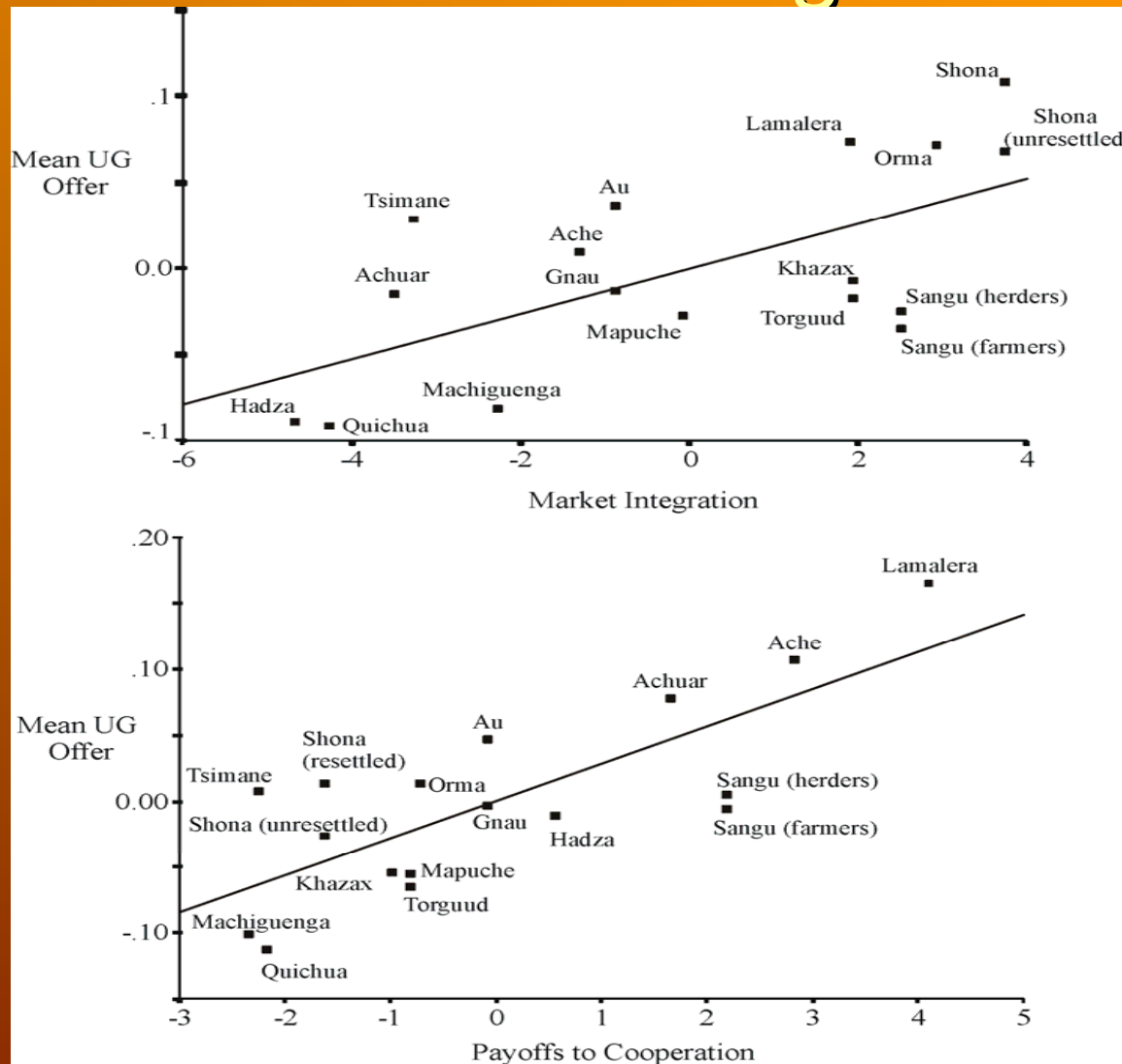
# The ultimatum game



# The ultimatum game



# The ultimatum game



Fair offers correlate with market integration and cooperativeness in everyday life

# The ultimatum game

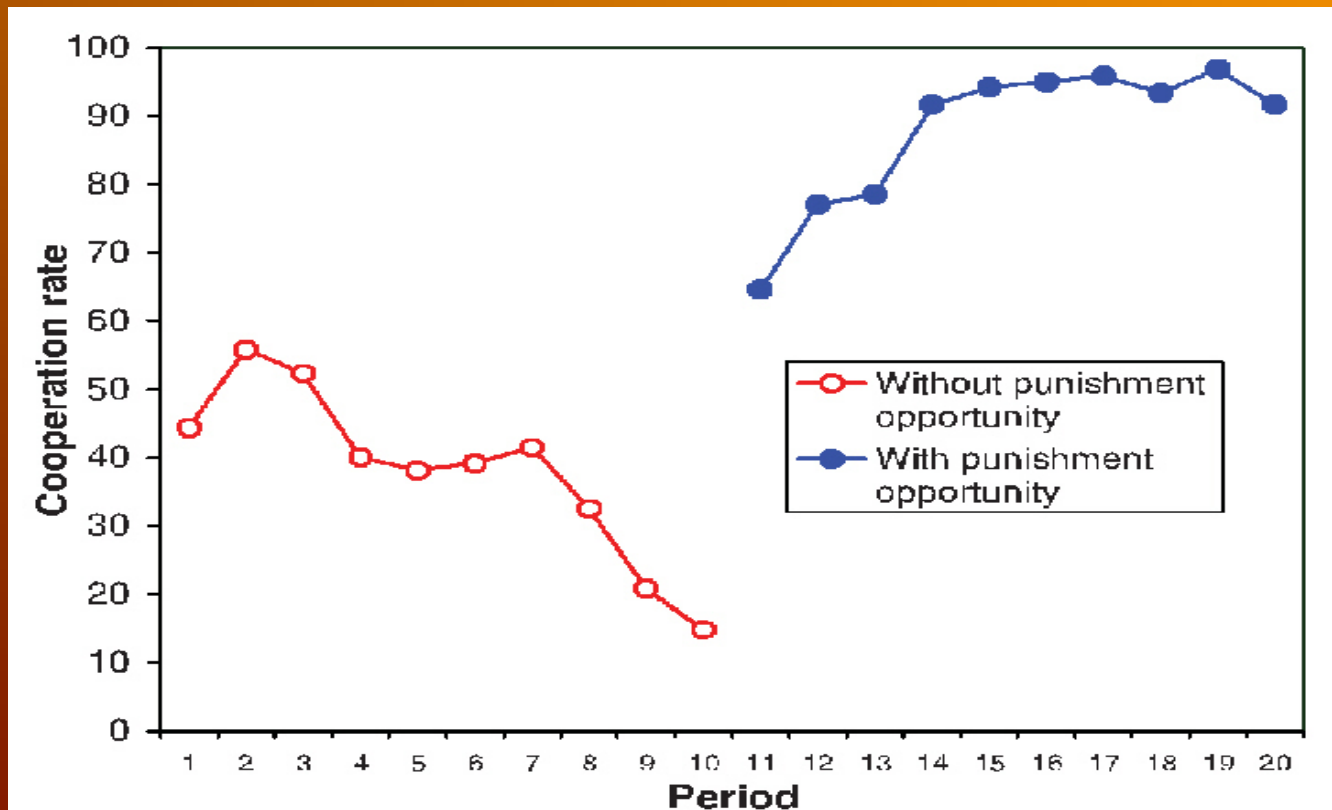
- ✦ However with one proposer and several responders or with one responder and two proposers, the results coincide or are close to the Nash equilibrium predictions
- ✦ Why ?

# The public goods game

n players with endowment  $y$  decide on their contribution  $g$ , gaining  $p_i = y - g_i + m \sum g_k$

Nash eq.  $g_i = 0$  ( $m < 1 < mn$ )

(Cooperative production, use of resources)

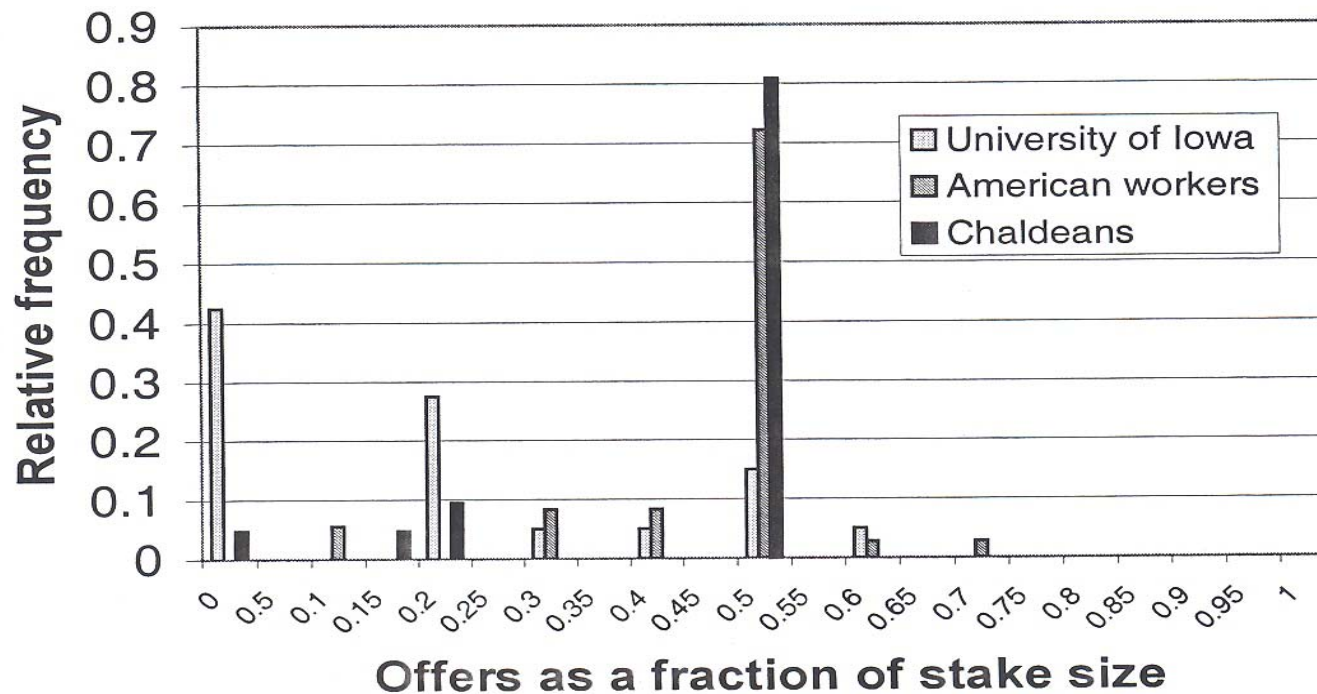


# The dictator game

As in the ultimatum game, but no possibility of refusal by the responder

Nash eq.  $x=0$

(Giving anonymously to strangers)



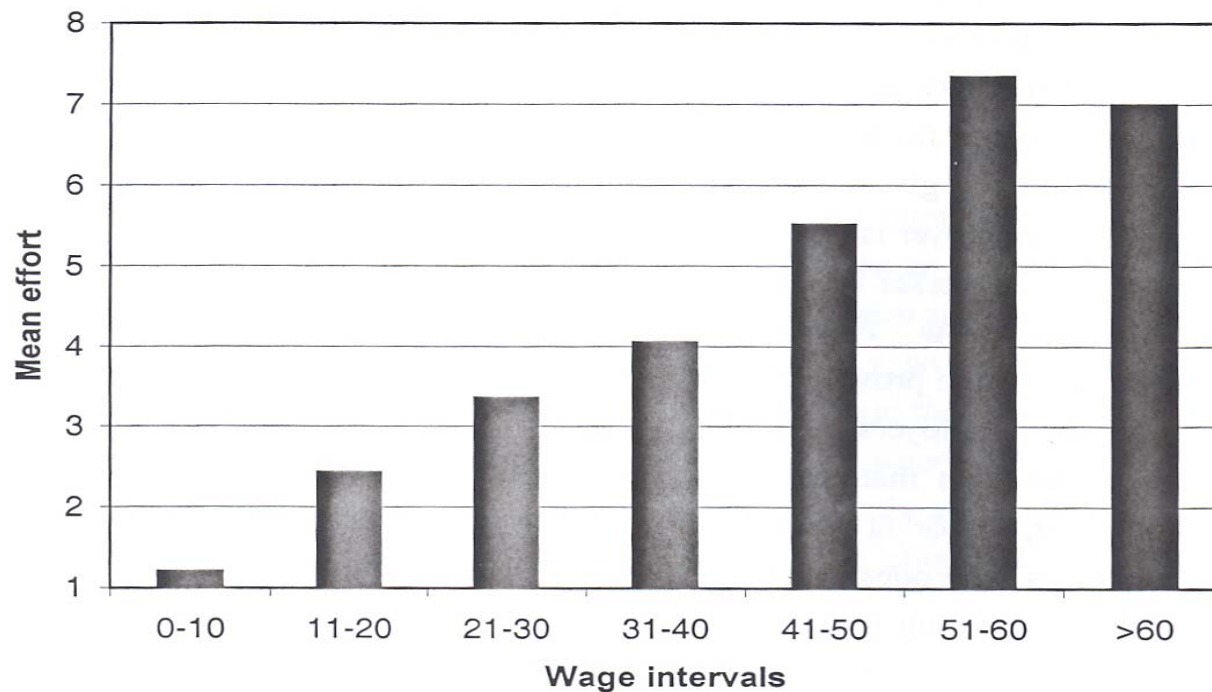


# The gift-exchange game

Employer offers the worker a wage  $W$  for a minimal effort  $e$ . If the worker refuses, payoffs are  $(0,0)$

If he accepts  $(ke-W, W-C(e))$   $1 < k < 10$

Nash eq.  $e=1, W$  minimal  
(Nonenforceability of performance)

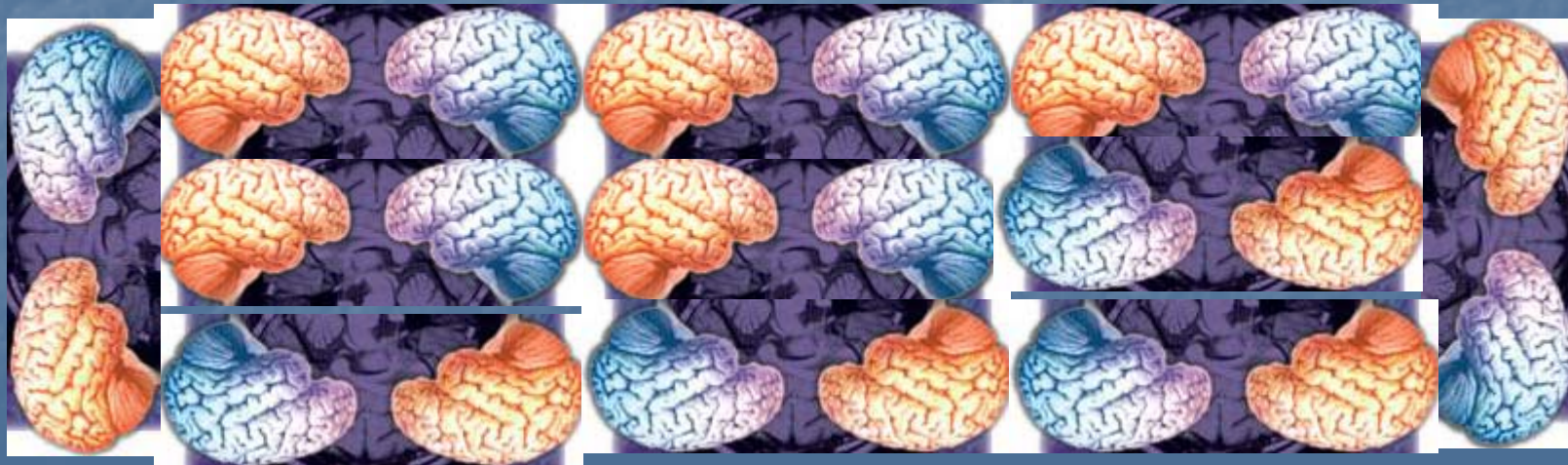


# 3 - Neurological input

A two-persons game is a two-brains confrontation

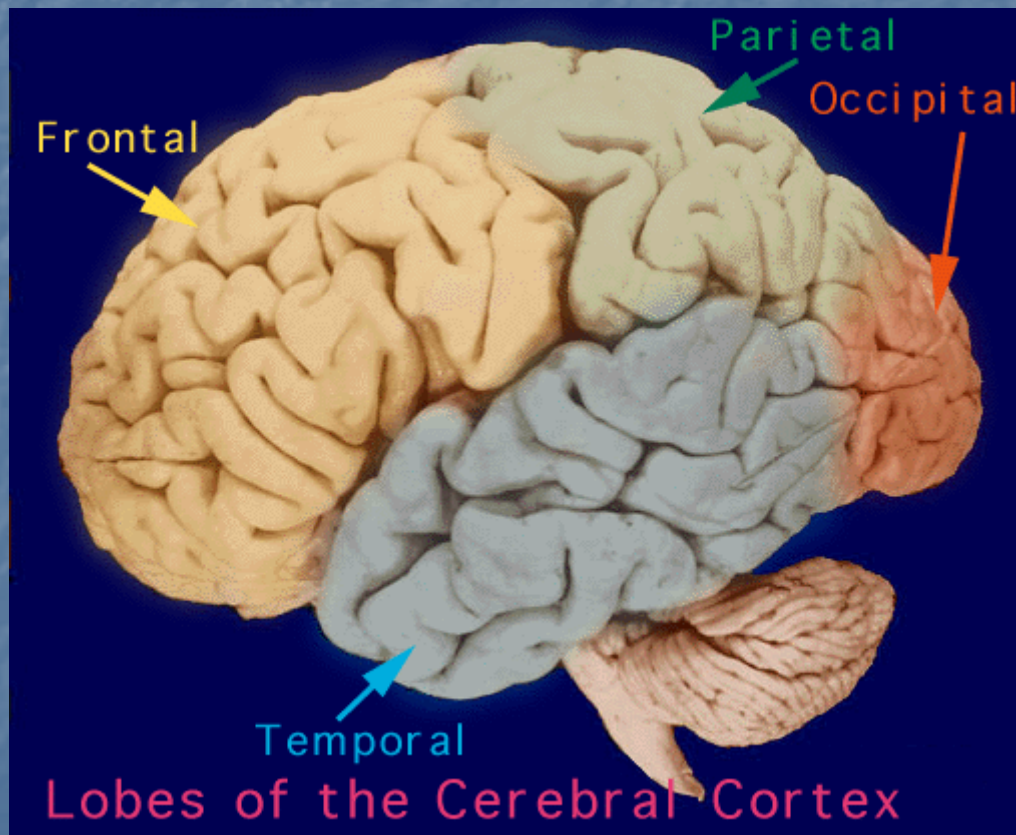


and an economy is a large brain crowd



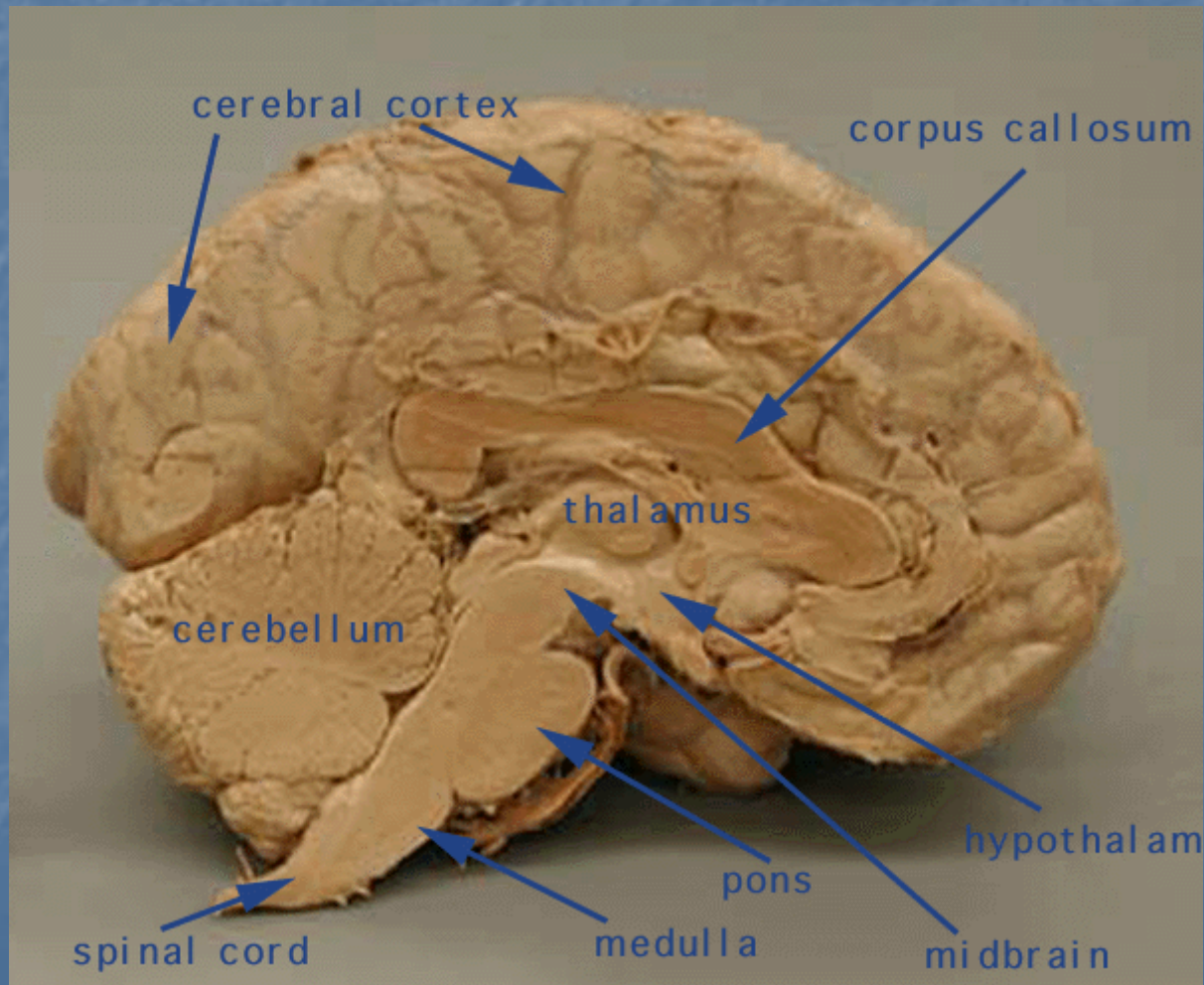
# Neurological input

and a brain is not only a cortex (left) frontal lobe,

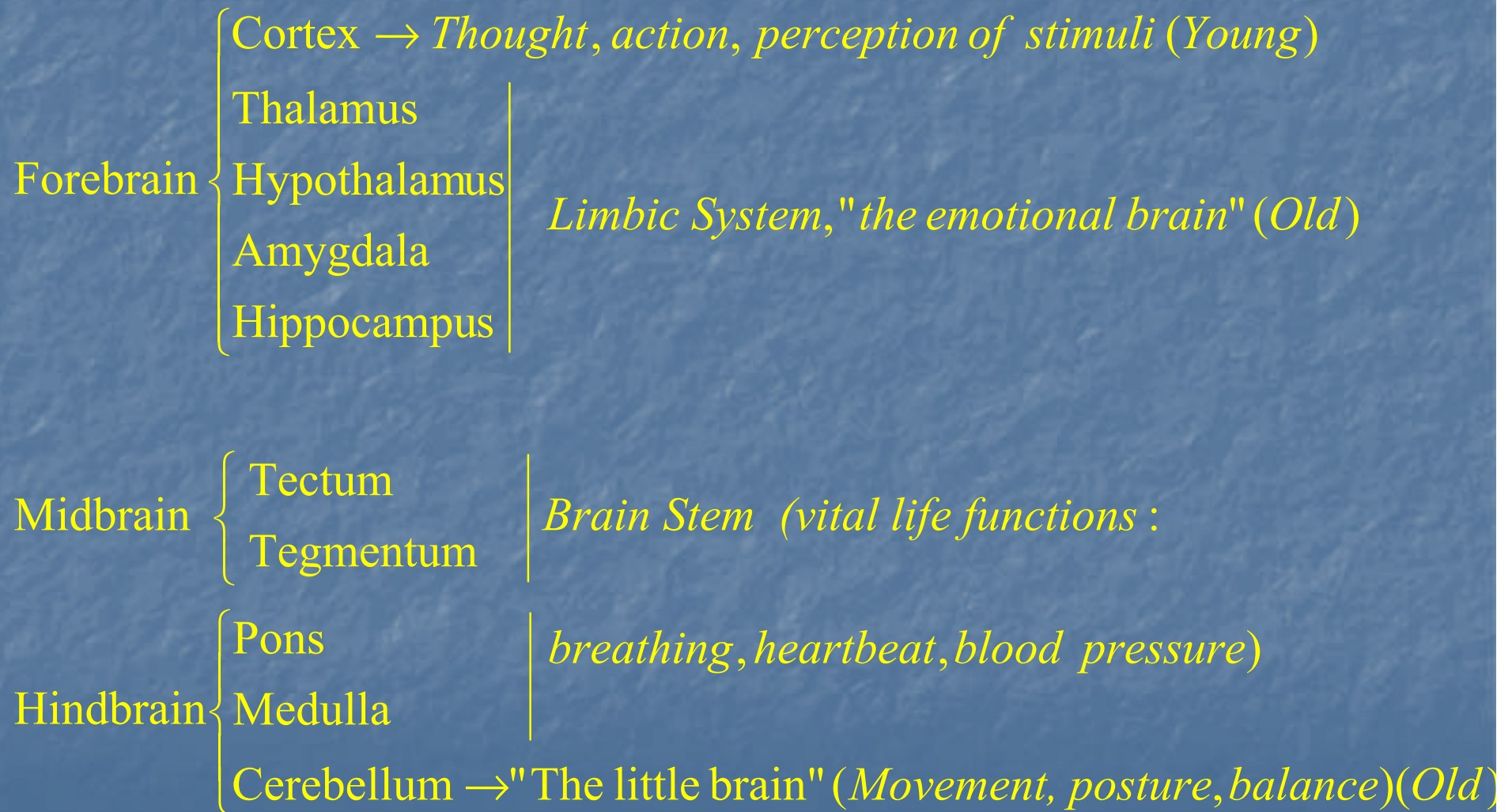


# Neurological input

it has many other specialized parts, with different evolutionary ages



# Neurological input



# Neurological input

- Many brain activities are automatic, rapid processes which typically occur without awareness. No intervention of the deliberative cortex and the language module.
- Experiment (Whalen et al. J. Neuroscience 8 (1998) 411): 40 ms flashes of happy and angry faces activate the amygdala, without people being aware of what they saw.
- Conscient actions are preceded by a much earlier reaction of the limbic system, which modulates the conscient deliberation.
- Beware also of “irrationality” of the rational modules :
  - Experiments with music and light flashes. Tendency to mentalize a synchronization where there is none.
  - The hindsight bias : Overwriting of what was previously believed. Past events may seem predictable. Erroneous attribution of intentions to other agents.

# Techniques to “see” the brain in action

- EEG

Electrical activity outside the brain. Good time resolution ( $\sim 1\text{ms}$ ), spatial resolution poor and does not record interior brain activity

- PET

Measures blood flow in the brain. Better spatial resolution than EEG, but poorer time resolution. Limited to short tasks, because radioactivity decays.

- fMRI

Measures changes in the blood oxygenation. Weak signal, better spatial resolution than PET ( $\sim 3\text{mm}$ )

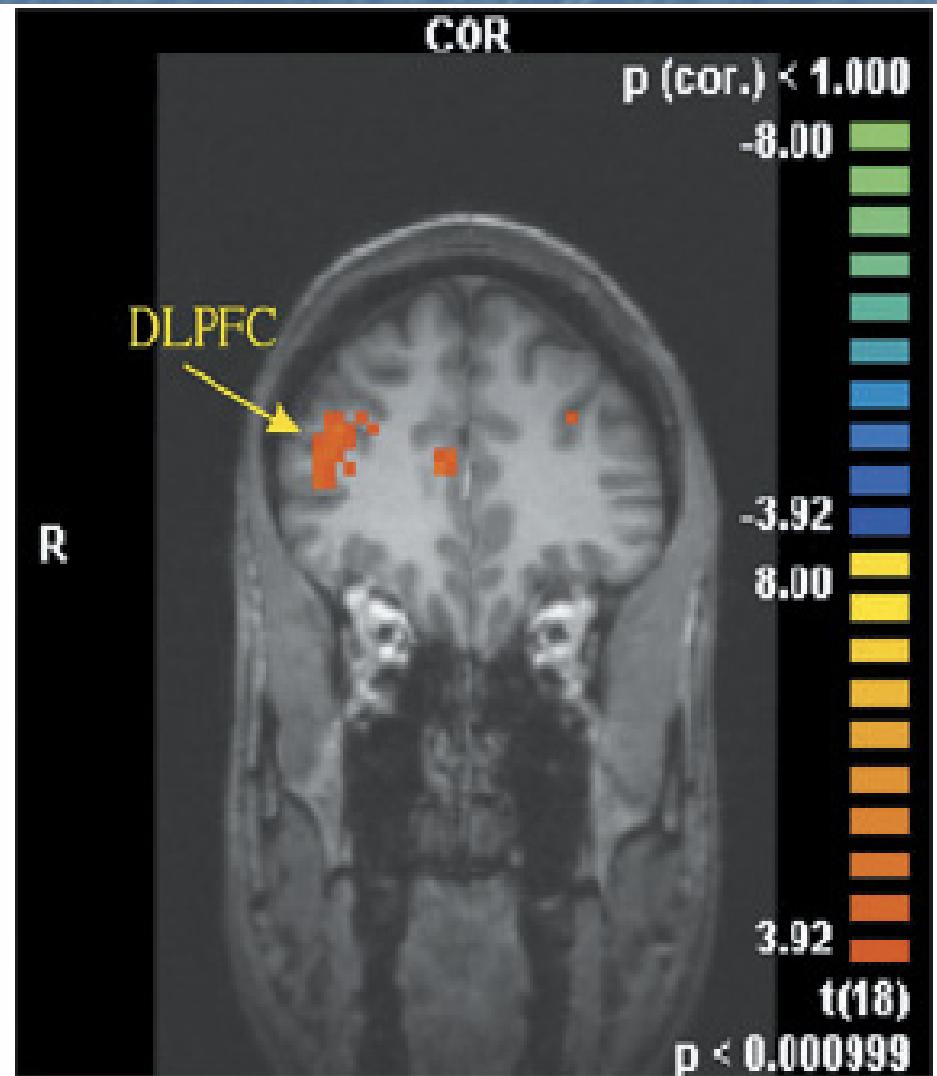
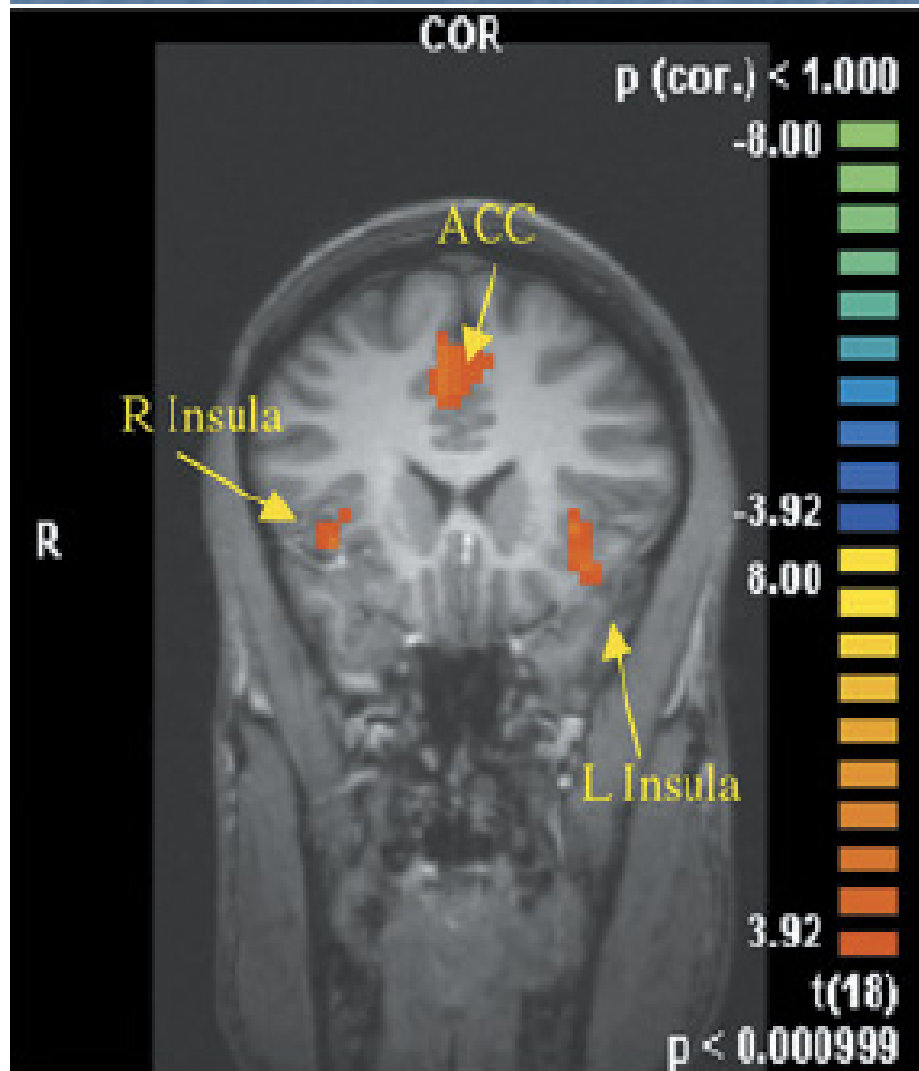
- Single neuron measurements

- Psychopathology

- Brain damage in humans

# Unfair offers in the ultimatum game

(Sanfey et al., Science 300 (2003) 1755)





# Unfair offers in the ultimatum game

fMRI – Unfair offers activate prefrontal cortex (PFC), anterior cingulate (ACC) and the insula

Interpretation:

- ACC (executive function area) struggles to resolve the conflict between wanting money (PFC) and disliking being treated unfairly (Insula)
- Insula activated for pain, disgust, etc.

# The neural basis of strong reciprocity

*Strong reciprocity = altruistic punishment*

Punishing unfair behavior (or social norm violators) even at a cost to himself

- *The trust game with punishment*

(de Quervain et al. Science 305 (2004)1254)

- Player A and B receive 10 MU

Player A may transfer to B either 0 or 10

Transferred quantity is multiplied by 4

Player B decides to transfer half or nothing

- In case of no transfer, player A has 1 minute to decide whether to punish or not (p up to 20 points)

- Punishment costs p to A and 2xp to B

- Player A is PET scanned during the decision minute

# The neural basis of strong reciprocity

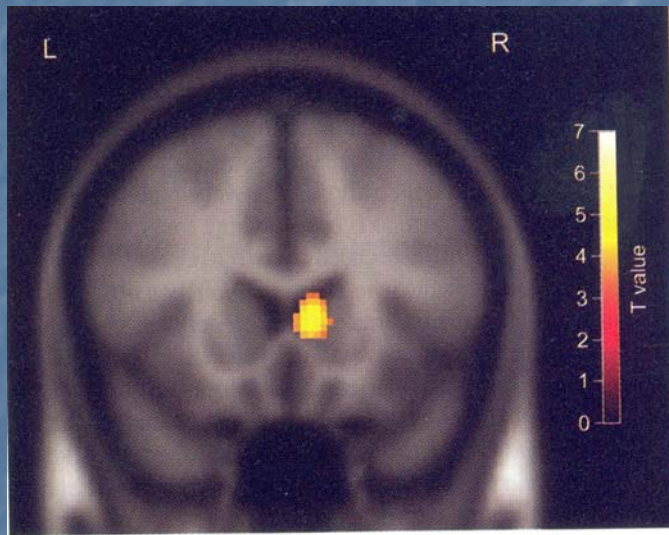
- *Several protocols*

IF – Intentional and free

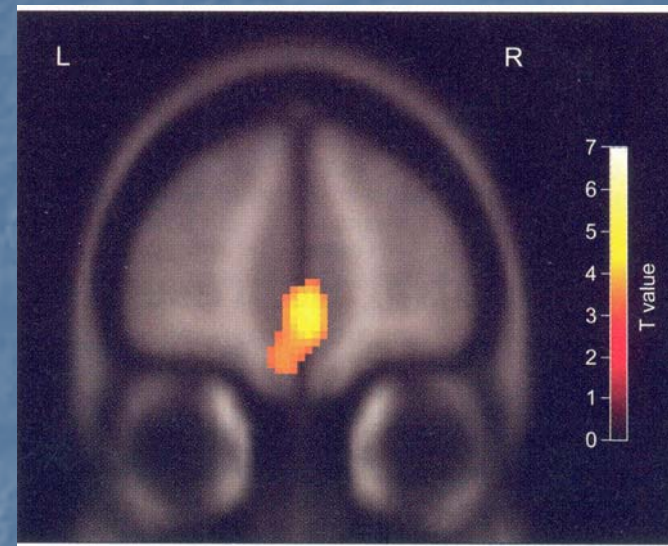
IC – Intentional and costly

IS – Intentional and symbolic

NC – Non-intentional and costly



Activation of the caudate nucleus  
(IC+IF)-(IS+NC)



Activation of prefrontal cortex  
IC – IF

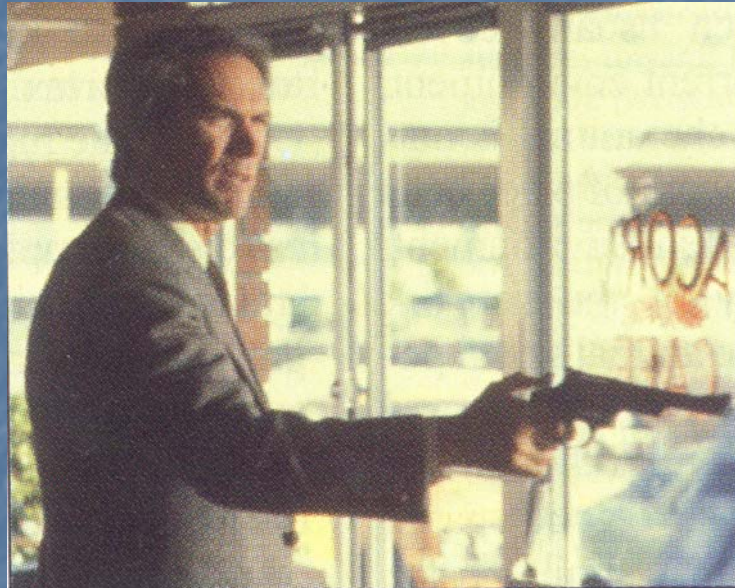
# The neural basis of strong reciprocity

## *Interpretation :*

- Activation of the caudate nucleus (region associated with reward processing, anticipation of pleasure)
- Activation of prefrontal cortex when punishment is costly (integration of the benefits and costs of punishing)
- The same caudate region is activated when people rewards cooperators.  
(Rilling et al. Neuron 35 (2002) 395)
- Punishment of defectors is altruistic in the biological sense but not in the psychological sense
- Conclusion : a satisfying social outcome is sweet, but revenge is sweet too

# The neural basis of strong reciprocity

*Brian Knutson illustration of altruistic punishment:*



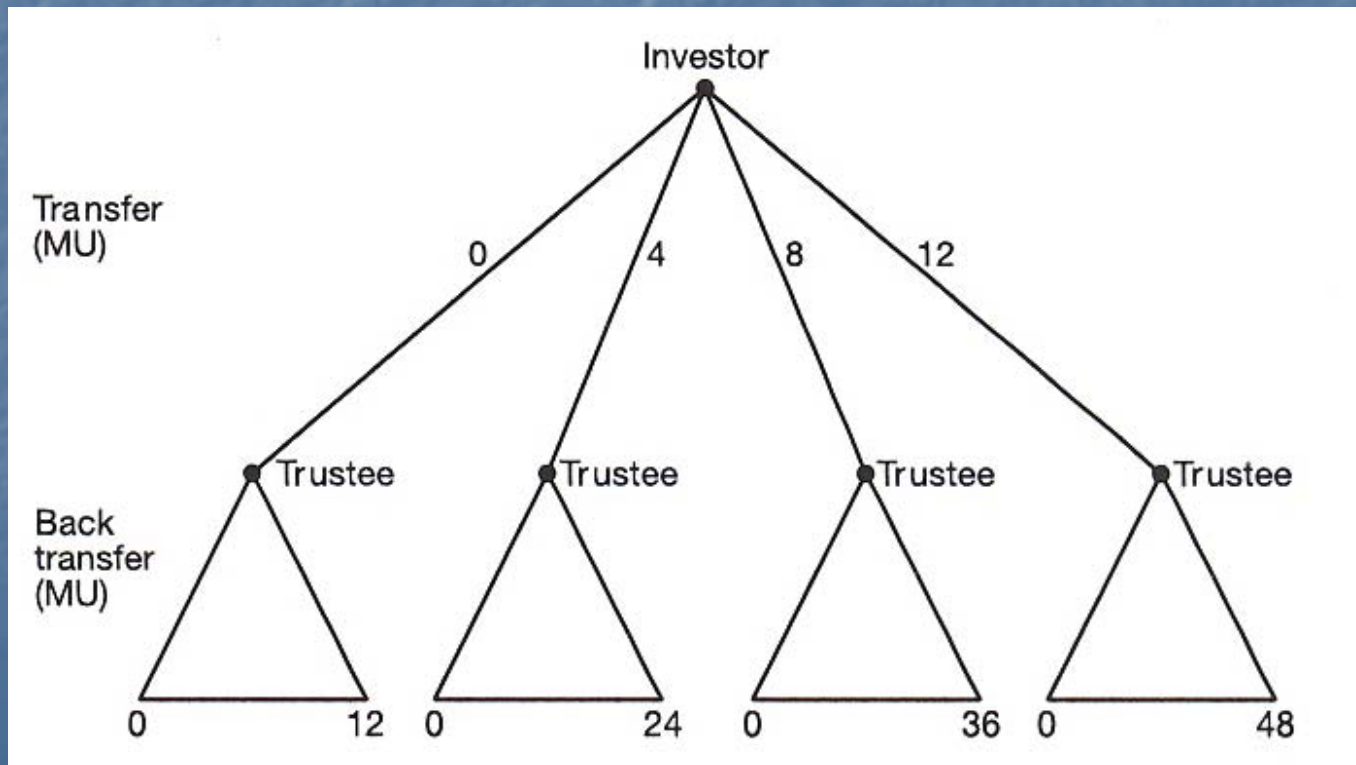
*Go ahead, make my day !*

“Dirty” Harry informs a norm violator that he anticipates pleasure from inflicting punishment

# Oxytocin increases trust

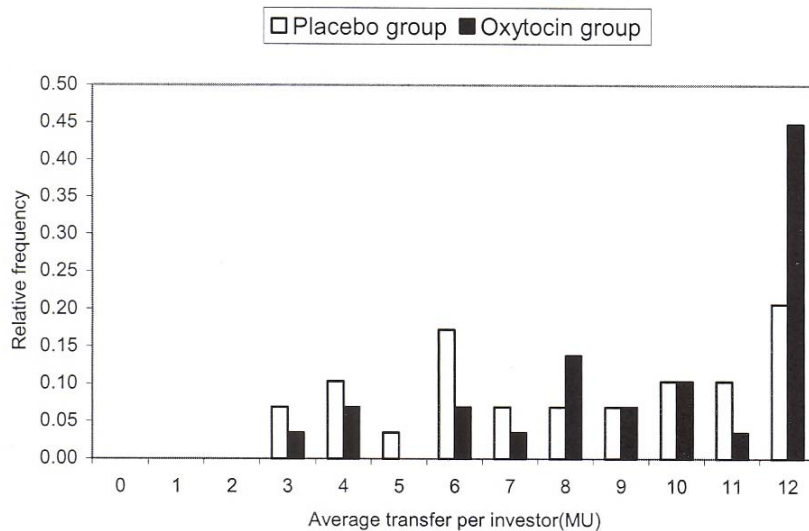
(Kosfeld et al. Nature 435 (2005) 673)

- Oxytocin – a small peptide produced naturally in the hypothalamus
- Acts on some functional targets (inducing labour and lactation) and in brain regions (amygdala, nucleus accumbens). It facilitates approach behavior
- The trust game

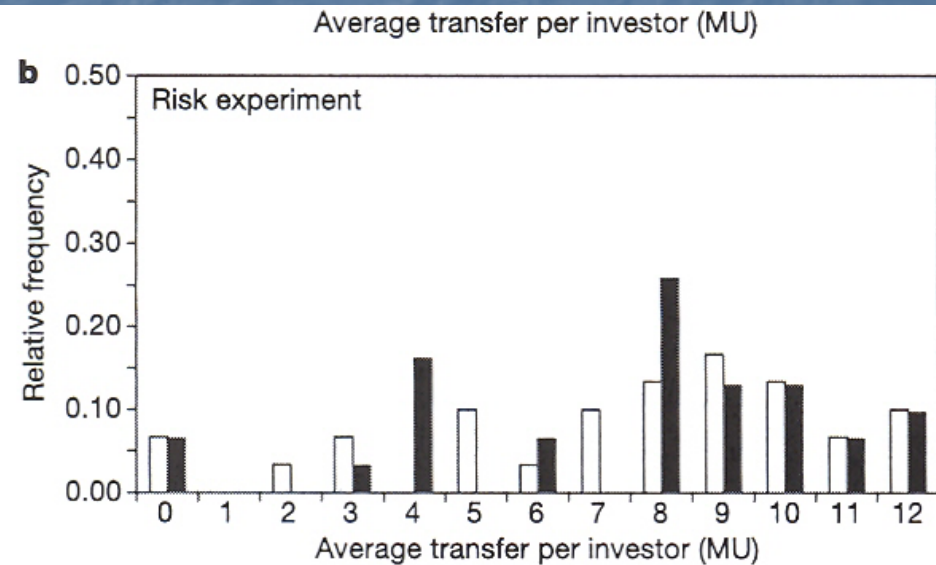


# Oxytocin increases trust

- The players receive a intranasal dose either of oxytocin or of a placebo
- The game is either played with an human trustee (trust) or with a computer (risk)

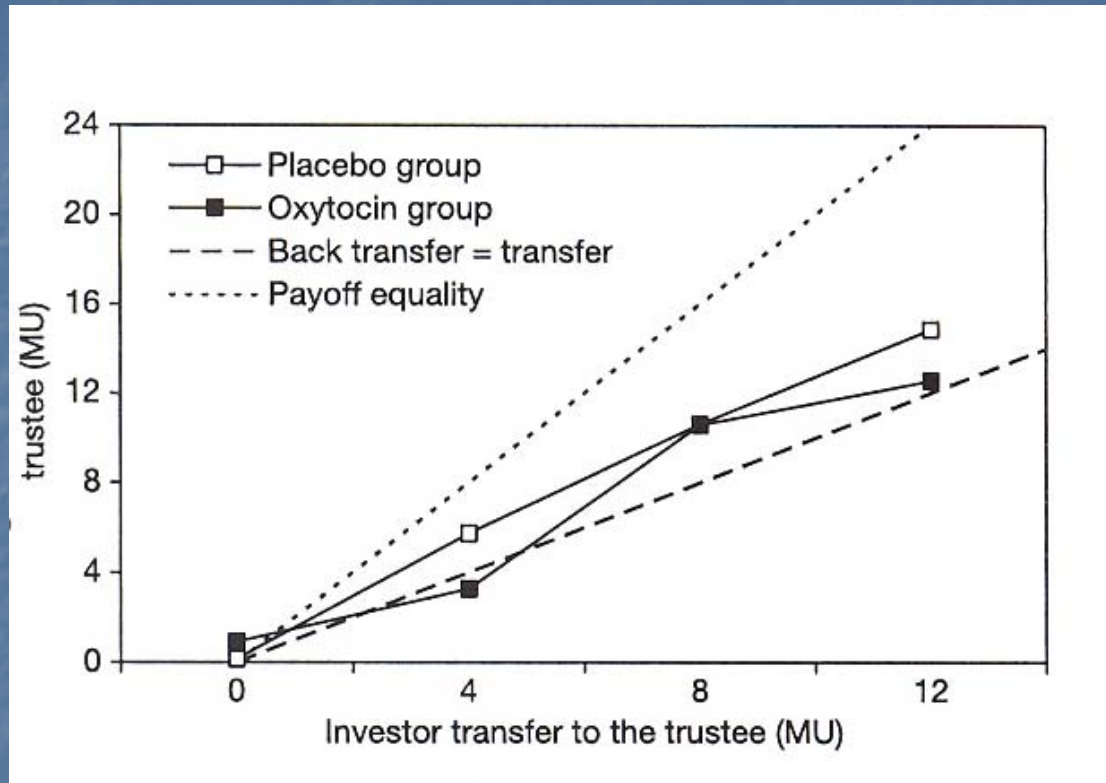


Trust



Risk

# Oxytocin increases trust



- Strong effect on investors (in the trust experiment) but not on trustees
- Reciprocity not affected by oxytocin



# Other experiments

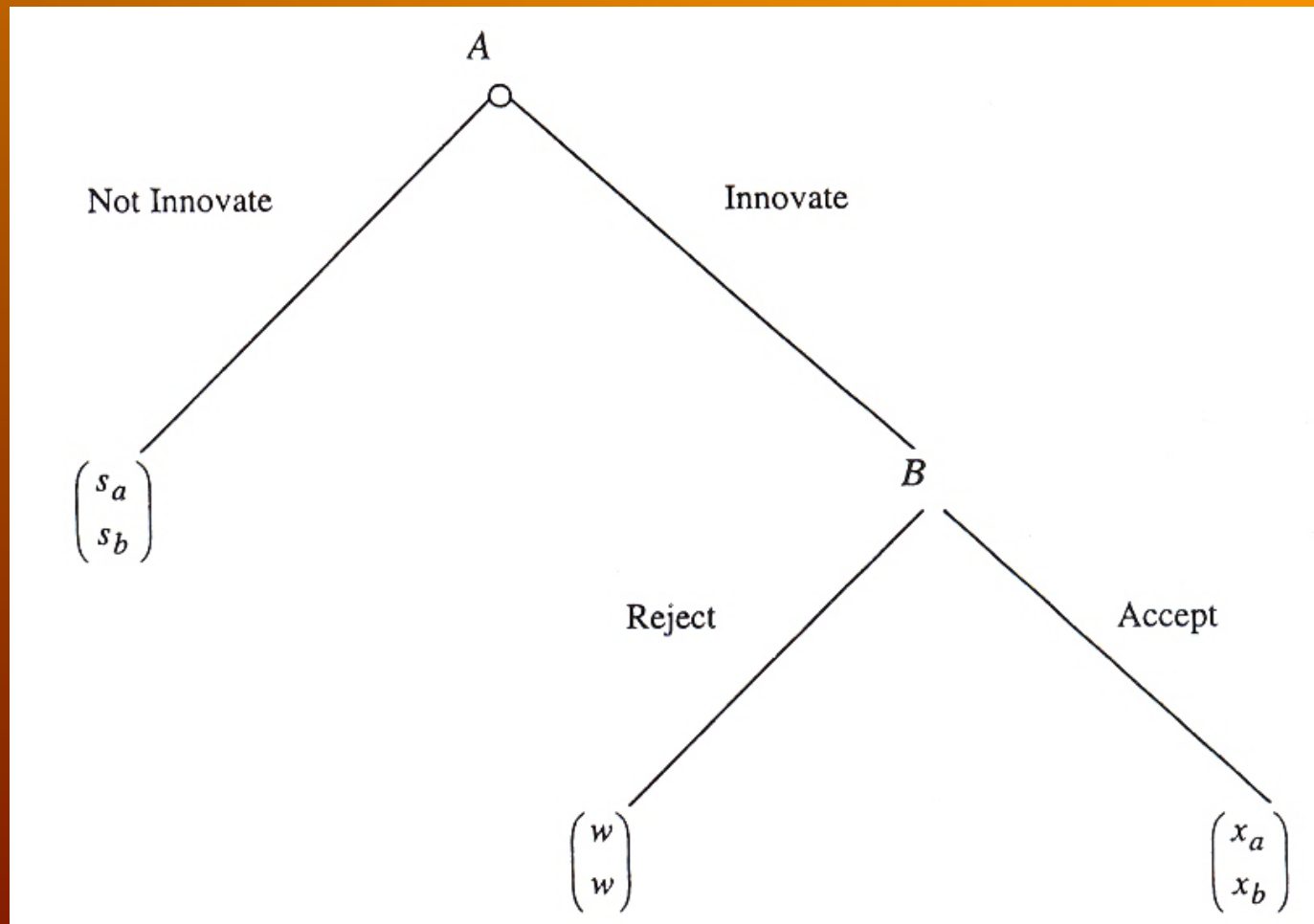
- Normal versus prefrontal cortex damage decisions (Bechara et al. Science 275 (1997) 1293)
- Brain activity during monetary incentive task (Knutson et al. NeuroImage 12 (2000) 20)
- Neural responses to monetary gains and losses (Breiter et al., Neuron 30 (2001) 619)
- Gains versus losses activity in the OFC (O' Doherty et al., Nature Neuroscience 4 (2001) 95)
- Mirror neuron activation (Keysers Neuron 31 (2001) 155)
- Neural basis for social cooperation (Rilling et al., Neuron 35 (2002) 395)
- Gains versus losses activity in the cortex (Dickhaut et al. PNAS 100 (2003) 3536)
- Social exclusion (Eisenberger et al. Science 302 (2003) 290)
- Social cognition and self-referential thought (Mitchell et al., J. Cognitive Neuroscience 17 (2005) 1306))
- Uncertainty in decision-making (Hsu et al., Science 310 (2005) 1680)
- Responses of the cingulate cortex in economic exchanges (Tomlin et al., Science 312 (2006) 1047)
- The effects of ketamine (Corlett et al., Arch. Gen. Psychiatry 63 (2006) 611)
- Neural coding of reward (Dreher et al., Cerebral Cortex 16 (2006) 561)
- Neurons encoding economic value (Padoa-Schioppa et al., Nature 441 (2006) 223)
- etc. etc.

## 4 - Impact of neuroeconomics on innovation

- Innovations (new products, economic structure changes, reform in an organization) increase the welfare of some people but may hurt others.
- An innovation that is a potential Pareto improvement, may then be resisted by some,
- Envy, reciprocity, uncertainty concerning a change in the status quo and not only monetary losses play a role in the rejection
- Anticipating the resistance, the innovators might decide not to innovate.
- Case studies (Lewis 1955, Foster 1967, Kuznets 1968, Kennedy 1988, Mokyr 1990, Alesina and Drazen 1991, Fernandez and Rodrik 1991, Inglehart 1997, Mui 1995, Platteau 2000)
- Fairness prevents market clearing (Fehr et al. 1993)
- A laboratory game

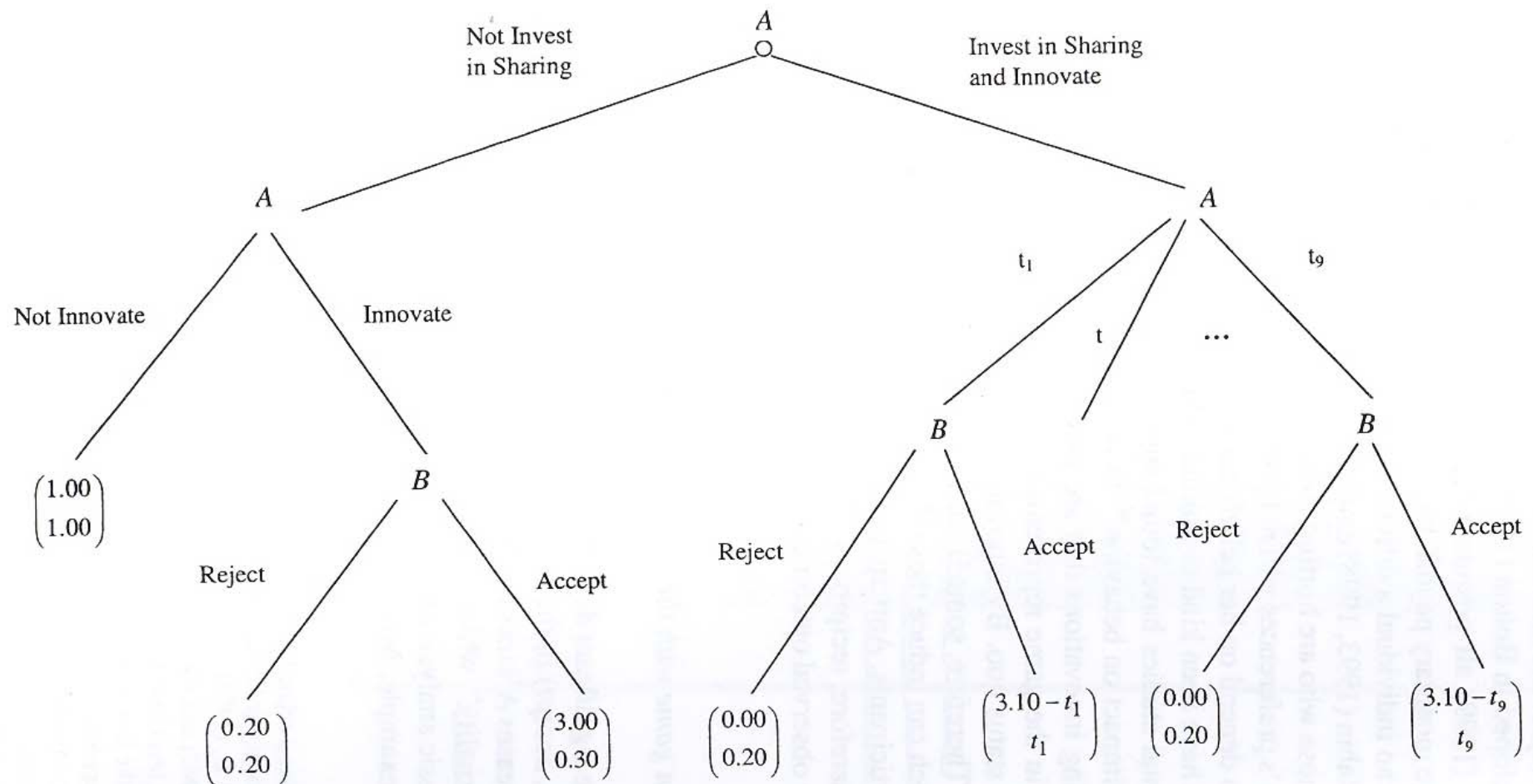
# Impact of neuroeconomics on innovation

- *"Fairness and sharing in innovation games"*  
(Cason and Mui, J. Econ. Behav. and Organ. 48  
(2002) 243)



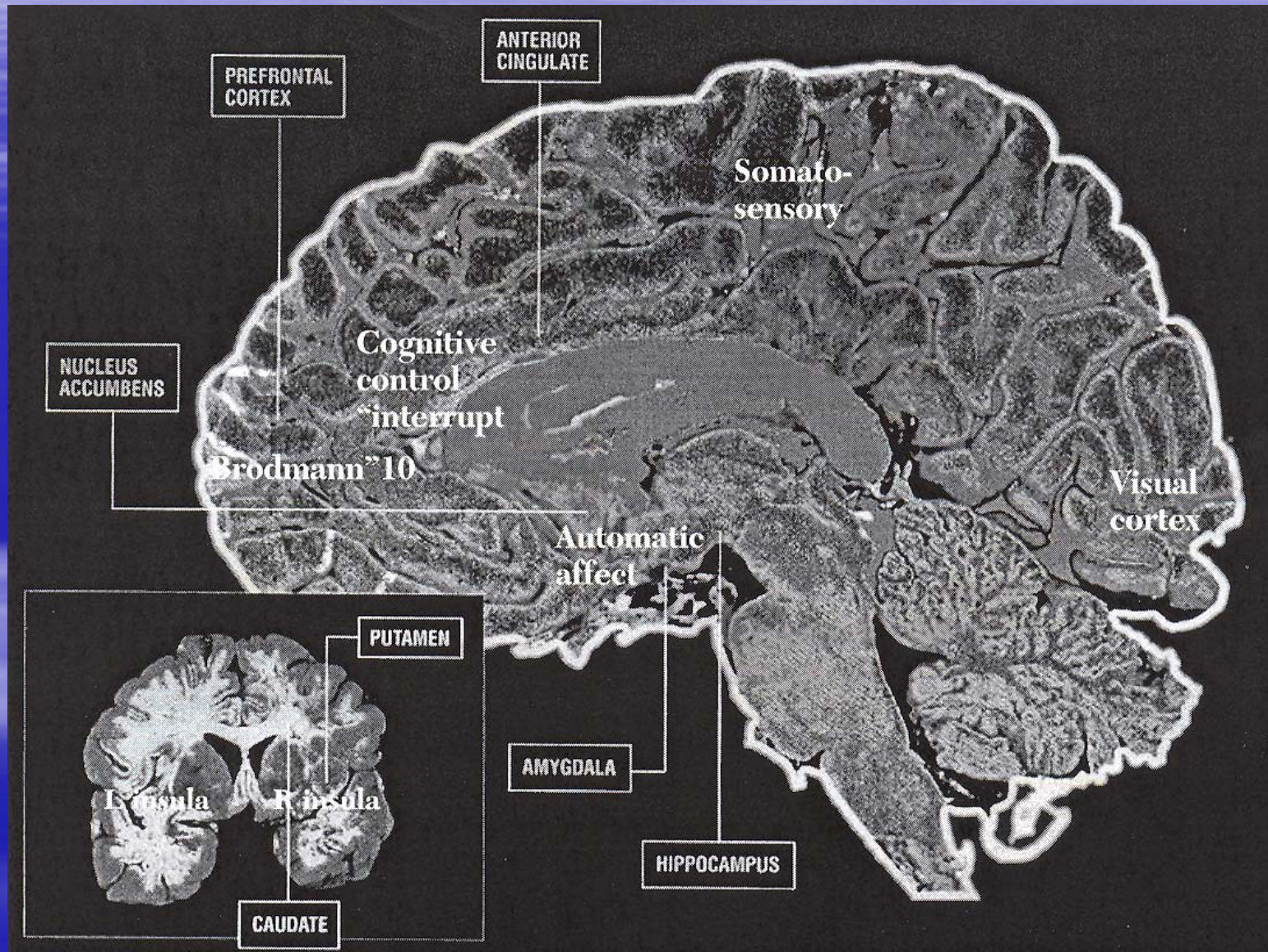
# Impact of neuroeconomics on innovation

- *"Fairness and sharing in innovation games"*  
(Cason and Mui, J. Econ. Behav. and Organ. 48 (2002) 243)



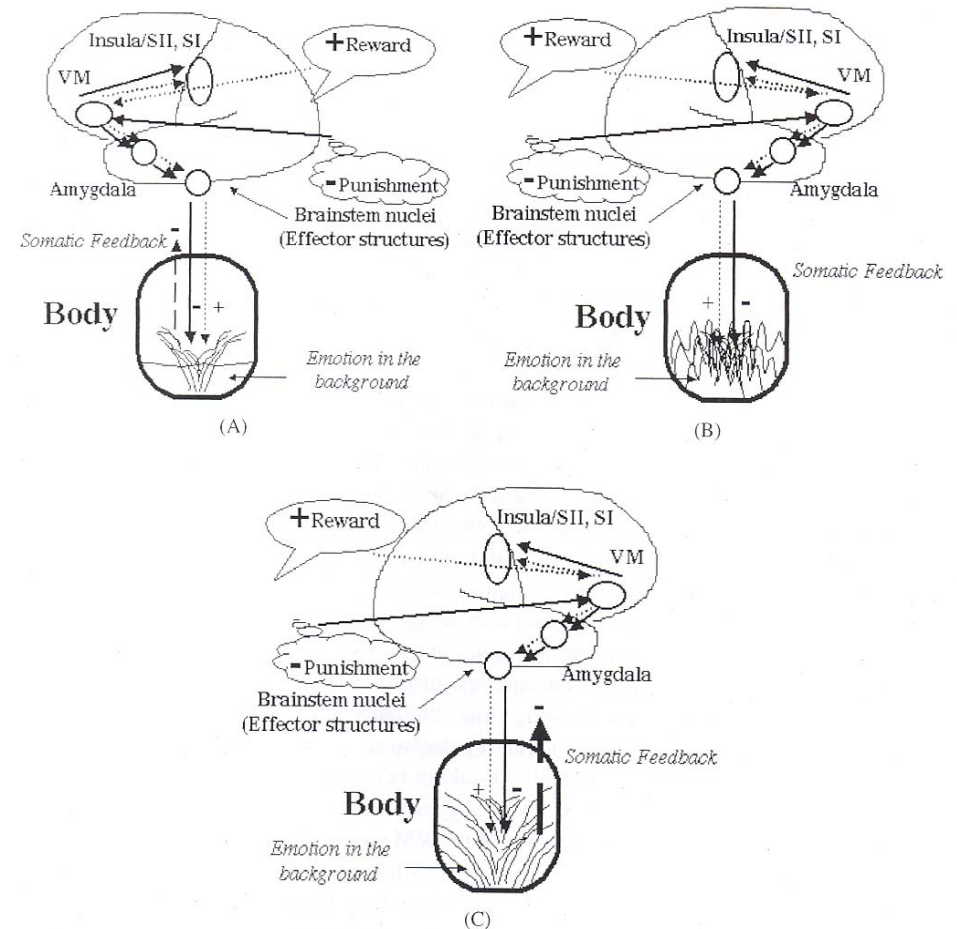
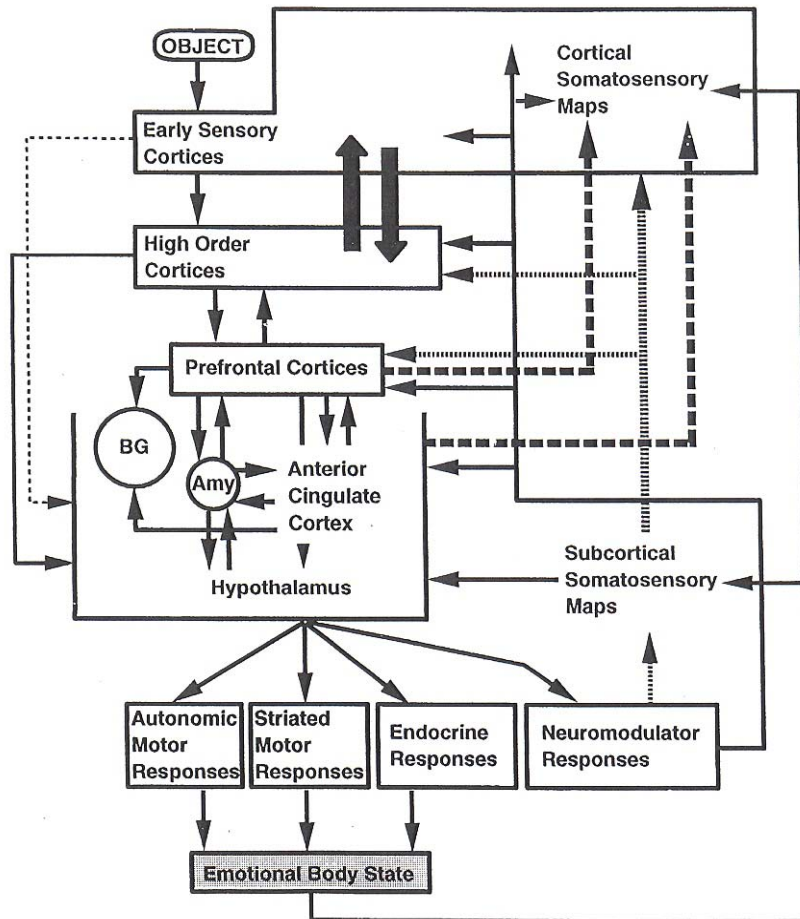
# 5 - Modelling neuroeconomics

- The economic brain



# Modelling neuroeconomics

- Some detailed neurological reaction circuits

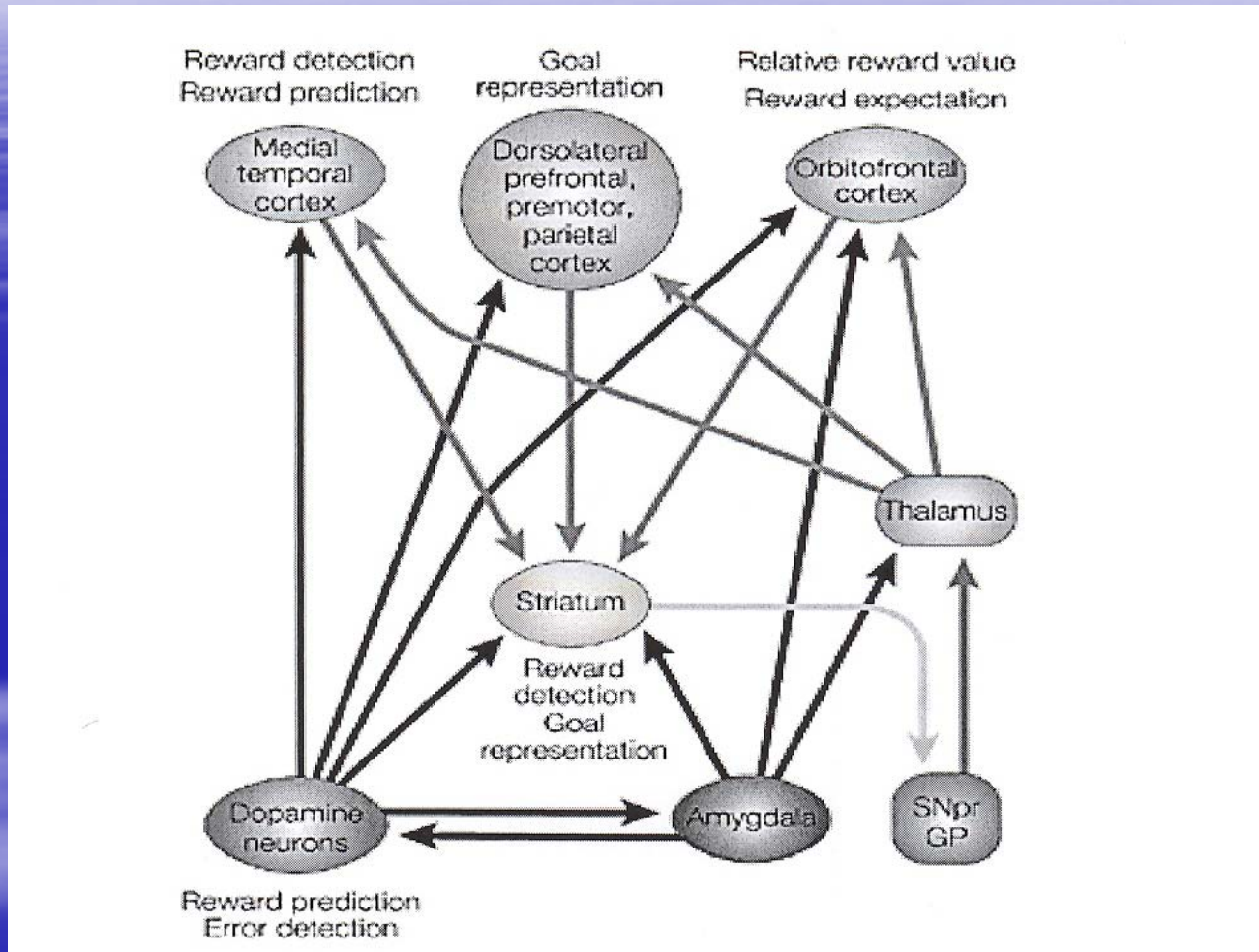


- The limbic system relates to everything (Damasio 98)

Somatic activation and decision making (Bechara 2005)

# Modelling neuroeconomics

- Some detailed neurological reaction circuits



- Reward processing (Schultz 2000)

# Modelling neuroeconomics

- Are there any simple modelling concepts amenable to mathematical treatment ?
- Several concepts :
  - *Inequality aversion* (Fehr, Schmidt)
  - *Reciprocity* (Bowles, Gintis, Falk, Fischbacher)
  - *Beliefs, preferences and constraints* (Heinrich, Boyd, Bowles, Camerer, Fehr, Gintis)
- From payoffs to utility functions
- Game theory with operators



# Inequality aversion. The INA operator

- $\otimes M_i$  = space of payoffs and utilities, N players
- $g_i$  = payoff of player i ;  $s_i = \{s_{i,a}\}$  strategies of player i ;  $s$  = set of all strategies
- $\otimes g_i \in \otimes M_i \xrightarrow{\text{INA}} \otimes u_i \in \otimes M_i$
- $u_i(s) = g_i(s) - (1/N-1) \sum_{k \neq i} (g_k - g_i) \varepsilon_{\alpha\beta}(g_k - g_i)$
- with  $\varepsilon_{\alpha\beta}(x) = \alpha$  ( $x > 0$ ) and  $\varepsilon_{\alpha\beta}(x) = -\beta$  ( $x < 0$ )
- Typically  $\alpha > \beta$
- After the application of the INA operator, Nash equilibrium is found for the  $u$ 's
- This operator leads to an utility function identical to the one of Fehr and Schmidt

# Inequality aversion. The INA operator

- Example : Ultimatum game

	<i>A</i>	<i>R</i>
4:1	4*	0
3:2	3	0
2:3	2	0
1:4	1	0

$g_P$

	<i>A</i>	<i>R</i>
4:1	1*	0
3:2	2	0
2:3	3	0
1:4	4	0

$g_R$



# Inequality aversion. The INA operator

- The INA operator seems OK
- But is not !
- Example :  $\alpha=0.7$        $\beta=0.4$

	$A$	$R$		$A$	$R$		$A$	$R$		$A$	$R$			
8:2	8*	0		8:2	2*	0	→	8:2	5.6	0*		8:2	-2.2	0*
5:5	5	0		5:5	5	0	<i>INA</i>	5:5	5	0		5:5	5	0

	$A$	$R$		$A$	$R$		$A$	$R$		$A$	$R$			
8:2	8*	0		8:2	2*	0	→	8:2	5.6	0*		8:2	-2.2	0*
10:0	10	0		10:0	0	0	<i>INA</i>	10:0	6	0*		10:0	-7	0*

$g_P$

$g_R$

$u_P$

$u_R$

- The result is the same in both cases. The utility of the 8:2 proposal for the responder is the same in both cases
- But one knows that experimentally that proposal is accepted more often in the second case

## Reciprocity. The RECI operator

- A simplified version of the ideas of Falk and Fischbacher
- Kindness of  $j$  towards  $i$   
$$K_{ji}(s_1 \dots s_j \dots s_N) = g_i(s) - (1/n_{s_j}) \sum g(s_1 \dots s_j \dots s_N)$$
- $n_{s_j}$  = number of strategies of player  $j$
- $$u_i(s) = g_i(s) - (1/N-1) \sum_j (K_{ij} - K_{ji}) \varepsilon_{\alpha\beta}(K_{ij} - K_{ji})$$
- Nonlocal operator in strategy space
- Instead of using the differential of payoffs to compute the utility, the kindness differential is used
- Takes care of intentions



# Calculation of Nash equilibria for mixed strategies

	<i>A</i>	<i>R</i>		<i>A</i>	<i>R</i>
8:2	5.8	-2.8	8:2	-1.85	-1.6
5:5	4.6	-1.75	5:5	4.3	-1

$u_P$

$u_R$

$$X_P = p(2.25a - 1.05) + 6.35a - 1.75$$

$$X_R = a(-5.55p + 5.3) - 0.6p - 1$$

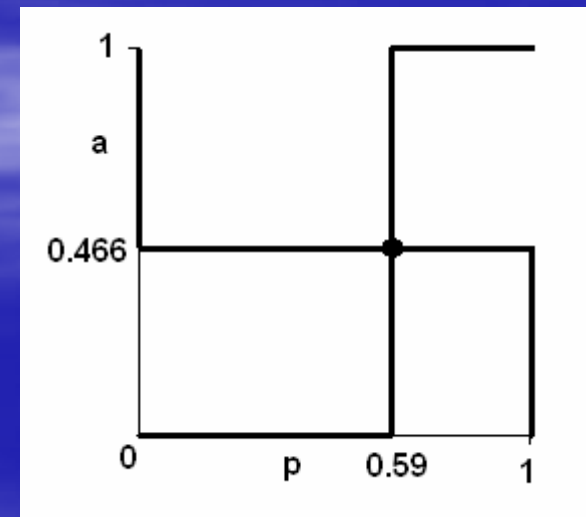
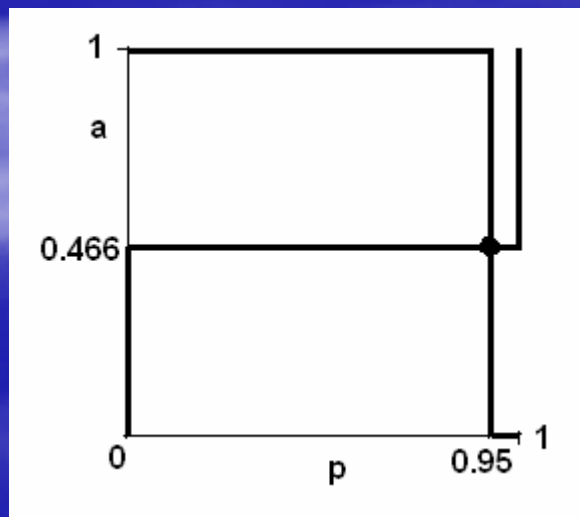
	<i>A</i>	<i>R</i>		<i>A</i>	<i>R</i>
8:2	6.8	-2.8	8:2	-0.1	-1.6
10:0	7.6	-3.5	10:0	-4.2	-2

$u_P$

$u_R$

$$X_P = p(-1.5a + 0.7) + 11.1a - 3.5$$

$$X_R = a(3.7p - 2.2) + 0.4p - 2$$



## Concluding questions

- “Game theory with operators” is simply a way to systematize and unify the computation of utility functions
- Is the RECI operator sufficiently universal ?
- Insofar as the feasible strategies of each player are the simplex of all pure strategies, existence of equilibrium points for the utilities is guaranteed by the Nash theorem
- In the case of social equilibrium (Debreu) the operators should not spoil contractibility of the set of feasible strategies
- If more than one operator is needed, what about commutativity properties ?
- Etc.



# Some additional references

- ◆ *Neuroeconomics* :  
C. Camerer, G. Loewenstein and D. Prelec; J. of Economic Literature 43 (2005) 9-64  
A. Bechara and A. R. Damasio; Games and Economic Behavior 52 (2005) 336-372
- ◆ *Inequality aversion* :  
Fehr and Schmidt; Quarterly J. of Economics 114 (1999) 817-868
- ◆ *Reciprocity* :  
Falk and Fischbacher; Games and Econ. Behavior 54 (2006) 293-315
- ◆ *Evolutionary aspects of strong reciprocity* :  
S. Bowles and H. Gintis; Theor. Pop. Bio. 65 (2004) 17-28.  
R V M; Advances in Complex Systems 7 (2004) 357-368
- ◆ *An alternative to model deviations from classical Nash equilibrium* :  
R V M; Quantum Information Proc. 4 (2005) 1-12

A sunset scene with a bright sun in a red sky and mountains in the foreground. The sun is a bright yellow star in the upper center, casting a glow. The sky is a deep red, and the mountains are dark silhouettes. The water in the foreground is dark with some light reflections.

*The end*

*<http://label2.ist.utl.pt/vilela/>*