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Session 405: Predicting Patient Behavior by Brain Lesion Site
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WELCOME!

• Introductions
• Where do you work?
• We’re all learning!

I. Neuroanatomy and the Impact on Cognitive Processing

Gross Anatomy – Terminology
cog n i tion (noun)
• /käɡˈniSH(ә)n/
• The mental action or process of acquiring knowledge and understanding through thought, experience, and the senses
• Result: turning perception, sensation, ideas, or intuition into a meaningful response to our environment
Gross Anatomy – Terminology

Neuroplasticity: An overlying term used to describe the ability of the brain to creating lasting change throughout a lifetime

- Prior to late 20th century science reported the brain was in a fixed state by adulthood
- This is false – fMRI, PET scans indicate ongoing fluidity
- Neuroplasticity encompasses both microscopic changes in individual neurons and larger-scale changes such as cortical remapping in response to injury

Physical Facts About The Brain

Gray matter (outer part)
- Contains the cell bodies, dendrites and axon terminals of neurons
- Location of synapses

White matter (inner part)
- Bundles of myelinated axons, which connect various gray matter areas of the brain to each other, and carry nerve impulses between neurons

Brain Function

- Brains use about 20% of the total blood and 20% of the total oxygen that is circulating through the body at any given time
- If blood supply to the brain is cut off for more than 8 to 10 seconds, loss of consciousness will occur
- The human brain can survive for between 4 and 6 minutes without any oxygen
- In an awake state can generate 10 - 23 watts of energy
Gross Anatomy – A Model Neuron

- Synapse: Nerves do not fuse with one another, but rather end near one another and communicate via the synapse, or synaptic cleft.
  - Messages between cells is chemical (neurotransmitters)
  - Messages along a single cell is electrical (impulse)

Gross Anatomy – A Model Nerve

- Glial cells surround neurons and provide support for and insulation between them.
- Glial cells are the most abundant cell types in the central nervous system.
- Types of glial cells include oligodendrocytes, astrocytes, ependymal cells, Schwann cells, microglia, and satellite cells.
In human neuroanatomy, axons within the brain, called fibers, can be categorized on the basis of their course and connection into:

1. Association fibers
2. Projection fibers
3. Commissural fibers

**Association fibers**
- Unite different parts of the same cerebral hemisphere
- Two kinds: (1) those connecting adjacent gyri = short association fibers (GREEN), (2) those passing between distant parts = long association fibers (RED)

**Projection fibers**
- Consist of efferent (motor) and afferent (sensory) fibers
- Unite the cortex with lower parts of the brain and the spinal cord
Commissural fibers (RED)
- AKA “transverse fibers”, these white-matter structures connect the two hemispheres of the brain
- Includes:
  - Corpus callosum
  - Anterior/posterior commissure
  - Hippocampal commissure

**Corpus Callosum**
- Largest commissural fiber system in the human brain
- Consists of about 200-300 million axons that connect left and right cerebral hemispheres
- Essential to the communication between the two hemispheres

**Corpus Callosum: Anterior Commissure**
- AKA the precommissure
- A bundle of nerve fibers (white matter) that connecting the two temporal lobes of the cerebral hemispheres across the midline
- AC is categorized into two fiber systems:
  - 1) the olfactory fibers: contains decussating (crosses over) fibers from the olfactory tracts, vital for the sense of smell and chemoreception
  - 2) the non-olfactory fibers: plays a key role in pain sensation, more specifically sharp, acute pain

AC also interconnects the amygdala and temporal lobes, contributing to the role of memory, emotion, speech and hearing
Gross Anatomy – Nerve Tracts

• Corpus Callosum: Posterior Commissure (PC)
  – PC plays a role in the connection between the **right occipital cortex (vision) and the language centers (temporal) in the left hemisphere**
  – Why is this important?
    – Visual information from the left side of the visual field is received by the right visual cortex and then transferred to the word form system in the left hemisphere through the PC and the splenium
  – Disruption of the PC fiber pathway can cause:
    – Alexia without agraphia – can’t read word, but can write word
    – Inability to perform vertical eye movement

Gross Anatomy – Frontal Lobe

• Largest of all cranial lobes, about 1/3 of hemisphere
• Contains 4 important gyri, precentral gyrus, and three horizontal gyri
• Houses Executive Functions “thinking skills” and “social cognition”
• Frontal lobes hit maturation in the early to mid 20’s, marking the changes seen in adult vs adolescent behavior/decision making/risk taking
• Frontal lobes of the female brain matures by 21, males 25 (sorry guys, we’re slower)

Gross Anatomy – Frontal Lobe

• Extremely vulnerable to injury due to their location at the front of the cranium, proximity to the sphenoid wing and their large size
Gross Anatomy – Temporal Lobe

- Home to the primary auditory and language cortices
- Contains the hippocampus: plays a key role in the formation of long-term memory
- The superior temporal gyrus includes an area (within the Sylvian fissure) where auditory signals from the cochlea first reach the cerebral cortex
- The arcuate fasciculus: a neural pathway connecting the posterior temporal - parietal junction with the frontal cortex
- For the majority of right-handed humans the language centers of the brain are located in the left temporal lobe

NON LANGUAGE FUNCTIONS

- Ventral (underside) temporal cortices are involved in high-level visual processing of complex stimuli such as faces (fusiform gyrus) and scenes (para-hippocampal gyrus)
- Anterior parts of this ventral stream for visual processing are involved in object perception and recognition
- We will talk about the visual system and this will make more sense – but think about “what” (ventral) vs “where/how” (dorsal) streams of visual processing

NON LANGUAGE FUNCTIONS

- The medial temporal lobes (near the sagittal plane that divides left and right cerebral hemispheres) are thought to be involved in episodic/declarative memory
- This afternoon we will talk more about the hippocampus, located deep within the temporal lobes
Gross Anatomy – Temporal Lobe

Presentations in presence of lesions in temporal lobe:

**LEFT HEMISPHERE**
- Deficits in expressive language (verbal/written) as well as receptive language (auditory/reading)
- Slowed auditory processing of information heard

**RIGHT HEMISPHERE**
- Altered recognition of visual context (e.g., faces)
- Loss of tonal or prosodic function (e.g., music) – this will make more sense soon!
- Non-verbal based recall (e.g., where was the car parked?) because of hippocampus + parietal lobe ties
- Alterations in personality (i.e., egocentrism, perseveration)

Gross Anatomy – Parietal Lobe

- Motor strip is located in frontal lobe just anterior to the central sulcus
- Sensory strip is located in the parietal lobe just posterior to the central sulcus

- Specializes in determining spatial sense
- Highly involved in navigation
- Comprised of the somatosensory cortex and the dorsal stream of the visual system
- Parietal cortex can map objects perceived visually into body coordinate positions
Neurophysiology - Parietal Lobe

- Integrates sensory information from various parts of the body and in the manipulation of objects
- Referred to by vision scientists as the dorsal stream of vision (as opposed to the ventral stream in the temporal lobe)
- This dorsal stream has been called both the 'where' stream (as in spatial vision) and the 'how' stream (as in vision for action)
- The posterior parietal cortex (PPC) receives somatosensory and/or visual input
  - Through motor signals, this then controls movement of the arm, hand, as well as eye movements

Jay's Thought: Perhaps this is why screen time for young children under 3 may not be ideal. Object play with toys builds parietal lobe connections and eye-hand coordination.

Neuropathology – Right Parietal Lobe

Clinical presentations in presence of lesions:
- Altered proprioception (body in space)
- Altered 2-point discrimination/tactile recognition
- Altered visuospatial processing/poor visual guidance of hands
- Altered left-right discrimination
- Altered ability to direct movement in space (fly kite/video games)
- "Alien Hand Syndrome": condition in which a person experiences their left hand acting seemingly on its own, without control over the actions

Neuropathology – Left Parietal Lobe

Gerstmann’s syndrome: associated with lesion to the dominant (usually left hemisphere in right hand dominant Pt's) parietal lobe near the angular gyrus

Characterized by four primary symptoms:
- Dysgraphia/agraphia: deficiency in the ability to write
- Dyscalculia/acalculia: difficulty in learning or comprehending mathematics
- Finger agnosia: inability to distinguish the fingers on the right hand
- Left-right disorientation
Gross Anatomy – Occipital

- Contains the primary visual cortex located along medial plane of occipital lobe
- Associated visual cortex along adjacent cortex
- Where visualizations in dreams originate

MORE TO COME SOON!

Gross Anatomy – Cerebellum

- Located posteriorly, vital to motor control
- Does not initiate movement: why?
- Contributes to coordination, precision, and accurate timing
- Receives input from sensory systems of the spinal cord and from other parts of the brain, then integrates into fine motor movement
- Damage to the cerebellum does not cause paralysis – but will result in disorders in fine movement, equilibrium, posture and motor learning

Clinical presentations in presence of lesions:
- Ataxia – dysfunction of coordinated movement
- Dysmetria - undershoot or overshoot of intended position with the hand, arm, leg, or eye

Neurophysiology – Cerebellum

- Cognitive Impact of Cerebellar lesions:
  - fMRI research indicates a tie between the cerebellum and higher level cognitive functions
  - Pathways link not only the prefrontal cortex, superior temporal regions, posterior parietal lobes, and hippocampus to the cerebellum, but there are also very specific pathways that link the cerebellum back to these areas of the brain
  - Cerebellar-cognitive affective syndrome (CCAS) includes changes in personality, impairment of linguistic abilities, and disturbance of higher-order functions including reasoning and memory
  - Cognitive dysmetria/dysmetria of thought: difficulty in coordinating and monitoring the process of receiving, processing, and expressing information
Gross Anatomy – Insula

Location:
- Portion of cerebral cortex folded deep within the lateral sulcus
- Overlying tissue = operculum (lid)
- Opercula are formed from parts of the frontal, temporal, and parietal lobes
- The anterior insula is interconnected to regions in the temporal and occipital lobes, orbitofrontal cortex, and inferior frontal gyrus

Neurophysiology – Insula

Functions:
- Involved in consciousness and play a role in diverse functions usually linked to emotion or the regulation of the body's homeostasis
- Involved in self-perception, motor control, self-awareness, cognitive functioning, and interpersonal experience
- Thus, it is involved in psychopathology

Multimodal sensory processing:
- Functional imaging studies show activation of the insula during audio-visual integration tasks

Interoceptive awareness
- Involved in empathy and metacognitive emotional feelings (thinking about why we feel the way we feel about something)
- fMRI results show that the structure and function of the right frontal insula is correlated with the ability to empathize with the pain of others
- Greater right anterior insular grey matter volume correlates with increased accuracy in the subjective sense of the inner body
Neurophysiology – Insula

Social emotions
• The anterior insula processes a person’s sense of disgust both to smells and to the sight of contamination and mutilation even when just imagining the experience
• In social experience, it is involved in the processing of norm violations, emotional processing, empathy, and social decision making

Emotions
• The insula is believed to process convergent information to produce an emotionally relevant context for sensory experience
• The right anterior insula is significantly thicker in people that meditate

Insula: Clinical Significance

Progressive expressive aphasia:
• What is that?
  – Deterioration of normal language function that causes individuals to lose the ability to communicate fluently while still being able to comprehend single words and intact other non-linguistic cognition
• Found in a variety of degenerative neurological conditions including Pick’s disease, motor neuron disease, corticobasal degeneration, frontotemporal dementia, and Alzheimer’s disease
• Associated with hypometabolism and atrophy of the left anterior insular cortex

Gross Anatomy – Limbic

• Structures within the limbic system: the amygdala, hippocampus, thalamus, hypothalamus, basal ganglia, and cingulate gyrus
Gross Anatomy – Limbic

- A complex set of structures found on the central underside of the cerebrum
- Comprising inner sections of the temporal lobes and the bottom of the frontal lobe
- Combines higher mental functions and primitive emotion into a single system often referred to as the emotional nervous system
- Responsible for both our emotional lives and also our higher mental functions (e.g., learning, formation of memories)

Gross Anatomy – Limbic

- Amygdala: emotion center of the brain
- Hippocampus: essential to formation of new memories about past experiences
- Thalamus and hypothalamus: associated with changes in emotional reactivity

Gross Anatomy – Limbic

- Cingulate gyrus:
  - Coordinates smells and sights with pleasant memories
  - Induces an emotional reaction to pain
  - Helps regulate aggressive behavior

- Basal ganglia: organizing motor behavior and coordinating rule-based, habit learning
II. Optic System And Visual Perception

Vision Vocabulary - Anatomy

- **Optic Nerve**: nerve fibers from the retina to the optic chiasm
- **Optic Chiasm**: the X-shaped structure formed at the point below the brain where the two optic nerves cross over each other
- **Optic Tract**: nerve fibers from chiasm to the lateral geniculate nucleus in the thalamus

Vision Constructs

- **Visual Perception**: the ability to see and interpret (analyze and give meaning to) the visual information that surrounds us
- **Visual Acuity**: sharpness of vision, measured by the ability to discern letters or numbers at a given distance according to a fixed standard
- **Visual field**: external area visible to one or both eyes without movement
- **Retinal fields**: is the focused representation of the visual field
- **Peripheral Vision**: side vision; what is seen on the side by the eye when looking straight ahead
Visual Physiology: Step-By-Step

• Ciliary muscle fibers innervated by the oculomotor nerve (CNIII) effect the tension on the lens of the eye allowing focusing
• Light refracted by the cornea and lens project on to the retina
• The process of refraction through a convex lens causes the image to be flipped
• Thus when the image hits the retina it’s inverted/upside down

Visual Physiology: Step-By-Step

• Light energy is then converted by the retinal photoreceptor cells into nerve impulses
• Nerve impulse carry electro-chemical messages along the optic nerves to the optic chiasm
• In the optic chiasm nerve fibers move to both contralateral and ipsilateral hemispheres
• That’s confusing…why?

Visual Physiology: Step-By-Step

Because (simplified):
• Visual fields are divided into nasal and temporal nerve fibers
• Nerves from the left nasal and right temporal fields travel to the right optic tract
• Nerves from the right nasal and left temporal fields travel to the left optic tract
Visual Physiology: Step-By-Step

Lateral Geniculate Nuclei (LGN):
- Is a relay center in the thalamus for the visual pathway
- Receives major sensory input from the retina
- Main central connection for the optic nerve to the visual cortex in the occipital lobe
- In humans, each LGN has six layers of neurons (grey matter) alternating with optic fibers (white matter)

Visual Physiology: Step-By-Step

- Thalamic projections from the LGN’s to the visual cortex via the optic radiation fibers
- Interpretation of visual images and movement occurs in primary and associated visual cortex in the occipital lobes
- Primary visual cortex projects to the adjacent visual association regions where visual information is elaborated and synthesized with experiences in memory for recognition

Visual Physiology: Vascular Supply

Vascular sources for vision:
- Posterior Cerebral Artery
- Middle Cerebral Artery
- Anterior Choroidal Artery (off ICA)

EFFECT OF CVA?
Neuropathology of the Occipital Lobe

Clinical presentations in presence of lesions:

• If one occipital lobe is damaged, the result can be homonymous vision loss from similarly positioned “field cuts” in each eye
• Lesions in the parietal-temporal-occipital association area are associated with color agnosia, movement agnosia, and agraphia
• Damage to the primary visual cortex can cause blindness due to the holes in the visual map on the surface of the visual cortex
• Occipital lesions can cause visual hallucinations

Visual Based Disorders

• Skull Formation and shearing effect on Optic system

Visual Based Disorders: TBI

Effect of shear injuries upon vision:

• If patient experience an acceleration-deceleration injury (TBI) the optic pathway may be torn
• Clinical observation would reveal function associated with vision processing and perception are significantly affected
  – May cause blurred vision, double vision, decreased peripheral vision and blindness
• Although optic nerve injuries are common after TBI dx is challenged by overlying changes in behavior making testing difficult until further cognitive recovery has occurred
Visual Based Disorders: TBI

Type of shear injuries effecting vision:
- Traumatic optic nerve injury
- Optic chiasm and related pathways
- Ocular motor neuropathies
- Axonal injuries
- Loss of retinal ganglion cells

Symptoms of shear injury upon vision:
- Photophobia
- Double vision
- Blurred vision
- Loss of vision
- Palsy of optic muscles
- Visual processing difficulties

III. Executive Functions Of The Frontal Lobe

Neurophysiology - Frontal Lobes
- Frontal Lobes and Neurotransmitters:
  - Contain most of the dopamine-sensitive neurons in the cerebral cortex
  - Dopamine system is associated with reward, attention, short term memory tasks, planning and motivation
  - Dopamine tends to inhibit and select sensory information arriving from the thalamus to the forebrain
Frontal Lobe Behavioral Control

- House executive functions:
  - Initiation
  - Impulse Control
  - Pragmatics/Social behavior
  - Mediation of social behavior
  - Attention to detail
  - Processes related to memory
  - Reasoning/Decision Making
  - Insight /Judgment
  - Sustained concentration
  - Organization/Problem Solving
  - Interpretation of environmental feedback

Cognitive Pyramid

- Vigilance, Alertness, Arousal
- Concentration and Attention to Stimuli
- Organization and Sequencing
- Problem Solving
- Reasoning/Logic
- Insight/Judgment
- Self-actualization

Frontal Lobe (FL) Behavioral Control

- FL’s house ability to recognize future consequences resulting from current actions
- Mediates choice making between good and bad actions (or better and best)
- Override and suppress unacceptable social responses
- Determine similarities and differences between things or events
Frontal Lobe (FL) Behavioral Control

- Plays an important part in retaining longer term memories which are not task-based
- These are often memories associated with emotions derived from input from the brain’s limbic system
- Modifies those emotions to generally fit socially acceptable norms
- Social cognition/Pragmatics: eye contact, proximity, humor, volume, topic maintenance, topic shifting

Shear Injury and Anxiety


Background:
- In the chronic stages of moderate-severe traumatic brain injury (TBI), progressive hippocampal volume loss, continuing well after acute neurological insults have resolved, has now been well documented
- Elevated anxiety symptoms are associated with compromise to the medial temporal lobes

Objective:
- Examine whether higher anxiety symptoms predict greater hippocampal volume loss in moderate-severe TBI

Method:
- Longitudinal behavioral and magnetic resonance imaging (MRI) data taken 5 to 12 to 30 months post-injury for 80 participants
- Anxiety symptom and MRI data collected at a minimum of 2 time points
Shear Injury and Anxiety


Results:
• Higher anxiety symptoms at 5 and at 12 months following moderate-severe TBI predicted significant later volume loss in the right hippocampal complex and the right hippocampal head
• Right hippocampal volume and volume change however didn’t predict subsequent anxiety scores or anxiety change scores
• Unilateral effect: anxiety led to tissue change, but tissue changes did not necessarily lead to anxiety

Shear Injury and Behavioral Health


Research Summary:
• TBIs are associated with a lifelong increased risk of experiencing clinically-significant anxiety, highlighting the chronic nature of TBI sequelae
• Positive lifestyle changes (e.g., increasing physical activity, reducing alcohol consumption) may decrease the risk of anxiety problems in the early years after a TBI
• Comorbid anxiety and depression was common, indicating that both should be monitored and treated

Therapy Implications: Physical Therapists

FL damage could mean:
• Difficulty judging safety of a surface by vision (this links to optic fx, perhaps to dorsal “how” stream)
  — I see that patch of ice, but no need to slow down, right?
• Difficulty inhibiting speed of movement to accommodate weakness or disequilibrium (avoiding crashing into door frame)
• Over estimating global physical strength and balance
• Forgetting weight bearing restrictions (degree of distraction?)
• Judging amount of weight being applied to leg/foot
• Lack of sequencing for safe transfers, steps to getting out of w/c
Therapy Implications: Occupational Therapy

FL damage could mean:
- ADL sequences are disordered, steps missing, task breakdown
- A lack of integration of new physical limitations into predicting time to complete task, tools needed
- Lack/limited initiation of compensation (Yah, I know what to do, but I can’t make myself do it when I need to do it)
- Needing multiple repetitions to learn new hemi-techniques
- Poor money management skills, acalculia, kitchen safety
- Initiating the placement of splints, completing exercises for grip strength between sessions

Therapy Implications: Speech Therapy

FL damage could mean:
- A disregard of one’s behavior upon the environment around them, specifically egocentrism (pragmatic savvy)
- Inability to self monitor and recognize task breakdown
- Assistance needed to initiate review for errors, judge worst/better/beat repair options
- Inability to judge nonverbal cues in social situations
  - My SLP is standing up, walking to doorway, turning sideways, no eye contact
- Poor presupposition skills in conversation and over use of pronouns vs proper nouns to guide listener’s narrative
- Unsafe self feeding (poor rate and portion size control) leading to aspiration and falling back to more restrictive diets (R CVA especially)

IV. Communication And Left Hemispheric Functions
Neurophysiology – Temporal Lobe

Auditory Functions
– Temporal lobes are involved in auditory perception
– Location of the primary auditory cortex for hearing
– Adjacent areas in the superior, posterior and lateral parts of the temporal lobes are involved in high-level auditory processing

Communication Functions
– Language center of brain
– Important for the processing of semantics in both language and vision
– Wernicke’s area is key to receptive/comprehension
– Broca’s area, in the frontotemporal lobe, is key to expressive language
– Broca’s and Wernicke’s are connected by the arcuate fasciculus, an association fiber

Arcuate Fasciculus (association fibers)
– Unite different parts of the temporal lobe
– Short association fibers link Broca’s to Geschwind’s, Geschwind’s to Wernicke
– Long association fibers link Broca’s to Wernicke’s
Neurophysiology – Temporal Lobe

• Arcuate fasciculus (AF): bidirectionally connects caudal temporal cortex and inferior parietal cortex to locations in the frontal lobe
  – Left Hemisphere: damage to the inferior parietal lobe that extends into the subcortical white matter and damages the arcuate fasciculus results in conduction aphasia
  – The symptoms of conduction aphasia suggest:
    • The connection between posterior temporal cortex and frontal cortex plays a vital role in short-term memory of words and speech sounds that are new or have just been heard
    • The arcuate fasciculus connects these two regions and circulates information back and forth, possibly contributing to short-term memory

Neurophysiology – Temporal Lobe

• Geschwind’s territory
• Discovered in 1960’s by Norman Geschwind, a neurologist
• fMRI have shown that the inferior parietal lobe (angular gyrus and supramarginal gyrus) is connected by large bundles of nerve fibers to both Broca’s area and Wernicke’s area
• Appears to mature later, explaining why children typically learn to read/write around 5-6 years old

Neurophysiology – Temporal Lobe

• The left inferior parietal lobe (LIPL) lies at a key location in the brain, at the junction of the auditory, visual, and somatosensory cortices, with which it is strongly connected
• Neurons in LIPL have the particularity of being multimodal: can process different kinds of stimuli (auditory, visual, sensorimotor, etc.) simultaneously
• This makes the LIPL an ideal candidate for capturing the multiple properties of spoken and written words: their sound, written appearance, semantic function, etc.
• LIPL may thus help the brain to classify and label things, which is a prerequisite for forming concepts and thinking abstractly
Neurophysiology – Temporal Lobe

• Arcuate fasciculus (AF)
  – Right Hemisphere:
    • In nine out of ten people with tone deafness, the superior arcuate fasciculus in the right hemisphere could not be detected
    • Process of articulating specific words (syntax, grammar) merged with emotional context (i.e., prosody), is processed by the corresponding anatomical regions in the non-dominant (right) hemisphere
    • Primary function is visuospatial processing, but also with processing prosody (They are in the white house, White House)

Why isn’t my patient following my commands?

• Causes of lack of command following:
  – Hearing acuity?
  – Rate of therapist’s speech?
  – Grammatical complexity?
  – Internal/external distraction vs focused attn?
  – Wernicke’s disconnect?
  – Slow auditory processing? (watch foreign language TV)

Not using key words (HOME, CHOCOLATE, NAPTIME)

V. Spatial Processing And Right Hemispheric Functions
Neurophysiology – Right Lobe

Attention to detail:
Defined: The ability to concentrate on a specific feature of a visual stimuli and likely ties to figure ground: ability to discern something from its background
– Picking out the spatula in junk drawer
– Deciding what is watts per hour vs total cost due on electric bill when both are numbers
– Discerning her black gloves from his black gloves in closet

Divided visual attention:
• Ability to track back to where you “left off” above or below
  – Regardless of hemineglect, often right brain injuries struggle to divide visual attention even if from the top to bottom, and go back to top of page
  – Given a table/graph task with content questions below graph – patient will write answer on wrong line or struggle with horizontal/vertical axes for TV Guide’s channels vs time of programs

Perception:
• Visual field perception deficits cause a person to have difficulty perceiving and processing any information on the left visual field (left-sided neglect/cut, homonymous hemianopsia)
  – e.g., individuals with RHD may have difficulty with reading words on the left side of a page, eating food on the left side of their plate, or acknowledging the left side of their body
  – Gestalt perception deficits where the patient does not recognize an object as a “unified whole” when viewing a portion of the object
    – The mind has an innate disposition to perceive patterns in the stimulus based on certain rules
    – These principles are organized into five categories: Proximity, Similarity, Continuity, Closure, and Connectedness
Neurophysiology – Right Lobe

- Reasoning and problem solving:
  - Difficulty identifying that there is a problem (e.g., ran out of medication) (perhaps a Gestalt error?)
  - Difficulty initiating and ultimately generating a solution (e.g., call the pharmacy, although verbal reasoning = left hemispheric, thus "I know I should call, but do I get up and grab phone?")

- Spatial Memory:
  - Difficulty recalling previously learned nonverbal information and learning new nonverbal information
  - Where did I park the car in the lot at the store?

Neurophysiology – Right Lobe

- Organization:
  - Difficulty with systematically arranging information and planning
  - Often reflected in communication difficulties, such as trouble telling a story with events in the right order; giving directions, or maintaining a topic during conversation
  - Note the lap table in the hospital room, usually cluttered

- Insight:
  - Difficulty recognizing problems and their impact on daily functioning,
  - Pt has trouble predicting impact of their choices upon family members

Neurophysiology – Right/Left Lobes

- Anosognosia:
  - A "lack of insight", a symptom of brain injury or of severe mental illness experienced by some that impairs a person’s ability to understand and perceive his or her illness

- Social communication (pragmatics):
  - Difficulty interpreting abstract language such as metaphors, making inferences, and understanding jokes
  - Problems understanding nonverbal cues and following the rules of communication (e.g., saying inappropriate things, not using facial expressions, talking at the wrong time)
Right Hemisphere and Social Pragmatics


- Faces provide a constantly changing source of information about other people’s moods, intentions, and the focus of their attention
- In humans, a face-selective region in the posterior superior temporal sulcus (pSTS) is believed to be a cortical locus for processing the dynamic aspects of faces, such as facial expression and eye gaze
- Like the pSTS, the amygdala has been strongly implicated in neuroimaging studies of facial expression recognition
- Neural pathways link these two structures when humans are involved in facial recognition and judging eye gaze

Right Temporal Lobe: Spatial Awareness


- Many mammals spatial awareness stems from bilateral function of temporal cortices
- Spatial awareness in humans is a function largely confined to the right superior temporal cortex
- Location is topographically reminiscent of that for language on the left in humans
- Lateralization of spatial awareness parallels the emergence of an elaborate representation for language on the left side

What does this mean for PT/OT/ST

- Right hemispheric injuries will allow most patients to have intact verbal expression
- Due to the changes to the functioning of the temporoparietal regions, the patient may have difficulty with spatial tasks, visuospatial organization (both in 3D and on paper/pen tasks), and attention to detail
- Injury to the right hemisphere may result in both left neglect/field cuts and inattention to recognize visual incongruency (e.g., what I’m reading doesn’t make sense)
VII. Memory: How The Hippocampus And The Amygdala Partner

Hippocampus

- Deep inside the medial temporal lobes lie the hippocampi (singular)
- Left and right hippocampi, one in each hemisphere
- Commisural fibers link the right and left hippocampi via the hippocampal commissure

Hippocampus

- Vital to the consolidation of short term recall into long term recall
- Damage results in difficulty with anterograde amnesia, or the ability to lay down new memory (new learning)
- Damage however does not appear to have an effect on long term, consolidated memory recall
- Key factor in spatial navigation
- One of the first areas to show damage with Alzheimer’s Disease
- Hippocampus weighs the importance of episodic acts and decides which should be kept as memories
  - Who remembers there being traffic this morning?
  - Who remembers how many blue cars drove by them?
Hippocampus


- The hippocampus is especially sensitive to global reductions in oxygen level in the body.
- Periods of oxygen deprivation (hypoxia) which are not fatal may nonetheless result in particular damage to the hippocampus.
- Even a single hypoxic event can lead to premature aging of the hippocampal tissue, and thus long term accelerated effects upon memory function/decline.

Medical events that could lead to hypoxia, and reduction in hippocampal function:
- Heart attack, respiratory failure, sleep apnea, carbon monoxide poisoning, near-drowning, etc.

Jay’s Thought: Who is treating patients s/p CABG? Noticing any patterns?

Hippocampal Function


- In the human hippocampus, task-related activity may be localized to only one hemisphere.
- Lateralization may enable the left and right hippocampus to support complementary functions in human episodic memory (a dual processor?)
- The left hemisphere is vital to language processing.
- The right hemisphere is vital to visuospatial attention.

What does this mean for PT/OT/ST

- Left hemispheric injury could lead to the patient having difficulty recalling your verbal instructions.
- Right hemispheric injury could lead to the patient having difficulty recalling motorically “how” the task is performed.
- What would be an example of PT/OT/ST task we would need to consider R vs L hippocampal injury impacting patient performance?
- If someone has a R hemispheric injury should they talk through the sequence while they do the sequence to utilize their bilateral processors?
Hippocampal Function

Multiple studies have indicated the hippocampus contains “place” cells that construct mental maps of position. Thus it appears hippocampal function affects:

- Our sense of where we are in 3D space
- Identifying where things external to us are located in space
- Understanding of body in space to object in space relationship (how close am I to the light switch?)
- Learning and recalling routes and spatial routines (e.g., get to the store, how to complete a basic ADL like dressing)


Results:

- Profound improvement of physical fitness and increase in individual anaerobic threshold
- Significant differences in the activation pattern of the left anterior hippocampus during the pair-associates task after the intervention between test/control groups
- Significant positive correlation between changes in exercise-induced BDNF and left anterior hippocampal activation
- The brain’s motor network activation was significantly stronger after the exercise intervention

Memory Therapy

<table>
<thead>
<tr>
<th>Learning</th>
<th>Storage</th>
<th>Retrieval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehearsal (verbal or motor)</td>
<td>No control over storage</td>
<td>Review Notes</td>
</tr>
<tr>
<td>Image</td>
<td></td>
<td>Decode Acronyms</td>
</tr>
<tr>
<td>Taking Notes</td>
<td></td>
<td>Association (go out on counter to remind you to write a thank-you card)</td>
</tr>
<tr>
<td>Formulating acronyms</td>
<td></td>
<td>Put things in obvious place (DVD on counter to return to Red Box)</td>
</tr>
<tr>
<td>Repetition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periodic cues from others to repeat task (spaced retrieval)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memorize distractions</td>
<td>Sleep</td>
<td>Focus attention</td>
</tr>
<tr>
<td>Make eye contact with speaker</td>
<td>Nutrition</td>
<td>Take a break – think of it later</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm clock on cell phone</td>
</tr>
</tbody>
</table>
VII. Recovery From Acceleration/Deceleration Injuries: Diffuse Axonal Injuries (DAI)

Diffuse Axonal Injury

- Most common/devastating type of TBI
- Damage from DAI occurs over a more widespread area than in focal brain injury
- There can be extensive lesions in white matter tracts
- DAI is a major cause of unconsciousness and persistent vegetative state after head trauma
- Cause = shearing forces from head rapidly accelerated or decelerated
- Results from rotational forces or severe deceleration
- MVA most frequent cause of DAI, but can also occur in falls, assaults

Diffuse Axonal Injury

- Nerve cells in human brain less capable of cellular division/regeneration than other cells
- There are limitations to recovery of sensorimotor and cognitive functions after lesions to the CNS
- Studying (briefly, I promise) synaptic physiology is a natural place to understand injury and nutritive processes between neurons
Diffuse Axonal Injury

• Nutritive material (trophic) is shared between neurons
• Tropic factors support cellular maintenance on both the sending/receiving sides of the synapse
• If pre/post synaptic terminals degenerate the neuron will also degenerate
• Severing an axon affects the pre/post synaptic connections of the damaged neuron, as well as the affected cell

Diffuse Axonal Injury: Primary injury

Physiology of neural injuries
• Understanding the events that occur after cellular injury helps to explain spontaneous recovery after trauma, vascular accidents, tumor, and metabolic insufficiencies
• Injury to the axon results in one of two types of degenerative changes
  – Axonal (retrograde) reaction - changes in the proximal segment moving towards cell body
  – Wallerian (anterograde) degeneration - changes in the distal segment moving toward terminal ends of neuron

Diffuse Axonal Injury: Primary injury

Axonal (retrograde) reaction:
• Injury extends from the site of injury back towards the cell body
• Degenerative changes occur in the cell body in response to the axon being severed
Diffuse Axonal Injury: Primary injury

- What are these degenerative changes?
  - Interruption of trophic (nutrient) factors that flow from the axon toward the cell body
  - Reprogramming of the cell body due to metabolic changes
  - Complex reactive and degenerative changes (called chromatolysis) occur after axonal injury to the neuron
  - Organelles within the cell body (organelles) undergo structural changes during initial 24-28 hours, as cell prepares to recover or begins process of cellular death
  - Cytologic change in the cell body including swelling of the organelles and dissolution of the Nissl bodies (intracellular structures key to protein synthesis)

Diffuse Axonal Injury: Primary injury

The bad news:
- Cells severely injured do not survive = beyond repair
- These cell eventually atrophy, and further degenerate into debris
- The body will “clean away” debris through phagocytosis
  - Phagocytosis is complete within 3-6 months

Diffuse Axonal Injury: Primary injury

The good news:
- During this time of initial injury to the neuron, there could be regenerative changes
  - Cellular RNA and protein synthesis are accelerated
  - Reformulation of a plasma membrane occurs in an attempt to regenerate the severed axon and prevent cellular death
  - If the axon can be repaired, chromatolysis (reactive and degenerative changes) ends and cell resumes its normal appearance
  - Restoration may however take months
Diffuse Axonal Injury: Primary injury

**Wallerian degeneration:**
- Anterograde degeneration that occurs in the segment of the axon that is detached from the cell body
- The axon cannot survive without nutrient (tropic) factors from the cell body
- When axon is transected/snapped degeneration occurs in first 1-2 days after injury
- Distal portion of the axon severed from cell body swells and begins to degenerate within 12-20 hours after injury
- Axon and myelin sheath are broken down and disintegrate within 7 days
- Phagocytosis begins

Diffuse Axonal Injury: Primary injury

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Diffuse Axonal Injury

**Secondary injury – calcium influx:**
- Occurring hours to days after injury, causing significant damage
- When brain tissue coils/recruits axons stretch
- Stretch causes disruption to and degradation to the cytoskeleton (cell "skeleton")
- Stretch also opens sodium channels in the cell membranes surrounding axon
- Causes calcium to flood cell = "Nuclear meltdown of cell"
Ray of Hope: Neuroplasticity vs Neurogenesis

Our brain has a remarkable ability to change

**Neuroplasticity:**
Defined: Changes in neural pathways and synapses that occur due to our behavior, responses to the environment, or neural processes
- During the process of neuroplasticity, the brain engages in:
  - synaptic pruning, deleting the neural connections that are no longer necessary or useful
  - strengthening the necessary ones

**Neurogenesis:**
- Ability to create new neurons and connections between neurons throughout a lifetime
- Also referred to as synaptogenesis
- Neuroplasticity and neurogenesis have significant implications for healthy development, learning, memory, and recovery from brain damage
  *The neurons that fire together, wire together!*

VIII. Agitation Management Strategies
Rancho Los Amigos Levels of TBI Recovery

- Medical scale to assess traumatic brain injury
- Based on cognitive and behavioral presentation
- Named after Ranchos Los Amigos Medical Center in Downey, California

Level 1: No Response
Total Assistance - Therapies not involved
- Complete absence of observable change to:
  - Visual/Auditory/Tactile/Proprioceptive/Vestibular stimuli
  - Painful stimuli

Level 2: Generalized Response
Total Assistance
- Generalized reflex response to painful stimuli
- Responds to repeated auditory stimuli with increased or decreased activity, highly delayed
- Response to stimulation is not localized to the source of the input
  - Iced washcloth to face may result in “fetal-like” movement
  - Painful stim to nail beds results in head shifting on pillow

Level 3: Localized Response
Total Assistance
- Responses directly related to type of stimulus
- Withdrawal or vocalization to painful stimuli
- Turns toward or away from auditory stimuli
- Blinks when strong light crosses visual field
- Follows moving object passed within visual field
- Responds to discomfort by pulling tubes or restraints
- Responds inconsistently to simple commands
- May respond to some persons (especially family and friends) but not to others
Level 3: Localized Response

What clinicians can do:

- Slow simple commands
- Exaggerated pauses between commands
- Constant reorientation
- Frequent breaks

**GOAL OF THERAPY:** “Increase the frequency and accuracy of the patient’s response to auditory, tactile, and visual stimulation to > XYZ percent”

Level 4: Confused/Agitation

**Maximum Assistance**

- Alert/heightened state of activity
- Purposeful attempts to remove restraints or tubes or crawl out of bed
- Very brief and usually non-purposeful moments of divided attention
- Absent short-term memory
- May cry out or scream out of proportion to stimulus even after its removal

Level 4: Confused/Agitation

- Aggressive or flight behavior
- Unable to cooperate with treatment efforts
- Verbalizations incoherent, inappropriate to activity or environment
- Mood may swing from euphoric to hostile with no apparent relationship to what’s happening
Level 4: Confused/Agitation

What clinicians can do:
- Constant reorientation without expectation of recall
- Allow as much movement as is safe
- Frequent movement in w/c to decrease restlessness
- Do not attempt to force tasks – follow patient's lead within safety limits
- Minimize noise, move slowly, speak softly

Level 5: Confused Inappropriate

Maximum Assist

What patient may do:
- Alert, not agitated but may wander randomly or with a vague intention of going home
- May be able to perform previously learned tasks with structure/cues such as wash face, brush teeth
- Responds appropriately to simple commands
- Able to briefly converse on a social, automatic level
- Verbalizations quickly become inappropriate or confabulatory

Level 5: Confused Inappropriate

What patient can't do:
- May become agitated in response to external stimulation, and/or lack of environmental structure
- Severely impaired recent memory; not oriented to place, situation, or time
- Confusion of past and present
- Inappropriate use of objects, using objects for wrong task/outcome
- Lack of goal directed, problem solving, self-monitored behavior
Level 5: Confused Inappropriate

What clinicians can do:
• Repeat info as needed, do not assume retention
• Keep it simple
• Rest break when patient loses focus
• Passive orientation upon arrival and departure
• Focus on tasks that increase participation and attention to task

Level 6: Confused Appropriate

Moderate Assistance
• Inconsistently oriented to person, time and place
• Able to attend to highly familiar tasks in non-distracting environment for 30 minutes with moderate redirection
• Remote memory has more depth and detail than recent memory
• Supervision still necessary for old learning (e.g. self care)
• Emerging awareness of appropriate response to self, family and basic needs
• Moderate assist to problem solve through barriers to task completion

Level 6: Confused Appropriate

What clinicians can do:
• Expect to repeat information and commands
• Reference events that have just occurred
• Assist with initiation and perseverance
• Encourage participation even if patient does not understand extent of problems
• Use rehab journal and frequently reference contents
Level 7: Automatic Appropriate

Minimal Assistance For Daily Living Skills

- Consistently oriented to person/place
- Moderate assistance for orientation to time
- Minimal supervision for new learning, fairly good carry over
- Attends to highly familiar tasks in a non-distraction environment for at least 30 minutes with minimal assist, improved initiation

Level 7: Automatic Appropriate

- Minimal supervision for safety in routine home and community activities
- Unrealistic planning for the future
- Overestimates abilities
- Unable to think about long-term consequences of a decision or action
- Unaware of others’ needs and feelings
- Oppositional/uncooperative
- Unable to recognize inappropriate social interaction behavior

Level 7: Automatic Appropriate

What clinicians can do:

- Refer to schedules/rehab journals
- Expect rigidity
- Verbalize rationale for tasks in simple terms
- Minimize distractions
- Ongoing education with family/friends
- Take meaningful breaks – do intervention in novel places (i.e., gift shop, atrium, etc)
- Prep family for return to home
Level 8: Purposeful Appropriate

Stand By Assistance
• May be home and attending OP therapies
• Consistently A & O x 4
• Independently completes familiar tasks for 1 hour in distracting environments
• Able to recall and integrate past and recent events
• Uses assistive memory devices to recall daily schedule, “to do” lists and record critical information for later use with stand-by assistance

Level 8: Purposeful Appropriate

Social Cognitive Characteristics:
• Acknowledges others’ needs and feelings and responds appropriately with minimal assistance
• Depressed/irritable/argumentative/self-centered
• Low frustration tolerance/easily angered
• Uncharacteristically dependent/independent
• Able to recognize and acknowledge inappropriate social interaction behavior while it is occurring and takes corrective action with minimal assistance

Level 8: Purposeful Appropriate

What clinicians can do:
• Talk to patient as adult
• Engage in decision making
• Avoid inferential humor – misunderstood
• Reiterate healthy choices (e.g. CD/ETOH)
• Gently point out barriers to success as learning opportunities, not examples of failure
• Encourage independence
• Repeat/expand TBI/CHI education