BRAIN INJURY AND EXECUTIVE DYSFUNCTION

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What is Executive Functioning?

- The term 'executive function' is used as an umbrella for various complex cognitive processes and sub-processes. Most attempts to define executive function resort to a list of examples (such as task-switching, planning, or that other useful umbrella term 'working memory'), which reflects the fact that executive function is by no means a unitary concept.
- The neuropsychological literature converges on the view that successful performance on tests of executive function is critically dependent on the frontal cortex; indeed the terms 'executive function' and 'frontal lobe function' are often used synonymously.
- However, recent theories have suggested that this view is simplistic and subcortical regions may also be critically involved. Neuropsychological deficits of patients with Parkinson's disease, for example, suggest that striatal structures play a role in the mediation of executive processes.
- Oxford Journals, British Medical Bulletin, (2003),Volume65, Issue1 Pp. 49-59

Executive Functions

- Consist of those capacities that enable a person to engage successfully in independent, purposive, self serving behavior.
  - *Lezak (1995)

Executive Functions

- Collection of processes that are responsible for guiding, directing, and managing cognitive, emotional and behavioral functions, particularly during novel problem solving.
- An umbrella of interrelated functions that are responsible for purposeful, goal directed, problem solving behavior.

Measured by neuropsychological assessment.

- Gioia, Espy, Isquith, 2003

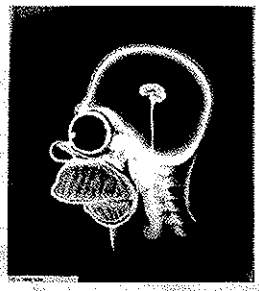
Ask How or Whether a person goes about doing something?

Will you do it, if so How?

Questions about Executive Functions???

Neuroimaging of executive dysfunction

- As discussed above, executive dysfunction is associated with a range of neurological and psychiatric disorders. The ubiquity of executive impairments, often in the absence of structural damage to the prefrontal cortex, is intuitively consistent with the network view of executive function. A dynamic and flexible neuronal network could be compromised in many different ways, and to different extents. It could also, potentially, prove more robust in the face of traumatic insult than a fixed one-to-one mapping between structure and function.
- Oxford Journals, British Medical Bulletin, Volume65, Issue1 Pp. 49-59



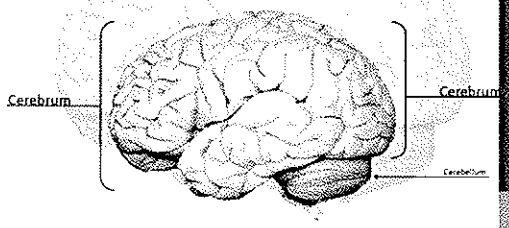
The Human Brain

Part I:

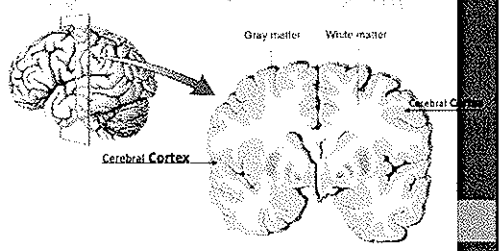
The Cerebrum

Lobes, the Cerebral Cortex, and Cortical Regions of the Brain

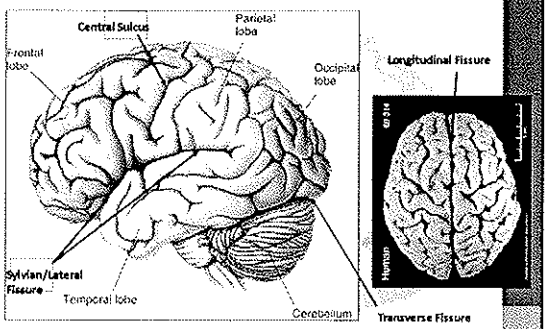
Cerebrum -The largest division of the brain. It is divided into two hemispheres, each of which is divided into four lobes.



Cerebral Cortex - The outermost layer of gray matter making up the superficial aspect of the cerebrum.

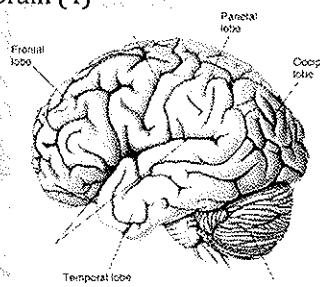


Specific Sulci/Fissures:



Lobes of the Brain (4)

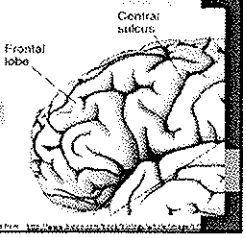
- Frontal
- Parietal
- Occipital
- Temporal



* Note: Occasionally, the Insula is considered the fifth lobe. It is located deep to the Temporal Lobe.

Lobes of the Brain - Frontal

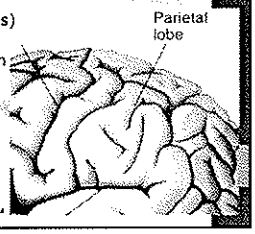
- The Frontal Lobe of the brain is located deep to the Frontal Bone of the skull.
- It plays an integral role in the following functions/actions:
  - Memory Formation
  - Emotions
  - Decision Making/Reasoning
  - Personality



Investigation (Phineas Gage)

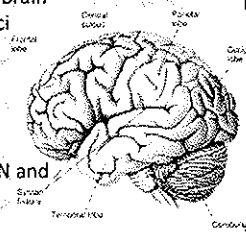
Lobes of the Brain - Parietal Lobe

- The Parietal Lobe of the brain is located deep to the Parietal Bone of the skull.
- It plays a major role in the following functions/actions:
  - Senses and integrates sensation(s)
  - Spatial awareness and perception (Proprioception - Awareness of body/ body parts in space and in relation to each other)



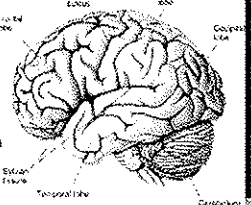
Lobes of the Brain – Occipital Lobe

- The Occipital Lobe of the Brain is located deep to the Occi Bone of the Skull.
- Its primary function is the processing, integration, interpretation, etc. of VISION and visual stimuli.



Lobes of the Brain – Temporal Lobe

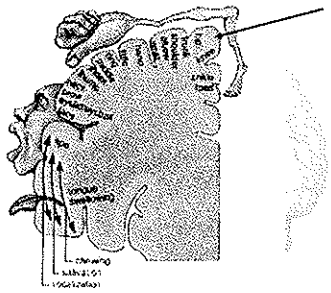
- The Temporal Lobes are located on the sides of the brain, deep to the Temporal Bones of the skull.
- They play an integral role in the following functions:
  - Hearing
  - Organization/Comprehension of language
  - Information Retrieval (Memory and Memory Formation)



"Whoa! That was a good one! Try it, Hobbs—just poke his brain right where my finger is."

Q: Assuming this comical situation was factually accurate, what Cortical Region of the brain would these doctors be stimulating?

A: Primary Motor Cortex



* This graphic representation of the regions of the Primary Motor Cortex and Primary Sensory Cortex is one example of a HOMUNCULUS:

Homunculus

Further Investigation

Phineas Gage: Phineas Gage was a railroad worker in the 19th century living in Cavendish, Vermont. One of his jobs was to set off explosive charges in large rock in order to break them into smaller pieces. On one of these instances, the detonation occurred prior to his expectations, resulting in a 42 inch long, 1.2 inch wide, metal rod to be blown right up through his skull and out the top. The rod entered his skull below his left cheek bone and exited after passing through the anterior frontal lobe of his brain.

Frontal

Remarkably, Gage never lost consciousness, or quickly regained it (there is still some debate), suffered little to no pain, and was awake and alert when he reached a doctor approximately 45 minutes later. He had a normal pulse and normal vision, and following a short period of rest, returned to work several days later. However, he was not unaffected by this accident.

Learn more about Phineas Gage: http://en.wikipedia.org/wiki/Phineas_Gage

Frontal

TRAUMATIC BRAIN INJURY

What is Traumatic Brain Injury (TBI)?

Severe TBI - Demographics

- 1.5 million cases per year in U.S. (Population 300 million)
- Causes: Motor vehicle accident (~45%), falls (~30%), occupational accidents (~10%), recre accidents (~10%), assa (~5%)
- Highest risk: children, adolescent/young adult men, elderly

Severe TBI - Pathophysiology

- TBI is a process, not an event!
  - Secondary injury can be more damaging than primary injury
- 4 Main Mechanisms of Brain Injury
  1. Brain Contusion
  2. Increased intracranial pressure (↑ ICP)
  3. Diffuse Axonal Injury
  4. Stroke (ischemic and/or hemorrhagic)

Mechanism 1: ↑ Brain Contusion

- A brain contusion is defined by cell death accompanied by hemorrhage (leakage of blood)
- The soft brain tissue is vulnerable to contusion in head trauma
- The contusion often occurs at a site distant from the point of impact

Cross brain image from http://neuropathology.neuropath.edu/chapter6/chapter6aContusions_dir_sht.htm#Contusion

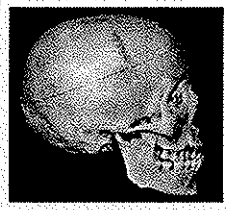
Mechanism 2: ↑ ICP
- Understanding the Determinants of Intracranial Pressure -

- The volume of the intracranial vault =
- Intracranial Contents:
  - 80% brain tissue
  - 10% blood
  - 10% cerebrospinal fluid

- An increase in the volume of any of these intracranial contents causes increased intracranial pressure
  1. The brain can swell (edema)
  2. Excess blood can accumulate due to hemorrhage
  3. Cerebrospinal fluid can accumulate due to blockage of outflow

Mechanism 2: ↑ ICP

- Key Concept #1: The intracranial vault is a fixed volume --> Bone does not expand!



Skull image from www.mrsu.edu

Mechanism 2: ↑ ICP

- Key Concept #2: There is only one way out of the intracranial vault --> the opening at the base of the skull known as the *foramen magnum*

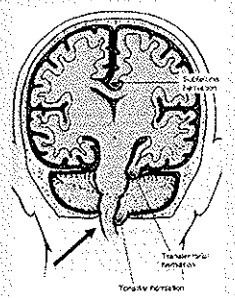
Skull base image from www.ooic.tcdss.edu

3D CT Angiogram from www.sumtminnie.com/.../

Mechanism 2: ↑ ICP

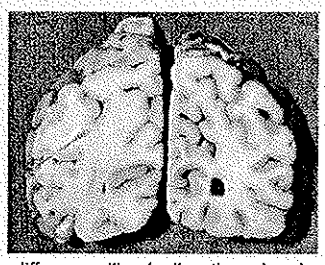
- Key Concept #3:

When the brain is squeezed through the foramen magnum (herniation), the brainstem is compressed, the patient stops breathing, and the patient dies



Herniation schematic from Robbins and Cotran, Pathologic Basis of Disease, 7th ed. Philadelphia, Elsevier, 2005.

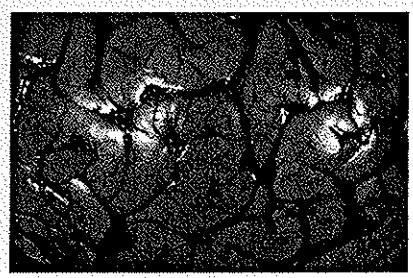
Causes of ↑ ICP: Swelling



Observe diffuse swelling (yellow tissue) and expansion of brain tissue into ventricles

Gross brain specimen from neuropathology.neoucom.edu

Causes of ↑ ICP: Swelling



Observe widening and flattening of gyri on brain surface

Mechanism 3: Diffuse Axonal Injury

- Occurs in up to 1/2 of traumatic brain injuries[1]
- Is a diffuse form of injury, meaning that damage occurs over a more widespread area than in focal brain injury
- Involves the shearing of axons in the white matter tracts

1. http://en.wikipedia.org/wiki/Diffuse_axonal_injury

Mechanism 3: Diffuse Axonal Injury

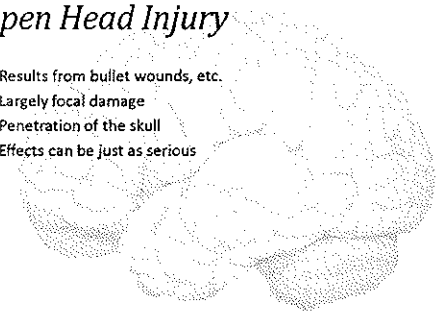
- Is one of the major causes of unconsciousness and persistent vegetative state after head trauma.
- Over 90% of patients with severe DAI never regaining consciousness (those that do wake up often remain significantly impaired)

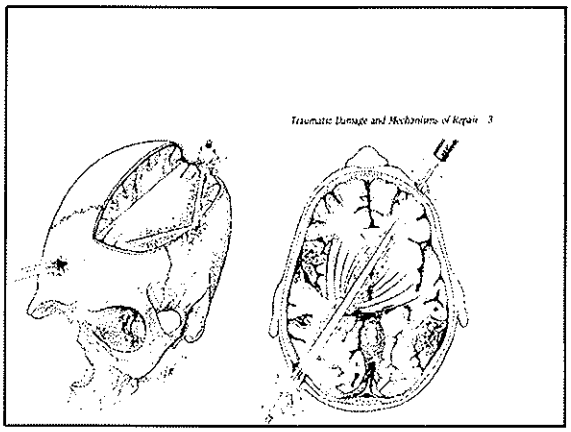
Mechanism 4: Stroke

- Ischemic Stroke
  - Caused by decreased oxygen delivery to brain tissue
  - Can occur in trauma secondary to swelling, which compresses nearby arteries
- Hemorrhagic Stroke
  - Decreased oxygen delivery because blood is leaking into brain tissue and not entering the capillary network
  - Can occur as a primary or secondary injury

Open Head Injury

- Results from bullet wounds, etc.
- Largely focal damage
- Penetration of the skull
- Effects can be just as serious



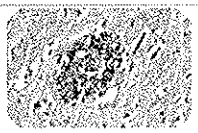


Alzheimer's Disease and the Brain

Plaques and Tangles: The Hallmarks of AD

The brains of people with AD have an abundance of two abnormal structures:

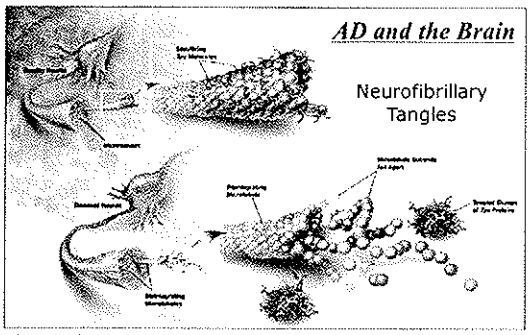
- beta-amyloid plaques, which are dense deposits of protein and cellular material that accumulate outside and around nerve cells
- neurofibrillary tangles, which are twisted fibers that build up inside the nerve cell



An actual AD plaque

An actual AD tangle

AD and the Brain



Neurofibrillary Tangles

Neurons have an internal support structure partly made up of microtubules. A protein called *tau* helps stabilize microtubules. In AD, *tau* changes, causing microtubules to collapse, and *tau* proteins clump together to form neurofibrillary tangles.

Slide 38

AD and the Brain

The Changing Brain in Alzheimer's Disease

Pet Scan of Normal Brain

No one knows what causes AD to begin, but we do know a lot about what happens in the brain once AD takes hold.

Pet Scan of Alzheimer's Disease Brain

Slide 39

Mechanisms of Injury

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Acceleration

- Direct blow to the head
- Skull moves away from force
- Brain rapidly accelerates from stationary to in - motion state causing cellular damage

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Acceleration

Deceleration

- Head impacts a stationary object (e.g., car windshield)
- Moving skull stops motion almost immediately
- However, brain, floating in cerebral spinal fluid (CSF), briefly continues moving in skull towards direction of impact, resulting in significant forces that damage cells

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Deceleration

Coup/Contra-Coup

Injury resulting from rapid, violent movement of brain is called coup and contra-coup. This action is also referred to as a cerebral contusion.

- **Coup**: an injury occurring directly beneath the skull at the area of impact
- **Contra-coup**: injury occurs on the opposite side of the area that was impacted

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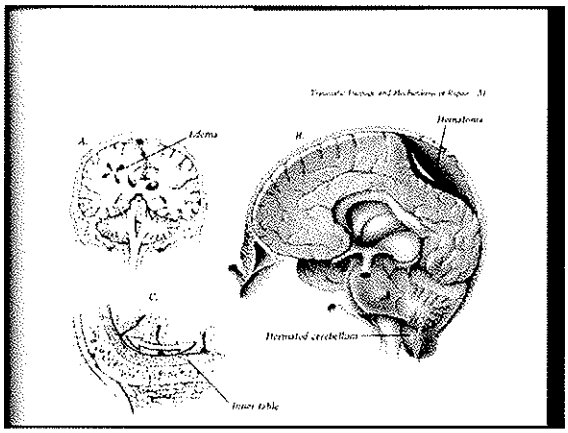


TBI: Changes in functioning

- Loss of consciousness/coma
- Other changes due to the TBI
- Post-traumatic amnesia (PTA)

What Do We Mean by Severity of Injury

- Amount of brain tissue damage

How to measure "severity"?

- Duration of loss of consciousness
- Initial score on Glasgow Coma Scale (GSC)
- Length of post-traumatic amnesia
- Rancho Los Amigos Scale (1 to 10)

Mild injury

0-20 minute loss of consciousness GCS = 13-15

PTA < 24 hours

Moderate injury

20 minutes to 6 hours LOC GCS = 9-12

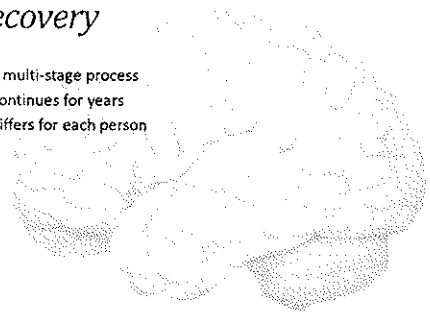
Severe injury

> 6 hours LOC GCS = 3-8

What Happens as the Person with Moderate or Severe Injury Begins to Recover After Injury?

Recovery

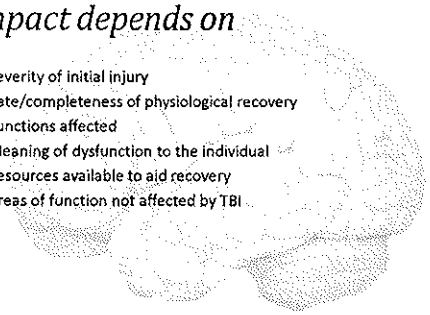
- A multi-stage process
- Continues for years
- Differs for each person



What is the Long-term Impact of a Moderate or Severe TBI in the Person's Functioning?

Impact depends on

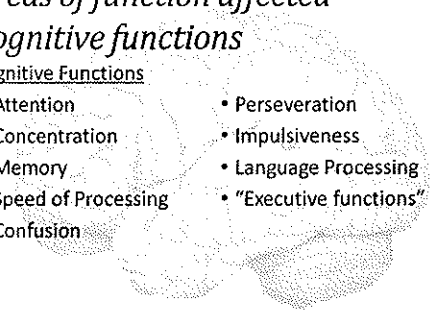
- Severity of initial injury
- Rate/completeness of physiological recovery
- Functions affected
- Meaning of dysfunction to the individual
- Resources available to aid recovery
- Areas of function not affected by TBI



Areas of function affected
Cognitive functions

Cognitive Functions

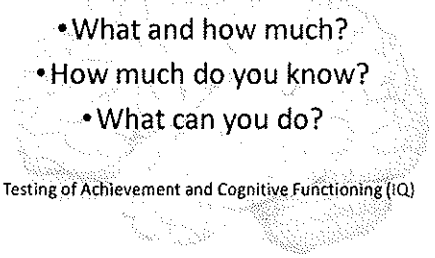
- Attention
- Concentration
- Memory
- Speed of Processing
- Confusion
- Perseveration
- Impulsiveness
- Language Processing
- "Executive functions"



Questions about Cognitive Functioning????

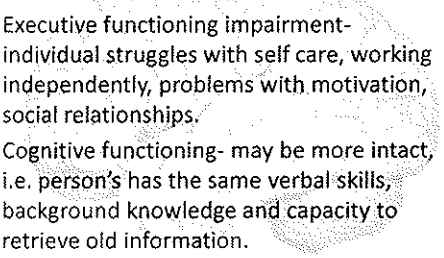
- What and how much?
- How much do you know?
- What can you do?

- Testing of Achievement and Cognitive Functioning (IQ)



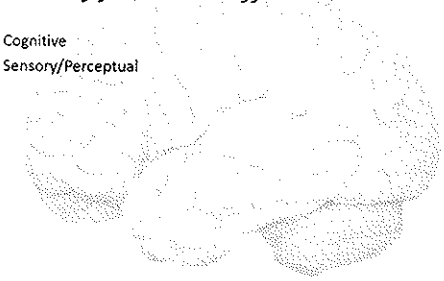
Differences between Cognitive and Executive functioning?

- Executive functioning impairment- individual struggles with self care, working independently, problems with motivation, social relationships.
- Cognitive functioning- may be more intact, i.e. person's has the same verbal skills, background knowledge and capacity to retrieve old information.



Areas of function affected

- Cognitive
- Sensory/Perceptual

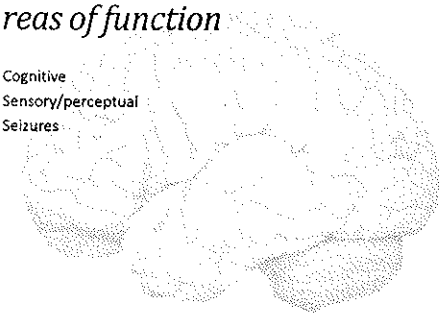


Sensory/perceptual functions

- Vision
- Hearing
- Smell
- Vestibular
- Taste
- Touch
- Balance

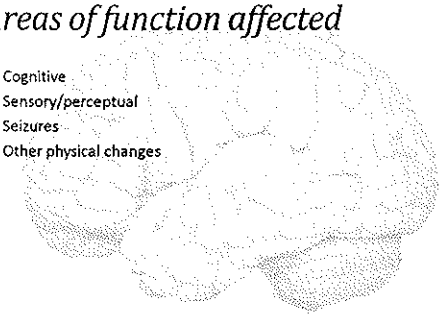
Areas of function

- Cognitive
- Sensory/perceptual
- Seizures



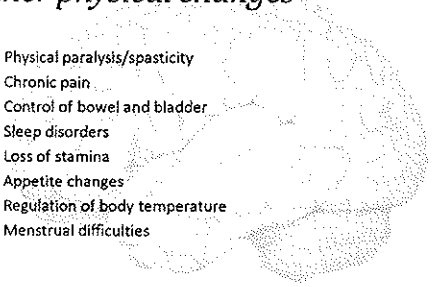
Areas of function affected

- Cognitive
- Sensory/perceptual
- Seizures
- Other physical changes



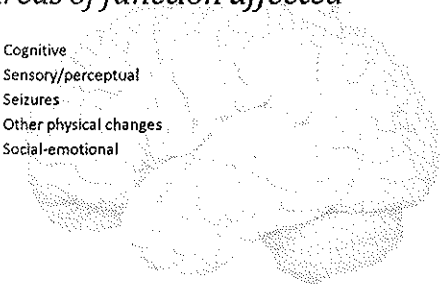
Other physical changes

- Physical paralysis/spasticity
- Chronic pain
- Control of bowel and bladder
- Sleep disorders
- Loss of stamina
- Appetite changes
- Regulation of body temperature
- Menstrual difficulties



Areas of function affected

- Cognitive
- Sensory/perceptual
- Seizures
- Other physical changes
- Social-emotional



Social-emotional

- Dependent behaviors
- Emotional lability
- Lack of motivation
- Irritability
- Aggression
- Depression
- Disinhibition
- Denial/lack of awareness

Executive Functioning Skills

- Behavior Rating Inventory of Executive Functioning (BRIEF) Clinical Scales Eight Domains of Executive Functioning:

1. Inhibit
2. Shift
3. Emotional Control
4. Initiate

Executive Functioning Skills Cont.

5. Working Memory
6. Plan Organize
7. Organization of Materials
8. Monitor

Inhibit

- Assessment of inhibitory control and impulsivity
- The ability to resist impulses and ability to stop one's own behavior at the appropriate time.
- Difficulty with self control
- Problems with acting without thinking
- Start an activity without listening or developing a plan or organizing materials.

Shift

- Ability to move freely from one situation, activity or aspect of a problem to another as the circumstances demand.

The ability to:

- 1. Make Transitions

Shift cont.

- 2. Tolerate Change
- 3. Problem Solve Flexibility
- 4. Switch or Alternate Attention
- 5. Change Focus from One Mindset or Topic to Another.

Emotional Control

- The impact of executive function problems on emotional expression and ability to modulate emotional responses.

Could have difficulty with:
Emotional outbursts
Sudden mood changes

Initiate

- The ability to begin a task or activity and to independently generate ideas, responses or problem solving strategies.
- Begin, start and get going on tasks, activities and problem solving approaches appropriately.

Working Memory

- Hold information in the mind for the purpose of completing a task, encoding information or generating goals, plans and sequential steps to achieving goals.
- Holding information in active memory for further processing, encoding and mental manipulation.

Working Memory Cont.

Essential for activities:

Multistep activities, follow instructions and perform mental manipulations (i.e. mental arithmetic).

Plan and Organize

- Ability to manage current and future oriented task demands.
- Plan- Ability to anticipate future events, set goals, develop appropriate sequential steps ahead of time in order to carry out a task or activity.

Plan and Organize

- Organize- ability to bring order to information and gather main ideas when learning or communicating information.

Organization of Materials

- Orderliness of work and play.
- Are materials and belongings well organized?
- Readily available for projects or assignments?
- Are the belongings or materials easy to locate?

Monitor

- Task oriented monitoring or work checking habits.
- Self monitoring or interpersonal awareness.

Monitor

- Task Monitoring- Is the goal done appropriately?
- Self Monitoring- Is the person keeping track of the effect that his or her behavior is having on others?
- Social interactions

Executive System Intervention

- Demonstrating purposeful, goal directive activity
- Displaying an active problem solving approach
- Exerting self control
- Demonstrating maximal independence
- Exhibiting reliable and consistent behavior and thinking
- Demonstrating positive self efficacy
- Exhibiting internal locus of control

Gioia, Espy, Isquith, 2003

Neuropsychological Assessments

- Wechlser Memory Scale-Fourth Edition (WMS-IV)
- Wechsler Adult Intelligence Scale (WAIS-IV)
- Delis Kaplan Executive Function System (D-KEFS)
- Trail making
  - Task switching, interference, attention and concentration
- Neurodevelopmental Psychological Assessment(NEPSY-2)
- Tinker Toys Test
  - Initiation, planning, structuring, and carrying out independently
- Porteus Maze Test
  - Planning and foresight
- Tower Test
  - Planning, puzzle solving

Skills to Improve

- Goal Setting: An initial decision about a choice of a goal to pursue. (What do I need to accomplish?)
- Self-awareness of strengths/weaknesses: (How easy or difficult is a task or goal?)
- Organization/Planning: Development of an organized plan. (What do we need? Who will do what? How long will it take?)
- Flexibility/Strategy: As complications or obstacles arise while working toward the goal. (Should I ask for assistance?)
- Monitoring: A review of the goal. (How did I do?)
- Summarizing: What worked and what didn't work?

Teacher's/advocates

- Basic Tenets
  - Teaching goal directed, problem-solving process.
  - Implementing the process within positive, meaningful everyday routines.
  - Providing Real-world relevance and application of strategies and routines.
  - Involving everyday people (parents, teachers, coworkers, and peers) as models and "coaches."
  - Including the child in the design of the intervention as much as possible.

Increasing Executive Functioning Skills

- Provide real-world relevance
  - Practice the use of the routine
  - Involve everyday people
- Teaching goal directed problem solving process
  - To internalize multistep problem solving
  - Integrate into daily routines
  - With external support promote generalizations to new situations

Real-World Interventions

- Routine should promote:
  - Goal
  - Planning
  - Action
  - Self-Monitoring/Evaluating
  - Strategic adjustment of plans and actions

Executive System Intervention

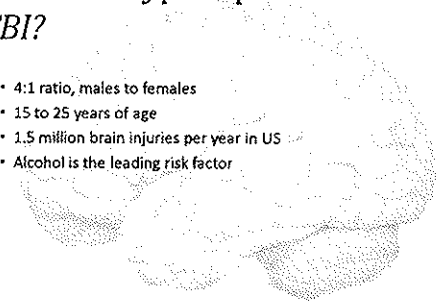
- Establish Regular behavioral/ cognitive routines to maximize independent, goal oriented problem solving and performance.
- Structure an environment and external environmental preconditions.

Recovery vs. "Improvement"

How Common is TBI, and Who is the Typical Person with TBI?

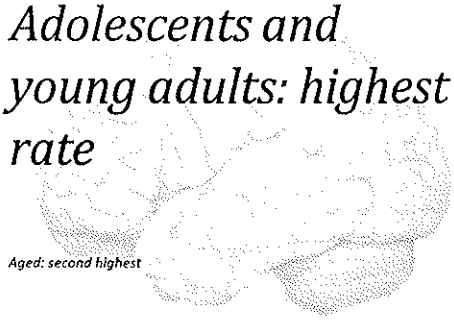
Who is the typical person with TBI?

- 4:1 ratio, males to females
- 15 to 25 years of age
- 1.5 million brain injuries per year in US
- Alcohol is the leading risk factor



Adolescents and young adults: highest rate

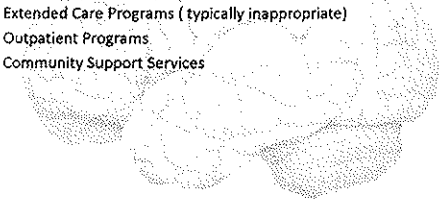
Aged: second highest



What is the Course of Treatment for Those with TBI?

Integrated System of Care

- Inpatient Rehabilitation Programs
- Coma Recovery Programs (rarely used)
- Extended Care Programs (typically inappropriate)
- Outpatient Programs
- Community Support Services

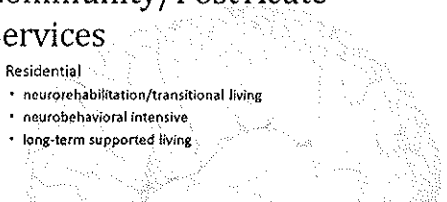


Community/Post Acute Services

- Outpatient
  - In clinic
  - At home/work/community

Community/Post Acute Services

- Residential
  - neurorehabilitation/transitional living
  - neurobehavioral intensive
  - long-term supported living



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