

Neuroeconomics: An Introduction

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5/29/2015

Outline

- Colin F. Camerer (2007), “Neuroeconomics: Using Neuroscience to Make Economic Predictions,” *Economic Journal*, 117, C26-C42.
- Introduction
- Neuroscientific Facts and Tools
- Neuro evidence about economic behavior:
 - Evidence for rational choice principles
 - Evidence for behavioral economics principles
 - Evidence for new psychological variables
- Conclusion

Introduction

- What is **Neuroeconomics**? It...
- Seeks to ground microeconomic theory in details about how the brain work
 - Subfield of behavioral economics and experimental economics
- Supplies theories and experimental designs for neuroscience (to study **higher-order cognition**)
- Essentially, it **uses Neuroscience methods to investigate Economic (Cognitive) questions**
 - Economics + Neuroscience + Psychology

Introduction

- Is this a sharp turn in economic thought?
- Back in 1900, maybe yes...
- Pareto (1897)
 - "It is an empirical fact that the natural sciences have progressed only when they have taken secondary principles as their point of departure, instead of trying to discover the essence of things.
 - ...Pure political economy has therefore a great interest in relying as little as possible on the domain of psychology."

Introduction

- Jevons (1871), Theory of Political Economy
- I hesitate to say that men will ever have the means of measuring directly the feelings of the human heart. It is from the quantitative effects of the feelings that we must estimate their comparative amounts.
- This pessimism led to the **as if** approach...

Introduction

- Milton Friedman (1953): Positive Economics
- If **assumption A** makes formal **predictions P**:
 1. **Assumption A** should be judged by the accuracy of the **predictions P** they imply.
 2. A (empirically) false **assumption A** should be tolerated if it makes accurate **predictions P**
- Do you agree with this?
 - Why or why not?

Introduction

- Principle (1) is fine, but principle (2) is not
- If (2) holds, that means there is a **hidden repair condition R** so that
 - $(\text{not-}A \text{ and } R) \rightarrow P$
- Hence, we should go find **condition R**
 - Why stick with $A \rightarrow P$???

Introduction

- Behavioral (**R**) vs. rational choice (**A**) models:
 - Loss-aversion
 - Learning and limited strategic thinking
 - Preference for immediate rewards
 - Preferences over social allocations (fairness, etc.)
- Technology allows us to observe the brain
- Why not look for more **accurate assumptions**
- to make **even better** predictions?

Introduction

- Theory of the **firm**
 - Before 1970: reduced-form production function
 - After 1970: contract theory models **firm structure**
- "The **new** theory of the **firm** replaces the (perennially useful) fiction of a **profit-maximizing firm** which has a single goal, with a more detailed account of..."
- how **components** of the **firm** – **individuals, hierarchies, and networks** – interact and communicate to determine **firm** behavior."

Introduction

- Theory of the **brain**
 - Before 2002: reduced-form **utility** maximizer
 - After 2002: neuroeconomics model **brain structure**
- "The *neuroeconomic* theory of the *individual* replaces the (perennially useful) fiction of a *utility-maximizing individual* which has a single goal, with a more detailed account of...
- how *components* of the *individual* - *brain regions*, *cognitive control*, and *neural circuits* - interact & communicate to determine *individual* behavior."

Introduction

- Example:
 - Fudenberg and Levine (2006), "A Dual-Self Model of Impulse Control," *American Economic Review*, 96(5), 1449-1476 – LR vs. SR player
 - Shefrin and Thaler (1988) – planner-doer
 - Benhabib & Bisin (2005) – executive/automatic
 - Brocas & Carillo (2005) – cortical control vs. emotional process, etc.
- Outlook: Can we explain Macro phenomena?

Neuroscientific Facts

- The brain is **weakly modular**,
- The brain is also **plastic** (responsive to environment as "software" are "installed")
- **Attention** and **consciousness** are scarce
 - How should the brain use them economically?
 - Montague (2007): **Holy grail of Neuroeconomics I**
- Why studying animals is interesting?
 - **Human brain** = extra neocortex + **primate brain**
 - **Primate brain** = some neocortex + mammalian brain

Neuroscientific Tools

- Tools are **complements** because
 - Each tool compensates for weakness of others
- Graduate students should **master one tool**
 - that can help answer the questions at hand
- **Neural evidence** about economic behavior:
 - Evidence for **rational choice principles**
 - Evidence for **behavioral economics principles**
 - Evidence for **new psychological variables**

Neuroscientific Tools

- fMRI (Good spatial resolution, BOLD)
- PET (Radioactive glucose, more direct)
- Lesion patients (Causal, but limited obs)
- TMS, TDCS (Causal, but not all regions)
- Single neuron recording (only in primates)
- EEG, MEG (Good temporal resolution)
- Psychophysical recording (GSR, PDR, heart rate, respiratory rate, etc.)
- Eyetracking (Information search + PDR)

Evidence for Rational Choice Principles

- Monkey's **lateral intraparietal cortex (LIP)** neurons fire at rates correlated to EV of juice rewards (triggered by saccades)
 - Platt and Glimcher (Nature 1999)
- Monkey **trade off** juice & image exposure
 - Deaner et al. (Current Bio. 2005)
- Monkey learn to play approximately **MSE**
 - Glimcher et al. (GEB 2005), Camerer et al. (?)

Evidence for Rational Choice Principles

- **OFC** neurons express values of choice
 - Padoa-Schioppa and Assad (Nature 2006)
- **Neural currency** creates tradeoffs
 - Conover and Shizgal (GEB 2005)
- Capuchin monkeys exchange tokens for food rewards and **respond to price change, obey GARP**
 - Chen et al. (JPE 2006)

Evidence for Rational Choice Principles

- **Bayesian** Model of Human Visual Speed Perception
 - Stocker and Simoncelli (Nature Neuro. 2006)
- vs. Human **Violations of Bayes' Rule**
 - Kahneman (AER 2003)
- This is humans, not monkeys, but can you think of experiments to test when Bayes' rule fails?

Evidence for Behavioral Economics Principles

- Time Discounting: **Quasi-hyperbolic** utility

$$U(c_0, \dots, c_t, \dots) = u(c_0) + \beta \sum_{t=1}^{\infty} \delta^t u(c_t)$$

- **β areas:** emotional limbic system (MFC, cingulate, ventral striatum)
- **δ areas:** lateral OFC, dorsolateral cortex
– McClure et al. (Science 2004)

Evidence for Behavioral Economics Principles

- Ambiguity-aversion: **Ellsberg Paradox**
 - 20 "red or blue" balls in urn; one ball is drawn...
- Are you willing to bet the ball drawn is red?
- Are you willing to bet the ball drawn is blue?
- **Ambiguity-averse** if say no to both bets
 - Home bias, robust control in macroeconomics,...
 - Scottish law: guilty, not guilty, and **unproven**

Evidence for Behavioral Economics Principles

- **Ambiguity vs. risk** conditions activate DLPFC, OFC, amygdala (vigilance area)
- Higher ambiguity-aversion parameter
=> Higher **OFC** activation
 - Hsu et al. (Science 2005)
 - (More later...)

Evidence for Behavioral Economics Principles

- Limited Strategic-thinking:
- **Cognitive Hierarchy**
 - Camerer et al. (QJE 2004)
- Heterogeneous levels of thinking
 - **Step-0**: randomize
 - **Step-1**: BR to randomization
 - **Step-2**: BR to mixture of step-0 and step-1, etc.
- Low types have **non-equilibrium beliefs**

Evidence for Behavioral Economics Principles

- Bhatt and Camerer (GEB 2005) ask subjects:
 1. Their own **choices** (what will you do?)
 2. **1st order** beliefs
 - what do you think **she will do?**
 3. **2nd order** beliefs
 - what do you think **he thinks you will do?**
- Q1-3 induce same brain activity if equilibrium
 - non-equilibrium subjects don't (Q2 different)

Equilibrium = State of the Mind!!

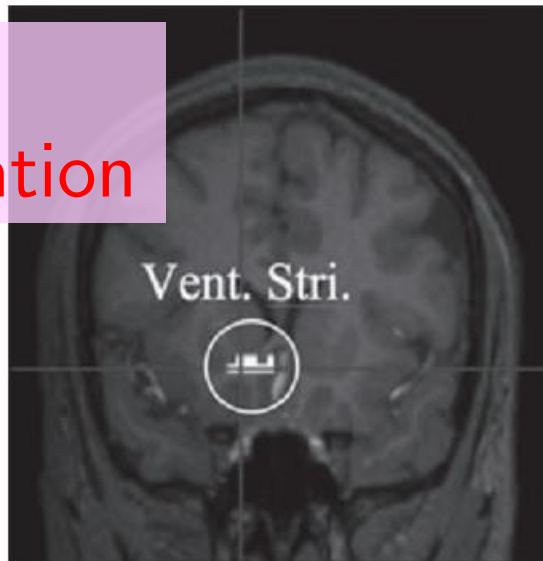
Evidence for Behavioral Economics Principles

Contrast: Choosing vs. 1st Order Belief

(a) In equilibrium

(b) Out of equilibrium

Reward
Anticipation



Not
Reasoning
Strategically
about others

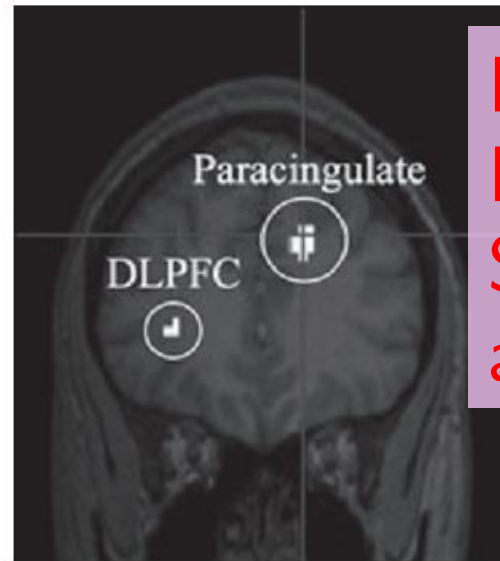


Fig. 1. *Differences in Brain Activity During Choosing a Strategy and Expressing a Belief About Another Player's Strategy* (Bhatt and Camerer, 2005).

Equilibrium Trials (a) Show only a Difference in Ventral Striatum (a Reward Anticipation Area). Out-of-equilibrium Trials (b) Show Stronger Activity in Choosing than in Belief Expression (Highlighting Paracingulate and Dorsolateral Prefrontal (DLPFC) areas), which Suggests Subjects are not Reasoning Strategically About Other Players.

Evidence for New Psychological Variables

- Neuroeconomics...
- not only provides data for existing theory,
- but also **point to new variables** that influence behavior
- Can preference be **innovated** just like R&D innovates production functions?
- Only few examples up to now...
 - Can you come up with a new one?

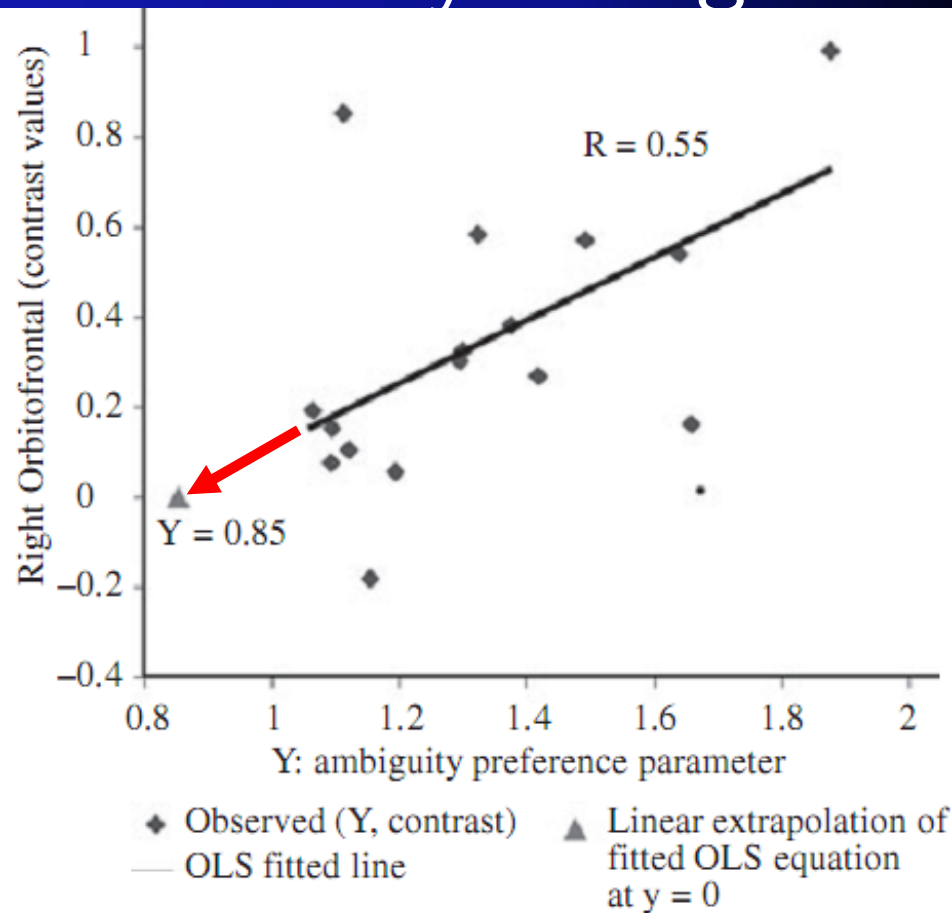
Evidence for New Psychological Variables

- OFC activation **produces** ambiguity-aversion
 - Hsu et al. (Science 2005)
 - **OFC lesion** patients show no ambiguity aversion
- $\gamma = 0.82$ for right OFC lesion patients (fMRI results predict $\gamma = 0.85$)

Evidence for New Psychological Variables

OFC
activity

NO
activity!



Ambiguity
Aversion

Fig. 2. Correlation Between Individual-specific Ambiguity-aversion Parameters γ Estimated from Choices (x -axis, Higher γ is more Ambiguity-aversion) and Differential Activity in Right Orbitofrontal cortex in Ambiguous vs. Risky Gamble Evaluation (y -axis).

Evidence for New Psychological Variables

- **PDR** predicts lying in cheap talk games
 - Wang, Spezio and Camerer (2010)
- **Disrupting DLPFC** with TMS makes you
- **accept unfair offers** in the ultimatum game
 - Wout et al. (Neuroreport 2005) and Knoch et al (Science 2006)
 - based on Sanfey et al. (Science 03)
- **Oxytocin** doses increase trust in trust game
 - Kosfeld et al. (Nature 2005)

Conclusion

- Future research
- **Multiple-process** theories of the brain
 - What is the best **dual-self** (or triple-self) model?
 - Can we find these selves in the brain?
- Neural evidence of **behavioral distinctions**
 - Loss aversion? Emotion for self-image? Framing?
- Can **state-dependent preference** explain this?
 - Are you aware of these influences on your **state**?

Conclusion

- The **Mindless Critique**: (In the past,) Economics is only about **making choices**.

But:

1. Why can't we consider **intermediate processes**?
2. **Neuroeconomics I**: How come we **chose to develop** our brains into its current form?
3. Response from History of Economic Thought:
 - If Edgeworth were alive today,
 - Would he just be making boxes,
 - Or **also** recording the brain?

Neuroeconomics: A View from Neuroscience

- Montague, Read (2007) Neuroeconomics: A View from Neuroscience. *Functional Neurology*, 22(4): 219-234.
- **Holy Grail 1** (from Neuroscience side)
- How does neural tissue sustain itself and process information **efficiently**?
 - Unlike computers who don't worry about heat
- This is **Neuroeconomics I**
 - **How economics can help neuroscience!**
 - Just like game theory helping theoretical biology...

Neuroeconomics: A View from Neuroscience

- **Holy Grail 2** (from Economics side)
- Can we find a **Theory of the Brain** that explains more human behavior?
 - Like Theory of the **Firm** in IO
 - EX: Fudenberg and Levine (2006)
- Some already covered above
- See Montague (Func. Neuro. 2007) for a **consumer's** account for this...

Neuroeconomics: Where We Stand?

- Bits and pieces are coming together
- **fMRI** (most common/advance) has great spatial resolution (areas of the brain), but
 - **Temporal resolution** is still 2 second per scan
 - **Activation** is indirect, not causal (only trace hemodynamic blood flow into brain regions)
- However, combining several tools gives a much clearer picture

Neuroeconomics: Where We Stand?

- Economics can guide experimental design
 - And can benefit from opening the black box
- SPM8 – Matlab Toolbox for fMRI data/GLM
- Can you think of a study to do yourself?
- Remember, since Imaging data are noisy:
 - Need 90+ trials per subject (to aggregate)
 - Need very clean design (treatment vs. control)
 - Interaction is difficult (typically only 1 scanner)

Recent Advancements

- [Chen, Nelson and Hsu \(2015\)](#), From "Where" to "What": Distributed Representations of Brand Associations in the Human Brain. *Journal of Marketing Research*, Forthcoming.
- [Saez, Set, and Hsu \(2014\)](#), From Genes to Behavior: Placing Cognitive Models in the Context of Biological Pathways. *Frontiers in Neuroscience*.
- [Zhu, et al. \(2014\)](#), Damage To Dorsolateral Prefrontal Cortex Affects Tradeoffs Between Honesty And Self-Interest. *Nature Neuroscience*, 17: 1319-1321.

Recent Advancements

- Bertoux et al. (2014), Behavioral variant frontotemporal dementia patients do not succumb to the Allais paradox. *Frontiers in Neuroscience*.
- Set, et al. (2014), Dissociable Contribution Of Prefrontal And Striatal Dopaminergic Genes To Learning In Economic Games. *PNAS*, 111: 9615-9620.
- Smidts, et al. (2014), Advancing Consumer Neuroscience. *Marketing Letters*.

Recent Advancements

- [Zhu, Mathewson and Hsu \(2012\)](#), Dissociable neural representations of reinforcement and belief prediction errors underlie strategic learning, *PNAS*, 109(5), 1419-1424.
- [Zhu, Walsh and Hsu \(2012\)](#), Neuroeconomic measures of social decision-making across the lifespan, *Frontiers in Decision Neuroscience*, 6:128.
- [Takahashi, et al. \(2012\)](#), Honesty mediates the relationship between serotonin and reaction to unfairness, *PNAS*, 109(11), 4281-4284.