

Cognitive Construction of Space: Part II

Renjie Yang

Capital Normal University
Department of Philosophy

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The Story of Epistemology So Far

- Kant claimed to had explained why arithmetic and geometry can be known *a priori* with certainty.
- He also claimed that he provided a refutation of Hume's skepticism about induction. Although the metaphysical skepticism is still there.
- Kant's idea is that the Euclidean space and time is the pure form of our intuition.
- But is that true? Can we learn about how we know where thing are using empirical methods?

The Construction of Space

How our senses and motor systems construct space?

Vision



Hearing



Touch



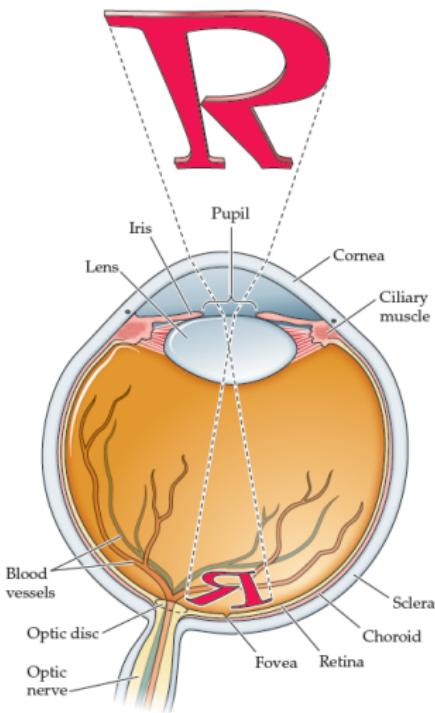
Body position

Movement

Balance

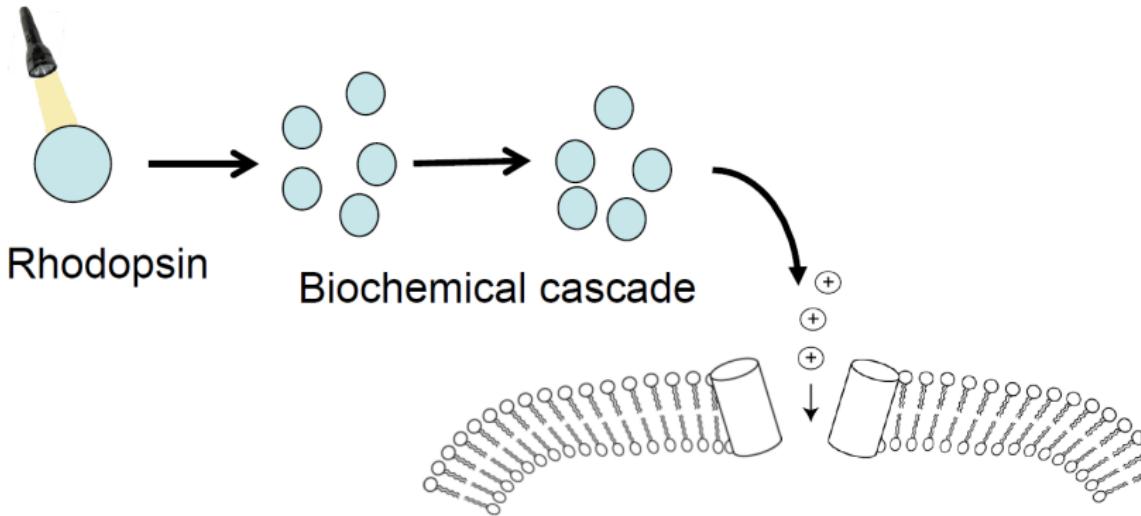


Visual System



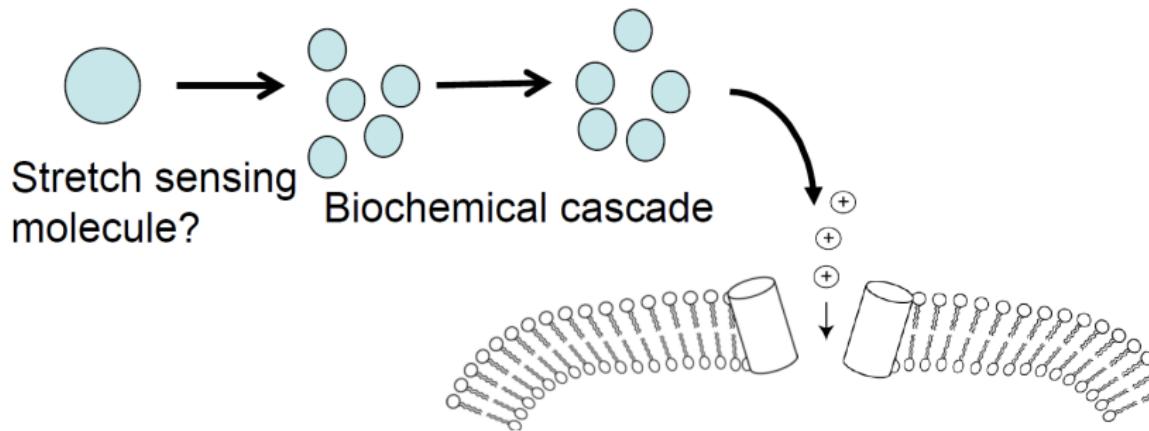
Behavioral Neuroscience, Figure 10.1

Visual Sensation

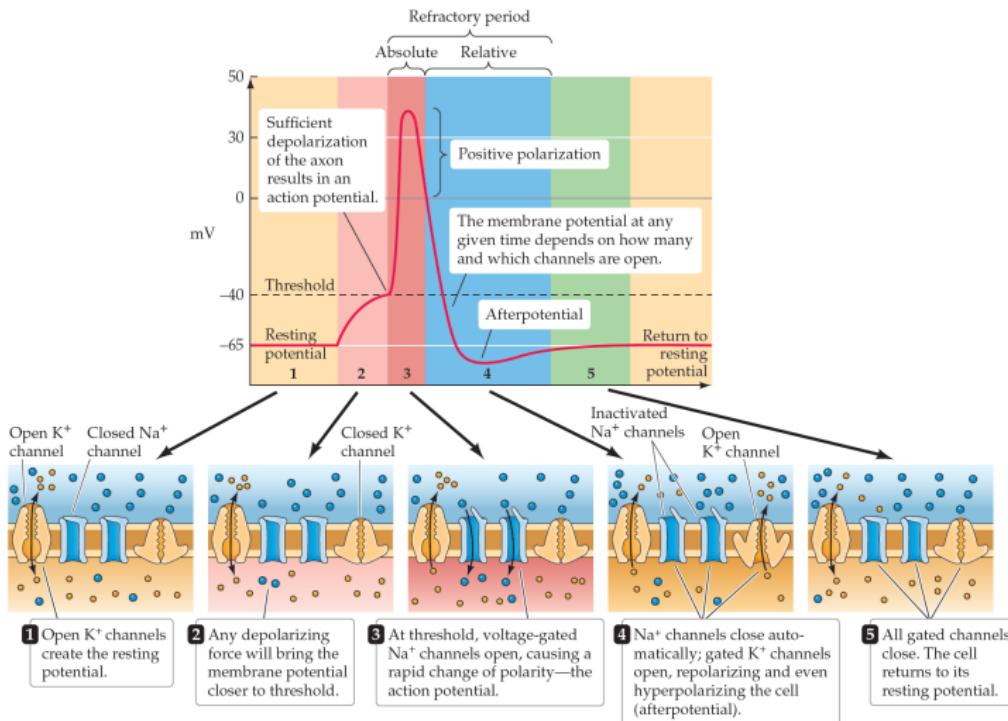


Possible mechanotransduction mechanism 2

Lackner, J. R. (1988)



The Action Potential



Outline

- ① Visual Perception
- ② Spacial Image Formation
- ③ Body Position Sensing
- ④ Neural Signals
- ⑤ **Brain Maps**
- ⑥ Sound and Brain Representations
- ⑦ Reference Frames and Navigation
- ⑧ Memory and Cognition

Figure-Ground Segregation

Rubin's Face-Vase Illusion

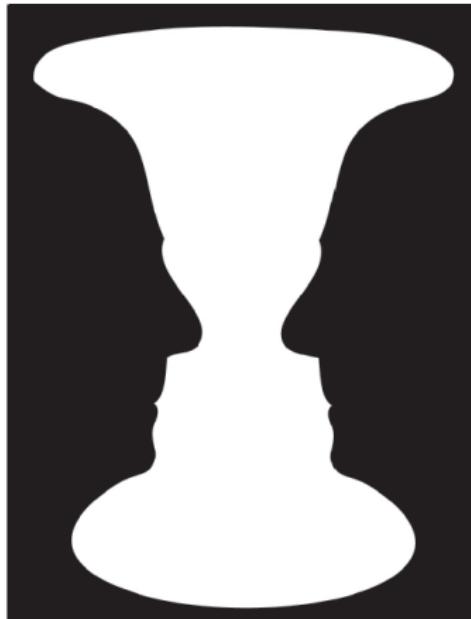
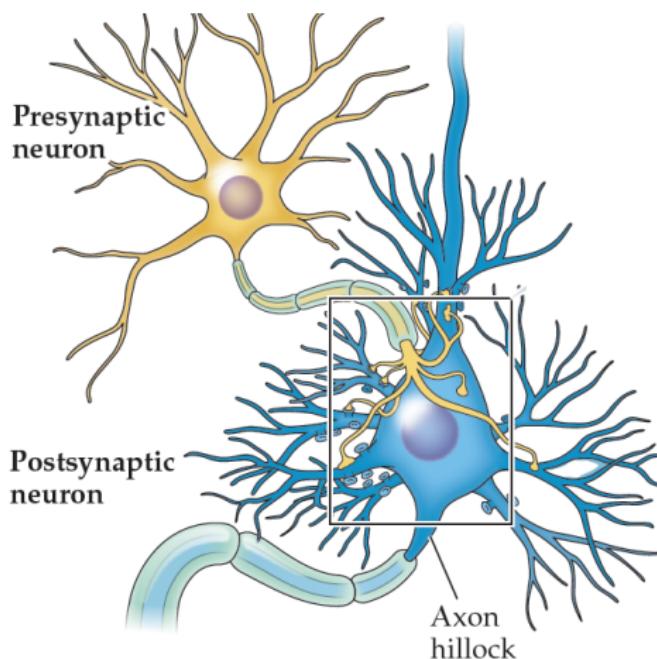


Figure-Ground Segregation

M. C. Escher "Mosaic II"

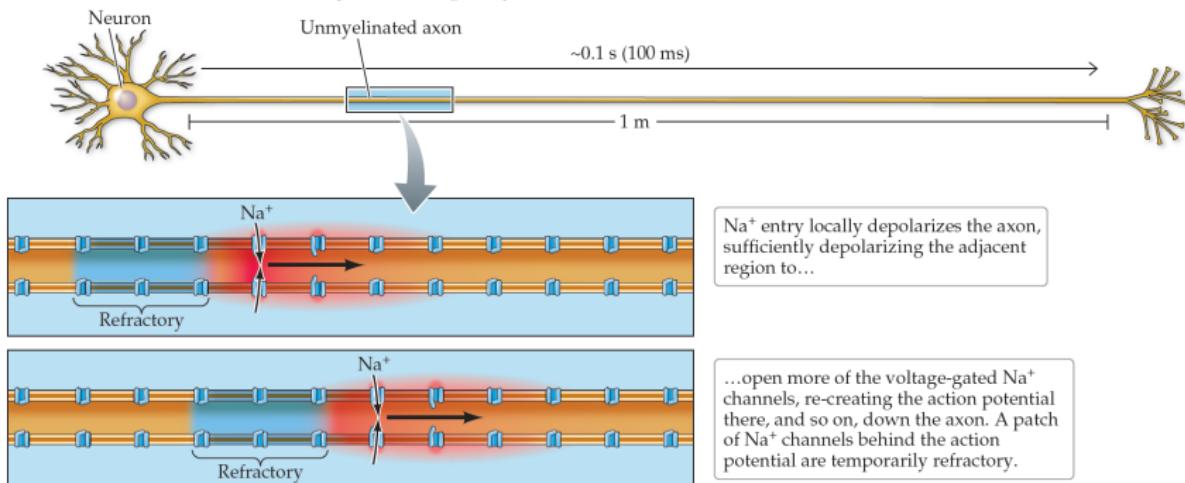


Neural Communication



Propagation of Action Potential

(A) Slow (10 m/s) conduction of action potential along unmyelinated axon

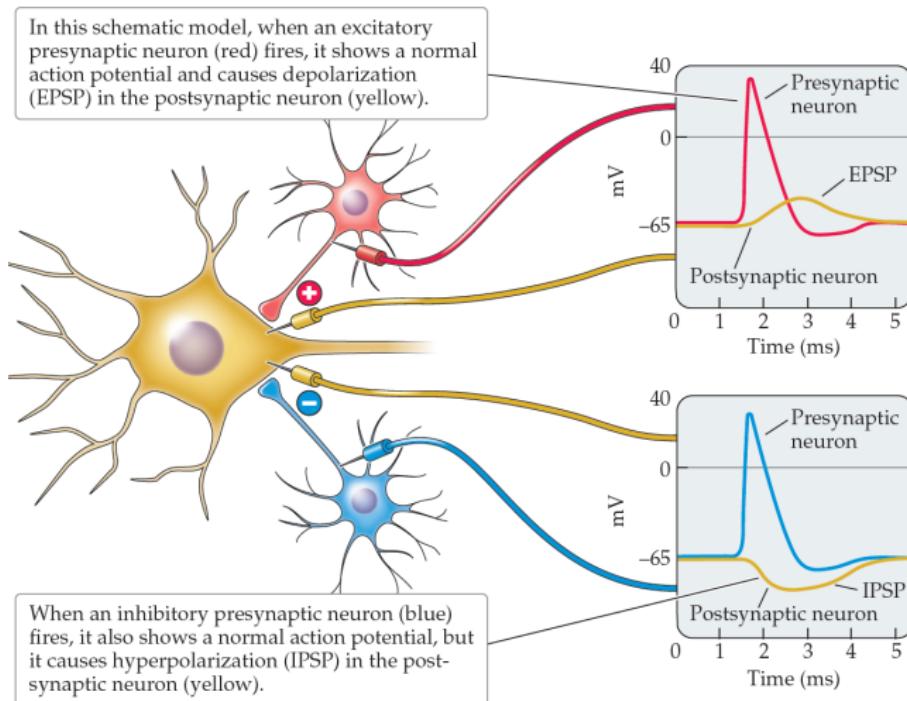


Biological Psychology, Figure 3.8

Postsynaptic Potentials

- Postsynaptic potentials are brief changes in the resting potential. 2 types:
- Excitatory postsynaptic potential: produces a small local depolarization, pushing the cell closer to threshold. This is caused by opening of Na^+ channels on the post-synaptic membrane.
- Inhibitory postsynaptic potential: produces a small hyperpolarization, pushing the cell further away from the threshold. Caused by the influx of Cl^- into the cell. Not action potential, just the small fluctuation of input information for a neuron.

Postsynaptic Potentials

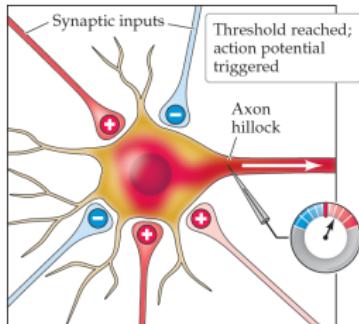


Postsynaptic Potentials

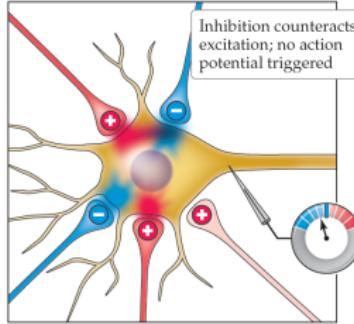
- Neurons perform information processing to integrate synaptic inputs.
- A postsynaptic neuron will fire an action potential if a depolarization that exceeds threshold reaches its axon hillock.
- Discovered by another Nobel Winner: Charles Sherrington (1932 Nobel Prize)

Postsynaptic Potentials

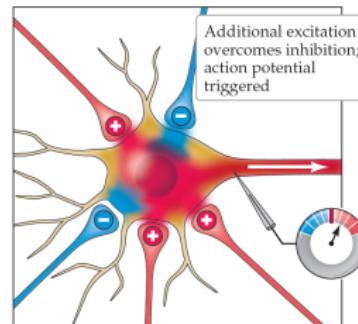
(A) Excitatory inputs cause the cell to fire



(B) Inhibition also plays a role



(C) The cell integrates excitation and inhibition



Biological Psychology, Figure 3.10

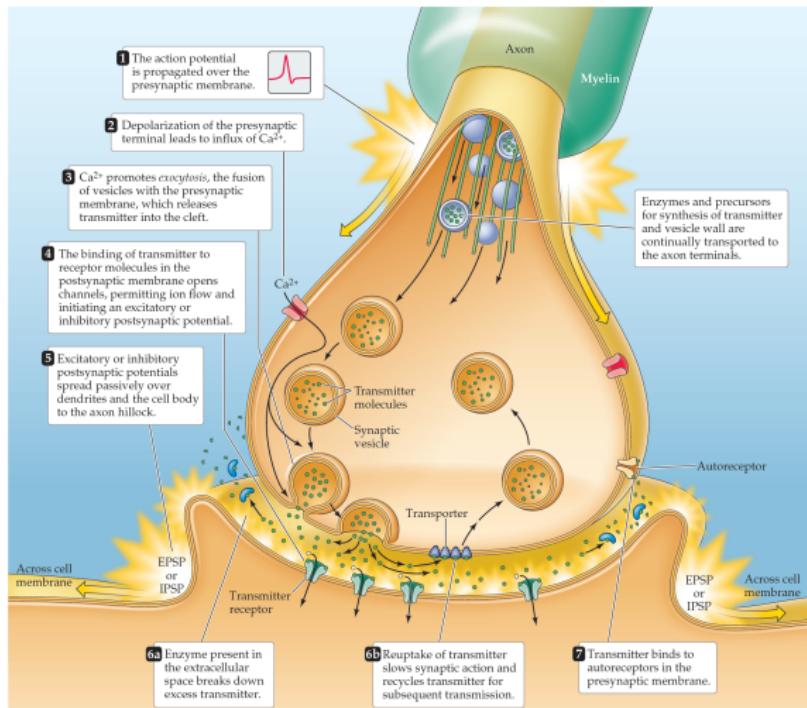
The Sequence of Transmission

- ① Action potential travels down the axon to the axon terminal.
- ② Voltage-gated calcium channels open and calcium ions (Ca^{2+}) enter.
- ③ Ca^{2+} entry causes synaptic vesicles to fuse with membrane and release transmitter into the cleft.
- ④ Transmitter molecules cross the cleft to bind to special receptor molecules in the postsynaptic membrane, leading to the opening of ion channels in the postsynaptic membrane.

The Sequence of Transmission

- ⑤ This ion flow creates a local EPSP or IPSP in the postsynaptic neuron.
- ⑥ Synaptic transmitter is either (a) inactivated (degraded) by enzymes or (b) removed from the synaptic cleft by transporters, so the transmission is brief and accurately reflects the activity of the presynaptic cell.
- ⑦ Synaptic transmitter may also activate presynaptic autoreceptors, regulating future transmitter release.

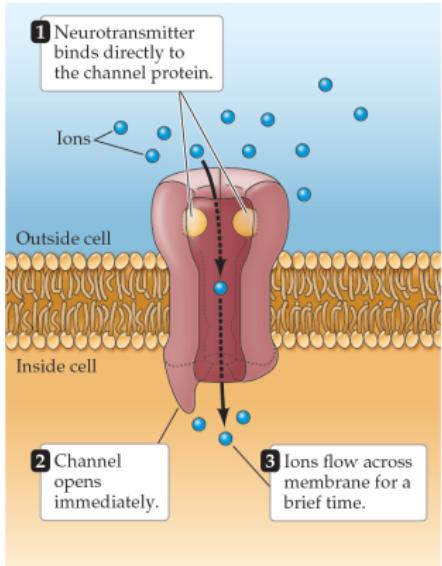
The Key Figure



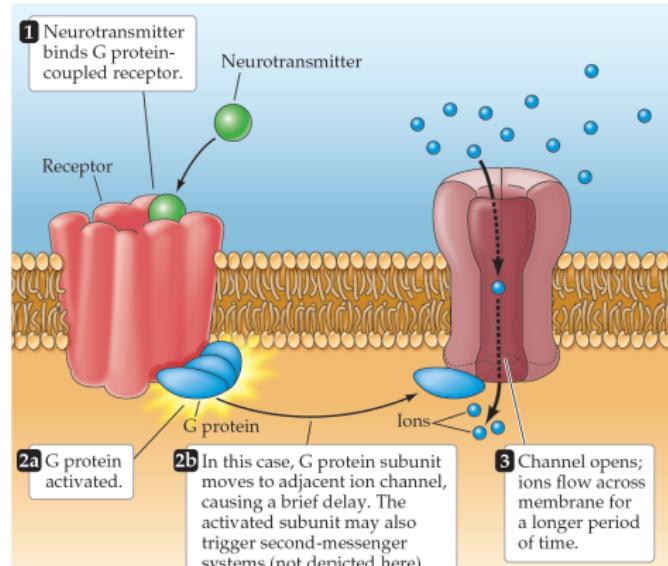
Biological Psychology, Figure 3.12

Receptors

(A) Ionotropic receptor (ligand-gated ion channel; fast)



(B) Metabotropic receptor (G protein-coupled receptor; slow)

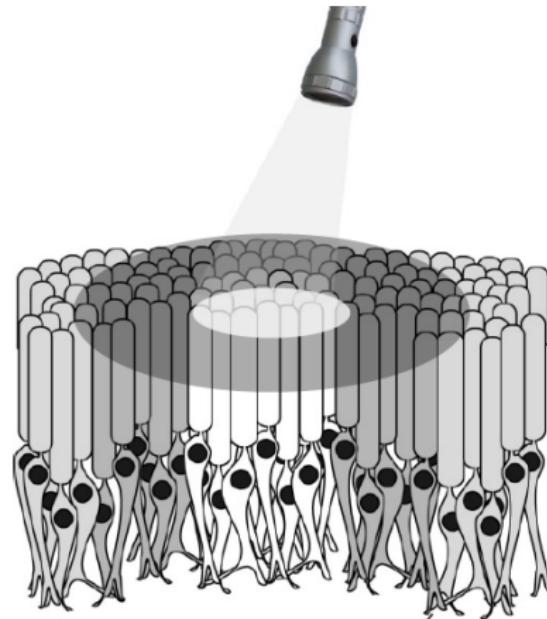


Biological Psychology, Figure 3.16

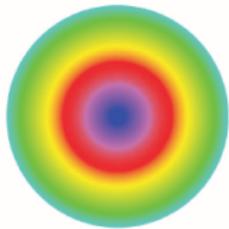
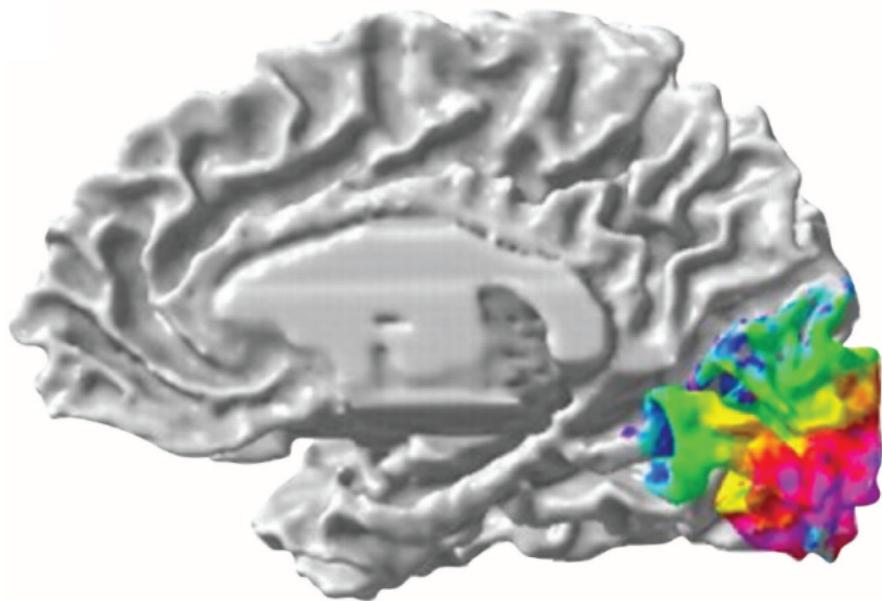
Center Surround Organization

Hubel and Wiesel Video I

[http://www.science.smith.edu/departments/neurosci/
courses/bio330/h%26w.html](http://www.science.smith.edu/departments/neurosci/courses/bio330/h%26w.html)

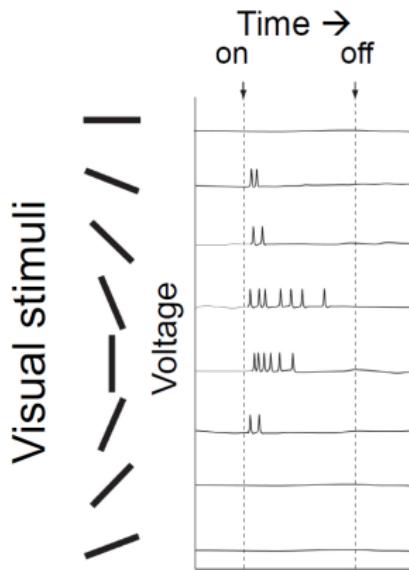


Retinotopic Maps

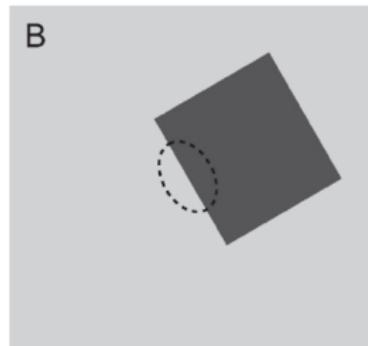
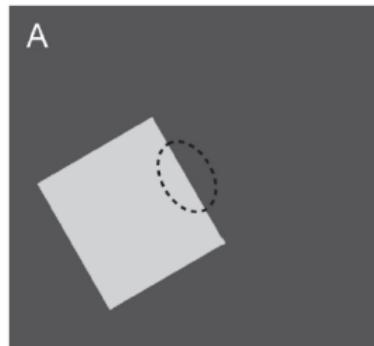


Orientation Selectivity

Hubel and Wiesel Video II



Border Ownership Selectivity



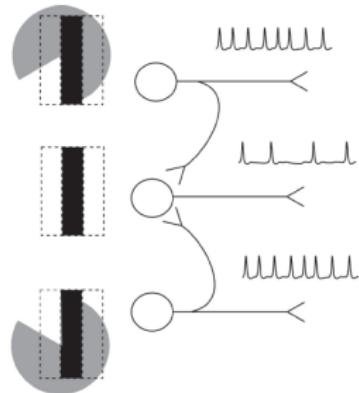
Zhou, H., H. S. Friedman and R. Von Der Heydt
(2000). J. Neurosci. 20(17): 6594-6611.

Kanizsa Triangle: Illusory Contours

a

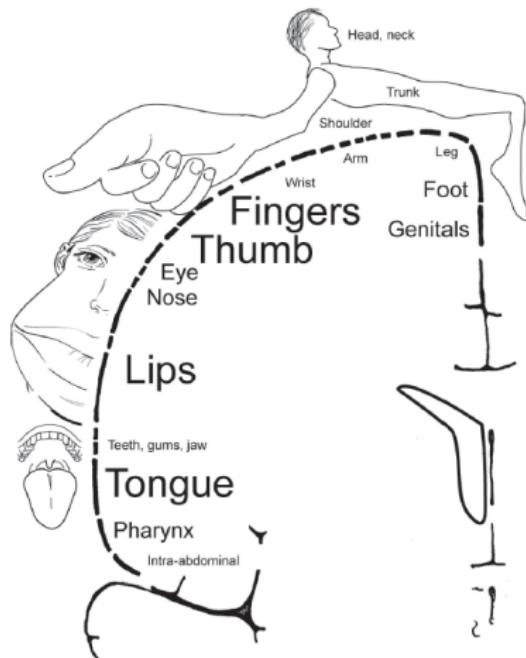


b

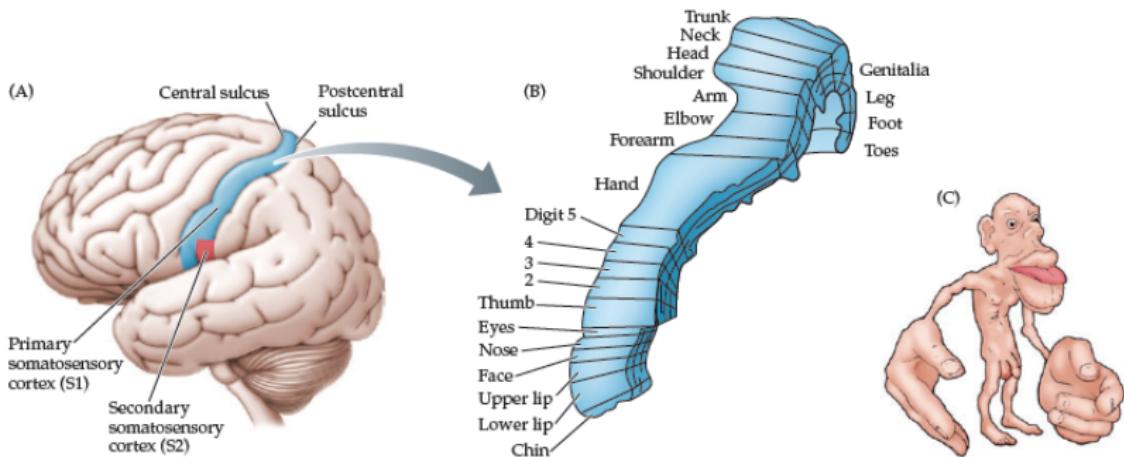


Phantom Limb and Body Map

Amputees feel like missing limb is still present



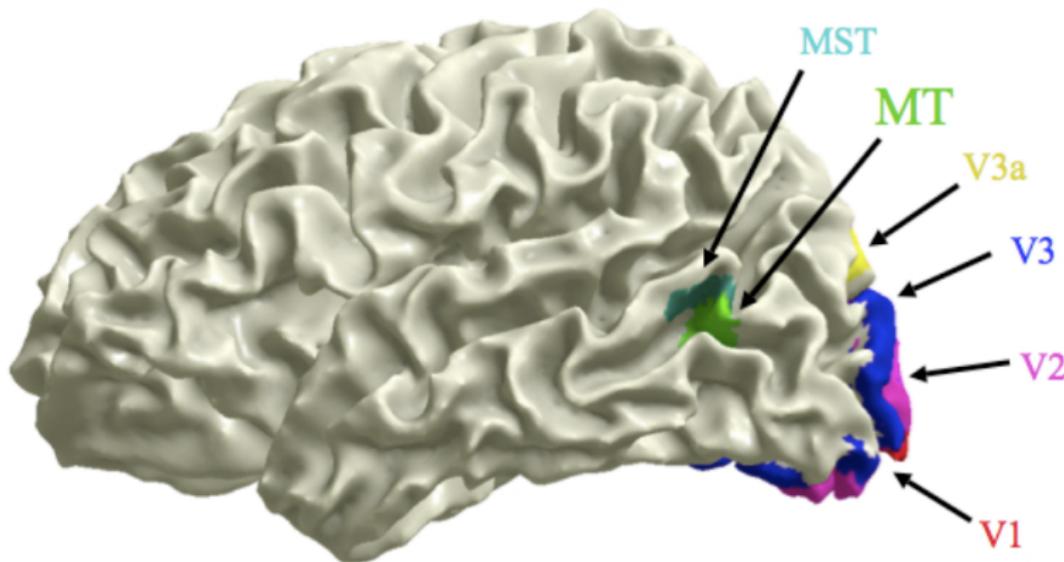
The Body Map



8.10 REPRESENTATION OF THE BODY SURFACE IN SOMATOSENSORY CORTEX

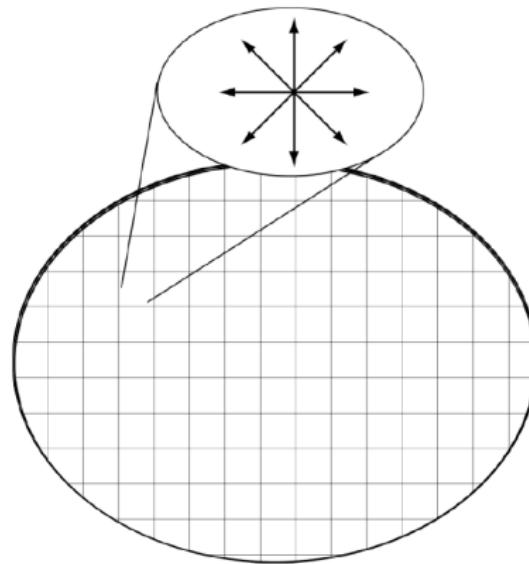
CORTEX (A) The locations of primary (S1) somatosensory cortex on the lateral surface of the parietal cortex. Secondary somatosensory cortex (S2) is much smaller than S1. (B) The order and size of cortical representations of different regions of skin. Note that information from the various parts of the hand and fingers takes up much more room than does information from the shoulder. (C) The *homunculus* (literally, "little man") depicts the body surface with each area drawn in proportion to the size of its representation in the primary somatosensory cortex.

Motion Perception



Retinotopic Map and Velocity Submap

Hubel and Wiesel Video III



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- ⑥ **Sound and Brain Representations**
- ⑦ Reference Frames and Navigation
- ⑧ Memory and Cognition

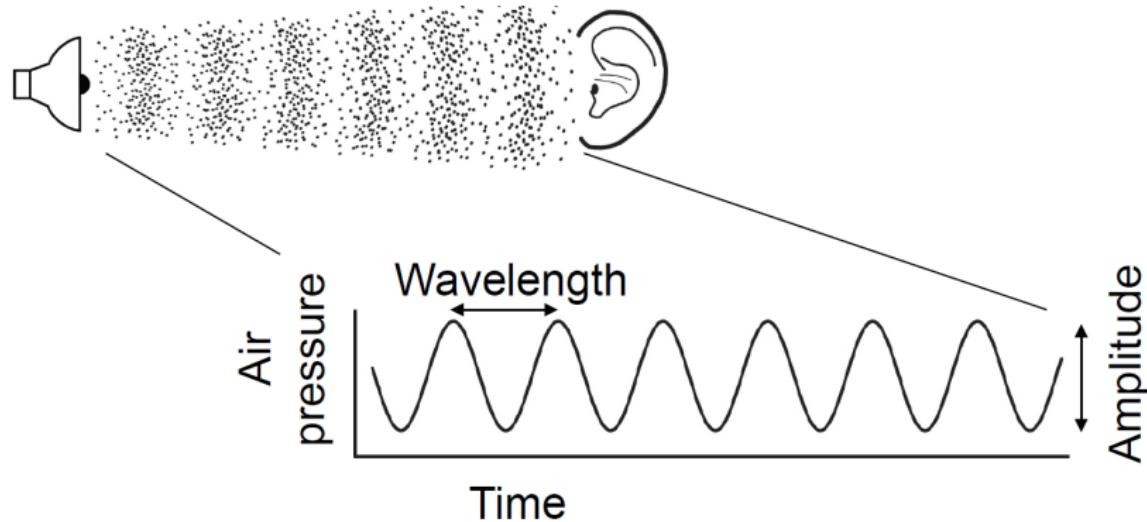
Sound is a Pressure Wave

Compression

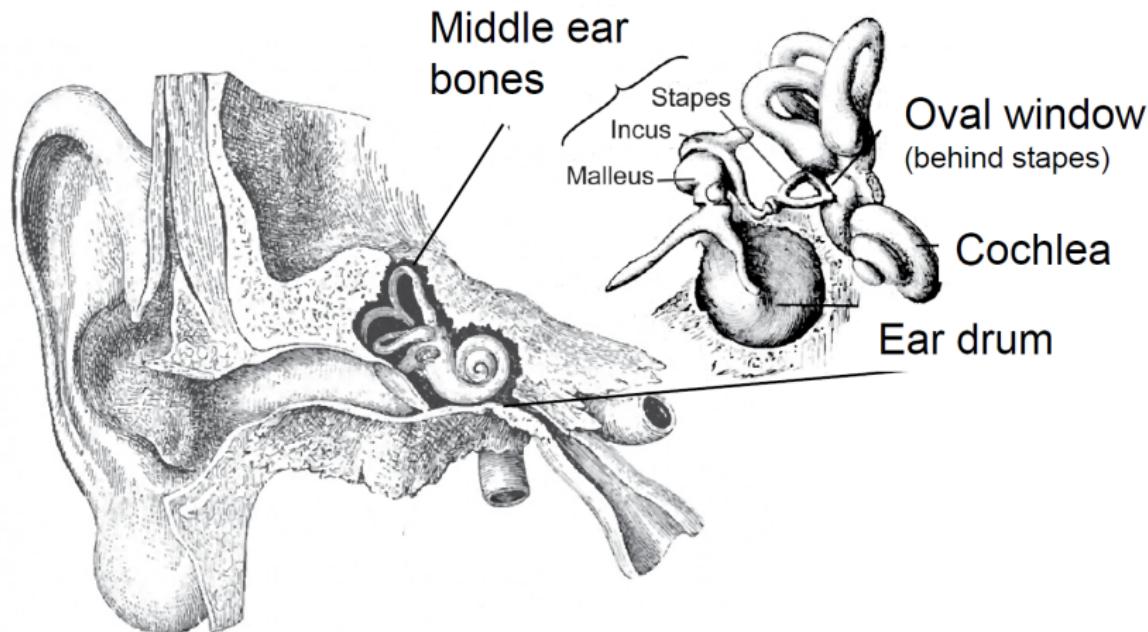
Rarefaction



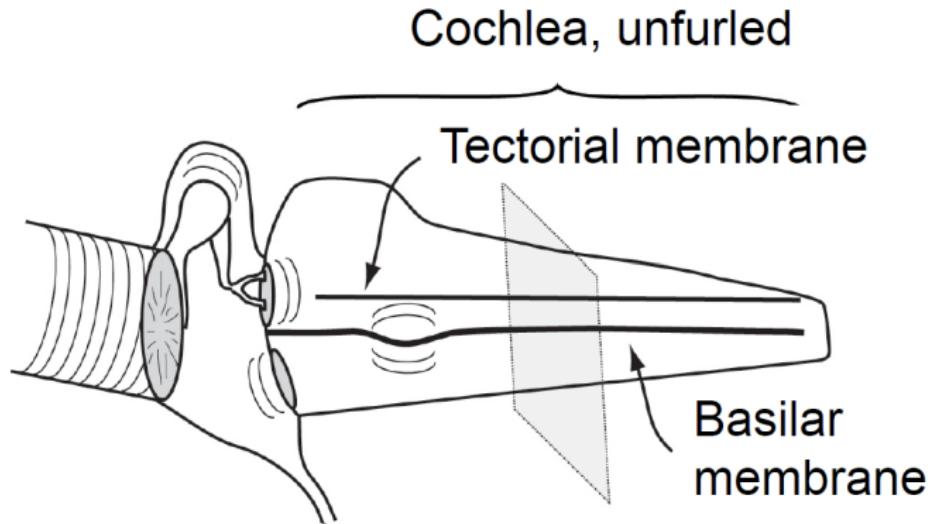
Sound is a Pressure Wave



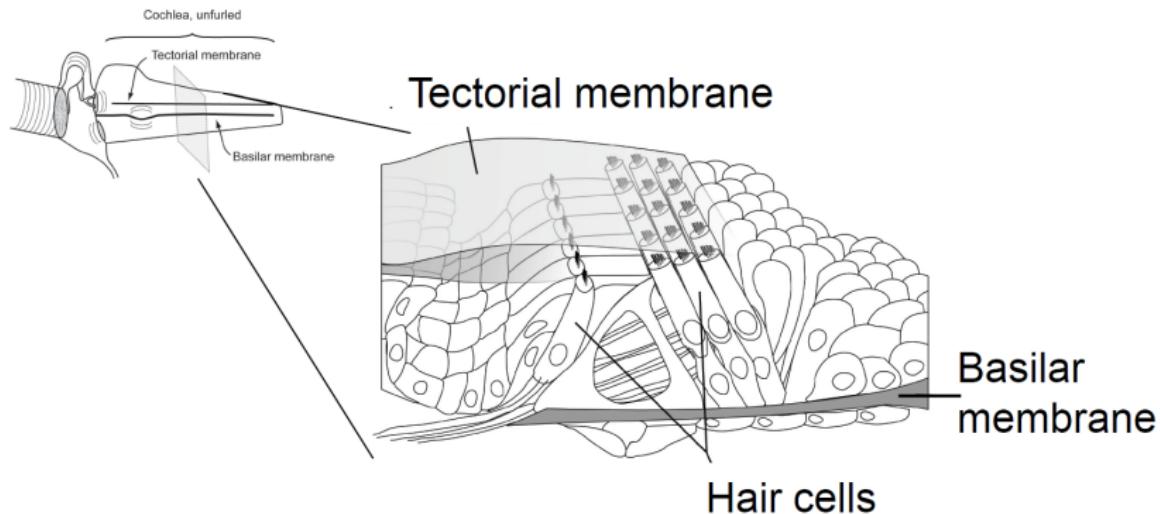
The Structure of the Inner Ear



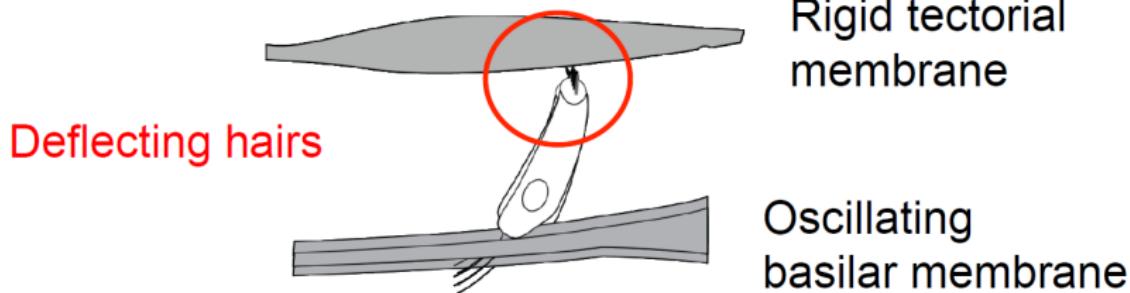
The Structure of the Cochlea



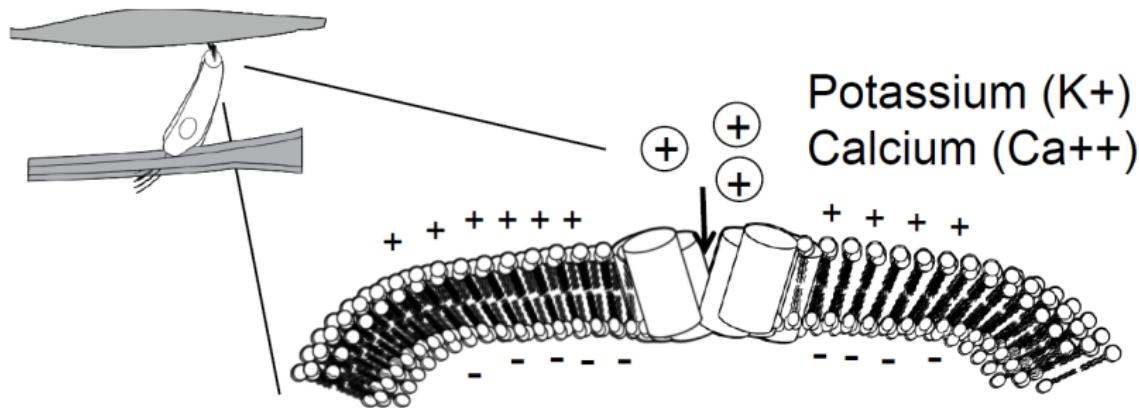
The Structure of the Cochlea



Auditory Transduction

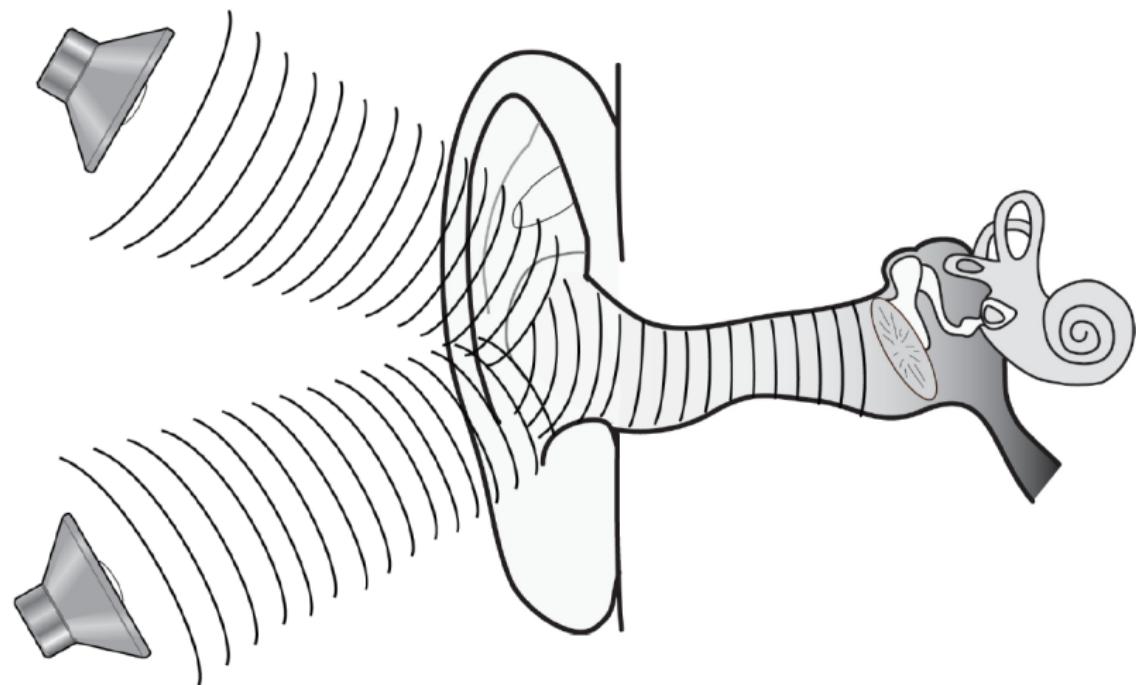


Auditory Transduction

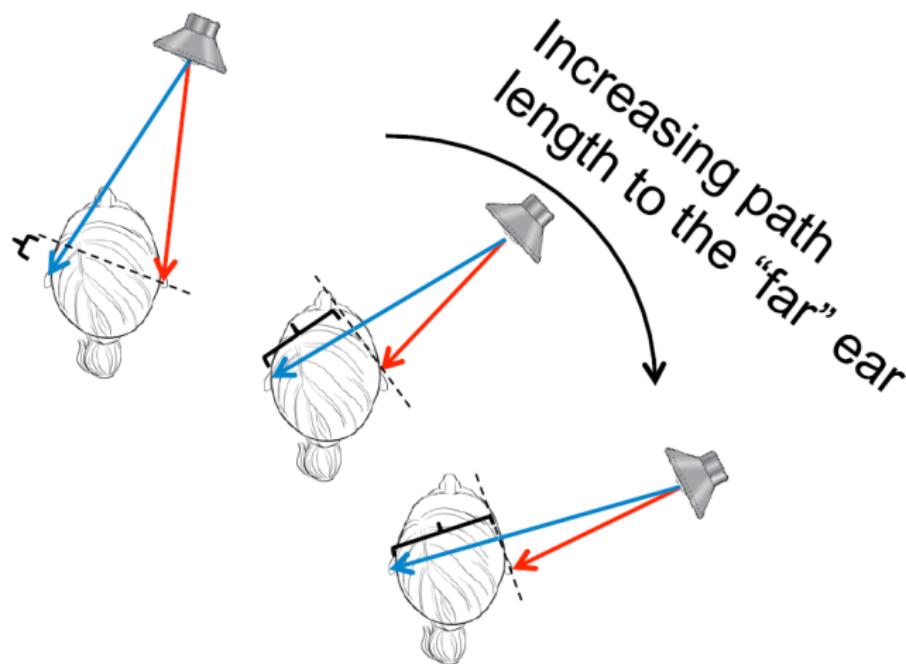


Potassium (K^+)
Calcium (Ca^{++})

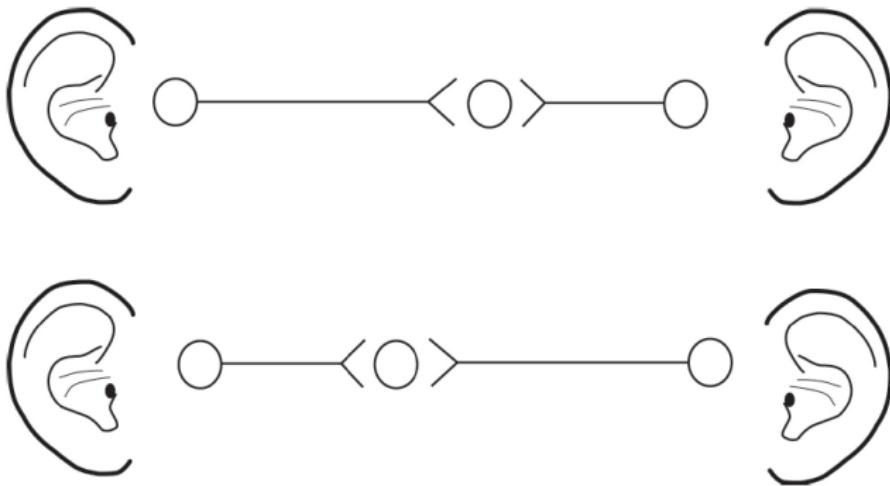
No image formation



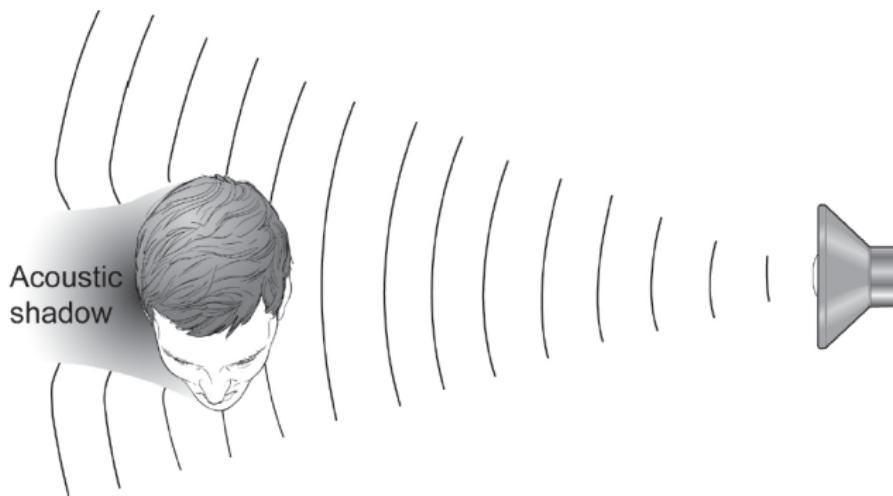
Computing Sound Location



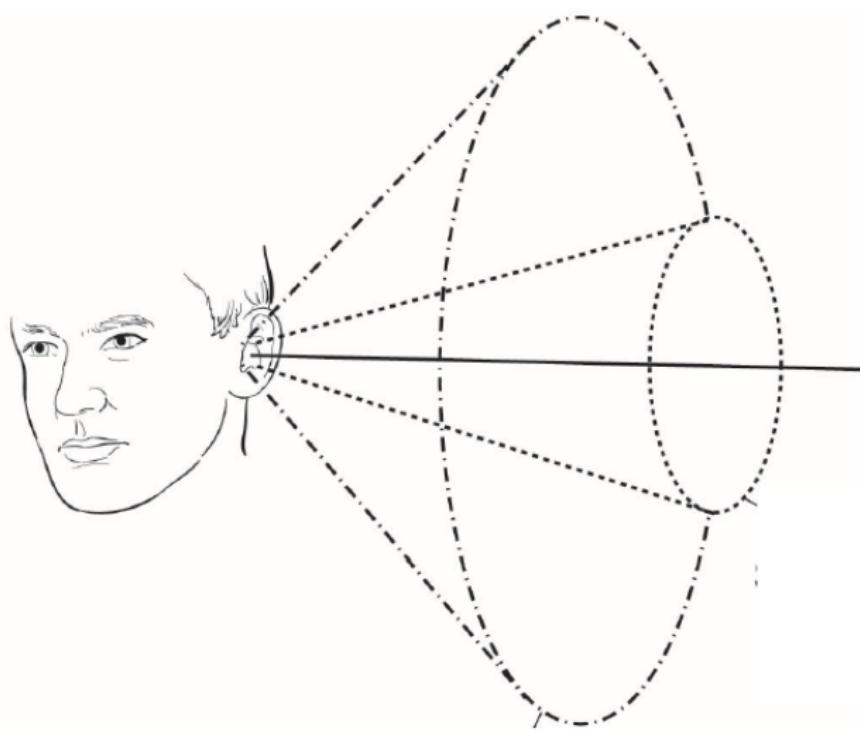
Detecting Interaural Timing Differences: Delay Lines



Interaural Level Differences

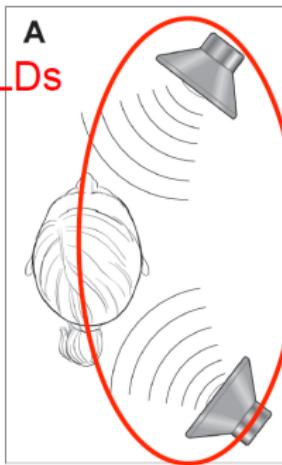


The Cone of Confusion



Solution: Head Movement

Same ITD, ILDs

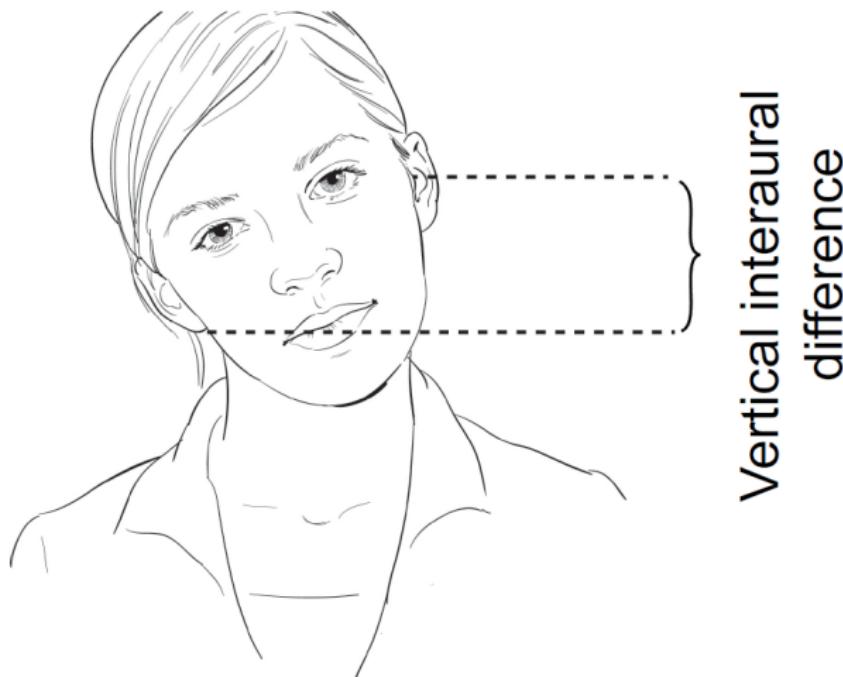


B

Different
ITD, ILDs



Solution: Head Movement



Symbol Representations

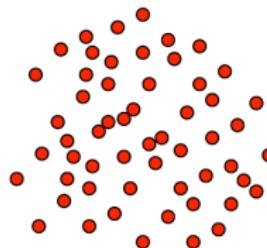
- Symbol

0	0	1	1	1	0	0	0
---	---	---	---	---	---	---	---

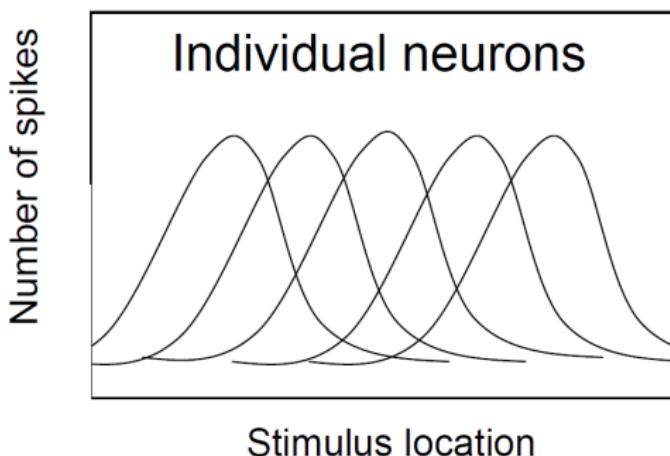
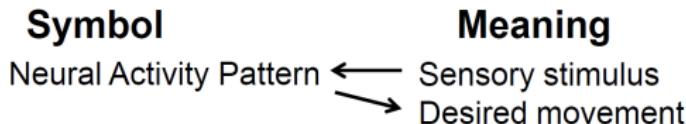
$$2^5 + 2^4 + 2^3$$

$$32+16+8 = 56$$

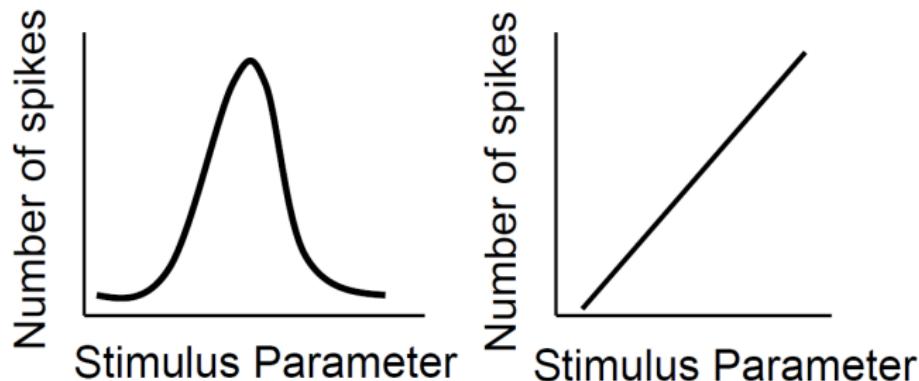
- Meaning



Neural Representations



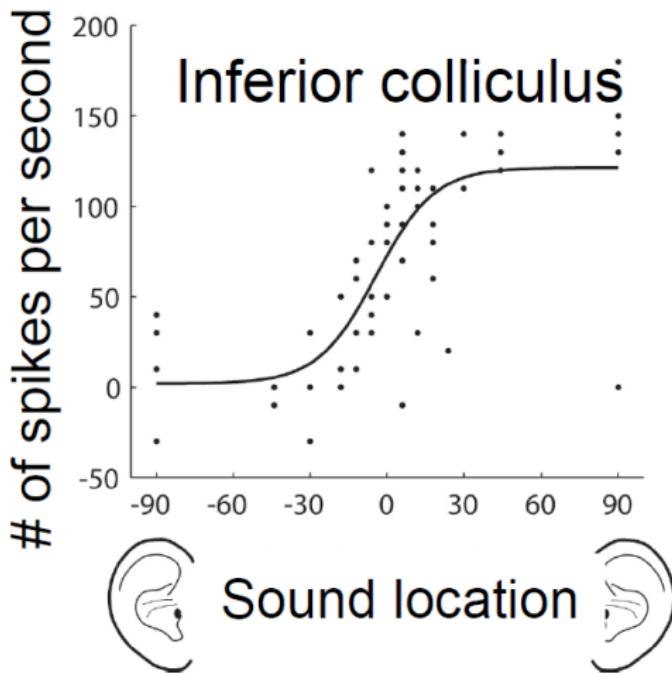
Maps/Tuning vs. Meters/Proportional Coding



Testing Auditory Coding



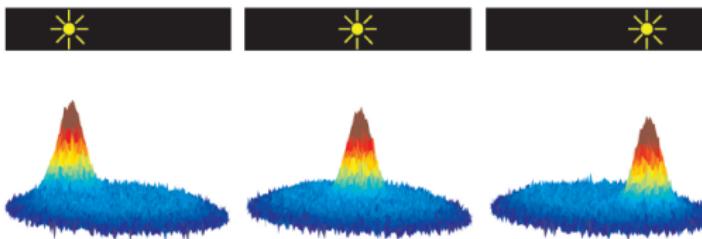
Coding of Sound Location



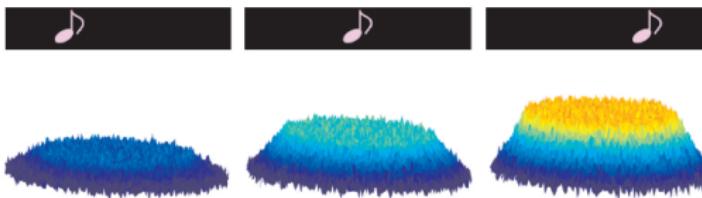
Werner-Reiss and Groh, J. Neurosci, 2008

Integration of Image and Sound Location Coding: Superior Colliculus

Visual map: tuning and receptive fields



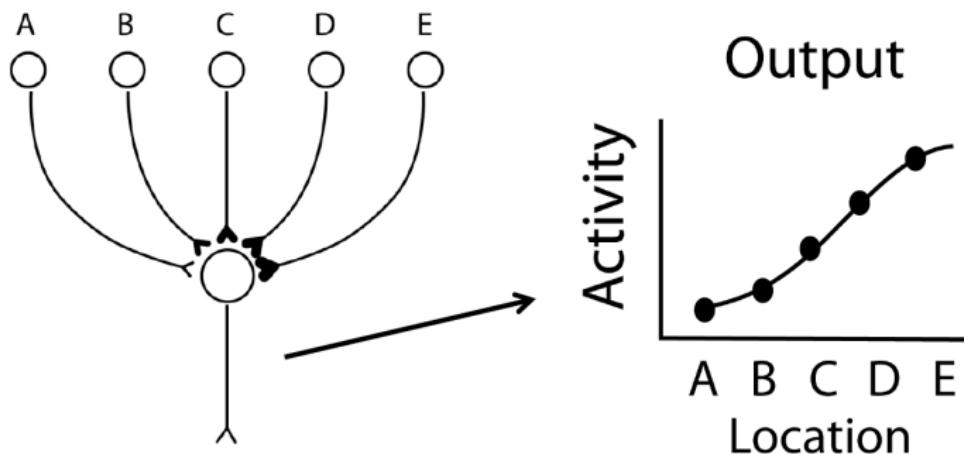
Auditory meter: proportional coding



Werner-Reiss and Groh, J. Neurosci, 2008

Integration of Image and Sound Location Coding: Superior Colliculus

Superior Colliculus neurons

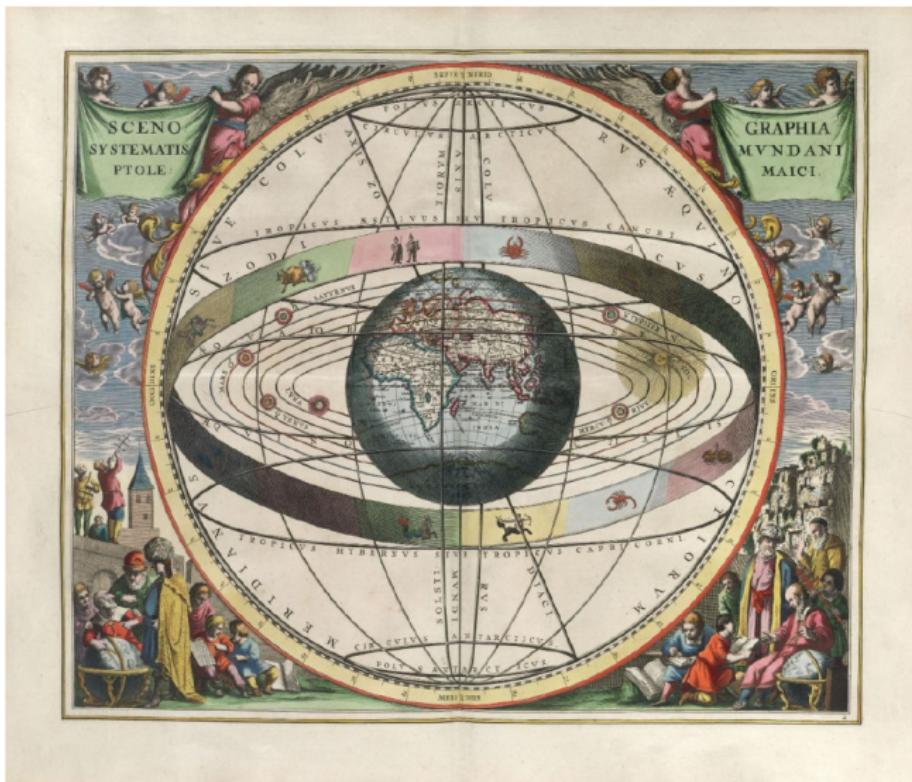


Outline

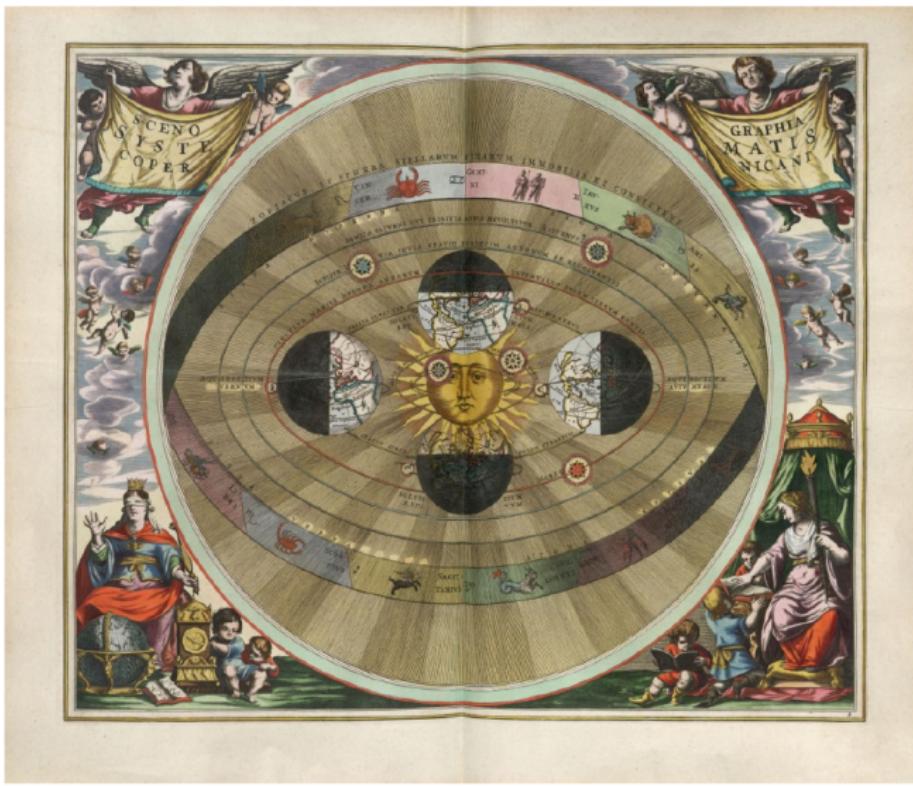
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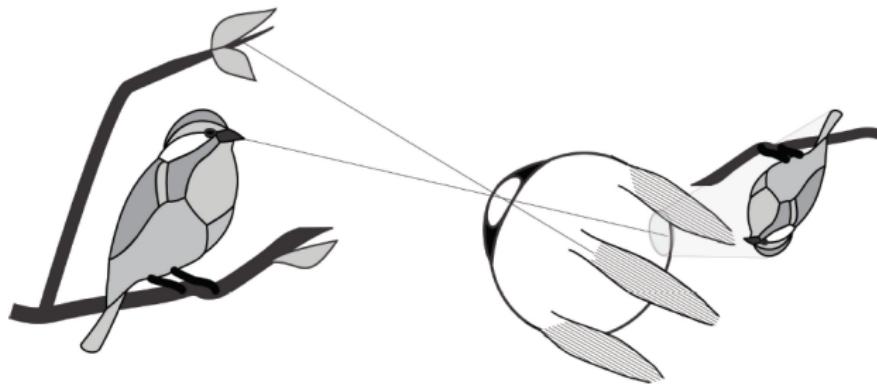
Ptolemy: Earth at center



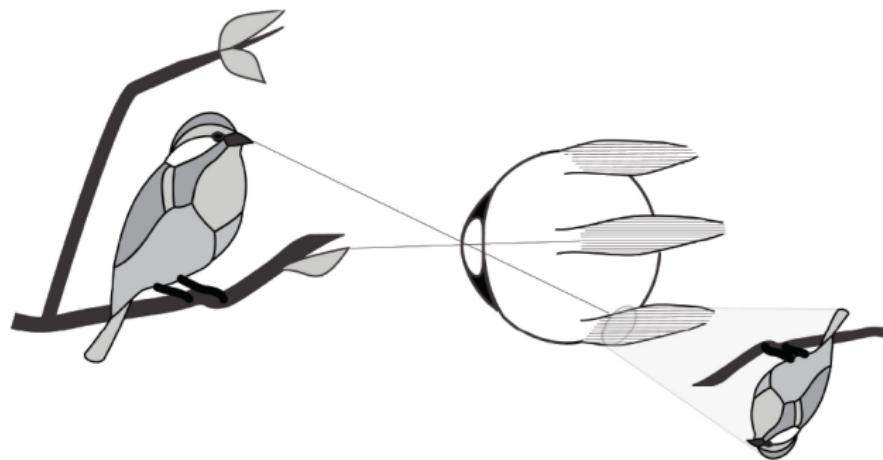
Ptolemy: Earth at center



Location Constancy

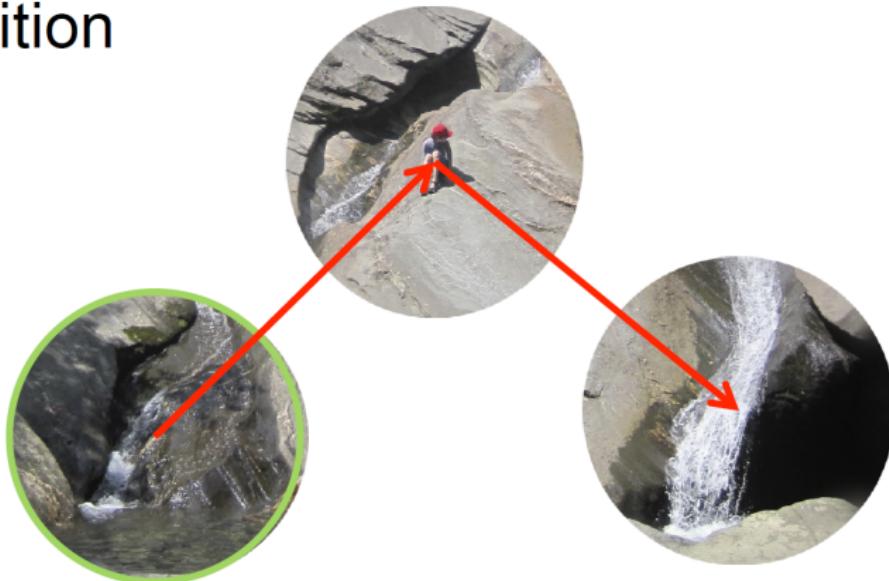


Location Constancy



Synthesizing a Mental Visual Image

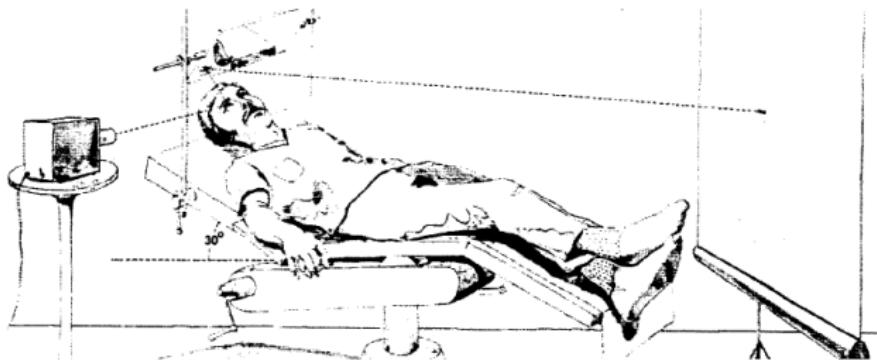
sition



Synthesizing a Mental Visual Image

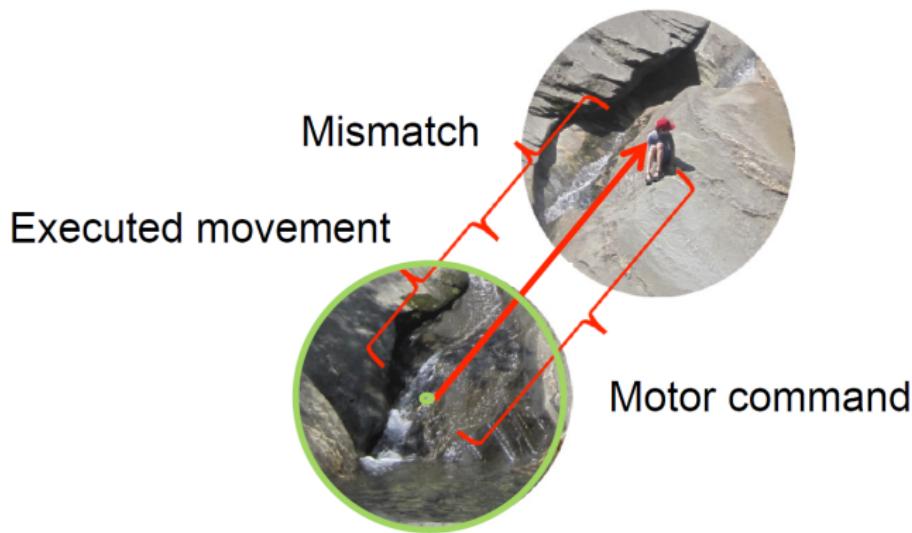


Stevens' Experiment

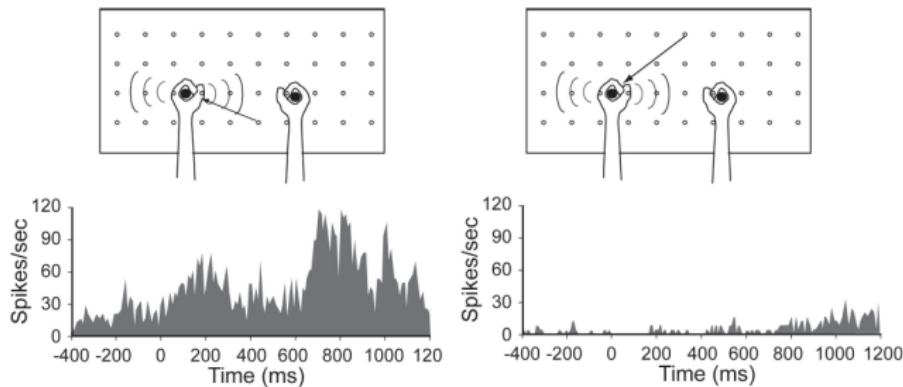


Stevens, J. K., R. C. Emerson, G. L. Gerstein, T. Kallos, G. R. Neufeld, C. W. Nichols and A. C. Rosenquist (1976). Vision Research 16(1): 93-99.

Stevens' Experiment



Coordinating Between Vision and Touch

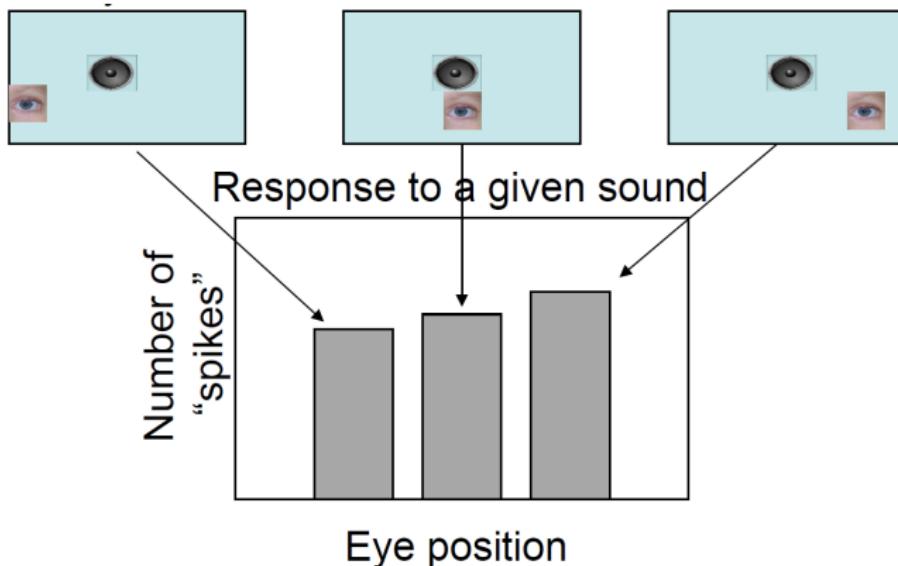


Groh and Sparks, J. Neurophys. 1996

The McGurk Effect

Video

Coordinating Between Vision and Sound

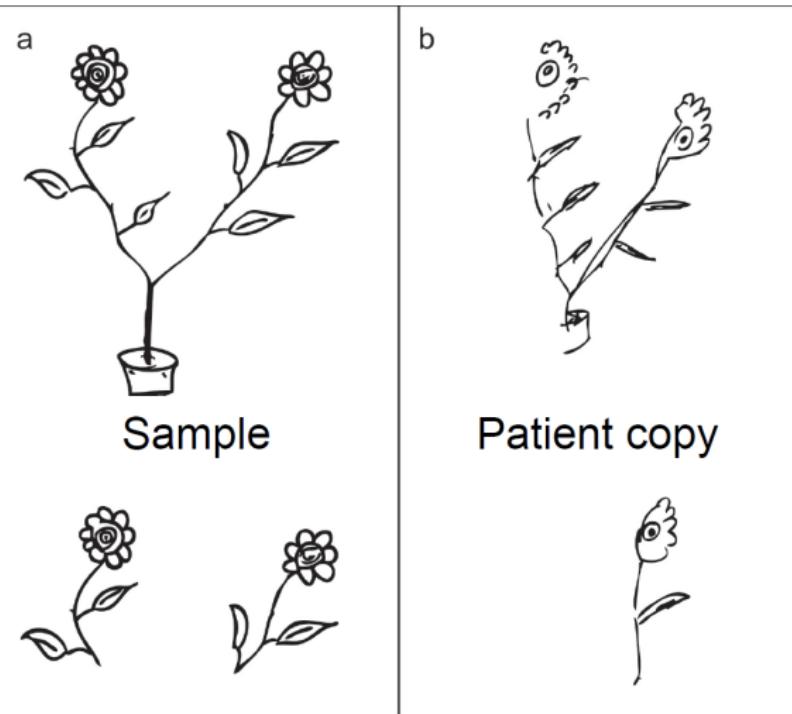


Groh JM, Trause AS, Underhill AM, Clark KR, Inati S (2001) Eye position influences auditory responses in primate inferior colliculus. *Neuron* 29:509-518.

Outline

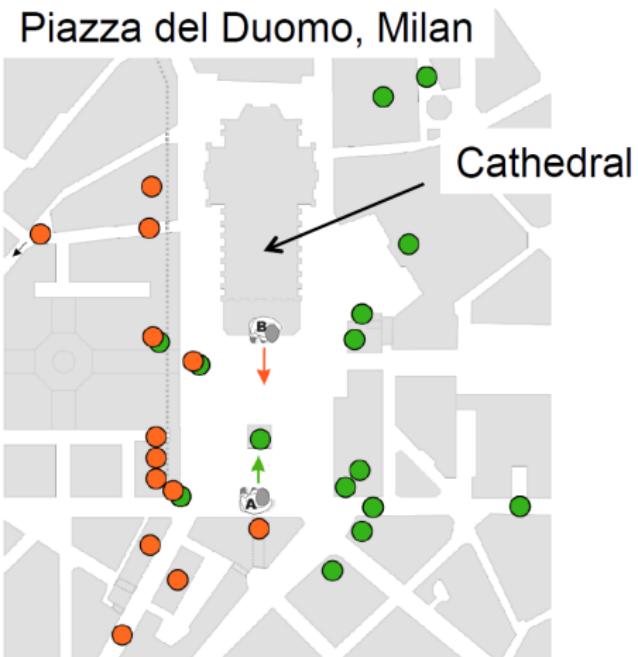
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- ⑧ **Memory and Cognition**

Lesions of Parietal Cortex



Marshall and Halligan J. Neurology 240:37-40(1993)

Parietal Cortex and Reference Frames



Bisiach and Luzatti "Unilateral neglect of representational space."
Cortex 14 (1978):129-133.

Morris Water Maze Task



Hippocampal “place cell” Neurons are Sensitive to Location



Space and Memory are Linked

- Memory needed for navigation
- “Episodes” occur in spatial locations
- Location serves as an index to retrieve those memories

What is Right about Kant

- We do construct the space.
- The construction is not subject to our free will.
- Spatial experience is part of our intuition.

What is Wrong about Kant

- We do need experimental methods to investigate our cognitive faculties.
- Our spatial experience can be changed and learned.
- The spatial experience is not just inside of our mental world. It is out there in the real world.
- Perception can be a source of knowledge about the object world, although not necessarily reliable.
- Condition of possibility of spatial experience is not unique.
- We simply cannot stop at Kant. General level descriptions of knowledge are abstract, and we need details even for a comprehensive understanding.

Reference

- Jennifer M. Groh. (2014) *Making Space: How the Brain Knows Where Things Are*, Harvard University Press.
- S. Marc Breedlove, Neil V. Watson. (2016) *Behavioral Neuroscience*, 8th edition. Sinauer Associates, Inc. Publishers.
- Wikimedia Commons <https://commons.wikimedia.org/>
- Jennifer M. Groh's Slides on "Brain and Space"