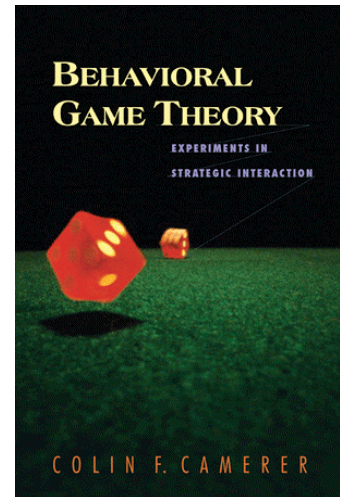# "Strategic IQ" and a cognitive hierarchy of types

Colin F. Camerer, Caltech

- **Strategic thinking:**
  - reasoning about what others will believe, value and choose
- **Standard theory: equilibrium**
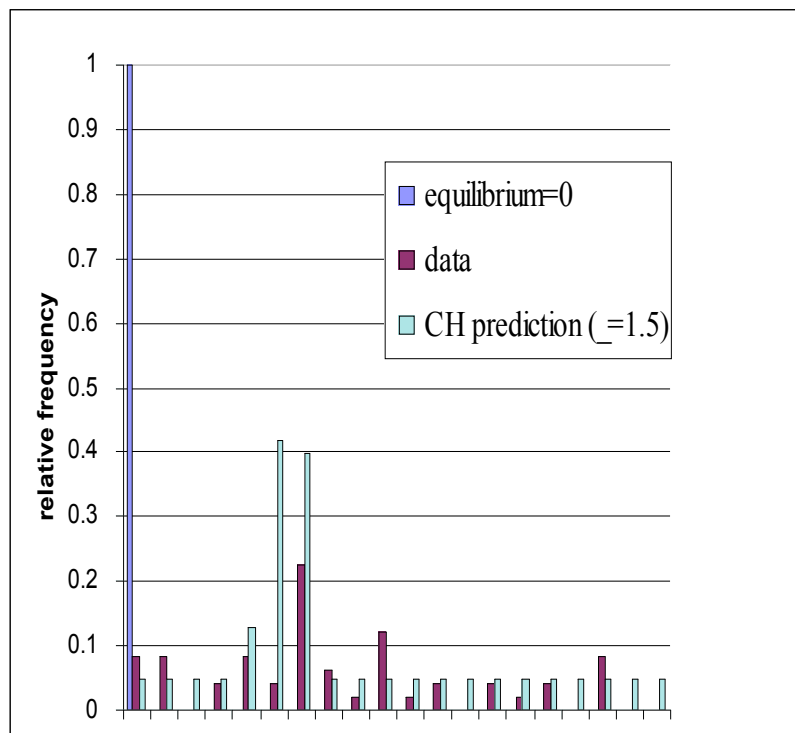- **Cognitive hierarchy**
  - allows "types"

Plan of talk
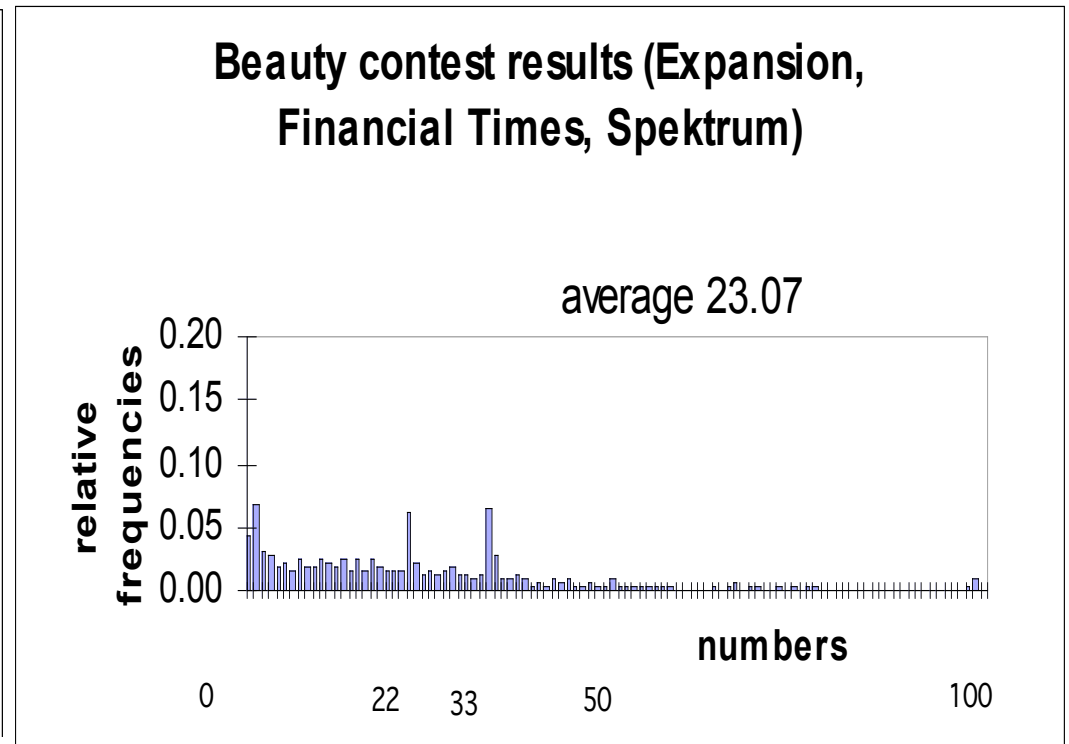
1. Behavioral evidence
2. Eyetracking
3. fMRI

1. Behavioral evidence

- "Beauty contest" game (BC)
  - Choose [0, 100]
  - Closest to (2/3)*average wins
  - Many experiments
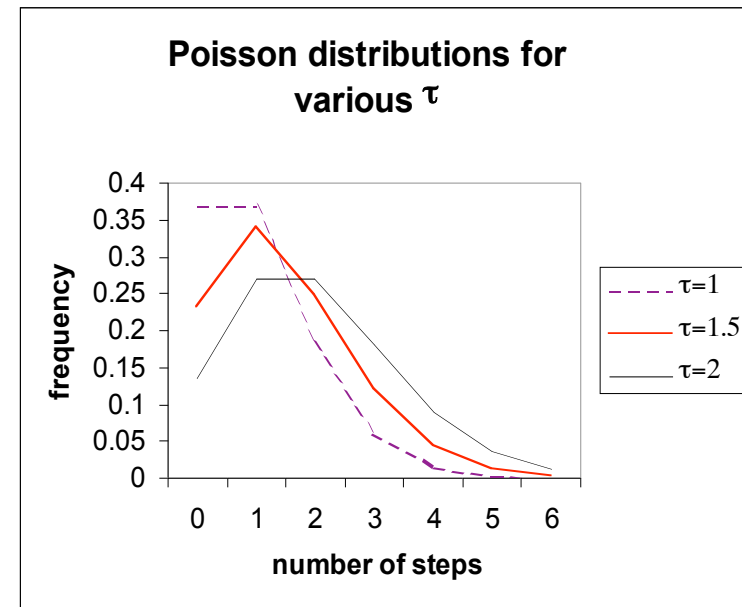
Results from lab and 'field' (newspapers)

Ho, Camerer Weigelt AER 98   Nagel+ AER

Cognitive hierarchy theory

- Components
  - Distribution of steps f(k)
  - 0-step choose heuristically
  - k-step think others are 0,..k-1
    - CH: Truncated actual f(k)
    - Level-k: all are k-1
  - What is f(k)?
    - Estimated
    - Parameterized
    - E.g., Poisson $f(k)=e^{-\tau}\tau^k/k!$
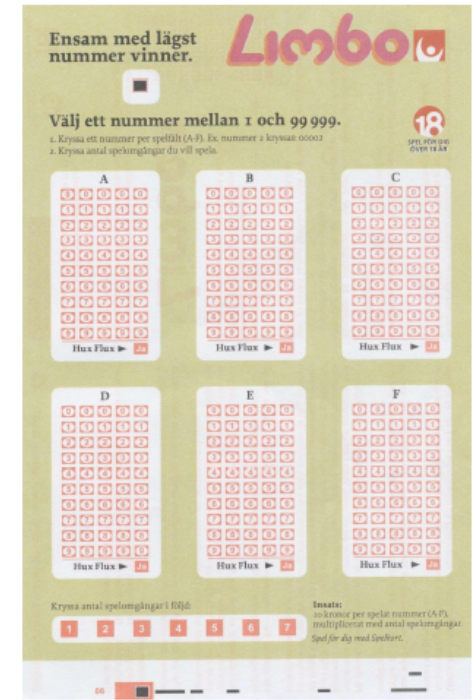   (from $f(k)/f(k-1) \propto 1/k$)

Poisson distributions for various τ

Online calculator @
http://groups.haas.berkeley.edu/simulations/ch/default.a
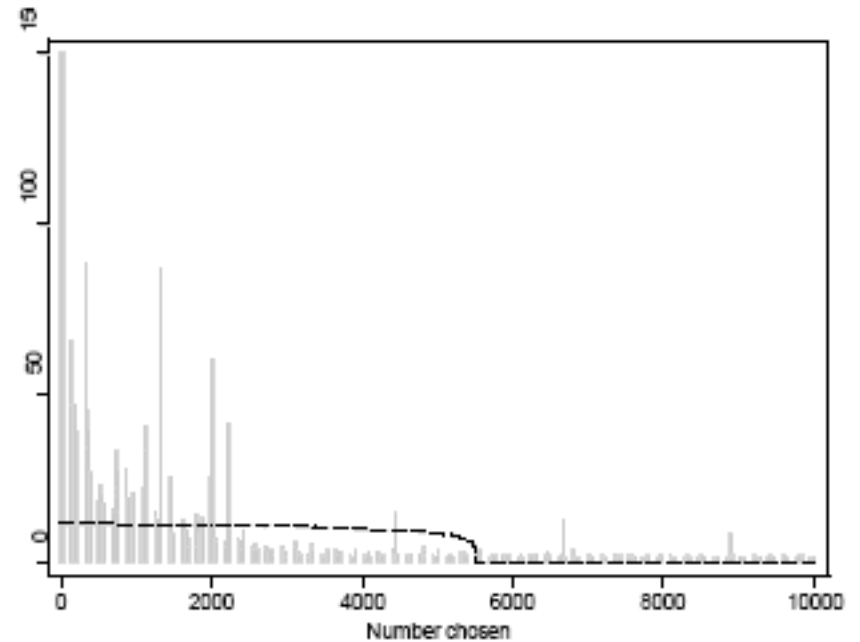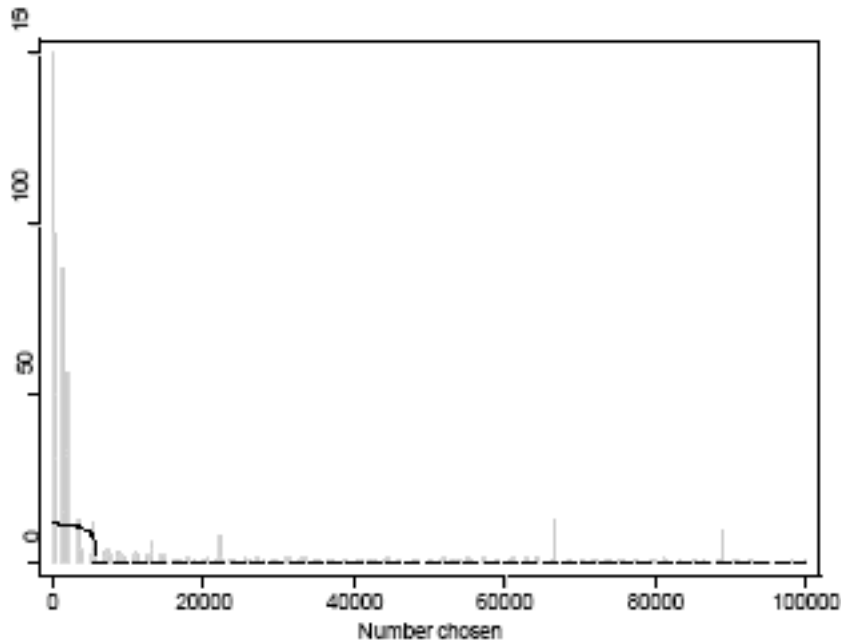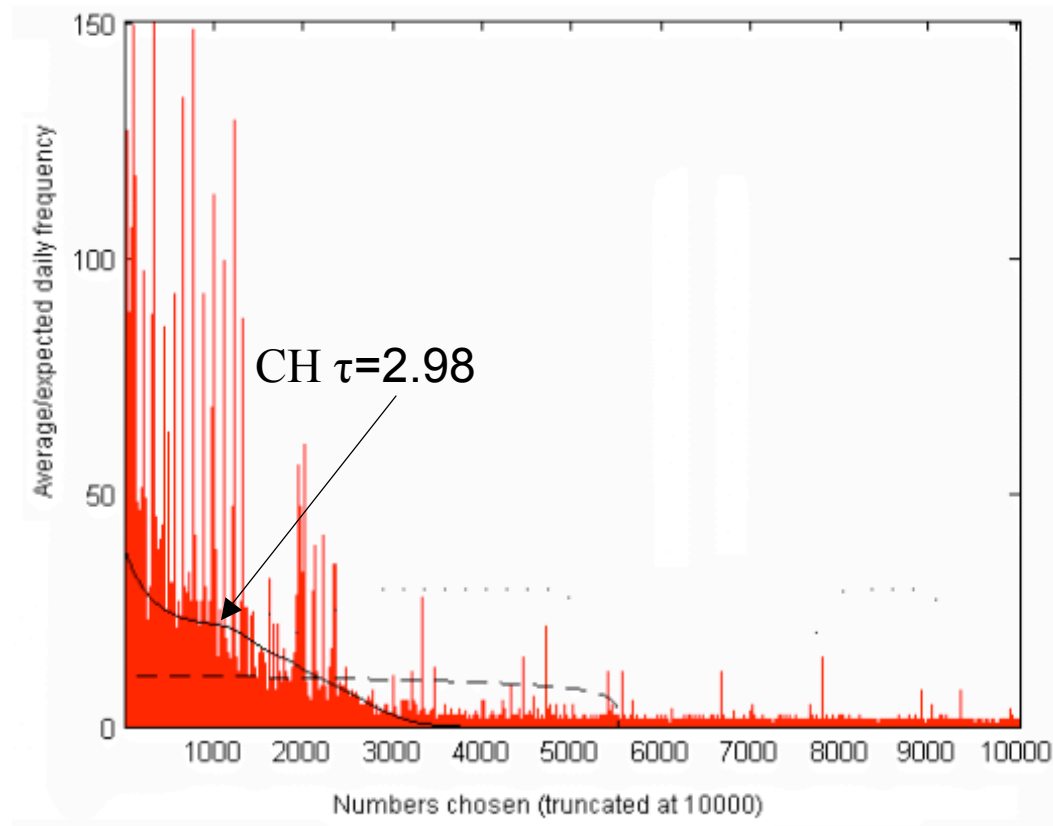
Lowest unique positive integer game (LUPI)

- Swedish lottery

- n=53,000 players

- Choose k from 1 to 99,999

- Lowest unique number wins 10,000€

- If n is Poisson distributed…

  – mixed equilibrium solves $e^{np(k+1)} = e^{np(k)} - np(k)$

Poisson equilibrium is a surprisingly good approximation (week 1)…
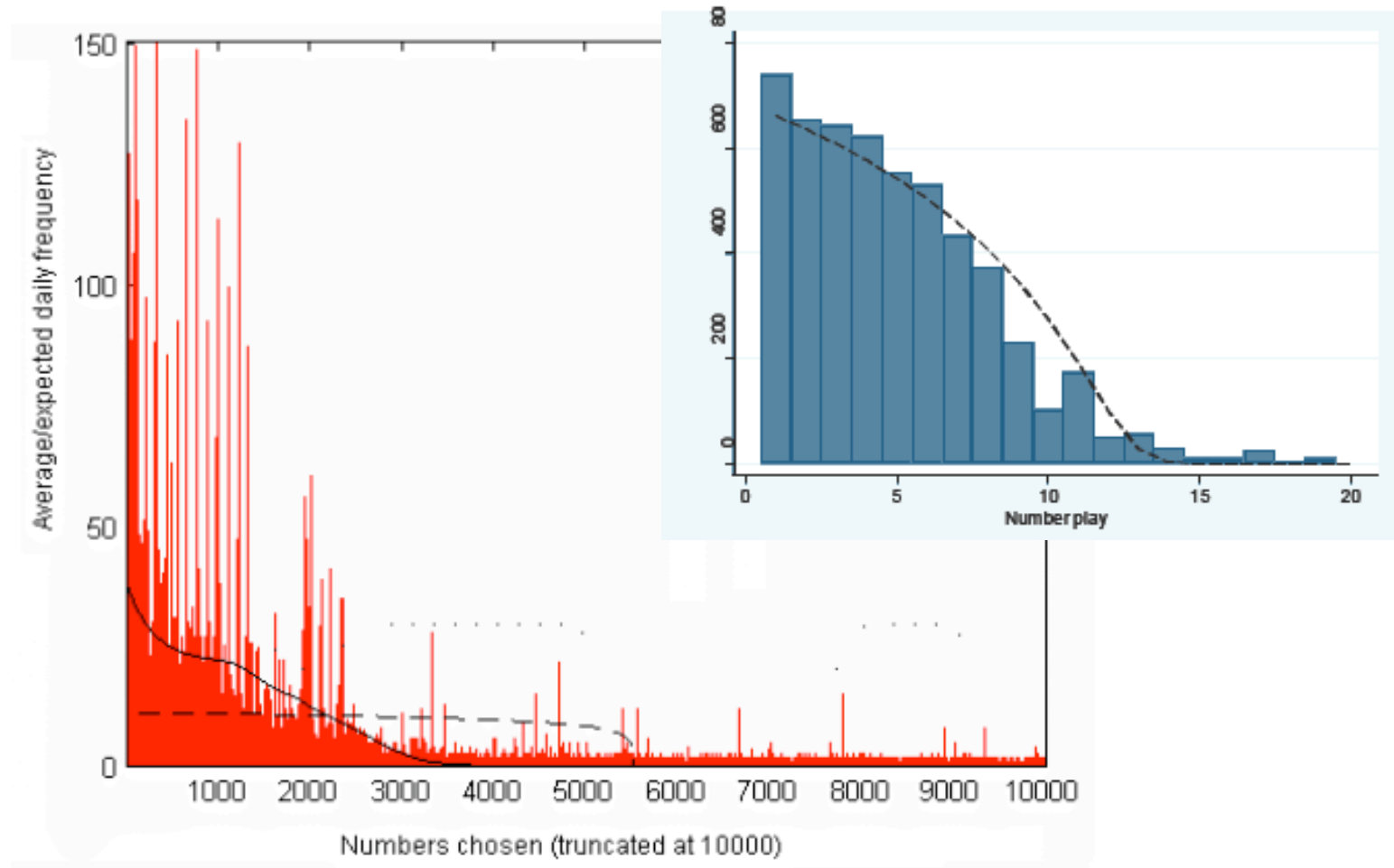
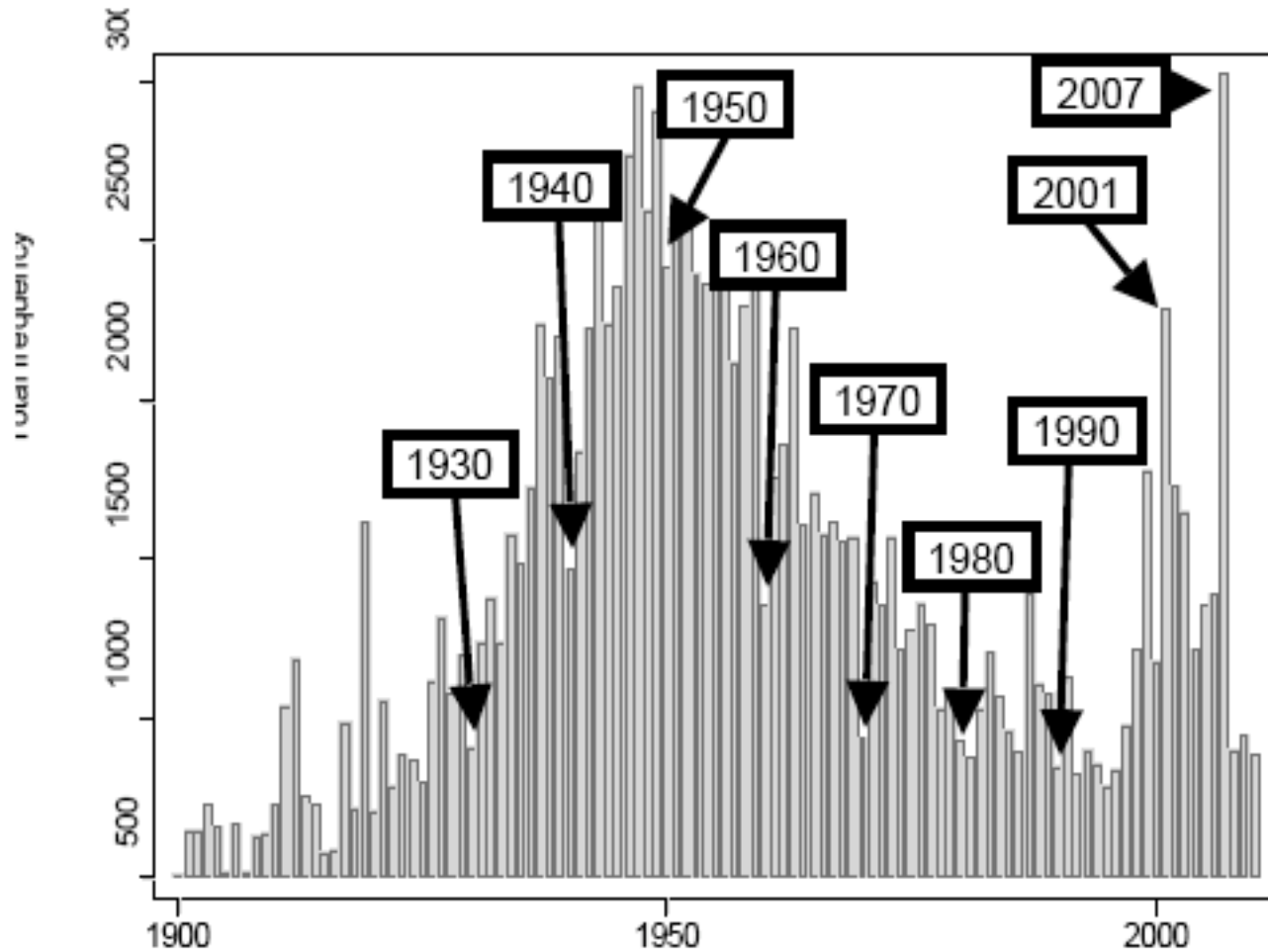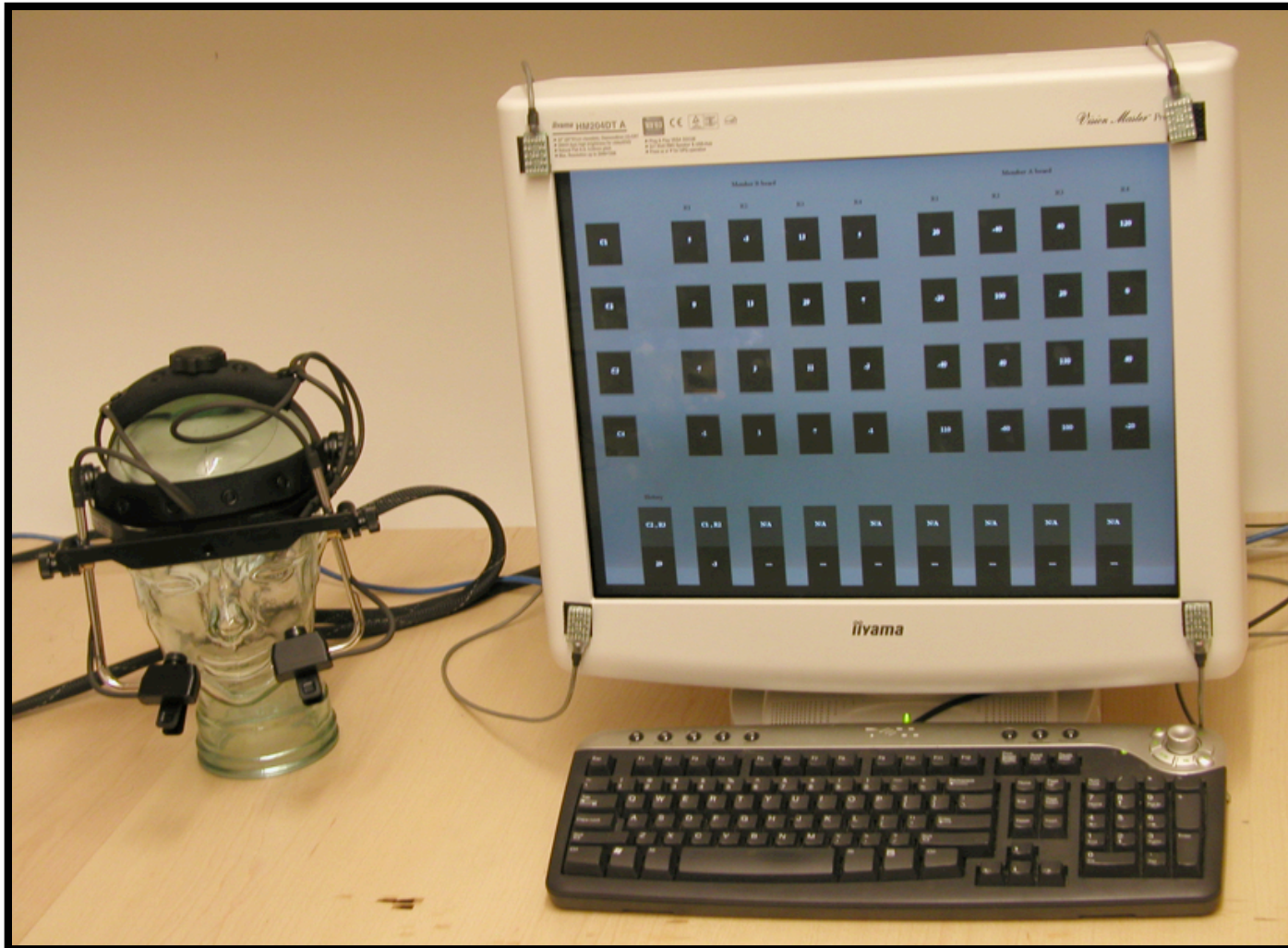# ...but cognitive hierarchy fits deviations

Lab (weakly) replicates field deviations

Anti-focal focal points

2. Eyetracking

Typical pattern of looking:
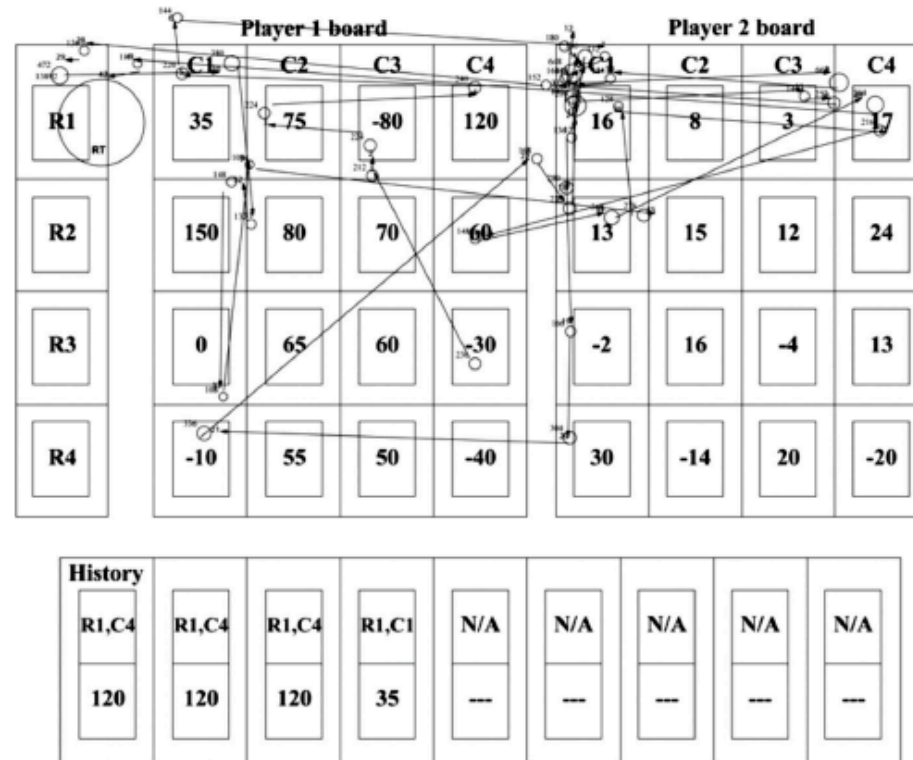## Own (4050ms) > Other (2700ms) suggests level 0, level 1

FIGURE 2. An example of the experimental task display.

Knoepfle, Wang, Camerer JEEA 09

Limited *strategic planning ahead* in bargaining (Camerer 93+ book; Johnson+ 02 JEcTheory)
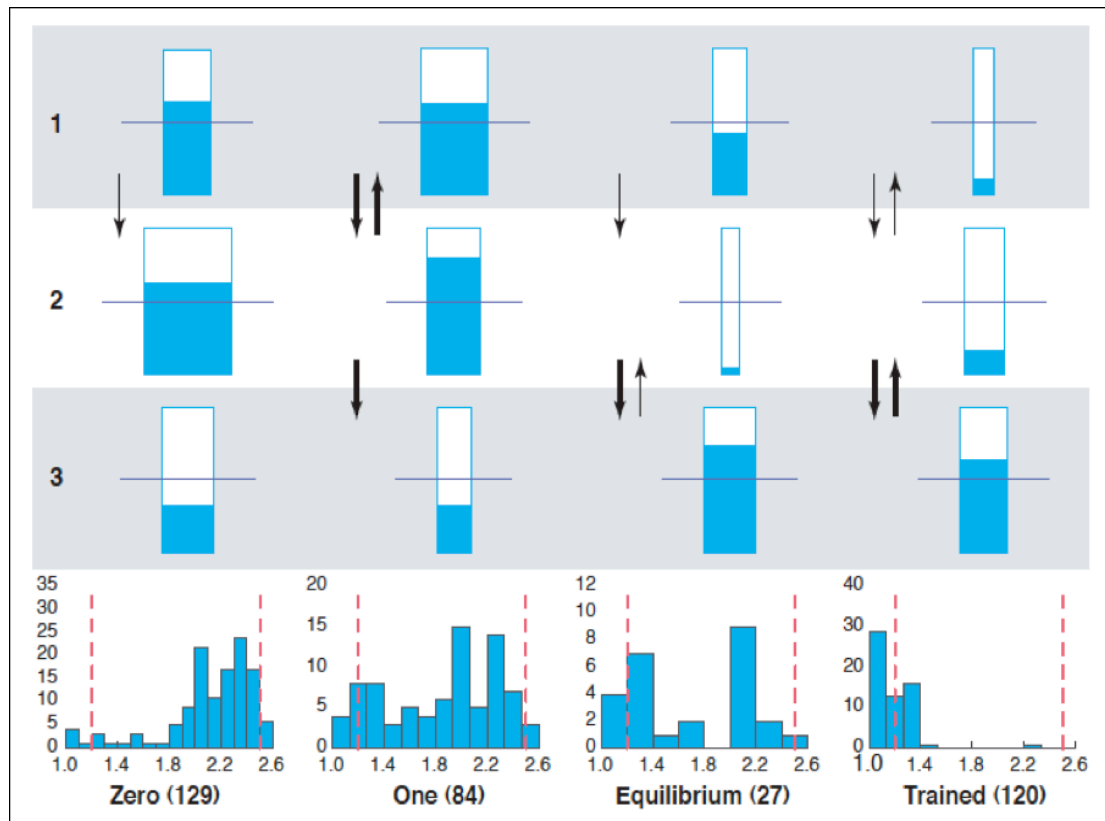
3-stage bargaining

1:    $5   p1

2:    $2.50 p2

3:    $1.25 p1
    Subgame perfect:
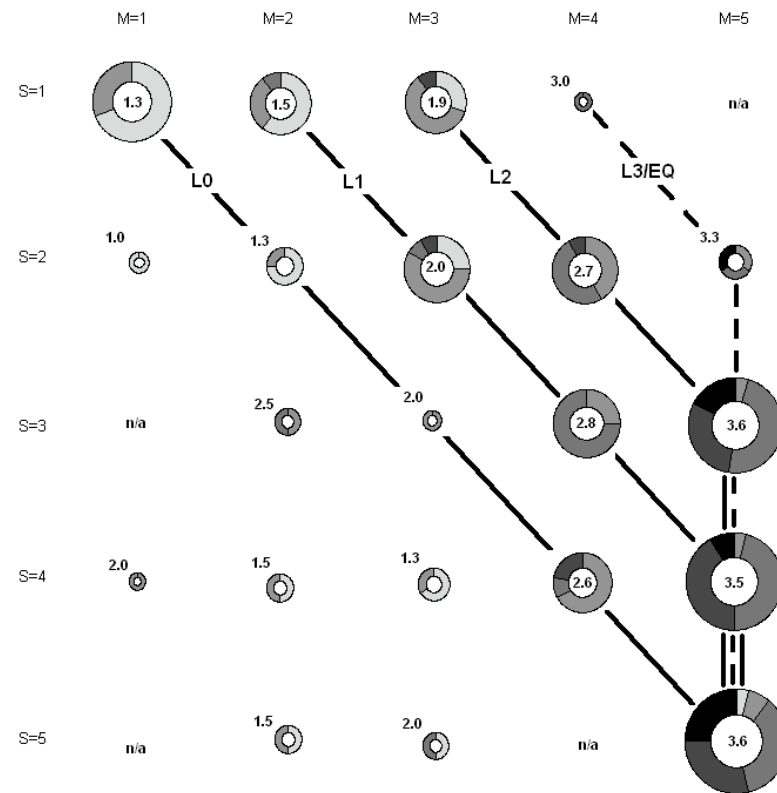   p1 offers $1.25
      (=2.50-1.25)

Games with an incentive to exaggerate

- Sender learns state S $\in$ {1, 2,..5}

- Sends message

- Receiver gets message, *not S*

- Receiver chooses action A

- Conflict of interest
  - Receiver wants A=S
  - Sender wants A=S+1

Common "overcommunication": many messages = states

Wang, Spezio, Camerer AER in press

Sender lookups show attention to S, S+1
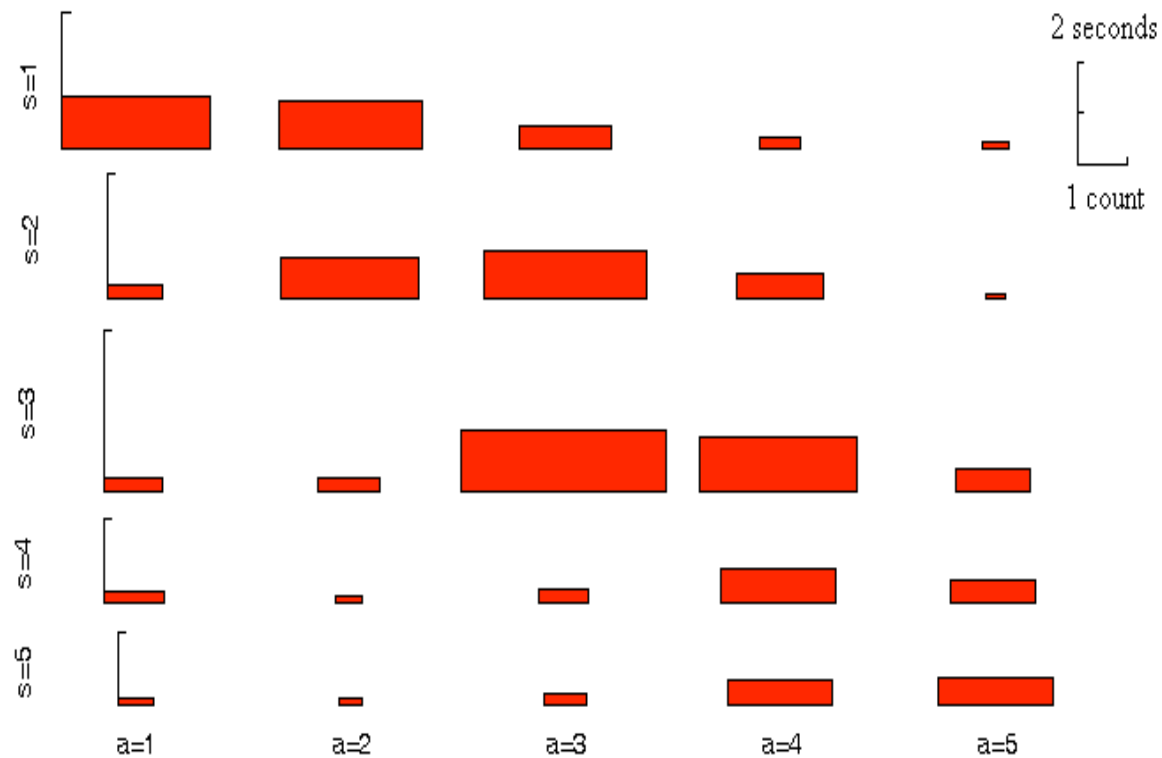
3. fMRI

a. Dominance-solvable games

b. Beauty contest games

c. "Yard-sale" bargaining

d. Influence value ("strategic teaching")

Cross-subjects: Strategic IQ (earnings) and activity during choice

- (-) L Insula
- too self-focussed or perceived social risk

- (+) caudate, precuneus/PCC
- Reward
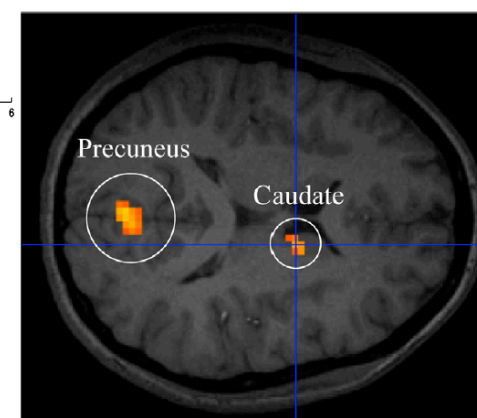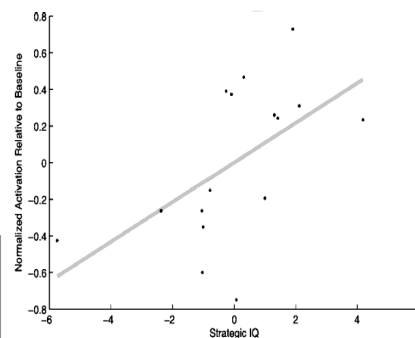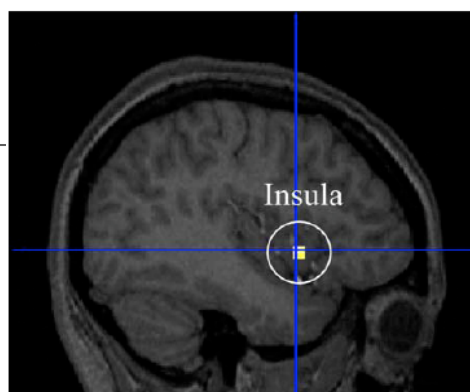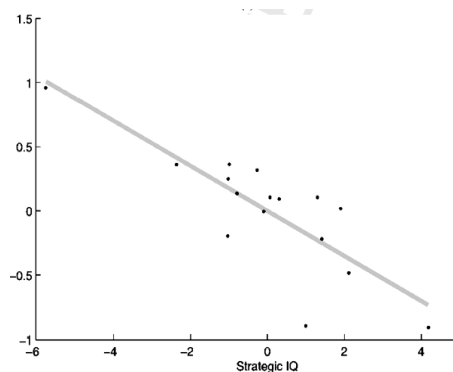
b. Beauty contest games with various p (x-axis)
Level 1   choose p*50
Level 2 choose p*p*50
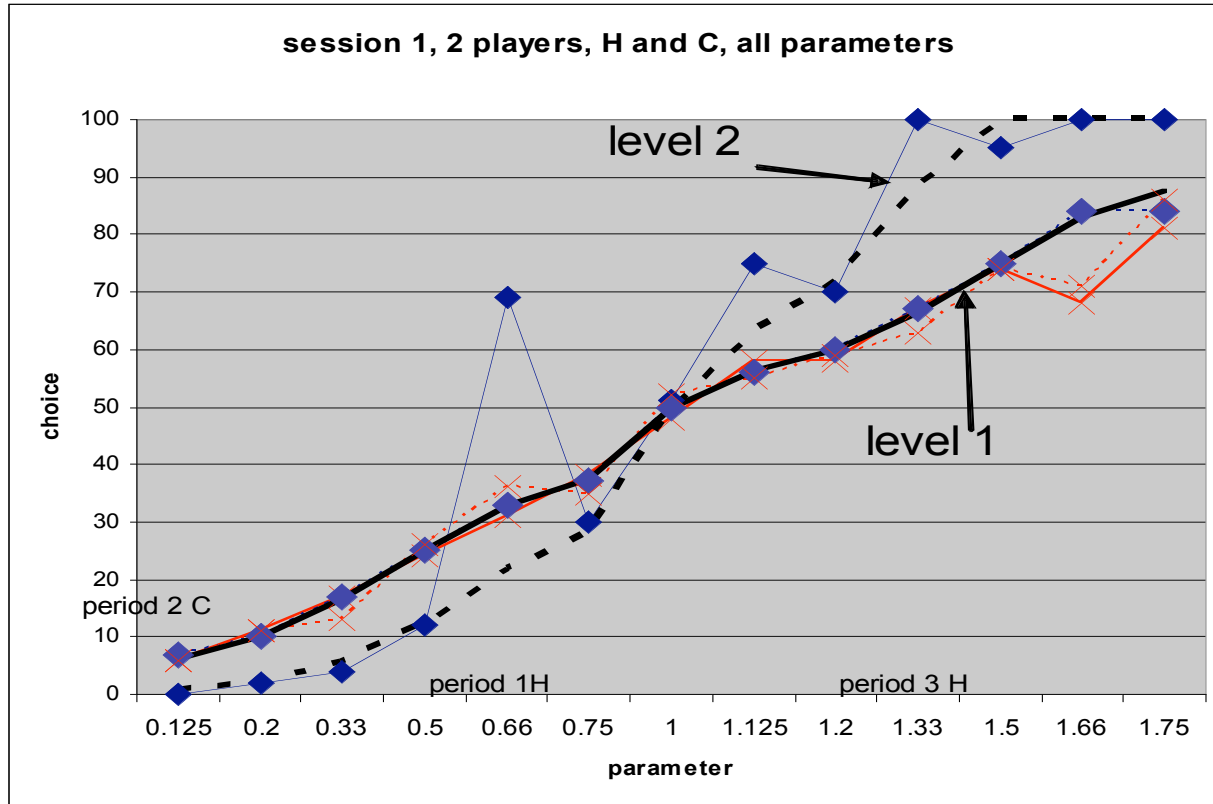
Coricelli, Nagel PNAS in press

Human > Computer
random effect analysis N=20
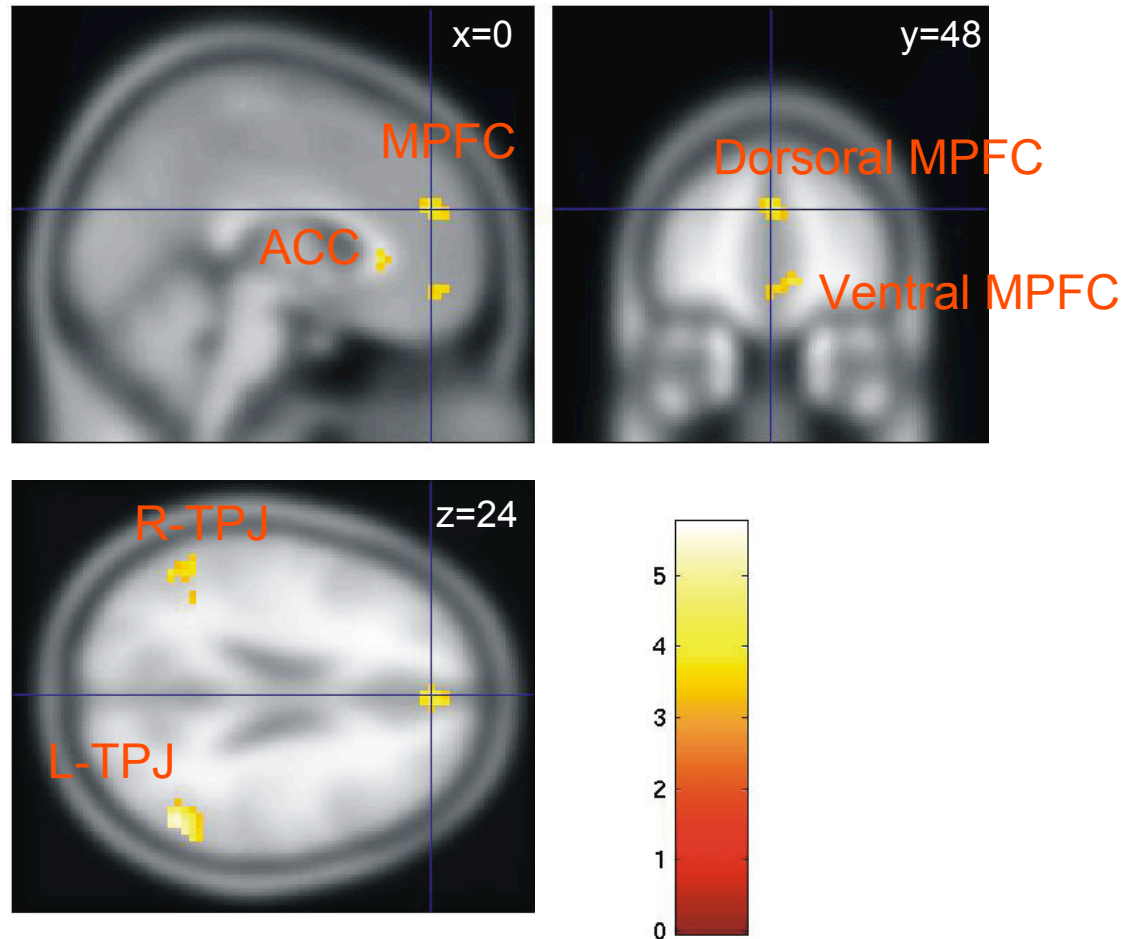
Human>computer contrast for high (level 2)>low (level 1)

High level of reasoning
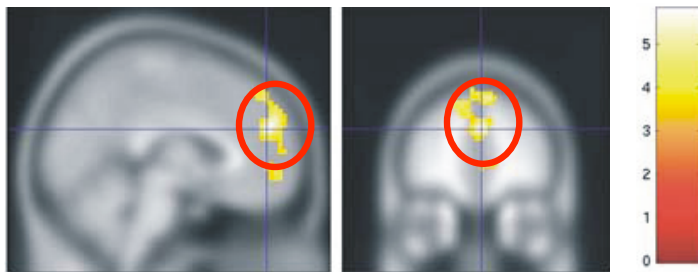
roi BA10 high-reasoning
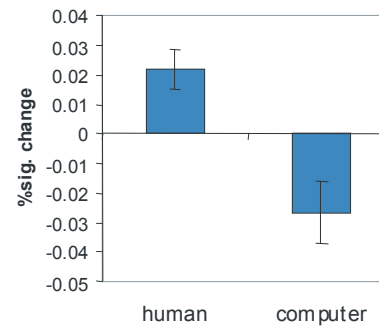
Low level of reasoning
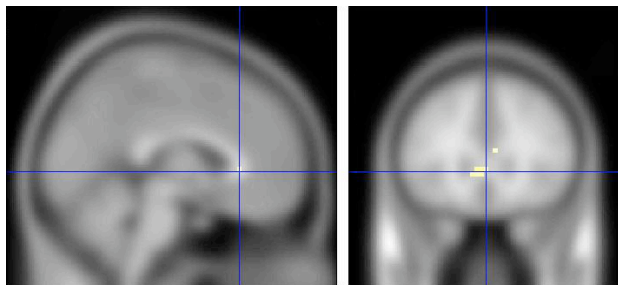
roi BA10 low-reasoning
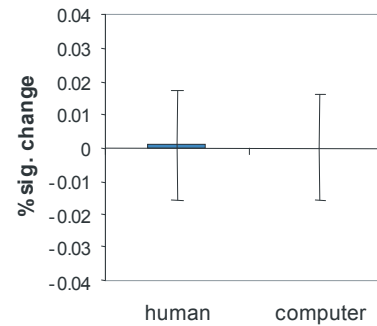
Paracingulate cortex: BA32 & BA10
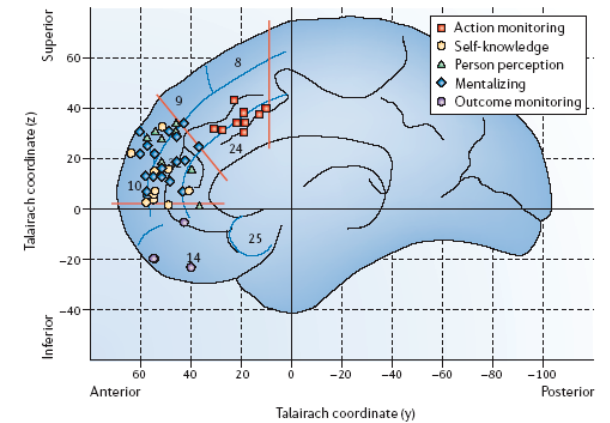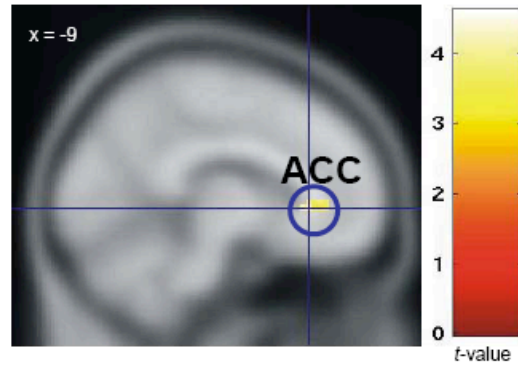
Activity in dMPFC correlated with "strategic IQ" (chance of winning)
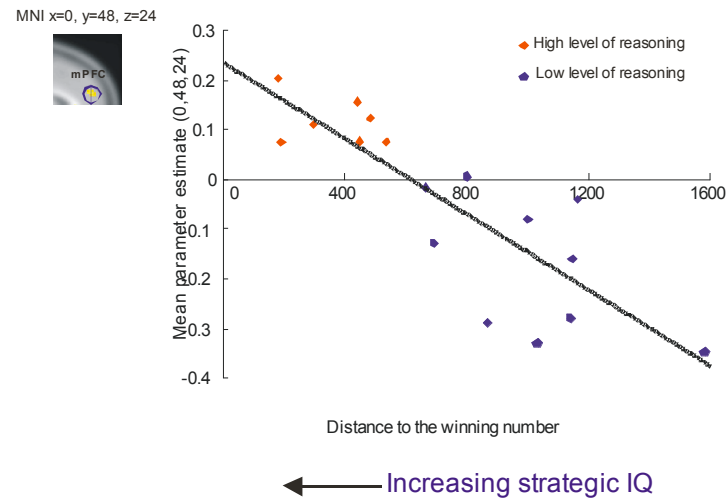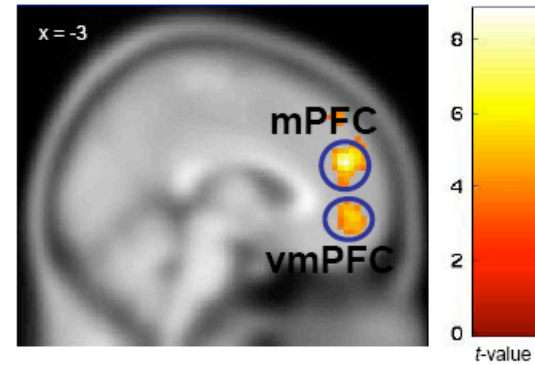
C. "Yard-sale" bargaining: buyer value v ∈ {1,2..10}
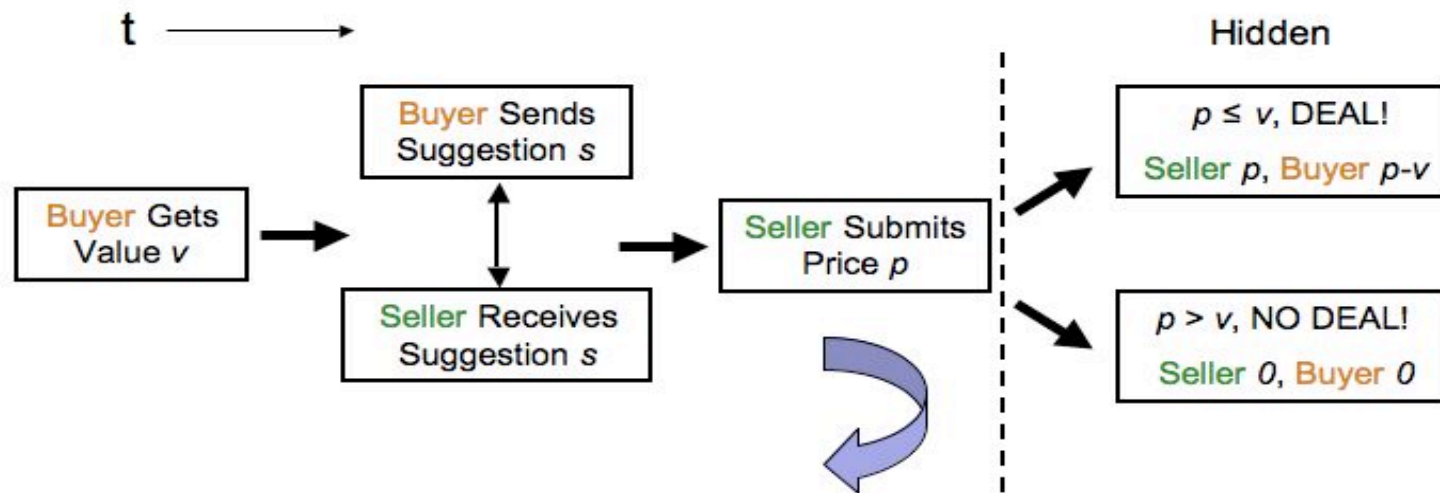
Like a "yard sale" where sellers sell "worthless" goods and haggle

Three types of information revelation (correlation of s with v):
Uninformative, truthful, strategists

Bhatt, Lohrenz, Camerer, Montague in prep

Incrementalists (left) suggest .5v Strategists (right) mimick
value= 8, send 2 (big profit)
value=2, send 8 (small opportunity loss)

Cognitive Hierarchy Model

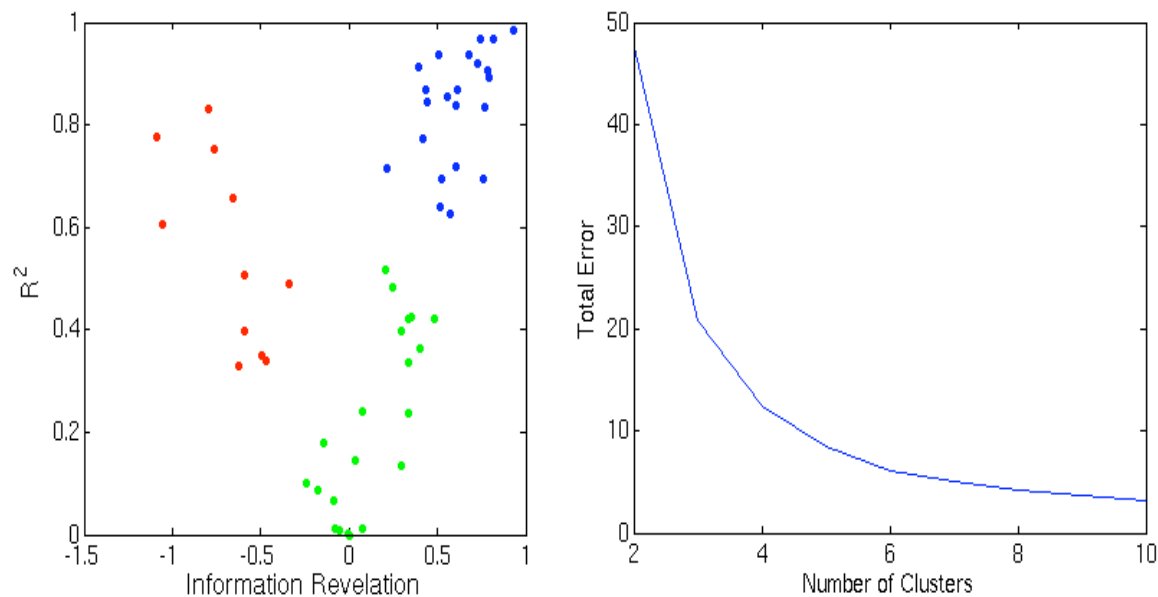|	Buyer	Seller
Level-0	Impoverished model of seller. Sends $\alpha \cdot v$, α in [0,1]	Impoverished model of buyer. Is credulous and chooses $p = s + \varepsilon$
Level-1	Assumes she's dealing with a level-0 seller. Sends low suggestion.	Assumes she's dealing with a level-0 buyer. Performs inference to determine beliefs about α. Chooses price optimally given updated beliefs.
Level-2	Assumes seller is *probably* level-1 $\Rightarrow$ thinks seller believes she is level-0 and is determining likely values for α. **Estimates effects of suggestion on seller beliefs for α.** Sends low suggestions when v is high (paying trials), and high suggestions when v is low (credibility building trials).	Initially assumes that buyer is probably level-1 but allows for the possibility that they are level-0 with some α. Performs inference over both these scenarios given the history of suggestions.[*] [*]Inference will generally not distinguish well between level-0 with low α and level-1 behavior. But the presence of many high suggestions will increase seller belief that the buyer is a high-α level-0.

Strategists > Nonstrategists

- Restrosplenial cortex
  - episodic memory
  - negative emotions
  - cognitive mapping
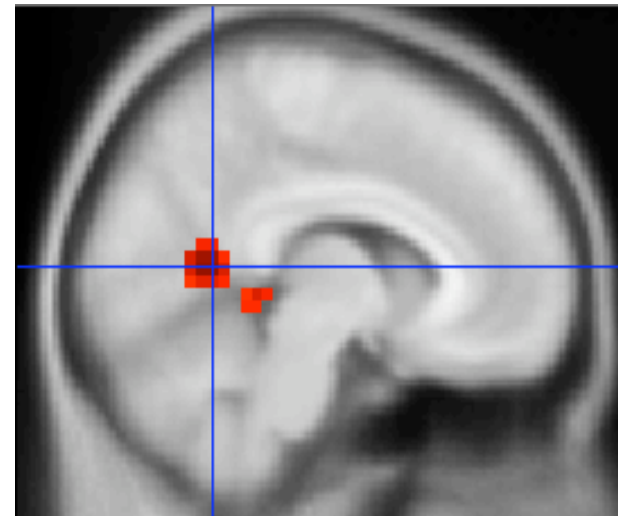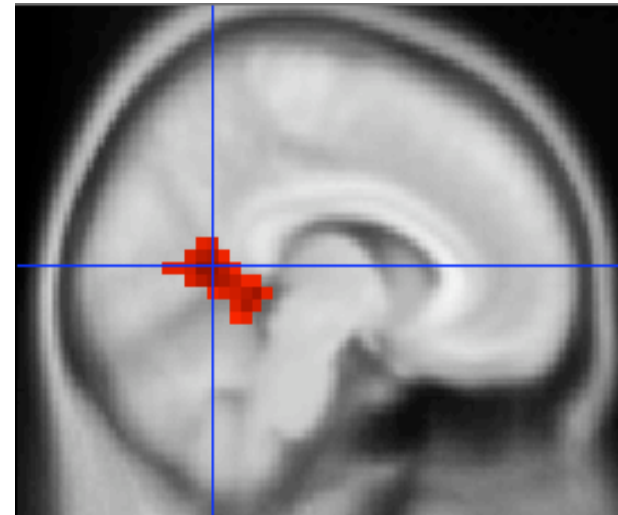
Short-term memory (STM) correlates with strategic thinking steps (r≈.20)

	C	D
A	60,20	60,10
B	80,20	10,10

Table 1: A game solvable by iterated dominance
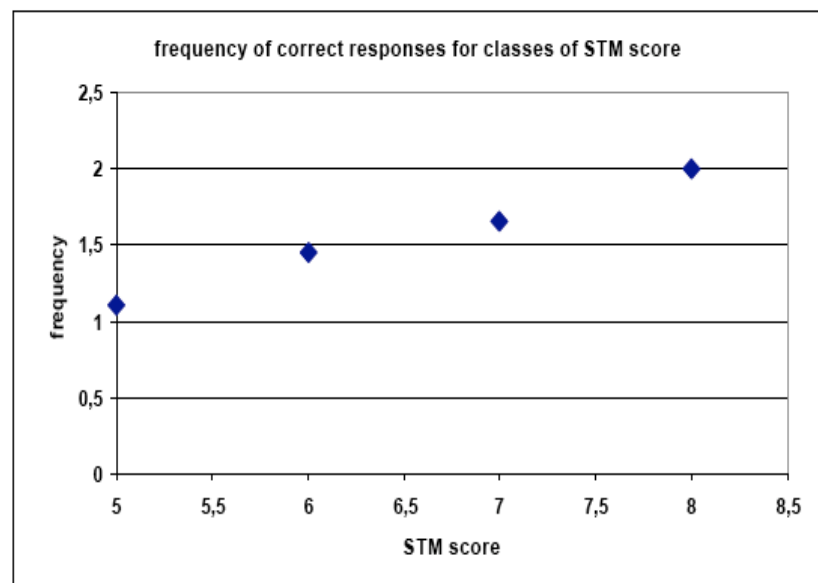

frequency of correct responses for classes of STM score

Devetag, Warglien JEcPsy 03

# To-do list

- Proper psychometrics
- Possible dimensions……..in classes of games
  - Randomization   mixed equilm
  - iterated reasoning   dom-solvable
  - Inferring hidden information   private info
  - emotional forecasting   reciprocity
  - planning ahead   extensive-form
  - social acuity   coordination

Conclusion

Beauty contest results (Expansion, Financial Times, Spektrum)

- Cognitive hierarchy of types
  - Lab, field, eyetracking, fMRI
- Some within-person stability
  - Games 1-10 vs 11-20 r=.60
- Many open questions
  - Are there distinct types?
  - Closer link to ToM regions
    - Beliefs, intentions, attributions
  - Disorders of strategic thinking
    - Paranoia, gullibility, autism(s)
  - Experience and expertise
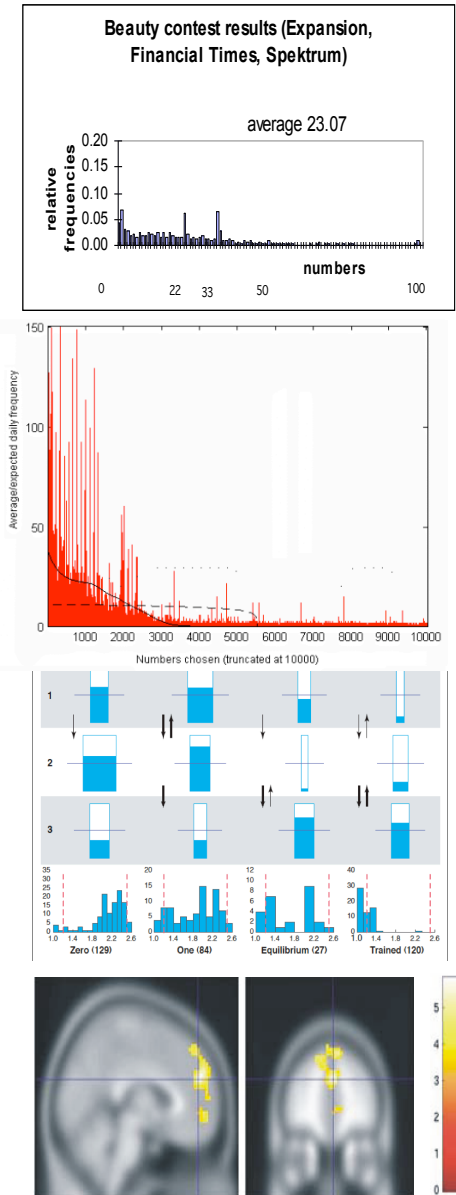
Collaborators

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- Read Montague

Illinois
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Iowa
- Dan Tranel

INSEAD
- Hilke Plassman

National Taiwan University
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NYU
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- Peter Sokol-Hessner
- Elizabeth Phelps

Rutgers
- Mauricio Delgado

FIL
- Benedetto De Martino