Cognitive Psychology

Heuristics & Biases

Overview

- **How do we make decisions under uncertainty?**
  - Rational choice theory
  - The Tversky-Kahneman challenge
  - The Evolutionary psychology response
  - Probabilities vs relative frequencies
- Adaptive biases, and error-management theory

Ben Franklin’s advice to his nephew

“If you doubt, set down all the Reasons, pro and con, in opposite Columns on a Sheet of Paper, and when you have considered them two or three Days, perform an Operation similar to that in some questions of Algebra; observe what Reasons or Motives in each Column are equal in weight, one to one, one to two, two to three, or the like, and when you have struck out from both Sides all the Equalities, you will see in which column remains the Balance [...] This kind of Moral Algebra I have often practiced in important and dubious Concerns, and tho’ it cannot be mathematically exact, I have found it extremely useful. By the way, if you do not learn it, I apprehend you will never be married.”

I am ever your affectionate uncle,

B. FRANKLIN

Rational choice theory: One theory about decision-making

Marry or not? Go the party or stay home and study? Etc.

Assumes

- that people have transitive preferences and can state them
- that they consider all available information about the options,
- the probability of events,
- their costs and benefits,
- and decide based on which produces the best outcome.

Rational choice and its detractors

Do people actually do this?

The Tversky-Kahneman revolution

People use rules of thumb (heuristics),

They do not calculate probabilities in their heads.

These heuristics can lead to systematic biases and distortions.

The representativeness heuristic

”Steve is very shy and withdrawn, invariably helpful, but with little interest in people or in the world of reality. A meek and tidy soul, he has a need for order and structure and a passion for detail”.

Is Steve:

- a farmer?
- a salesman?
- an airline pilot?
- a librarian?
- a physician?

People ignore base rates, if given other info

”Dick is a 30 year old man. He is married with no children. A man of high ability and high motivation, he promises to be quite successful in his field. He is well liked by his colleagues”

Is he an engineer or a lawyer? Two groups of subjects:

Half told that the group had 70 engineers and 30 lawyers, the other half told group had 70 lawyers and 30 engineers.

Both judged his probability of being an engineer to be 50% (but with no personality sketch, they gave the correct probabilities)

Availability heuristic (1)

What is more frequent, dying from shark attacks or from falling airplane parts?

Availability heuristic

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Shark attacks get a lot of publicity, but falling airplane parts kill 30 times more people.

The likelihood of an event is assessed, in part, by the relative ease of recall, or the ease with which they can imagine similar events (availability).

Availability heuristic (2)

Are there more words that begin with the letter k or have k in the third position?

Availability heuristic

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Most people think there are more works that start with k, but there are about twice as many words with k in the 3rd position

It’s easier to think of words that start with k, so we think they are more common

Other cognitive biases

Framing effects: When Kahneman and Tversky asked people to hypothetically decide what procedure to take to cure a disease, most preferred a procedure that saved 80 percent of people to one that killed 20 percent.

Adjustment and anchoring: people make estimates by starting from an initial value and adjusting it up or down. The adjustments are usually insufficient - the estimates are anchored to the initial values.

The evolutionary psychology rebuttal

Is the brain just badly designed?

The Evolutionary Psychology response:

Heuristics produce good results in real life circumstances when information is given as it would have appeared in the EEA

Cognitive heuristics

A heuristic is a rule of thumb, like perceptual heuristics:

-- If the circle is shaded on the bottom it's a bump, not a dent

-- If it's fuzzy it's probably farther away (a distance heuristic).

Usually correct, but not always: optical illusions find those cases

Tversky & Kahneman describe "cognitive illusions" that illustrate the mind's cognitive heuristics

The availability heuristic re-considered

The subjective probability of traffic accidents rises temporarily when one sees a car overturned by the side of the road.

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- Things easier to recall are usually more frequently encountered
- Things change, more recent information more valuable
- Mismatch: brain evolved to get information directly, not via media

Another example: The gambler’s fallacy

A coin has just come up heads four times in a row. Is it more likely to come up heads or tails on the next flip?

People who say tails are falling prey to the gambler’s fallacy. After observing a long run of heads, they feel that tails are now due.

The gambler’s fallacy is the belief that these sequential flips are not independent. Why do so many people fall prey to this fallacy?

Another example: The gambler’s fallacy

fair coins, dice, & roulette wheels are very specifically engineered so that flips are independent.

But in the real world, most events involve processes where future events are not independent of past ones.

The longer I gather in this food patch the more likely it is to be used up.

Even with random things like the weather, sequential weather events are not independent

The Linda problem (probability version)

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 of the following is more probable?

1. Linda is a bank teller

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

The conjunction fallacy

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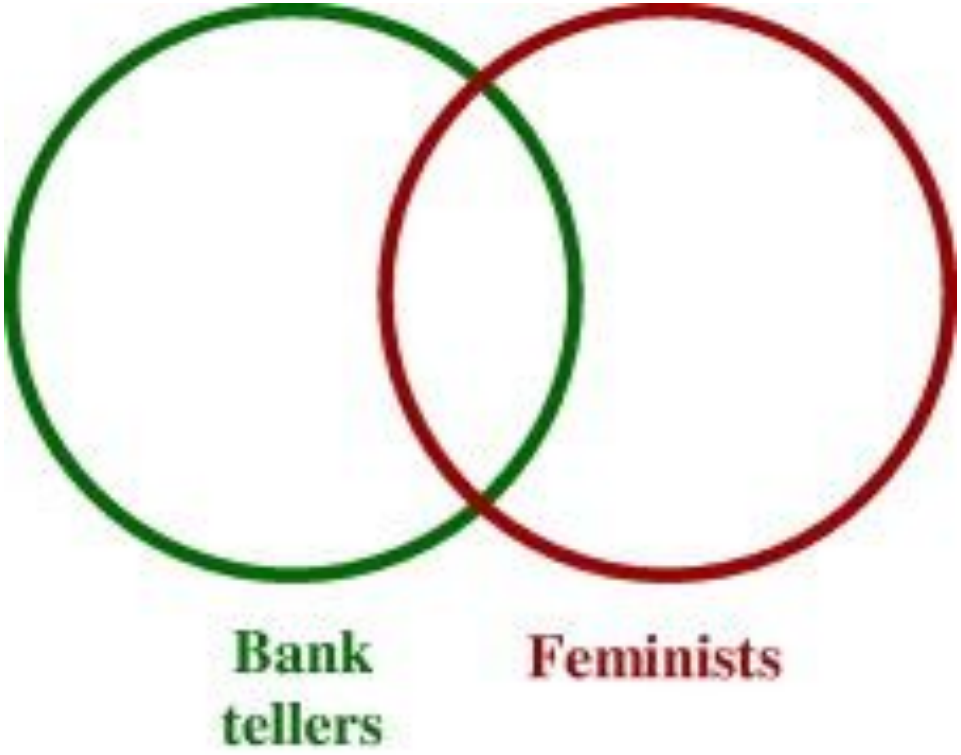
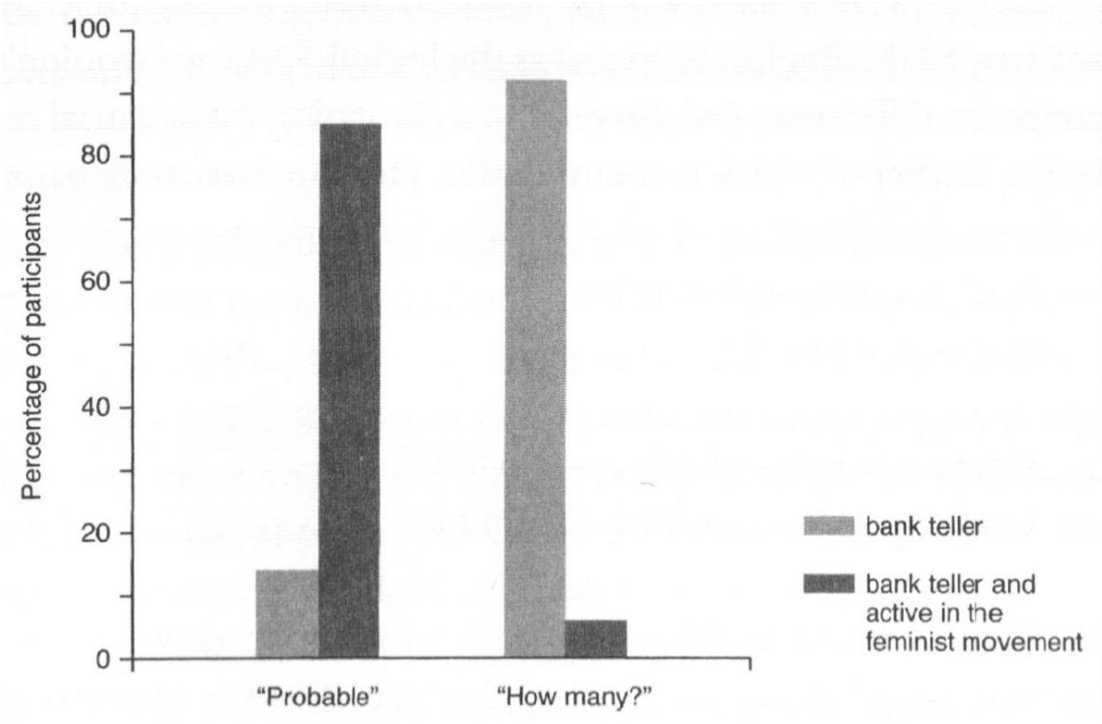


The Linda problem (frequency version)

There are a hundred people who fit the description above. How many of them are:

(1) 1. bank tellers

(2) bank tellers and active in the feminist movement



from Hertwig and Gigerenzer, eported in Gigerenzer 2007

The mammogram problem in probabilities

The probability of breast cancer is 1% for a woman at age forty who participates in routine screening.

If a woman has breast cancer, the probability is 80% that she will have a positive mammogram.

if a woman does not have breast cancer, the probability is 9.6% that she will also have a positive mammogram.

Imagine a woman in this age group who had a positive mammogram in routine screening. What is the probability that she has breast cancer?

A hard problem! But important.

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$$p(C|M) = \frac{p(C)p(M|C)}{p(C)p(M|C) + p(-C)p(M|-C)} = \frac{(.01)(.80)}{(.01)(.80) + (.99)(.096)} = .078$$

The correct answer is 7.8%, but 95% of 100 physicians judged it to be between 70% and 80%

The mammogram problem in frequencies

Imagine an old, experienced physician in an illiterate society. She has no books or statistical surveys and therefore must rely solely on her experience. Her people have been afflicted by a previously unknown and severe disease. Fortunately, the physician has discovered a symptom that signals the disease, although not with certainty.

In her lifetime, she has seen 1,000 people, 10 of whom had the disease. Of those 10, 8 showed the symptom; of the 990 not afflicted, 95 did.

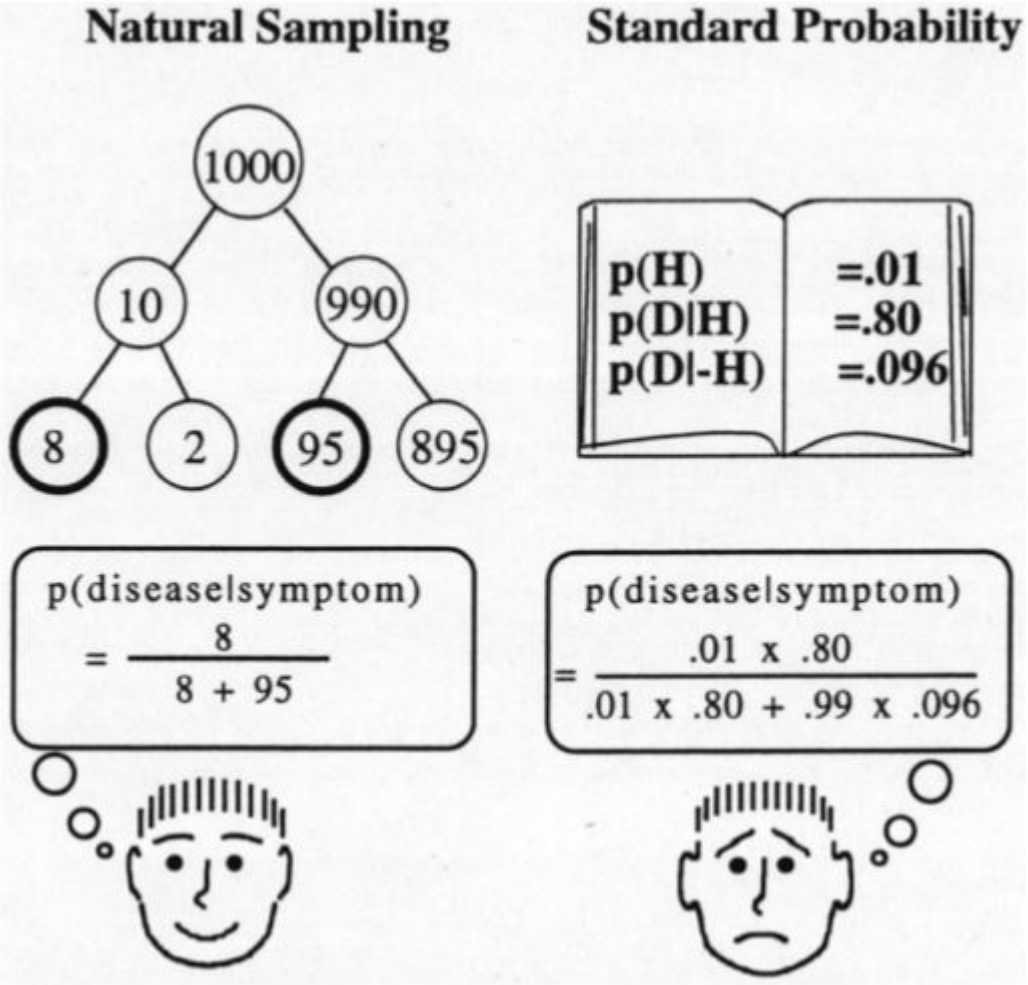
Now a new patient appears. He has the symptom. What is the probability that he actually has the disease?

Gigerenzer and Hoffrage 1995

The mammography solution, in frequencies

“In her lifetime, she has seen 1,000 people, 10 of whom had the disease. Of those 10, 8 showed the symptom; of the 990 not afflicted, 95 did.”

- 103 (95+8) people have shown the symptom
- 8 people have had the disease
- The likelihood that a person with the symptom also has the disease is 8/103 (7.8%)


Natural Sampling
Standard Probability
1000
10
990
8
2
95
895
p(H) =.01
p(D|H) =.80
p(D|-H) =.096
p(disease|symptom)
= 8 / 8 + 95
p(disease|symptom)
= .01 x .80 / .01 x .80 + .99 x .096

Probabilities vs. frequencies: A real-life story

Defense attorney Dershowitz argued that O.J.'s prior beatings of his murdered ex-wife were not relevant. He stated that only about 1/10 of 1% of wife batterers actually murder their wives.

Statistician I. J. Good disputed that conclusion in an article in *Nature.*

He wrote his analysis using 6 equations starting with Dershowitz's estimate that the probability of a battered woman being killed by her husband is at least 1/10,000:

$$p(\mathrm{G}|\mathrm{Bat}) > (1/10)\,(1/1{,}000) = 1/10{,}000 \qquad \text{(Good-1)}$$

Therefore, the prior odds (O) are:

$$\mathrm{O}(\mathrm{G}|\mathrm{Bat}) > 1/9{,}999 \approx 1/10{,}000 \qquad \text{(Good-2)}$$

Furthermore, the probability of a woman being murdered given that her husband has murdered her (whether he is a batterer or not) is unity:

$$p(\mathrm{M}|\mathrm{G}\text{ and }\mathrm{Bat}) = p(\mathrm{M}|\mathrm{G}) = 1 \qquad \text{(Good-3)}$$

Because there are about 25,000 murders per year in the US population of about 250,000,000, Good estimates the probability of a woman being murdered, but not by her husband, as:

$$p(\mathrm{M}|\bar{\mathrm{G}}\text{ and }\mathrm{Bat}) = p(\mathrm{M}|(\bar{\mathrm{G}}) \approx 1/10{,}000 \qquad \text{(Good 4)}$$

From Equations Good-3 and Good-4, it follows that the likelihood ratio is about 10,000/1; therefore, the posterior odds can be calculated:

$$\mathrm{O}(\mathrm{G}|\mathrm{M}\text{ and }\mathrm{Bat}) > 10{,}000/10{,}000 = 1 \qquad \text{(Good-5)}$$

That is, the probability that a murdered, battered wife was killed by her husband is:

$$p(\mathrm{G}|\mathrm{Bat}\text{ and }\mathrm{M}) > 1/2 \qquad \text{(Good-6)}$$

Good’s argument in natural frequencies

Think of 10,000 battered married women. Within one year, at least one will be murdered by her husband. Of the remaining 9,999 who are not killed by their husbands, one will be murdered by someone else.

Thus we expect at least two battered women to be murdered, at least one by her husband, and one by someone else.

Therefore, the probability p(G|Bat and M) that a murdered, battered woman was killed by her husband is at least 1/2.

The point of the story

The brain’s heuristics work splendidly, but only if you give it inputs (data) of the sort it experienced in its evolutionary past.

Your calculator expects data in base 10. If you enter data in base 2, don’t complain that its algorithm is wrong.

We evolved in a world where we experience data in frequencies (counts), not probabilities. Given a problem in that form, people are able to solve it.

Adaptive biases

It’s not that the human mind lacks cognitive biases, but many of the cognitive heuristics are ’adaptively biased’.

Examples?

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1. Smoke-detector principle (over-response to dangerous threats)
2. Perceptual biases (many optical illusions)
3. Emotional biases (fear makes slopes look steeper, etc)
4. Men more likely than women to infer sexual intent

“Error-management theory”: evolved perceptual & cognitive biases

Summary

We solve problems using “heuristics” -- rules of thumb

These heuristics sometimes fail. But usually work well in real life, with information as we would have received it in the EEA

People are good intuitive statisticians when presented with natural frequencies (count) data, not probabilities.

Many of our cognitive, perceptual, and emotional heuristics are biased in ways that are adaptive (“error-management theory”)