Objectives

- Brief history of theories of frontal-lobe functions
- Process approach to the assessment of higher-level executive functions
- Present a case study to (a) illustrate the importance of the process approach to the assessment of executive functions; and (b) present a new theory of orbital-prefrontal functions
Phineas Gage

- Accident: September 13, 1848
- Age: 26
- Occupation: Foreman, Track Construction Team
Dr. Harlow’s Impressions

- At first, Gage appeared to make a full recovery.
- No apparent changes in his intellectual faculties.
- “He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desire.”
- “His contractors, who regarded him as the most efficient and capable foreman in their employ previous to his injury, considered the change in his mind so marked that they could not give him his place again.”
- “Gage was no longer Gage”

Frontal-Lobe Functions in the 1930s-1940s

- Goldstein & Scheerer (1941): Loss of the abstract attitude
- Goldstein (1944): Deficient foresight
- Brickner (1936) Problems with intellectual synthesis

Goldstein-Scheerer Object Sorting Test (1941)
Frontal-Lobe Functions in the 1940’s-1960s

- Hebb & Penfield (1945): Patient KM showed improvement in cognitive and personality functioning following bilateral resection of prefrontal cortex for intractable seizures

- Teuber & Weinstein (1954): 90 WW-II veterans with penetrating missile wounds to prefrontal cortex: no consistent cognitive deficits

- Teuber (1962): “The Riddle of Frontal Lobe Function in Man”

Frontal Lobes: Silent or Highest Levels of Thinking?

Frontal-Lobe Functions in Circa 2011

<table>
<thead>
<tr>
<th>Orbital Prefrontal</th>
<th>Dorsolateral Frontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognition: Silent</td>
<td>Cognition: Executive functions</td>
</tr>
<tr>
<td>Emotions: Discontrol</td>
<td>Emotions: Flat affect; apathy</td>
</tr>
</tbody>
</table>
Executive Functions

- Abstract Thinking
- Concept Formation
- Problem Solving
- Creativity
- Fluent Thinking
- Simultaneous Processing
- Planning and Organization
- Inhibit Responses to Concrete Environment

Emotional/Personality Changes Associated With Prefrontal Damage

- Disinhibition/Inappropriate Behavior
- Jocularity/Child-Like Behavior
- Impulsivity
- Emotional Lability
- Poor Judgment
- Lack of Insight
- Downward Social/Occupational Functioning

Is the Orbital Prefrontal Cortex Cognitively Silent?
Traditional Executive Function Tests

- Trail Making Test, Partington, 1938
- Verbal Fluency Test, Thurstone, 1939
- Category Test, Halstead, 1944
- Wisconsin Card Sorting Test, Grant & Berg, 1948; Heaton, 1981

Edith Kaplan

Traditional Approach: Uses a single achievement score for each test (e.g., time to completion; number correct). Problem: Often don’t know why a patient performed poorly on the test.

Process approach: Error types and strategies are the best windows into the underlying brain functions of the patient. New tests should be design to pull for errors in patients with even subtle brain dysfunction.
Rationale for Development

- Process Approach
- Design tests to pull for different types of errors
- Score and provide normative data on multiple variables, e.g. error types and strategies
- Broad Range of Tasks
- Verbal vs. Nonverbal Tasks
- Children and adults (8 to 89)
- Alternate Forms
- National normative study

Dellis-Kaplan Executive Function System™ © 2009 Delis-Kaplan

Overview
- Trail Making Test
- Verbal Fluency Test
- Color-Word Interference Test
- Design Fluency Test
- Tower Test
- Twenty Questions Test
- Proverb Tests

Relatively New Tests
- Sorting Test
- Word Context Test

Modifications of Common Clinical Tests
- Trail Making Test
- Verbal Fluency Test
- Design Fluency Test
- Color-Word Interference Test

Modifications of Experimental Tasks
- Tower Test
- Twenty Questions Test
- Proverb Tests
**Verbal Tests**
- Verbal Fluency Test
- Word Context Test
- Proverb Test

**Visual-Spatial Tests**
- Design Fluency Test
- Tower Test

**Verbal and Visual-Spatial Modality**
- Sorting Test
- Twenty Questions Test
- Color-Word Interference Test
- Trail Making Test

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**CASE STUDY**
Assessing the elusive cognitive deficits associated with ventromedial prefrontal damage: A case of a modern-day Phineas Gage

M. KLEINBERG, J.S. ROSS, M. VIAS, A. R. ABLEMAN, and J.S. BAEGER

Department of Neurosurgery, University of Pittsburgh, Pittsburgh, PA.

Abstract
Cognitive deficits following experimental brain damage (TBI/TWQ) have been elusive, with most studies reporting purely emotional and behavioral changes. The present case illustrates the utility of a process approach to assessing cognitive deficits following TBI/TWQ. In an age 27-year-old male, the bilateral medial prefrontal cortex was severed by a 3-foot-long steel rod, resulting in a frontal lobe injury. Despite complete prefrontal anatomical and functional integrity, the individual exhibited impaired decision-making, social judgment, and empathy. The case highlights the importance of assessing cognitive functions beyond the traditional domains of memory and attention. The case also raises questions about the nature and extent of cognitive deficits following TBI/TWQ.

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**Modern Day Phineas Gage**

- 66-year-old male at time of testing
- Education: 14 years, skipped 6th grade, mostly A student
- Occupation: Accelerated promotions to Sergeant in Army; Infantry Instructor
- TBI at age 27 while in military
C.D.’s Current IQ Scores

Pre- and Post-Injury Work History

<table>
<thead>
<tr>
<th>Phineas Gage</th>
<th>CD</th>
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<tbody>
<tr>
<td>Age at injury: 27</td>
<td>Age at injury: 26</td>
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<tr>
<td>Tamping iron through left</td>
<td>Metal rail crushed left frontal skull</td>
</tr>
<tr>
<td>frontot skull</td>
<td>Bilateral prefrontal damage,</td>
</tr>
<tr>
<td></td>
<td>left &gt; right</td>
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<tr>
<td>Railroad construction</td>
<td>Sergeant/infantry instructor in Army</td>
</tr>
<tr>
<td>foreman</td>
<td>Bilateral prefrontal damage,</td>
</tr>
<tr>
<td></td>
<td>left &gt; right</td>
</tr>
<tr>
<td>Pre-Injury: “Most efficient</td>
<td>Pre-Injury: Accelerated promotions in military</td>
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<tr>
<td>and capable foreman”</td>
<td></td>
</tr>
<tr>
<td>Post-Injury: Dramatic</td>
<td>Post-Injury: Dramatic social/occupation decline</td>
</tr>
<tr>
<td>social/occupation decline</td>
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</tr>
<tr>
<td>Premorbid IQ: ?</td>
<td>Premorbid Verbal IQ: at least 119 (90%)</td>
</tr>
<tr>
<td>Post-Injury: Normal</td>
<td>Post-Injury: Normal on most neuropsychological tests</td>
</tr>
<tr>
<td>intellectual faculties</td>
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</tbody>
</table>
C.D.’s Scores on the DKEFS Design Fluency Test

C.D.’s Scores on the DKEFS Color-Word Interference Test

C.D.’s Scores on the DKEFS Trail Making Test
C.D.'s Scores on the DKEFS Verbal Fluency Test

C.D.'s Scores on the DKEFS Verbal Fluency Test

Categorical Hierarchy of the Minneba Objects of the DKEFS Verbal Fluency Test
Patient EB’s Questions for “Spoon”

1. Do you drink it? (No)
2. Do you smell it? (No)
3. Does it go in water? (No)
4. Do you cook on it? (No)
5. Do you get milk from it? (No)
6. Does it bark? (No)
7. Does it keep food cold? (No)
8. Do you get juice out of it? (No)
9. Is it in the wild? (No)
10. Is it yellow? (No)
11. Does it bark? (No)
12. Does it use gasoline? (No)
13. Does it fly? (No)
14. Do you eat it? (No)
15. Does it grow in the garden? (No)
16. Is it purple? (No)
17. Does it run on tracks? (No)
18. Does it hoot at night? (No)
19. Do you eat from it? (Yes)
20. Is it a plate? (No)

Percentage of Single-Item Questions

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Frontal Patients</td>
<td>67.6%</td>
</tr>
<tr>
<td>Control Subjects</td>
<td>31.0%</td>
</tr>
</tbody>
</table>
D-KEFS Sorting Test

2 groups.
3 cards in a group.
The cards in each group are the same in some way.
Tell how you sorted both groups.
Make different groups each time you sort.

C.D.’s Scores on the DKEFS Sorting Test

CD’s Scores on Verbal Memory Tests
C.D.’s Scores on CVLT-2 Process Measures

<table>
<thead>
<tr>
<th>Z Score</th>
<th>Trials 1-5 Recall Level</th>
<th>Trials 1-5 Intrusions</th>
<th>Trials 1-5 Recall Level</th>
<th>Delayed Recall Level</th>
<th>Delayed Intrusions</th>
<th>Delayed Recall Level</th>
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<tbody>
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</table>

C.D.’s Intrusions

- Penguin x 6
- Duck x 3
- Asparagus x 2

Frontal Patients: fewer unique intrusions repeated frequently
Alzheimer Patients: more unique words repeated less often

Is the Orbital Prefrontal Cortex Cognitively Silent?
Factors Contributing to Silent View

- Many traditional executive-function tests scored only in terms of “Time to Completion”
- Failed to score process measures such as error types
- Tended to be single-level executive-function tasks

Higher-Level cognitive functions organized in a continuum
- Single-level or less complex executive-function tasks can detect dorsolateral frontal dysfunction
- Dual- or multi-level executive-function tasks are need to detect orbital prefrontal dysfunction
- A process approach is needed to go beyond time to completion measures and also score and norm error types
- Impulsive errors on tasks with speed/accuracy tradeoffs; Cognitive inflexibility; disinhibited response strategies

Hierarchical Theory of Frontal Organization of Executive Functions

| Orbital Prefrontal Multi-Level Executive Function Tasks | Dorsolateral Frontal Single Level Executive-Function Tasks |
Abstract

“The anterior prefrontal cortex, or Brodmann’s area 10, is one of the least well understood regions of the brain….In recent years, investigators have attempted to integrate findings from functional neuroimaging in humans to generate models that might describe the contribution that this area makes to cognition….The results indicate a specific role for this region in integrating the outcomes of two or more separate cognitive operations in the pursuit of a higher behavioural goal.”

Ramnani & Owen, 2004
Figure 1. A summary of the connectivity between parietal cortex and other brain regions. The thalamorectal and subthalamopallidal projections correspond with different parietal regions, with which it communicates. Projections are associated with somatosensory processing areas (barrel field, agranular), and parietal opercular regions with dorsolateral prefrontal cortex. The research is based on the findings of several studies (e.g., de Curtis, 2006; Petrides).