Language and Higher Cortical Function

MHD Clinical Correlation – Neuroscience Block

Gregory Gruener, MD, MBA, MHPE
Vice Dean for Education, SSOM
Professor, Department of Neurology
LUHS a member of Trinity Health
Commissural connections

**Corpus callosum** - Projects from cortical area to mirror image (+ other areas)
- Genu – frontal lobes
- Anterior body – frontal lobe
- Posterior body – parietal lobe
- Splenium – occipital and temporal lobe

**Anterior commissure** - Interconnects temporal lobe & components of olfactory system

Association bundles or fasciculi

- Corticocortical connections in the same hemisphere
- Not all begin or end at the same point
- Fibers travel in both directions, leaving and entering

Cerebral cortex - Generalities

- Types of cortex
  - Neocortex – most of cortex (6-layers)
  - Archicortex – hippocampus (3-layers)
  - Paleocortex – telencephalon base, olfactory (3-5 layers)

- Neocortex “factoids”
  - Cerebral cortex (GM + WM) ~ 82% brain mass
  - Human brain ~ 86 billion nerve cells (19% are in cerebral cortex)
  - 80% are pyramidal cells, 20% non-pyramidal

- “Relationship” between Brodmann’s number and function

- Areas differ in neocortical structure/connections
  - Function may be localized there, participates in or facilitates that function within other structures
“Types” of neocortical areas

**Primary** - “Direct link to the world”: Inputs from thalamic nuclei and outputs to brainstem and spinal cord. Contains precise, but distorted body map(s)

**Unimodal** - “More complex response functions”: Adjacent to primary cortical areas, same “function, but less precise” body map(s)

**Multimodal** - “High level intellectual functions”: Association areas send converging inputs; may respond to multiple stimuli or under particular circumstances

---

**Neocortex Layers**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
<th>Area</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortexal</td>
<td>Upper limit of thalamus</td>
<td>Other cortical</td>
<td>Outer band of Heschl’s gyrus</td>
</tr>
<tr>
<td>Cortexal</td>
<td>Lower limit of thalamus</td>
<td>Other cortical</td>
<td>Inner band of Heschl’s gyrus</td>
</tr>
</tbody>
</table>

---

*Nolte J. The Human Brain, 6th ed., 2009*
Neocortex hierarchical processing of information

Hypothalamus
Primary Sensory Cortex
Unimodal Sensory Cortex
Premotor Cortex
Paralimbic Cortex
Limbic Cortex
Thalamus
Primary Motor Cortex
Multimodal Cortex

EEG Characteristics of sleep

Sleep Roles
- Restoration and recovery
- Consolidation of memory and daily experiences
- Brain growth and development

Characteristics of non-REM and REM sleep

<table>
<thead>
<tr>
<th></th>
<th>Non-REM Sleep</th>
<th>REM Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG</td>
<td>Large amplitude, slow frequency, synchronized</td>
<td>Low amplitude, fast frequency, desynchronized</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>Decreased</td>
<td>Almost abolished</td>
</tr>
<tr>
<td>Arousal level</td>
<td>Progressively higher</td>
<td>Highest</td>
</tr>
<tr>
<td>Mental activity</td>
<td>Vague dreams</td>
<td>Detailed, visual, emotional dreams</td>
</tr>
<tr>
<td>Autonomic activity</td>
<td>Increased parasympathetic Slow, regular pulse and respiration</td>
<td>Increased sympathetic Irregular pulse and respiration</td>
</tr>
</tbody>
</table>
“Regulation” of sleep-wake cycles

Approximately 10,000 neurons in the hypothalamus use retinal inputs to adjust to the day-night cycle. Neurons within the preoptic area and medullary reticular formation “turn-off” wakefulness. The flip-flop analogy represents the rapid and complete transitions between wake and sleep states.

Modularity of the cerebral cortex

Functional Connectome
Speech consists of phonation and articulation

- **Phonation**: sound production by moving vocal cords
  - Laryngeal muscles innervated by CN X
  - **Dysphonia**: hoarse, whispering, breathy

- **Articulation**: sound production by actions and varied positions of lips, tongue, palate, pharynx
  - Facial, oral muscles innervated by CN VII, IX, X, XII
  - **Dysarthria**: slurred, choppy, indistinct

Language – multimodal or symbolic communication

- Language centers in the dominant (usually left)
  - **Aphasia**: disorder of previously acquired language ability with impaired communication by means of any modality
  - **Prosody**: semantic and emotional meaning conveyed by changes in vocal pitch, inflection, melody or tone of speech (non-dominant hemisphere)
  - **Aprosodia**: poor prosodic comprehension when listening or lack of prosody when speaking

Characteristics of language

- **Fluency**: ease, facility and quantity of speech, regardless of content or meaning
- **Comprehension**
- **Repetition**: time-honored test phrase: “no ifs, ands or buts”
- **Paraphasias** (word or syllable substitutions)
  - Phonemic or literal: syllable (“sully” for “silly”)
  - Semantic or verbal: word (“blue” for “green”)
  - Neologism: nonsense word (“scatifang”)

Testing language

- Engaging in spontaneous conversation, Naming items, Repeating phrases, Answering questions, following spoken or written commands, Reading passages, Writing to dictation

Role: A distributed cortical network around the sylvian fissure

- Left hemisphere is dominant for language

Anatomical Network:

- Broca area (left frontal operculum and left inferior frontal gyrus)
- Wernicke area (posterior temporal gyrus, supramarginal gyrus and angular gyrus)
- Left middle temporal gyrus and anterior temporal cortex

Clinical deficits or syndromes:

- **Broca aphasia**
- **Wernicke aphasia**
- **Conduction aphasia**
Language “localization”

Geschwind, 1972

Language – Neocortical network

<table>
<thead>
<tr>
<th>Aphasic Syndrome</th>
<th>Lesion Site</th>
<th>Verbal Fluency</th>
<th>Verbal Repetition</th>
<th>Verbal Comprehension</th>
<th>Verbal Naming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca (motor)</td>
<td>1</td>
<td>non-fluent</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Wernicke (sensor)</td>
<td>2</td>
<td>fluent</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Conduction</td>
<td>3</td>
<td>fluent</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Global</td>
<td>1, 2, 3</td>
<td>non-fluent</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Transcortical Motor</td>
<td>4</td>
<td>non-fluent</td>
<td>good</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Transcortical Sensory</td>
<td>5</td>
<td>fluent</td>
<td>good</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Anomic</td>
<td>6</td>
<td>fluent</td>
<td>good</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Mixed Transcortical</td>
<td>4, 5, 6</td>
<td>non-fluent</td>
<td>good</td>
<td>poor</td>
<td>poor</td>
</tr>
</tbody>
</table>

Language localization (this detail is not on the exam)
**Perceptual - Motor – Neocortical network**

- **Role:** Historical name for this difficulty – “Parietal Lobe Syndrome”
  - Visual perception of extrapersonal space, perceptual-motor coupling for motor control

- **Anatomical Network**
  - Temporo-parieto-occipital junction (integrates sensory information)
  - Premotor cortex (generates the motor programs that are appropriate to accomplish the motor task and forwarded to the primary motor cortex that encodes the motor acts)
  - Inferior frontal gyrus and frontal operculum (generates motor program to cranial nerve nuclei and pattern generators); speech production, lateralized to the left hemisphere

- **Clinical deficits or syndromes:**
  - **Apraxia** - inability to conceptualize and perform a skilled, learned act on command
  - **Limb apraxia**
Executive function – Neocortical network

**Role:** Historical name for this difficulty – “Frontal Lobe Syndrome”
- Executive functions (Decision making, inhibition of inappropriate behavior)
- Social behavior (recognition of emotions of others, insight and empathy).

**Anatomical Network:**
- Primarily made up of the prefrontal cortex that is an integral component of other networks (emotion and social, attention and memory).
- Dorsolateral prefrontal cortex - highly interconnected with other prefrontal areas, cortical association areas and paralimbic areas.
- Medial prefrontal and orbitofrontal - interconnected with the cingulate gyrus, anterior insula, hippocampus and amygdala.

**Clinical deficits or syndromes:**
- Lateral prefrontal syndrome (Dysexecutive syndrome)
- Ventromedial prefrontal syndrome (“acquired sociopathy”)
**Emotion and Social – Neocortical network**

- **Role:**
  - Acquisition of fear responses, emotional processing, social recognition and behavior

- **Anatomical Network:**
  - Amygdala serves as the hub, interacts with the orbitofrontal, medial frontal cortex and the anterior and mid portions of the cingulate gyrus

- **Clinical deficits or syndromes:**
  - Bilateral dysfunction - impaired recognition of facial expression and emotions
  - Contributes to cognitive/behavioral manifestations of neurodegenerative disorders
  - Mediates some emotional/autonomic manifestations of temporal lobe seizures
  - **Klüver-Bucy Syndrome** - Severe bilateral injuries of the amygdala results: difficulty in recognizing objects, excessive visual attentiveness, loss of normal fear/anger responses, marked indiscriminate hypersexuality, changes in eating behavior

---

**Directed attention – Neocortical network**

- **Role:**
  - Attention can be considered the ability to selectively enhance the detection of certain stimuli at the expense of others.

- **Anatomical Network:**
  - Brainstem neuromodulator system - generalized arousal.
  - Anterior insular cortex and anterior midcingulate cortex - maintain attention
  - Lateral parietal and frontal cortex
    - Dorsal network - bilateral and comprises goal-directed attention (top-down)
    - Ventral network - right hemisphere and is stimulus driven (bottom-up).

- **Clinical deficits or syndromes:**
  - **Neglect** – impairment of spatial relationships between the body and its surroundings
  - **Extinction** – an inability to detect simultaneous stimuli on both sides of the body
Diffuse neuromodulatory system

Function of the serotonergic and adrenergic systems:
- Sleep-arousal mechanisms
- Integrative behavioral and neuroendocrine functions
- Modulate actions of other neurotransmitters
- Brain growth and development
- Pain suppression

Diffuse neuromodulatory system

Directed attention – Neocortical network
Object and Face Recognition - Neocortical network

- **Role:**
  - Recognition of tactile, visual or auditory features of an object that allows perception of that object as a whole.
- **Anatomical Network:**
  - Multimodal cortex located within the temporal lobe where all these modalities are integrated (ventral visual stream)
- **Clinical deficits or syndromes:**
  - **Auditory agnosia** - usually a bilateral lesion of unimodal auditory cortex
  - **Prosopagnosia** - inability to identify faces - lesion of the fusiform gyrus.
  - **Tactile agnosia (astereognosis)** - usually a lesion in the primary sensory cortex
  - **Visual object agnosia** - usually a lesion of the fusiform gyrus
Learning-Memory – Neocortical network

- **Role:**
  - Learn, store and retrieve information about autobiographical (events, places and time) and semantic knowledge (factual knowledge that is learned; historical events, categories, features of things). The medial temporal lobe initiates the steps in learning facts and names and more permanent storage occurs in the lateral temporal lobe.

- **Anatomical Network:**
  - Medial temporal lobe [includes the hippocampal formation, entorhinal cortex (gateway for neocortical inputs into the hippocampal formation), perirhinal cortex and parahippocampal cortex].

- **Clinical deficits or syndromes:**
  - Amnesia – ability to learn and recall information (loss of autobiographical and semantic memory; usually in the setting of bilateral temporal cortex damage)