

## Bayesianism in Cognitive Science

Central question: what capacities and mechanisms underlie rational thinking?

**The problem:** How do our minds get so much from so little? We build rich causal models, make strong generalizations, and construct powerful abstractions, whereas the input data are sparse, noisy, and ambiguous—in every way far too limited.



**The Bayesian answer:** *Computational* models that perform *probabilistic (Bayesian) inference* over *hierarchies of flexibly structured representations*.

The bottom line: at a sub-personal level, your cognitive system is using Bayes' Rule to acquire concepts and language from scarce data received from the environment.

### Bayes' Rule

$$P(A|B) = \frac{P(B|A) P(A)}{P(B)}$$

↑ THE PROBABILITY OF "A" BEING TRUE GIVEN THAT "B" IS TRUE  
 ↓ THE PROBABILITY OF "B" BEING TRUE GIVEN THAT "A" IS TRUE  
 THE PROBABILITY OF "A" BEING TRUE  
 THE PROBABILITY OF "B" BEING TRUE

**Example 1.** We observe John coughing (d), and we consider three hypotheses as explanations: John has h1, a cold; h2, lung disease; or h3, heartburn. Use Bayes' rule, and probability values of your choice, to explain why it only seems compelling that John has a cold.

**Example 2.** We are conducting a test on a rare disease. A positive result means that, according to the test, the subject is infected. The following characteristics are known about the test and the disease:

- If a person is infected, the person has a 99% chance of testing positive.
- When a healthy person is tested, the test has a 99% chance of giving a negative result.
- A mere 0.1% of the population is infected with the disease.

If a person is tested positive for the disease, what is the probability that the person actually has the disease?

### Bayesianism in Cognitive Science

- 1) How does abstract knowledge guide learning and inference from sparse data?
  - a. Bayes' rule.
- 2) What forms does abstract knowledge take, across different domains and tasks?
  - a. Richly structured, expressive representations (graphs, trees, diagrams; not sentences).
- 3) How is abstract knowledge itself acquired?
  - a. Bayes' rule, applied to choosing how to structure one's representation of the world.



### Questions/Objections:

- Does Bayesianism fit with thinking that our cognitive machinery is shaped by natural selection?
- Does Bayesianism square with our difficulties with probabilistic inference?
- Are our minds really performing these calculations or can they just be modeled as doing so?