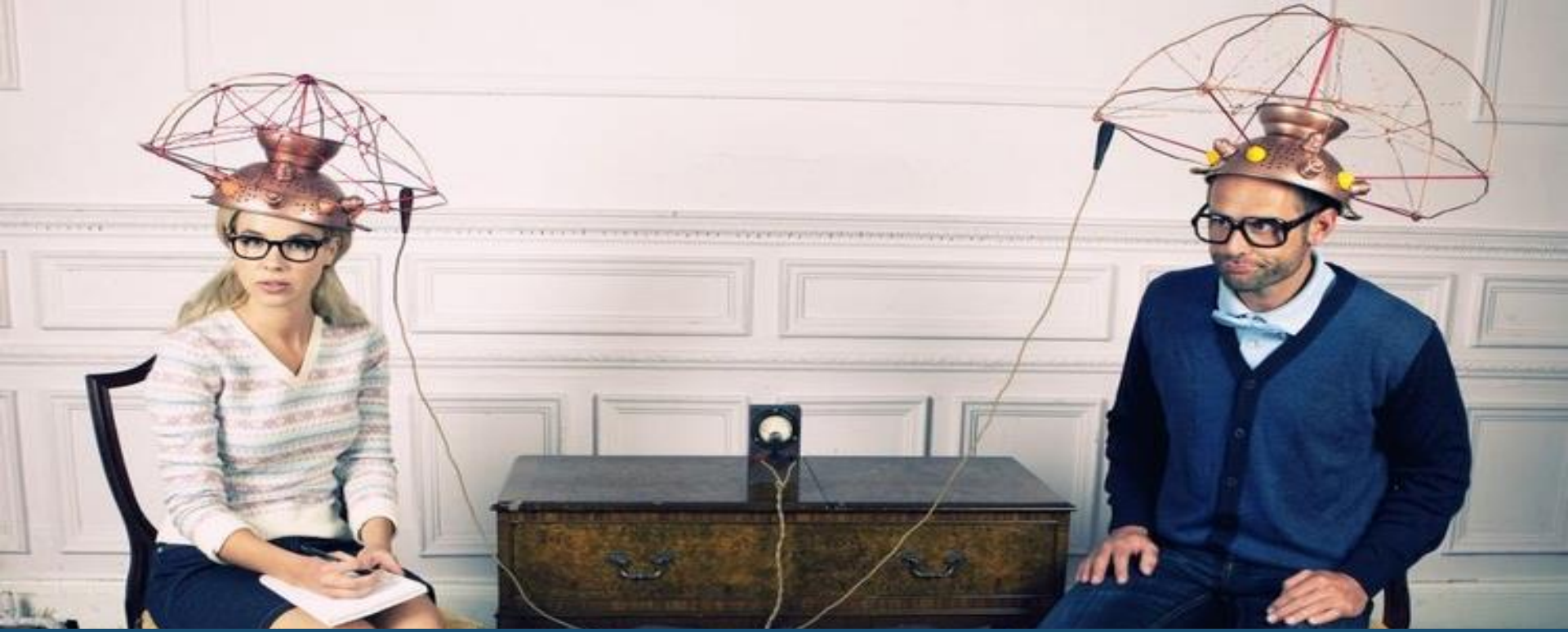

Experimental Economics

Strategic behavior with boundedly-rational players

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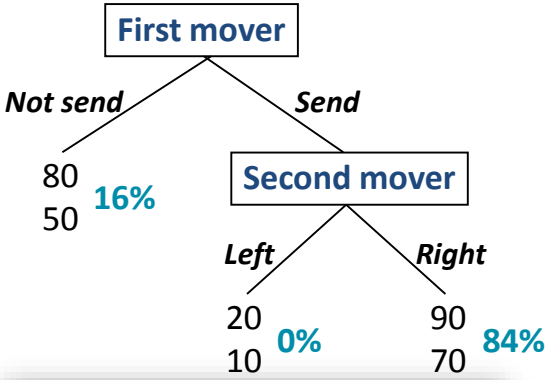
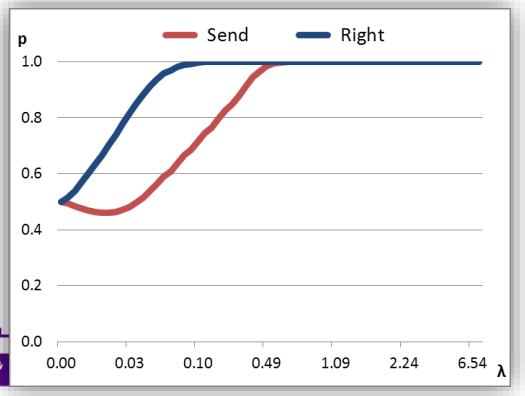
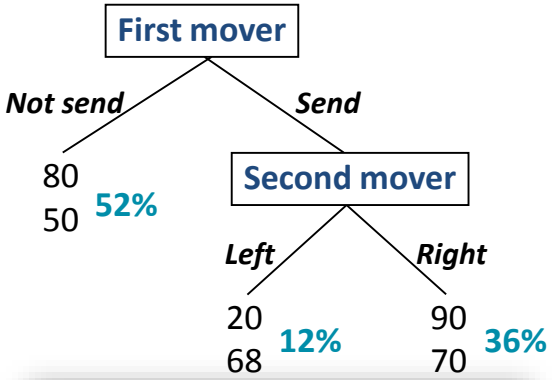
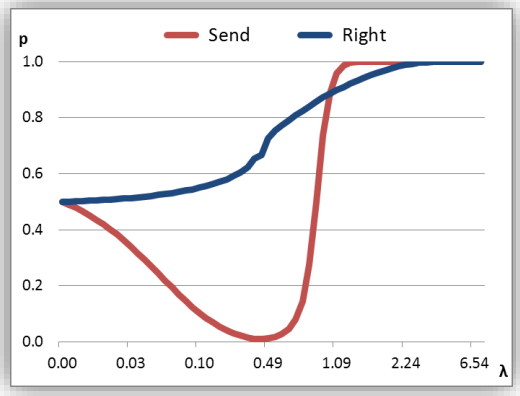
QUANTAL RESPONSE EQUILIBRIUM

How do we model deviations from rationality? (Goeree & Holt 2001)









Quantal response equilibrium (Goeree et al. 2005)

- Smoothens discontinuous best responses according to a regular quantal response function
  - **Interiority:** $P_{is} > 0$ for all s
  - **Continuity:** P_{is} is differentiable
  - **Responsiveness:** $\partial P_{is}/\partial \pi_{is}$ for all s
  - **Monotonicity:** $\pi_{is} > \pi_{ir}$ implies $P_{is} > P_{ir}$
- Logit quantal response equilibrium

$$P_{is} = e^{\lambda \pi_{is}} \Big/ \sum_r e^{\lambda \pi_{ir}}$$

COGNITIVE HIERARCHIES

How do we model the interaction between different types of boundedly-rational individuals to capture persistent deviations from competitive equilibria?

THE BEAUTY CONTEST

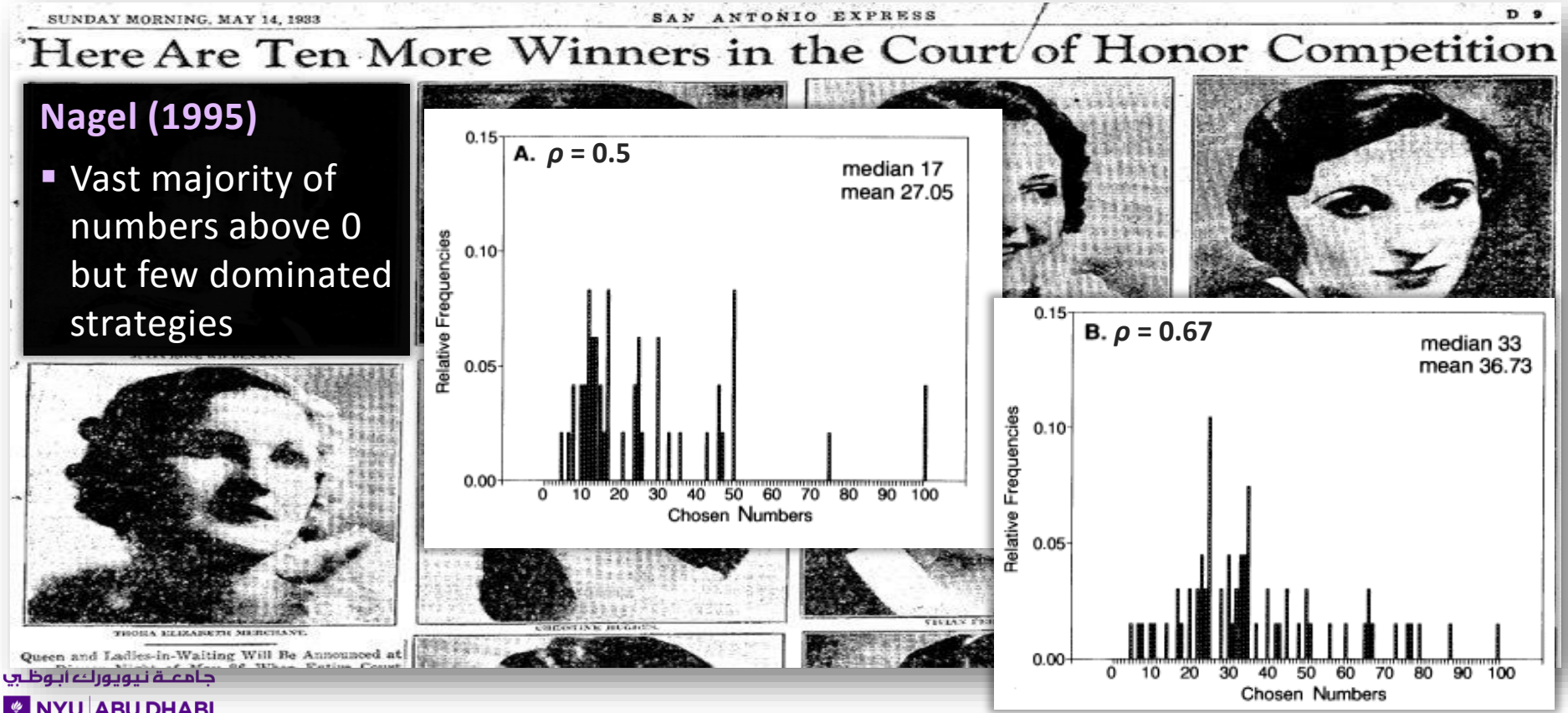
"It is not a case of choosing those [faces] that, to the best of one's judgment, are really the prettiest, nor even those that average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees." – *Keynes (1936)*

THE BEAUTY CONTEST

The guessing game (Moulin 1986)

- n players simultaneously choose a number $s \in [1, 100]$
- The winner is the player whose number is the closest to $\rho \times$ average s (ties are broken randomly)
  - Standard Nash equilibrium is:
    - Everyone chooses 1 if $\rho < 1$
    - Everyone chooses 100 if $\rho > 1$
- The game captures Keynes' intuition and at a basic level some of the incentives in asset markets

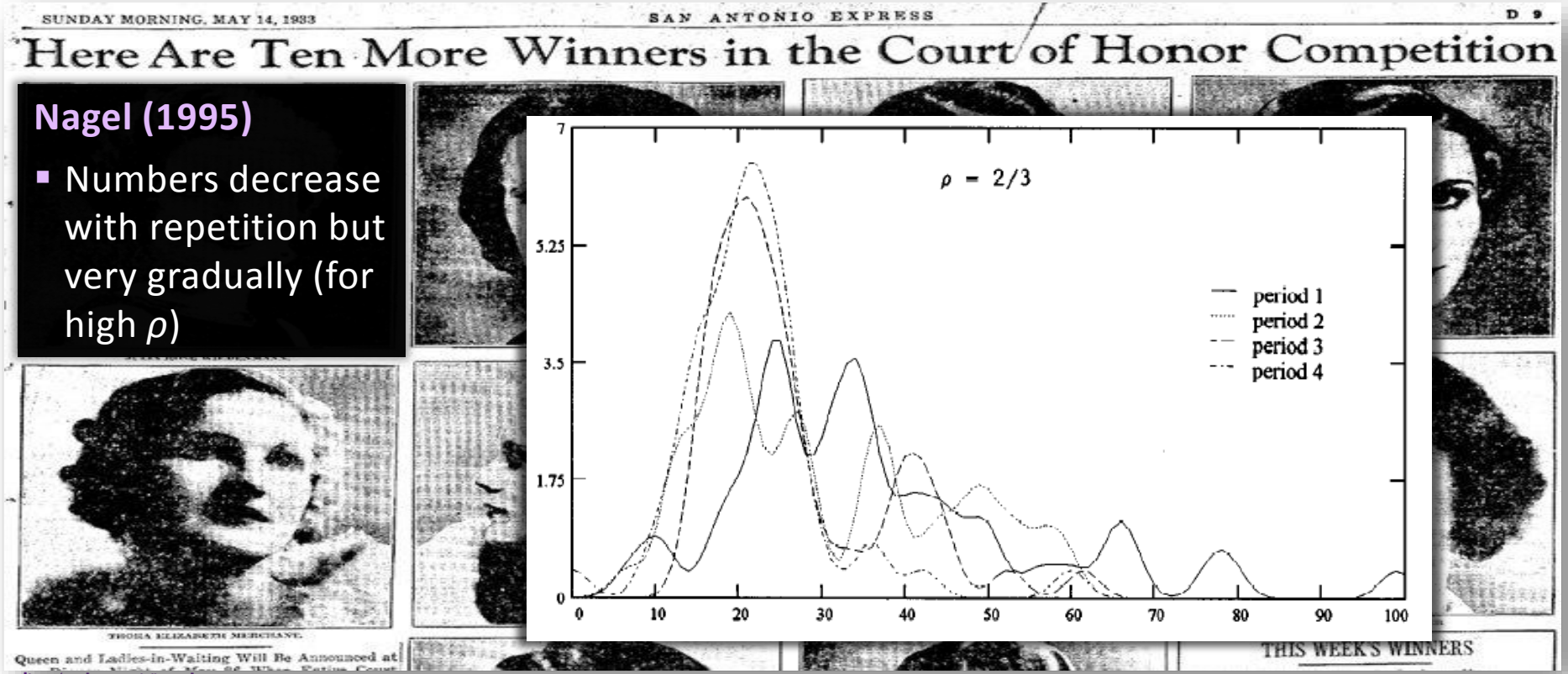
THE BEAUTY CONTEST



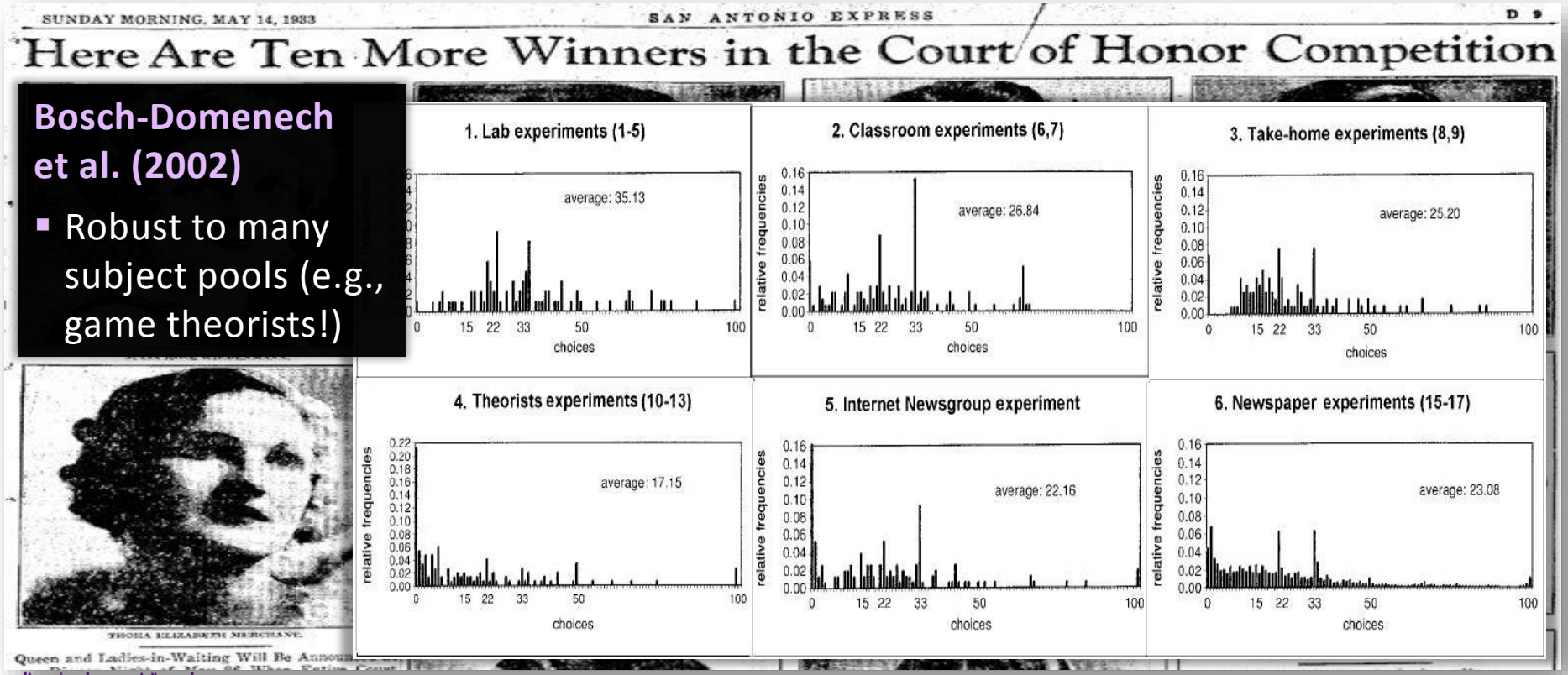
Nagel (1995)

- Vast majority of numbers above 0 but few dominated strategies

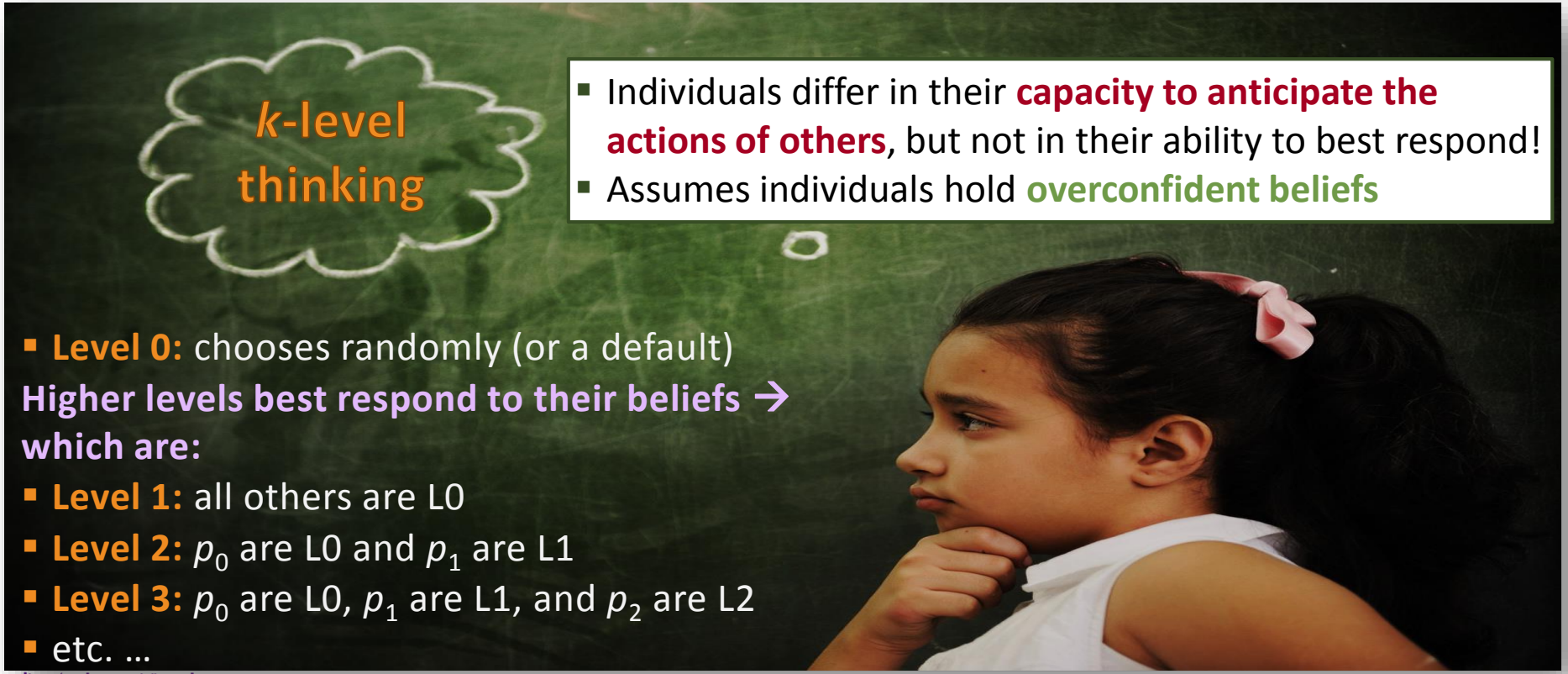
THE BEAUTY CONTEST



THE BEAUTY CONTEST



COGNITIVE HIERARCHIES



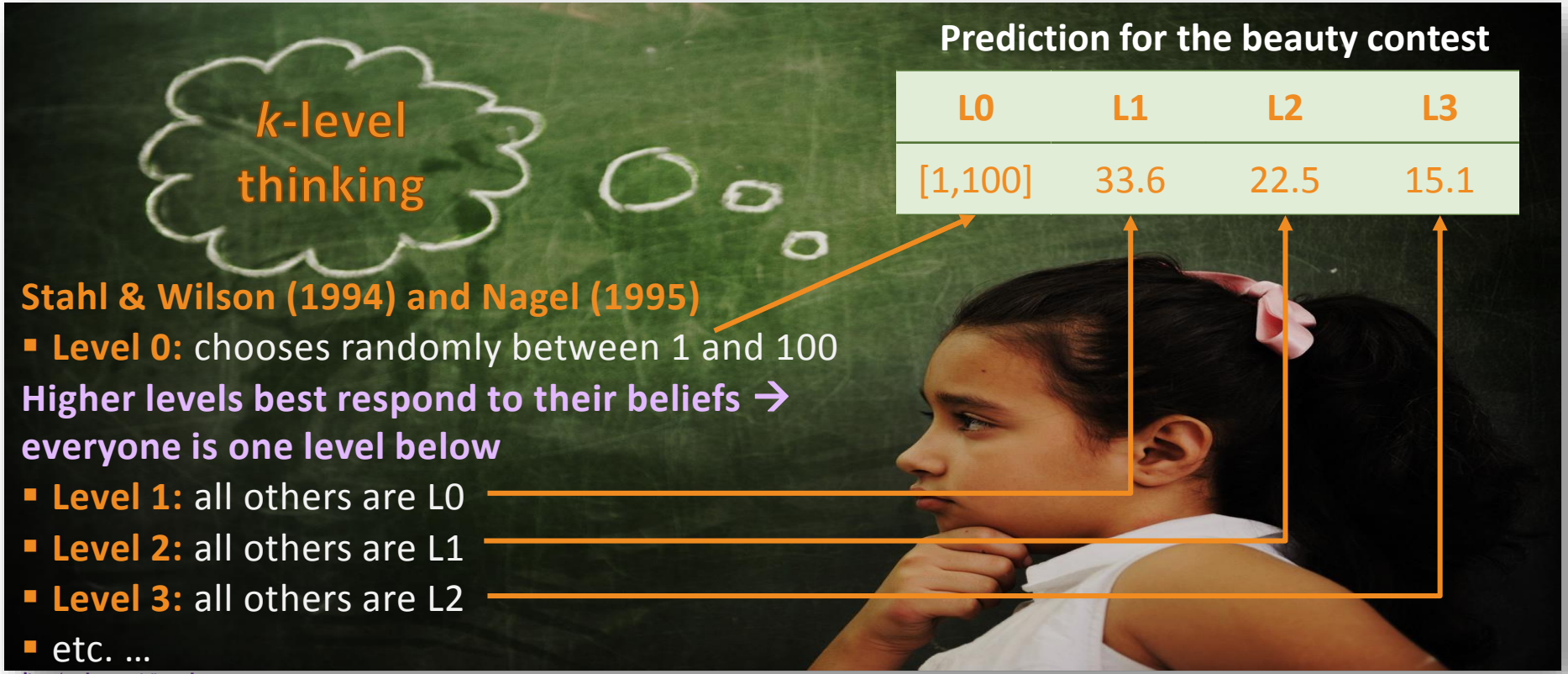
- Individuals differ in their **capacity to anticipate the actions of others**, but not in their ability to best respond!
- Assumes individuals hold **overconfident beliefs**

- **Level 0:** chooses randomly (or a default)

Higher levels best respond to their beliefs → which are:

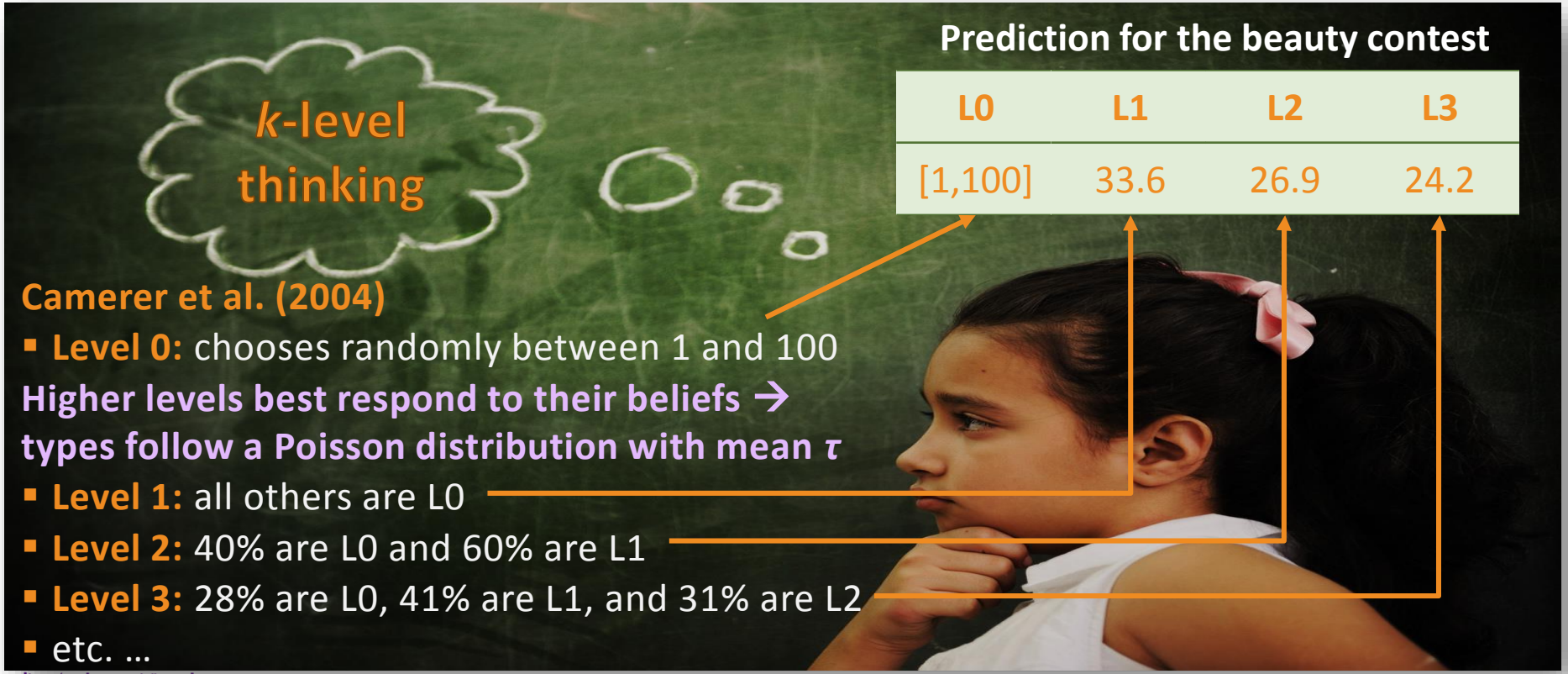
- **Level 1:** all others are L0
- **Level 2:** p_0 are L0 and p_1 are L1
- **Level 3:** p_0 are L0, p_1 are L1, and p_2 are L2
- etc. …

COGNITIVE HIERARCHIES



COGNITIVE HIERARCHIES

COGNITIVE HIERARCHIES



Prediction for the beauty contest

L0	L1	L2	L3
[1,100]	33.6	26.9	24.2

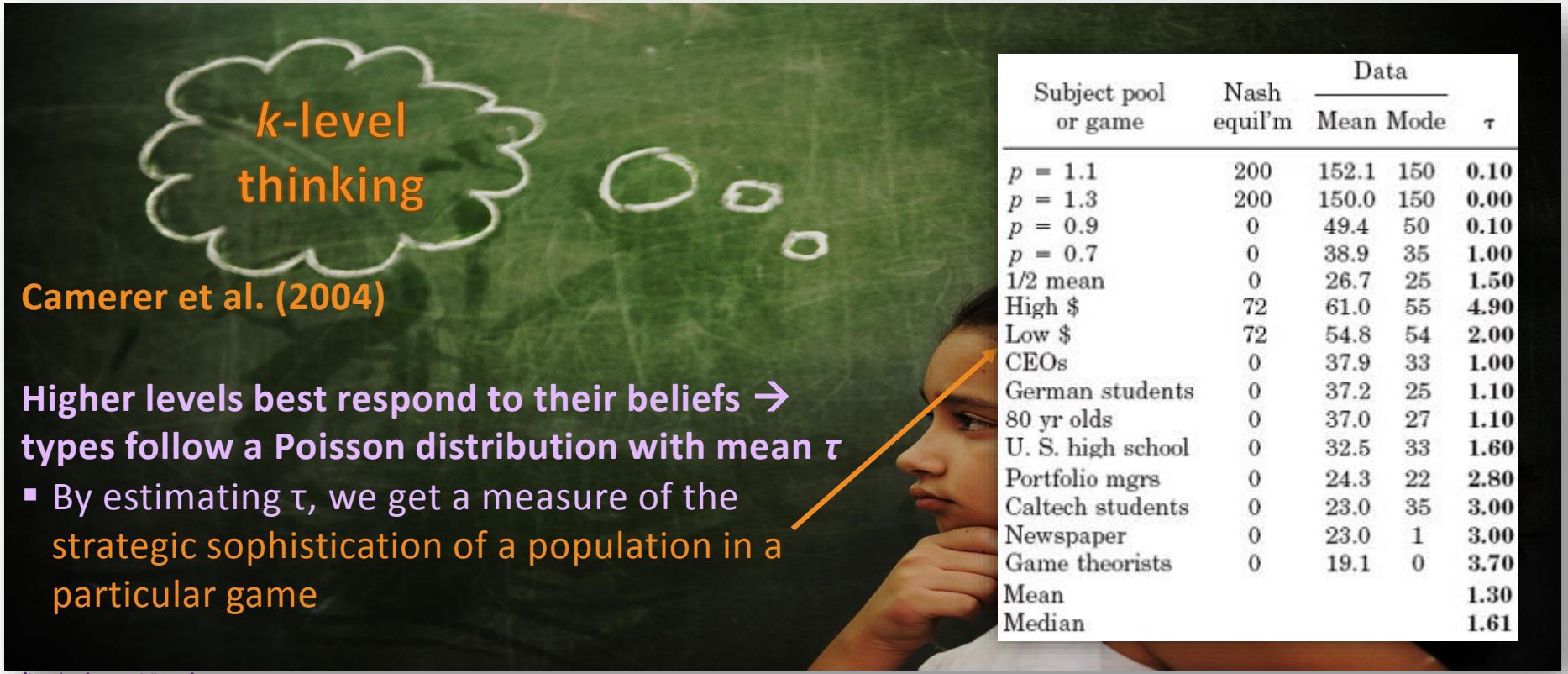
Camerer et al. (2004)

- **Level 0:** chooses randomly between 1 and 100

Higher levels best respond to their beliefs → types follow a Poisson distribution with mean τ

- **Level 1:** all others are L0
- **Level 2:** 40% are L0 and 60% are L1
- **Level 3:** 28% are L0, 41% are L1, and 31% are L2
- etc. …

COGNITIVE HIERARCHIES



Camerer et al. (2004)

Higher levels best respond to their beliefs → types follow a Poisson distribution with mean τ

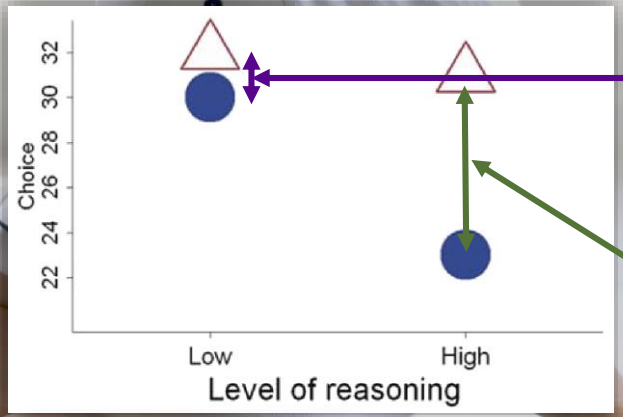
- By estimating τ, we get a measure of the strategic sophistication of a population in a particular game

Subject pool or game	Nash equil'm	Data		τ
		Mean	Mode	
$p = 1.1$	200	152.1	150	**0.10**
$p = 1.3$	200	150.0	150	**0.00**
$p = 0.9$	0	49.4	50	**0.10**
$p = 0.7$	0	38.9	35	**1.00**
1/2 mean	0	26.7	25	**1.50**
High $	72	61.0	55	**4.90**
Low $	72	54.8	54	**2.00**
CEOs	0	37.9	33	**1.00**
German students	0	37.2	25	**1.10**
80 yr olds	0	37.0	27	**1.10**
U. S. high school	0	32.5	33	**1.60**
Portfolio mgrs	0	24.3	22	**2.80**
Caltech students	0	23.0	35	**3.00**
Newspaper	0	23.0	1	**3.00**
Game theorists	0	19.1	0	**3.70**
Mean				**1.30**
Median				**1.61**

COGNITIVE HIERARCHIES

What are the different levels really capturing? (Coricelli & Nagel 2009)

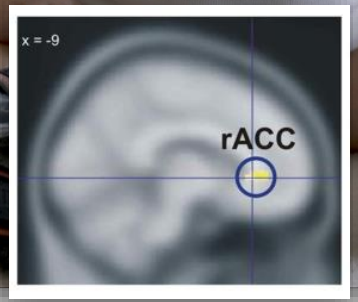
- fMRI experiment with 20 subjects
- 12 values of ρ between 0.125 and 1.125
- Play repeatedly vs. **computers** who pick at random and vs. **humans**



Compare play vs. **humans** and ● vs. **computers** △

- **Low level** thinkers
  - Rostral anterior cingulate cortex → self-referential
- **Higher level** thinkers
  - medial and ventral prefrontal cortex → **theory of mind**

Capacity to put yourself in some else's shoes



HIGHER-ORDER RATIONALITY

Kneeland (2015)

- Do you think that others think that other's are rational?

Game 1

Your earnings

Your actions \ Player 2's actions	D	E	F
A	20	14	8
B	16	2	18
C	0	16	16

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	12	16	14
E	8	12	10
F	6	10	8

Player 3's earnings

Player 3's actions \ Player 4's actions	J	K	L
G	8	20	12
H	0	8	16
I	18	12	6

Player 4's earnings

Player 4's actions \ Your actions	A	B	C
J	14	18	4
K	20	8	14
L	0	16	18

Game 2

Your earnings

Your actions \ Player 2's actions	D	E	F
A	20	14	8
B	16	2	18
C	0	16	16

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	8	12	10
E	6	10	8
F	12	16	14

Player 3's earnings

Player 3's actions \ Player 4's actions	J	K	L
G	8	20	12
H	0	8	16
I	18	12	6

Player 4's earnings

Player 4's actions \ Your actions	A	B	C
J	14	18	4
K	20	8	14
L	0	16	18

HIGHER-ORDER RATIONALITY

Kneeland (2015)

- **R1:** Ignores Player 2's incentives → same choice in both games
- **R2:** Notices that Player 2 has different dominant strategies in the two games → plays A in Game 1 and B in Game 2

Game 1

Your earnings

Your actions \ Player 2's actions	D	E	F
A	20	14	8
B	16	2	18
C	0	16	16

Game 2

Your earnings

Your actions \ Player 2's actions	D	E	F
A	20	14	8
B	16	2	18
C	0	16	16

HIGHER-ORDER RATIONALITY

Kneeland (2015)

- **R1:** Ignores Player 2's incentives → same choice in both games
- **R2:** Notices that Player 2 has the same incentives in both games → same choice in both games

Game 3

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

Game 4

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

HIGHER-ORDER RATIONALITY

Kneeland (2015)

- **R3:** Notices that Players 2 and 3 have the same incentives in both games → same choice in both games

Game 3

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	14	18	4
E	20	8	14
F	0	16	18

Game 4

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	14	18	4
E	20	8	14
F	0	16	18

HIGHER-ORDER RATIONALITY

Kneeland (2015)

- **R4:** Notices that Player 4 has different dominant strategies in the two games → anticipates the reaction of Players 2 and 3 and plays A in Game 3 and C in Game 4

Game 3

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	14	18	4
E	20	8	14
F	0	16	18

Player 3's earnings

Player 3's actions \ Player 4's actions	J	K	L
G	20	14	8
H	16	2	18
I	0	16	16

Game 4

Your earnings

Your actions \ Player 2's actions	D	E	F
A	8	20	12
B	0	8	16
C	18	12	6

Player 2' earnings

Player 2's actions \ Player 3's actions	G	H	I
D	14	18	4
E	20	8	14
F	0	16	18

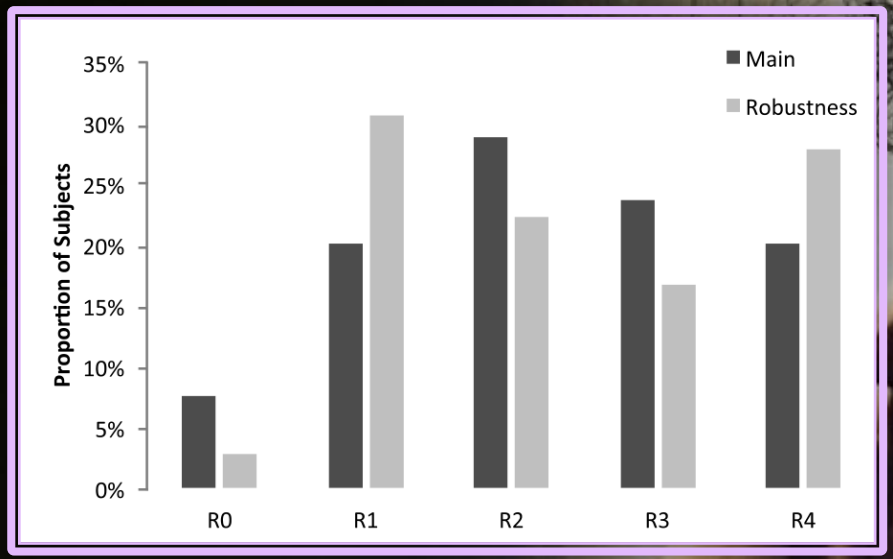
Player 3's earnings

Player 3's actions \ Player 4's actions	J	K	L
G	20	14	8
H	16	2	18
I	0	16	16

HIGHER-ORDER RATIONALITY

Kneeland (2015)

- **Results:** Fairly even distribution between R1, R2, R3, and R4



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