Models of human decision-making

Nick Chater

Ivo Vlaev

Maurice Grinberg

Neil Stewart

Gordon D. A. Brown

Ben Seymour

Ray Dolan

OVERVIEW

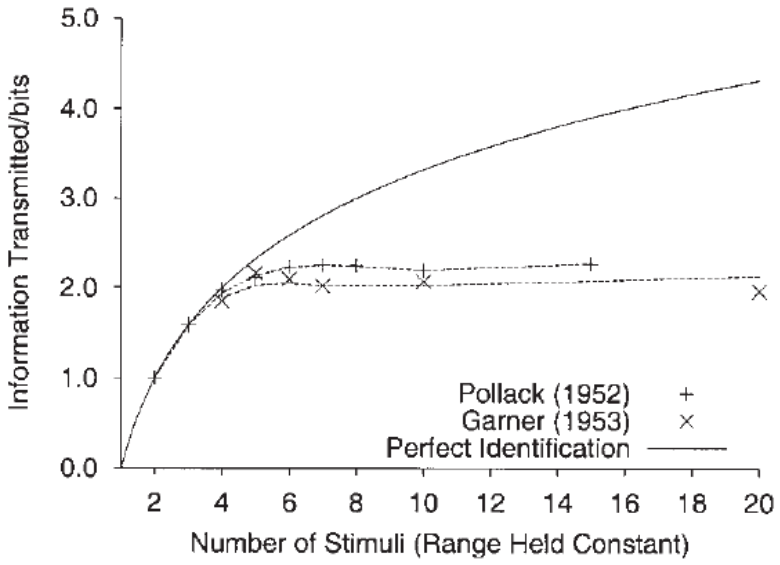
1. MAGNITUDE PERCEPTION WITHOUT INTERNAL SCALES?
2. DECISION WITHOUT INTERNAL SCALES?
3. VALUATION WITHOUT INTERNAL SCALES?
4. REINFORCEMENT LEARNING MEETS PRISONER'S DILEMMA

1. MAGNITUDE PERCEPTION WITHOUT INTERNAL SCALES?

Stewart, N., Brown, G. D. A., & Chater, N. (2005). Absolute identification by relative judgment. *Psychological Review*, *112*, 881-911.

ABSOLUTE MAGNITUDE IDENTIFICATION: THE PUZZLE

- E.g., assign tones to numbers (1-5; 1-7 etc) by loudness
- Its hard!
- As if about five bins…



SIMILAR RESULTS ACROSS TYPES OF MAGNITUDE

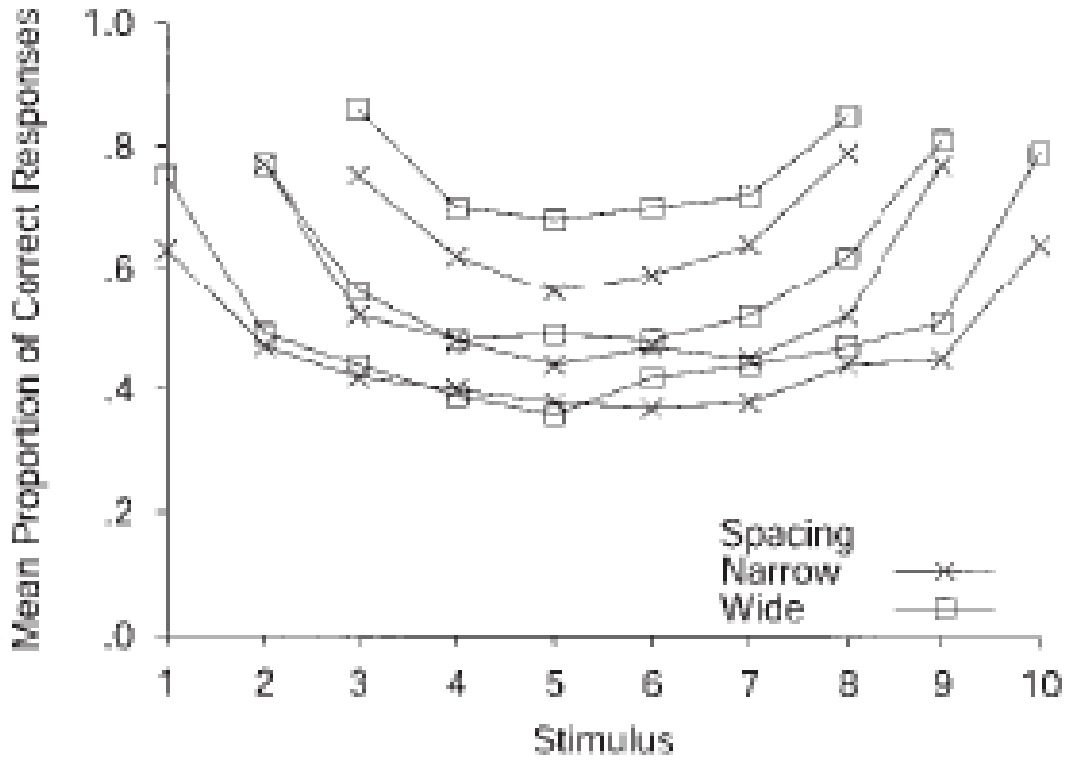
The Limit in Information Transmitted for a Variety of Stimulus Attributes

Attribute	Source	Limit/bits
Frequency of a tone	Hartman (1954)	2.3
	Pollack (1952)	2.3
	W. Siegel (1972)	1.6
Intensity of a tone	Garner (1953)	2.2
	Norwich, Wong, and Sagi (1998)	2.2
	Braida and Durlach (1972; from calculations by Marley and Cook, 1984)	1.9
Saltiness of a solution	Beebe-Center, Rogers, and O'Connell (1955)	1.7
Sweetness of a solution	Beebe-Center, Rogers, and O'Connell (1955)	1.7
Intensity of odor	Engen and Pfaffmann (1959)	1.5
Bisection of a scale	Hake and Garner (1951)	3.2
	Coonan and Klemmer (as reported in Miller, 1956)	3.2/3.9
Line length	Baird, Romer, and Stein (1970)	2.4
	Pollack (as cited in Miller, 1956)	2.6/3.0
Angle of inclination	Muller, Sidorsky, Slivinske, Alluisi, and Fitts (1955; as cited in Garner, 1962, and Laming, 1984)	4.5
	Pollack (as cited in Miller, 1956)	2.8/3.3
Area	Pollack (as cited in Miller, 1956)	2.6/2.7
Area of a circle	Alluisi and Sidorsky (1958)	2.7
Area of a square	Eriksen and Hake (1955a)	2.0
	Eriksen and Hake (1955b)	2.8
Area of complex figure	Baird, Romer, and Stein (1970)	2.1
Hue	Chapanis and Halsey (1956)	3.1
	Eriksen and Hake (1955b)	3.3
	Conover (1959; as cited in Garner, 1962)	3.5
Brightness	Eriksen and Hake (1955b)	2.3
Cutaneous electrical intensity	Hawkes and Warm (1960)	1.7

Note. Limits separated by a slash denote limits for short and long duration stimulus exposure.

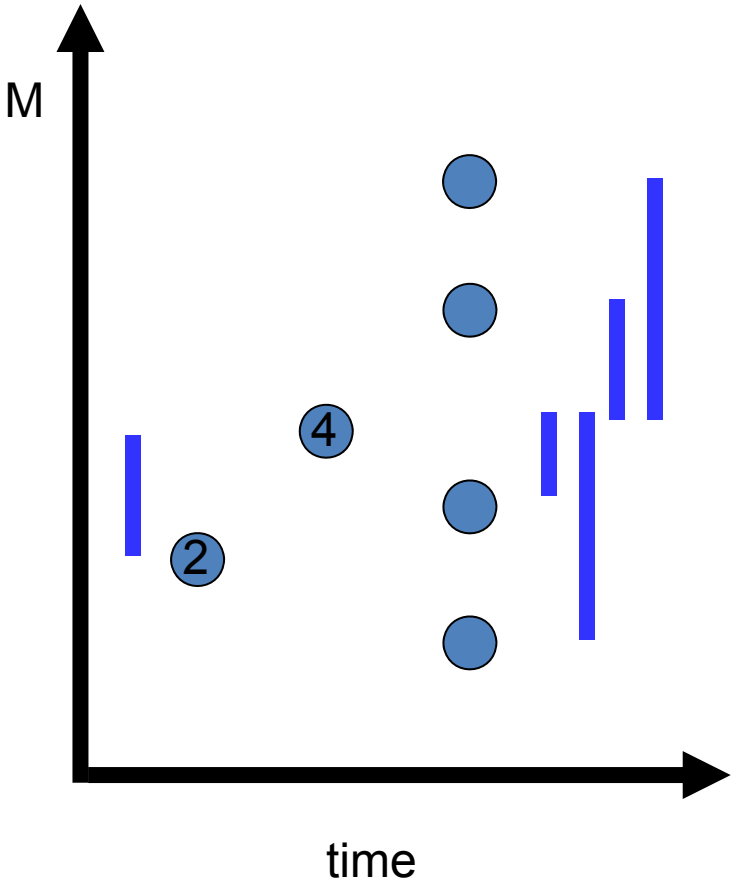
AND SPACING HARDLY MATTERS

A



A RELATIVE JUDGMENT MODEL

- Relative judgment model (Stewart et al, 2005, cf. Laming)
- Consider relative sizes of "jumps" between stimuli
- Mostly, current and last jump (but not entirely)



An even simpler model (may) work purely by binary comparisons of current stimulus vs. prior stimuli, gaps, etc.

2. DECISION WITHOUT INTERNAL SCALES?

Stewart, N., Chater, N., & Brown, G. D. A. (2006). Decision by sampling. *Cognitive Psychology*. *53*, 1-26.

WHAT THE COGNITIVE SYSTEM DOESN'T HAVE

No underlying "psychoeconomic" scales for

- utility
- subjective probability
- time

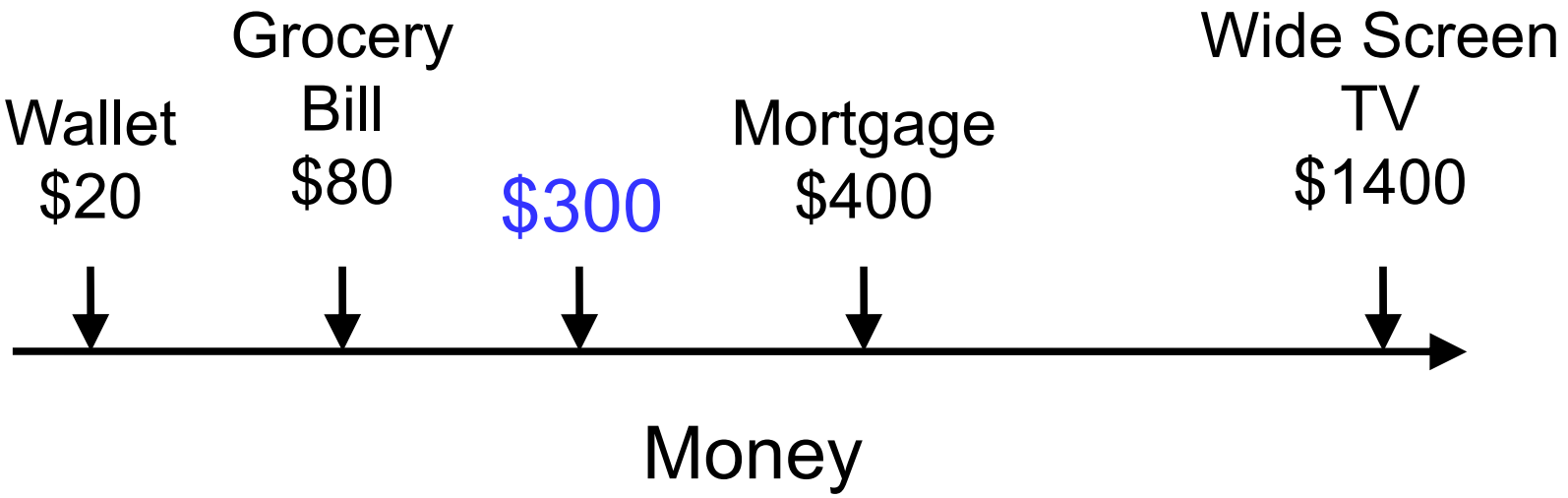
∴ there are no relationships (e.g., trade-offs) between scales

WHAT THE COGNITIVE SYSTEM DOES HAVE

- Only binary judgments
  - >, <, =
- Values are compared with a small sample of "anchors"
  - from memory
  - from context
- All dimensions (gains, losses, delay, probability, quality, etc) are equal, despite different roles in "rational" model
- Preferences are *constructed*, depending on sampled anchor values (e.g., Slovic, 1995)

ONLY RANK MATTERS

What is the utility of $300? Here its 3rd of 5 items



∴ KEY ISSUE: HOW DO PEOPLE SAMPLE COMPARISON ANCHORS?

From *memory*

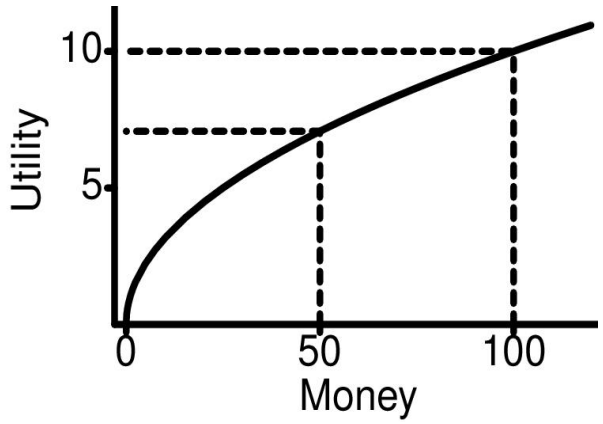
- Assume that samples from memory mirror distribution in the "world" (Anderson)
- Estimate using external "proxies" (e.g., via google™)

From *task context*

- e.g., choice can be affected by "irrelevant" options
- Manipulate experimentally
  - Stewart, Chater, Stott & Reimers, 2003, *JEP*: *General*, *132*, 23-46.

DIMINISHING "UTILITY" OF MONEY

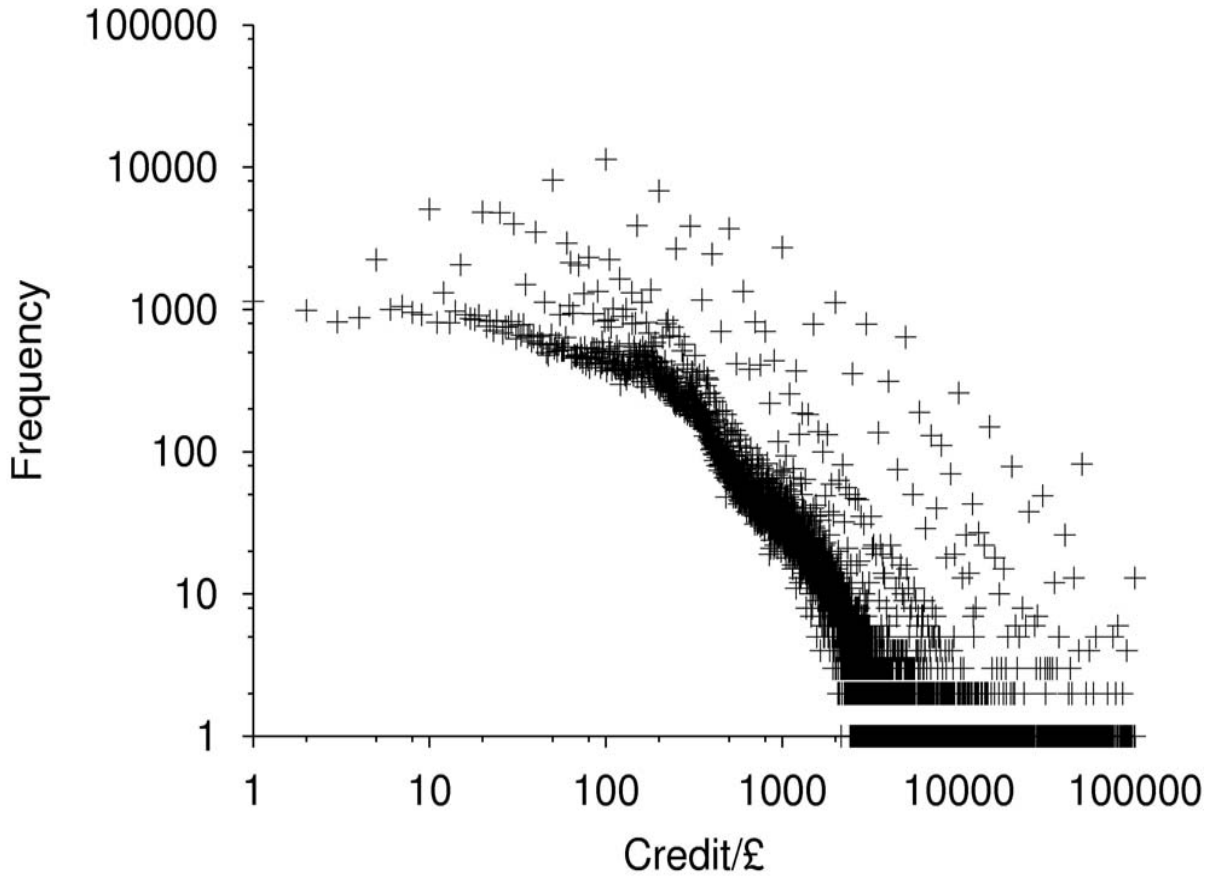
- Utility theory



- Implies risk aversion:
- *£50 for certain* preferred to *50% chance of £100*?

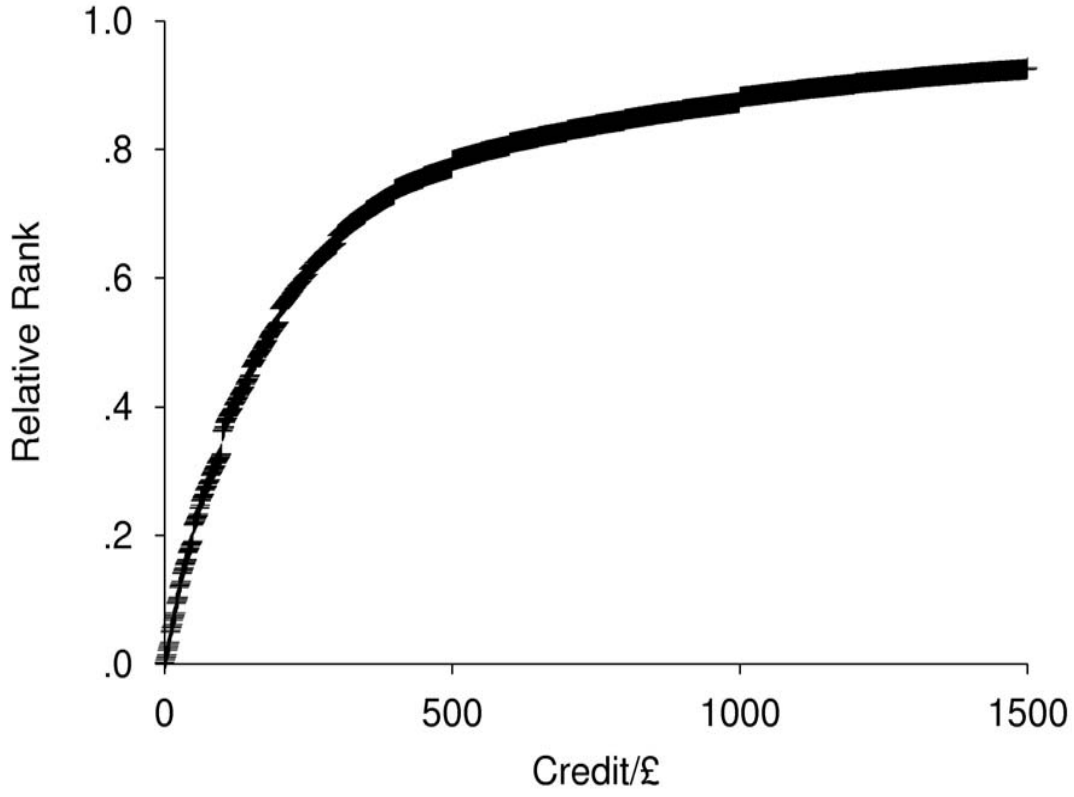
- DbS considers distribution of amounts of money
  - Only rank matters
  - So changes in money value will be valued by change in rank position in samples of amounts

ESTIMATED GAINS/LOSSES FROM A UK HIGH STREET BANK*



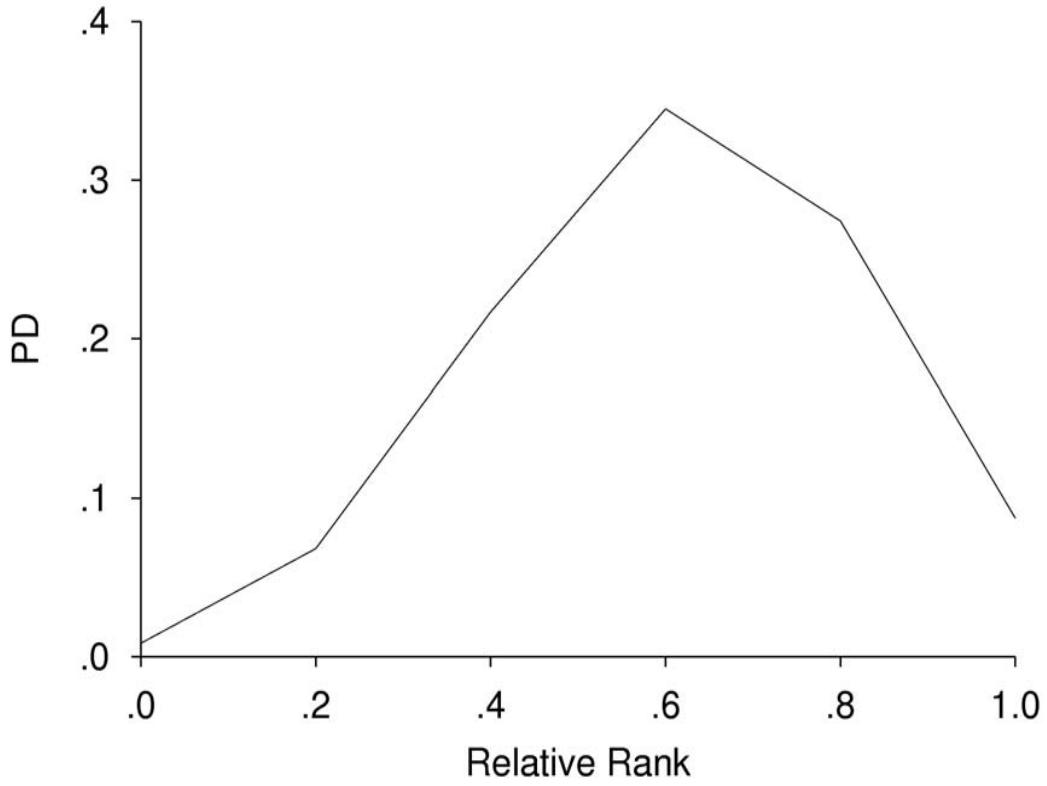
*Bank data analysed by Rich Lewis

RANK VS. MONEY GAIN
(COMPLETE SAMPLE)



Analogy of diminishing marginal utility of money in economics

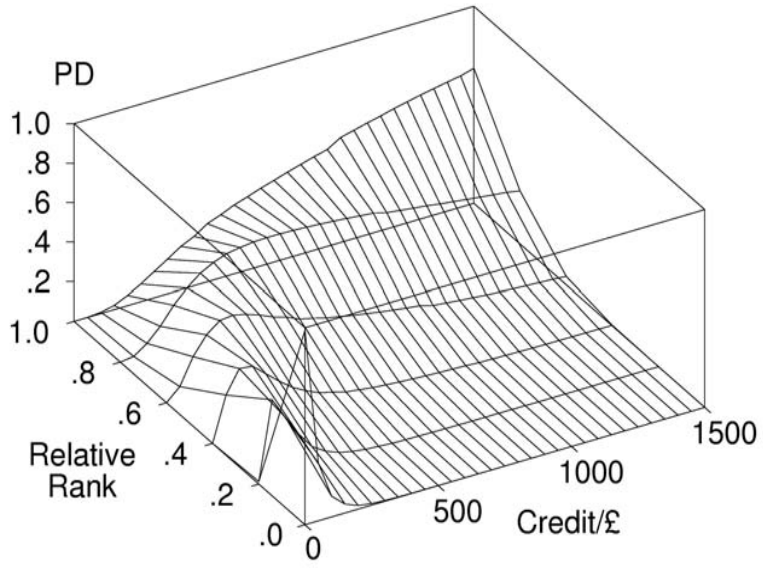
+$300 IS COMPARED WITH 5 RANDOM CREDITS

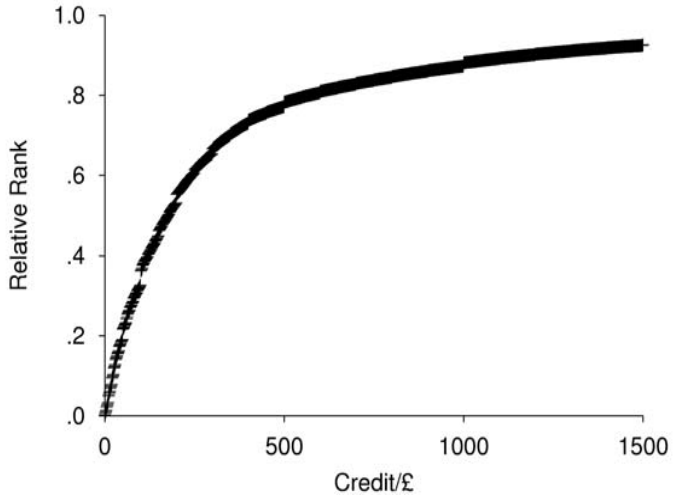


Probability distribution of relative ranks

relative rank of 0 = worst; relative rank of 1 = best.

COMBINE DISTRIBUTIONS FROM DIFFERENT CREDITS

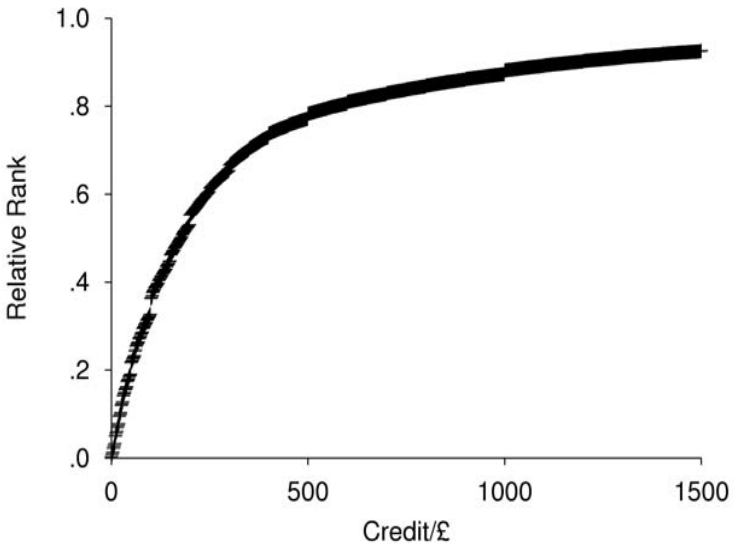




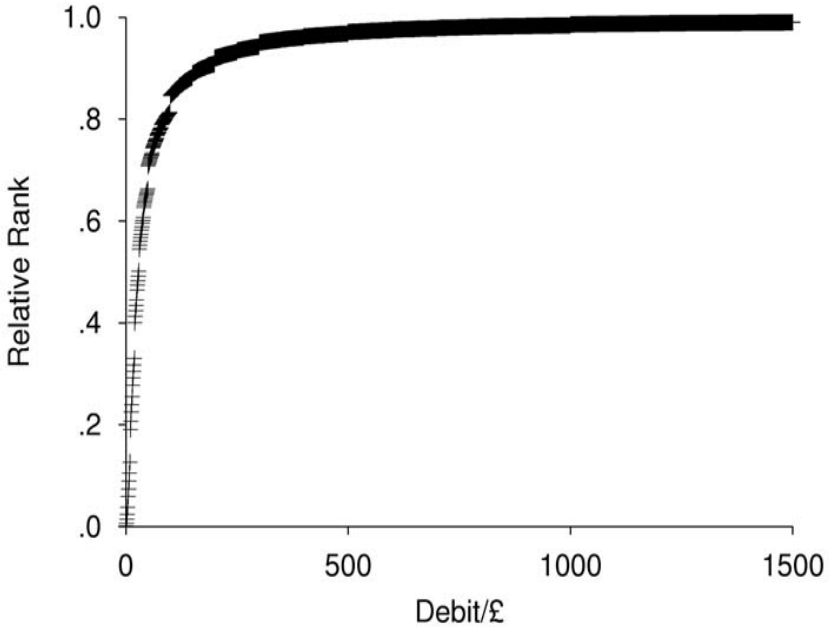
The ‘bend’ in relative rank, for small samples (left) is analogous to the curvature in the full credit-rank sample (right)

LOSSES LOOM LARGER THAN GAINS
(credits and debits, bank data)

Gains

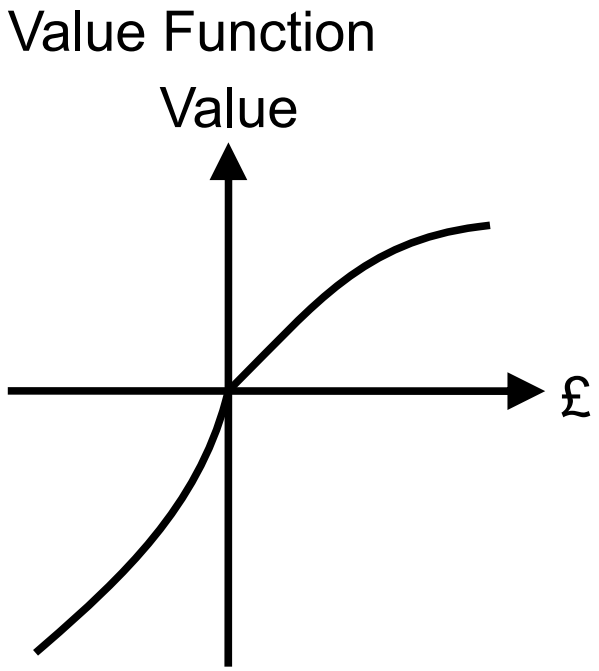


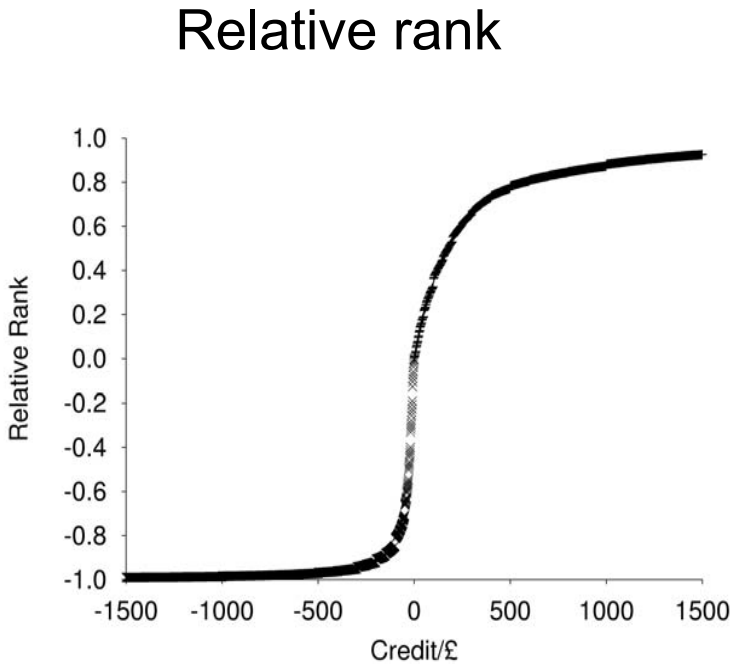
Losses



More small losses than small gains:
∴ £10 loss looms larger (in ranks)

PROSPECT THEORY'S VALUE FUNCTION, RECONSTRUCTED (cf. Kahneman & Tversky, 1979)

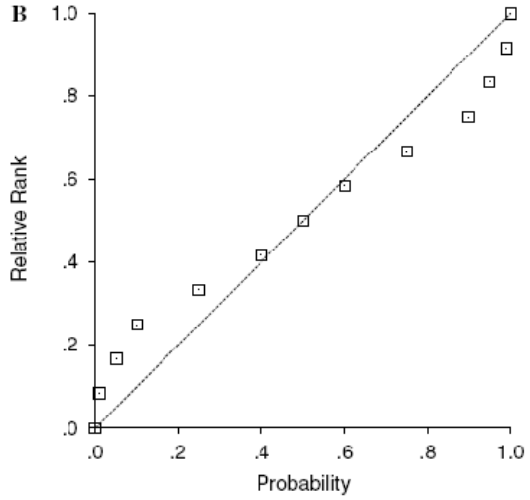


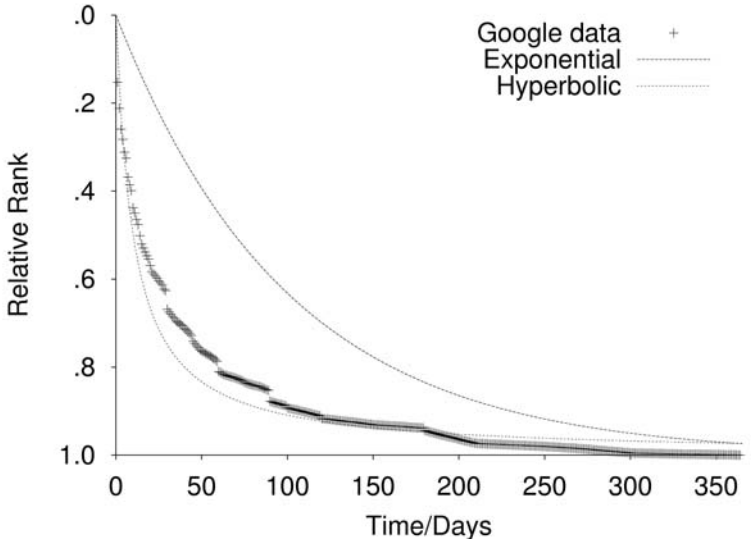


- -ively accelerating for gains
- +ively accelerating for losses

- losses worse than gains
- Discontinuity at zero

SIMILARLY, FOR RISK AND TIME…





- Judged probability (Gonzalez & Wu, 1999)
- Time discounting (google)

3. VALUATION WITHOUT INTERNAL SCALES?

Vlaev, I., Seymour, B., Dolan, R. & Chater, N. (under review). The Price of Pain and the Value of Suffering.

ECONOMICS TYPICALLY ASSUMES ENDOGENOUS PREFERENCES AND STABLE TRADE-OFFS BETWEEN GOODS AND MONEY

- E.g, can willingness-to-pay prices provide a measuring scale for experience?
- With traded goods, confound of *known* prices; so use novel, non-traded, stimuli.
  - Ariely, Loewenstein, and Prelec (2003) found that willingness-to-pay prices to avoid annoying sounds were biased towards price anchors, but were locally coherent ("coherent arbitrariness")
  - Current aim: to test preference formation at its root: direct test of (in)stability of valuation…

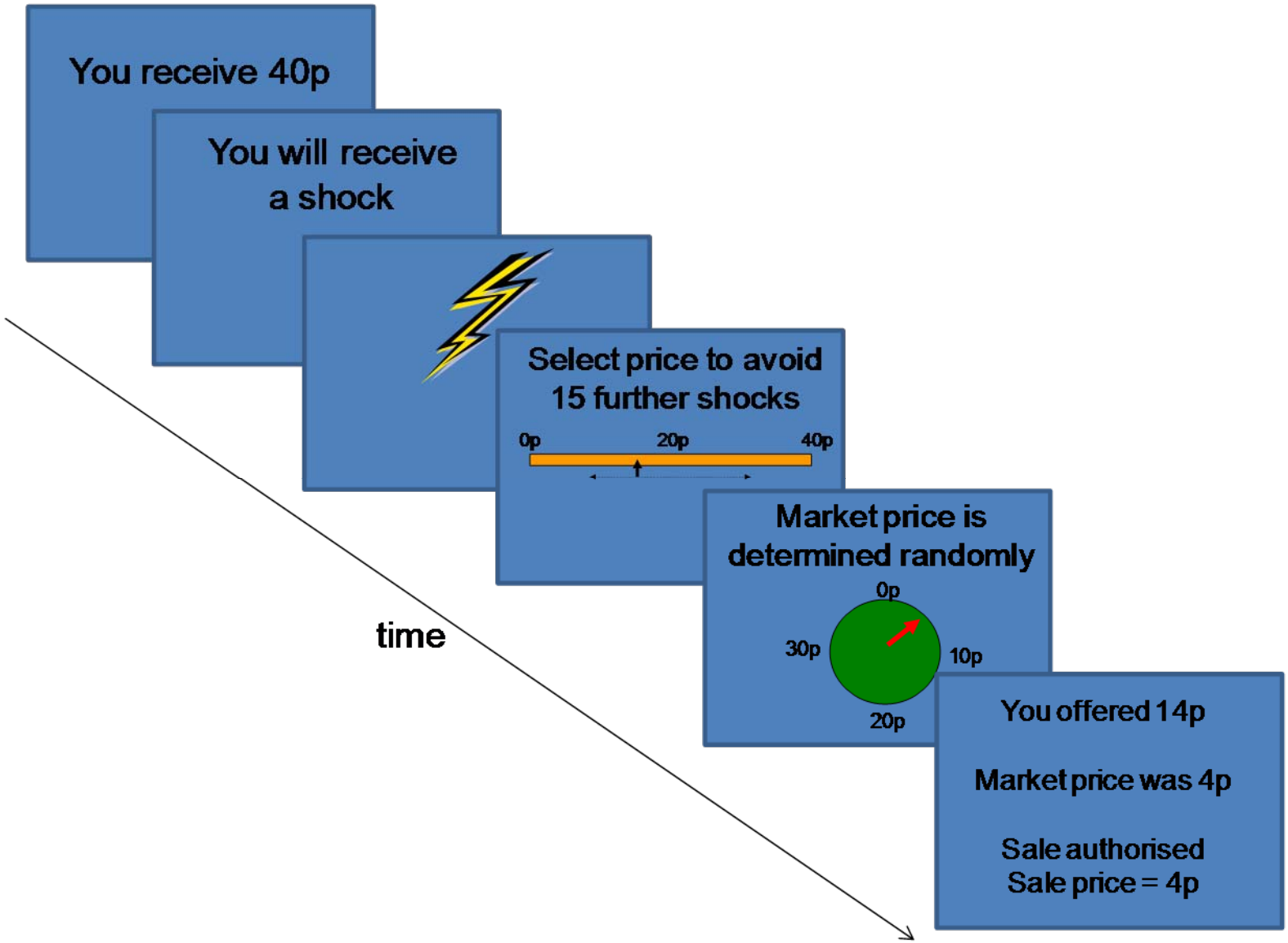
WE DESIGNED AN EXPERIMENTAL "MARKET" WHERE PEOPLE PAY MONEY TO AVOID PAINFUL ELECTRICAL SHOCKS

- Why use shocks?
  - Tangible experience but different from everyday stimuli
  - Can be evaluated and 'consumed' immediately
  - Consistently judged as aversive across people
  - Resistant to habituation through an experiment
  - Underlying neurophysiology is fairly well-understood
  - Affective properties dissociable from sensory properties

- Pain (and pain relief) is an important literature with great practical significance

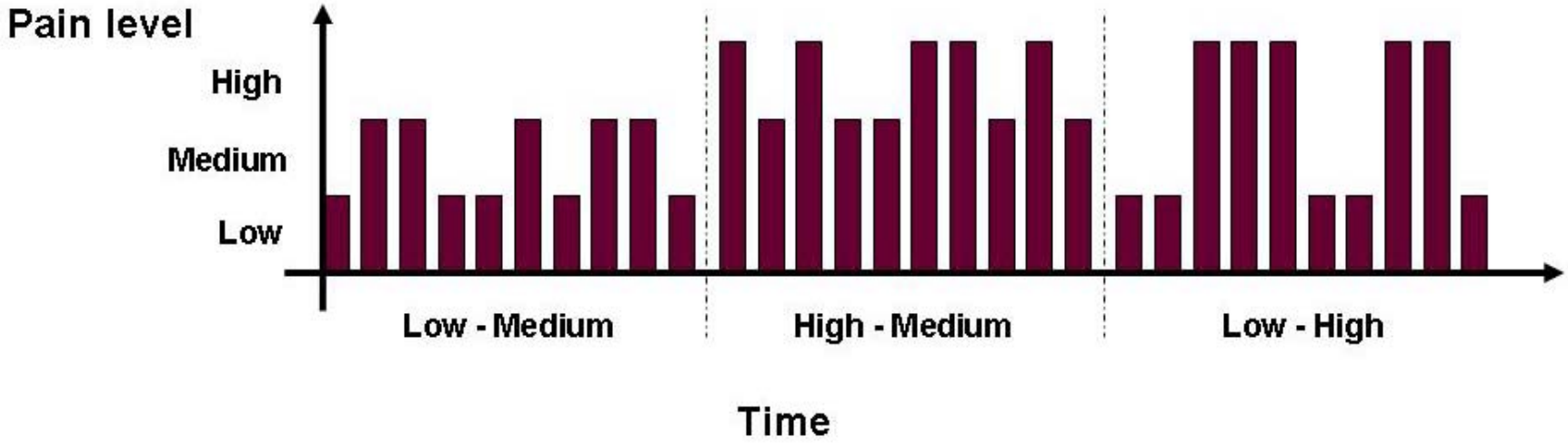
- Observing relativistic effects would imply that the price consumers pay (e.g., for health) may be substantially determined by
  - Current context
  - Recent experiences

EACH TRIAL INVOLVED BUYING RELIEF IN A COMPUTERISED SECOND PRICE AUCTION



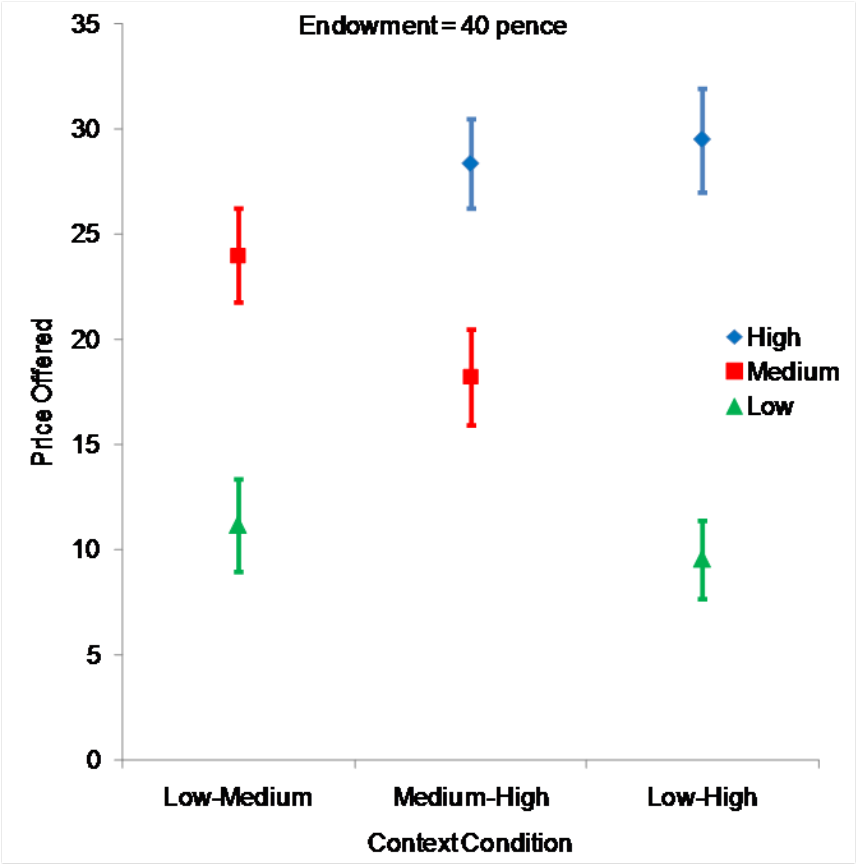
WE USED THREE PAIN LEVELS WITHIN-SUBJECTS AND TWO MONETARY ENDOWMENTS BETWEEN-SUBJECTS

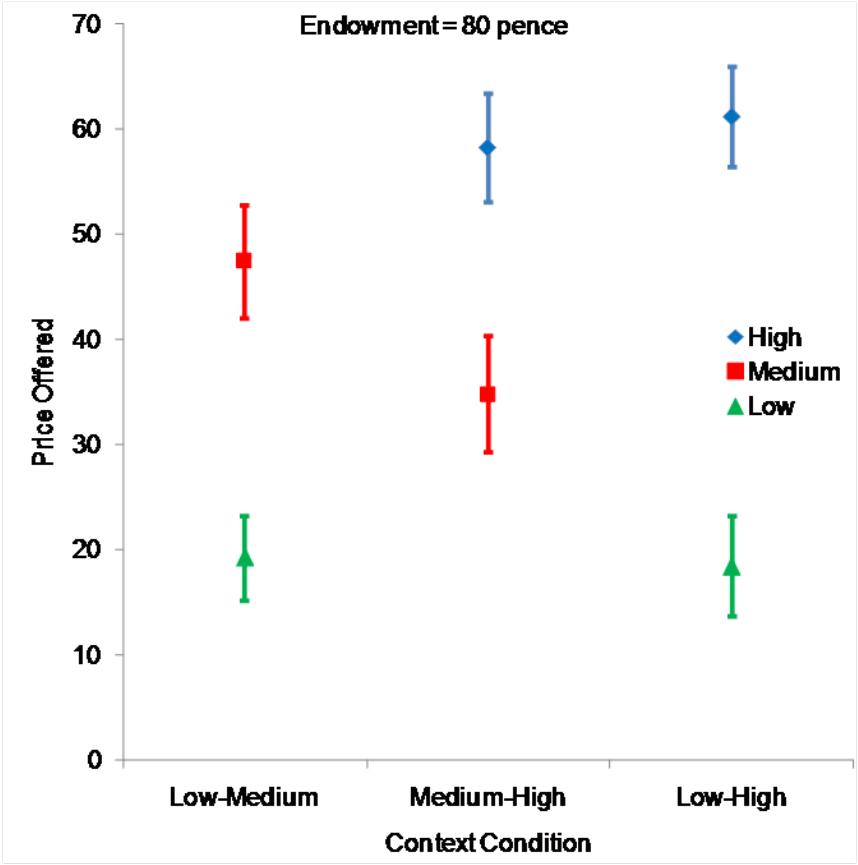
- Pain magnitudes were presented in pairs in three blocks of ten trials



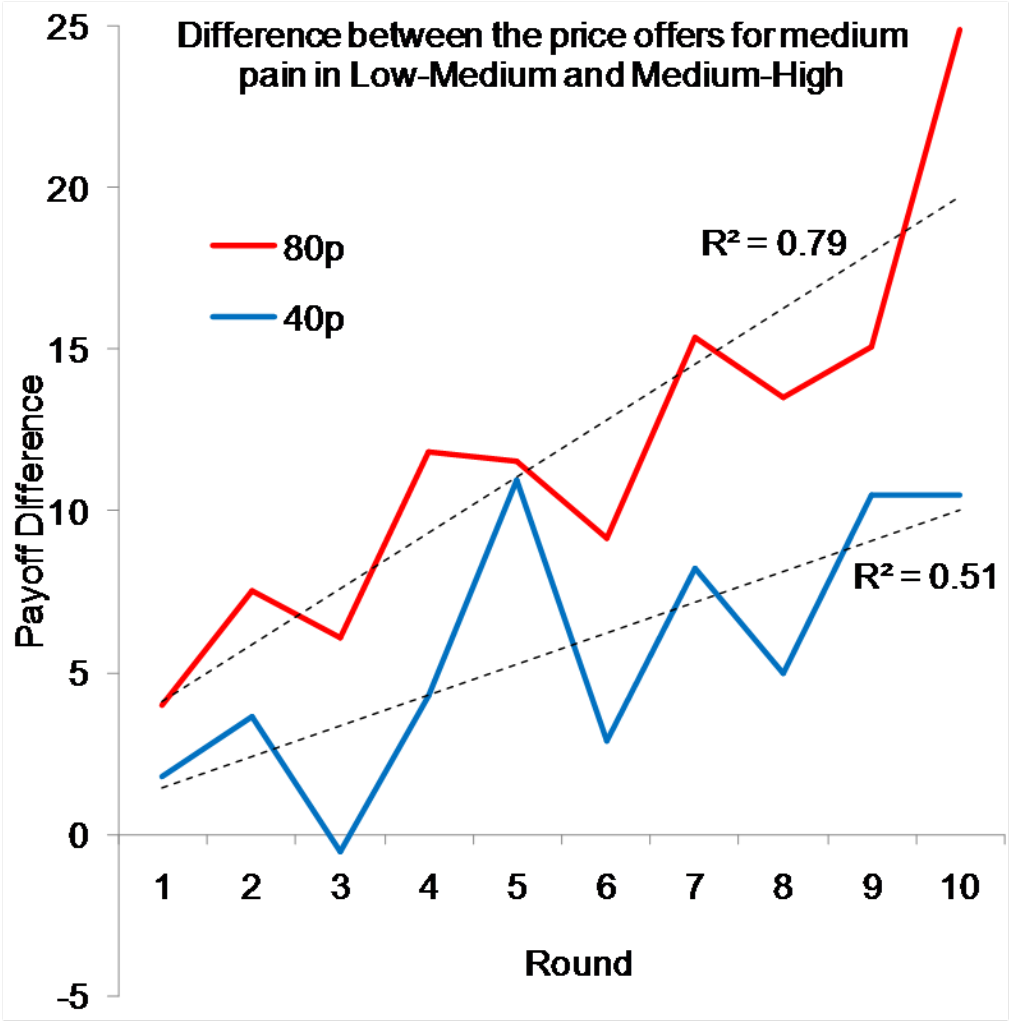
- Two endowment conditions
  - £0.40 per trial
  - £0.80 per trial

AVERAGE PRICE OFFERS DEPENDING ON ENDOWMENT AND CONTEXT PAIRING





DISCREPANCY PROVIDED BY THE CONTEXT INCREASES THROUGH EACH BLOCK

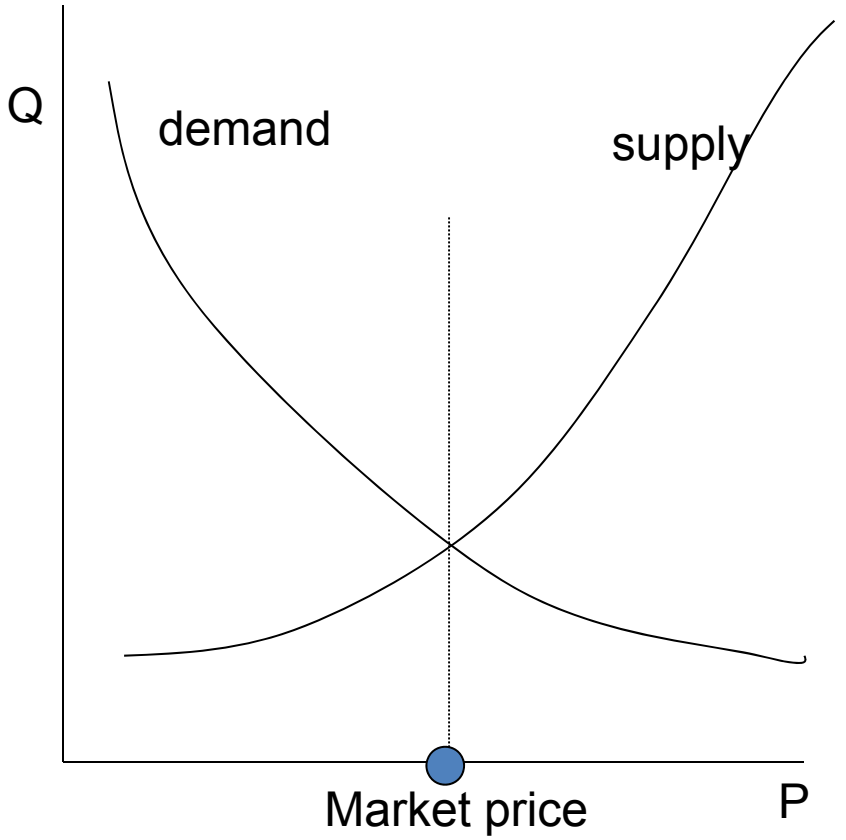


ANALYSIS IN TERMS OF DEMAND CURVES

Demand curve captures quantity of pain relief expected to sell at different prices

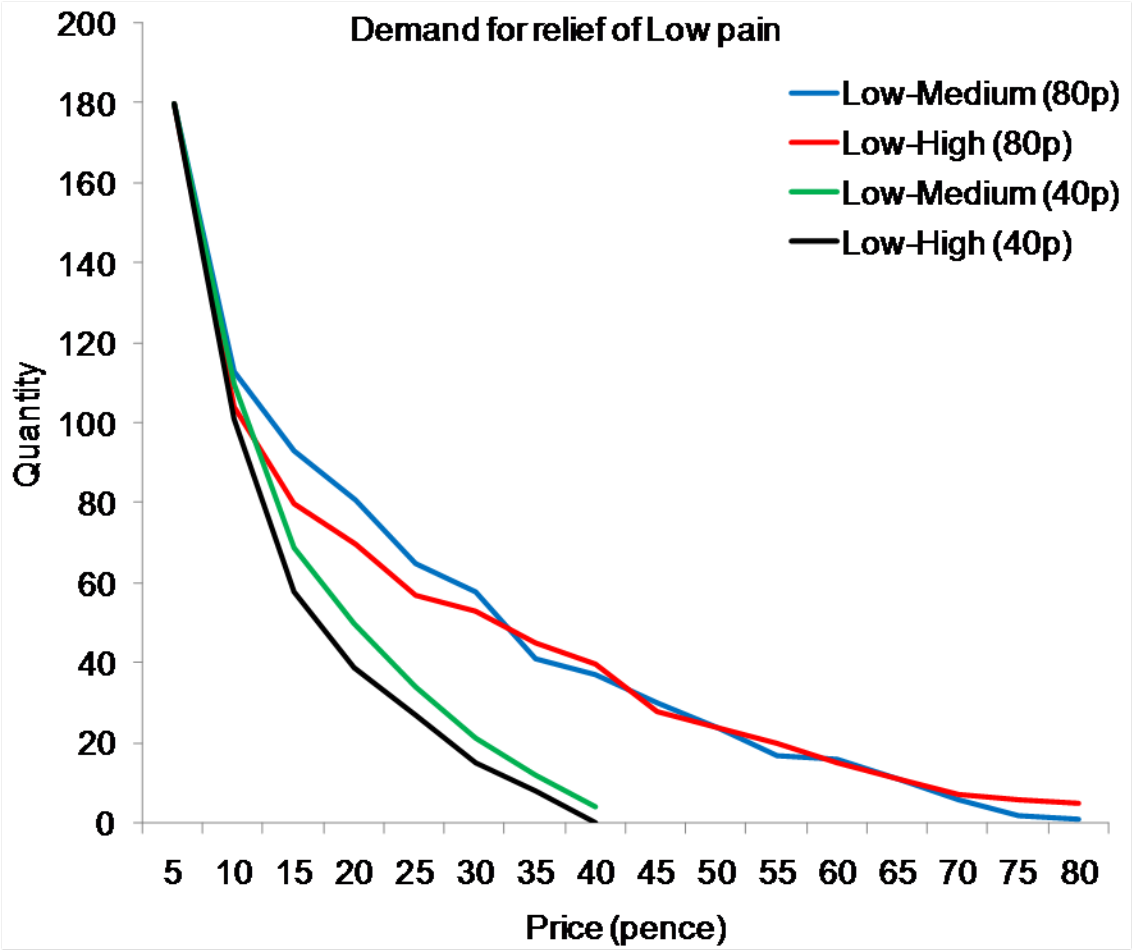
Economic theory assumes that demand curves are fixed by stable consumer preferences (and *prior* to information about price)

Prices then determined by interaction with supply curve

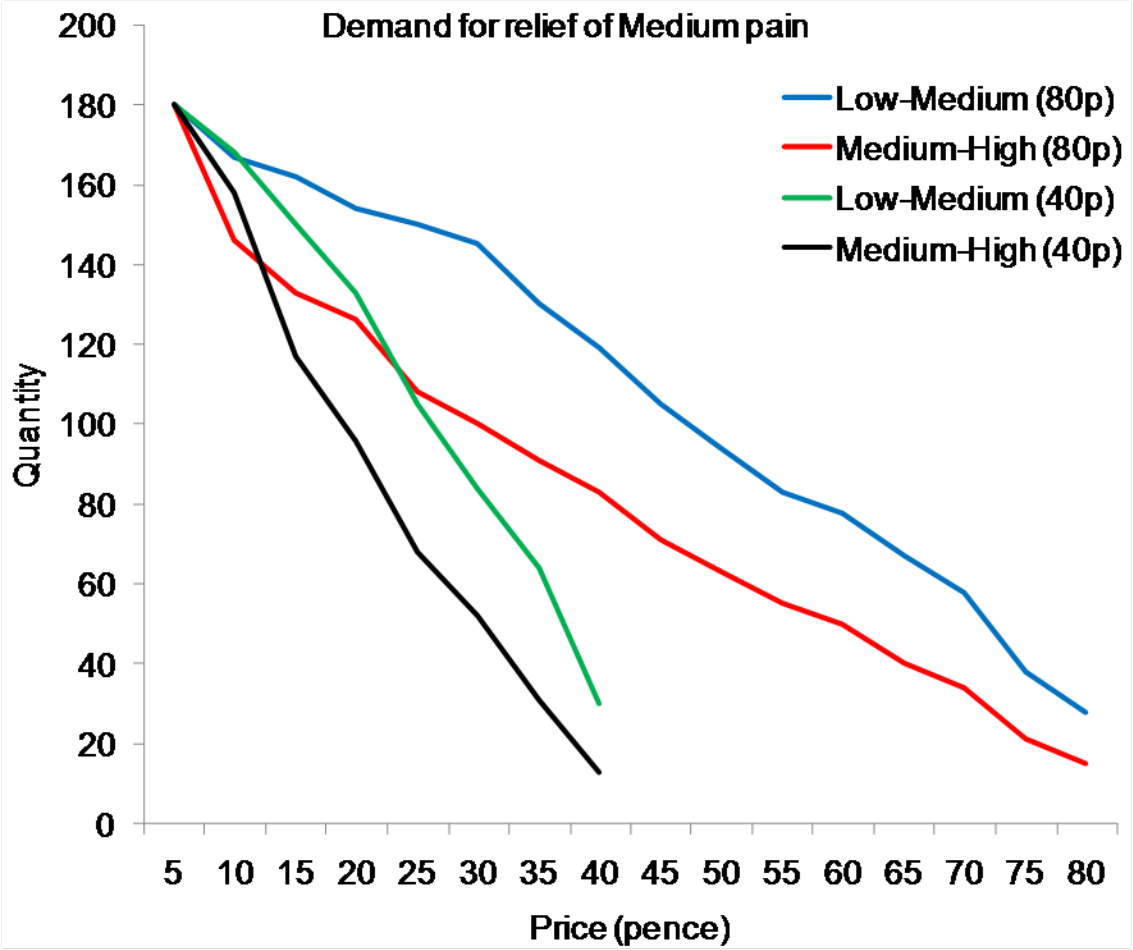


All curves flipped from standard orientation

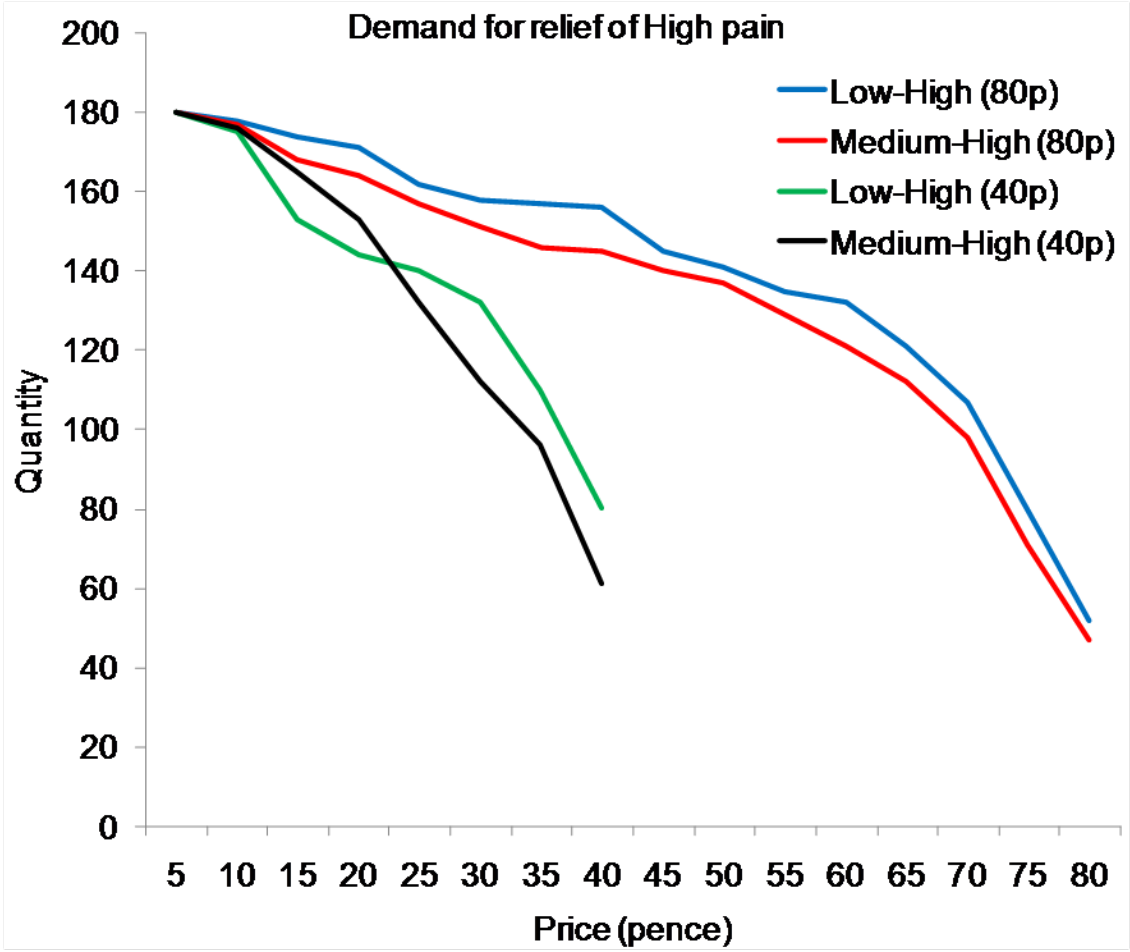
DEMAND CURVE FOR RELIEF FROM LOW PAIN



DEMAND CURVE FOR RELIEF FROM MEDIUM PAIN



DEMAND CURVE FOR RELIEF FROM HIGH PAIN

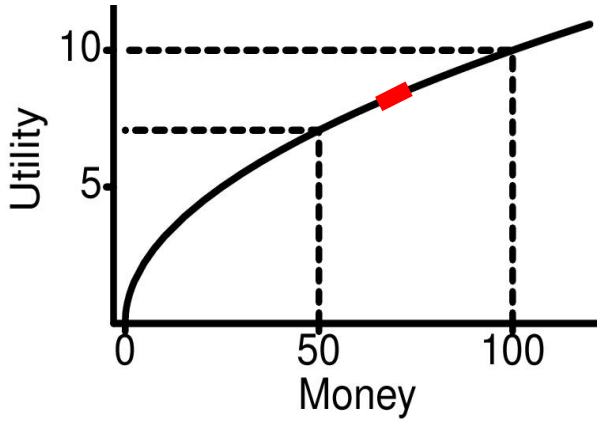


SECOND EXPERIMENT USED A WITHIN-SUBJECT DESIGN WHERE THE TWO ENDOWMENTS VARIED RANDOMLY BETWEEN TRIALS

- … replicated all our original results

- Confirmed that the value of, say £0.30, is not the same, whether chosen from £0.40 or £0.80 endowment
  - Failure of rationality as the value of £0.30 outside the experiment is the same (the foregone good is the same)

  - cf. existence of risk aversion with small stakes gambles (Rabin 2001)



SUMMARY AND CONCLUSIONS 1
THE UNANCHORED DECISION MAKER?

1. People may not have access to absolute perceptual magnitudes; but use a relative/rank-based coding

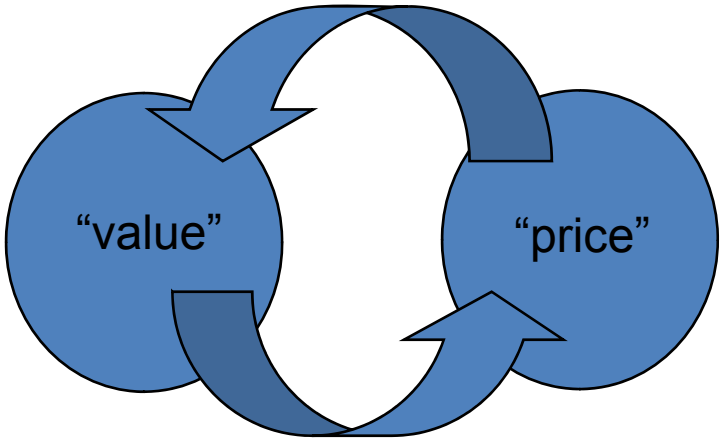
2. Decision making variables (monetary value, probability, time) computed on-line computation by ranks

   Hence, instability of risk-aversion, loss-aversion, etc…

3. Value of “pain” (and other subjective experience) is unstable

SUMMARY AND CONCLUSIONS 2
FEEDBACK LOOPS AND PRICE/VALUE INSTABILITY?

- So prices are likely to be unanchored
  - Booms and crashes?
- People will tend to view the status quo as natural
  - Current house prices soon seem ‘normal’
  - Wage increases rapidly ‘fade out’ as contributors to happiness
    - And even lottery wins
- Tax and other cost changes have *much* less long-term impact on behaviour than is typically expected

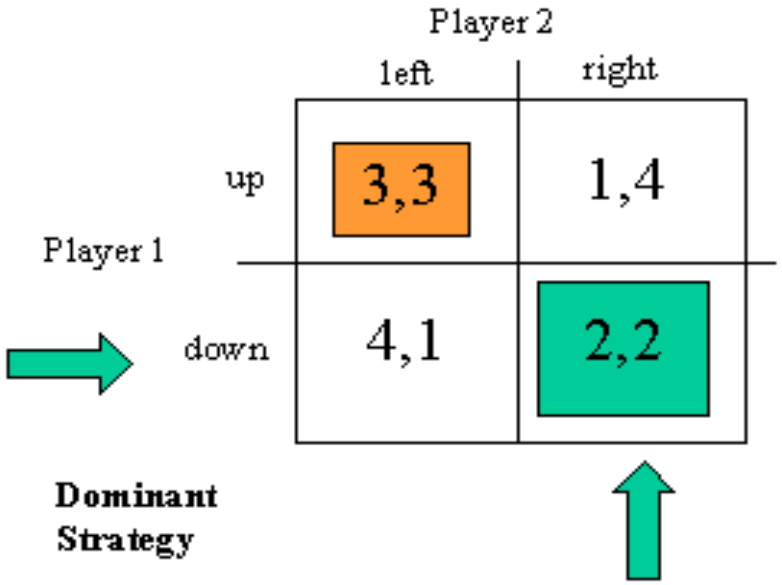


PEOPLE KNOW THE PRICE OF EVERYTHING,
BUT THE VALUE OF NOTHING

4. REINFORCEMENT LEARNING MEETS PRISONER'S DILEMMA

Chater, N., Vlaev, I., & Grinberg, M. (2008). *Journal of Experimental Psychology: General*, *137*, 403-421.

Interactive: Prisoner's dilemma



Original Prisoner's Dilemma

		Prisoner 2	
		Deny	**Confess**
Prisoner 1	**Deny**	**-1, -1**	**-10, 0**
	Confess	**0, -10**	**- 5, -5**

- If playing C, it would receive more reinforcement if it were to play D
- Reinforcement learning gradually eliminates C in favour of D

SIMPSON'S PARADOX MEETS PRISONER'S DILEMMA: AN EXPERIMENT

- How a positive correlation between agents' behaviour can arise?

		Other 1	Other 2
You	1	**-5 -5**	**-11 0**
	2	**0 -11**	**-6 -6**

very non-cooperative

Nasty game

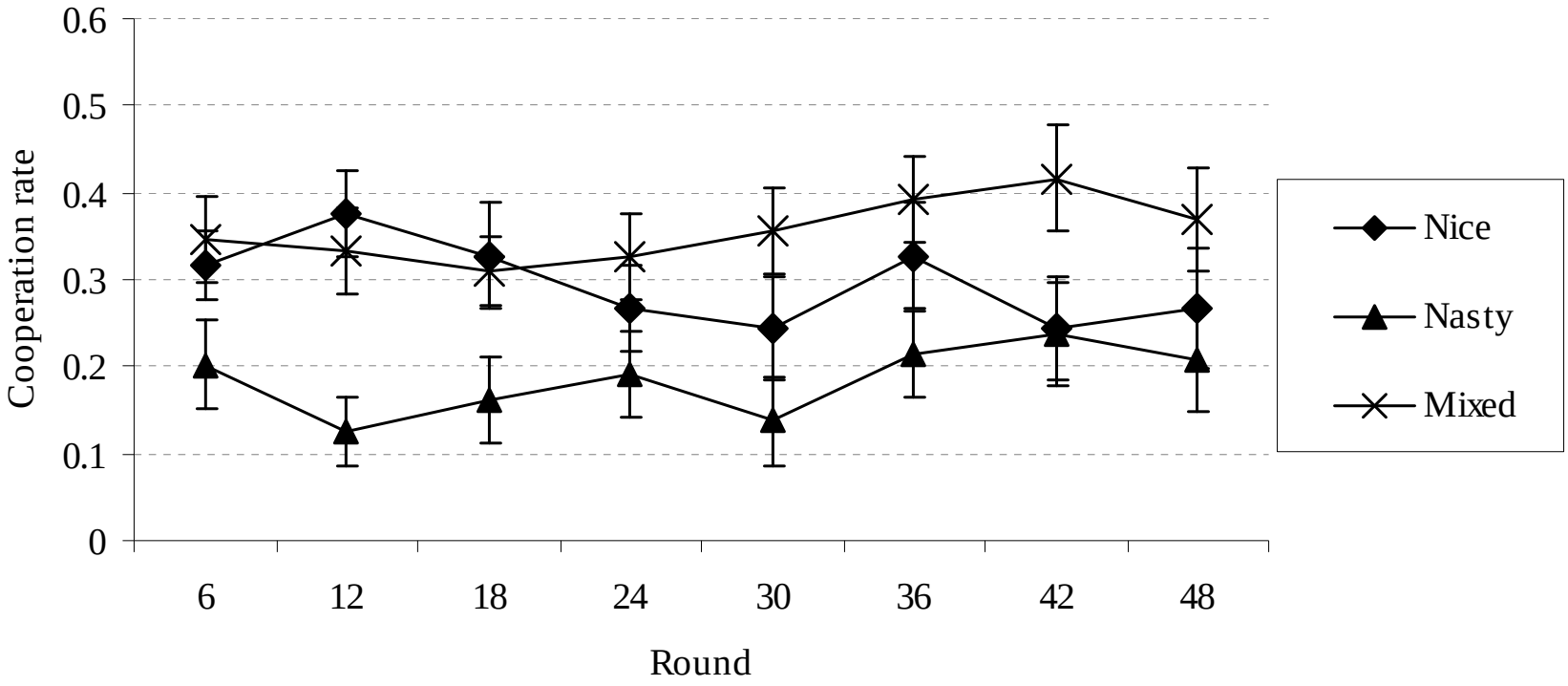
		Other 1	Other 2
You	1	**10 10**	**0 11**
	2	**11 0**	**1 1**

very cooperative

Nice game

SIMPSON'S PARADOX MEETS PRISONER'S DILEMMA: AN EXPERIMENT

Results: Cooperation rate



SIMPSON'S PARADOX MEETS PRISONER'S DILEMMA: AN EXPERIMENT

Our explanation for this effect requires that players' choices are correlated in the Mixed condition

Decision	Nice games	Nasty games
Cooperate	30%	8%
Defect	20%	42%

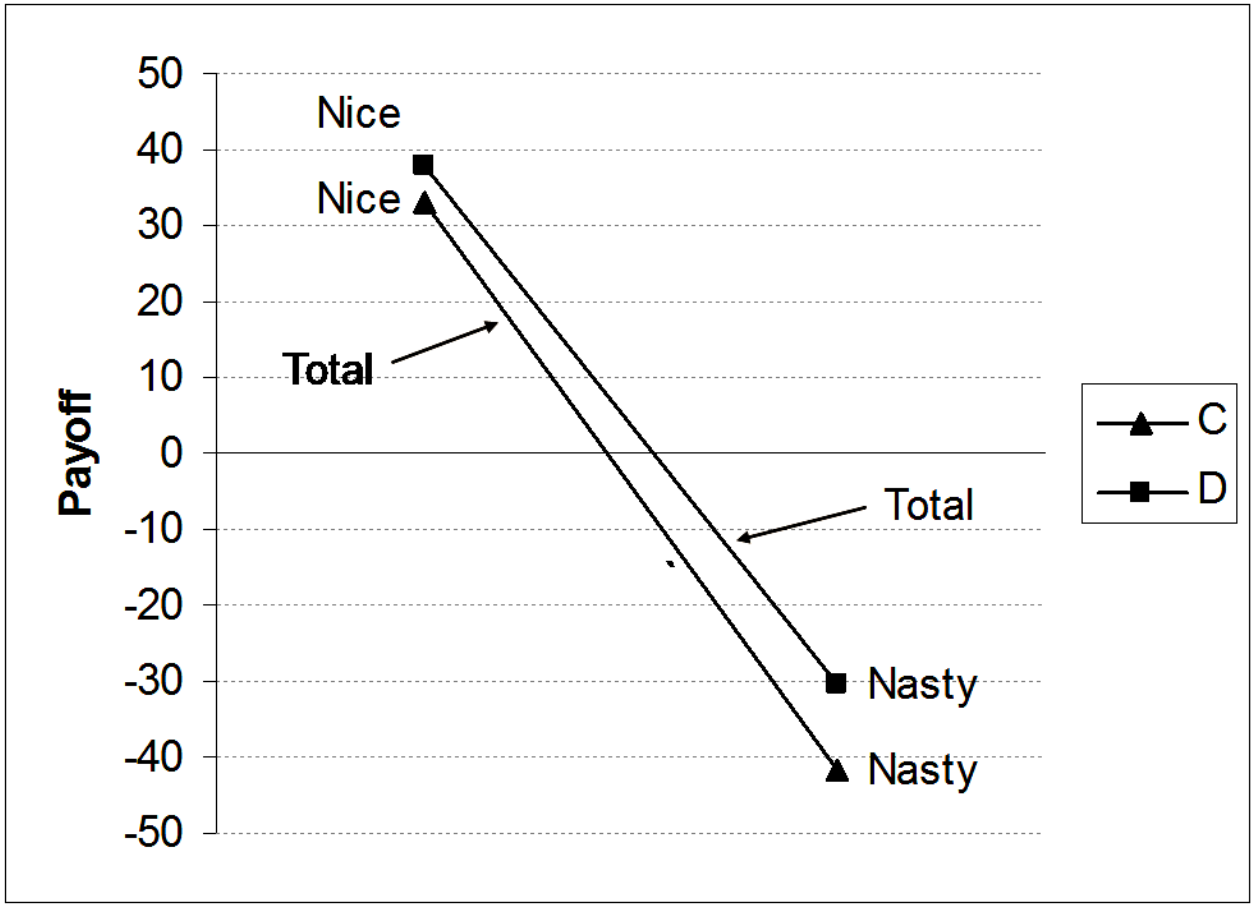
SIMPSON'S PARADOX MEETS PRISONER'S DILEMMA: AN EXPERIMENT

Average payoff for playing C and D in each of the three conditions

Decision	Nasty	Nice	Mixed
Cooperate	-40.4	17.6	19.5
Defect	-30.9	19.1	-13.8

SIMPSON'S PARADOX MEETS PRISONER'S DILEMMA: AN EXPERIMENT

How the Simpson's paradox has biased player's judgment of the utility of each strategy in the Mixed condition?



MODEL AND MULTI-AGENT SIMULATION

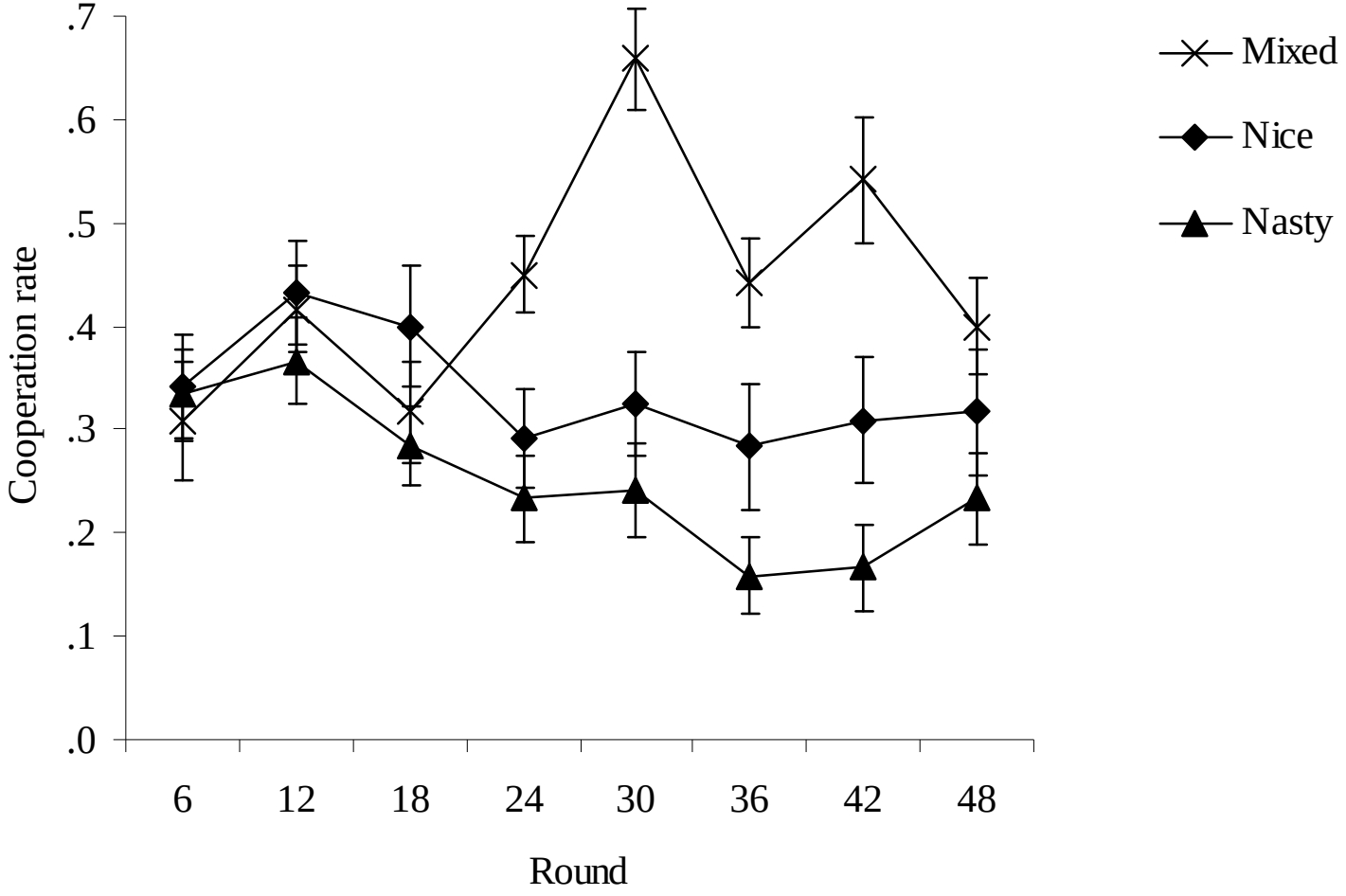
$$P(C) = \frac{U(C)}{U(C) + U(D)}$$

Herrnstein's Matching Law (1)

$$P(C \mid nasty) = kP(C \mid nice) \quad 0 < k < 1 \tag{2}$$

$$P(C) = \{P(C \mid nice) + P(C \mid nasty)\}/2 \tag{3}$$

MULTI-AGENT SIMULATION: COORDINATION



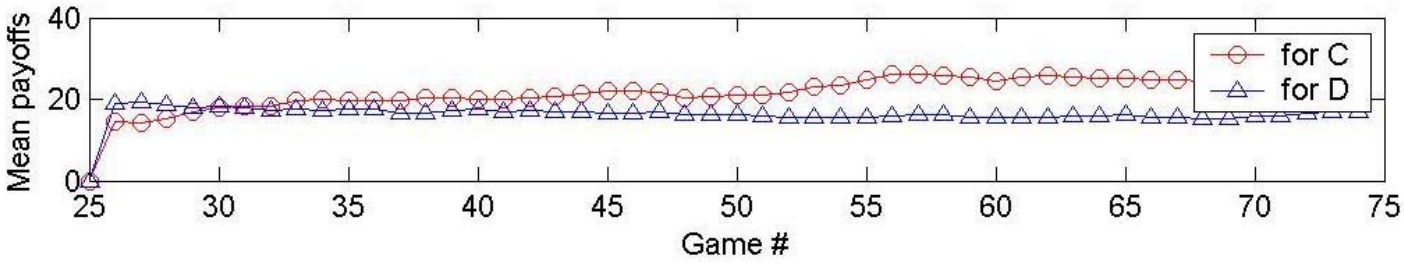
MULTI-AGENT SIMULATION: COORDINATION

Percentage of C and D responses in the Mixed condition show coordination of responses

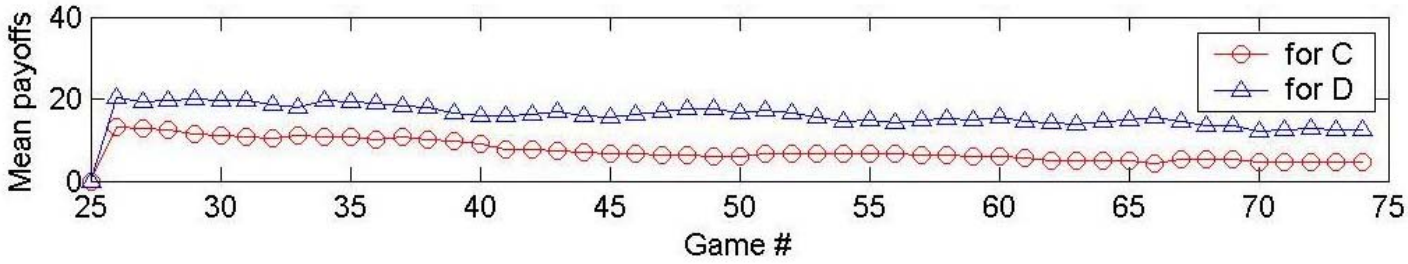
Decision	Nice games	Nasty games
Cooperate	36%	8%
Defect	11%	44%

MULTI-AGENT SIMULATION: REINFORCEMENT

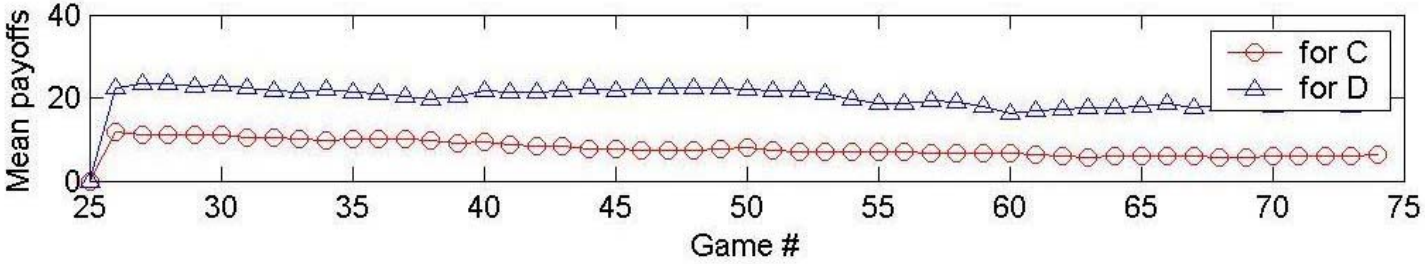
Mixed



Nice



Nasty



MULTI-AGENT SIMULATION: REINFORCEMENT

Average payoff for playing C and D in each of the three conditions:

Decision	Nasty	Nice	Mixed
Cooperate	9.1	9.4	22.4
Defect	20.2	16.1	17.3

COOPERATION VIA REINFORCEMENT LEARNING

- Any force that makes people liable to correlate their responses (e.g., kin, reciprocation, environmental variations) can lead to C being preferred by a reinforcement learner
- With potentially associated “Good Karma illusion”
- A cognitive error may help maintain human cooperation