Introduction to Physiological Psychology

Speech Production and Comprehension: Brain Mechanisms

- Our knowledge of the physiology of language comes primarily from seeing “what goes wrong” when certain areas of the brain suffer trauma.
First reported case of *aphasia* induced by localized brain trauma

“If thou examinest a man having a smash in his temple, thou shouldst place thy thumb upon his chin and thy finger at the end of his ramus, so that the blood will flow from his two nostrils [...] 

*If thou callest to him, he is speechless and cannot speak.*”

Edwin Smith Surgical Papyrus, written by an Egyptian field surgeon, 3000-3500 BC

Case 21

“When the patient was admitted to Bicetre at the age of 21, he had lost, for some time, the use of speech; he could no longer pronounce more than a single syllable, which he ordinarily repeated twice at a time; whenever a question was asked of him, he would always repeat *tan tan*, in conjunction with quite varied expressive gestures. For this reason, throughout the hospital, he was only by the name of Tan.”

Pierre-Paul Broca, 1861
Leborgne's Brain
displayed in the Dupuytren Museum (Paris)

Broca’s Area
Language Lateralization

- Most people are right-handed
- Almost all right-handed people have LH specialization for language (only ~4% show RH)
- Among left-handed people, a RH specialization for language is more common than among right-handed people... but it’s still pretty rare (only ~27% show RH).

If language is mainly LH, how can we talk about things ‘experienced’ by the RH?

- Connections between hemispheres allow information to flow between them.
  - Corpus Callosum (massive- ~200,000,000 axons)
  - Anterior Commissure (frontal cortex)
  - Hippocampal Commissure
Split-Brain Patients

- Split-brain patients cannot communicate (much) between their hemispheres.

- Objects presented only on the left (going to the right side of the brain) cannot be named or described verbally (which uses the left side).

- But, the left hand (controlled by the right hemisphere) can pick out the object!
Split-Brain Patients’ Hemispheres Function Separately

- Left hemisphere can *tell* what it has seen, but right hemisphere can only *show* it
  - Present a picture to the right visual field (LH)
    - Left hemisphere can tell you what it was
    - Right hand can show you, left hand can’t
  - Present a picture to the left visual field (RH)
    - Subject will *report* that they do not know what it was (because the LH in fact doesn’t!!)
    - Left hand can show you what it was, right can’t

Lateralization of Function

- For many functions the hemispheres do not differ and where there are differences, these tend to be minimal
- Lateralization of function is statistical, *not* absolute!
  - e.g. Right hemisphere has *some* language abilities
Lateralization of Function

**Left Hemisphere**
- “Language”
  - Even for deaf people!
- Words, letters
- The details

**Right Hemisphere**
- Emotional Prosody
- Music
- Spatial ability
- Faces, patterns
- The big picture

The best documented difference:
- LH/local ... RH/global

What Letter?
B B
B B
B B
B B
B B B B B
B B B B
B B B
B B B
B B B
B B B
B B
Language

- Language is not a unitary ability
  - Production vs. Comprehension

  - Production
    - Requires having something to say, being able to associate that “thing” with words, and making the mouth move appropriately

  - Comprehension
    - Begins in the auditory system (detection and analysis of sounds) but there is a difference between recognizing a word and comprehending it

- Each of these abilities can be individually compromised!
What can possibly go wrong?

- **Aphasia**
  - A difficulty with speech (either production or comprehension) caused by brain damage rather than, e.g. motor deficits or deafness

What can possibly go wrong?

- **Broca’s aphasia**
  - Difficulty in language *production*
    - Comprehension is normal
    - Know what they want to say, but can’t say it
    - “expressive aphasia”, slow laborious speech, full of disfluencies.
    - Although words are often mispronounced, words that *are* produced are usually meaningful
What can possibly go wrong?

- Broca’s aphasia
  - Typically function words are most compromised, with content words being relatively spared.
  - Aphasias are a spectrum

Yes... ah... Monday... er... Dad and Peter... and Dad... er... hospital... and ah...
Wednesday... Wednesday, nine o'clock... and oh... Thursday... ten o'clock, ah
doctors... two... and doctors... and er...
teeth... yah.
Sarah

What can possibly go wrong?

- Broca’s aphasia: not ONLY a production problem!
  - Although comprehension is good, it is not normal
  - *Agrammatism* is present in production, and grammatical clues such as word order, tense markers or function words aren’t successfully used in comprehension either.
What can possibly go wrong?

- Broca’s aphasia: not ONLY a production problem!
  - Anomia: a difficulty in finding words (in naming things).

What can possibly go wrong?

- Broca’s aphasia: not ONLY a production problem!
  - Articulation difficulties: mouth motor movements are disfluent, so words are often mispronounced.
What else can possibly go wrong?

- Wernicke’s aphasia
  
  Wernicke’s area - difficulty in comprehension; but production is generally meaningless
  
  - Unlike Broca’s Wernicke’s aphasics generally speak quite fluently, with normal prosody, natural-sounding rhythm and apparently normal grammatical constructions.
  
  - “jargon aphasia”, natural sounding rhythm and syntax, but output is meaningless (“word salad”)
  
  - neologisms

CLINICIAN: “Can you tell me what happened to you?”

“It just suddenly had a feffort and all the feffort had gone with it. It even stepped my horn. They took them from earth you know. They make my favorite nine to severed and now I’m a been habed by the …. Uh…. stam of fortment of my annulment which is now forever.”
Wernicke’s Aphasia

- Difficulty recognizing words
- Impaired comprehension (failure to grasp the meaning of words)
- Difficulty converting thoughts into meaningful words

Wernicke’s Area

- Wernicke’s area is also implicated in Pure Word Deafness
- Uncompromised recognition of non-speech sounds and intonation.
- Caused by disruption of auditory input to Wernicke’s area, or damage to Wernicke’s area itself.
Speech Comprehension: Mirror Neurons

- Mirror Neurons are activated when we perform an action ourselves or when we see another performing that action.

Transcortical sensory aphasia

- Wernicke’s aphasics can’t understand the meaning of words or “translate” their thoughts into meaningful words.
- This seems to be due to trauma to the ‘posterior language area’.
- Damage to just this area often results in transcortical sensory aphasia.
- These patients can recognize words: they can repeat back what you say… but can’t make ‘meaning’.
The fact that transcortical aphasia patients can perform repetition suggests that there is a direct connection between Wernicke’s area and Broca’s area. This is known as the *arcuate fasciculus*. 

A direct connection between Wernicke’s area and Broca’s area enables patients with transcortical sensory aphasia to repeat words that they cannot understand.
The arcuate fasciculus

- A bundle of axons that seems to bring information from Wernicke’s area to Broca’s area about the sounds of words (but not their meanings!)

- *Conduction aphasia* patients speak fluently, have pretty good comprehension, but fail at repetition tasks... suggesting that the AF is important in STM of words and recently heard speech sounds

![Diagram of brain](image)

Damage to the arcuate fasciculus disrupts repetition of speech sounds; causes conduction aphasia

This connection enables patients with conduction aphasia to express their thoughts in words
Anomic aphasia

- Speech of anomic aphasics is fluent and grammatical, and their comprehension is fine... but they appear to have difficulty finding the right words.
- Fluent anomia is caused by posterior lesions to the temporal or parietal lobes.
- Patients adopt *circumlocutions*: alternative ways of saying what they mean.

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- Aphasia in Deaf People

  - Some researchers believe that in the history of our species, sign language preceded spoken language—that our ancestors began using gestures to communicate before they switched to speech.

  - Several studies have found a linkage between speech and hand movements, which supports the suggestion that the spoken language of present-day humans evolved from hand gestures.
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- Aphasia in Deaf People

- These results suggest that the region of the brain that controls grasping is also involved in controlling speech movements.

Mirror Neurons in Broca's Area. PET scans show a region of the inferior left frontal lobe that was activated when a person saw a finger movement or imitated it.
Links Between Hand and Mouth. The graphs show lip opening and voice amplitude of subjects repeating syllables while watching someone grasping small and large objects. Adapted from Gentilucci, M. European Journal of Neuroscience, 2003, 17, 179-184.

Disorders of Reading and Writing

- The reading and writing skills of patients with aphasia almost always resemble their speaking and comprehending abilities
  - Wernicke's patients have difficulty reading and writing (just as they have difficulty understanding speech and speaking)
  - Broca’s patients often can comprehend what they can read, but it is slow... and reading aloud is very poor
  - Conduction aphasics have some difficulty reading... and will often make semantic paraphasias
Disorders of Reading and Writing

- **Pure Alexia**
  - Loss of the ability to read, while writing is preserved
  - Can recognize words that are spelled aloud
  - Appears to be a perceptual disorder, caused by lesions that interfere with visual information reaching the extrastriate cortex of the LH

On left: damage in L primary visual cortex (red arrow shows destroyed pathways) - R visual field would be ‘blind’, but could still read

On right: damage to posterior corpus callosum prevents info from R extrastriate cortex from reaching L hemisphere thus preventing subject from reading
What is reading, anyway?

- Reading involves at least 2 different processes
  - Direct recognition of the word as a whole
    - “sight reading”
  - Sounding out a word letter by letter
    - “sound reading”

When we see a *familiar* word, we normally recognize it by its shape
- Whole word reading
- “happy”

Unfamiliar words require the recognition of individual letters and knowledge of the sounds they make
- Phonetic reading
- “felicitous”
Dyslexias

- Dylexia is faulty reading
  - Acquired type caused by brain damage
  - Developmental type apparent when children learn to read

Surface dyslexia

- Deficit in whole-word reading, generally caused by lesion to L lateral temporal lobe
  - Must sound all words out (easier with regularly spelled words such as *hand* or *table*, or pseudo words such as *glab* or *trisk*, harder with irregular words like *yacht* or *pint*)
  - Must listen to own pronunciation to understand what they are reading
Dyslexias

- Phonological dyslexia
  - Can read whole-words but cannot sound words out (thus, difficulty with new words)
  - Caused by damage to L frontal lobe

Visual Word Form Area

- A region of the fusiform gyrus on the base of the temporal lobe that plays a critical role in whole-word recognition.
In summary...

- Specific areas are critical for language comprehension and production...
- But language uses a lot more of the brain than just those areas!