A Neuroeconomic Perspective on the Ultimatum Game

Mattia Pavoni, *San Raffele University (Milano)*

Outline

1. Why BES, in particular, could be interesting for hardcore economists?
    - Some reason and an argument
2. UG and fMRI as a paradigmatic example: assumptions and methods
    - Psychological Background (the role of emotions)
    - Neuroscientific Methodology (brain image -fMRI-)
    - Economic Formal Structure (Game Theory)
3. UG and fMRI: the experiment (Sanfey et al. 2003)
    - What can we observe?
    - What can we predict?

1. Why NEc could be interesting for hardcore economists?

Pragmatical reasons (Marchionni and Vromer 2010)

Neuroeconomics is hot.

- Over the last few years, all over the world many leading universities have started their own lab or centre for neuroeconomics.
- Papers explicitly presented under the banner of neuroeconomics frequently appear in leading science journals such as Nature and Science.
- Neuroeconomics has also received quite some attention in the popular press.
- Not surprisingly, economists have started to reflect on neuroeconomics and its relevance for economics

Scientific Reasons "Hard-Version" (Bernheim 2009)

Neuroeconomics might improve economics and (or) neuroscience.

"Economists seem to to be primarily interest in novel choice behavior that link "traditional" enviromental variables (such as price and taxes) to choice behavior in a more accurate way than existing models. "

Scientific Reasons "Weak Version": from "traditional" enviromental variables to psychological variables.

P1. Psychological variables are relevant for the economic behavior

P2. Psychological variables are brain determined

P3. We can look into our brain (methodological limitation)

C. Neuroeconomics might improve economics [and (or) neuroscience].

The "Weak Version": psychological variables

...following behavioral economics...

•BES tries to upgrade the assumptions of standard economic theory, exploiting psychological cues and giving them a strong neural foundation.

2. UG and fMRI as a paradigmatic example: assumptions and methods

UG and fMRI: the weak argumet

The Neural Basis of Economic Decision-Making in the Ultimatum Game, Sanfey et al., *Science* (2003)

P1. Standard economic models of human decision-making (such as UT) have typically minimized or ignored the influence of emotions on people's decision-making behavior, idealizing the decision-maker as a perfectly rational cognitive machine.

P2. Behavioral economists have identified additional psychological and emotional factors that influence decision-making. (Also CNs theory: distinction between automatic and controlled processes)

C. Applying functional neuroimaging techniques (a tool from neuroscience) we can investigate the relative contributions of cognitive and emotional processes to human social decision-making, improving our decision-making model

UG and *f*MRI as a masterpiece: Checking our assumptions

1. Psychological Background (the role of emotions)

+

2. Neuroscientific Methodology (brain image -*f*MRI-)

+

3. Economic Formal Structure (Game Theory).

Psychological backgroung:

the role of emotions

The Vulcanization of the Human Brain: A Neural Perspective on Interactions Between Cognition and Emotion, Cohen, Journal of Economic Perspective 2005

- Suboptimal choices are emotional driven.
- Alternative brain areas conflict during the decision process and the emotions have a key role.

➡ When disagreements arise, behavior reflects the outcome of a competition among systems

Emotions: a definition (Cohen 2005)

Emotions:

1. low-level psychological processes
2. engaged by stimuli (or memories) with evaluative significance (different for each type of emotion)
3. elicit strong and stereotyped behavioral responses.

P1. Psychological variables (emotion) are relevant for the economic behavior

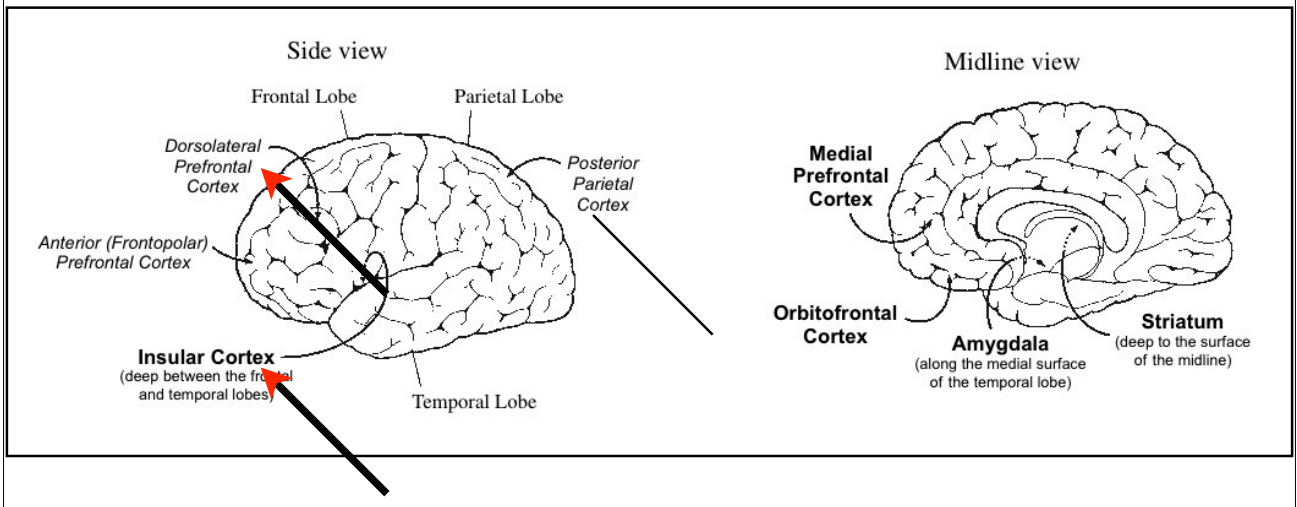
P. [By this definition] emotions are a type of valenced automatic response

C. Emotions are automatic processes associated with strong positive or negative utility

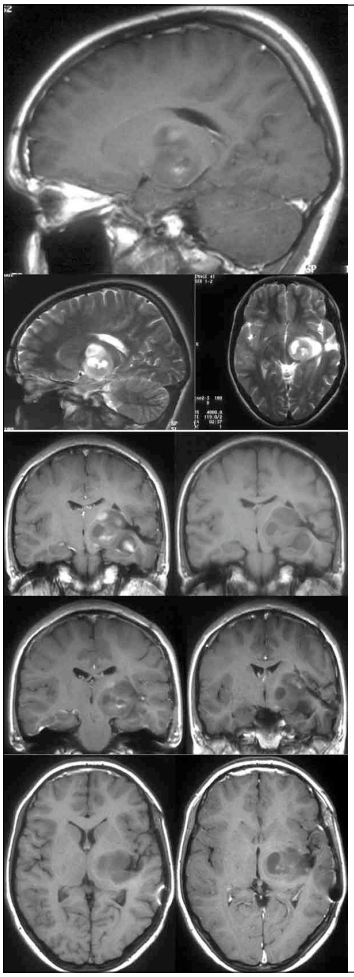
E.g.

"fear is a response to an aversive stimulus that leads to withdrawal, whereas visual recognition of a chair is also a rapid, automatic response, but does not carry specific value information nor command a particular behavioral response, unless one is tired and looking for a place to sit"

P2. Psychological variables are brain determined



Cohen (2005, p.9): Lateral (side) and medial (midline) views of the human cerebrum, identifying areas critically associated with decision making. Areas in bold have consistently been associated with emotional processing, while areas in italics have consistently been associated with higher level cognitive processes



Neuroscientific methodology: MRI (Magnetic Resonance Imaging)

Logothesis (Supplementary Information, 2008)

- MRI scanner is based on magnetically property of organic tissues
- Some atoms are sensitive to electromagnetic forces (given by the number of protons and neutrons in the nucleus)
- Hydrogen: the protons in its nucleus are in permanent motion around their axis. This motion give birth to a microscopic magnetic field

P3. We can look into our brain

(methodological limitation)

- *f*MRI is a type of specialized MRI scan. It measures the hemodynamic response (change in blood flow) related to neural activity in the brain
- However: "Inquire into the structure of a web of million of billion of neurons [10^{12}] of the human cortex, examining the regional blood flow […], looks like trying to reconstruct the maps of the cities of the world, using the airports' passengers flow as the only data." (Moro, 2006)

*f*MRI: selective activations? (N. Canessa)

- Specific cognitive tasks determine a stronger activation of specific brain areas
  - HOWEVER the brain is permanently supplied with blood in each of its parts: the brain is ALWAYS WHOLE active!
  - How can we talk about activation for a SINGLE task?
  - We must work in comparative terms: we have to *relate* the task to a baseline

Experimental Design (C. Ruff)

- Categorical designs
  Subtraction: Pure insertion
- Parametric designs
  Linear: cognitive dimensions

Cognitive Subtraction (C. Ruff)

Aim:

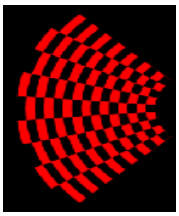
Neural structures computing process P?

Procedure:

Contrast: [Task with P] – [control task without P] = P

(the critical assumption of "pure insertion")

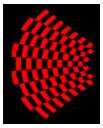
Example: Neuronal structures underlying face recognition?

 - 

Neuronal structures computing face recognition?

Cognitive Subtraction: Baseline-problems (C. Ruff)

"Distant" stimuli

 - 

Several components differ !

"Related" stimuli

 - 

"Queen!" "Aunt Jenny?"

P implicit in control task ?

Same stimuli, different task

 - 

Name Person! Name Gender!

Interaction of process and task ?

Parametric Designs: General Approach (C. Ruff)

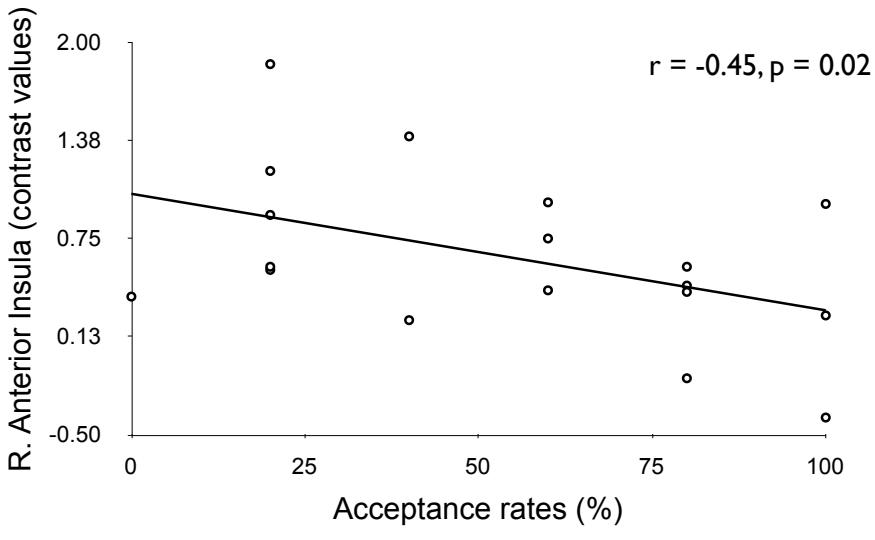
Parametric designs approach the baseline problem by:

Varying a stimulus-parameter of interest on a continuum, in multiple (n>2) steps...

... and relating blood-flow to this parameter

E.g.: UG (Sanfey et al. 2003)

Acceptance rates of unfair offers (stimulus-parameter of interest) plotted against right anterior insula activation for each participant (blood-flow)



Temporal resolution: *f*MRI "basic logic" (N. Canessa)

Time-series

- fMRI: a whole brain activity image each "x" seconds (e.g., each 2 sec),
- during a period of "n"minutes (e.g. 5 min, 150 images),
- during this period, the subject ripetitively accomplishes task A, and ripetitively accomplishes task B
- Statistical Analysis: in which areas (voxels) does brain activity vary in association to task A, (or B, or A-B)?

Game Theory (GT)

The Ultimatum Game (UG) (Guala 2008)

•two people are randomly and anonymously matched; one as proposer and one as responder.

•it is told they will play a game exactly one time

•The proposer is endowed with an amount of money, and suggests a division of that amount between himself and his responder.

•The responder observes the suggestion and then decides whether to accept or reject.

•If the division is accepted, then both earn the amount implied by the proposer's suggestion.

•If rejected, then both the proposer and responder earn nothing.

UG: Normative Solution

(Houser and McCabe 2009)

Economic theory based on self-interested preferences suggests that responders should accept any positive offer and, consequently, proposers should offer the smallest possible positive amount.

UG: Behavioral Data

- most proposers offer between 40% and 50% of the endowed amount
  - this split is almost always accepted by responders
- when the proposal falls to 20% of the endowment it is rejected about half of the time
  - rejection rates increase as the proposal falls to 10% and lower

UG anomaly (Guala 2008)

Anomaly respect to what?

The "standard prediction" (accept every positive offer) is actually derived from a fairly complex machinery

- a theory of strategic play (a theory of rationality)
- a set of assumptions about people's preferences and beliefs (self-interest assumption)
    - people prefer more money to less
    - they do not care about others' payoffs

3. UG and fMRI: the experiment (Sanfey et al. 2003)

The Neural Basis of Economic Decision-Making in the Ultimatum Game

Alan G. Sanfey, James K. Rilling, Jessica A. Aronson,
Leigh E. Nystrom, and Jonathan D. Cohen
Science 13 June 2003

1. the experimental design (N= 19)

- player introduced to 10 partners
  - emphasized social nature of task
- player scanned while playing Ultimatum Game
  - responding to offers from 10 partners
- player compensated one-third of earnings
  - received between $48-$60

Ultimatum Game offers

10 human offers

1 offer per partner

5 fair offers

$5:$5

5 unfair offers

1 of $7:$3

2 of $8:$2

2 of $9:$1

10 computer offers

5 fair offers ($5:$5)

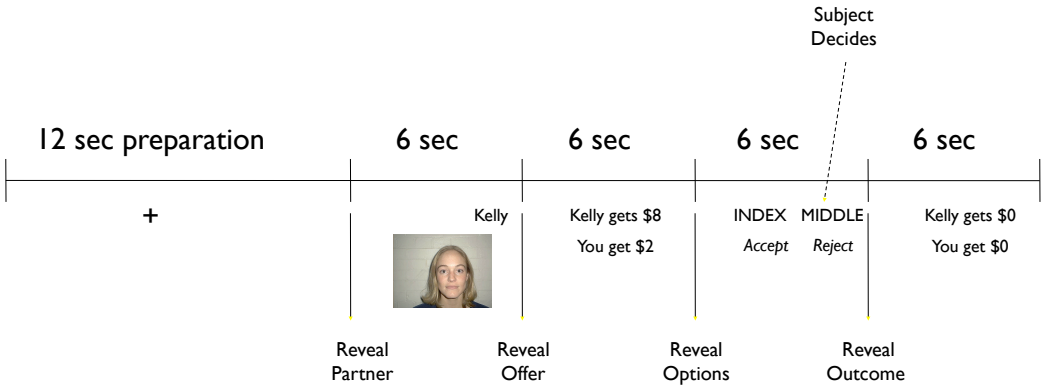
5 unfair offers ($7:$3; $8:$2; $9:$1)

10 control trials

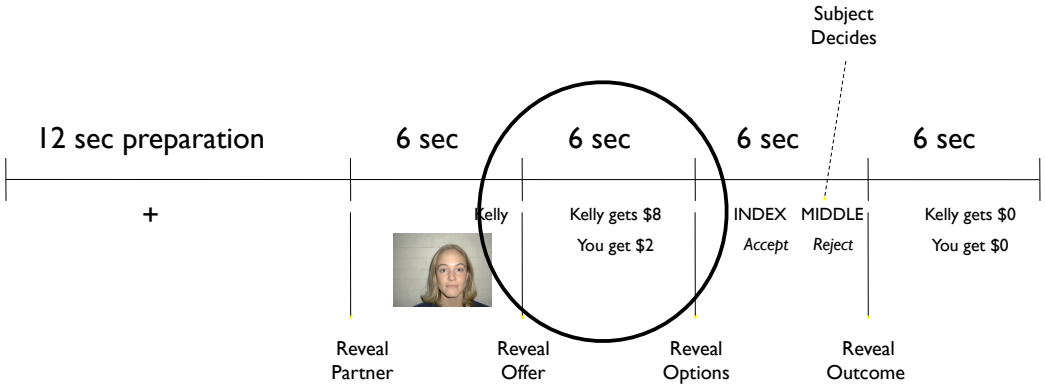
player receives cash reward

5 x $5, 1 x $3, 2 x $2, 2 x $1

Ultimatum Game: trial



Ultimatum Game: trial



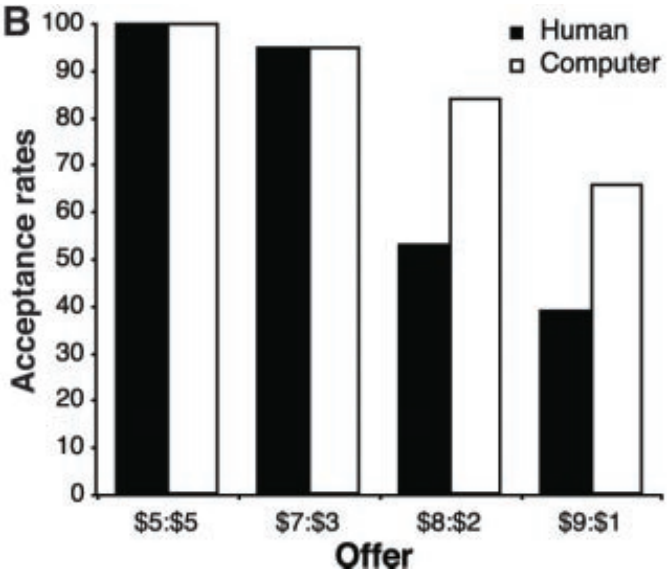
2. The Hypothesis: unfair offers and the conflict

- Unfair offers lead to conflict between cognitive –accept– and emotional –reject– motives
- We may expect to see represented in brain areas implicated in cognitive and emotional modes of thought (with additional regions possibly mediating these competing goals).
- the magnitude of activation in these structures might explain variance in subsequent decision to accept or reject these offers

The Results

- What can we detect?
- What can we predict?

UG: Human VS Computer



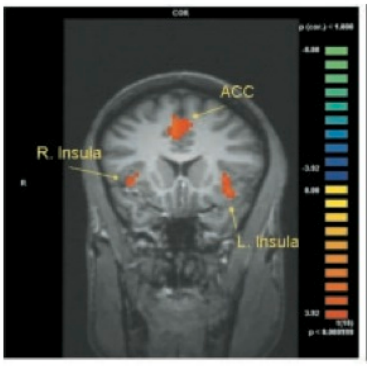
fMRI results: basic questions

- what brain areas are more active for an unfair offer than a fair offer?
  - anterior insula
  - dlPFC
  - anterior cingulate cortex
- can we use brain activity to predict decision behavior?
- what are the roles of emotion and cognition?

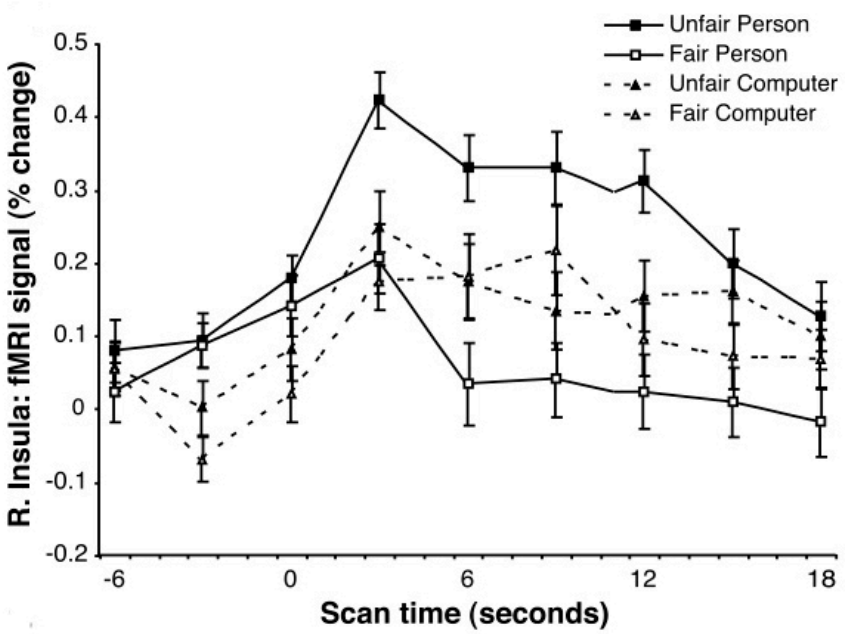
anterior insula

- involved in autonomic arousal and negative states
  - pain
  - hunger
  - thirst
- specific emotions
  - anger
  - disgust

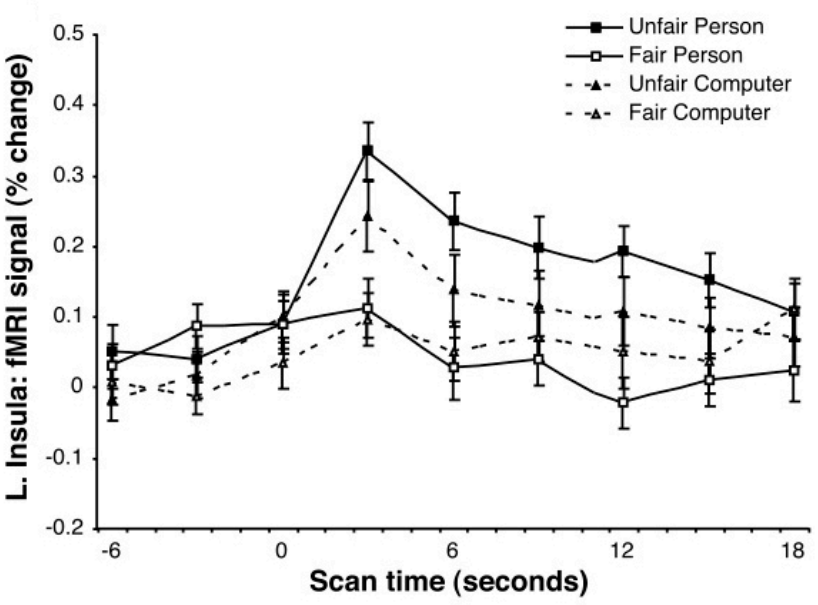
  (physical - also moral?)



right anterior insula: time course

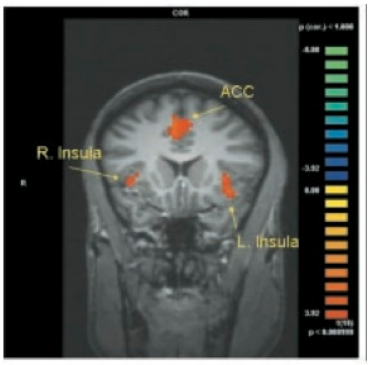


left anterior insula: time course

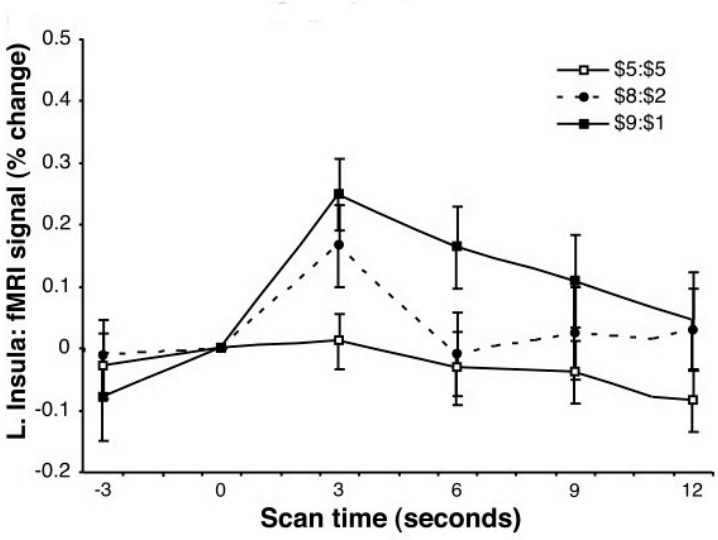


left anterior insula: offer magnitude

area more active for
$9:$1 offer than $8:$2

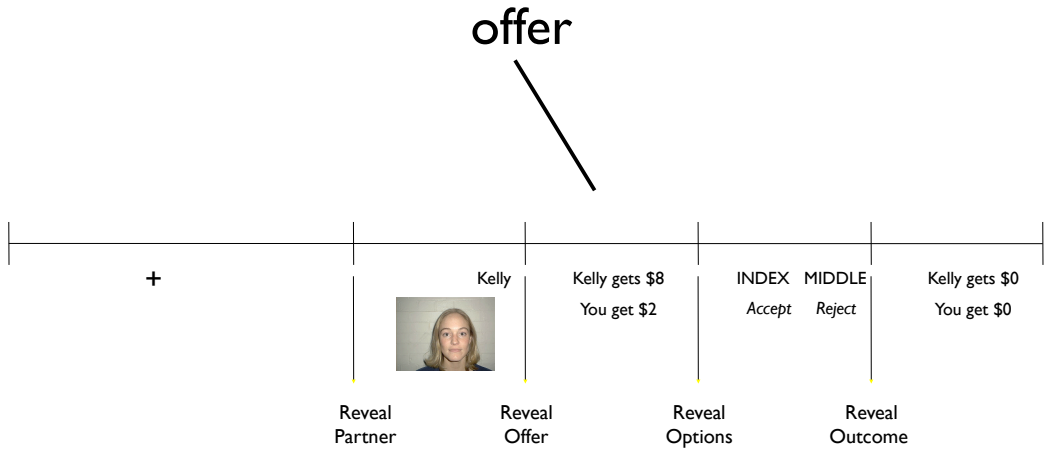


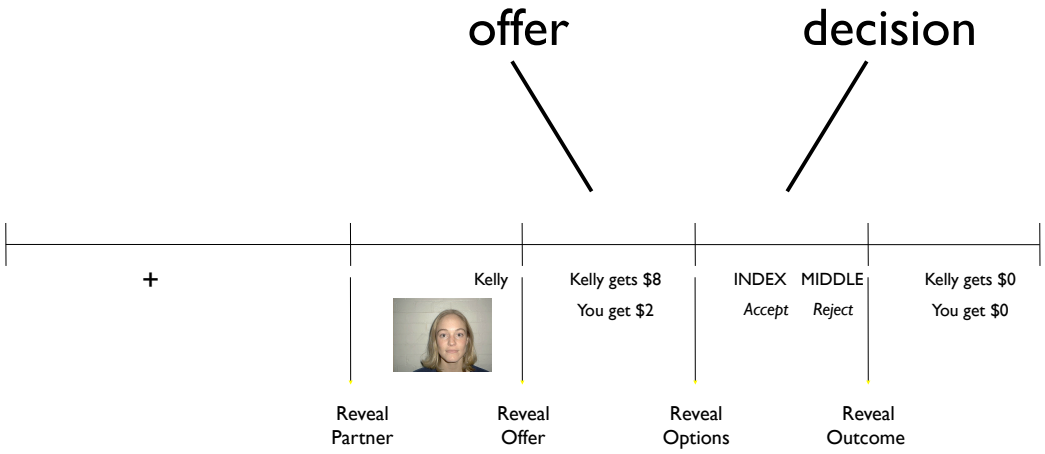
left anterior insula: offer magnitude



anterior insula and behavior

- can anterior insula activity to the offer be used to distinguish decision behavior?

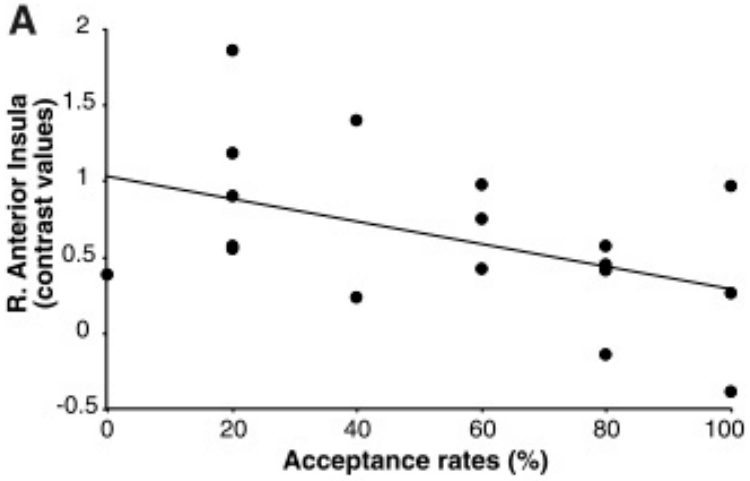




anterior insula and behavior

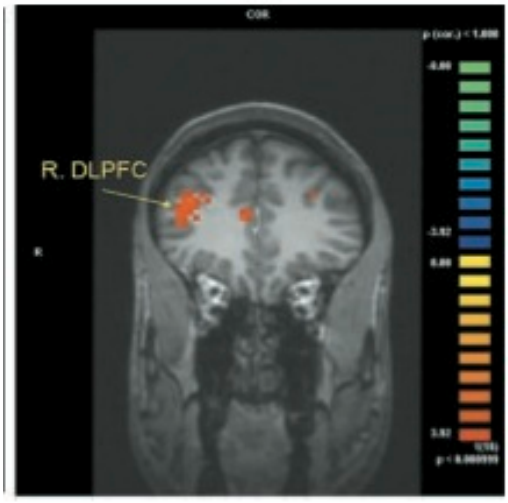
- can anterior insula activity to the offer be used to distinguish decision behavior?
- insular activation at:
  - subject level
  - trial level

anterior insula activity and individual subjects

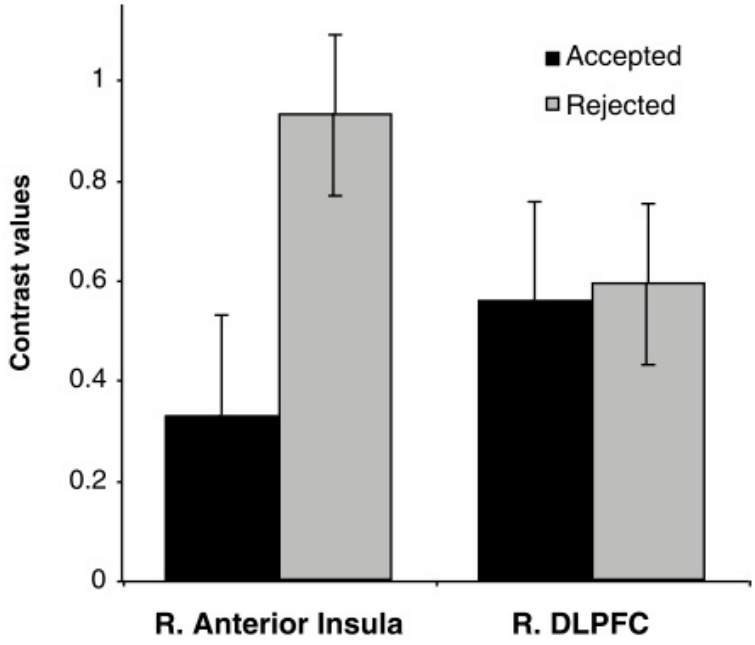


dorsolateral prefrontal cortex

- involved in:
  - executive control
  - goal maintenance
  - working memory
- one goal of UG
  - make money

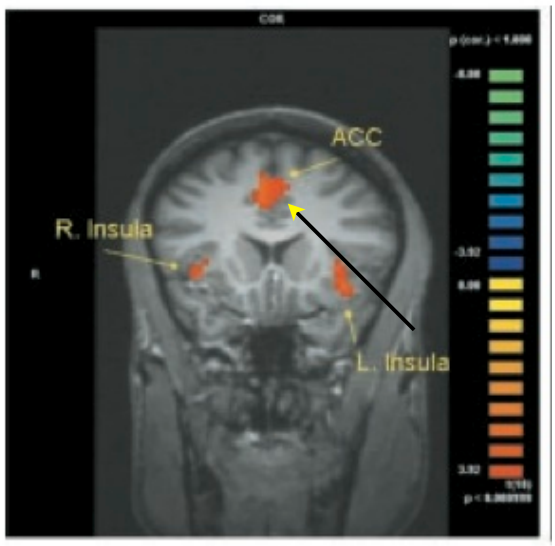


anterior insula & dlPFC



anterior cingulate cortex

- involved in:
  - cognitive conflict
  - error detection



Ultimatum Game: summary

- insula responsive to negative affect
  - more active for unfair offers
- dlPFC works to maintain goal state (make money)
  - choose to accept unfair offer when dlPFC more active than anterior insula

3. Could Neuroeconomics actually improve Economics?

Is the "Weak Version" satisfied?

P1. Psychological variables are relevant for the economic behavior

P2. Psychological variables are brain determined

P3. We can look into our brain (methodological limitation)

C. Neuroeconomics might improve economics and (or) neuroscience.

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