Cognitive Function in Cerebrovascular Accident (CVA) & Traumatic Brain Injury (TBI): Assessment and Treatment

Part 1
Martha S. Burns, Ph.D., ccc-slp
February, 2020

Lecture Outline Part I

• Review of **cognitive processes**
  - Basic processing of sensory input
  - Review of organization of the nervous system
  - Review of research approaches to neuroscience
  - Attention (sustained, selective, alternating)
  - Memory (working, short-term, long-term, prospective)
  - Executive function (reasoning, self-monitoring, judgment, initiation/inhibition, organization)

• Review of **etiologies** which may cause cognitive impairments
  - TBI
  - R hemisphere damage
  - Dementia
  - Other cerebrovascular causes (CVA, anoxia/hypoxia)

DeHaene, 2009

Overview of Recent Neuroscience Research

DeHaene, 2009

Human Limbic System
Lesion studies used in localization replaced by dynamic imaging

- New Data on how brain regions work simultaneously – networks – data from 2002 - present
- New Data on how these networks develop and become wired – neuroplasticity
- New imaging techniques and single unit response research provide new data
- New Data on how brains vary by processing capacity and efficiency

The left hemisphere of Broca’s famous patient Leborgne
This patient was only able to speak the syllable ‘tan’. After Leborgne died, Broca investigated his brain and inferred that the damaged area in the left ventral frontal lobe (Brodmann’s areas 44 and 45) is crucial for speech production.

Nature Reviews Neuroscience 5; 812-819 (2004);
doi:10.1038/nrn1521
USING HUMAN BRAIN LESIONS TO INFER FUNCTION: A RELIC FROM A PAST ERA IN THE FMRI AGE?

Network measurement, construction and analysis Bassett and Sporns, 2017
Diffusion Tensor Imaging

- Measures diffusion (motion) of protons in water molecules.
- Direction of proton motion within a voxel can be described by a “tensor”.
- Proton diffusion tends to be relatively isotropic in gray matter.
- The linear structure of fiber tracts constrains proton diffusion and produces **anisotropy**.

Tractography through dMRI

HCP – future directions
Attention

• Models of attention
  – Neuroscience/neurochemical model
  – Functional (clinical) model of Sohlberg and Mateer

Sohlberg and Mateer (APT, 1989)) Model

• Sustained Attention
• Alternating Attention
• Selective Attention
• Divided Attention

WORKING MEMORY

Behavioral Self-Regulatory Functions

- VMPFC – emotional processing including:
  - Reward processing
  - Behavioral self-regulation
  - Social Cognition

Saxe, Rebecca
Uniquely human social cognition
Current Opinion in Neurobiology 2006, 16:235–239

Brain regions implicated in human social cognition. (a) Medial regions (b) Lateral regions
Detecting presence of an intentional actor - right extrastriate body area (green). Reasoning about others’ representation of mental states - the right temporo-parietal junction (blue). Perceiving intentional action - posterior right superior temporal sulcus. (pink) in medial prefrontal cortex, two regions are apparent: ventralMPFC associated with attributing emotion (red) and dorsal MPFC, possibly linked to reasoning about triadic relations (yellow). The posterior cingulate region, not discussed in this article but commonly recruited for social cognitive tasks, is shown in white.

Comparison of the two types of joke shows activation in the medial prefrontal cortex, which is shown in a single subject.
Understanding pathology and treatment

TBI and Post Concussion Syndrome

- Mechanisms of head injury
- Rancho Recovery stages
- The role of executive function

Mechanisms of TBI: Primary Lesions

- Diffuse
  - axonal injury - shearing strains
- Focal
  - contusions - bruises
  - lacerations - tears and cuts
  - coup and contre-coup lesions

Causes of Brain Injury

- Falls
- Recreation
- Shaken Infant Syndrome
- Violence
- Motor Vehicle Violence
- Bicycles
- Motor Vehicle
Bleeding: Increases the pressure within the brain pushing brain tissue downward and inward toward the only opening in the skull, where the brain stem and spinal cord enter.

Rotational forces: cause twisting and reverberation of the brain inside the skull

Swelling: Compression of the blood vessels prevents the flow of oxygen and other nutrients, which starves the brain cells, eventually killing them.

Secondary Lesions

- Diffuse (see CT scan slides)
  - Cerebral edema
  - Raised intracranial pressure
  - Ischemia
  - Brain shift and herniation
  - Cerebral atrophy and ventricular enlargement
- Focal - hemorrhages/hematomae (CT scans)
  - extradural (epidural); subdural; intracerebral

Anterior and Middle Cranial Fossa in Traumatic Brain Injury: Relevant Neuroanatomy and Neuropathology in the Study of Neuropsychological Outcome

Erin D. Bigler
Brigham Young University and University of Utah

Neuropsychology
2007, Vol. 21, No. 5, 515–531
Biomechanics of Head Injury

- Mechanical loading (see slides)
  - static
  - dynamic
    - contact loading
      - local skull distortions or fractures
    - contusions and lacerations
    - shock waves cause small intracerebral hemorrhages
  - intertial loading
    - translational and rotational acceleration
TBI progression over time – Bigler, 2016

Different White Matter Effects From Different TBI Pathologies

Bigler, E. 2016

TBI – Secondary factors Bigler, 2016

Bigler, 2016
LISTENING TO THE BRAIN FOR CONCUSSION CARE

Nina Kraus

www.brainvolts.northwestern.edu

Biological indices of concussion

Neuroimaging

Electrophysiology

Blood markers

Genetics

Limitations

Biological marker identifies concussions

90% concussions

95% controls

... why?

Attributes of a "seen" object

Shape ... sphere

Dimensionality ... 3D

Color ... yellow

Solidity ... yes

Pattern ... none

Movement ... no

Transparency ... no

Texture ... fuzzy

... why?

materialistic
Attributes of sound

Pitch: high
Timbre: crunchy
Intensity: loud
Timing: fast
Consonance: dissonant
Location: straight ahead
Movement: left to right

Auditory vs. Visual Processing Speed

Cochlea

Retina

Sound

Light

Action potential every 1 ms!

≤ 40 ms for photons striking retina to trigger action potential
Auditory Processing Speed

Left Ear  |  Auditory Brain  |  Right Ear

even < 1 ms!

Practical Advantages of FFR
- Objective
- Uniform
- Repeateable
- Vleted
- Mobile
- Fast

Head Injury
- mild & moderate TBI

Practical Advantages of FFR

SOUNDWAVE
- da high
- da?
- oboe

BRAINWAVE

Turgeon et al., 2011
Turgeon et al., 2012
Saunders et al., 2015; Vander Werff, 2012; Bergman et al., 1987; Bamiou et al., 2000; Fligor et al., 2002; Musiek et al., 2004
Focal Lesions

- RH CVA
  - CVA represents a disruption of the cerebral vascular system

Stroke Progression

Glasgow Coma Scale
Post Traumatic Amnesia

PTA
- Confusional state of 'clouded consciousness' following TBI
- Present in 30% patients
- Transient stage between loss of consciousness and return to full consciousness
- Duration correlates well with GCS, length of hospital stay
- Predicts outcome
  - Cognitive recovery
  - Functional abilities
  - Return to work

The different stages of recovery

**Brain Death**
- Absence of heartbeat, respiration

**Coma**
- Absence of conscious awareness

**Vegetative State**
- Loss of consciousness

**Minimally Conscious State**
- Responds to pain
- Able to show some communication

**Conscious State**
- High level of consciousness, full recovery

Medical TBI Recovery Scale

<table>
<thead>
<tr>
<th>BRAIN DEATH</th>
<th>VEGETATIVE STATE</th>
<th>MINIMALLY CONSCIOUS STATE</th>
<th>LOCKED-IN SYNDROME</th>
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<tbody>
<tr>
<td>Level 1</td>
<td>Non-Response</td>
<td>Total Assist</td>
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<td>Level 2</td>
<td>Minimal Response</td>
<td>Total Assist</td>
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<tr>
<td>Level 3</td>
<td>Agitated</td>
<td>Total Assist</td>
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<tr>
<td>Level 4</td>
<td>Confused</td>
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</table>
Domain Specific Tests of Attention

Determine if an attention problem is one of the underlying factors contributing to an individual’s learning problems.

Pass/Fail criterion scores indicate whether performance matches that of individuals with normal attention skills.

- Listens to single words presented on the tape and raises a thumb when the target word is heard.

Written by the author of SCAN-3: Tests for Auditory Processing Disorders

Auditory Continuous Performance Test (ACPT)

Author(s): Robert W. Keith, Ph.D.

Screen for auditory attention deficits

At a Glance:
Administration: 10 minutes
Scores: Pass/Fail criterion score
Audio Available: Yes
Qualification level: B-Level
Publication Date: 1994
Ages / Grades: 6:0 through 11:11

Test of Everyday Attention

Key Information
- Measure selective attention, sustained attention and attentional switching

Author(s):
- Ian H Robertson,
- Ian Nimmo-Smith,
- Tony Ward,
- Valerie Ridgeway

Publication Year:
- 1994

Age Range:
- 18 years to 80 years

Administration:
- Individual - 45 to 60 minutes

Qualification Code:
- CL1

TEA

- There are eight subtests of the TEA:
  - Map search - Subjects have to search for symbols on a coloured map. The score is the number out of 80 found in 2 minutes. This subtest is age-sensitive and suitable with all brain-damaged patients, including those with Alzheimer’s disease. It measures selective attention and loads on the same factor as the Stroop test and the d2 cancellation test.
  - Elevator counting - Subjects are asked to pretend they are in an elevator whose door indicator is not functioning. They therefore have to establish which ‘floor’ they have arrived at by counting a series of tape presented tones. This is an established measure of sustained attention sensitive to right frontal lesions.
  - Elevator counting with distraction - Subjects have to count the low tones in the pretend elevator while ignoring the high tones. This was designed as a subtest of auditory selective attention.
  - Visual elevator - Here, subjects have to count up and down as they follow a series of visually presented ‘doors’ in the elevator. This reversal task is a measure of attentional switching and hence of cognitive flexibility. It is self-paced and loads on the same factor as the number of categories on the Wisconsin Card Sorting Test.
  - Auditory elevator with reversal - The same as the visual elevator subtest except that it is presented at fixed speed on tape.
  - Telephone search - Subjects must look for key symbols while searching entries in a simulated classified telephone directory.
  - Telephone search dual task - Subjects must again search in the directory while simultaneously counting strings of tones presented to a tape recorder. The combined performance on subtests 6 and 7 gives a measure of divided attention.

New materials - As we constantly aim to improve our materials, the CDs originally included in this test have now been changed to a USB.

* This test is available to professionals other than Psychologists, however further training will be required. For details of training, please see Cognitive Assessment Training - Online.
TEA (King and Turkstra, 2015)

Purpose
Measures
• Selective attention,
• Sustained attention, and
• Attentional switching
uses everyday materials.
• Developed for use with
clinical and typical
populations.

Strengths
• Three versions are available:
A, B, and C.
Test-retest reliability meets
relaxed criterion after 1 week
on alternate forms, but only
for overall score.

Attention (continued)

• Divided Attention
• Response Inhibition

Working Memory Assessments and Interventions
Auditory-verbal Working Memory

Now write down as many words as you can recall. You have one minute.

Memory and the Limbic System

Physical Exercise – Helps keep the Hippocampus “FIT”

- Recent findings in humans suggest that aerobic exercise can lead to increased hippocampal volume and enhanced cognitive functioning in children and elderly adults.

Krug and Turkstra, 2015

<table>
<thead>
<tr>
<th>Domain</th>
<th>Specific Tests</th>
<th>Test Purpose</th>
<th>Strengths</th>
<th>Limitations</th>
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</thead>
<tbody>
<tr>
<td>Attention</td>
<td>Test of Everyday Attention (TEA)</td>
<td>Measures selective attention, sustained attention, and attentional switching using everyday materials. Developed for use with clinical and typical populations.</td>
<td>Three versions are available: A, B, and C. Test-retest reliability meets relaxed criterion after 1 week on alternate forms, but only for overall score.</td>
<td>Standardized on individuals with unilateral stroke not TBI. Small standardization sample: 154 adults ages 18–80 years. Has four factors that do not correspond to four cluster scores.</td>
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<tr>
<td>Domain Specific Tests:</td>
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<td>Information Processing Speed</td>
<td>WJ-III Cognitive Battery</td>
<td>To measure cognitive efficiency (i.e., individual’s ability to perform automatic, cognitive tasks under pressure and with focused attention.) Standard Battery Test 6: Visual Matching Extended Battery Tests 16: Decision Speed; 18: Rapid Picture Naming; and 20: Pair Cancellation.</td>
<td>Large standardization sample. Test-retest reliability meets relaxed criterion for children ages 7-11 years. Test-retest reliability meets strict criterion. Cluster and total scores have modest correlations with similar tests. Factor analysis shows that speed is a separate factor with low correlations with other factors.</td>
<td>Relatively limited norms for children compared to adults (e.g., test-retest reliability data from 54 adults ages 26-79 years). Individuals with TBI not included in standardization sample.</td>
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| Declarative Memory | Rivermead Behavioral Memory Test (RBMT) – Version 3 | To identify everyday memory problems and monitor change over time. Third edition includes novel task learning. | High inter-rater reliability. Good face validity. Moderate correlation with clinician reports of everyday memory problems and low but significant correlations with patient-reported memory problems. Low to moderate correlation with scores on other memory battery. | 24 subtests but factor analysis supports only the General Memory Index score (i.e., subtest scores not interpretable as standalone scores). Clinical sample in standardization included only 19 adults with TBI, none with mTBI. Alternative form reliability moderate, limiting use in measuring change over time. |
Executive Functions - Definitions

- Four domains (Cicerone, et al., 2006)
  - Executive cognitive functions
  - Behavioral self-regulatory functions (cognitive control)
  - Activation regulating functions
  - Metacognitive processes

Executive Functions

- Most of what is known about EF is based on patients with DLPFC lesions
  - However, because of connections between lateral-frontal and posterior brain regions, DAI can cause Executive dysfunctions
- Control and direction of lower level automatic functions for
  - Planning
  - Monitoring
  - Activating
  - Switching
  - Inhibiting
- Working memory (limited capacity process for short-term storage, monitoring, and manipulation of information) are fundamental processes that mediate EF

Task Switching

- Card sorting
- Go/no-go (Simon says)
  - Can increase complexity to increase task switching

Response inhibition – Stroop-like test

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<th>GREEN</th>
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Response inhibition – Stroop-Like Test

Q & A