How the Brain Functions

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Brad Folley, Ph.D.
Central Nervous System
The Human Brain
Brain Facts

- The brain is highly compact. Smoothing out the wrinkles, the brain would cover 2 1/2 square feet.

- The brain has about 100 billion neurons. There are more potential connections between neurons than there are atoms in the universe.

- A fetus grows neurons at the rate of 250,000 per minute. A person is born with nearly all the neurons of an adult, but the neural networks are not mature yet.
Brain Facts

- Information speeds range from 3 to 330 feet/sec
- We don’t use 10% of our brains, we use all of it. . . .some functions, such as complex memory, involve many areas at once.
- You do not lose brain cells as you age normally, but some functions decline.
- Brain tissue has no pain receptors, so although it registers pain from all over the body, it does not feel pain itself.
Brain Organization

- **Up/Down**
  - Higher regions complexity increases
  - Lower regions serve more basic functions

- **Left/Right**
  - Left hemisphere processes details
  - Right hemisphere processes

- **Front/Back**
  - Posterior regions take in information
  - Frontal regions output information
Brain Structure

- Cerebrum
  - Left Hemisphere
  - Right Hemisphere
  - Corpus Callosum
Brain Structure

- Hippocampus
  - Memory
  - Spatial Cognition

- Amygdala
  - Emotions (fear)
  - Memory
Subcortical Structures

- Basal Ganglia
  - Fine control of movement
  - Work in conjunction with the frontal lobes (filters)

- Thalamus
  - Sends sensory information to cortex

- Hypothalamus
  - Temperature control
  - Basic drives (hunger)

- Pons
  - Nerve fiber crossroads

- Medulla
  - Vital functions (heartbeat, respiration)
Regional Cortical Function
Motor and Sensory Cortex

- Sensory Cortex
  - Input from peripheral nerves
- Motor Cortex
  - Output of motor commands
Visual Perception

- Light is processed by the retina
- Information travels to occipital cortex
Left and Right Vision

- Right side of space
  - Left occipital lobe

- Left side of space
  - Right occipital lobe
Visual Cognition

- Where
  - Spatial

- What
  - Object
Prosopagnosia
Prosopagnosia
Handedness

- **Left Hemisphere**
  - Language
  - Symbol decoding
  - Details

- **Right Hemisphere**
  - Global analysis
  - Spatial attention
Hemispheric Specialization

- The left and right hemispheres process the same stimuli, extracting different information
Language

- Visual cortex
- Printed language
- Auditory Cortex
- Spoken language
Language Processing

**Language in brain**

*Simplified model of language processing in brain*

When you read, listen to speech, or speak, a network of thousands of neurons is activated in your brain. This figure gives an overview of brain regions that have been suggested to participate in various stages of language processing.

**Reading text**
- "S-N-O-W" feature analysis
- individual letters
- whole word
- meaning
- sound form

Understand speech
- "S-N-O-W" acoustic analysis of sound waves
- recognition of speech sounds
- recognition of word form
- meaning

**Speaking**
- meaning
- selection of sound form
- syllabification
- articulation of speech sounds
- "S-N-O-W"

**Time after seeing/hearing a word**
- Feature analysis: visual cortex
- 0.1 s
- Analysis of letter strings
- 0.15 s
- Meaning: left
- 0.4 s
- Right
- 0.7 s
- Selection of sound form
- 1 s
- Articulation of speech sounds (motor cortex)

Here is a combination of regions that different brain imaging methods have suggested to participate in analysis of meaning of words.

More info:
Paul Broca (1824-1880)

- Expressive Speech
- Aphasia
- Mr. Leborgne
- “Tan”
Broca’s Aphasia

Ah ... Monday ... ah, Dad and Paul Haney [himself] and Dad ... hospital. Two .. .ah, doctors ... and ah ... thirty minutes .. .and yes ... ah ... hospital. And, er, Wednesday ... nine o'clock. And er Thursday, ten o'clock .. .doctors. Two doctors ... and ah ... teeth. Yeah, ... fine.
Carl Wernicke (1848-1905)

- Receptive language
  - Comprehension
  - Understanding writing and speech

- 1873 - Patient with stroke
  - Could hear and speak
  - Could not understand what was said
Wernicke’s Aphasia

- I can't tell you what that is, but I know what it is, but I don't know where it is. But I don't know what's under. I know it's you couldn't say it's ... I couldn't say what it is. I couldn't say what that is. This shu--that should be right in here. That's very bad in there. Anyway, this one here, and that, and that's it. This is the getting in here and that's the getting around here, and that, and that's it. This is getting in here and that's the getting around here, this one and one with this one. And this one, and that's it, isn't it? I don't know what else you'd want
Prefrontal Cortex

- Proportionately larger in humans
- Planning, judgment, generating ideas, switching, inhibiting, sustaining attention, initiating,
- Gives us “inner control”, without it we rely only on the environment
- Central executive
Memory

- Sensory Memory
  - <1 second, not conscious

- Short Term Memory
  - Storage
  - Several seconds, 7±2 (George Miller)

- “Working” Memory
  - Short-term manipulation

- Learning
  - Memory progress over time

- Long Term Memory
  - Days to decades
Types of Memory

Memory

Declarative
- Episodic
- Semantic
- Working

Non-declarative
- Priming
- Procedural
- Conditioning
Episodic Memory

- Events in a particular place at a specific time

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<td>Recognition</td>
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<td>Tower</td>
<td>Space x</td>
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Procedural Memory

- Mirror Tracing Task
Neuroanatomy of Memory

- Prefrontal Cortex
- Hippocampus
  - Amnesia
  - Anterograde
- Subcortical Regions
  - Thalamus
  - Mamillary bodies
Hippocampus and Memory

Dorsal Stream: Spatial

Ventral Stream: Object
Semantic Memory

McClelland and Rogers, 2003
Other Functions

- Emotions
  - Transient
  - Prefrontal Cortex, amygdala, hypothalamus, and other regions
- Mood
  - More stable pattern
- The Social Brain
  - Prefrontal Cortex
  - Phineas Gage
Thank you for your attention

Questions?