Introduction to Cognitive Science

(6: Bayesianism in CogSci)

(Ch. 7)

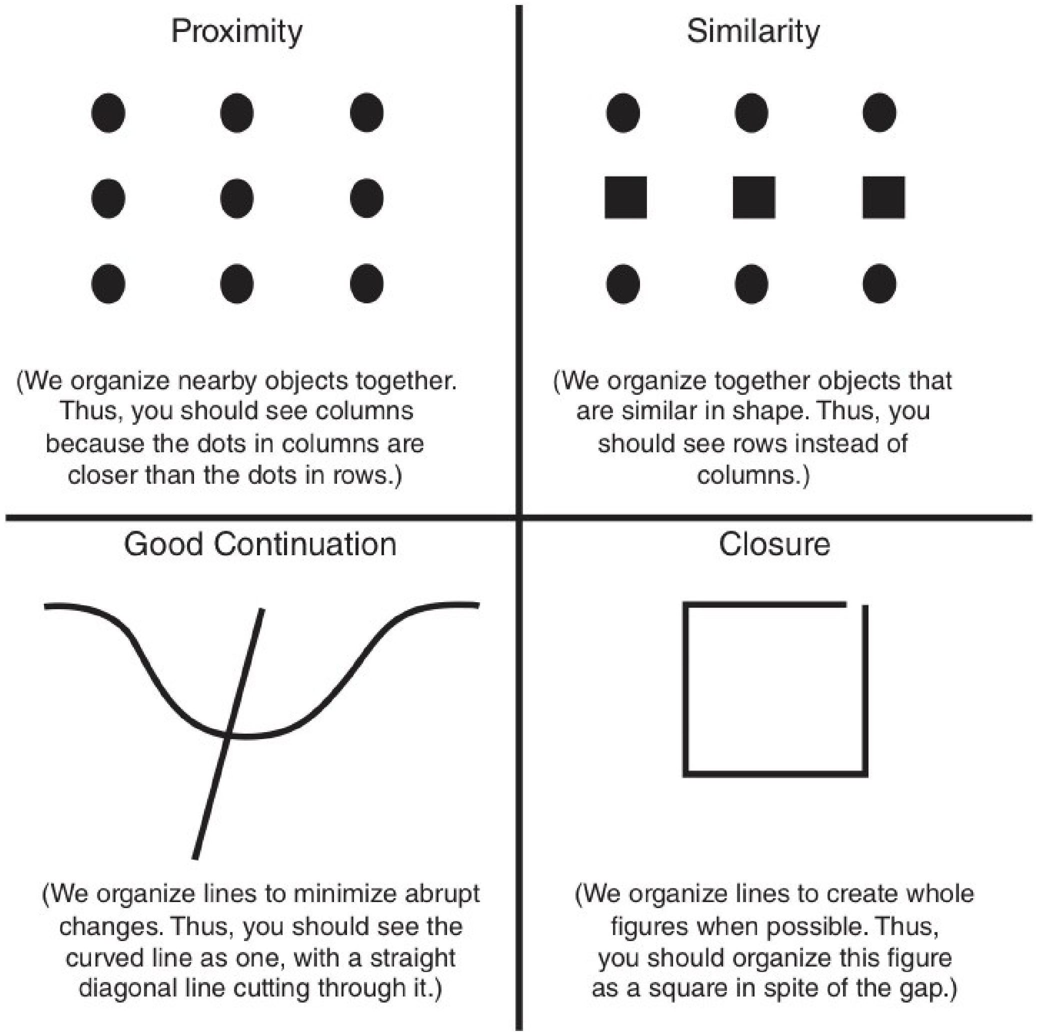
Basics

- Probability, conditional probability, Bayes' theorem
  - https://seeing-theory.brown.edu/
- Key ideas:
  - Belief comes in degrees, which can be modelled as probabilities (OR fuzzy)
  - Learning is updating probabilities
- Knowledge as justified true belief

1983, Iriving Rock: The Logic of Perception

- Seems like the obvious place to apply probability
- Perceptual inference is top-down:
  - Gestalt: the visual system imposes a structure to the retinal image
  - How do the Gestalt principles work?

Gestalt principles



1983, Iriving Rock: The Logic of Perception

- Perceptual systems aim to derive a hypothesis (H) about the layout of the enviroment
- All they have is the evidence from the retina (E)
- Each perceptual system tries to find the H that is most probable given the E
- Perceptual systems store information about the likelyhood of each environmental setup (P(H))
- Also store info on how likely different types of sensory stimulation are, given different layouts of the enviroment (P(E|H))

Applications

- Binocular rivalry
- Neuroeconomics:
  - Brain maximizes expected utility
  - Assumes rationality (by trying to model this maximization)
- Neurons that code for expected utility

Neurons and utility

- How the eyes move:
  - Saccadic movements: scan the enviroment
  - Smooth pursuit eye movement: track moving objects
- Monkeys can be trained to perform saccadic eye movements:
  - Flash a red spot on the right side of the screen. When a monkey makes a saccadic move, gets fruit juice

Neurons and utility

- What happens in the brain between visual detection and saccade?
  - Both ends well understood, but the middle isn't.
  - What happens between detection and initiation of the saccade?
- Platt and Glimcher (2003): a set of complex experiments suggesting that the lateral intraparietal area is carrying out Bayesian calculations

Principal pathways for saccade production

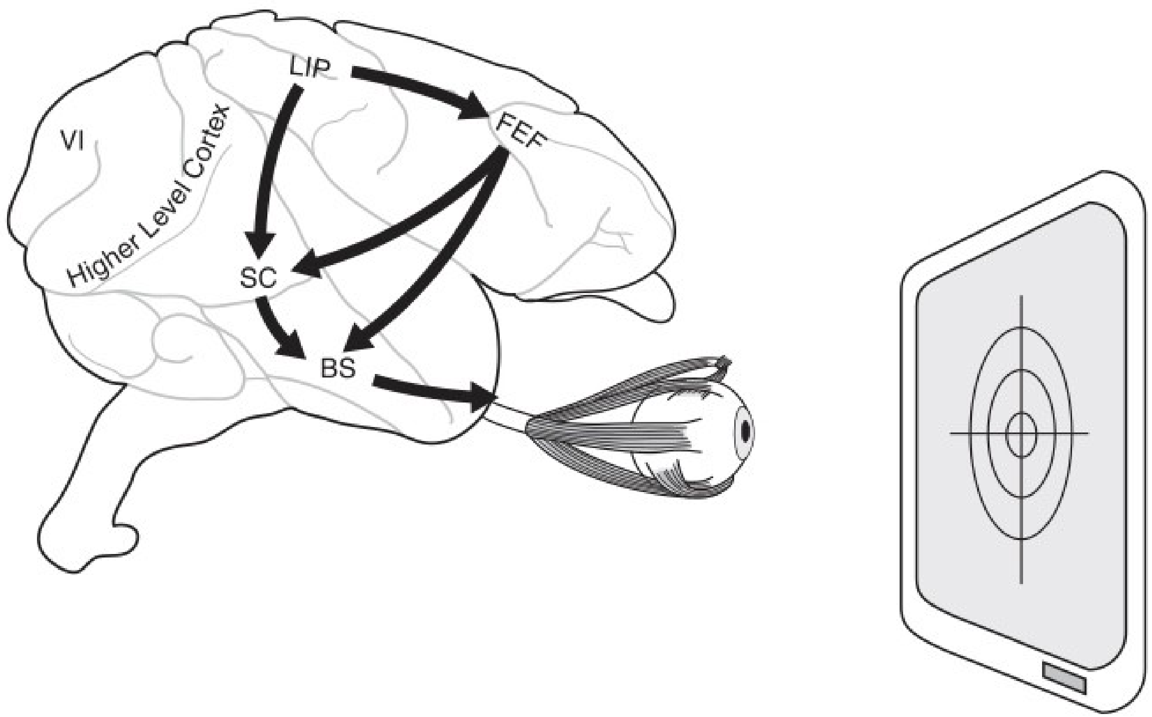


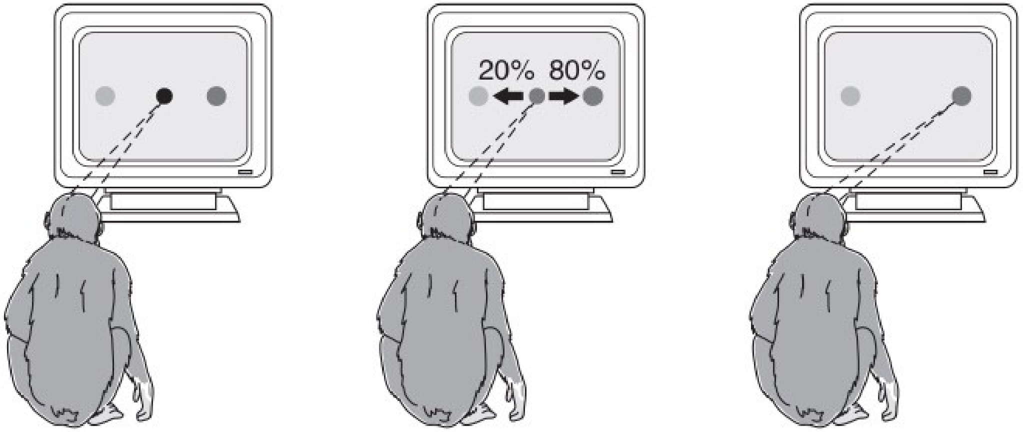
Figure 7.6 The principal pathways for saccade production. LIP = lateral intraparietal area. FEF = frontal eye field. SC = superior colliculus. BS = brain stem. Note that, while LIP and the FEF are cortical structures, SC and BS are much more primitive areas and not part of the forebrain at all. (Figure 10.2 from Glimcher 2003: 230)

Experiments

- A monkey trained to push a lever when it sees a red light on the right-hand side of the visual field: constant reward: 4ml of juice
    - Reward always delivered with the probability of 1, utility constant
- The idea is to vary probability and utility and see which neurons are sensitive to this

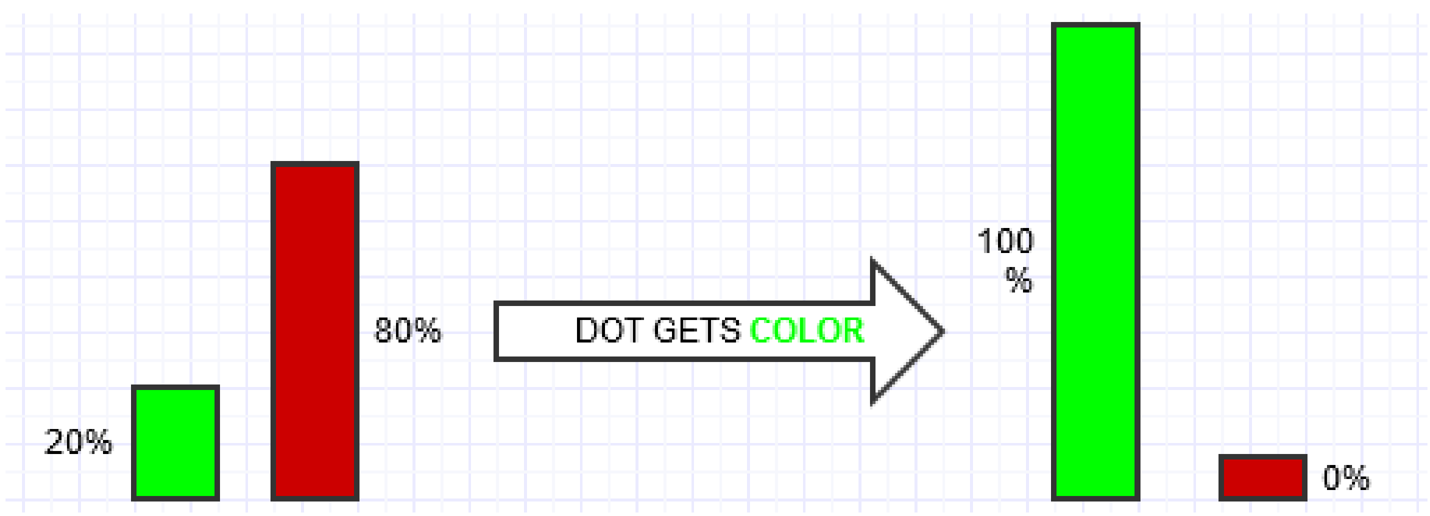
Probability experiments

- Red/green for left/right saccade (80% green in image)
  - A saccade to the right was more likely to get rewarded
  - Blocks of 100 trials with the same probability (after that the monkeys would have figured the pattern)



Probability neurons

- A typical LIP neuron which processes the left field had a much higher firing rate in blocks where the red was higher
  - This is the firing rate before (which, arguably, estimate the probability, not the ones that react)
  - After the change in color, the firing rate was going to be maximal, even though the probability of that saccade would be low



Utility: difference between expected and gained constant, but still proportional!