

# **The Keynesian Beauty Contest: Economic System, Mind, and Brain**

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# Goal of this talk

Point of departure - Keynesian Beauty Contest Metaphor

- Your online experiment, theory, behavior
  - A (general) model of interactive situations
  - Bounded rational model: Level-K
  - Neural system: subjects in an fMRI machine
- => Consequences for (behavioral) macro economic modeling?

General goal: a fruitful interaction between experimental, behavioral, empirical, and theoretical macro economists with elements from natural sciences, psychology, and humanities.

Or, to change the metaphor slightly, **professional investment** ...competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors

; .....It is not a case of choosing those which, to the best of one's judgment, **are really the prettiest, nor even those which average opinion genuinely thinks the prettiest.** We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practise the fourth, fifth and higher degrees.

Some experiments

# This conference online experiment:

- Your choice,  $y(i)$ , closest to TARGET:

**Best response:**  $y(i) = 10 + 2/3 \text{ avg}$

With  $\text{avg}$ =avg behavior of others;

10 represents a commonly known fundament value or a known choice of a (big) player

- Payoff according to distance to target

## Theoretical properties:

- Nash-Rational Expect. Equilibrium: 30 (unique and Pareto optimal)
- Uncertainty differences:

(A) choices from  $[0,100]$ ; dominated areas:  $<10$  and  $>76.666$

(B) choices from any number: no dominated areas

=> Uncertainty higher in (B) than in (A) when choices are considered outside the equilibrium (e.g. noise)

# Experimental Design

## 2 treatment variables: interval and subject pool

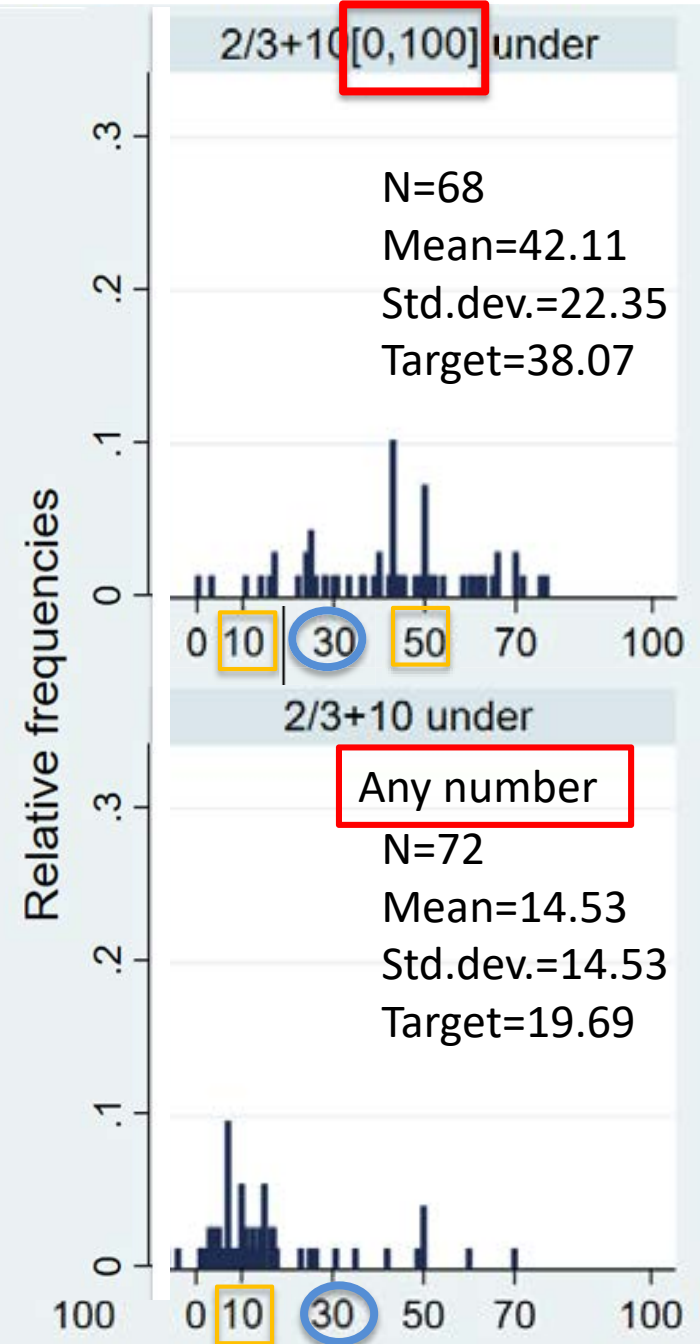
1. a.) Choices from **bounded** interval [0,100]  
b.) Choices from **unbounded** interval: all numbers
2. a.) **Conference** participants against conference participants;  
b.) Conference part. against undergraduates  
b.) **Undergraduates** against undergraduates
  - N=184 conference participants (2 conferences)
  - N= 140 undergraduate students

Actual data in first period  
from participants of London and  
Milan conferences and  
undergraduates (Barcelona and  
Kassel)

Undergraduates:  
target:  $2/3$  avg +10

Bounded interval

Any number





Relative frequencies

2/3+10[0,100]vs under

2/3+10[0,100] under

Conf. vs undergraduate

N=41  
Mean=37.26  
Std.dev.=22.25  
Target=38.07

N=68  
Mean=42.11  
Std.dev.=22.35  
Target=38.07

0 10 30 50 70 100

0 10 30 50 70 100

2/3+10 vs under

2/3+10 under

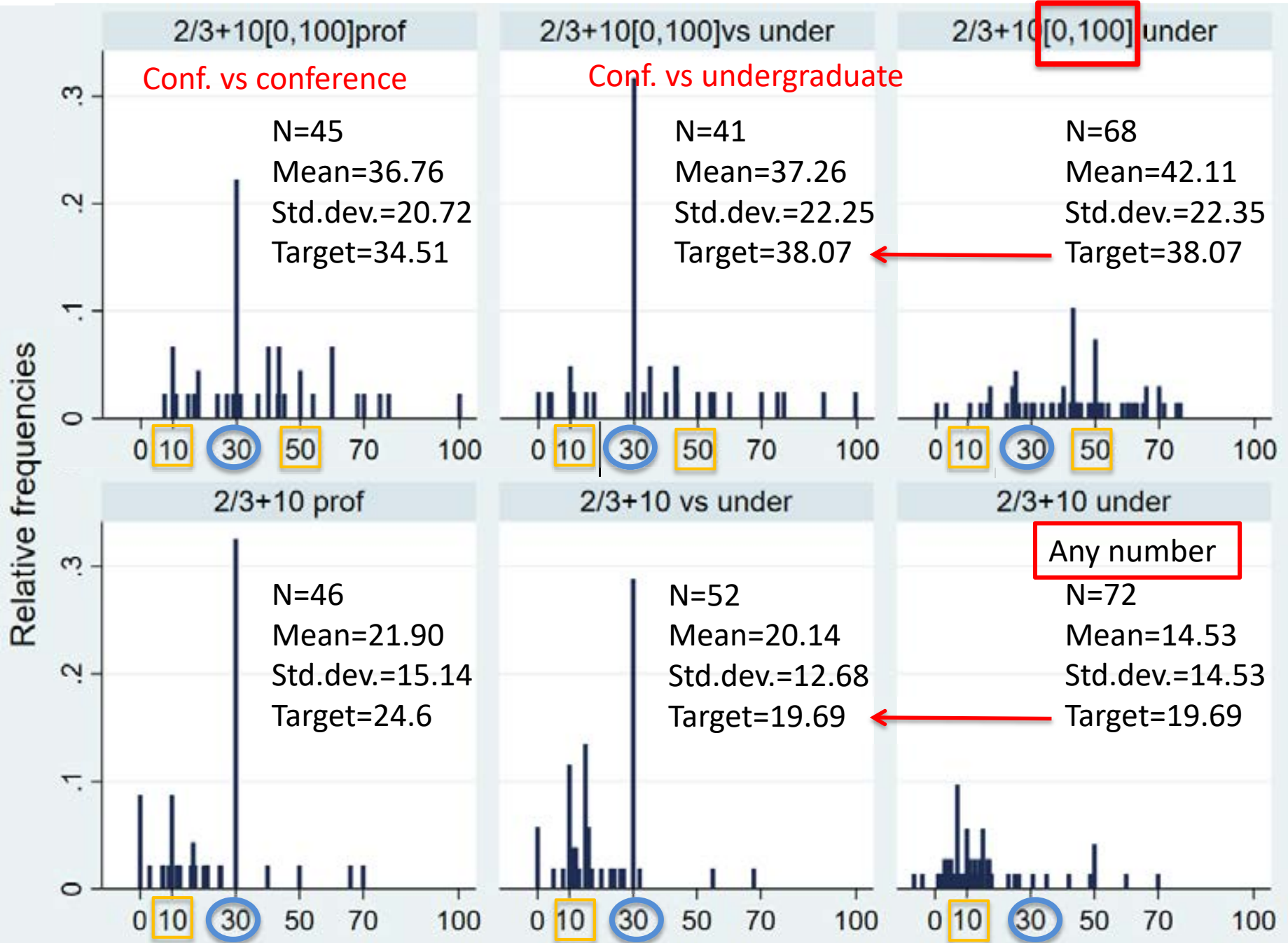
Any number

N=52  
Mean=20.14  
Std.dev.=12.68  
Target=19.69

N=72  
Mean=14.53  
Std.dev.=14.53  
Target=19.69

0 10 30 50 70 100

0 10 30 50 70 100



# Behavior over time

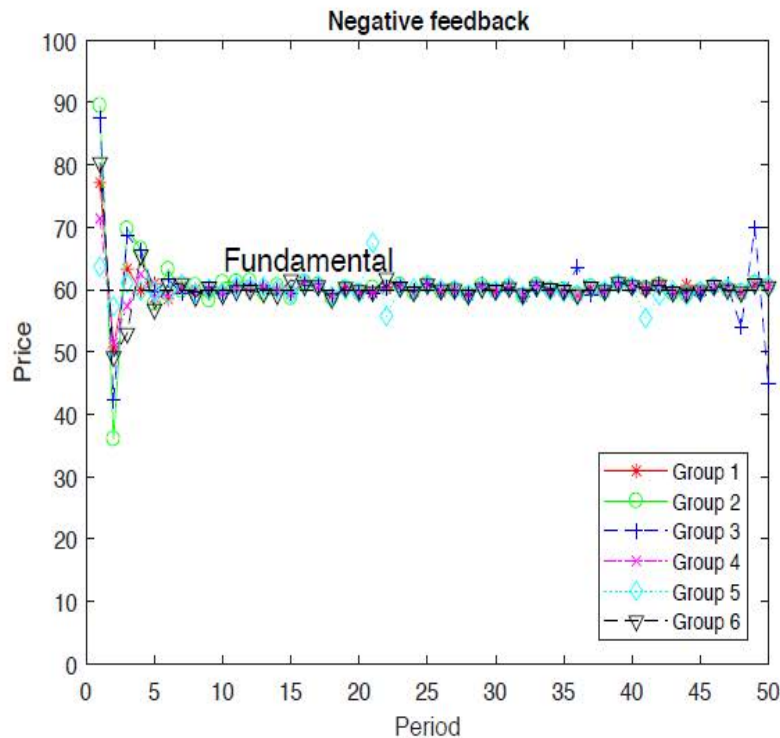
(experiment from **Heemeijer et al. (2009)**)

# Datasets Behavior over time, no knowledge of parameters

Markets of strategic substitutes Markets of strat.complements

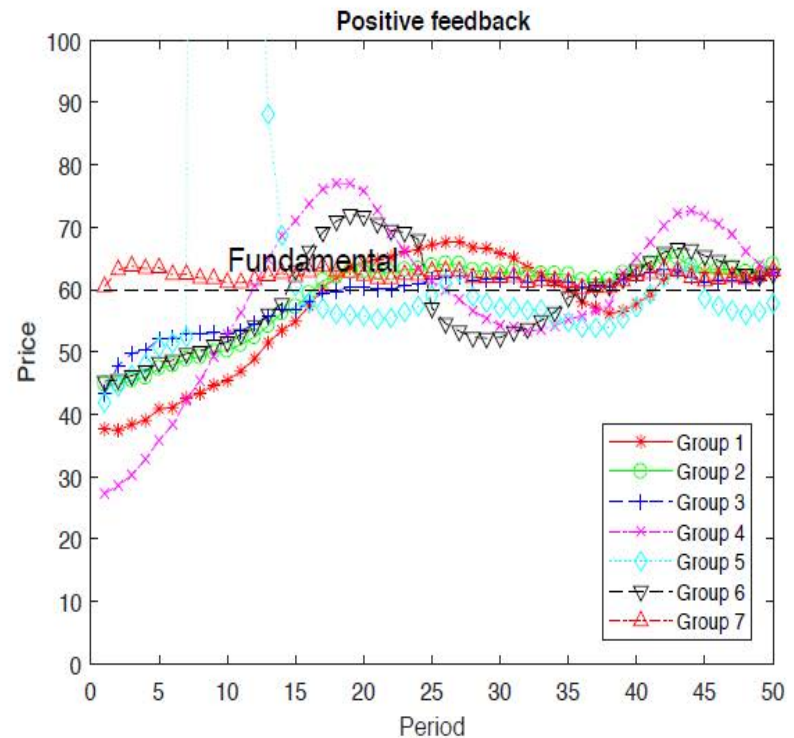
$$p_t = \frac{20}{21}(123 - \bar{p}_t^e) + \varepsilon_t,$$

negative feedback



$$p_t = \frac{20}{21}(\bar{p}_t^e + 3) + \varepsilon_t.$$

positive feedback



REE  
60

Finding structure through and in  
Economic System – Mind - Brain

# Codependency of the System, Mind, and Nature

guided by economic theory, experiments, neuro science

(Economic) System – a priori



**Mind**

(rational or **bounded**)

Equilibrium (apriori, objective)

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**Reference points**

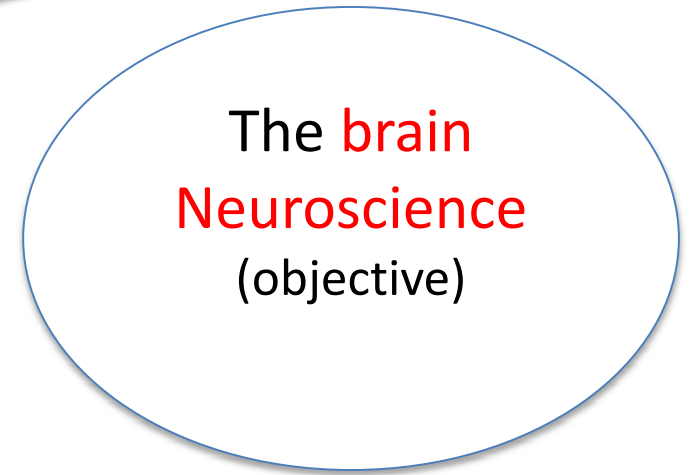
**Level-K vs randomness**

Sentiments

Adaptive reasoning, etc.

(subjective)

**Nature**



# The economic system

# Generalized Beauty Contest

**Optimal choice (best response) for player i:**

$$y_t^i = \hat{E}_t^i(c_t + b f(y_t^1, \dots, y_t^N) + d f(y_{t+1}^1, \dots, y_{t+1}^N) + \varepsilon_t^i)$$

- $f(\cdot)$ : (aggregated) behavior of all players
  - E.g. average, median, sum, max, min
- $c$ : constant, e.g. fundamental value (known or not)
- $b, d$  = parameters:
  - $b, d < 0$  strategic substitutes
  - $b, d > 0$  strategic complements
- $\varepsilon(i)$ : exogenous idiosyncratic (noisy) variable,  $N(\lambda, \sigma^2)$



# Examples for “Beauty contest games”

New-Keynesian models (Woodford, 2003; Galí, 2008; Walsh, 2010)

Agg Demand  $y_t = \bar{y}_{t+1}^e - \sigma(i_t - \bar{\pi}_{t+1}^e - \rho) + g_t$

Agg Supply  $\pi_t = \kappa y_t + \beta \bar{\pi}_{t+1}^e + u_t$

Taylor rule

$$i_t = \rho + \phi_\pi (\pi_t - \pi)$$

– Inflation prediction reduced (under a certain belief formation for the output gap) to:

$$\pi_t = c + b \bar{\pi}_{t+1}^e + v_t \quad \hat{E}_{t-1}^i \pi_t = \pi_t$$

Learning to forecast game

	Strategic substitute	Strategic complement
Continuous Strategies	Basic BC game: $b < 0$	$b > 0$
	General equilibrium with sentiments	
	Cournot Ultimatum game Cobweb	Bertrand Some auctions Asset markets BC with fundamental NK-models, Growth model
	Strategic heterogeneity (some with $b > 0$ , some $b < 0$ )	
	Neither substitute nor compl   Public goods	
Discrete Strategies	Entry game Global game (congestion) Negative assortative matching	Stag Hunt game Global game (attack or not) Positive assortative matching
	Strategic heterogeneity: matching pennies, fashion cycles	
	Neither substitute nor compl   Prisoners' dilemma (dominant strategies)	

# Mind

The Behavioral Level k model  
between randomness and equilibrium

Keynesian reasoning (level k model),  
related to unawareness/inattention in strategic interaction

- **Level 0:** no game form recognition; zero intelligence, - automatic choice; favorite number, salient number
- **Level 1:** game form recognition, but no theory of mind as Playing against NATURE
- -----
- **Level 2:** model others as level 1 players => theory of mind
- **Level k:** model others as level k-1 players
- ...
- **Equilibrium:** Nash, rational expectation, fixed points
- -----
- **ADD NOISE TO ALL LEVELS;**

**Variations: higher level players give best response to a distribution of lower level players; Poisson distribution; add cognitive cost.**

Introduced in Nagel (1995), **Variations:** Stahl Wilson (1995), Camerer and Ho (2004); Alaoui, Penta (2017)

# Application of the level-k model

- Experimental economics, for many different experiments
- Microeconomics, e.g. Crawford bargaining (2015)
- Epistemic game theory, e.g. Kets (2012)
- Macroeconomics, e.g. Garcia Schmidt, Woodford (2016)
- Business field experiments: classifying managers

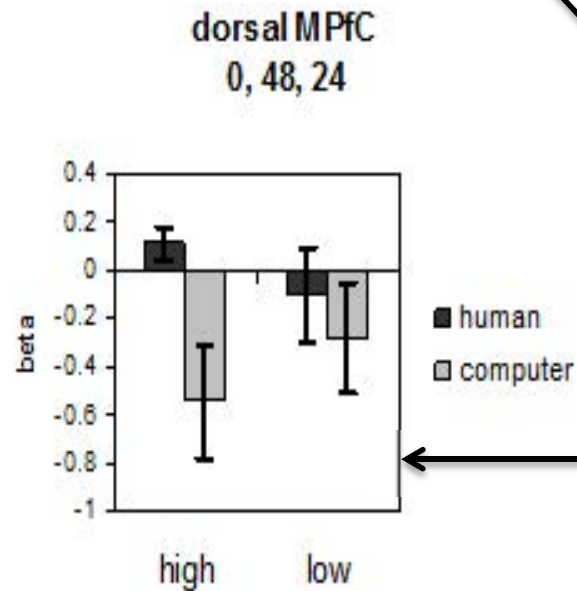
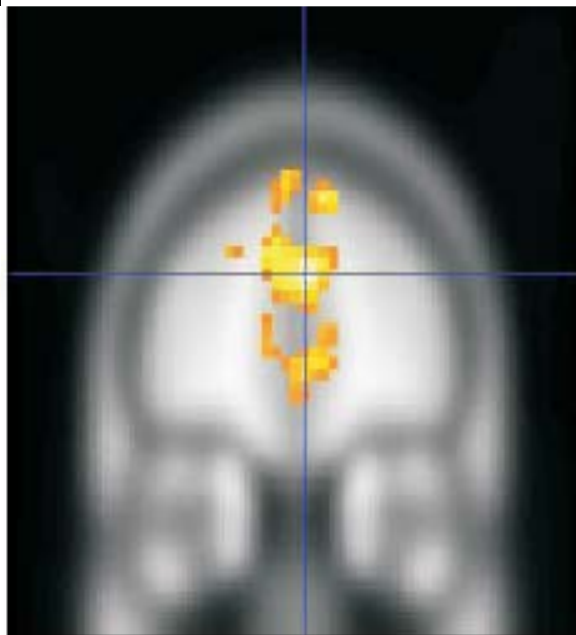
Nature  
Brain

Objective of design: Link between stimulus (model, rules), behavior, physiological data (e.g. brain activity), to understand thought processes

Stimulus: Rules of the BC game

e.g. target 2/3-average

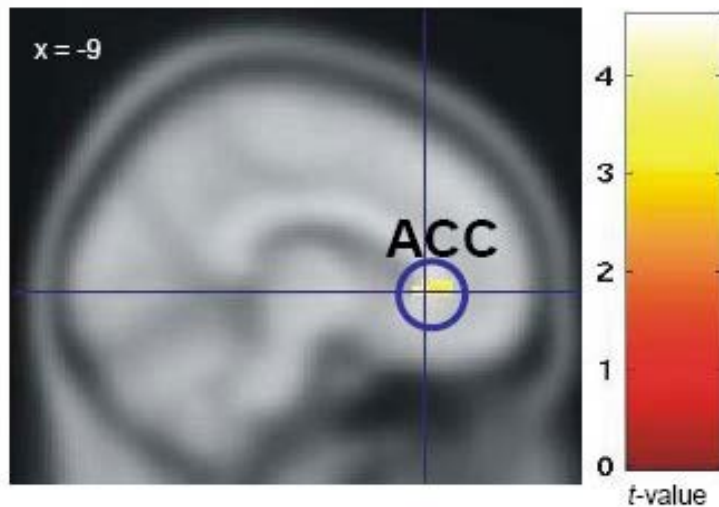
Behavior against humans and computer



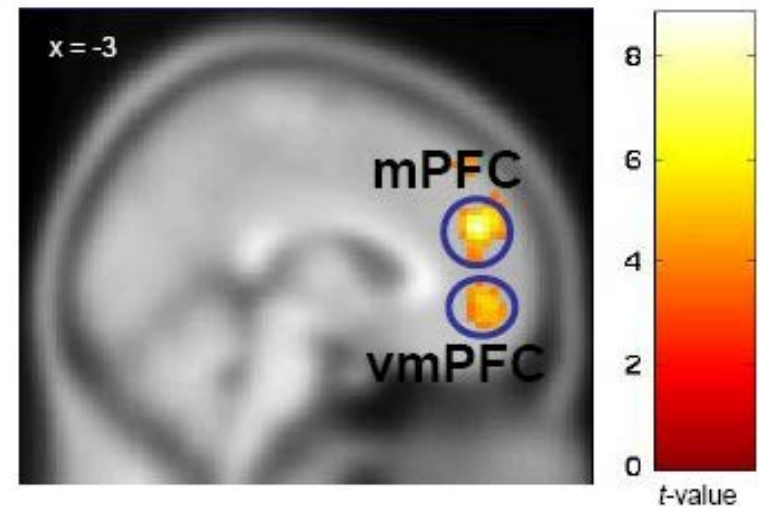
Level k model:  
HIGH vs LOW

# High vs. low level of reasoning

Low level of reasoning



High level of reasoning



“CHOOSING 33”

“CHOOSING 22”

Heterogeneity is visible in the brain



# Discussion

Aim of talk: (behavioral) microfoundation of (behavioral) macro theory through game theory and experimental and behavioral economics, psychology, neuroscience, humanities:

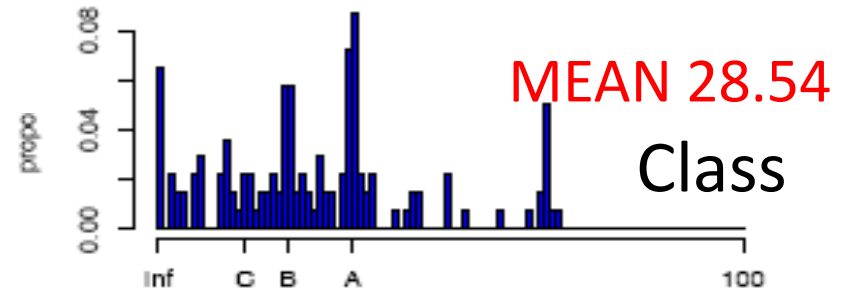
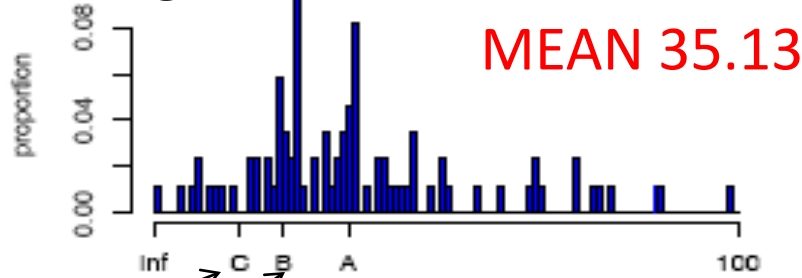
- Economic models
- Uncertainty through parameters of the situations and other players
- Bounded rationality in stylized situations
- Experts (conference participants) and non-experts (undergraduates)
- Brain data supports different levels of reasoning

=> Construction of “Hegel” system: Economic system-Mind-Brain

Critical questions:

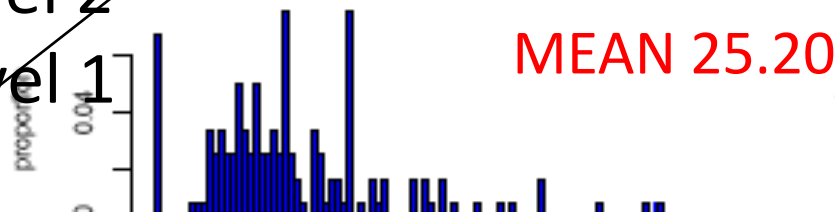
- Can we import it to macro theory or field data? YES!
  - Behavioral macro: add level k to traditional models
    - QE, Forward guidance plus level k: better empirical evidence (e.g QE works)
  - Survey data include our Beauty contest games: guess others guesses and try to discover level-k reasoning and the consequences of this for other choices.

Nagel, 1995 Lab

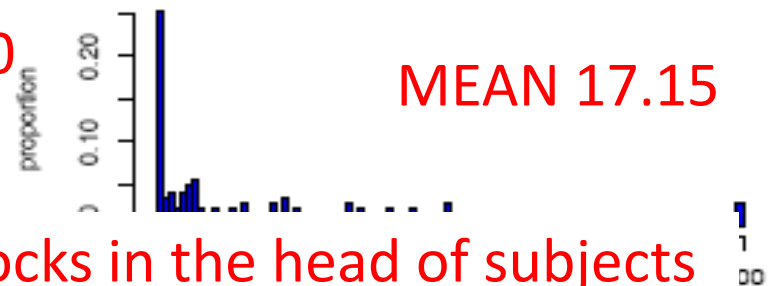


C=level 3  
 B=level 2  
 A=level 1

Take home

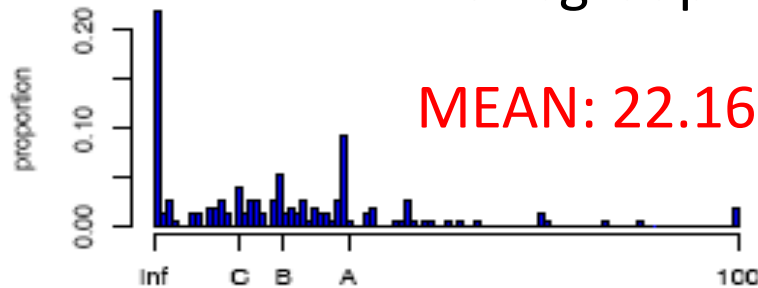


Economists



Interpretation: uncorrelated shocks in the head of subjects  
 => Behavior far away from equilibrium; mixture model

News group



Newspaper

