Decision making in ABM

Agents with Agency

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Course IDEM 112: Agent-based modeling and simulation (ABM-ABS)

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Outline

1. Games, decisions, and simulation
2. Descriptive and normative theories
   a. Bayesian Risk
   b. Fast and Frugal Heuristics
   c. Cumulative Prospect Theory
3. Practicalities

Part 1

GAMES, DECISIONS, AND SIMULATION

Outline

- An astonishingly short introduction to game theory
- A Game of ~~Thrones~~ pennies
- The relationship between game, and decision theory
- The disclosure game
- Why simulate?

Game Theory

- The study of strategic interactions.
- Or, of social situations (psychology perspective)

The basic ingredients of a game are players, rules, and a way of keeping score.

This very abstract definition covers things like poker, ice hockey, the game of thrones, rock-paper-scissors and so on.

But could also include less obviously game like things: job interviews, a group of people deciding which movie to see, or how to split the bill for dinner.

A game of… Pennies*

		Player two	
Player one		H	T
	H	2, 2	0, 1
	T	1, 0	1, 1

*Technically, this game is the Stag Hunt.

Slightly harder*

		Player two	
Player one		H	T
	H	1, -1	-1, 1
	T	-1, 1	1, -1

*And actually the matching pennies game.

Incomplete information

	Player two	
Player one		
	H	T
H	?, ?	?, ?
T	?, ?	?, ?

A third player

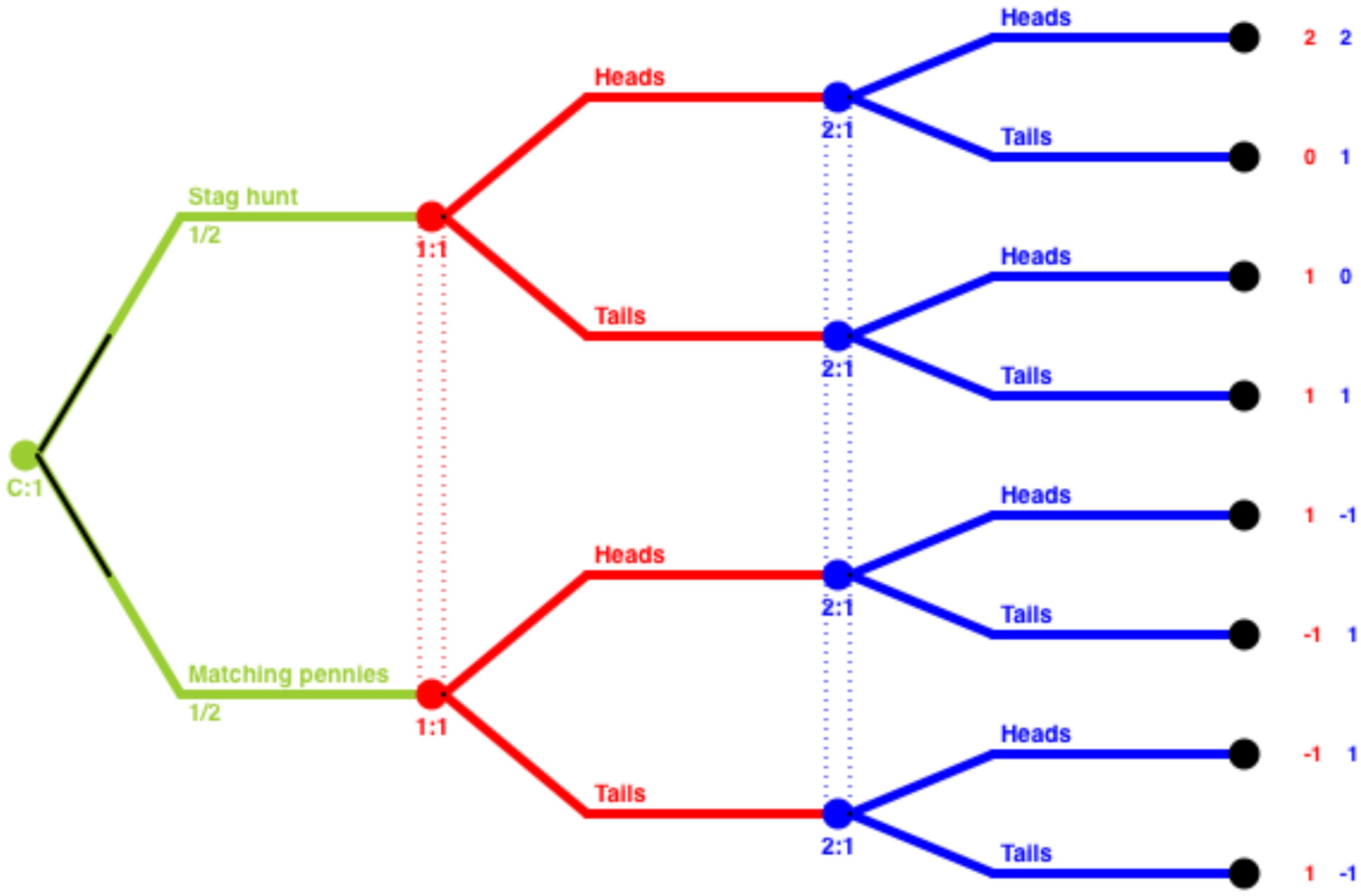
‘Nature’ chooses

p=0.5 p=0.5

	Player two		
Player one		H	T
	H	2, 2	0, 1
	T	1, 0	1, 1

	Player two		
Player one		H	T
	H	1, -1	-1, 1
	T	-1, 1	1, -1

Extensive form



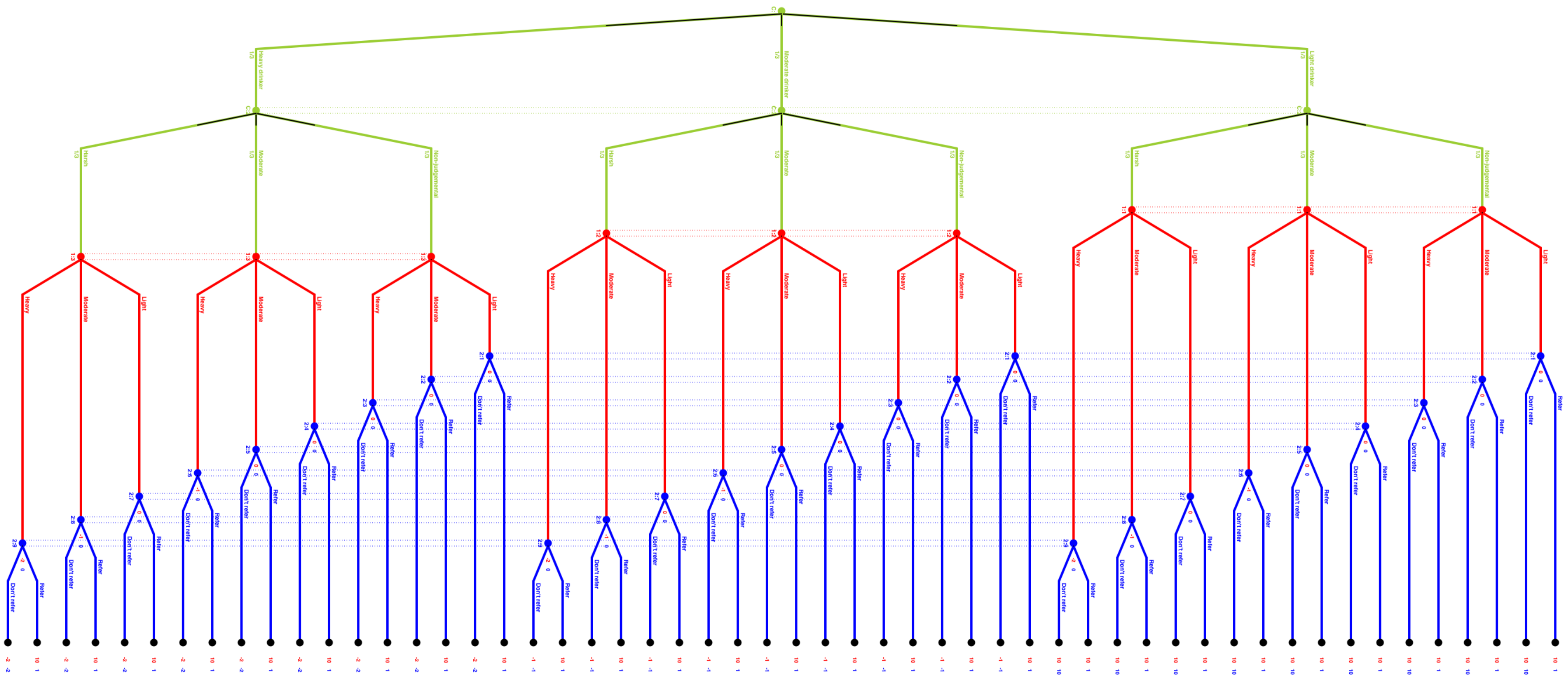
The disclosure game

Players: Women, and midwives.

Scenario

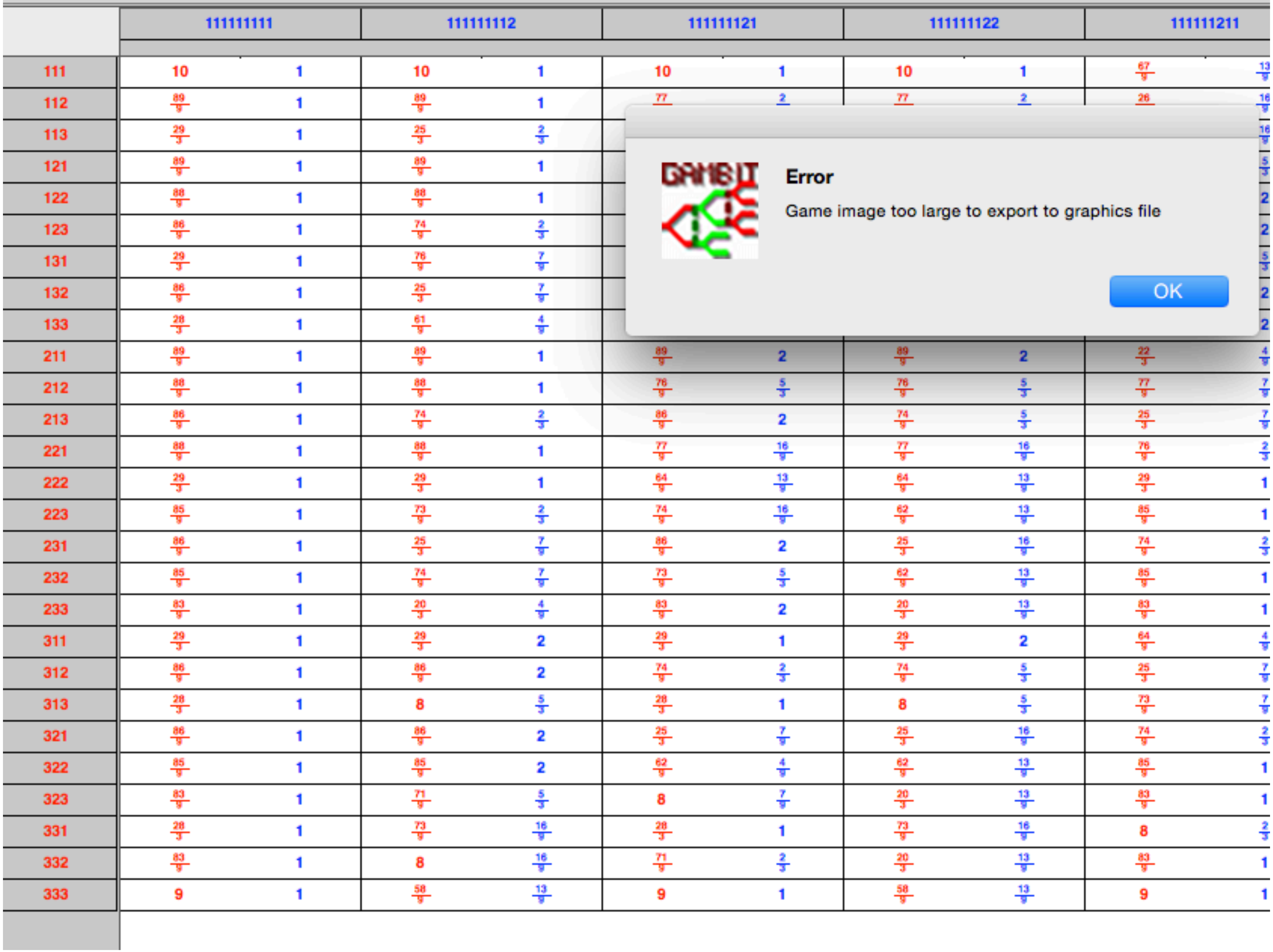
- Over several appointments, women decide what to tell the midwife about how much they drink (nothing, a bit, or a lot). The midwife decides if they should be referred to a specialist, and depending on how judgemental they are, might tell them off for drinking.
- Women want to avoid getting told off for how much they drink, midwives don’t want to refer unnecessarily.
- Both want a healthy pregnancy.

Extensive form disclosure game*



*This is the *simplified* version.

Normal form?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Error
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OK

Why simulate?

- Pretty simple scenario – but quite a complicated game
- Fair to say it is non-obvious what the outcomes will be
- Usual Game Theoretic approach of looking for equilibrium not very helpful (there are dozens)
- More interested in seeing how play changes as players learn
- So, it makes sense to get some (simulated) people, to actually play it

Decision theory and games

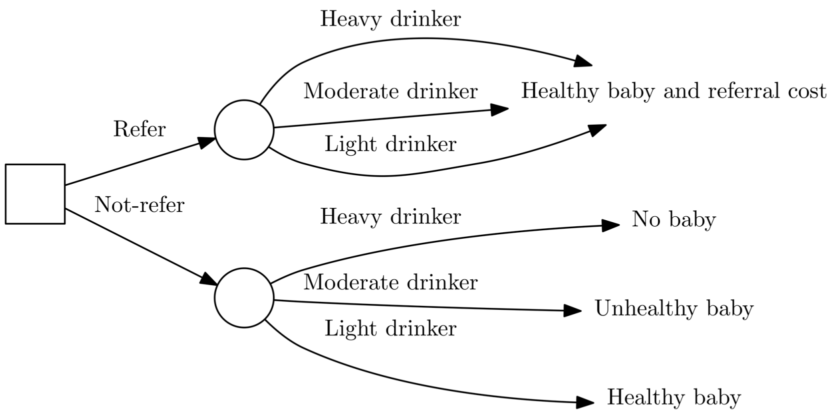
- Strong relationship between games and decisions
- One player games are equivalent to decision problems*
- Games against nature are equivalent to decision problems
- When a player chooses their move, they are clearly making a decision
- Can treat any game as ‘against nature’…
- And one game of *n* players becomes *n* decision problems.
- Other player is a black box, an unknown probability distribution.

Changes the focus from strategy, and information acquisition to how decisions are made.

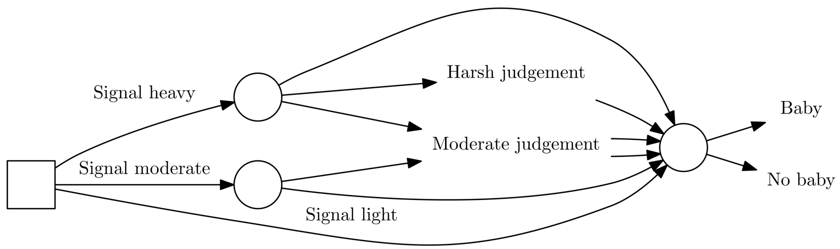
*But worth noting that decision problems needn’t be individual only!

Disclosure decision problems

Midwives



Women



Part 2

Descriptive and normative Theories

Outline

- Descriptive and normative: the debate
- Rational decision making
  - Bayesian Risk
- Ecologically rational decision making
  - Fast and Frugal Heuristics
- City size game
- Dealing with frustratingly irrational humans
  - Cumulative Prospect Theory

Descriptive and Normative

Descriptive

- How *do* decide
- Prediction
- Explanation

Normative

- How *to* decide
- Decision support
- Analytically tractable

A note on utility

1. Utility is a surprisingly woolly concept
2. Not as simple as monetary value == utility
3. Actually a function unique to the individual
4. Usual assumptions
   - Complete
   - Transitive
   - Convex
   - Independent

In practice, 2 & 4 are usually ignored.

Rational decision making

- More mature area
- Underpinning of economic theory – rational agent model
- Consider all possible outcomes, and probabilities
- Use the expected utility to make choices
- Usual assumptions:
  - Perfectly rational
  - Perfectly informed
  - Perfect communicators
  - Unlimited computational power

Bayesian risk example

Knowing the loss incurred by all outcome, and having used Bayesian inference* to produce likelihoods for them, choose the least risky option.

(Loss determined by a loss function, L)

Risk = sum of each L(outcome) * probability of it, for all outcomes

*For substantially more on Bayesian methods, check out Jason's talk on Thursday.

Lever Pulling

Using a very simple loss function, where L(outcome) = -outcome.

Red Lever	**Blue Lever**	**Purple Lever**
80% chance of €7 20% chance of nothing	11% chance of €100 89% chance of losing €5	Certain €6
R=0.8*-7+0.2*-0=-5.6	R=0.11*-100+0.89*5=-6.55	R=1*-6=-6

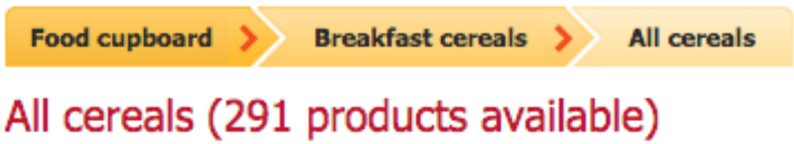
Conclusion: pull the blue lever

Ecological rationality

- Fast and frugal heuristics
- Rationality can only be determined in context
- Specific heuristics for different kinds of problems
- Limited cognitive powers
- Satisfice* (choose first acceptable option), not optimise

*Coined by Herbert Simon, who suggests they are usually equivalent anyway.

The cereal aisle: a satisficing example



- Why don’t people have nervous breakdowns at the supermarket?
- 291 cereals, all subtly different
- Optimise by evaluating all 291…
- Or satisfice by choosing the first ‘good enough’ cereal you see

The city size game

Time for game, borrowed from Goldstein, Daniel G., and Gerd Gigerenzer. "Models of ecological rationality: the recognition heuristic." Psychological review 109.1 (2002): 75.

Which city in each pair is the biggest?

Which is bigger?

	City A	City B
1.	Columbus (0.8 million)	New York (8.5 million)
2.	Baton Rouge (229K)	North Las Vegas (227K)
3.	Nashville (600K)	Mesa (500K)
4.	Garden Grove (175K)	Huntsville (186K)
5.	Albuquerque (556K)	Forth Worth (793K)
6.	Austin (885K)	Jacksonville (843K)

A heuristic for lever-pulling

- Lexicographic heuristic
- Take the most likely outcomes from your choices. If one is obviously better, choose that. If not, look at the second most likely, and so on.

Red Lever	**Blue Lever**	**Purple Lever**
80% chance of €7 20% chance of nothing	11% chance of €100 89% chance of losing €5	Certain €6
Most likely: €7	Most likely: -€5	Most likely: €6

Conclusion: pull the red lever

An obvious question about that heuristic

Q: What do you do if you have tie, that looks like this:

Outcome	A	B	C
Most likely	2	2	-2
2nd most	5	1	1000

A: As far as I know, no canonical answer, so up to you whether to discard, or keep C

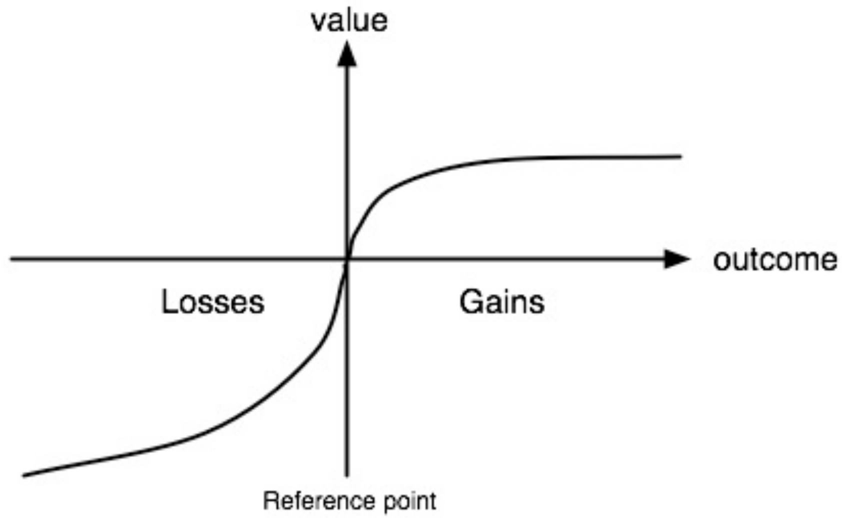
Systematic deviations from rationality

- Purely rational theories are faulty*
- People deviate systematically from rational behaviour, e.g.
  - Too generous in the ultimatum game
  - Loss aversion
  - Probability distortion
  - Risk aversion/risk seeking
- Solution: patch the theory to correspond to real behaviour

*Or, for the economists in the room: humans are faulty.

Cumulative Prospect Theory

- Based on earlier Prospect Theory, corrects some mathematical issues, allows non-binary choices
- Distorts the value of an outcome, based on probability, magnitude, and whether it is a gain or a loss



Weighting probabilities

Gains

$$w(p) = \frac{p^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})^{\frac{1}{\gamma}}}$$

Losses

$$w(p) = \frac{p^{\delta}}{(p^{\delta} + (1-p)^{\delta})^{\frac{1}{\delta}}}$$

Generally set $\gamma > \delta$.

Distorting value

Value distorted such that losses are more painful than gains are enjoyable.

$$v(x) = \begin{cases} f(x) \text{ } if \text{ } x > 0 \\ 0 \text{ } if \text{ } x = 0 \\ \lambda g(x) \text{ } if \text{ } x < 0 \end{cases}$$

$$f(x) = \begin{cases} x^{\alpha} \text{ } if \text{ } \alpha > 0 \\ \ln(x) \text{ } if \text{ } \alpha = 0 \\ 1 - (1 + x)^{\alpha} \text{ } if \text{ } \alpha < 0 \end{cases}$$

$$g(x) = \begin{cases} -(-x)^{\beta} \text{ } if \text{ } \beta > 0 \\ -\ln(-x) \text{ } if \text{ } \beta = 0 \\ (1 - x)^{\beta} - 1 \text{ } if \text{ } \beta < 0 \end{cases}$$

Cumulative prospect levers

- Knowing all the outcomes etc. etc.
- Outcome and a probability together are a *prospect*
- Calculate CPT value of each prospect*
- Choose the alternative with the highest sum of CPT values

Red Lever	**Blue Lever**	**Purple Lever**
80% chance of €7 20% chance of nothing	11% chance of €100 89% chance of losing €5	Certain €6
CPT value=3.4	CPT value=4.2	CPT value=4.8

Conclusion: pull the purple lever

*See handout for the working out.

Decisions and the brain

If any of these models are ‘true’, should be able to find an implementation in the brain – neuroeconomics.

Look for *neural correlates*, neuronal firing rates linked to magnitude and probability of a reward.

- Platt, Michael L., and Paul W. Glimcher. "Neural correlates of decision variables in parietal cortex." Nature 400.6741 (1999): 233-238.
- Padoa-Schioppa, Camillo, and John A. Assad. "Neurons in the orbitofrontal cortex encode economic value." Nature 441.7090 (2006): 223-226.
- Christopoulos, George I., et al. "Neural correlates of value, risk, and risk aversion contributing to decision making under risk." The Journal of Neuroscience 29.40 (2009): 12574-12583.

Learning to decide: bad news

No one true theory of learning
☹

Learning to decide: good news

Lots of options, among them:

- Frequency counting
    - Fast, cheap, simple to implement
- Statistical methods (Bayesian inference – see Jason's talk for more on this!)
    - Handling of bias, better cognitive plausibility?
- Error correction models (Rescorla-Wagner, Temporal Difference)
    - Better neurological plausibility

Alternative approaches

Lots.

- Simpler heuristics: Minimax, maximax, maximin
- Classic economics: Expected Utility Maximisation, random utility models.
- Explicit handling of time: EU with discounting, Lowenstein-Prelec.
- Neural network based: ACT-R, Daw
- Reinforcement learning style: Q-Learning, TD models
- Ad hoc heuristics, neural nets, threshold models

Part 4

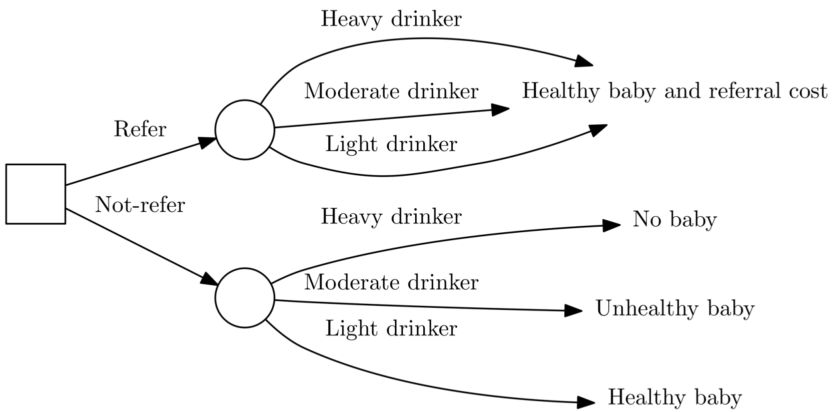
PRACTICALITIES

Outline

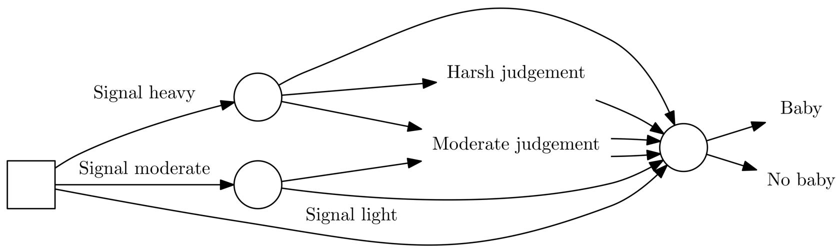
- Levers in the disclosure game
- Which is best?
- Does it actually matter – example from the disclosure game
- Gotchas

Levers in the disclosure game

Midwives



Women



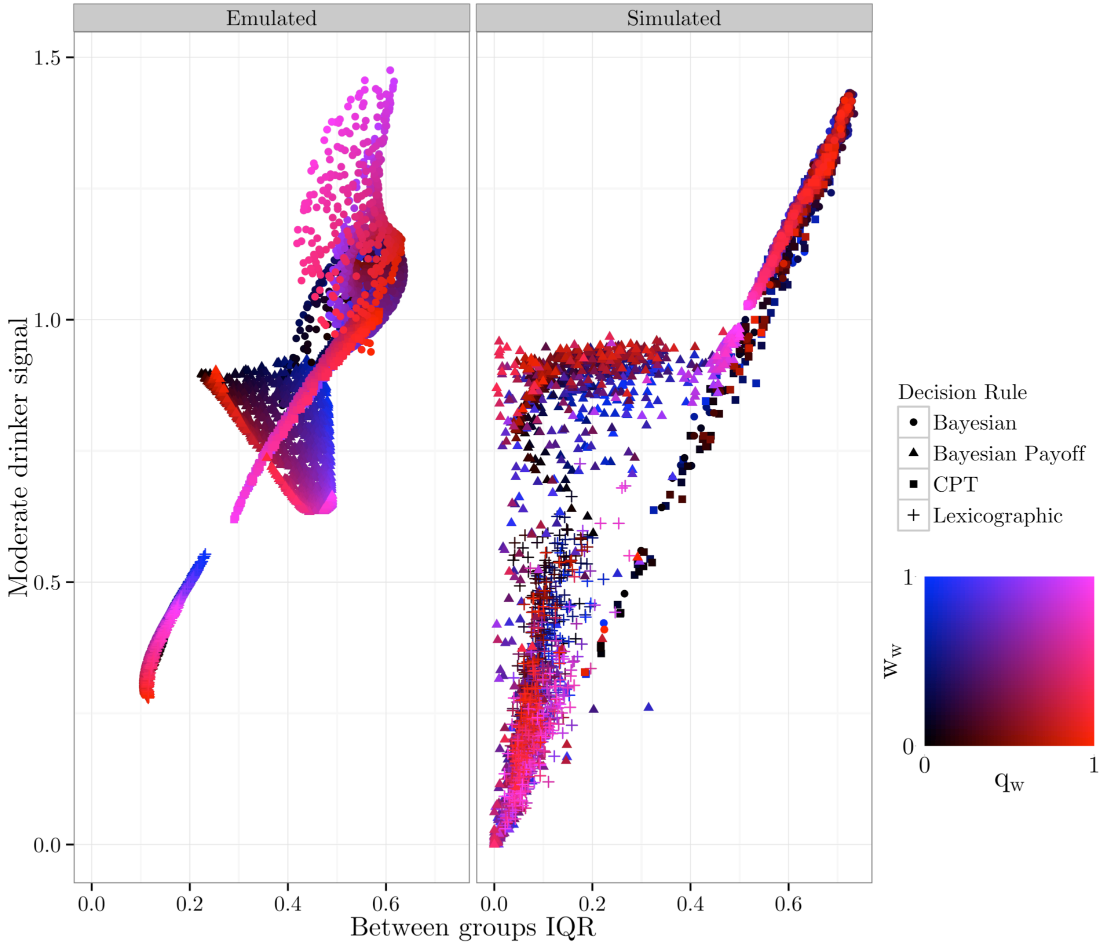
Which is best?

It depends

It totally matters

Outcome space of disclosure game simulation.

Shows separation by both decision problem representation, and decision rule.



Gotchas

- No one true theory
- Tendency to assume that all decisions are
  - Binary
  - One shot
  - From description
  - In the moment
- Lack of comparability – how would you solve the cities problem with prospect theory?
- Choice of model impacts problem representation
- Not necessarily necessary!
- How do you parameterise?

To be continued…

- **After a brief coffee break:**
  Discussion on modelling decision makers in demography (with Frans, Anna, and me)

- **After a brief lunch break (14^{00}):**
  Computer lab on RNetLogo (with Sebastian, and Francisco)

Thank you!

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https://github.com/greenape

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