



Erasmus Centre for Neuroeconomics



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Economic Rationality, Emotions and Uncertainty – Lecture 8

Neuroeconomics: How the brain makes decision

Clement Levallois – October 1st, 2009.

Minor provided by



Department of Marketing
Rotterdam School of Management
&
Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen

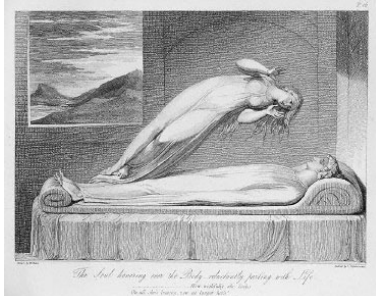
“These men will be composed, as we are,
of a soul and a body; and I must first
describe for you the body;

“Then, also separately, the soul;

“And finally I must show you how these
two natures would have to be joined
and united to constitute men. ...



René Descartes, *L'Homme*, 1664. Cited by
Paul Glimcher (2003).

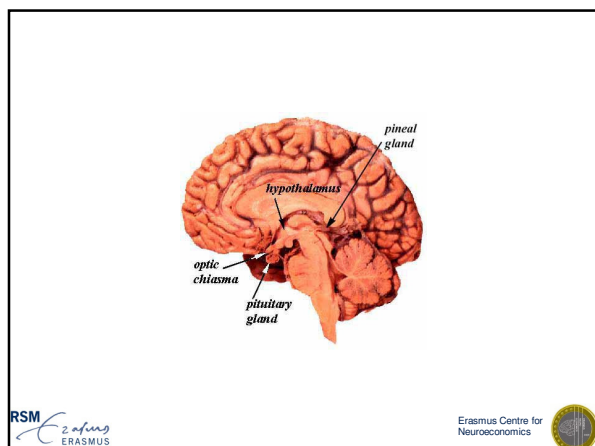





The Soul leaving her Body, eternally joining with Life.
(The soul leaves the body at death.)

a metaphor of dualism



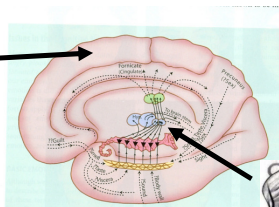
Descartes' error

"soul" is a bodily product,
Not "outside the body"

[and we now prefer to call it
"cognition"]



Descartes' error perpetuated?



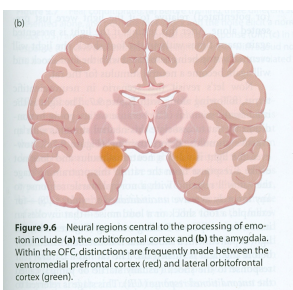
The limbic system for
emotions... and the rest of
the brain for rationality.

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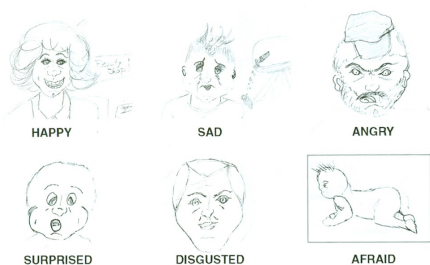
Emotions are distributed



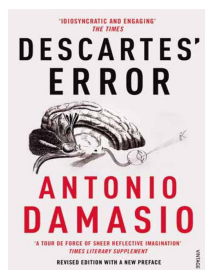
Example: role of amygdala



Example: role of amygdala



Descartes's error... but how to fix it?



(1994)



The somatic market hypothesis

Hypothesis: Emotions and rationality are closely tight.

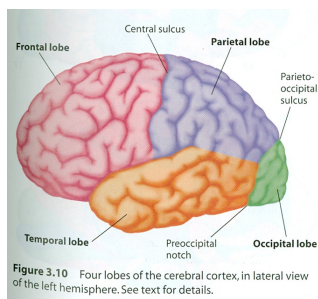
Proof: with an experiment.



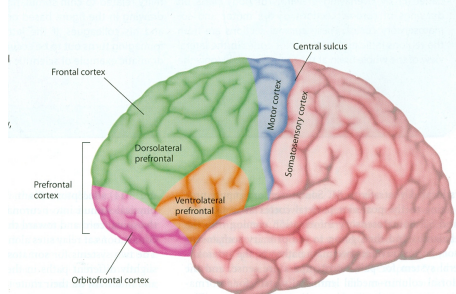
Iowa Gambling Task



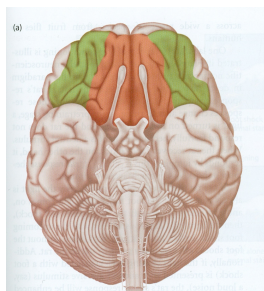
Patients with damage to VMPFC



Patients with damage to VMPFC



Patients with damage to VMPFC

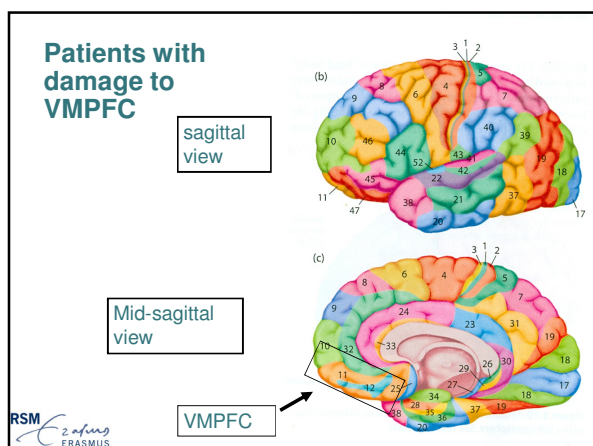


Green: lateral orbitofrontal cortex

Orange: ventromedial prefrontal cortex (VMPFC or VMF)

Green + orange: orbitofrontal cortex (OFC)







Skin conductance responses

After turning a card (good or bad)

Normal subjects: skin conductance reaction

vmPFC patients: skin conductance reaction

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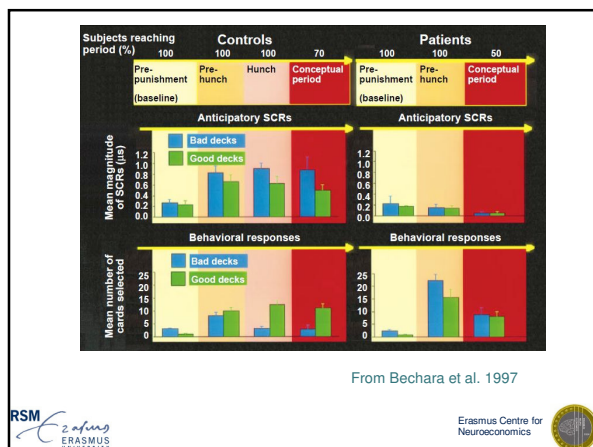
Skin conductance responses

Before turning a card (good or bad)

Normal subjects: skin conductance reaction

vmPFC patients: no skin conductance reaction





The somatic marker hypothesis

Memories of the feelings evoked by emotions experienced in past decisions...

... are retrieved when similar decisions are taken a new time

... which pushes the individual to make the choice corresponding to the feelings recalled.



Hence the title of Bechara, Tranel and Damasio (in *Cognition*, 1997):

“Deciding Advantageously Before Knowing the Advantageous Strategy”

Suggests that rational decisions are preceded or encouraged by emotional feelings.



The somatic marker hypothesis said differently:

According to the sm hypothesis,

“The main function of the orbitofrontal cortex is to interpret physiological arousal so that emotional experience can then enhance cognition.”

Gazzaniga et al., 2009.



Challenges to the somatic marker hypothesis

- Patients with spinal cord injuries perform well at the Iowa Gambling Task
 - (but what about their SCR? Is it different?)
 - DLPFC patients perform as badly as VMPFC patient at IGT
 - But when a learning phase is included, VMPFC improve, while DLPFC don't.
- } North & Carroll, 2001
- } Fellows & Farah, 2005



North & Carroll (2001)

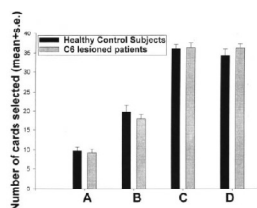
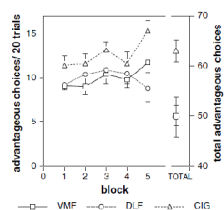


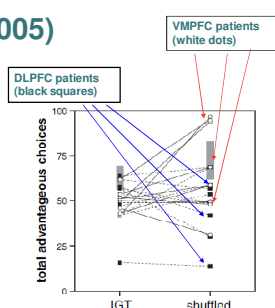
Fig. 1. Number of cards selected from each deck by spinal injury and healthy control subjects. Decks A and B are disadvantageous, C and D are advantageous.



Fellows & Farah (2005)



1. Normal IGT



2. IGT with bad draws from the start.



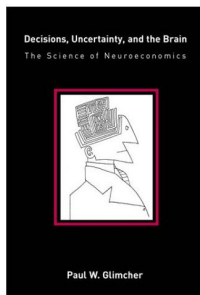
What is left of the somatic market hypothesis?

Attempts to tie decision-making to emotions via lesion studies and IGT experiments seem to need much more effort.

Another path to think about rationality and emotions has been explored.



Descartes' error: the other one

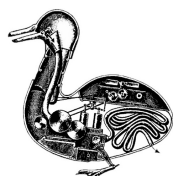


(2003)



The criticism of Descartes' mechanism

Descartes compared the movements of the body to the mechanics of a machine.



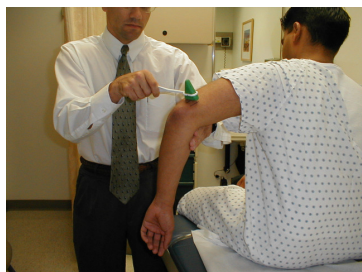
Jacques de Vaucanson's mechanical duck, 1738

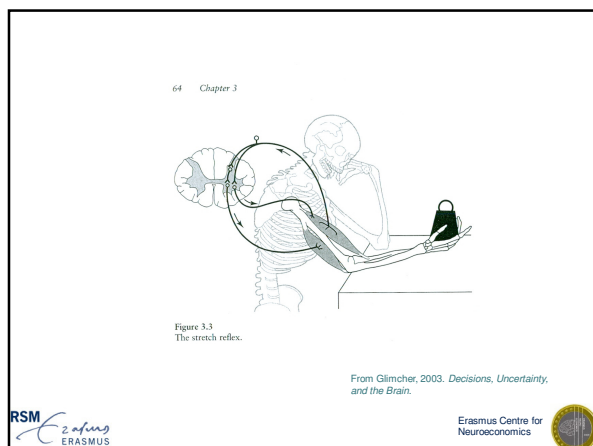


From Glimcher, 2003. *Decisions, Uncertainty, and the Brain*.



Descartes' mechanism is still much around through the reflex paradigm



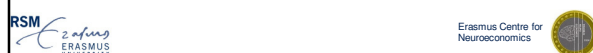


Food for thought...

Is the somatic market hypothesis an example of a reflex-like type of explanation?

(SCR + Emotions => Decisions)

That would mean that Damasio et al. are still very much in a Cartesian deterministic paradigm... !



Problems of the reflex paradigm

- | | | |
|---|---|-------------------------------------|
| <ul style="list-style-type: none"> - simple behaviors - basic emotions (fear, joy, anger, ...) | } | Reflex paradigm seems to do the job |
| <ul style="list-style-type: none"> - higher order behavior - <u>uncertainty</u>: intuitively, we feel that our behavior is not a succession of reflex-like mechanisms | } | Reflex paradigm seems insufficient |



Explaining behavior via the computational goal to be achieved

- Darwinian evolution shaped behavior to maximize fitness
- So we should expect that behaviors will be efficient

→ Neuronal organization and activity should reflect this efficiency property



Computational efficiency at the behavioral level

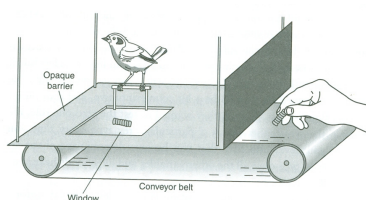


Figure 9.1
Krebs's mealworm foraging experiment.

Small prey
scotched to the
conveyor belt
(small worm)
Big prey (bigger
worm):
Bird should prey
worms at a rate
depending on
the difficulty of
catching them.



From Glimcher, 2003, *Decisions, Uncertainty, and the Brain*.



Still a mechanistic approach?

The point of the laboratory work is that it shows that great tits have the **machinery** for making decisions about optimal prey choice, and they could only have acquired this **machinery** through the action of natural selection in the wild.

John Krebs et al., 1977



A mechanistic approach?

Cognitive functions can be studied by imagining which neural organization would support a given computational goal.

Computational approach to behavior.

Neuroeconomics as conceived by Paul Glimcher.

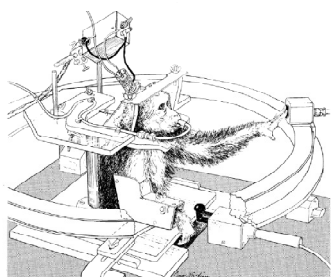
Rather than:

Cognitive functions can be studied by studying how a stimulus coming from the environment (or the rest of the brain) can trigger a behavior.

Cartesian, reflex-like approach to behavior.



Visual attention in monkeys



Visual attention in monkeys

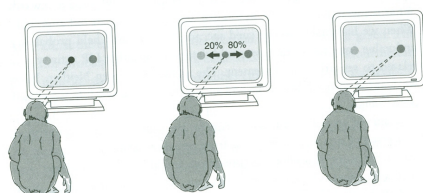


Figure 10.11
Changing probability that a movement will produce a reward in blocks.



Visual attention in monkeys

Efficient behavior for the monkey:

- Maximize the reward (Berry Berry juice)
- How?



Visual attention in monkeys



Figure 10.11
Changing probability that a movement will produce a reward in blocks.

1. Keep track of how much juice is awarded on the left, and on the right
2. Keep track of how likely it was, in past trials, to be rewarded when looking at left, and right
(= the monkey must remember *prior probabilities*)
3. Keep track of this probability with each new trial.
(= the monkey must remember *posterior probabilities*)

Probabilities x reward => Expected (Bayesian) utility



Visual attention in monkeys

If area LIP participated in solving the computational problem of deciding where to look

And

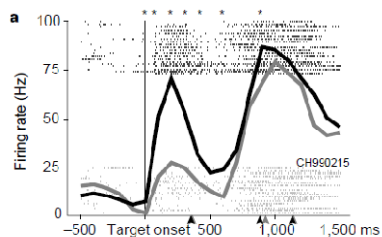
If that computational problem could be solved rationally only be a system that kept track of probability,

Then

"The activity of neurons in area LIP might well be influenced by the likelihood that a movement would yield a reward."



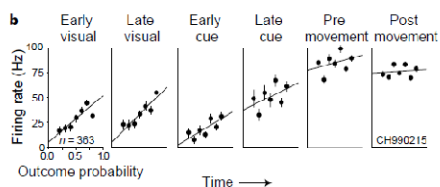
Visual attention in monkeys



From Platt and Glimcher (1999)



Visual attention in monkeys



From Platt and Glimcher (1999)



Two kinds of uncertainty

- So far we considered:

Epistemological uncertainty: uncertainty related to our poor knowledge of the world.

(as in: the monkey not knowing where the lamp will light up)

What about Irreducible uncertainty?



Two kinds of uncertainty

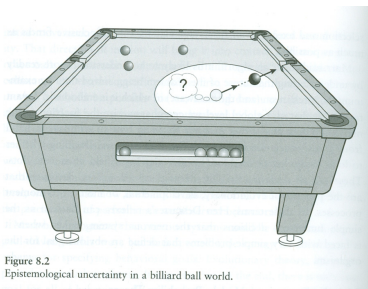


Figure 8.2
Epistemological uncertainty in a billiard ball world.



From Glimcher, 2003. *Decisions, Uncertainty, and the Brain*.

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Two kinds of uncertainty

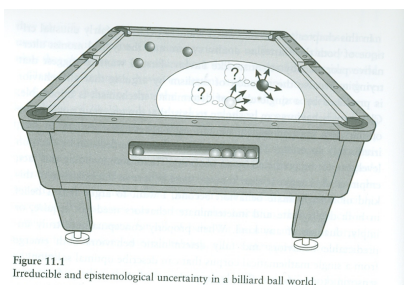


Figure 11.1
Irreducible and epistemological uncertainty in a billiard ball world.







From Glimcher, 2003. *Decisions, Uncertainty, and the Brain*.

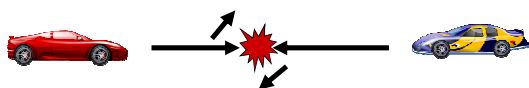
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Strategic uncertainty

		
	$-100, -100$	$50, -10$
	$-10, 50$	$1, 1$

The chicken game



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What is the best strategy for ?

It should choose depending on the choice made by the other car.

- If the other car goes straight too often, then it should deviate
- If the other car deviates too often, then it should go straight.


 How much is "too often"?




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Expected gains for to go straight

Let's call "y" prob. for  to go straight
two cases:

There is a prob y that  will go straight: There is a prob (1-y) that  will deviate:

Gains to  to go straight:
 $y \times (-100)$

Gains to  to go straight:
 $(1-y) \times (50)$


$$\text{Total for } \textcolor{blue}{\text{car}}: y \times (-100) + (1-y) \times (50) = -150y + 50$$



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Expected gains for to deviate

Let's call "y" prob. for  to go straight
two cases:

There is a prob y that  will go straight: There is a prob (1-y) that  will deviate:

Gains to  to deviate:
 $y \times (-10)$

Gains to  to deviate:
 $(1-y) \times (1)$

$$\text{Total for } \textcolor{blue}{\text{car}}: y \times (-10) + (1-y) \times (1) = 1 - 11y$$





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Optimal choice for

If gains of going straight > gains deviating
 \Rightarrow Go straight



$$\begin{aligned} -150y + 50 &> 1 - 11y \\ -139y &> -49 \\ y &< 35.25\% \end{aligned}$$

\Rightarrow If  goes straight less than 35% of the time, then  should always go straight.



Optimal choice for

Given that the payoff matrix is the same for the two cars, the conclusion is the same for the red car:

\Rightarrow If  goes straight less than 35% of the time, then  should always go straight.



Nash equilibrium with mixed strategies

When the 2 cars play their best strategies,

Each converge towards "go straight: 35% of the time". This is a Nash equilibrium because given their opponent's behavior, no car has a better strategy to play.

Conclusion: it is in the best of the 2 cars to vary their choice **unpredictably, but around the 35% figure on average**



What about monkeys?

(different task, but identical in structure to the chicken car game)

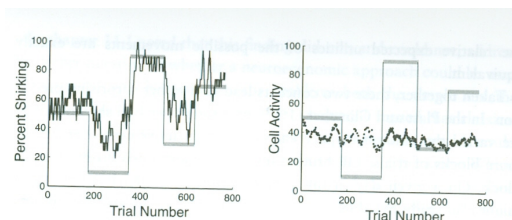


Figure 12.5

From Dorris and Glimcher (2004)



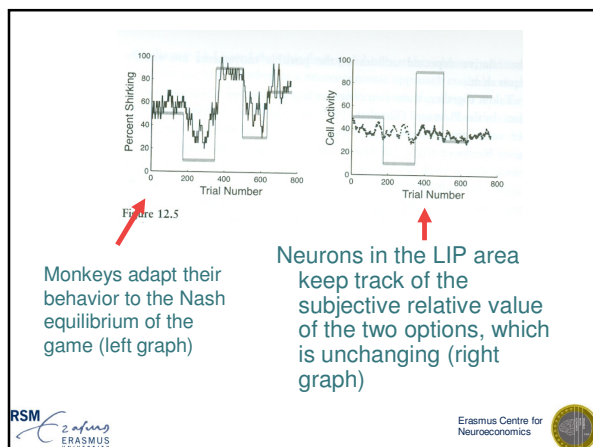


Figure 12.5

Monkeys adapt their behavior to the Nash equilibrium of the game (left graph)

Neurons in the LIP area keep track of the subjective relative value of the two options, which is unchanging (right graph)



Is Cartesian dualism / determinism disproved?

- Behavior is not deterministic: probabilities are recorded in the brain.
- **Not deterministic behavior can be explained without a rationality / emotions dualism**
(as in: "failures to achieve a rational decision are to be explained by the intrusion of emotions".
Rather, seemingly irrational behavior is explained as a feature of rationality itself: in an uncertain environment, uncertain behavior might be an optimal strategy)



Papers and books cited in this lecture

(all available from the Erasmus Library)

Bechara, Antoine, Antonio R. Damasio, Hanna Damasio, and Steven W. Anderson. "Insensitivity to future consequences following damage to human prefrontal cortex." *Cognition* 50, no. 1-3 (April 1994): 7-15.

Bechara, Antoine, Hanna Damasio, and Daniel et al Tranel. "Deciding advantageously before knowing the advantageous strategy." *Science* 275, no. 1293 (February 28, 1997): 1293-1295.

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Dorris, Michael C., and Paul W. Glimcher. "Activity in Posterior Parietal Cortex Is Correlated with the Relative Subjective Desirability of Action." *Neuron* 44, no. 2 (October 14, 2004): 365-378.



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Papers and books cited in this lecture

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Fellows, Lesley K., and Martha J. Farah. "Different Underlying Impairments in Decision-making Following Ventromedial and Dorsolateral Frontal Lobe Damage in Humans." *Cereb. Cortex* 15, no. 1 (January 1, 2005): 58-63.

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Krebs, John R., Jonathan T. Erichsen, Michael I. Webber, and Eric L. Charnov. "Optimal prey selection in the great tit (*Parus major*)."
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North, N.T., and R.E. O'Carroll. "Decision making in patients with spinal cord damage: afferent feedback and the somatic marker hypothesis." *Neuropsychologia* 39 (2001): 521-524.

Platt, Michael L., and Paul W. Glimcher. "Neural correlates of decision variables in parietal cortex." *Nature* 400, no. 6741 (July 15, 1999): 233-238.



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