Engineering for Humans (ELEC-D7010)

Heuristics and Biases in Human Decision-Making

Materials adapted from Aurélien Nioche

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Preface

Experiment 0

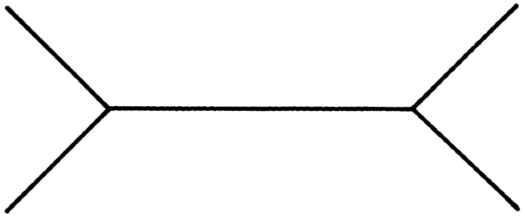


FIG. 3.—The Müller-Lyer illusion

Which line appears longer, **top** or **bottom**?

Müller-Lyer (1889), see Tversky & Kahneman (1986)

Preface

Experiment 0

Perceptual judgment makes the **top arrow appear longer than bottom**

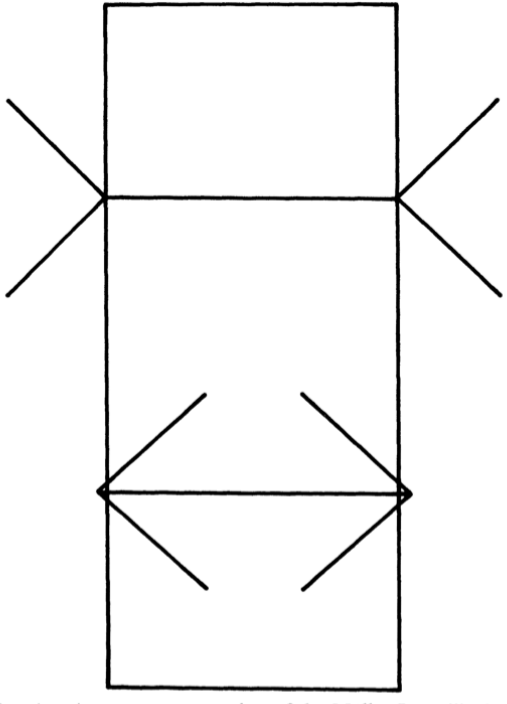


FIG. 4.—A transparent version of the Müller-Lyer illusion

Which line appears longer, **top** or **bottom**?

Müller-Lyer (1889), see Tversky & Kahneman (1986)

Preface

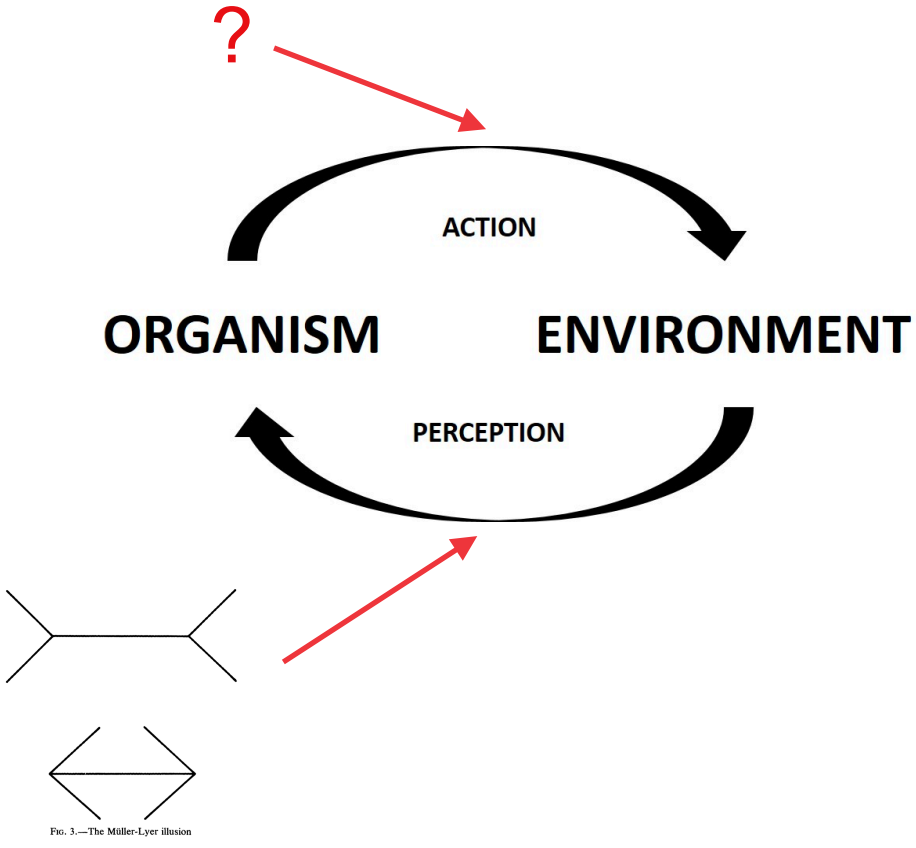


FIG. 3.—The Müller-Lyer illusion

Lecture Summary

Outline	Objectives
I. What?	Understand **what heuristics and biases are** and describe some examples of them
II. Why?	Contrast the **main hypotheses** that could **explain why** such heuristics and biases exist
III. Where?	Have an idea about how understanding of these heuristics and biases can be **applied** in **practice**

I. What?

What are heuristics and biases?

I. What?

Experiment 1

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which alternative is more* probable*?

1. Linda is a bank teller.
2. Linda is a bank teller and is active in the feminist movement.

I. What?

Experiment 1

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which alternative is more* probable*?

1. Linda is a bank teller.
2. Linda is a bank teller and is active in the feminist movement.

Correct answer: **Linda is a bank teller**

I. What?

Experiment 1

Heuristic:

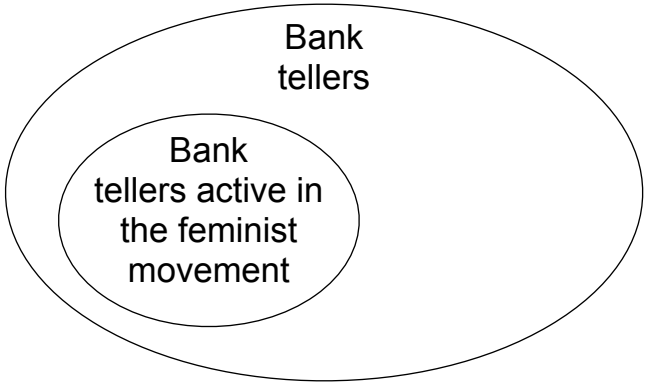
- **Representativeness: Conjunction fallacy*** (Tversky & Kahneman,1983)

The conjunction of two events is seen as more probable as a single event (this conjunction matching better with the *representation* of the situation)

⊗ Non-respect of probability theory

$P(A) \geq P(A \wedge B)$ and $P(B) \geq P(A \wedge B)$

P(*Linda is a bank teller*) = 0.05
P(*Linda is a feminist*) = 0.95
P(*Linda is a bank teller* and *Linda is a feminist*) = 0.05 × 0.95 = 0.0475



* fallacy = failure to apply a logical rule when it is obviously relevant

I. What?

Experiment 2

*Considering tosses of a coin, which sequence is **more likely**?*

- HTHTTH
- HHHTTT

I. What?

Experiment 2

*Considering tosses of a coin, which sequence is **more likely**?*

- HTHTTH
- HHHTTT

Correct answer: **Neither**

I. What?

Experiment 2

Heuristic:

- **Representativeness: Gambler's fallacy** (Kahneman & Tversky, 1974)

"If something happens more frequently than normal during a given period, it will happen less frequently in the future" (all sequences are supposed to *represent* a random process)

⊗ Non-respect of probability theory

As all tosses are assumed to be independent

$$P(\text{HTHTTH}) = P(\text{HHHTTT}) = 0.5 \times 0.5 \times \ldots = 0.5^6 = 0.015625$$

I. What?

Experiment 2B

*What is the probability of flipping a **head** after having already flipped **20 heads** in a row?*

I. What?

Experiment 2B

*What is the probability of flipping a **head** after having already flipped **20 heads** in a row?*

Correct answer: **0.5**

I. What?

Experiment 2B

Heuristic:

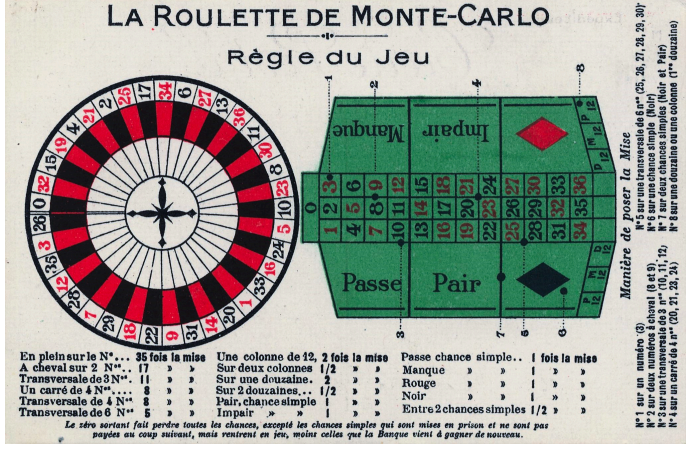
- **Representativeness: Gambler's fallacy** (Kahneman & Tversky, 1974)

"If something happens more frequently than normal during a given period, it will happen less frequently in the future" (all sequences are supposed to *represent* a random process)

⊗ Non-respect of probability theory

As all tosses are assumed to be independent

$$P(21 \text{ heads}) = P(20 \text{ heads } + 1 \text{ tail}) = 0.5 \times 0.5 \times \ldots = 0.5^{21} \approx 0.00000047$$



I. What?

Experiment 3-1

I give you **100 euros** and I propose you the following **bet**. *What do you prefer?*

A. **50 euros more** (for sure)

B. **100 euros more** with a **50-50** chance

I. What?

Experiment 3-2

I give you **200 euros** and I propose you the following bet. *What do you prefer?*

C. **Losing 50 euros** (for sure)

D. **Losing 100 euros** with a **50-50** chance

I. What?

Experiment 3-1

I give you **100 euros** and I propose you the following **bet**. *What do you prefer?*

A. **50 euros more** (for sure)

B. **100 euros more** with a **50-50** chance

I give you **200 euros** and I propose you the following bet. *What do you prefer?*

C. **Losing 50 euros** (for sure)

D. **Losing 100 euros** with a **50-50** chance

Rational answer: either **indifferent**, or **A & C** (risk averse), or **B & D** (risk seeking)

I. What?

Experiment 3

Bias:

- **Reference: Loss aversion** (Kahneman & Tversky, 1991)

Leads to inconsistent preferences with respect to the expected utility theory (Von Neumann & Morgenstern, 1953)

- *Expected values* are the same

  EV(100 euros + 50 euros for sure) = 150

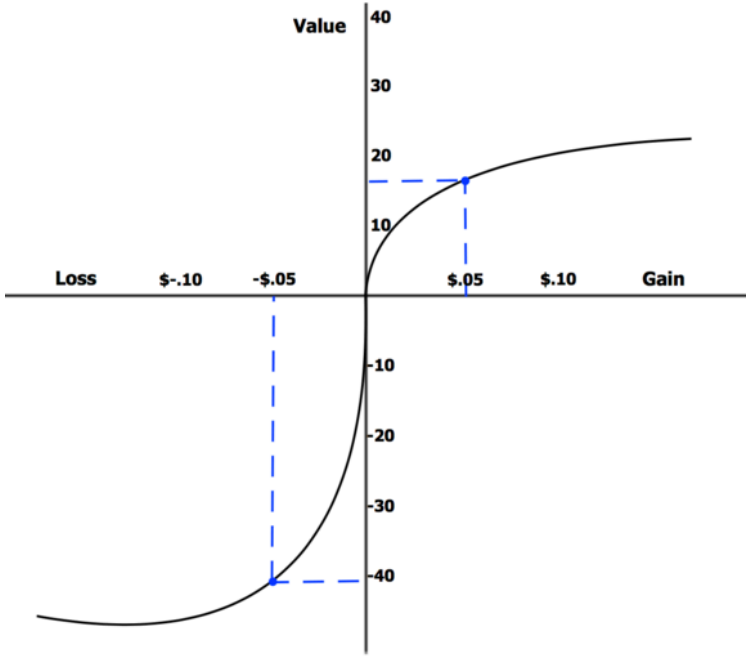
  EV(100 euros + 100 with 50-50 chance) = 150

  EV(200 euros - 50 euros for sure) = 150

  EV(200 euros - 100 euros with a 50-50 chance) = 150

- A constant attitude toward risk should lead to choose either both *safe* options, or both *risky* options

But **asymmetric utility functions** induce asymmetric attitude towards risk



I. What?

Experiment 3B-1

600 people are sick and you need to conduct a health plan. You dispose of two treatments.

What treatment do you prefer to use?

- Treatment A: **Save 200 lives**
- Treatment B: **33%** chance of **saving all 600** people, **66%** possibility of **saving no one**.

I. What?

Experiment 3B-2

600 people are sick and you need to conduct a health plan. You dispose of two treatments.

What treatment do you prefer to use?

- Treatment C: **400 people will die**
- Treatment D: **33%** chance that **no people will die**, **66%** probability that **all 600 will die**

I. What?

Experiment 3B

600 people are sick and you need to conduct a health plan. You dispose of two treatments.

What treatment do you prefer to use?

- Treatment A: **Save 200 lives**
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Rational answer: either **indifferent**, or **A & C** (risk averse), or **B & D** (risk seeking)

I. What?

Experiment 3B

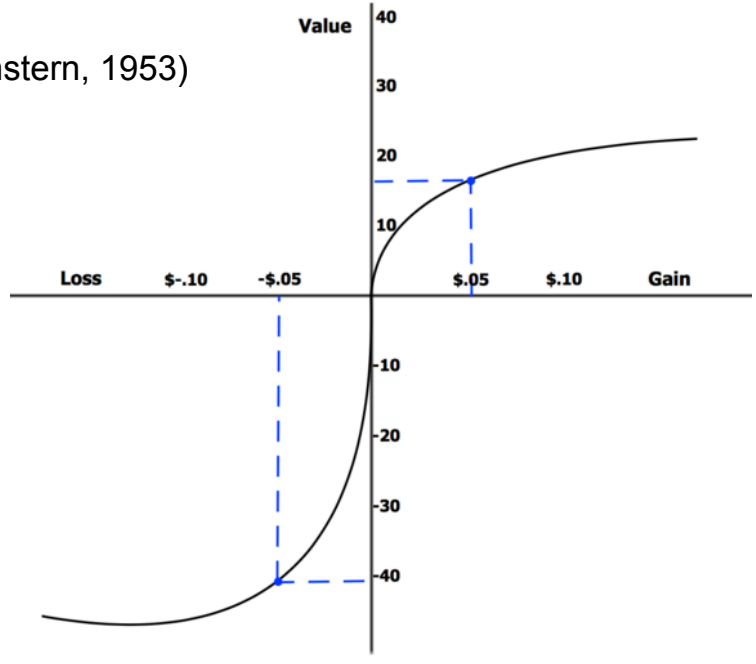
Bias:

- **Reference: Loss aversion**

Preference for avoiding losses to acquiring equivalent gains (reference point can induce change in preferences)

⊗ Lead to inconsistent preferences
regarding to the expected utility theory (Von Neumann & Morgenstern, 1953)

- All expected values are equal
- A constant attitude toward risk should lead to choose either both safe options, or both risky options



I. What?

Bias: Preference **deviating** from what could be expected under a **risk-neutral and rational decision-making process**

Heuristic: **Decision-making "rule of thumb":** cognitive process that helps finding adequate answers to difficult questions by ignoring information*

*How does a baseball player decide how to catch the ball?***

*adapted from Kahneman (2012, p.98) and Gigerenzer & Brighton (2008)
** Heuristics a one possibility (Gigerenzer, 2007)

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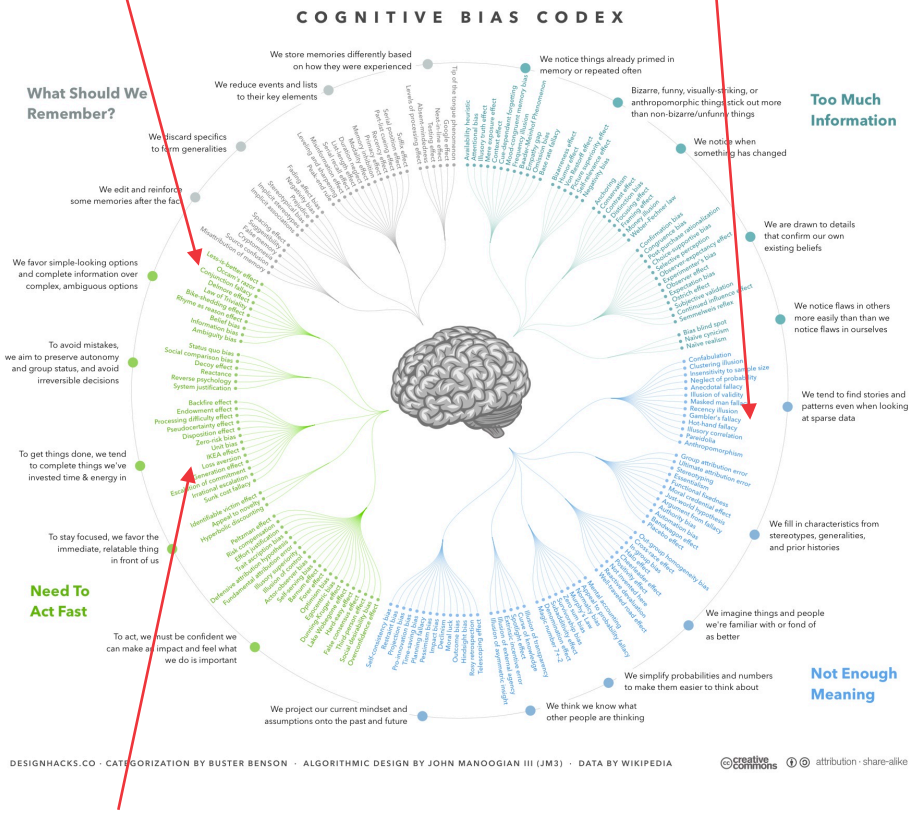
I. What?

- Many other **heuristics and biases** detected in addition to **representativeness** and **loss aversion**

XP 1: Bank teller and feminist?

XP 2: What is the probability of tail?



XP 3: 50 euros for sure?
100 euros with 50-50 chance?

Take-home message 1

Human decision-making is subject to systematic **heuristics and biases:**
The **way the information is presented** influences the **decision-making process**

II. Why?

Why are we using heuristics and why are we subject to biases?

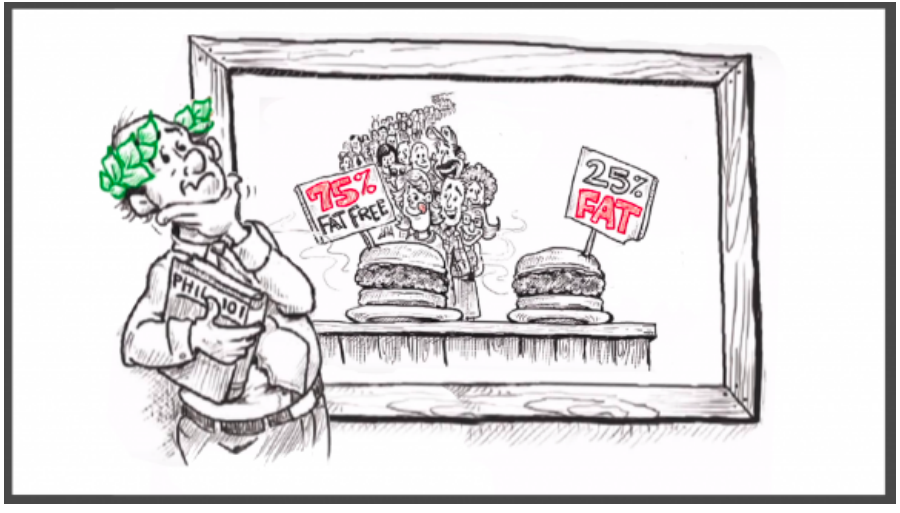
II. Why?

Hypothesis 1

- We are dumb

Hypothesis 1B

- **Bounded rationality** (Simon, 1954)
  - Instead of **optimising** people **satisfice**



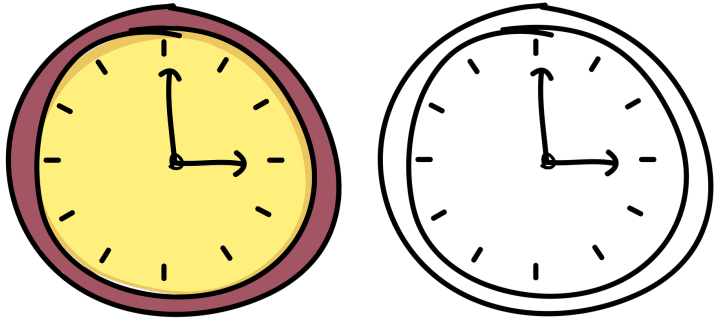
II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the ‘real world’

→ Adapting allows us to deal with **limited resources**

- **Time**: Realising a speed-accuracy tradeoff
- **Memory**: Realising a speed-accuracy tradeoff
- **Computation**: Large search space
- **Information**: Generalise from few examples



II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the 'real world'

Argument 1:

- Ability to realise a (not so bad) **speed-accuracy tradeoff**

Travelling salesman problem

Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city and returns to the origin city?

Number or routes for N cities = $(N-1)! = (N-1) \times (N-2) \times \cdots \times 2 \times 1$

E.g. number of routes for 15 cities = 43,589,145,600

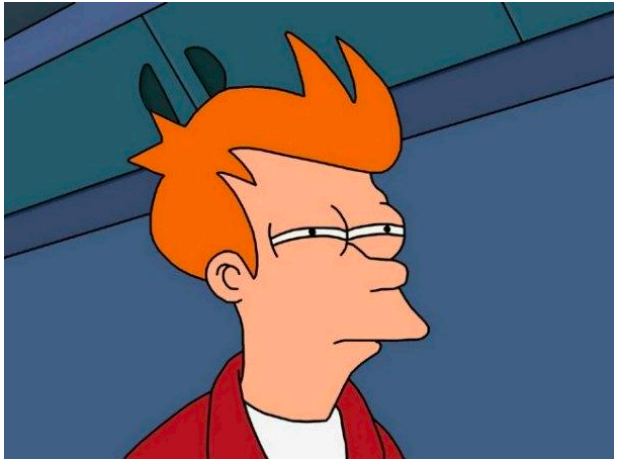
II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the ‘real world’

Argument 2:

- **Optimal/rational** solution can be… **doubtful** in practice!



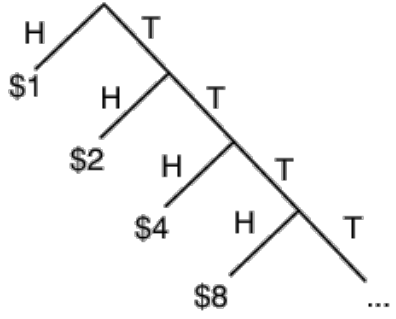
II. Why?

Experiment 4

I propose a game.

I will begin by tossing a coin. If **heads** appears, you win **one dollar** and the **game stops**. If **tails** appears, I **double the stake** and I toss the coin again. We will continue this process until heads appears.

I sell you the ticket **$10,000**. *Do you accept it?*



II. Why?

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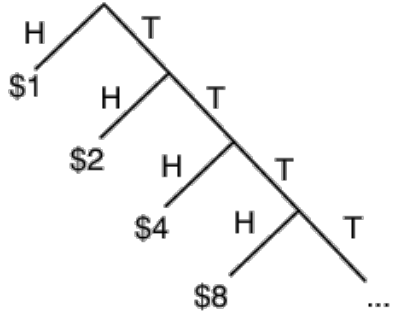


"Rational" answer: **Yes**

II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the 'real world'

Argument 2:

- **Optimal/rational** solution can be… **doubtful** in practice!

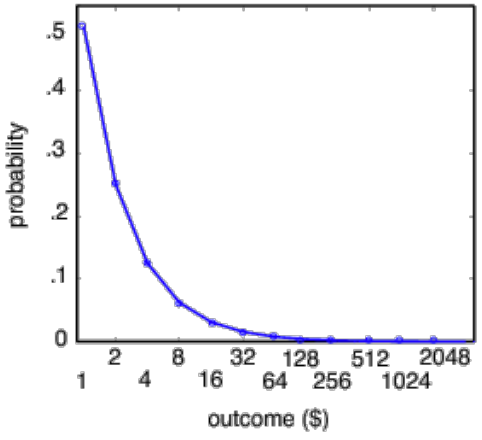
The Saint Petersburg paradox:

The expected value is: $\mathbb{E} = \frac{1}{2} \cdot 2 + \frac{1}{4} \cdot 4 + \frac{1}{8} \cdot 8 + \frac{1}{16} \cdot 16 + \cdots$

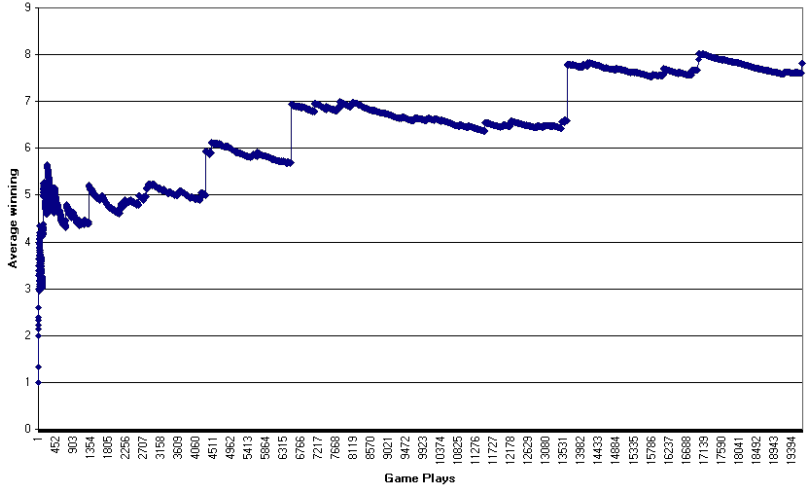
$= 1 + 1 + 1 + 1 + \cdots$

$= \infty$

Why does it appear as doubtful?



How can it make intuitively sense?



II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the ‘real world’

Argument 3:

- Biases provide a **better fitness**

Is there a grizzly?

Two types of **errors**:

- No, but I say yes (*false positive*)
- Yes, but I say no (*false negative*)

Which error is preferable from an evolutionist perspective?

II. Why?

Hypothesis 2

- In order to adapt to **constraints** of the 'real world'

Is there a grizzly?

Two types of **errors**:

- No, but I say yes (*false positive*)
- Yes, but I say no (*false negative*)

Which error is preferable from an evolutionist perspective?

Argument 3:

- Biases provide a **better fitness**

Answer: **false positive** errors

- **Error management theory** (Haselton & Buss, 2003)**:**
  A bias towards false positive errors can be helpful to survive!

Take home message 2

Heuristics and biases are not necessarily **flaws** in human decision-making process but also an **efficient mean** to interact with a **complex** environment

III. Where?

Where can this understanding of heuristics and biases be applied?

III. Where?

Marketing

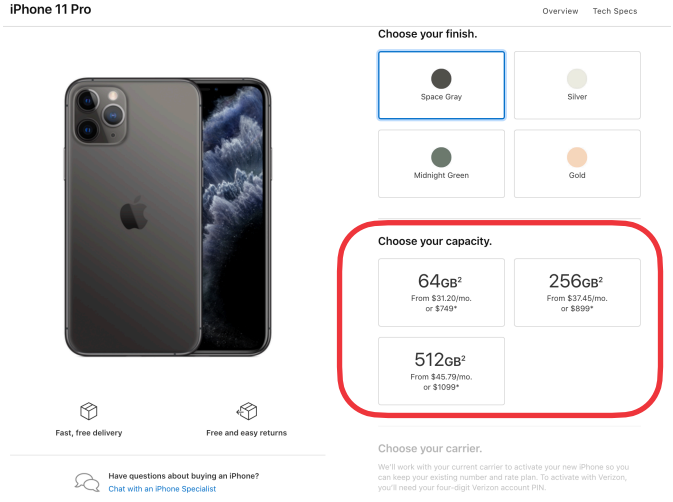
E.g. exploit heuristics to improve sales

Bias:

- **Decoy** (Huber & Puto, 1983)

A decision-maker swap his or her preference between two options when presented with a third option

Lead to inconsistent preferences*



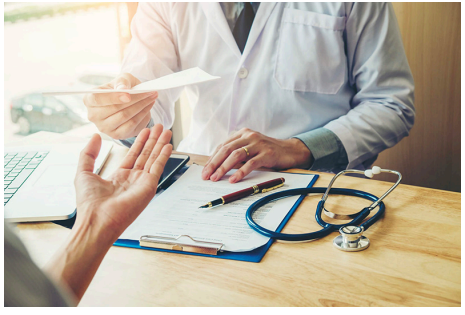
* It breaks the *independence axiom* (Von Neumann & Morgenstern, 1953)

- If an alternative *x* is chosen from a set *T*, and *x* is also an element of a subset *S* of *T*, then *x* must be chosen from *S*

III. Where?

Medical care

E.g. help physicians to improve diagnosis with metacognition



Increase of prostate cancer diagnoses following the introduction of the prostate-specific antigen screening test (Etzioni et al. 2002)

Bias:

- **Availability bias** (Kahneman & Tversky, 1974)

Preference for ‘easy to recall’ options

⊗ Can induce non-respect of probability theory

Recent experience with a disease may inflate the likelihood of its being diagnosed, neglecting the **base-rates**.

Conversely, if a disease has not been seen for a long time (is less available), it may be under-diagnosed

Cognitive Debiasing Strategies to Reduce Diagnostic Error*

Strategy	Mechanism/Action
Develop insight/ awareness	Provide detailed descriptions and thorough characterizations of known cognitive biases, together with multiple clinical examples illustrating their adverse effects on decision-making and diagnosis formulation.
Consider alternatives	Establish forced consideration of alternative possibilities e.g., the generation and working through of a differential diagnosis. Encourage routinely asking the question: What else might this be?
Metacognition	Train for a reflective approach to problem solving: stepping back from the immediate problem to examine and reflect on the thinking process.
Decrease reliance on memory	Improve the accuracy of judgments through cognitive aids: mnemonics, clinical practice guidelines, algorithms, hand-held computers.
Specific training	Identify specific flaws and biases in thinking and provide directed training to overcome them: e.g., instruction in fundamental rules of probability, distinguishing correlation from causation, basic Bayesian probability theory.
Simulation	Develop mental rehearsal, “cognitive walkthrough” strategies for specific clinical scenarios to allow cognitive biases to be made and their consequences to be observed. Construct clinical training videos contrasting incorrect (biased) approaches with the correct (debiased) approach.
Cognitive forcing strategies	Develop generic and specific strategies to avoid predictable bias in particular clinical situations.
Make task easier	Provide more information about the specific problem to reduce task difficulty and ambiguity. Make available rapid access to concise, clear, well-organized information.
Minimize time pressures	Provide adequate time for quality decision-making.
Accountability	Establish clear accountability and follow-up for decisions made.
Feedback	Provide as rapid and reliable feedback as possible to decision makers so that errors are immediately appreciated, understood, and corrected, resulting in better calibration of decision makers.[26]

*Based on information from: Slovic and Fischhoff (1977),[19] Fischhoff (1982),[15] Arkes (1986),[16] Plous (1993),[23] Croskerry (2002),[9] and Croskerry (2003).[10]

Croskerry (2003)

III. Where?

Applications to user technology

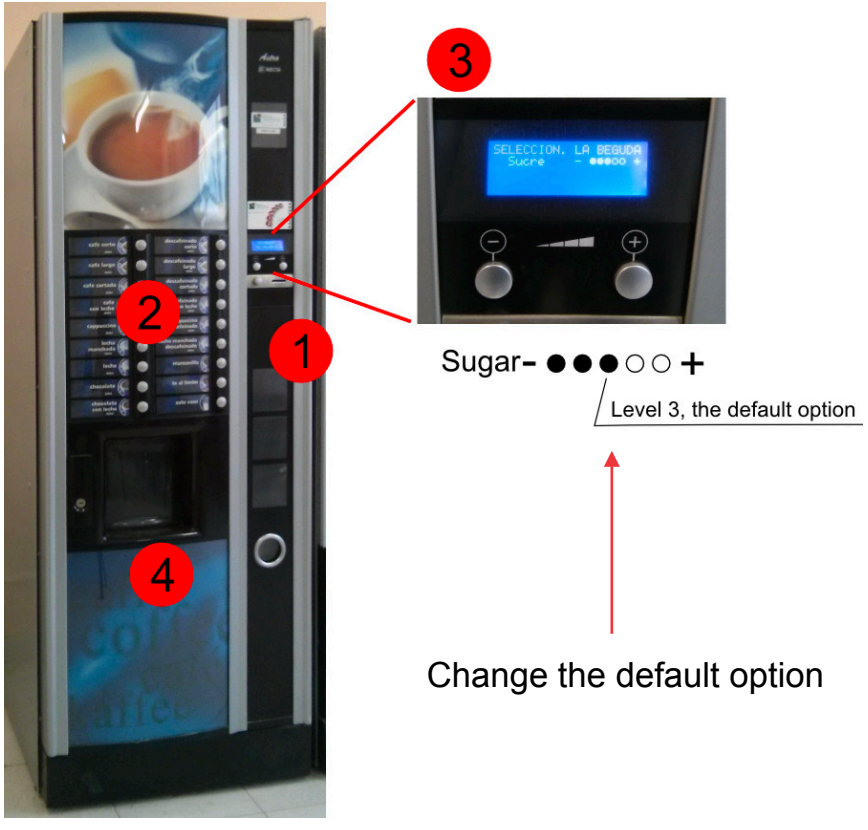
E.g. help people to have healthier food habits, by changing the default option

Bias:

- **Status quo** (Kahneman, Thaler, and Knetsch, 1991)

Preference for the current state

⊗ Can lead to inconsistent preferences



Thaler & Sunstein (2008)

Take home message 3

Effects of **heuristics and biases** can be exploited to **affect behaviour**

Lecture Summary

Outline	Objectives
I. What?	Understand **what heuristics and biases are** and describe some examples of them → **Human decision-making** is subject to systematic **heuristics and biases** **(e.g. representativeness, loss aversion)**
II. Why?	Contrast the **main hypotheses** that could **explain why** such heuristics and biases exist → **Heuristics and biases** can be an **efficient mean** to interact with a **complex** environment
III. Where?	Have an idea about how understanding of these heuristics and biases can be **applied** in **practice** → Effects of **heuristics and biases** can be exploited to **affect behaviour**

Q & A

For any further questions: aini.putkonen@aalto.fi

Take home messages

1. **Human decision-making** is subject to systematic **heuristics and biases** **(e.g. representativeness, loss aversion)**
2. **Heuristics and biases** can be an **efficient mean** to interact with a **complex** environment
3. Effects of **heuristics and biases** can be exploited to **affect behaviour**

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Materials adapted from previous year's lecture slides from Aurélien Nioche