Neurological Bases of Speech & Language

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SPEC 2231
Central Nervous System (CNS)

- Comprises the **brain & spinal cord**
- **peripheral nervous system** – conducts impulses toward or away from the CNS
- **CNS & PNS** monitor the body’s state by conducting messages from the senses & organs & responding to this info by conducting messages to the organs & muscles.
- **Neuron** – the basic unit of the nervous system
- A collection of neurons is a **nerve**.
- CNS & PNS transmit messages via nerves.
Neuron

Language development: An Introduction (Owens, 2008)
CNS cont.

• Spinal cord:
  ▪ At the lower end of the CNS.
  ▪ Transmits impulses between the brain & the PNS.
  ▪ At the top of the spinal cord: **brainstem** – consists of the medulla oblongata, the pons, the thalamus, & the midbrain, which regulate breathing & heart rate.

• Reticular formation –
  ▪ A compact unit of neurons in the brainstem.
  ▪ Integrates incoming auditory, visual, tactile, & other sensory inputs.
  ▪ Filters by inhibiting or facilitating sensory transmission.
CNS cont.

• **Thalamus** –
  Relays incoming sensory info to the appropriate area of the brain for analysis & prepares the brain to receive input.

• **Cerebellum** –
  At the rear of the brainstem, controls equilibrium.
Cerebrum

- On top of the brainstem & the cerebellum.
- Divided into the left & right hemispheres.
- Sensory & motor functions are contralateral – each hemisphere is involved with the opposite side of the body.
- Hemispheres are asymmetrical for specialized functions, such as language.
Cerebrum cont.

- White fibrous connective tracts covered by a gray **cortex** of mostly cell bodies in each hemisphere.

- 3 types of fiber tracts:
  - **association** – run between different areas within each hemisphere.
  - **projection** – connect the cortex to the brainstem & below.
  - **transverse** – connect the 2 hemispheres.

- The largest transverse tract is the **corpus collosum**.
Left Cerebral Hemisphere

Language development: An Introduction (Owens, 2008)
Cerebrum cont.

• The cortex has little hills called **gyri** & valleys called **fissures**, or **sulci**.

• Each hemisphere is divided into **4 lobes**: frontal, parietal, occipital, temporal

• **Central sulcus** – separates the frontal and parietal lobes.

• **Motor cortex** – in front of the central sulcus, controls motor movements.
Cortex cont.

• **Sensory cortex** – behind & parallel to the motor cortex, receives sensory input from the muscles, joints, bones, & skin.

• Motor & sensory functions are performed in specialized areas of the cortex.
Functions of the Cortex

1) Regulation –
• Responsible for the energy level & overall tone of the cortex.
• Maintains the brain at a basic level of awareness & responsivity.
• Occurs in the reticular formation.

2) Processing –
• Controls info analysis, coding, & storage.
• Occurs in the rear of the cortex.
Functions of the Cortex cont.

3) Formulation –

- Responsible for the formation of intentions & programs for behavior.
- Activates the brain for regulation of attention & concentration.
- Motor behaviors are planned & coordinated, but not activated.
- Occurs in the frontal lobe.
Hemispheric Asymmetry

• **Specialized** functions are generally lateralized to one hemisphere.

• In spite of asymmetries, info passes readily between the hemispheres via the **corpus callosum** & other transverse bodies.

• Brain functions are interconnected.

• **Specialization/ lateralization**
Hemispheric Asymmetry cont.

• Dominant hemisphere – the primary processing centers for a specific ability are housed primarily in one hemisphere. e.g., right hemisphere – comprehension of metaphorical language. left hemisphere – control of speech- & nonspeech-related oral movements.
- ~98% of humans are left-dominant for language (including almost all right-handed & 60% of left-handed people).
Right Hemisphere Dominance

- Some aspects of pragmatics.
- Comprehension & production of coherent discourse, speech prosody & affect, metaphorical language & semantics.
- Comprehension of complex linguistic & ideational material & of environmental sounds.
- Holistic processing by integration of info.
- Visuospatial processing.
Left Hemisphere Dominance

• Specialized for language in all modalities (oral, visual, & written)
• Linear order perception
• Arithmetic calculations
• Logical reasoning
• Step-by-step processing – e.g., rapidly changing sequential info, such as phonemes.
Brain Maturation

- Brain maturation & specialization are highly correlated.

- Indices of brain development:
  1) *gross brain weight* – Changes most rapidly from birth – age 2, at an adult level by age 12.
  2) *organization* – Chemical changes occur & internal pathways that connect parts of the brain become organized.
Brain Maturation cont.

• Neurons increase in size as dendrites & axons grow to form a web.
• **Myelination** – sheathing of the nervous system
• Neural pathways are identified – Basic wiring is determined by genes, but **experience** determines the pathways.
  - Use of neural pathways reinforces them, making them more efficient for future use.
Brain Maturation cont.

- Cell differentiation begins during the 16\textsuperscript{th} week of gestation.
- \textbf{Prenatal growth}: rapid growth in the brainstem & primary motor & somatic sensory cortices
- \textbf{Postnatal growth}: rapid growth in the cerebellum & cerebral hemispheres
- \textbf{Association tracts} for speech & language are mature by late preschool, but some areas for high linguistic functions are not mature until adulthood.
- Vocalization in newborns is controlled by the brainstem & pons.
- Maturation of the pathways between auditory & motor areas occurs early in the second year.
Brain Lateralization

• Main anatomical asymmetry in the brain is in the **left temporal lobe**. – May underlie left hemisphere dominance for speech & language reception & production.

• **Planum temporale** – white fiber tract beneath the temporal lobe, larger in the left hemisphere of ~2/3 of adults.

• When does lateralization occur?
Language Processing

• Methods used to identify where language is processed & produced:
  - Positron emission tomography (PET)
  - Magnetic resonance imaging (MRI)
  - Event-related potentials (ERPs)

• Language is a complex process performed by many areas of the brain.

• The **frontal & temporal lobes** of the **left hemisphere** are more active than other areas in speech perception & production.

• **Left insula** – an area of cortex between the frontal & temporal lobes that is active in speech production
Language Processing cont.

• Language comprehension & production don’t proceed in a strictly sequential manner.

i.e., comprehension:
phonetic ➔ phonological ➔ grammatical ➔ semantic

• Linguistic processing for comprehension & production depends on the person’s lexicon and stored linguistic rules.
Localization of Language

- **Processing** – begins with attending to auditory stimuli.
- Auditory signals received in the brainstem by the thalamus are relayed to:

  **Heschl’s gyrus** –
  - An area of each auditory cortex.
  - Distinguishes linguistic info from unimportant background noise.

- Coded **linguistic input** is sent to the **left temporal lobe** to be processed; **paralinguistic input** is sent to the **right temporal lobe**.

- Info is held in working memory in or near **Broca’s area** in the left temporal lobe.
Localization of Language cont.

- Info undergoes linguistic analysis in **Wernicke’s area** – in the left temporal lobe.
- **Angular gyrus & supramarginal gyrus** – assist by integrating visual, auditory, and tactile info and linguistic representation.
- Some word recognition and semantic decoding occur in the **right hemisphere**.
- Before storage, info is sent to the **hippocampus** in the left temporal lobe for consolidation.
Receptive Linguistic Processing

Language development: An Introduction (Owens, 2008)
Productive Linguistic Processing
Structures v. Processes

- **Structures** – fixed anatomical & physiological features of the CNS.
- Structures & their functions are similar across healthy individuals.
- The way structures organize, analyze, & synthesize linguistic info varies across people & tasks.
- **Information processing** – voluntary problem-solving strategies.
Info Processing

Involves cognitive processes for:

Attention
Perception
Organization
Memory
Concept formation
Problem-solving & transfer
Management/ executive function
Attention

Divided into:

**Orientation** – ability to sustain attention over time

**Reaction** – the amount of time required to respond to a stimulus
Discrimination

• Ability to identify stimuli differing along some dimension.

• Requires **working memory**, which is under the control of a **central executive** – supervises the organization & control of communication between systems & components.
Organization

• Organization of incoming sensory info is critical for later retrieval.

• If info isn’t well organized, or “chunked,” it will overload the storage capacity and impede memory.

• 2 organizational strategies:
  mediational – a symbol forms a link to some meaning
  associative – one symbol is linked to another
Memory

• The ability to recall info that has been previously learned or stored.
• After linguistic analysis, organized info is moved to short-term memory.
• Info is discarded or rehearsed in short-term memory for long-term memory.
• **Long-term memory** – info is retained by rehearsal or repetition and organization.
Memory cont.

- Memory is improved when linguistic info is **deep processed** – semantic interpretation & elaboration, relating to prior experience and knowledge.

- Words stored in different locations based on meaning, word class, sound pattern, & associational categories.
Levels of Info Processing

- **Top-down/ bottom-up processing**

**Bottom level –**
- Shallow analysis of perceptual data that places few demands on the brain.
- Data driven

**Top level –**
- Extraction & synthesis
- Conceptually driven, affected by expectations of the individual.
Levels of Info Processing cont.

• **Passive/active processing**

  **Passive** – Incoming data are analyzed in fragments until enough info can be combined to recognize a pattern.

  **Active** – Uses a comparator strategy that matches input with previously stored or a generated pattern or mental model.

• **Serial/parallel processing**

  **Serial** – one-at-a-time

  **Parallel** – simultaneous, processing accesses multiple levels of analysis at the same time.