

260-2017-01-13-levels-methods

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Prelude

Classic “Powers of Ten” movie by Charles and Ray Eames (10 min).

Today’s Topics

- Levels of analysis in the study of brain and behavior
 - Spatial
 - Temporal
- Methods to the madness

Review of key concepts

What does the practice of trephining suggest about our human ancestors?

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Which of the following statements about the Egyptians is false?

- A. They employed a word meaning “brain”.
- B. They removed the brain in the process of mummification.
- **C. They created detailed drawings of human brain anatomy.**

Levels of analysis

Spatial resolution

Spatial and Temporal Resolution

(Sejnowski, Churchland, and Movshon 2014)

Spatial Resolution in Detail

- Within an individual
 - molecular
 - * genetic
 - * receptor
 - chemical
 - * neurotransmitter
 - cellular
 - * neuronal firing

Spatial Resolution in Detail

- Internal to individuals
 - network
 - * lateral inhibition
 - area
 - region
 - system

Spatial Resolution in Detail

- External to individuals
 - Social
 - * Friends, family, teachers, others
 - Non-social
 - * neighborhood, school, state/region, country
 - * Physical environment

Temporal Resolution in Detail

- Within one lifetime
 - Microseconds
 - * detection position from acoustic stimulation
 - Milliseconds
 - * action potential

- Seconds
 - * changes in EEG power
 - * short-term memory

Temporal Resolution in Detail

- Within one lifetime
 - Minutes
 - * synaptic plasticity
 - Hours
 - * memory consolidation
 - Days
 - Weeks
 - Months

Temporal Resolution in Detail

- Within one lifetime
 - Years
 - * education & training
 - * disease processes
 - * cultural change

Temporal Resolution in Detail

- Across lifetimes
 - Centuries
 - * cultural changes
 - Millenia

Why does this matter?

- Different methods, different levels of analysis.
- Challenge of interpretation.
- Challenge of linking phenomena across levels.
 - How does the micro affect macro or vice versa?

Neuroscience methods

Methods to the madness

- Tools in the neuroscientist's toolkit
- What they tell us, and what they don't

Evaluating methods

- What is the question?
- What are we measuring?
 - Structure

- Activity
- Strengths & Weaknesses
 - Cost
 - Invasiveness
 - Spatial/temporal resolution

Spatial and Temporal Resolution

(Sejnowski, Churchland, and Movshon 2014)

Types of methods

- Structural
 - Mapping the circuitry
 - Anatomy
- Functional (next time)
 - What does it do?
 - Physiology/Activity

Mapping structures

- Cell/axon stains
 - Golgi stain – whole cells
 - * Camillo Golgi
 - Nissl stain – cell bodies only
 - * Franz Nissl
 - Cellular distribution, concentration, microanatomy

Golgi stain

Nissl stain

Retrograde vs. anterograde histochemical tracers

- *Retrograde* (from axon terminal to cell body); *anterograde* (from cell body to axon terminal)
- What connects where

Retrograde vs. anterograde tracers

Brainbow

(Lichtman, Livet, and Sanes 2008)

Brainbow

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Eyewire.org

Clarity

Mapping structures

- Computed axial tomography (CAT), CT
- X-ray based

Tomography

Tomography

<http://static.howstuffworks.com/gif/cat-scan-pineapple.jpg>

CT scan of stroke

Magnetic Resonance Imaging (MRI)

- Magnetic resonance
- Protons have spin (magnetic dipole)
- Align with strong magnetic field
- When perturbed, speed of realignment varies by tissue
- Realignment gives off radio frequency signals

MRI

<http://s.hswstatic.com/gif/mri-steps.jpg>

How MRI works

Structural MRI

- Tissue density/type differences
- Gray matter (neurons & dendrites & axons & glia) vs. white matter (mostly axons)
- MR Spectroscopy
- Region sizes/volumes

Structural MRI of the brain

Diffusion tensor imaging (DTI)

<https://www.simonsfoundation.org/wp-content/uploads/2012/02/hitting-nerve3.jpeg>

Diffusion tensor imaging (DTI)

- Type of structural MRI
- Reveals integrity/density of axon fibers
- Measure of connectivity

Voxel-based morphometry (VBM)

- Voxels (volume-based elements)
- Morphometry, measure (“metry”) form/morphology.
- How does brain size or thickness vary by age, disease status, etc.?

http://www.frontiersin.org/files/Articles/18691/fnhum-06-00184-HTML/image_m/fnhum-06-00184-g003.jpg

Next time

- Functional methods, including functional MRI (fMRI)

References

- Lichtman, Jeff W., Jean Livet, and Joshua R. Sanes. 2008. “A Technicolour Approach to the Connectome.” *Nature Reviews Neuroscience* 9 (6): 417–22. doi:10.1038/nrn2391.
- Sejnowski, Terrence J, Patricia S Churchland, and J Anthony Movshon. 2014. “Putting Big Data to Good Use in Neuroscience.” *Nature Neuroscience* 17 (11). Nature Publishing Group: 1440–1. doi:10.1038/nn.3839.