CIMVSP Panel Discussion

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Questions

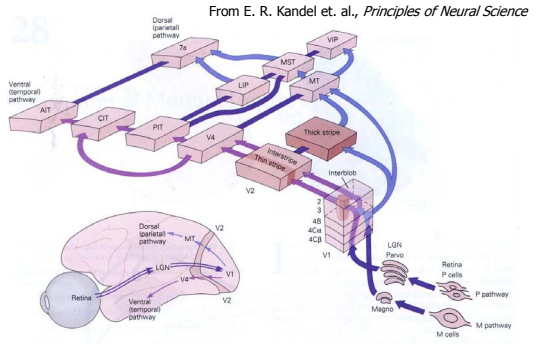
- Is there a single dominant functional/operational principle of brain function and biological intelligence?
- What is (are) your favorite principle(s) of brain function/biological intelligence, and why do you think so?
- What is needed to progress?

My interpretation: As engineers who hope to build "intelligent" systems, what aspect of the brain should we focus on?

My answer: The brain uses a distributed representation of input stimuli based on neurons selective along a multi-dimensional stimulus space.

Cortical Visual Processing

From E. R. Kandel et. al., *Principles of Neural Science*



Multidimensional selectivity

- Position
- Spatial frequency (size)
- Temporal frequency (change)
- Color

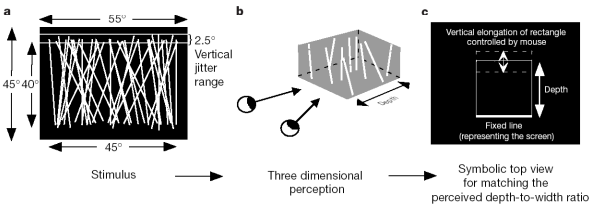
} Retina/ LGN

- Orientation
- Binocular Disparity (depth)
- Direction/speed of motion
- Curvature

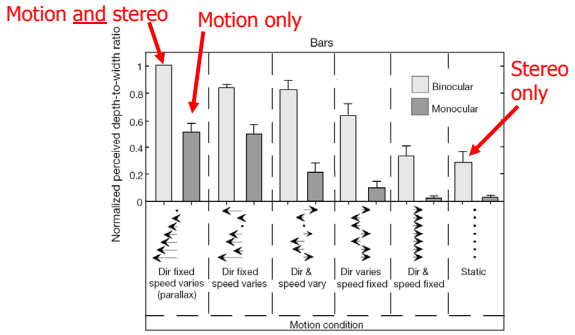
} Primary Visual Cortex (V1)

Why multidimensional selectivity?

- Measured in cortex
- Important perceptually
  - (van Ee and Anderson, *Nature*, 2001)



Improvement over isolated cues



Conjecture

- V1 (and visual cortex in general) reformats the visual data so that it is easier to intepret
  - I/O ratio for retina: 100/1 (compression)
  - I/O ratio V1: input:output ratio ~ 1:50 (expansion!)
- Neuromorphic systems for visual perception should simultaneously integrate information from all cues (orientation, disparity, motion) at a very early stage.

Why is this important?

- The brain's representation of input stimulus is what enables it to learn a wide variety of tasks
  - rapidly
  - flexibly
  - generically
  - efficiently
- Although we have focused on perception, it is likely that a similar principle will hold for action.

What is needed?

- Biology: Mapping the multidimensional selectivity of neurons in the visual cortex, especially in areas beyond V1
- Theory: Probabilistic models of the relationship between model neural responses and behaviorally relevant input stimulus variables
- Hardware: Efficient hardware architectures for simulating large populations of neurons with multidimensional selectivity
- Systems: Robotic systems that couple neuromorphic representations with action to generate behavior