How humans deal with uncertainty in decisions

Lev Ginzburg and Scott Ferson, Applied Biomathematics
Cognitive Aspects of Decision Making, Washington, 23 September 2008

Rationality

- Maximize expected utility (EU)
  - Pascal 1670; von Neumann & Morgenstern 1944
  - If making many such decisions, EU performs best
- Your probabilities must make sense
  - *Coherent* if bets don't expose you to sure loss

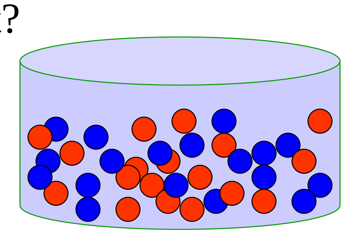
So why not use EU?

- Not how people act
- Needs a lot of information to use
- Probabilities are often inconsistent
- Unsuitable for important unique decisions
- Inappropriate if gambler's ruin is possible

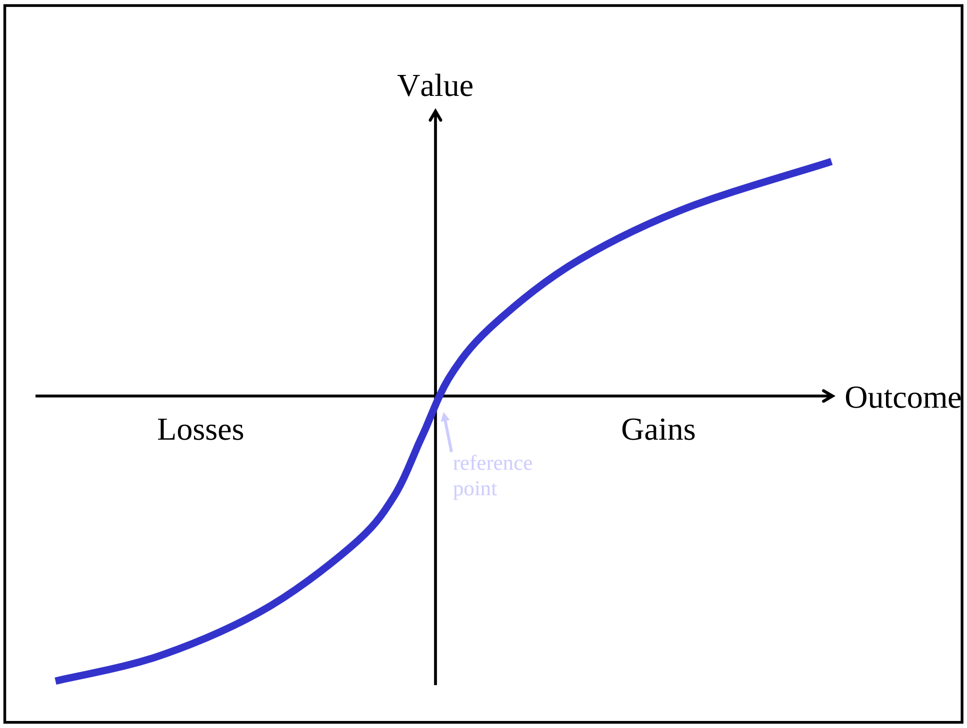
Risk aversion

- **Gamble:**
  - **EITHER** get $50
  - **OR** get $100 if a randomly drawn ball is red from urn with half red and half blue balls
- Which prize do you want?

$50

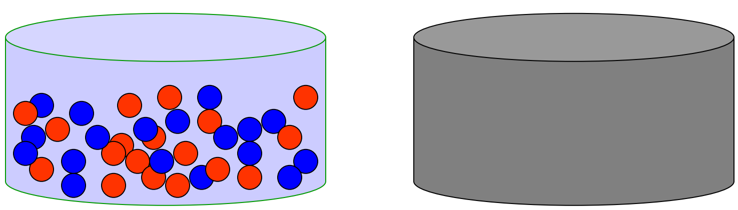


EU is the same, but most people take the sure $50



Ambiguity aversion

- Balls can be either red or blue
- Two urns, both with 36 balls
- Get $100 if a randomly drawn ball is red
- Which urn do you wanna draw from?



Montauk workshop

- Several modules in human brain
  - Strong clinical and neuroimaging evidence
  - Examples: cheater detection, language, etc.
  - Each is tuned to a specific kind of problem
  - Activated by sensory input in a particular format
  - Modules sometimes disagree with each other
- Irrationality is a hallmark of human decisions
  - Suicide bombers, philanthropy, lotteries, altruism, war, etc.
  - Other primates sometimes *more* rational
- Emotions crucial to decision making

Rationality = maximizing self interest

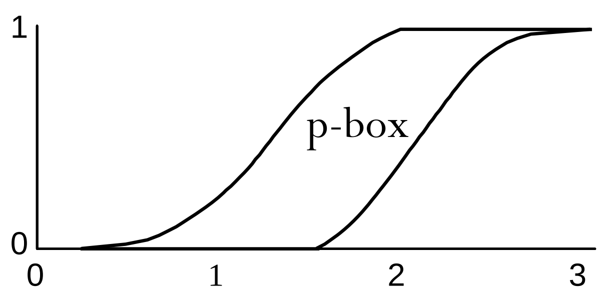
Import for risk assessment

- Risk analyses woefully incomplete
  - Omit important issues and thus understate risks
  - Neglect or misunderstand incertitude
- Presentations use very misleading formatting
  - Percentages, relative frequencies, conditionals, etc.
- Both problems can be fixed
  - By changing analysts' behavior, not the public's

Imprecision about probabilities

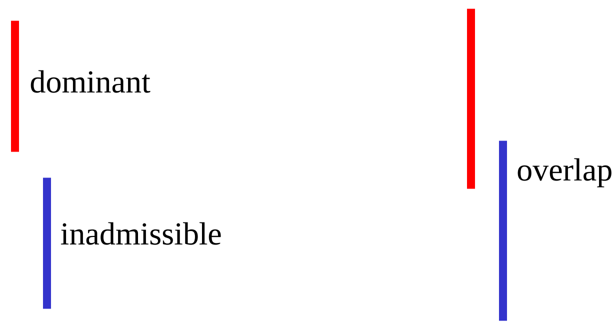
- Bayesian “rational agents” are compelled to either sell or buy any offered bet
  - But it’s not irrational to *decline to bet*
- Imprecise probabilities don’t require all bets
  - Interval probability for A is the range between the largest buying price and the smallest selling price you accept for the bet that A happens

Probability bounds analysis



Convenient and comprehensive software available for arithmetic, logic, comparisons and analysis

Interval dominance



Red is *preferred* to blue

Red is *incomparable* to blue

Bridges Knight’s decisions

1921

Under risk

Probabilities known

Maximize expected utility

EU

Under uncertainty

Probabilities unknown

Several possible strategies

maximin, Wald 1939

← **Under imprecision** →

Probabilities partially known

Different decision criteria

- Some criteria find a single decision
  - Γ-maximin picks the decision with the highest low
- Some criteria can yield sets of decisions
  - E-admissibility picks all decisions that may be best
  - The more precise the input, the tighter the outputs
- Different criteria are useful in different settings

Traditional Bayesian answer

- Allows *only one decision* (up to indiffernce)
  - No matter how much uncertainty is present
- Different analysts would get different answers
  - Depends on which prior we use for p
- Doesn't express doubt about the final decision

Take-home messages

- Improper to say you know more than you do
- Bayesian decision making always yields one answer, even if it is not really justified
- Prudent decisions under imprecision
  - More consistent with human psychology
  - Tells you when to reserve judgment

Applied Biomathematics research

NSF	Risk perception as neuroscience and anthropology
Pfizer	Perspective visualization of data through uncertainty
Sandia	Accounting for epistemic uncertainty
DHS	Spatial risk maps from imperfect incidence data
NASA	Aleatory and epistemic uncertainty in spacecraft design
BRGM	Bayesian methods in risk assessment
NIH	Detecting clustering of rare events in sparse data
USDA	Forest pest risk in dynamic landscapes

End

Ellsberg Paradox

- Balls can be red, black or yellow (probs are *R*, *B*, *Y*)
- A well-mixed urn has 30 red balls and 60 ***other*** balls
- Don't know how many are black, how many are yellow

Gamble A $R > B$ Get \$100 if draw red	**Gamble B** Get \$100 if draw black
Gamble C Get \$100 if red or yellow	**Gamble D** $R + Y < B + Y$ Get \$100 if black or yellow

Persistent paradox

- Most people prefer **A** to **B** (so are saying $R > B$) but also prefer **D** to **C** (saying $R < B$)
- Doesn't depend on your utility function
- Payoff size is irrelevant
- Not related to risk aversion
- Evidence for ambiguity aversion
  - Can't be accounted for by EU
  - Not resolved in Prospect Theory either

Dutch book example

Horse	**Offered odds**	**Probability**
Danger Spree	Evens	0.5
Windtower	3 to 1 against	0.25
Shoeless Bob	4 to 1 against	0.2
		0.95 (total)

A gambler could lock in a profit of 10, by betting 100, 50 and 40 on the three horses respectively

http://en.wikipedia.org/wiki/Dutch_book

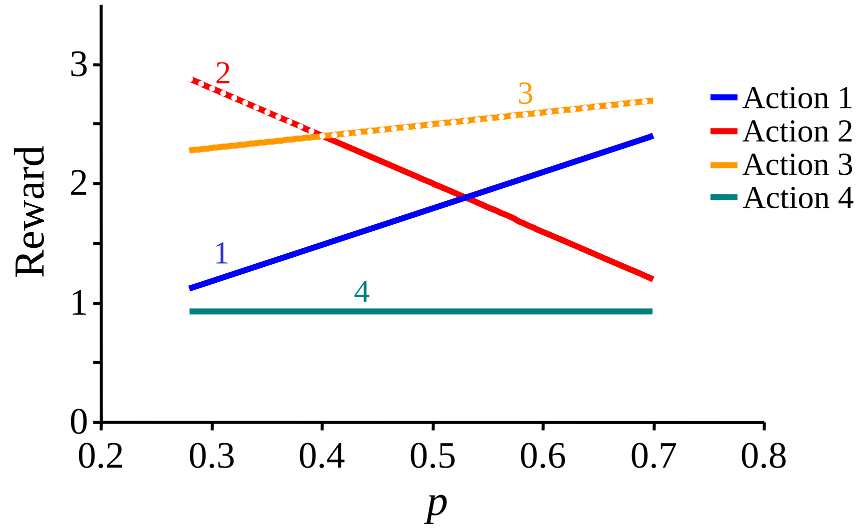
Comparing IP to Bayesian approach

- Axioms identical except IP doesn't use completeness
- Bayesian rationality implies not only avoidance of sure loss & coherence, but also the idea that an agent *must agree to buy or sell any bet at one price*
- "Uncertainty of probability" *is* meaningful, and it's operationalized as the difference between the max buying price and min selling price
- If you know all the probabilities (and utilities) perfectly, then IP reduces to Bayes

Why Bayes fares poorly

- Bayesian approaches don't distinguish ignorance from equiprobability
- Neuroimaging and clinical psychology shows humans strongly distinguish uncertainty from risk
  - Most humans regularly and strongly deviate from Bayes
  - Hsu (2005) reported that people who have brain lesions associated with the site believed to handle uncertainty behave according to the Bayesian normative rules
- Bayesians are too sure of themselves (e.g., )

E-admissibility



Multi-criteria decision analysis

- Used when there are multiple, competing goals
  - E.g., USFS' multiple use (biodiversity, aesthetics, habitat, timber, recreation,…)
  - No universal solution; can only rank in one dimension
- *Group* decision based on *subjective* assessments
- Organizational help with conflicting evaluations
  - Identifying the conflicts
  - Deriving schemes for a transparent compromise
- Several approaches
  - Analytic Hierarchy Process (AHP); Evidential Reasoning; Weight of Evidence (WoE); ***every approach has flaws***

Analytic Hierarchy Process

- Identify possible actions
  - buy house in Setauket / buy in Port Jeff / rent in Old Field
- Identify and rank significant attributes
  - location > price > school > near bus
- For each attribute, and every pair of actions, specify preference
- Evaluate consistency (transitivity) of the matrix of preferences by eigenanalysis
- Calculate a score for each alternative and rank

- Subject to rank reversals (e.g., without Perot, Bush beat Clinton)