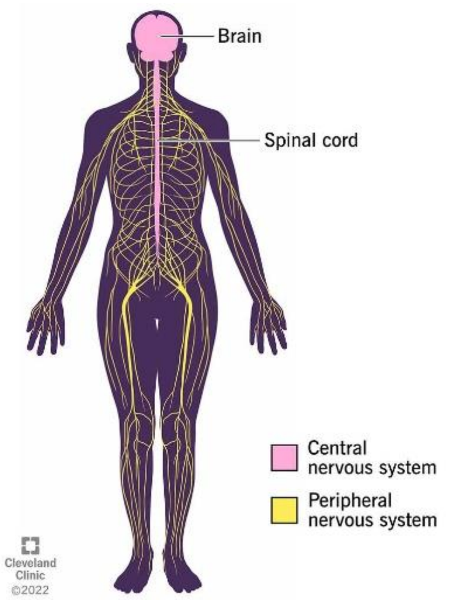
LING 0001 Lecture (S) **Week 10**: Oct 30, 2023

<u>Topic 16: Brain and Language</u> Prepared by Jonathan Lee

A. Neuroanatomy

A1. Nervous system

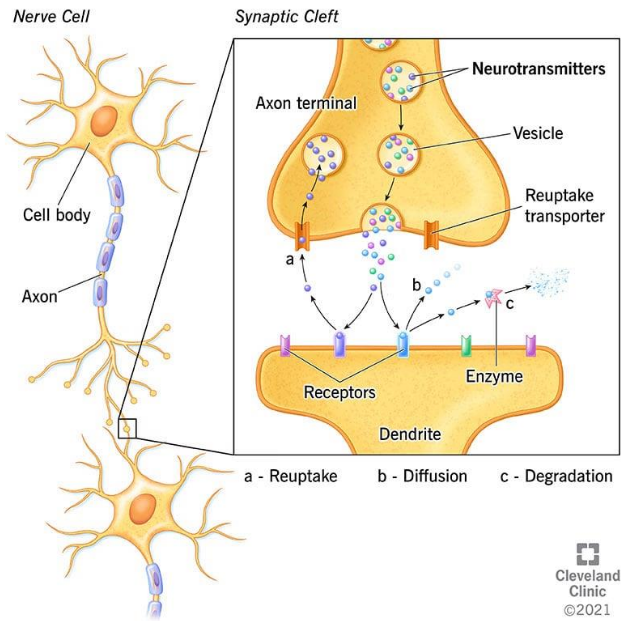


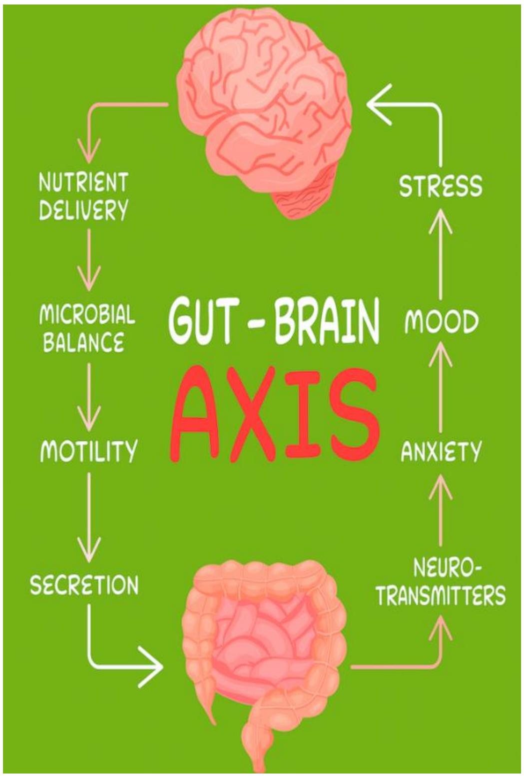
- Central Nervous System (CNS)
    - Brain
    - Spinal cord
- Peripheral Nervous System (PNS)
    - Cranial nerves
    - Spinal nerves

A2. Neuron and neurotransmitter

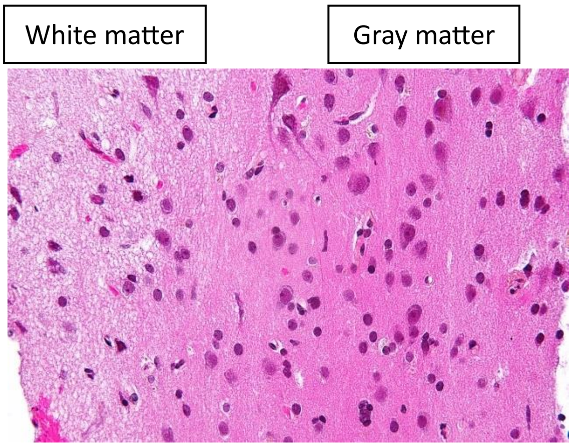
- **Neuron**
    - Dendrites
    - Cell body
    - Axon

- **Neurotransmitter**
    - dopamine (DA)
    - gamma-aminobutyric acid (GABA)
    - serotonin



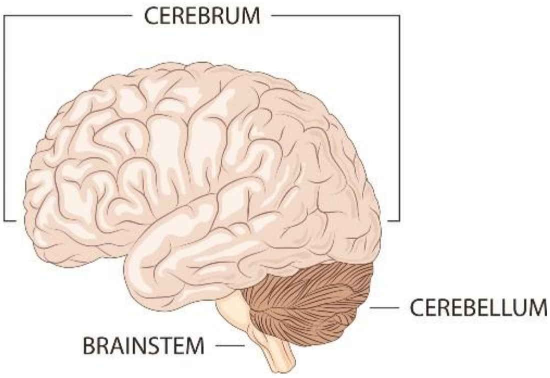


- Gray matter = cell body and dendrites
- White matter = axon and glial cells



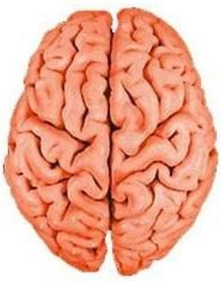
A3. Brain

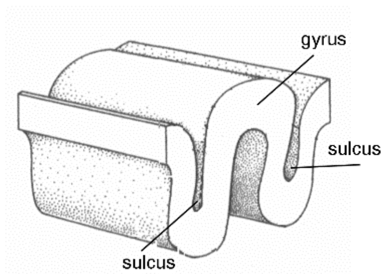
- Cerebrum
    - Cerebral hemispheres
        - Cerebral cortex
        - Basal ganglia
        - Hippocampus amygdala
    - Diencephalon
- Cerebellum
- Brainstem



A4. Cerebrum

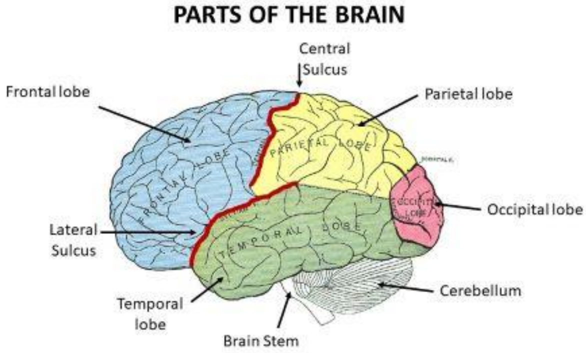
- ~70% of the entire nervous system
- Resemble a giant wrinkled walnut
- Can be imaginarily inflate to the size of a basketball
- Gyrus (gyri): the protruding rounded surface
- Sulcus (sulci): enfolded regions appearing as lines and creases
- Fissure: deep sulcus
    - Rolandic Fissure / Fissure of Rolando / Central Sulcus
    - Sylvian Fissure / Lateral sulcus

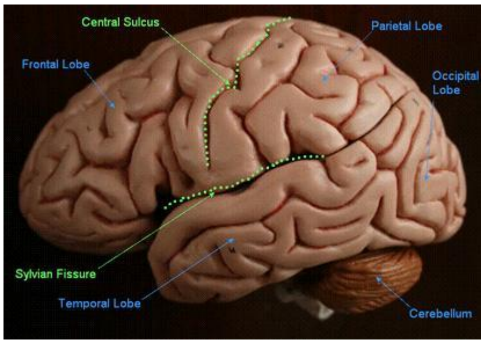




A5. Cerebral hemispheres

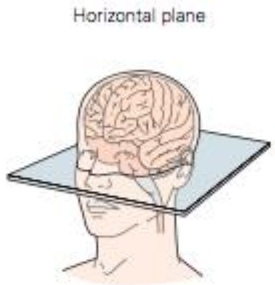
- Frontal lobe
  - Motor cortex
  - Executive functions
  - Attention
  - Working memory
  - Broca's area (left hemisphere)
- Temporal lobe
  - Auditory cortex
  - Word recognition
  - Face recognition
  - Wernicke's area (left hemisphere)
- Parietal lobe
  - Somatosensory cortex
  - Spatial processing (right hemisphere)
  - Orthography-phonology mapping
- Occipital lobe
  - Visual cortex

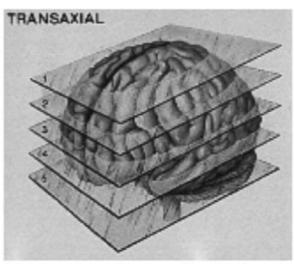


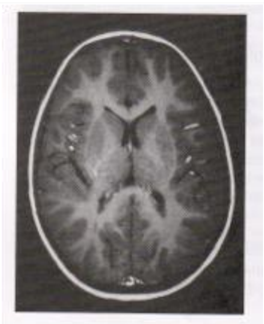


A6. Section planes

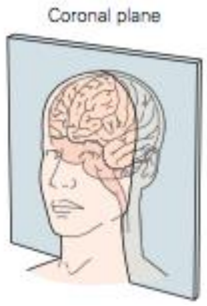
Horizontal/axial/transverse

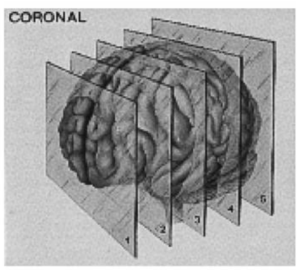


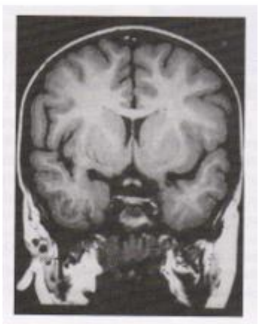




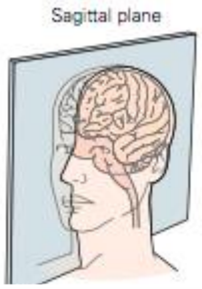
Coronal

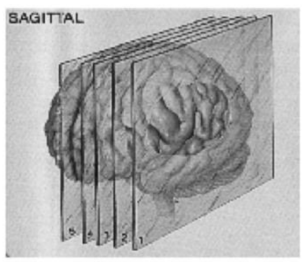


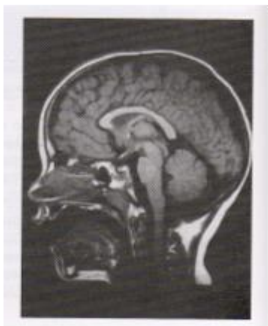




Sagittal





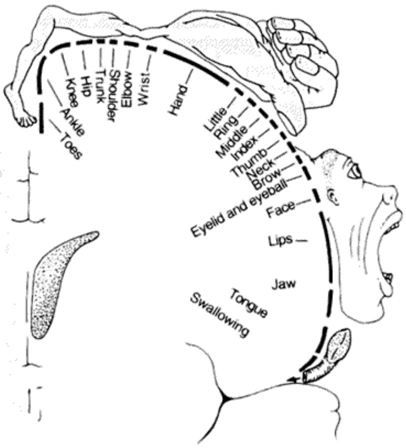


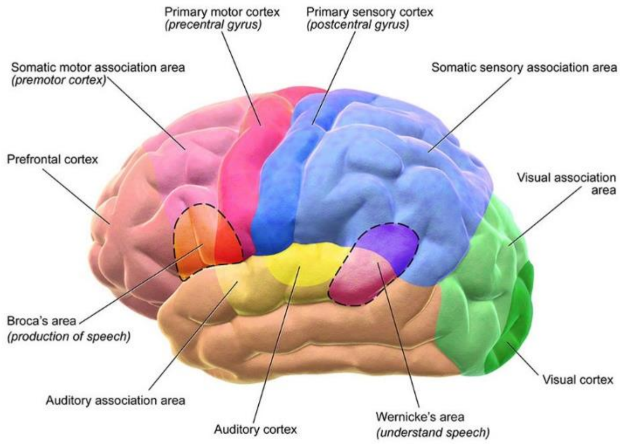
A7. Interactive brain models

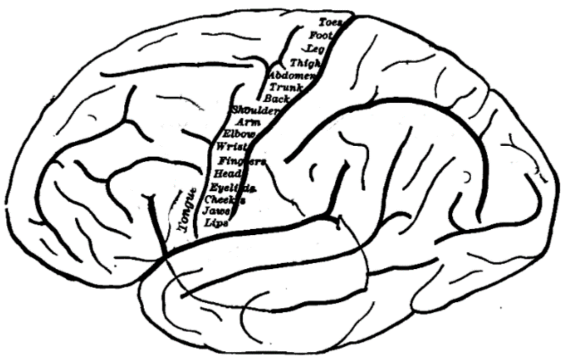
- https://www.brainfacts.org/3d-brain#intro=false&focus=Brain
- https://neurotorium.org/tool/brain-atlas/

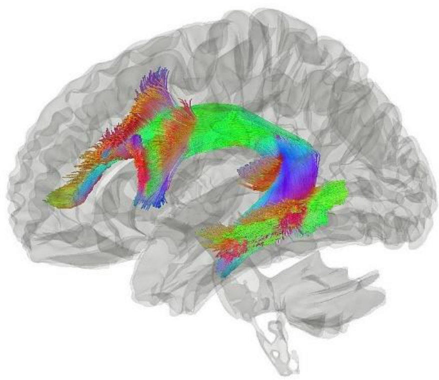
A8. Language in the brain

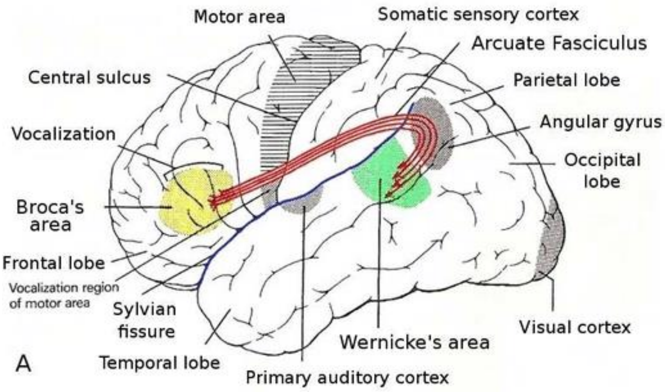
- Language functions are ***lateralized*** to the ***left hemisphere***
- ***Broca's area*** (language production) and ***Wernicke's area*** (language comprehension) are typically located in the left hemisphere, connected by the white-matter pathway ***arcuate fasciculus***
- Motor homunculus is a distorted representation of the human body based on a neurological "map" of the areas and proportions of the human brain dedicated to processing the motor functions for different parts of the body











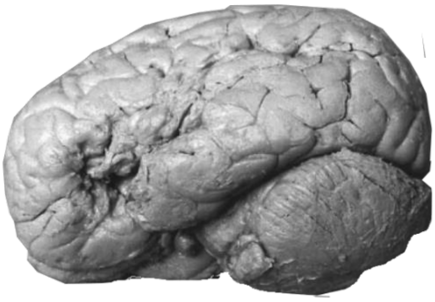
B. **Brain research methods**

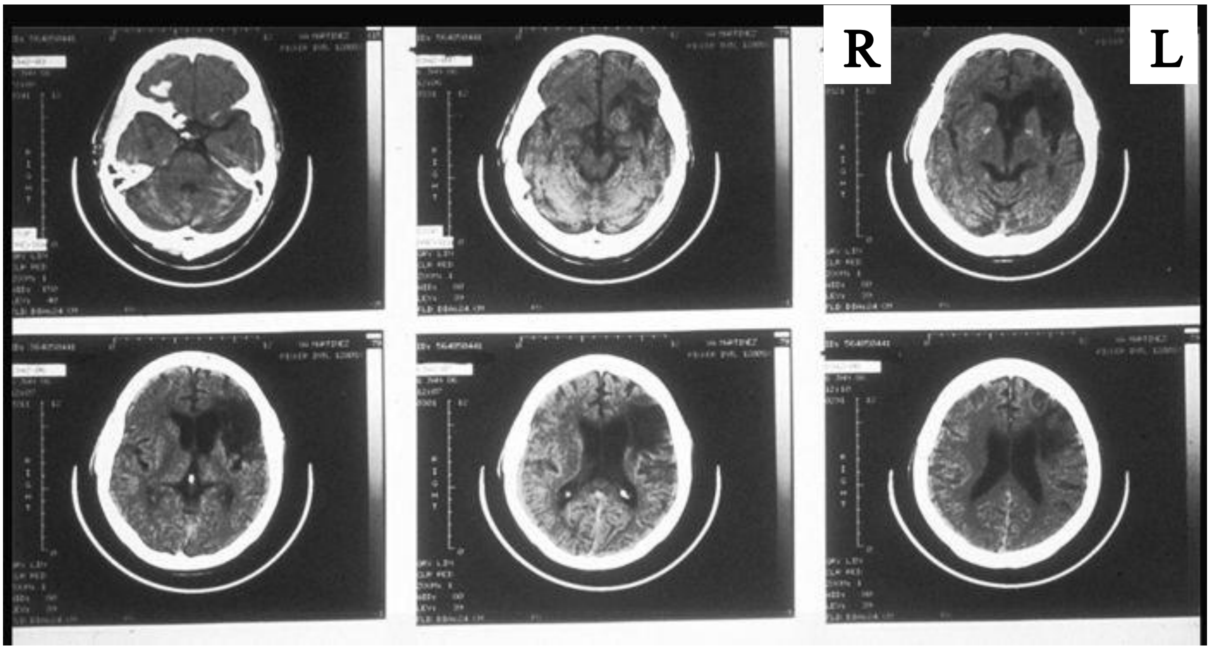
B1. Lesion methods

- Lesioned brain
    - Neurosurgery
    - Epilepsy patients
    - Stroke
    - Traumatic head injuries
    - Tumors
    - Viral infections

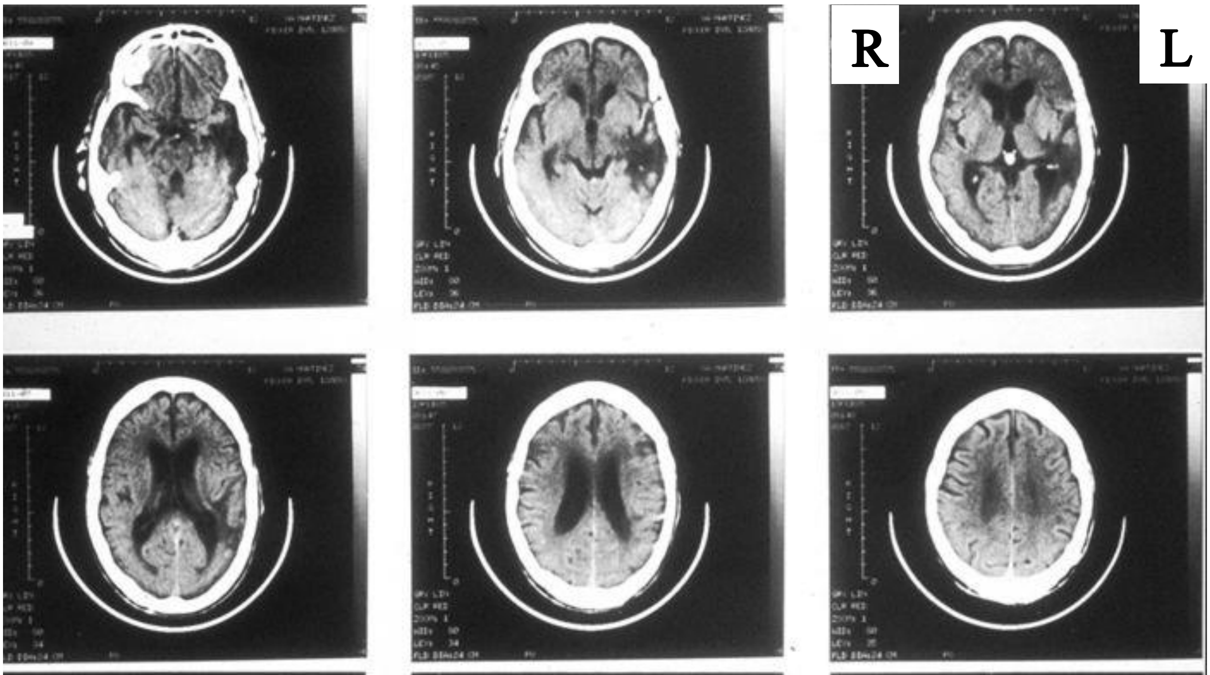
- Example: Broca's area
- Broca's aphasia (non-fluent aphasia)
    - Able to understand others
    - Can form ideas but cannot form sentences
    - Ungrammatical utterances
    - Lack of conjunctions and prepositions
    - May experience right facial weakness, hemiparesis, or hemiplegia
- https://www.youtube.com/watch?v=JWC-cVQmEmY&ab_channel=tactustherapy

- Functions of Broca's area: Speech production? Working memory? Hierarchical processing?



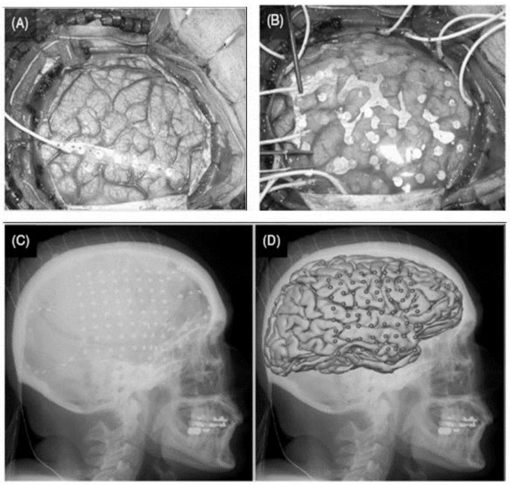


- Example: Wernicke's area
- Wernicke's aphasia (fluent aphasia, receptive aphasia)
    - Can form long, fluent, and grammatical sentences
    - Regular rhythm
    - Nonsense/meaningless content with made-up words
    - Poor word retrieval
    - Difficulty with repetition in words and sentences
    - Unable to comprehend others
    - Do not realize they are saying nonsense
- https://www.youtube.com/watch?v=3oef68YabD0&ab_channel=tactustherapy

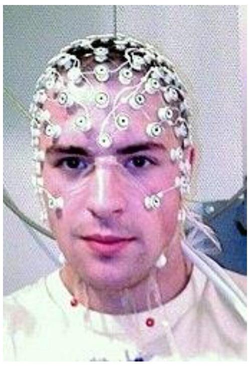


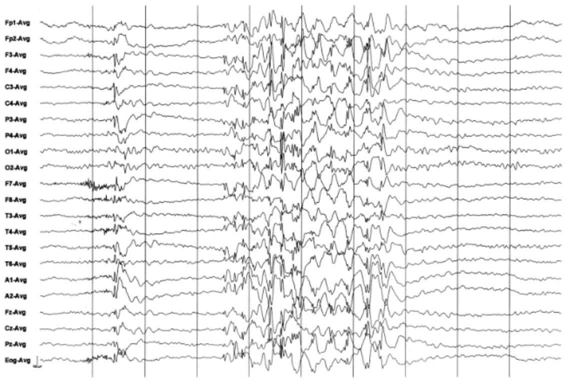
B2. Functional imaging

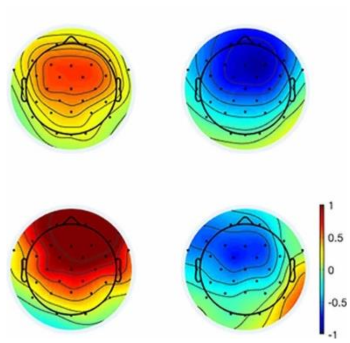
- Electrocorticography (ECoG)
- Intracranial electroencephalography



- Electroencephalography (EEG) / Event-related Potential (ERP)
    - Record the electrical activities of the brain
    - Very good temporal resolution (ms), very poor spatial resolution (3-4 cm)

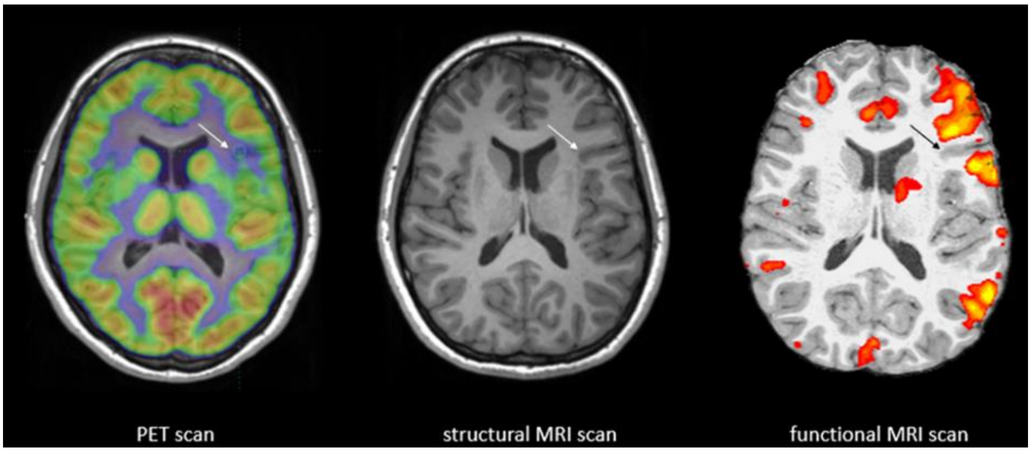




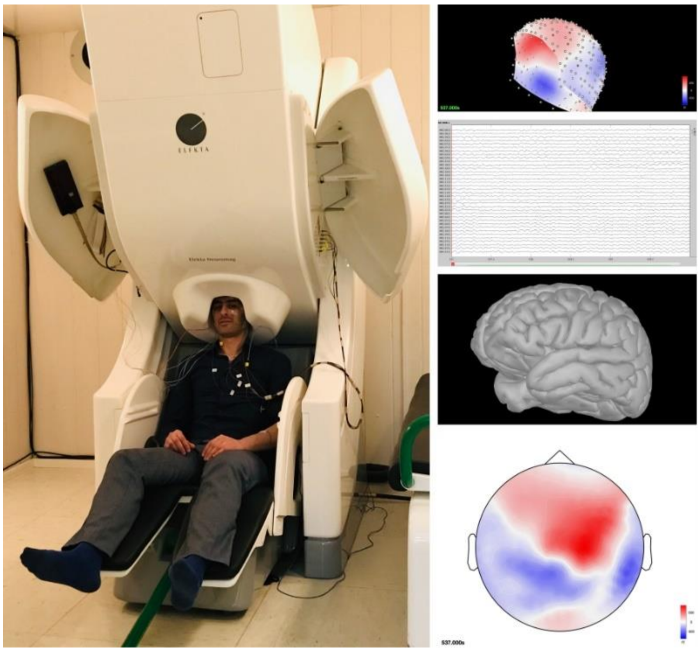


- Positron emission tomography (PET)
    - Involved radioactive tracers
    - Poor temporal resolution (30 s), good spatial resolution (10 mm)
    - Sensitive to the whole brain

- Functional Magnetic Resonance Imaging (fMRI)
    - Nobel Prize in Physiology or Medicine in 2003
    - No radioactivity involved
    - Poor temporal resolution (1-4 s), very good spatial resolution (7-10 mm)
    - Some brain regions are hard to image



- Magnetoencephalography (MEG)
    - Good temporal resolution (10 ms) and spatial resolution (2-3 mm)



- Trade-off between time and space

C. Rethinking neurolinguistics

C1. Mind/Brain dichotomy

- Examples: Word frequency and recency
    - Word frequency effects and recency effects (mind)
    - Localization of language processing and memory (brain)
    - But how are word frequency and recency effects actually implemented in the brain?

- Ontological Incommensurability Problem (Poeppel & Embick 2005)

Linguistic primitive units	Neural primitive units
Phonetic features	Dendrite
Phonemes	Neuron
Syllables	Synapses
Word	Neuronal ensembles
Phrase	Cortical areas

C2. Towards explanatory neurolinguistics

- Levels of adequacy (Chomsky 1965)
    - Observational adequacy
    - Descriptive adequacy
    - Explanatory adequacy (Universal Grammar)

- Levels of neurolinguistics (Embick & Poeppel 2015)
    - Correlational neurolinguistics
    - Integrated neurolinguistics
    - Explanatory neurolinguistics

C3. Language and memory (Ullman 1997, 2004)

- Declarative memory
    - Memory of facts (e.g., colors of a peach), including lexicon
    - Performing analogies
    - Hippocampus

- Procedural memory
    - Memory for processes and skills (e.g., riding a bike), including grammar rules
    - Broca's area and basal ganglia (dopamine)

C4. Morpho-phonological learning in Shimakonde (Bantu language)

- Wong et al. (2012), Wong et al. (2013), Ettlinger et al. (2014), Ettlinger et al. (2016)

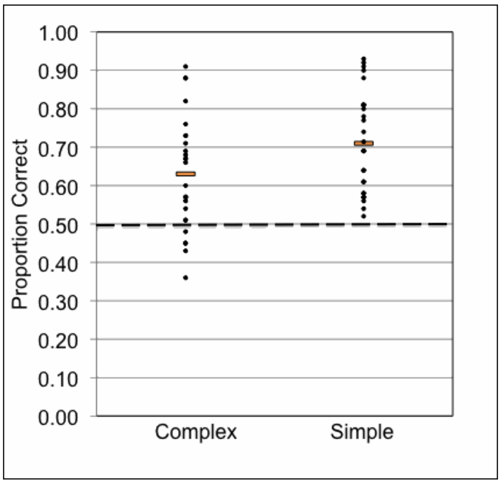
- Transparent (simple) grammar
    - "dog": vib (sg.) → vib-il (pl.) → ki-vib (dim.) → ki-vib-il (dim. pl.)

- Opaque (complex) grammar
    - "cat": pesh (sg.) → pesh-el (pl.) → ki-pish (dim.) → ki-pish-el (dim. pl.)

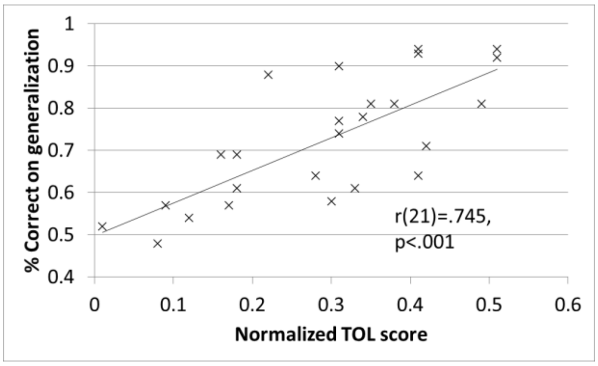
- Hypothesis 1 – Generative phonologists: rule ordering
    - Step 1: add suffix, vowel harmony (i.e., vib → vib-il; pesh → pesh-el)
    - Step 2: add prefix, vowel raising (i.e., vib-il → ki-vib-il; pesh-el → ki-pish-el)

- Hypothesis 2 – Functional phonologists: analogical lexicon
    - From other words, "duck" mez (sg.) → ki-miz-el (dim. pl.)
    - Analogically, "cat" pesh (sg.) → ki-pish-el (dim. pl.)

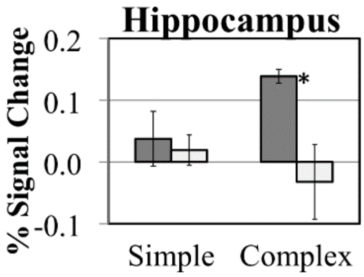
- Individual differences between participants (L2 learners)



- Simple grammar correlated with procedural memory (i.e., rules), but complex grammar correlated with declarative memory (i.e., lexicon/analogy)

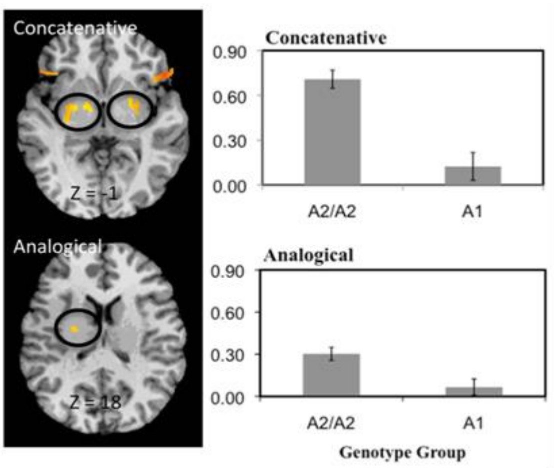


- Successful learners activate hippocampus (declarative memory) for complex grammar



- Conclusions for complex grammar
    - Analogical grammar (for phonologists)
    - Declarative process (for cognitive psychologists)
    - Hippocampal function (for systems neuroscientists)

- DRD2 polymorphism
    - A1A1, A1A2, or A2A2
    - Basal ganglia are responsible for releasing dopamine
    - Presence of A1 allele is associated with reduced D2 receptor binding in basal ganglia
    - A2A2 carriers activated basal ganglia and the frontostriatal system "naturally" more than A1 carriers



- “Explanatory” levels
    - Neurogenetics
    - Neurons and neurotransmitters
    - Systems
    - Memory (and memory power)
    - Behaviors (e.g., language abilities)