A variety of “Beauty Contest” games

These slides are adapted from slides originally prepared by Rosemarie Nagel

UPF-ICREA

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Nagel et al. on the guessing game/beauty contest

1. Nagel, Rosemarie "Unraveling in Guessing Games: An Experimental Study," *American Economic Review, 1995, Vol. 85 (5), pp 1313-1326.*
2. Duffy, John and Rosemarie Nagel "On the Robustness of Behavior in Experimental Beauty-Contest Games," *Economic Journal, Nov. 1997, Vol.107, pp 1684-1700.*
3. Bosch-Domenech A, Montalvo JG, Nagel R, Satorra A "One, Two, (Three), Infinity…: Newspaper and Lab Beauty-Contest Experiments", *American Economic Review, Dec. 2002, Vol. 92 (5), pp 1687-1701*
4. Grosskopf, Brit and Rosemarie Nagel "The Two-Person Beauty Contest,“ *Games and Economic Behavior 62 (2008) 93–99*
5. Corecelli, Giorgio and Rosemarie Nagel "Beauty Contest in the Brain: the Neural Basis of Strategic Thinking" working paper, 2008.
6. Chou, Eileen, Margaret McConnell, Rosemarie Nagel and Charles R. Plott "The control of game form recognition in experiments: understanding dominant strategy failures in a simple two person "guessing" game," *Experimental Economics*, forthcoming (2009).

Some other experiments building on Nagel '95

- Ho, T.-H., Camerer, C. & Weigelt, K. (1998). Iterated dominance and iterated best response in experimental "p-beauty contests". *American Economic Review, 88,* 947-969
- Weber, Roberto A. "'Learning' with no feedback in a competitive guessing game," *Games and Economic Behavior*, 44,1,134-144, JUL 2003
- Slonim, Robert L. "Competing against experienced and inexperienced players," EXPERIMENTAL ECONOMICS, 8,1, 55-75, 2005
- Kocher MG, and Sutter M "The decision maker matters: Individual versus group behaviour in experimental beauty-contest games," ECONOMIC JOURNAL, 115, 500, 200-223, JAN 2005
- Kocher M.G. & Sutter, M. (2006). Time is money – Time pressure, incentives, and the quality of decision-making. *Journal of Economic Behavior & Organization, 61,*375-392.

"Beauty Contest" Game

"…professional investment may be likened to those newspaper competitions in which the 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 as a whole; so that each competitor has to pick not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. 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 practice the fourth, fifth and higher degrees."
Keynes (1936, p. 156)

Rules

Choose a number between **0 and 100**. The winner is the person whose number is closest to **2/3 times the average of all chosen numbers**

For our exercise today, let's interpret **"average"** to be the **median.**

After we've collected the results, we'll graph them.

What happened?

- Hypotheses?
- Are players rational?
  - What does “rationality” imply in this game?
  - How should a rational player behave in a population in which not everyone is perfectly rational?

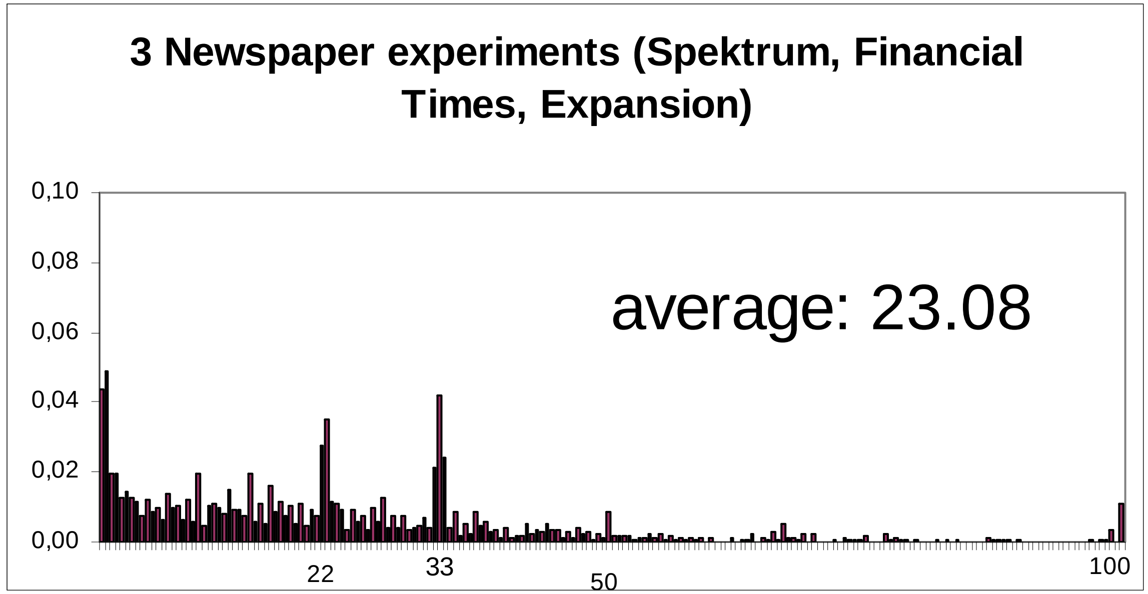
I. Basic Beauty Contest Game

- The rules of the basic beauty-contest game:
- ***N participants*** are asked to guess a number from the ***interval 0 to 100***.
- The winner is the person whose guess is closest to ***2/3 times the mean*** of the choices of all players.
- The winner gets a ***fixed*** prize of ***$20***. In case of a tie the prize ***is split*** amongst those who tie.
- The same game may be repeated ***several periods***
- History: subjects ***are informed*** of the ***mean, 2/3 mean*** and ***all choices*** in each period.
- Time to think: up to ***two weeks***
- ***Participants:*** *students, theorists, “newspaper readers” etc*

Rules, theories, and data for the basic game

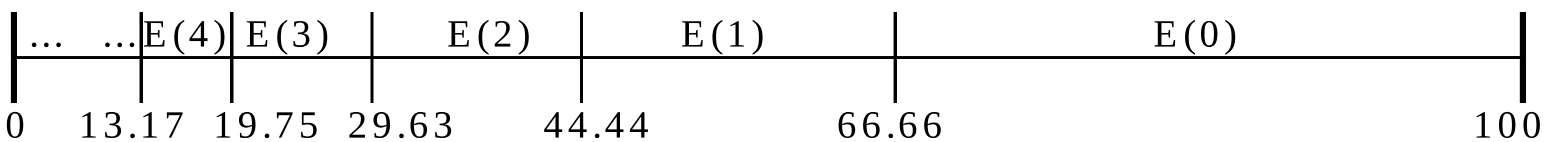
Rules

Choose a number between **0 and 100**. The winner is the person whose number is closest to **2/3 times the average of all chosen numbers**

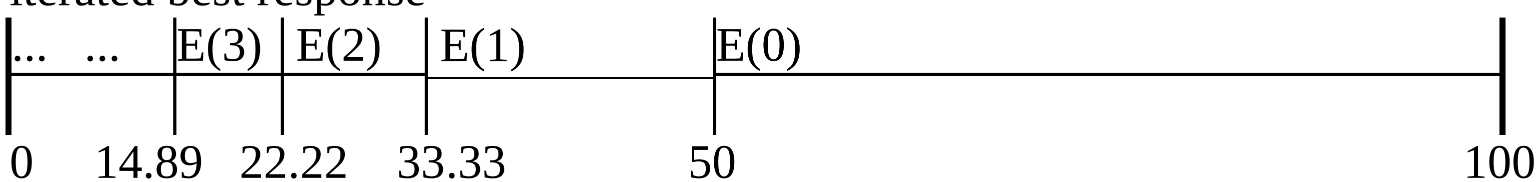


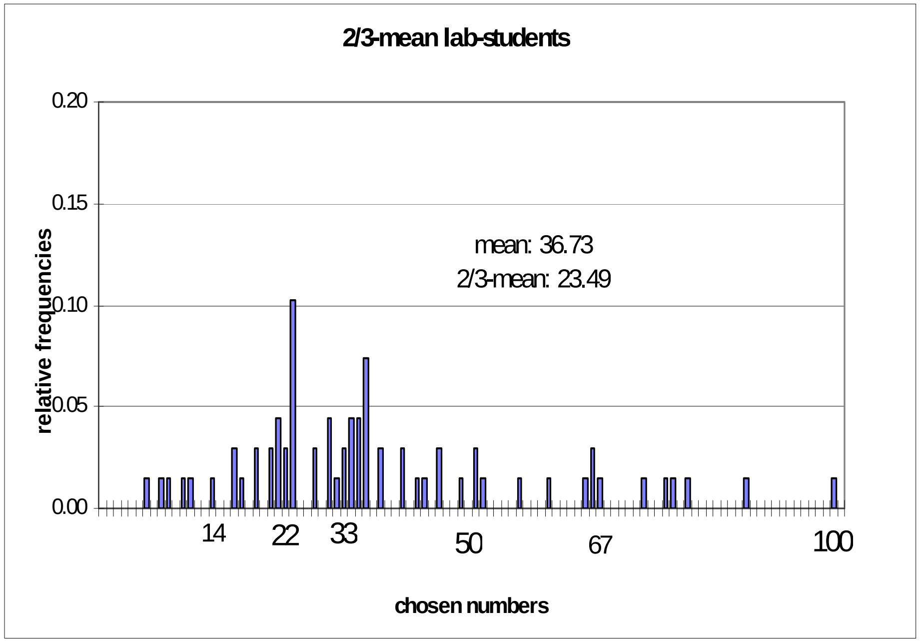
1. iterated elimination of dominated strategies

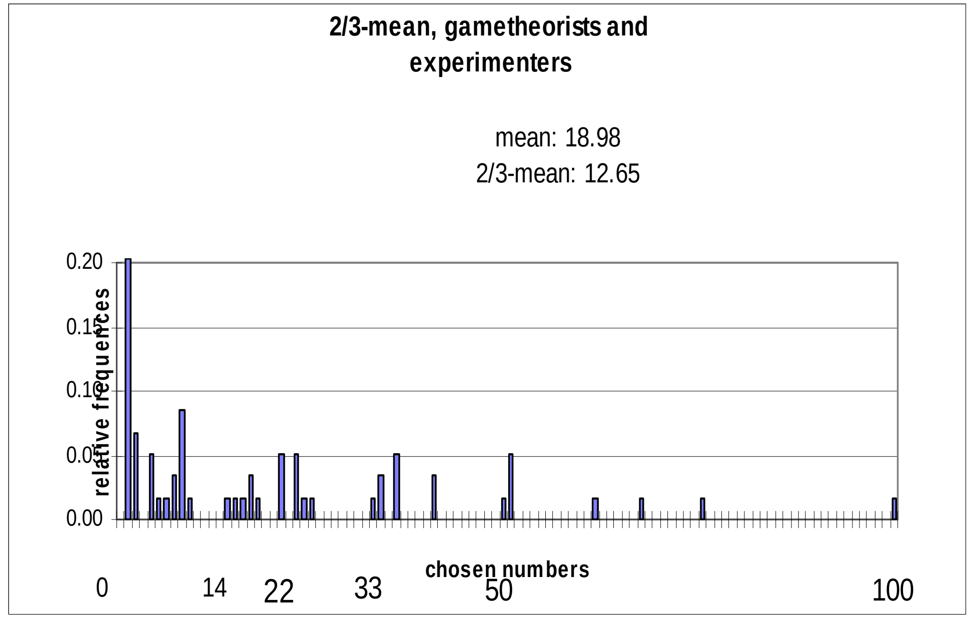
Equilibrium ←———— ITERATION

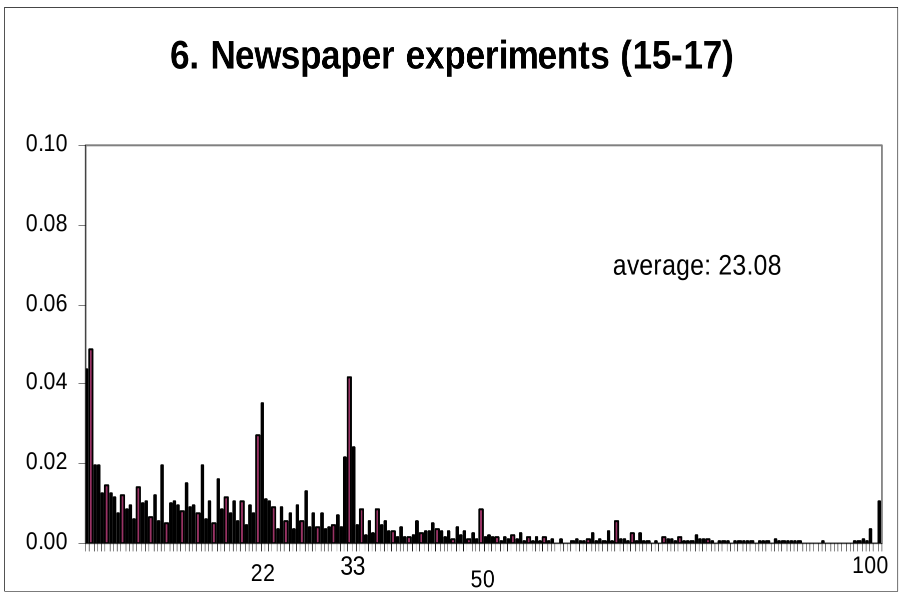


2. iterated best response





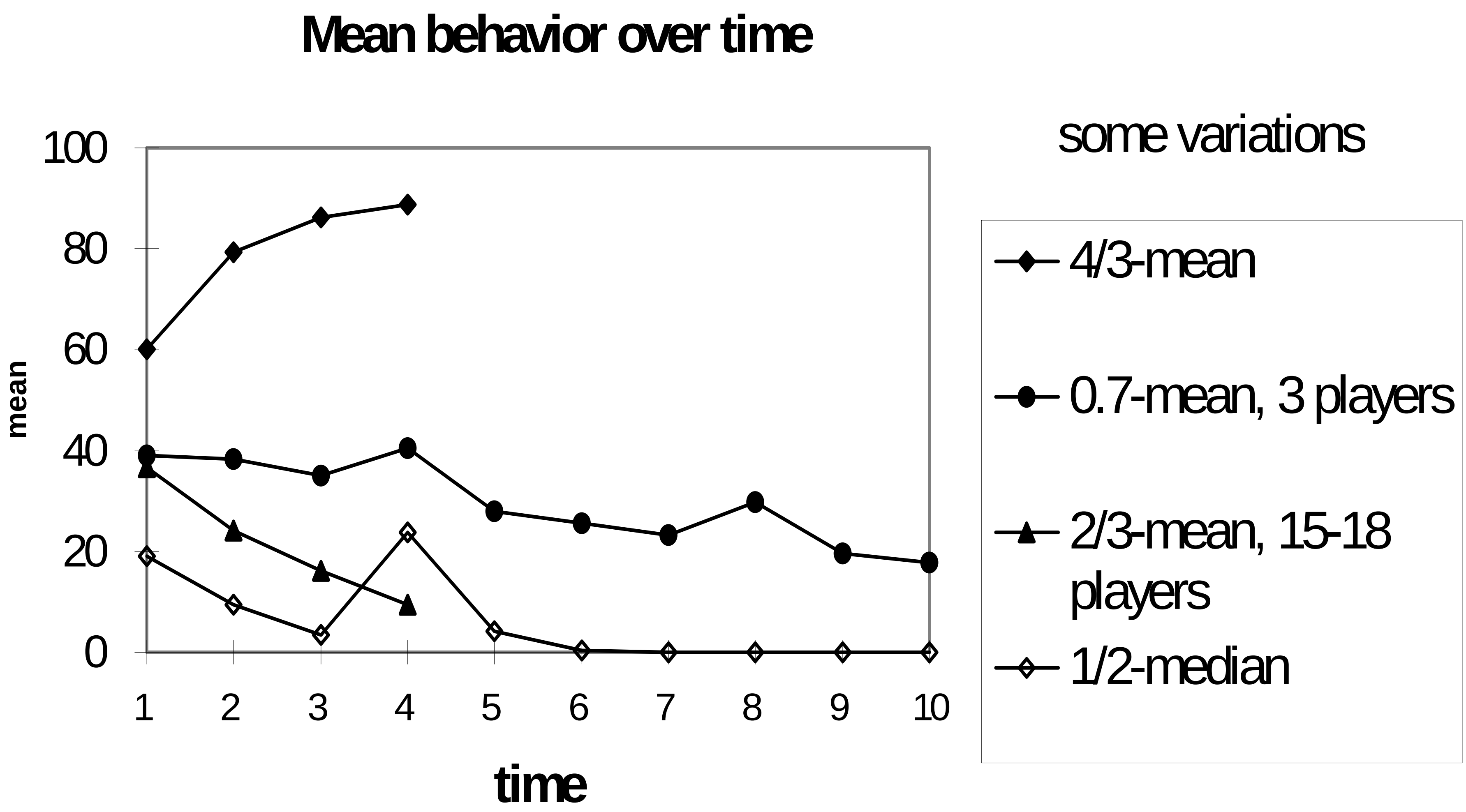




First period results with different populations (Nagel 1995, Bosch et al. 2002)

Iterated best reply model characteristics

- Not an equilibrium model: strategies of players are not all best replies to each other
- No common knowlegde of rationality
- Limited reasoning
- Best reply to own belief (no consistent beliefs)
- Random behavior is also a strategy



Nagel 1995, Camerer, Ho AER 1998)

Table 6.2

Choice Classification According to Depth of Reasoning *k* in 10-Round Sessions

1/2-Median Session

Round	1	2	3	4	5	6	7	8	9	10
k>3	0	0	0	0.15	0.08	0	0.15	0.23	0.62	1.00
k=3	0.08	0.08	0	0	0.08	0.08	0.31	0.31	0.23	0
k=2	0.38	0.31	0.62	0.46	0.31	0.54	0.54	0.46	0.15	0
k=1	0.54	0.38	0.31	0.15	0.08	0.15	0	0	0	0
k=0	0	0.23	0.08	0	0.08	0.08	0	0	0	0
k<0	0	0	0	0.23	0.38	0.15	0	0	0	0

1/2-Mean Session

Round	1	2	3	4	5	6	7	8	9	10
k>3	0	0	0	0	0.07	0	0.14	0.07	0.07	0
k=3	0	0.14	0	0	0.07	0.14	0.29	0.14	0.14	0
k=2	0.07	0.14	0.36	0.29	0.14	0.36	0.57	0.29	0.29	0.50
k=1	0.71	0.57	0.43	0.57	0.71	0.29	0	0.29	0.29	0.29
k=0	0.14	0	0.14	0	0	0.14	0	0.14	0	0
k<0	0.07	0.14	0.07	0.14	0	0.07	0	0.07	0.21	0.21

1/2-Maximum Session

Round	1	2	3	4	5	6	7	8	9	10
k>3	0	0	0	0	0	0	0	0	0	0.07
k=3	0.07	0.13	0	0	0	0	0	0	0	0.07
k=2	0.40	0.53	0.40	0.13	0.07	0.27	0	0.73	0.07	0.80
k=1	0.33	0.33	0.40	0.87	0.67	0.73	0.80	0.27	0.67	0.07
k=0	0.20	0	0.07	0	0.20	0	0.13	0	0.07	0
k<0	0	0	0.13	0	0.07	0	0.07	0	0.20	0

Note. Underlined numbers in table are modal frequencies. Reprinted with permission from Duffy & Nagel (1997).

Models that have been applied/developed with the different beauty contest data sets

In the first period:

- Iterated dominance
- Iterated best response model = level of reasoning model (typically 1-3 levels) (Nagel, AER 1995; Stahl, GEB 1996; Camerer, Ho AER 1998)). See also: Costa-Gomes and Crawford AER 2006.
- Bayesian reasoning model (Stahl JEBO 1998)
- Cognitive hierarchy model (Camerer, Chung, Ho, QJE 2004): best reply against probability distribution of all lower levels, one parameter to estimate)
- Mixture models (Bosch, Montalvo, Nagel, and Satorra 2005)

Behavior over time

- Directional learning model (Nagel AER,1995)
- Cournot model (Nagel, AER 1995)
- Variations of reinforcement model (Stahl, GEB 1996)
- Rule learning model (Stahl, GEB 1996)
- Bayesian learning model (Stahl JEBO 1998)
- Experienced weighted attraction model (Camerer and Ho, EMA 1999)

How to design an experiment to separate two hypotheses?

- (Many) people don’t play equilibrium because they are confused.
- (Many) people don’t play equilibrium because doing so (choosing 0) doesn’t win; rather they are cleverly anticipating the behavior of others, with noise.

- Why do players not play equilibrium? Here are two possible classes of explanations:
  - No clue about equilibrium behavior.
  - A fully rational player might realize what equilibrium behavior looks like, however doubts that all choose it.
    - Doubt about other players' rationality.
    - Belief about other players' doubts about rationality of Co-players…

- Hard to separate observationally, since equilibrium strategies are not in general best replies to (random) non-equilibrium choices of other players.

- Can we design an experiment to distinguish between these two hypotheses?

2 person guessing games

Grosskopf & Nagel (GEB 2008)

2-person Beauty-Contest Games:

Each player pick a number from 0 to 100, the person closest to 2/3 of the mean wins.

- Rational player chooses weakly dominant strategy 0.
- N=2 is very different from N>2 (dominant strategy equilibrium vs iterated elimination of dominated strategies)

3 treatments:

- **Full info: Learn choices of others in my group.**
- **Partial info:** Only learn if won or not.
- **No info**

	# Participants	Mean	Median	% Choices of zero
Full Information	36	35.43	32	5.56% (2)
Partial Information	46	29.98	31.15	13.04% (6)
No Information	52	40.62	41.50	11.54% (6)
Reverse Full Information*	36	16.55	10	16.67% (6)
Amsterdam, Netherlands	18	11.5	5	50% (9)
Burg Warburg, Germany	26	15.5	3	46.15% (12)
Kobe, Japan	16	41	29.5	31.25% (5)
Lund, Sweden	18	12.3	3	50% (9)
Orlando, U.S.	29	33.97	36	10.34% (3)
Erfurt, Germany	4	35.25	15.5	0 (0%)
Tucson, Arizona, U.S.	19	11.16	0	52.63% (10)
Cambridge, U.S.*	15	37.55	18.3	33.33% (5)
Trento, Italy*	24	8.05	9.55	50.00% (12)
Random Guess	33	45.3	47	3.03% (1)

TABLE III: Summary statistics of first round choices in the 2–person BCGs (lab treatments as well as out of the lab experiments)

* in all of these treatments the $n > 2$ BCG was played before the $n = 2$ BCG.

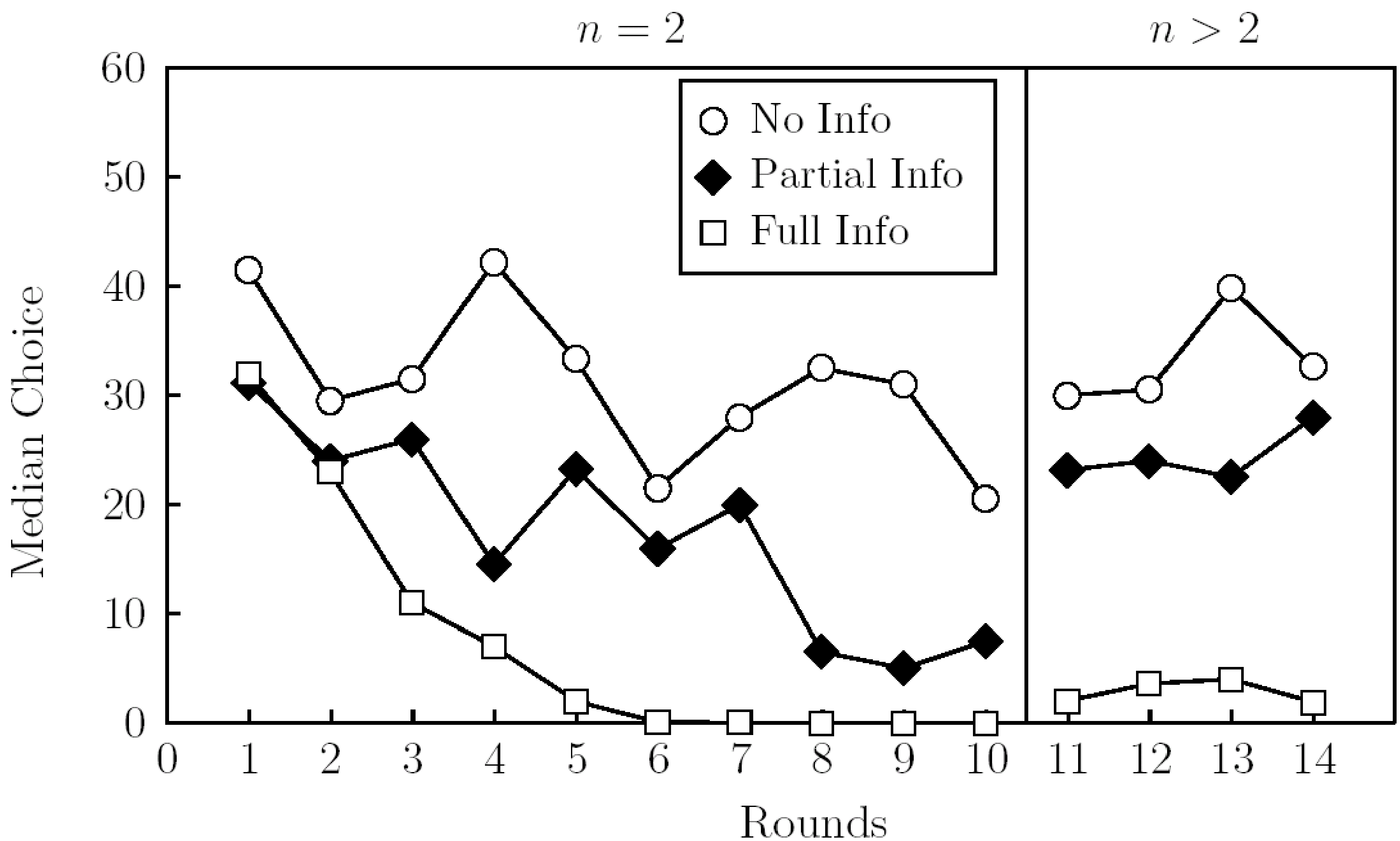


FIGURE 3: Median choices over time in the Full, Partial snd No Info Treatments

What has this series of experiments done?

- the first paper identifies some phenomena, very different from equilibrium behavior, although approaching it over time.
- the newspaper studies show these phenomena are robust, not a simple artifact of the lab
- and the N=2 paper shows that it involves some real confusion, not just very rational people with different beliefs about others…

More Variations

Learning

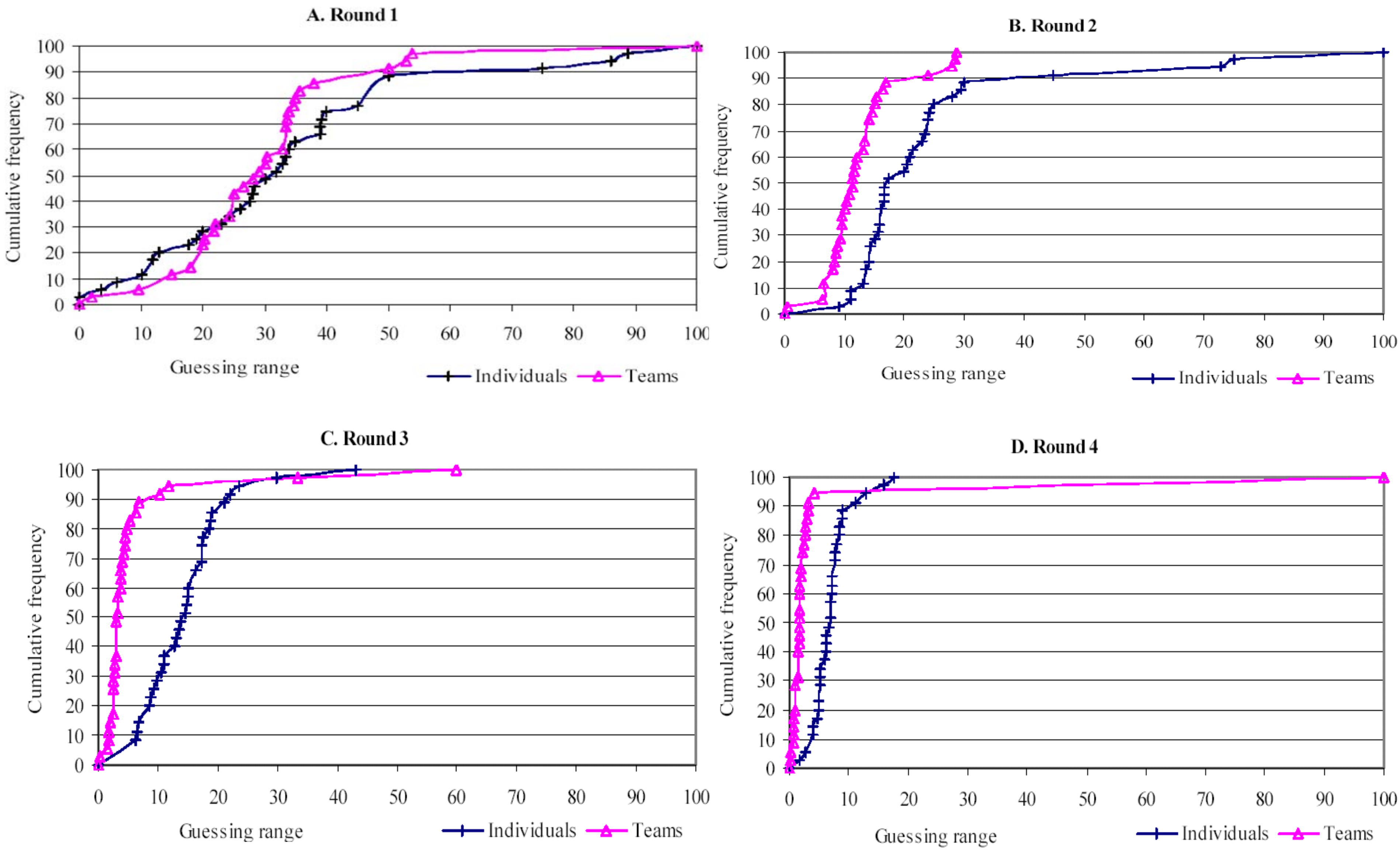
- A number of experimenters have sought to use the dominance-solvable structure of the game as a particularly simple environment in which to study how learning proceeds over time and repeated play.

Kocher MG, and Sutter M “The decision maker matters: Individual versus group behaviour in experimental beauty-contest games,” Economic Journal, 115, 200-223, JAN 2005

Abstract: Economics has devoted little attention to whether the type of decision maker matters for economic decisions. However, many important decisions like those on monetary policy or a company's business strategy are made by (small) groups rather than an individual. We compare behaviour of individuals and small groups in an experimental beauty-contest game. Our findings suggest that groups are not smarter decision makers per se but that they learn faster than individuals. When individuals compete against groups, the latter significantly outperform the former in terms of payoff.

Design: 17 individuals, and 17 groups of 3 people, all play in one game: 4 sessions.

Kocher and Sutter: Team (3 members determine a number) vs Individual behavior within the same group: Cumulative frequency of guesses



Slonim, Robert L. “Competing against experienced and inexperienced players,” Experimental Economics, 2005, 55-75

Abstract: In certain markets success may depend on how well participants anticipate the behavior of other participants who have varying amounts of experience. Understanding if and how people's behavior depends on competitors' level of experience is important since in most markets participants have varying amounts of experience. Examining data from two new experimental studies similar to the beauty contest game first studied by Nagel (1995), the results indicate that (1) players with no experience behave the same against competitors with and without experience but (2) players quickly learn to condition their behavior on competitors' experience level, causing (3) behavior to stop moving toward the equilibrium whenever new players enter the game and (4) experienced players to earn more money than less experienced players. The paper discusses the implications of the results for understanding and modeling behavior in markets in which participants have different amounts of experience.

Slonim 2005: Experienced vs. Inexperienced players

Table 1: Experimental Design for Treatment 1: *SAME*

			Player ID Assignments		
Supergame	Round	Period	Room A	Room B	Room C
1	1	1	3, 6, 8	1, 4, 5	2, 7, 9
	2	2			
	3	3			
2	1	4	3, 4, 9	5, 7, 8	1, 2, 6
	2	5			
	3	6			
3	1	7	2, 3, 5	1, 8, 9	4, 6, 7
	2	8			
	3	9			

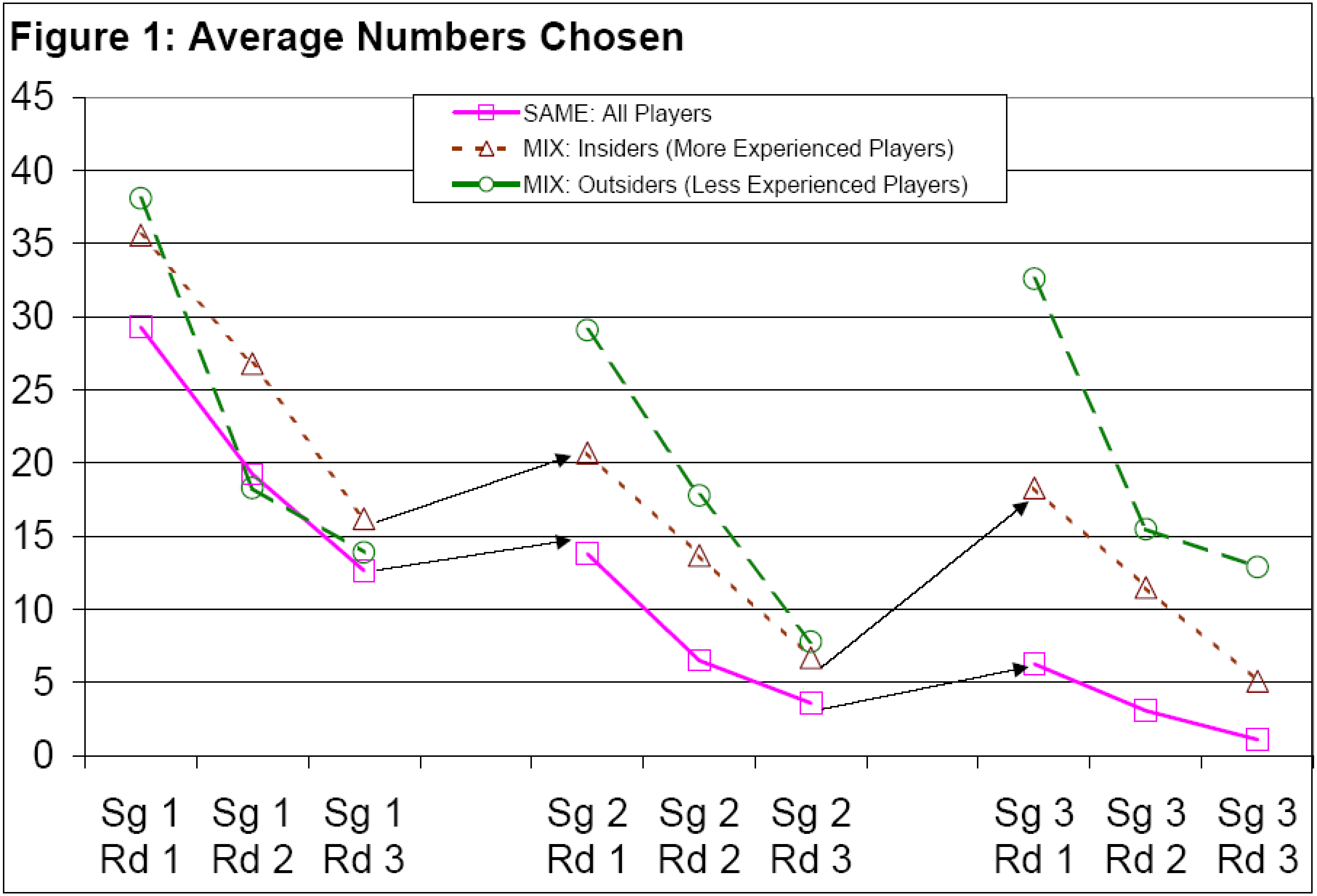
SAME: All subjects always have the same amount of experience

Table 2: Experimental Design for Treatment 2: *MIX*

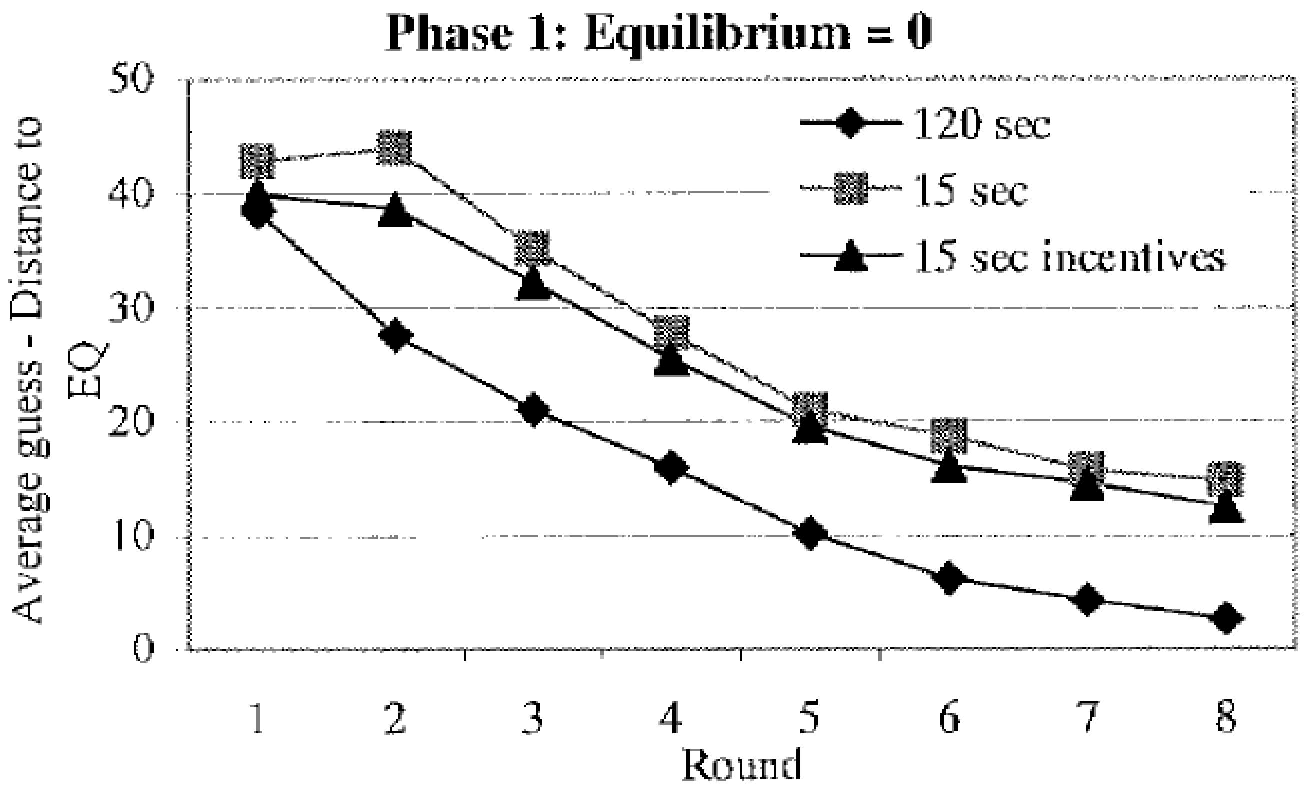
		Role	Insider	First Outsiders	Second Outsiders	Third Outsiders
Number in Each Role			1	2	2	2
Supergame	Round	Period				
1	1	1	**Played All Periods**	**Played**	DID NOT PLAY	DID NOT PLAY
	2	2				
	3	3				
2	1	4		DID NOT PLAY	**Played**	DID NOT PLAY
	2	5				
	3	6				
3	1	7		DID NOT PLAY	DID NOT PLAY	**Played**
	2	8				
	3	9				

MIX: Insiders have 3 and 6 rounds more experience than Outsiders in supergames 2 & 3, respectively

Slonim, Experimental Economics 2005



Time is money, JEBO, Kocher and Sutter, 2006



Weber, Roberto A. “'Learning' with no feedback in a competitive guessing game,” *Games and Economic Behavior*, 44,1,134-144, JUL 2003

Abstract: An assumption underlying current models of learning in games is that learning takes place only through repeated experience of outcomes. This paper experimentally tests this assumption using Nagel's (1995, Amer. Econ. Rev. 85, 1313-1326) competitive guessing game. The experiment consists of several periods of repeated play under alternative feedback conditions, including no-feedback conditions in which players receive no information between periods. If learning takes place only through reinforcement resulting from experienced outcomes, choices in the no-feedback conditions should not converge towards the Nash equilibrium. While less than under full information, there is convergence towards the equilibrium prediction in the no-feedback conditions. Varying priming given to subjects between periods does not affect the results

In this study, Nagel's game with $p = \frac{2}{3}$ and $X = \$6$ was used in an experiment with four information conditions. In each session, the game was repeated ten times with 8 to 10 players.

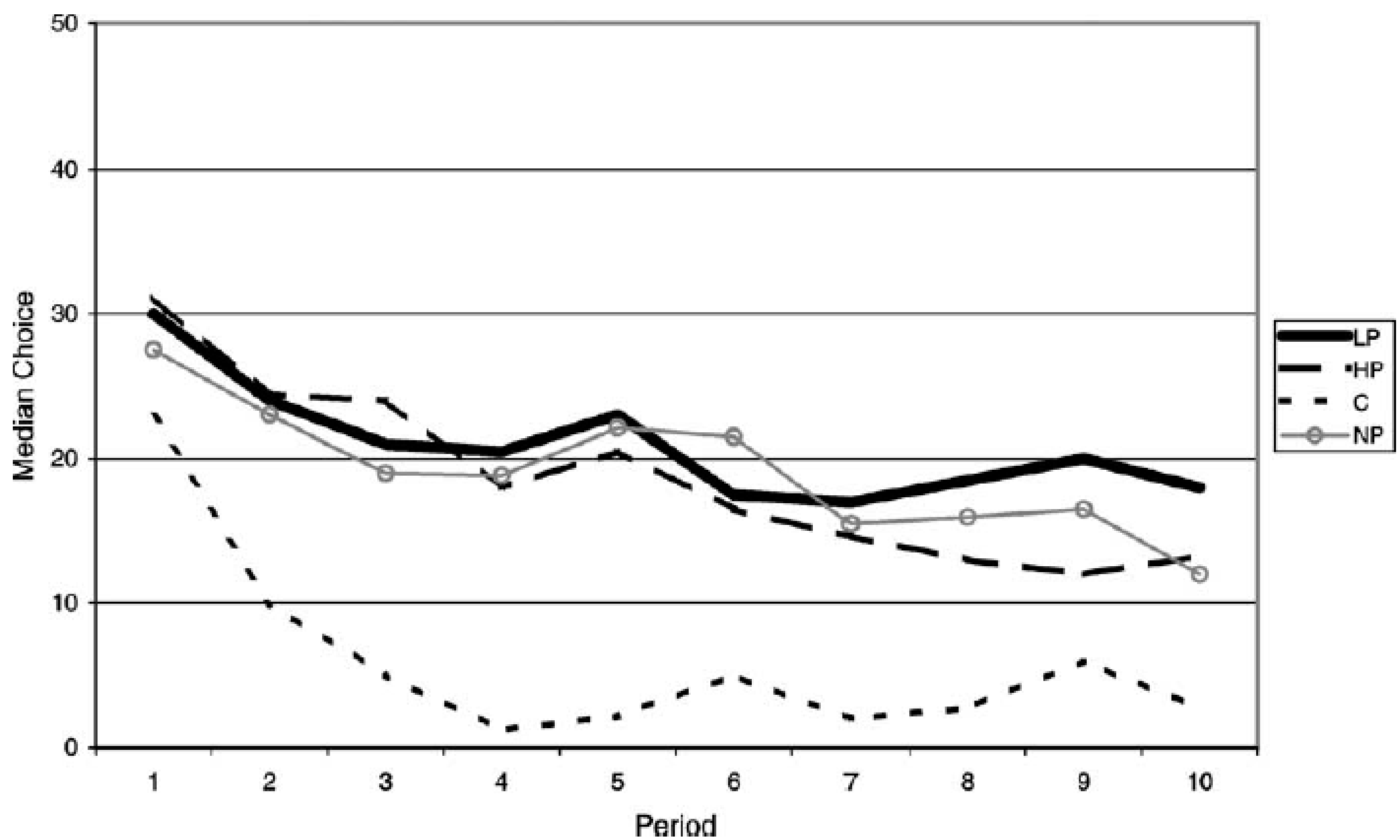
In the *control* condition (C), the experimenter wrote the average, target number, and participant number(s) of the winner(s) on a board at the front of the room at the end of each period. This treatment serves to replicate, with feedback, Nagel's results.

In the *no-feedback no-priming* condition (NP), the game was played ten times, but subjects received no feedback at the end of each period. Instead, after the experimenter recorded each subject's choice at the end of period t, he simply stated: "This concludes period t. We will now move on to period $t + 1$. Please make your choice by writing it on your record sheet." At the conclusion of the tenth period, subjects were informed of the average, target number, and participant number of the winner or winners for all ten periods.

In the *no-feedback low-priming* condition (LP), subjects again received no feedback at the end of each period. However, in this treatment, at the end of each period the experimenter told subjects that he had calculated the average and target number and determined who the winner or winners were. The participants were informed that the experimenter had done this, *but were not told the results*, and were then asked to make a choice for the next period.

The final treatment was the same as the LP condition, with one exception. In this *no-feedback high-priming* condition (HP), subjects were also given no feedback until the end of the session, but after the experimenter calculated the average in each period, participants were instructed to write down their guess of the value of the average. While this guess did not provide subjects with any new information and their earnings were not affected by the

R.A. Weber / Games and Economic Behavior 44 (2003) 134–144



Neural correlates of depth of strategic reasoning in medial prefrontal cortex
by Giorgio Coricelli and Rosemarie Nagel

- In the *human condition*, each participant of a group of 10 was asked to choose an integer between 0 and 100. In the *computer condition* one participant chose one number between 0 and 100 and a computer algorithm chose uniform randomly (and independently of the multiplier parameter) nine numbers between 0 and 100. The prize for the winner, whose number was closest to a known M (e.g., M=2/3) times the average of all choices, was 10 euros .... The computer condition should invoke low levels of reasoning (at or near level 1) according to the iterative reply model. In contrast, in the human condition a higher variety of levels of reasoning should be observed since players might have different ideas what other players choose. To be able to identify brain activity related to mental calculation most likely involved when deciding in the game, we introduced calculation tasks in which subjects were asked to multiply a given parameter or the square of a parameter with a given integer.

Motivation for neuro economics guessing game study (from Coricelli, Nagel 2008)

- We offer an interesting task for neuro scientists to think about thinking of others: interactive and with incentives
- Behavioral economists have developed models of behavior (fairness, reasoning, choice, etc)
- Here:
  - choices indicate levels of reasoning
  - But differentiation between random behavior and levels of reasoning may be difficult to detect
- Can neuro science techniques help us to differentiate between random vs low vs high levels of reasoning
- Lesion studies in our context (still to come)

Example of MRI scanner

Scanner

- a very powerful electro-magnet
- field strength of 3 teslas (T), ~60,000 times greater than the Earth's field

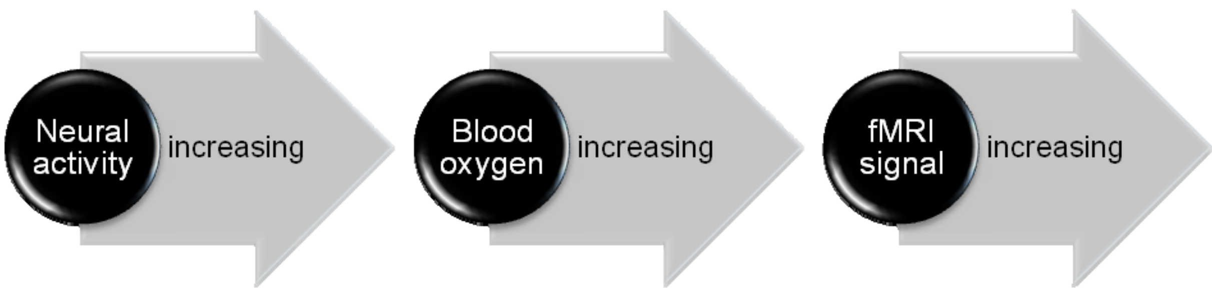
During the experiment:

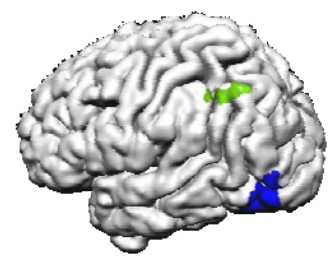
- subject lies in the scanner and is exposed to the stimuli
- scanner tracks the signal throughout the brain

Nature of fMRI activation

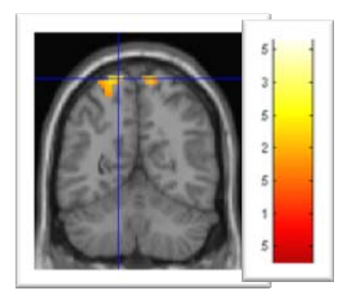
- When a brain area is more active it consumes more oxygen
- Changes in blood flow and blood oxygenation in the brain are indirect measures of neural activity

(Blood Oxygenation Level Dependent (BOLD) signal)





- Data is usually transformed into "activation" maps
- Activation maps show which parts of the brain are involved in a particular mental process



Experimental design
Conditions

Guessing game (session 1)

Human	Computer	Random
Target number = 2/3 *(mean all numbers) Choose a number between 0-100	Target number = 2/3 *(mean all numbers) Choose a number between 0-100	Choose a number between 0-100

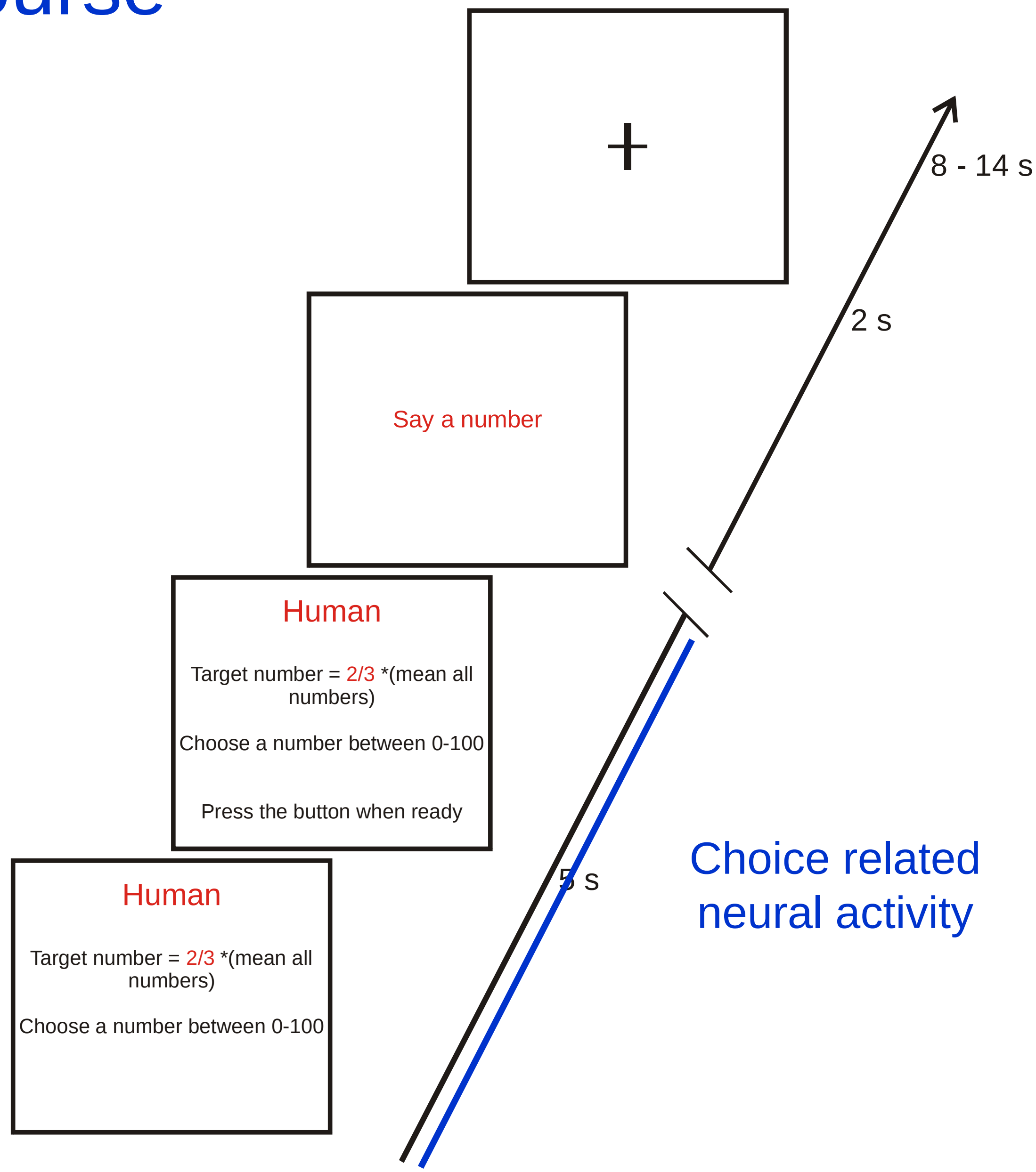
Calculation task (session 2)

Calculate	Calculate	Random
2/3 * 66	2/3 * 2/3 * 66	Choose a number between 0-100

Experimental design

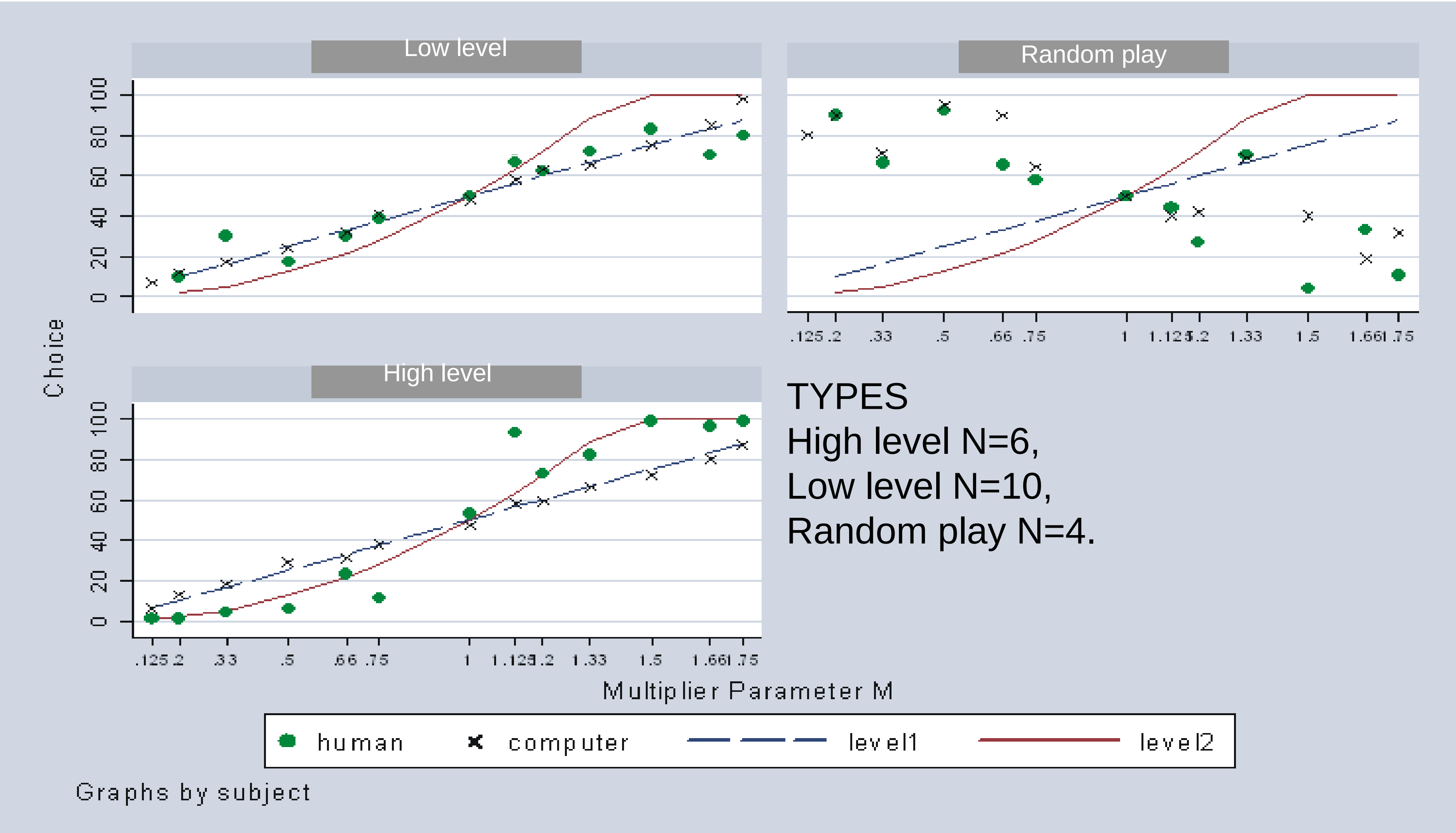
- 10 participants in each “session” (2 groups)
- one after the other person in scanner
- A subject pronounced the numbers speaking into a microphone in the scanner
- Parameters : 0.20, 0. 33,…. 1 …1.25, 1.66, 1.75
- 26 choices (13 human, 13 computer, 13 random)
- Contrast: Calculation tasks: 2/3 *40, ½*1/2*40
- NO info after a period
- Decision time measured
- All periods paid (10 euros per period)

Time course



+
8 - 14 s
Say a number
2 s
Human
Target number = 2/3 *(mean all numbers)
Choose a number between 0-100
Press the button when ready
Human
Target number = 2/3 *(mean all numbers)
Choose a number between 0-100
5 s
Choice related neural activity

Classification of types

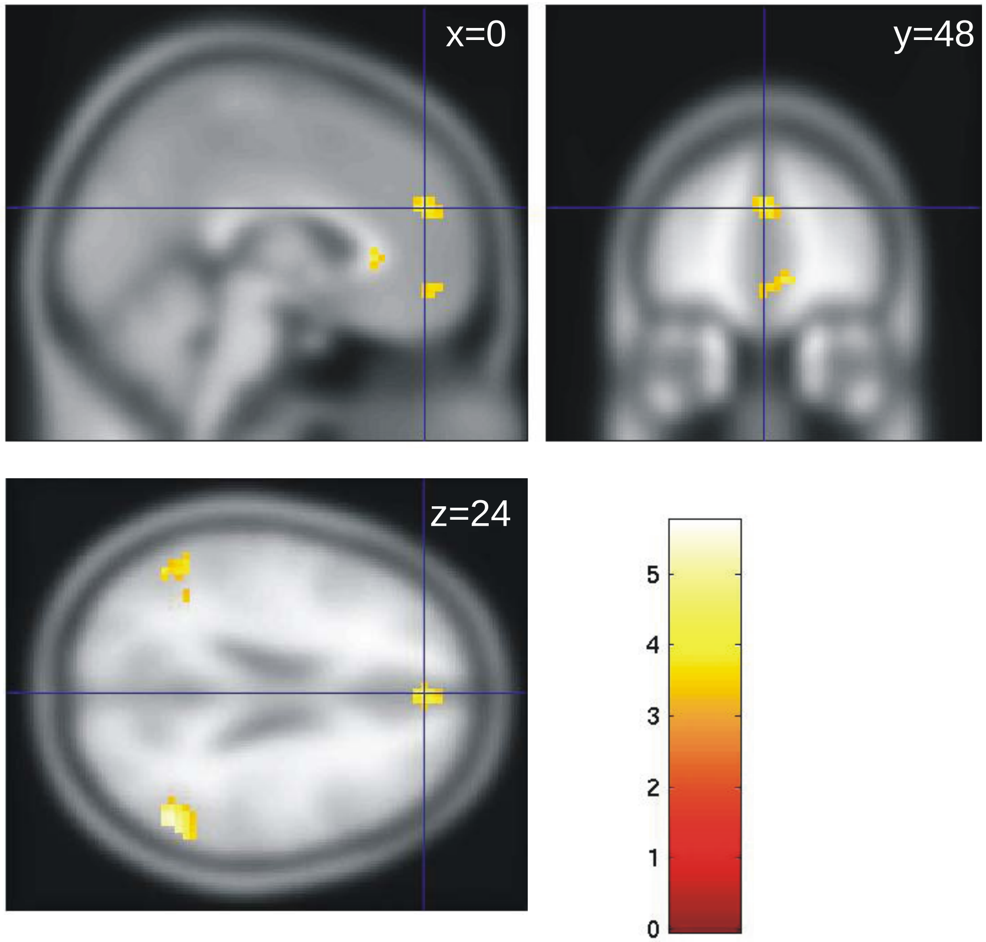


TYPES
High level N=6,
Low level N=10,
Random play N=4.

We measure the level of reasoning of a subject as the smallest **quadratic distance** between actual play and the theoretical value (iterated best reply model).

Human > Computer

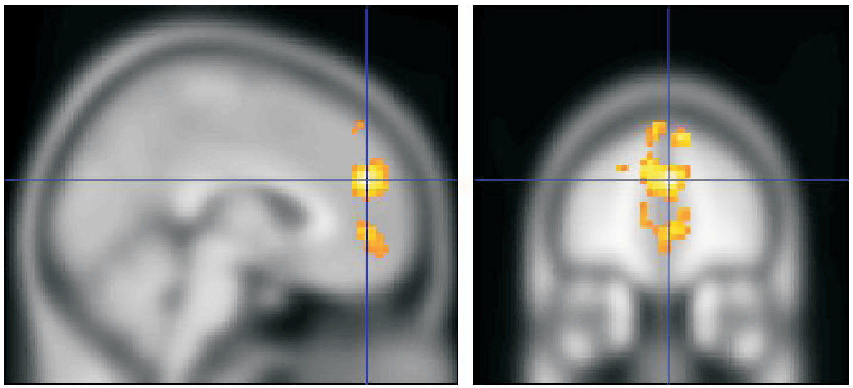
random effect analysis N=20



■ We found enhanced activity in the medial prefrontal cortex (MPFC), ventral anterior cingulate, [superior temporal sulcus (STS)] and bilateral temporo-parietal junction (TPJ) in human vs. computer condition

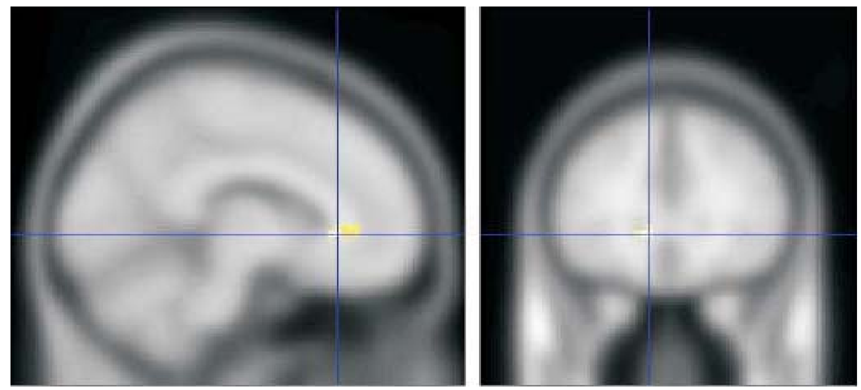
Dorsal and ventral MPFC: high-low distinction

High level of reasoning



■ High level: Third person perspective (dorsal MPFC) & thinking about others as "like me" (ventral MPFC)

Low level of reasoning



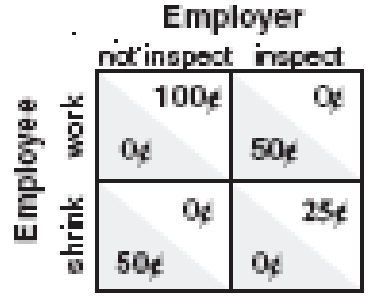
■ Low level: Self referential thinking Anterior Cingulate Cortex (ACC), our interpretation thinking of others as random players

Neural correlates of mentalizing-related computations during strategic interactions in humans

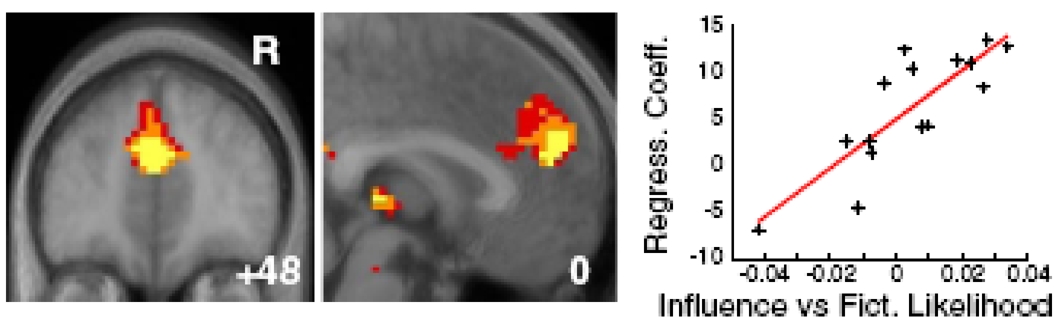
Alan N. Hampton[†], Peter Bossaerts[†‡], and John P. O'Doherty[†‡§]

PNAS | May 6, 2008 | vol. 105 | no. 18 | 6741–6746

Game payoff



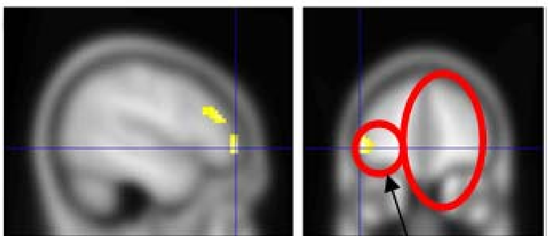
Model	Update rule
RL	$V^{a}_{t+1} = V^{a}_{t} + \eta(R_t - V^{a}_{t})$
Fictitious	$p^{*}_{t+1} = p^{*}_{t} + \eta(P_t - p^{*}_{t})$
Influence	$p^{*}_{t+1} = p^{*}_{t} + \eta(P_t - p^{*}_{t}) - \kappa(Q_t - q^{**}_{t})$



Frontal activity related with calculation

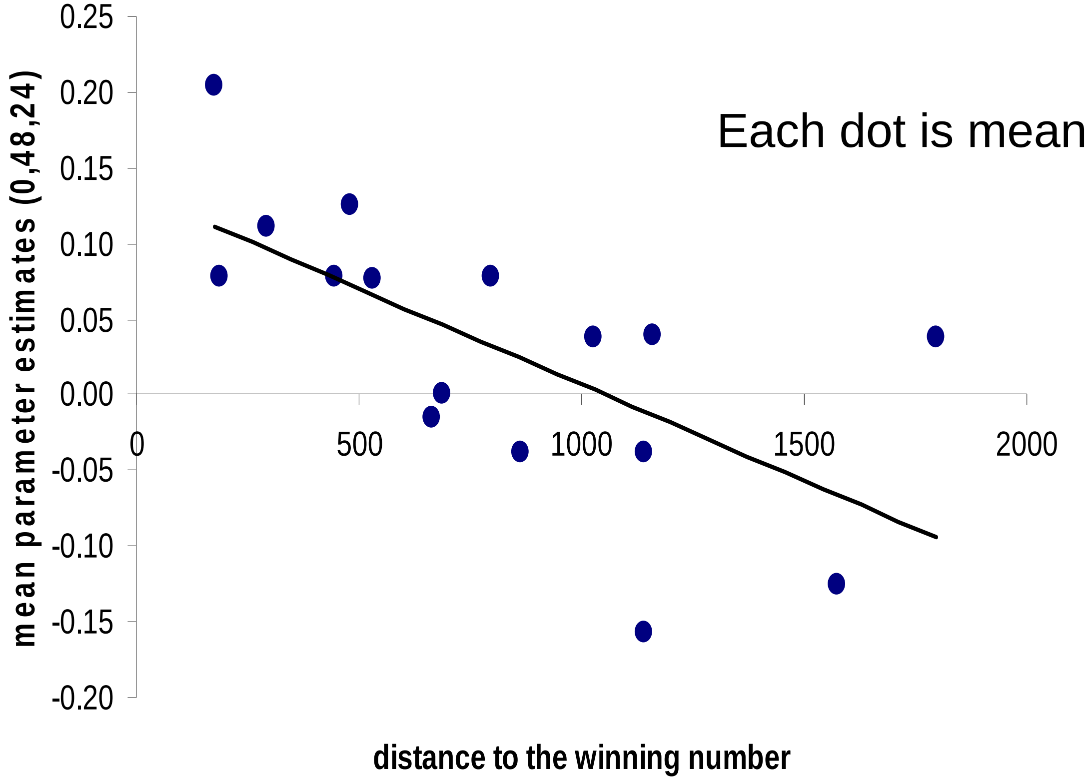
No mPFC

c1 & c2 > random



Lateral prefrontal cortex, related to calculation

Strategic IQ



Each dot is mean of single subject

Increasing strategic IQ

■ The activy in the MPfC is correlated (r = 0.67, P = 0.005) with our measure of Strategic IQ (the mean quadratic distance between own choices and winning number of each trial); the lower the QD the closer to the winning number.

Conclusions (neuro economics study)

- Sophisticated thinking and strategic IQ: level 2: best reply and belief that others also do best reply => differential activation in mPfC
- Thinking about others as random players does not activate mPfC, but instead ACC (level 1)
- TPJ and STS shows high activity for both level 1 and 2: thus a more general area of planning
- Calculation tasks don’t activate mPfC.

⇒Separation of types of thinking mapped in the brain.

⇒Experimenter does not induce type of thinking unlike in most neuro science studies

⇒Future work: designing experiments to find more different types (random and equilibrium types)

Main results of behavior in the different treatments (Nagel)

in the first period:

- clear distinction between different types of players, heterogeneity
- clear differences in behavior for different parameters p (e.g.,½ and 2/3)
- clear differences for different group sizes (e.g., 3 players vs 15 players), team vs indiv., experiences vs. non-experienced players
- low levels of reasoning, between 0 and 3 in most treatments, few equilibrium choices in student groups (thus few types only!)
- differences between different subject pools (game theorists vs students, newspaper population seems to be a mixture of student group and game theorist group)

behavior over time:

- (slow) convergence towards equilibrium in most treatments
- differences in convergence for different p and group sizes
- feedback matters for convergence
- continuous low level of reasoning
- slower convergence when prize is variable instead of fixed
- the behavior has been explained by various models

Importance for economics (Nagel)

- How does the reasoning process come about: randomly, cognitive process, deep vs low levels of reasoning.
  - Purposeful thinking or randomness.
- Interesting differences of cognition between level 1 and level 2 (made visual through brain data)
- Similar reinforcement learning, fictitious play vs Influence learning (Hampton et al.) = level 1 vs level 2!
- Thus through fMRI we find interesting connections between learning and reasoning. It does not matter whether actual data of opponent is given or whether this data is simulated by the subject.
- fMRI knowledge interesting to screen people?
  - Correlation between cognition and behavior made visible
  - Can people say what and how they think: e.g random behavior

Homework

- Write a 1 page “referee” report on Chou et al. (which is in the “Handouts” section of the course web page). Take a large view, and focus on what you think this work (and the work it refers to) tells us about the usefulness/limitations of experiments generally to tell us about theories of rationality, about the usefulness/generality of such theories, of experiments, etc.
  - Chou, Eileen, Margaret McConnell, Rosemarie Nagel and Charles R. Plott “The control of game form recognition in experiments: understanding dominant strategy failures in a simple two person “guessing” game,” *Experimental Economics*, forthcoming (2009).
- Read the Handbook chapter on public goods, in preparation for next week’s class.