

# Memory, Computerized Performance Testing & Monitoring

By Richard Soutar, Ph.D.

# Memory Is Not Local

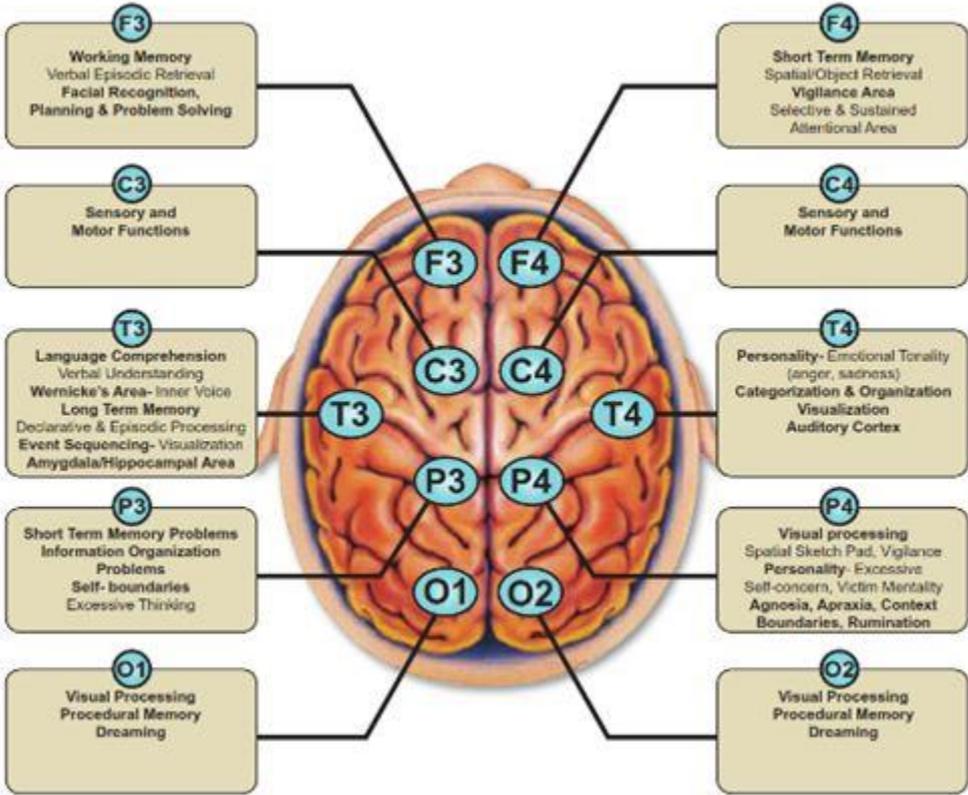
Karl Lashley, one of the most prominent of the 20<sup>th</sup> century researchers in learning and memory, was originally in search of a single biological locus of memory or “[engram](#)” however he ended up disproving his own theory suggesting that memories were not localized in one part of the brain rather they were spread out through the cortex.

Karl Spencer Lashley

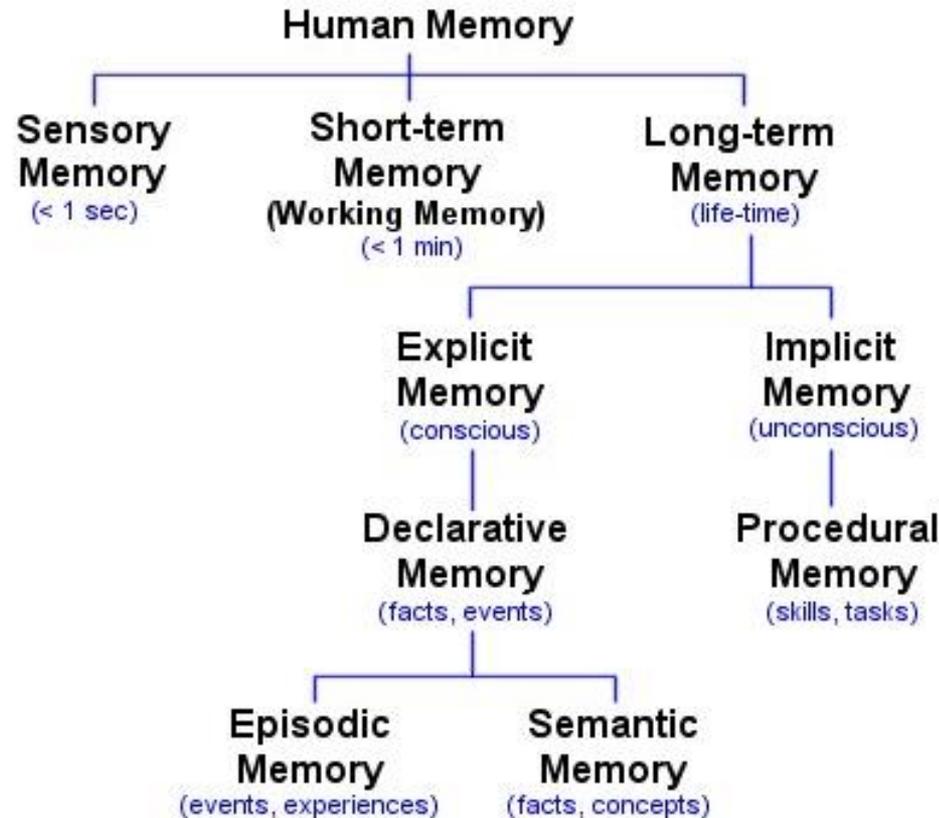


**There is no “memory center.”**

# Memory Is Diffuse In Function



# The Different Kinds of Memory



# Definitions & Examples

Memory System	Major Anatomical Structures Involved	Length of Storage of Memory	Type of Awareness	Examples
Episodic memory	Medial temporal lobes, anterior thalamic nucleus, mammillary body, fornix, prefrontal cortex	Minutes to years	Explicit, declarative	Remembering a short story, what you had for dinner last night, and what you did on your last birthday
Semantic memory	Inferolateral temporal lobes	Minutes to years	Explicit, declarative	Knowing who was the first president of the United States, the color of a lion, and how a fork differs from a comb
Procedural memory	Basal ganglia, cerebellum, supplementary motor area	Minutes to years	Explicit or implicit, nondeclarative	Driving a car with a standard transmission (explicit) and learning the sequence of numbers on a touch-tone phone without trying (implicit)
Working memory	Phonologic: prefrontal cortex, Broca's area, Wernicke's area Spatial: prefrontal cortex, visual-association areas	Seconds to minutes; information actively rehearsed or manipulated	Explicit, declarative	Phonologic: keeping a phone number "in your head" before dialing Spatial: mentally following a route or rotating an object in your mind

# Map System Explanations

## Memory Processing

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Memory processing has many dimensions and it is not unusual for individuals to be strong in several dimensions and weak in only one or two. Many of these dimensions are critical for academic performance and the tasks and procedures relating to technical and professional job positions. Difficulties with memory can also lead to misunderstandings and conflicts in personal relations and intimate relationships. It is not unusual for individuals to have a mild deficit and not be aware of the deficit and how it is undermining their effort to conduct their daily life successfully. Learning new skills and remembering schedules is critical to activities of daily living. Common key dimensions which may not be optimally functioning are listed below.

**Procedural** – The long-term memory of skills, procedures, or 'how to' knowledge. This skill is critical to academic and job performance because individuals must frequently learn in a rapid fashion the sequences to performing stages of a new task. This ability can be especially valuable in mastering skills at a job that lead to higher performance evaluation and promotions.

**Short Term** – The capacity for holding a small amount of information in mind in an active, readily available state for a short period of time. This ability is crucial to every aspect of social performance. It includes the ability to remember phone numbers, addresses, new rules in math exercise or aspect aspects of a new task, or what was just said in a conversation. Individuals with problems in this area may notice especially that they have difficulty following conversations and instructions.

**Working** – The memory for intermediate results that must be held during thinking. This is especially critical for analytical and mathematical thinking. Individuals must maintain many different facts in short term memory as they work to synthesize or order them in some sequence. Individuals with working memory problems have difficulty especially in areas of math performance and the completion of complex job tasks.

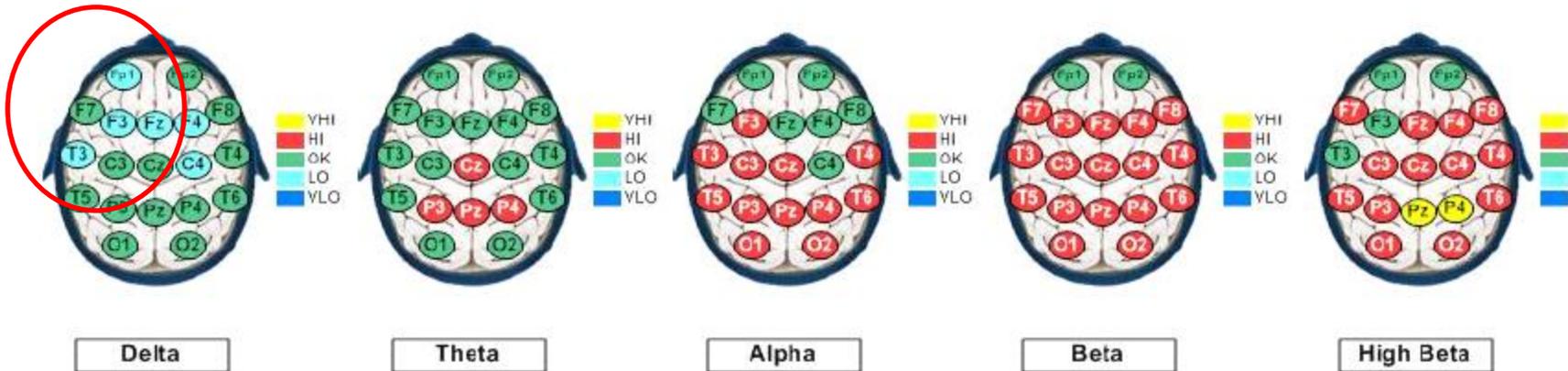
# Memory Process

- From an [information processing](#) perspective there are three main stages in the formation and retrieval of memory:
- [Encoding](#) or registration: receiving, processing and combining of received information
- [Storage](#): creation of a permanent record of the encoded information in short term or long term memory
- [Retrieval](#), *recall* or *recollection*: calling back the stored information in response to some cue for use in a process or activity

# Where To Train

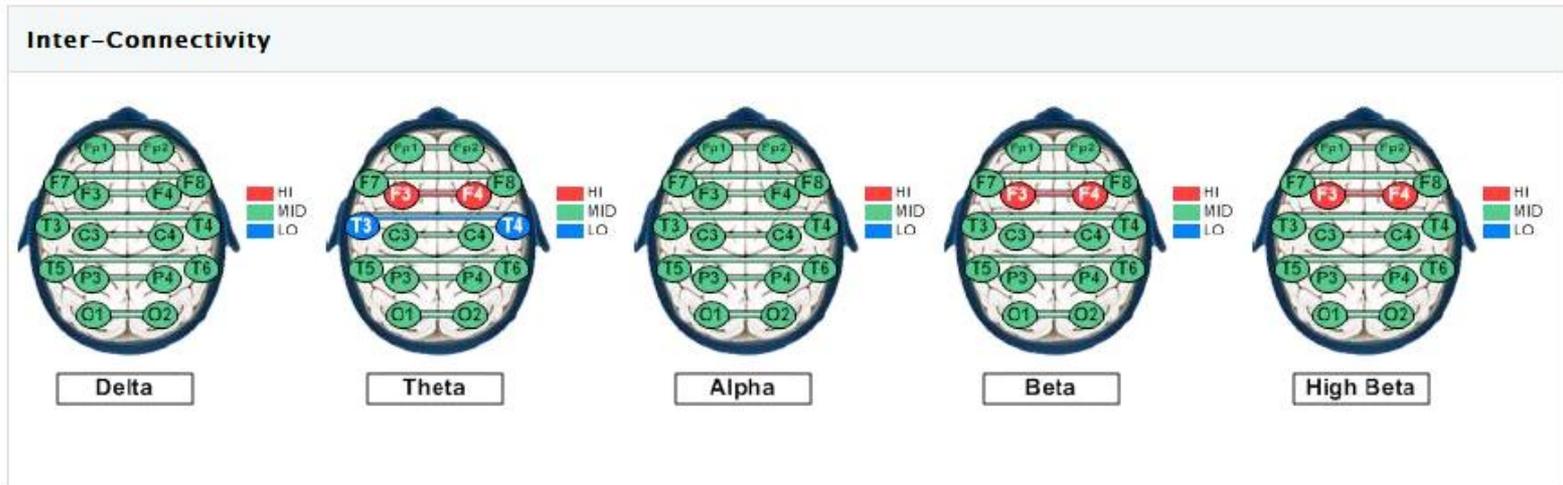
- Train at site of encoding?
- Train at site of retrieval?
- Train at site of storage?

## Trained Fp1



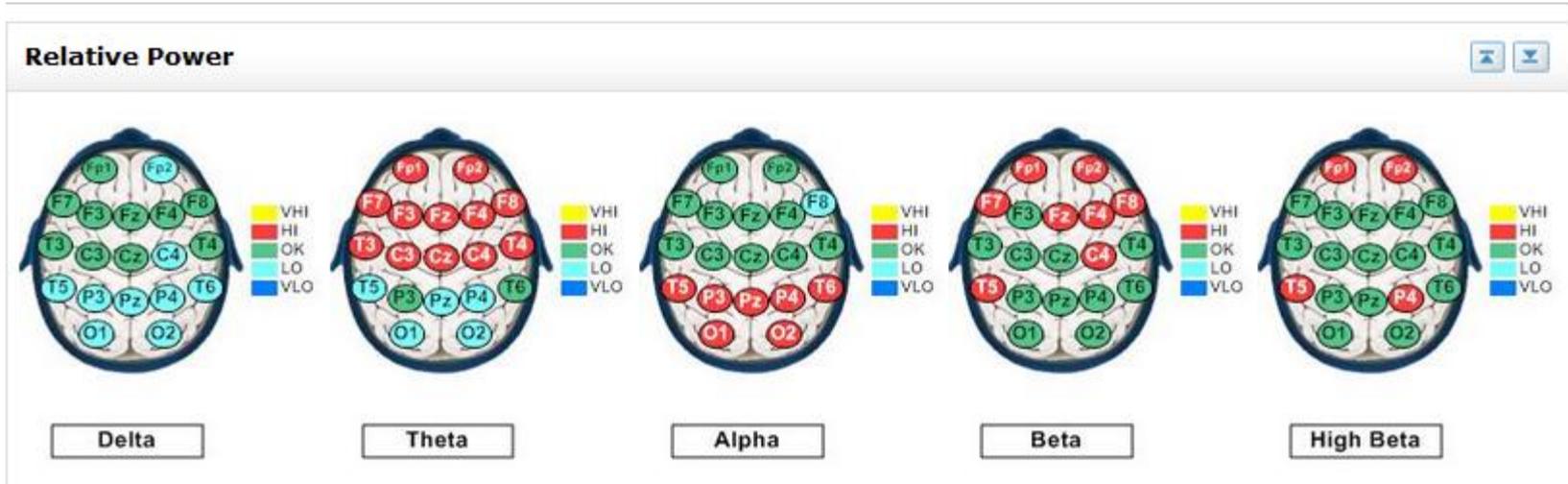
**Verbal Recall Problem- Declarative Memory: List Acquisition Test**  
**Pre Test 35 Percentile** **Post Test 85 Percentile**

# Coherence Good For Assessment Not a Prime Protocol Guide



**T3 -T4 are key Declarative Memory Sites and dysregulated but training in these areas do not generate improvement. The real problem is upstream at Fp1.**

# Sequential Memory Low Posterior Theta

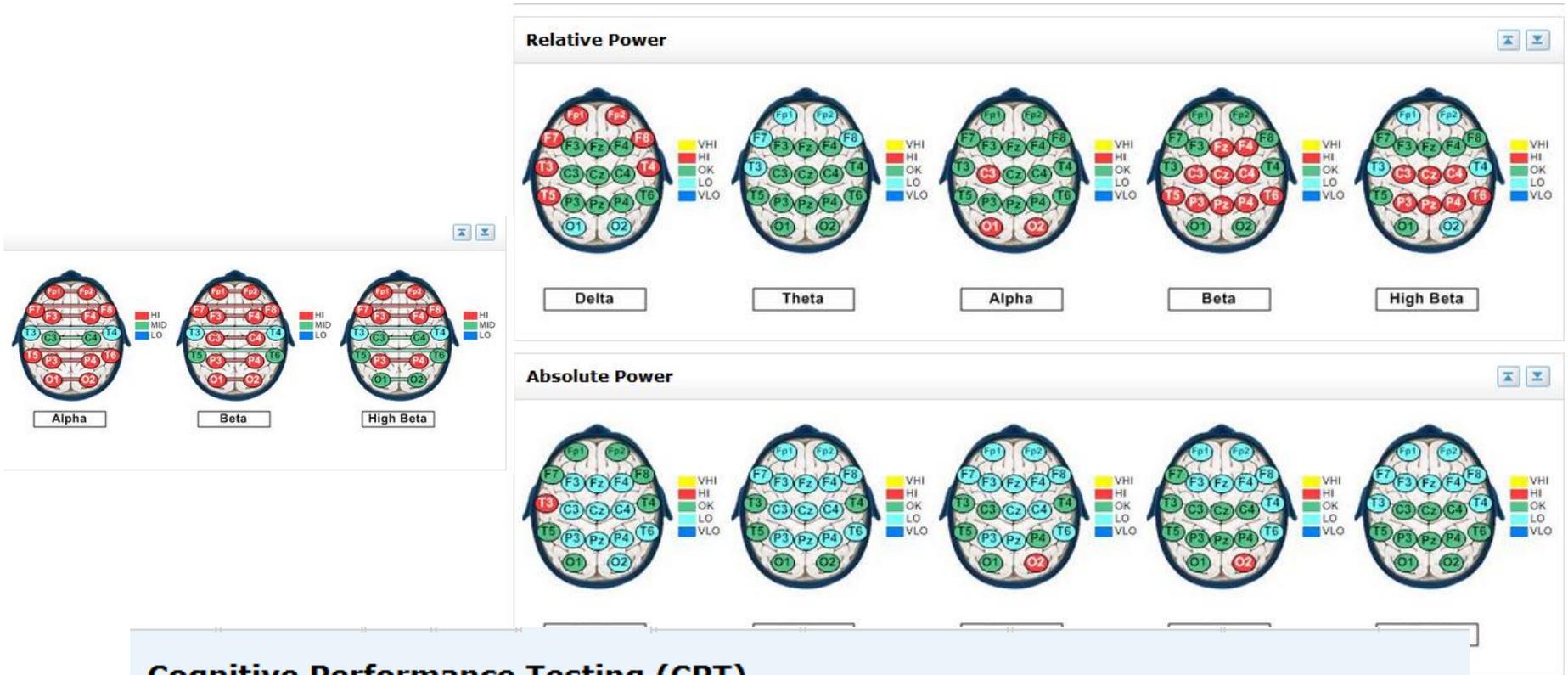


## Cognitive Performance Testing (CPT)

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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Short Term Memory	9	5	7	9	< 6	6 - 8	> 8
Working Memory	6	5	7	9	< 6	6 - 8	> 8
Sequential Memory	6	6	10	14	< 8	8 - 12	> 12
List Acquisition	62	55	65	84	< 60	60 - 70	> 70
Filtering	104	50	110	140	< 100	100 - 120	> 120

# Age Related Episodic Memory Loss

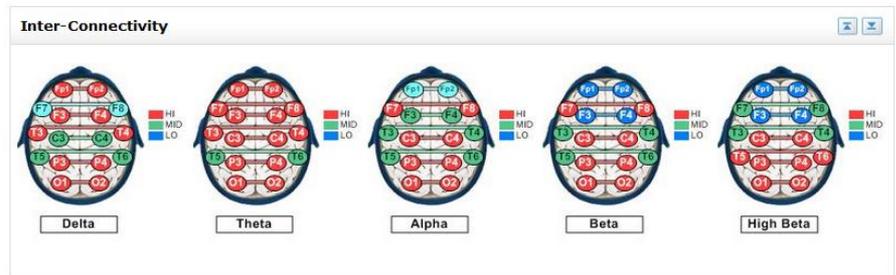
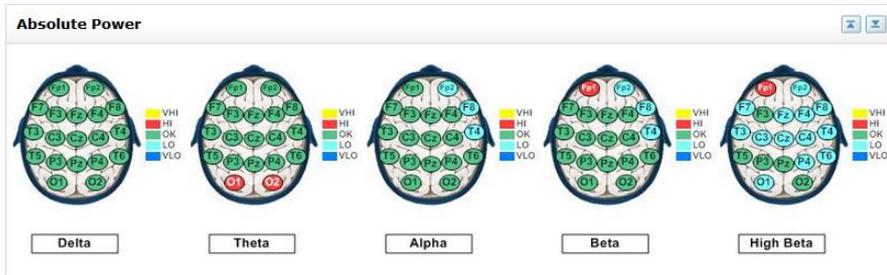


## Cognitive Performance Testing (CPT)

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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	94	70	90	100	< 85	85 - 95	> 95
Episodic Memory	2	4	6	9	< 5	5 - 7	> 7

# Sequential Memory



## Cognitive Performance Testing (CPT)

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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	99	70	90	100	< 85	85 - 95	> 95
Short Term Memory	9	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	8	5	7	9	< 6	6 - 8	> 8
Working Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	7	6	7	9	< 6	6 - 8	> 8
Sequential Memory	6	6	10	14	< 8	8 - 12	> 12
List Acquisition	63	55	65	84	< 60	60 - 70	> 70
Filtering	105	50	110	140	< 100	100 - 120	> 120
Episodic Memory	7	4	6	9	< 5	5 - 7	> 7
Executive Function	55	16	49	62	< 44	44 - 54	> 54
Spatial Sorting	30	11	28	45	< 23	23 - 33	> 33

# Parietal Hypercoherence Filtering Problems



## Cognitive Performance Testing (CPT)

[Expanded View](#)

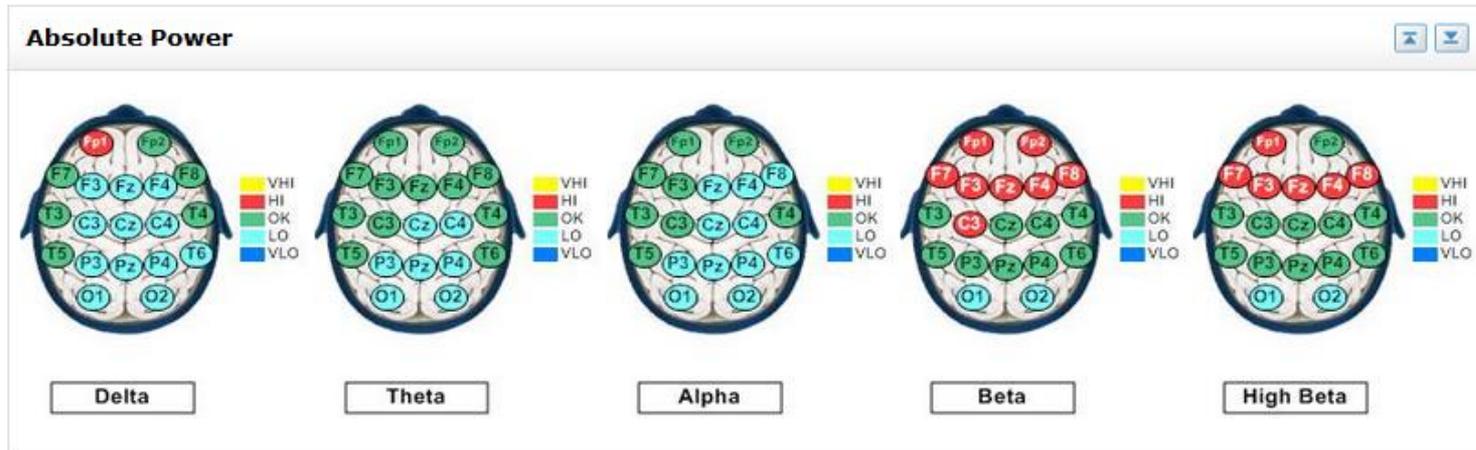
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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Short Term Memory	6	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Working Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	5	6	7	9	< 6	6 - 8	> 8
Filtering	66	50	110	140	< 100	100 - 120	> 120
Episodic Memory	4	4	6	9	< 5	5 - 7	> 7

# Auditory Working Memory

## Beta F7-F8; Delta F3-F4



### Cognitive Performance Testing (CPT)

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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Short Term Memory	6	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Working Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	5	6	7	9	< 6	6 - 8	> 8
Filtering	66	50	110	140	< 100	100 - 120	> 120
Episodic Memory	4	4	6	9	< 5	5 - 7	> 7

# Filtering 2; P3-P4 Beta Coherence



## Cognitive Performance Testing (CPT)

[Expanded View](#)

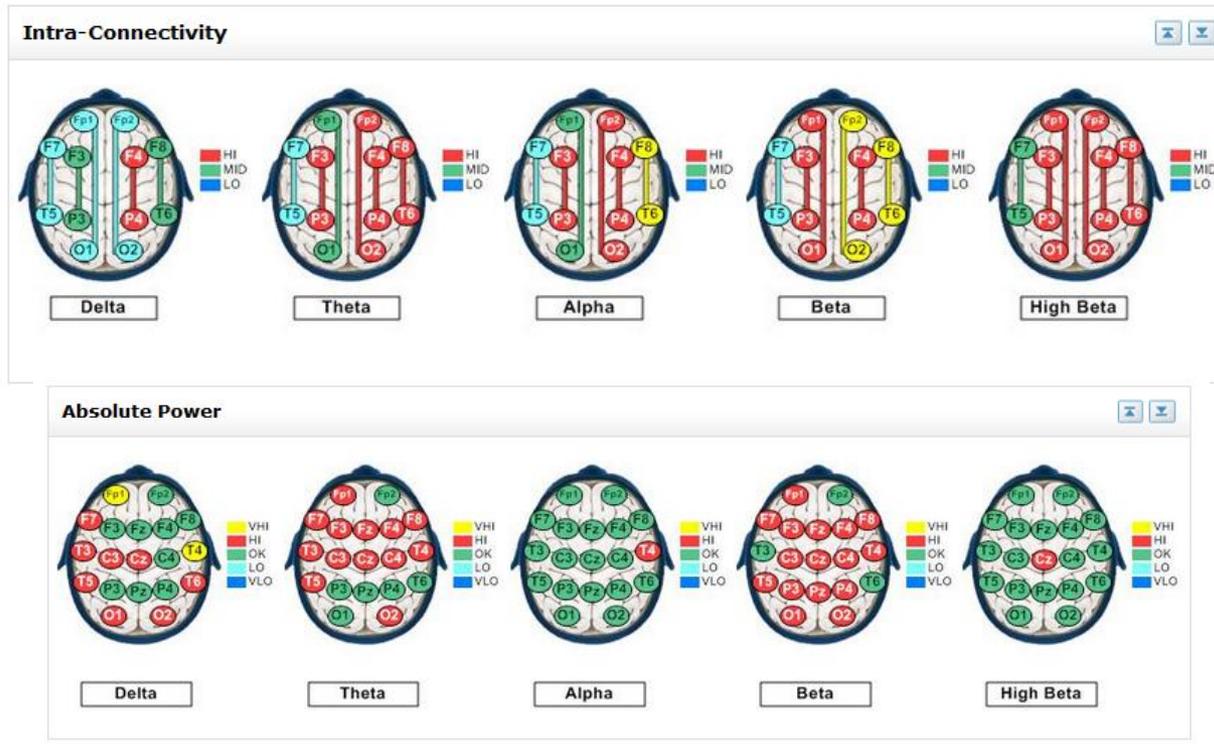
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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	97	70	90	100	< 85	85 - 95	> 95
Short Term Memory	8	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	6	5	7	9	< 6	6 - 8	> 8
Working Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	6	6	7	9	< 6	6 - 8	> 8
Sequential Memory	8	6	10	14	< 8	8 - 12	> 12
List Acquisition	55	55	65	84	< 60	60 - 70	> 70
Filtering	82	50	110	140	< 100	100 - 120	> 120
Episodic Memory	5	4	6	9	< 5	5 - 7	> 7
Executive Function	48	16	49	62	< 44	44 - 54	> 54
Spatial Sorting	14	11	28	45	< 23	23 - 33	> 33

# Spatial Sorting

## RH Coherence; F7-F8 Delta, Theta Beta



Sequential Memory	8	6	10	14	< 8	8 - 12	> 12
List Acquisition	55	55	65	84	< 60	60 - 70	> 70
Filtering	82	50	110	140	< 100	100 - 120	> 120
Episodic Memory	5	4	6	9	< 5	5 - 7	> 7
Executive Function	48	16	49	62	< 44	44 - 54	> 54
Spatial Sorting	14	11	28	45	< 23	23 - 33	> 33

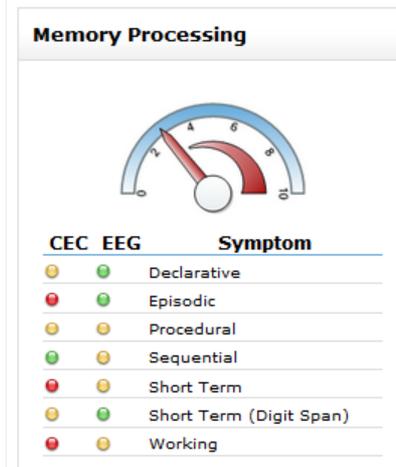
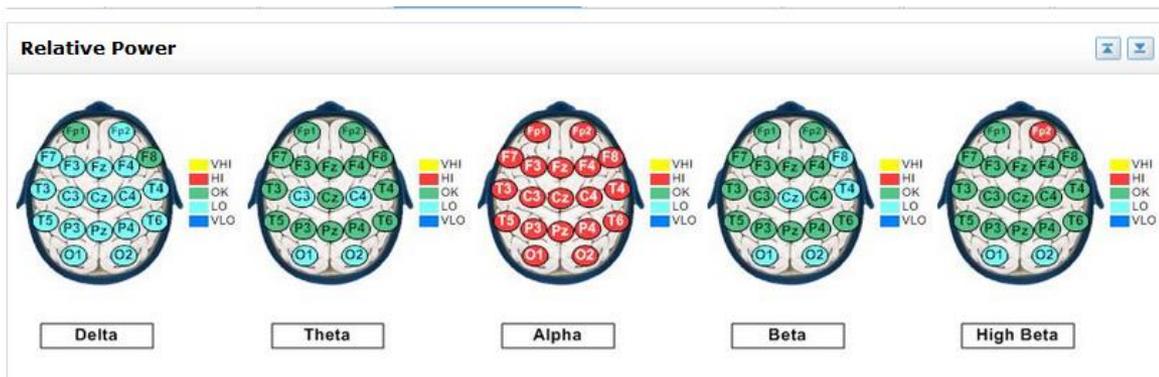
# Working Memory F3-F4 Delta, Theta



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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	95	70	90	100	< 85	85 - 95	> 95
Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Sequential Memory	4	6	10	14	< 8	8 - 12	> 12
Working Memory	5	5	7	9	< 6	6 - 8	> 8
Filtering	103	50	110	140	< 100	100 - 120	> 120
List Acquisition	60	55	65	84	< 60	60 - 70	> 70
Episodic Memory	8	4	6	9	< 5	5 - 7	> 7

# Sequential O1-O2, Working F3-F4 List Acquisition T3-T4/F3-F4

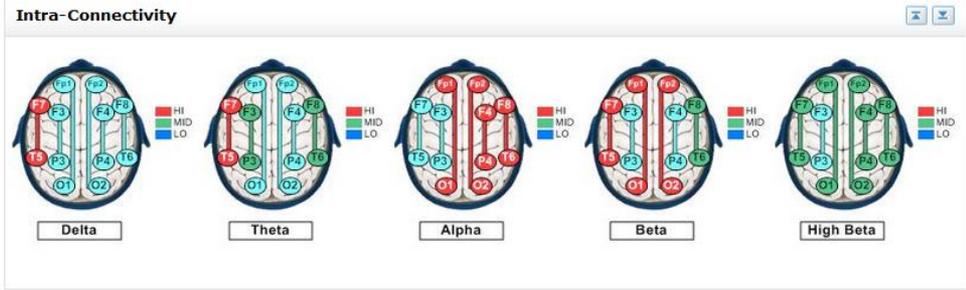
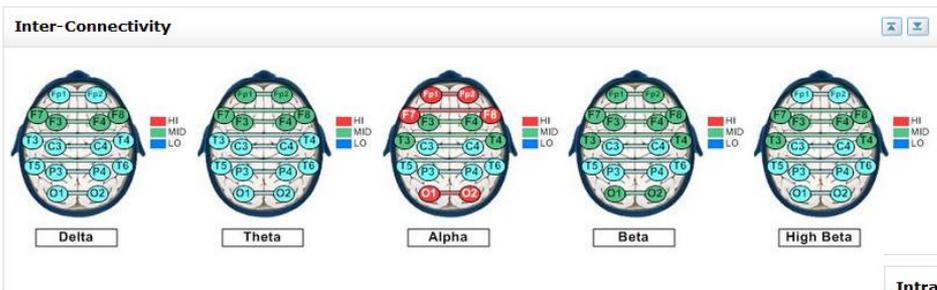


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Attention	99	70	90	100	< 85	85 - 95	> 95
Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Working Memory	5	5	7	9	< 6	6 - 8	> 8
Sequential Memory	7	6	10	14	< 8	8 - 12	> 12
List Acquisition	55	55	65	84	< 60	60 - 70	> 70
Filtering	105	50	110	140	< 100	100 - 120	> 120

# Coherence and List Acquisition



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Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
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Sequential Memory	7	6	10	14	< 8	8 - 12	> 12
List Acquisition	55	55	65	84	< 60	60 - 70	> 70
Filtering	105	50	110	140	< 100	100 - 120	> 120

# Working F3-F4; Sequential O1-O2 Auditory T4



## Cognitive Performance Testing (CPT)

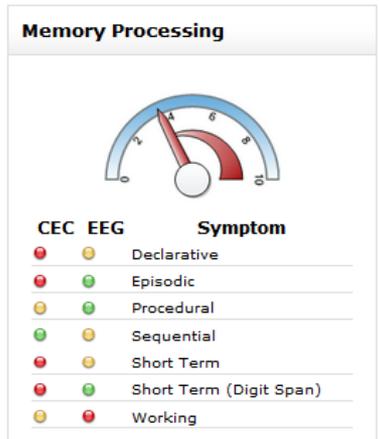
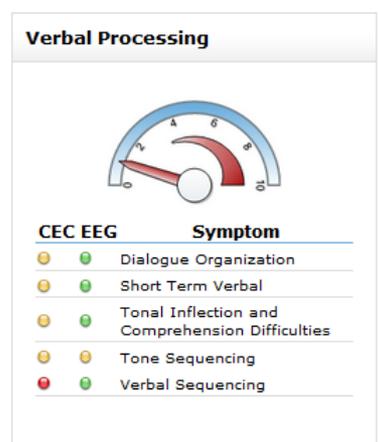
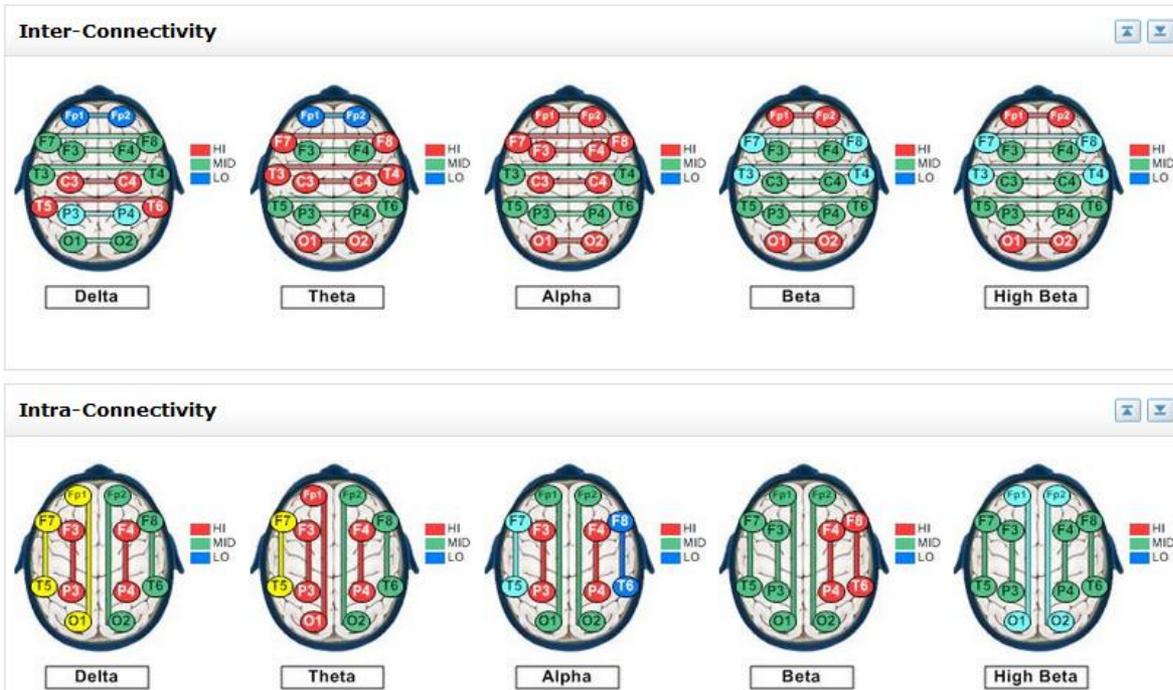
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Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	100	70	90	100	< 85	85 - 95	> 95
Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	6	5	7	9	< 6	6 - 8	> 8
Working Memory	5	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	5	6	7	9	< 6	6 - 8	> 8
Sequential Memory	5	6	10	14	< 8	8 - 12	> 12

# Dashboard Agreement



Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
Attention	100	70	90	100	< 85	85 - 95	> 95
Short Term Memory	7	5	7	9	< 6	6 - 8	> 8
Aud. Short Term Memory	6	5	7	9	< 6	6 - 8	> 8
Working Memory	5	5	7	9	< 6	6 - 8	> 8
Aud. Working Memory	5	6	7	9	< 6	6 - 8	> 8
Sequential Memory	5	6	10	14	< 8	8 - 12	> 12

# New Mind Computerized Performance Tests For Cognitive Tracking

- N = 900
- Statistically Normed
- Based on Standard Formats Such as Digit Span
- Most tests under five minutes
- Can be taken from home
- Auto Selected from qEEG
- Auto Tracking

# Comprehensive Output

## Cognitive Performance Testing (CPT)

 Expanded View

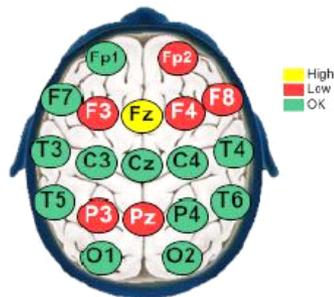
 Close Report

 Download Report

Cognitive Performance Test	Client Score	Lowest Score	Average	Best Score	Below Average Range	Average Range	Above Average Range
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Short Term Memory	9	6	7	9	< 7	7 - 8	> 8
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Aud. Working Memory	5	6	7	9	< 6	6 - 8	> 8
Sequential Memory	6	6	10	14	< 8	8 - 12	> 12
List Acquisition	54	55	65	84	< 60	60 - 70	> 70
Filtering	106	50	110	140	< 100	100 - 120	> 120
Episodic Memory	6	4	6	9	< 5	5 - 7	> 7
Executive Function	57	60	90	120	< 80	80 - 100	> 100
Spatial Sorting	27	55	65	84	< 60	60 - 70	> 70

# The CEC Generates a Hypothetical Headmap of Problem Areas

These hypothetical problem areas are identified through the CEC questions.



## CEC Response Assessment

Category	Response Count	Average Response
Anxiety	9	1.78
Depression	4	2.75
Impulsive	4	1.50
Attention	3	1.33
Memory	2	1.50

## CEC Responses

Answer	Question
3	Lack Of Motivation/ Poor Follow through
3	Procrastination/Puts Things Off
3	Difficulty With Decisions
3	Stuck On Thoughts
3	Stuck On Behaviors
3	Bargains Constantly
2	Short Attention Span & Focus

**Problem Area- Location links are based on fMRI Research**

# fMRI Research Distributed To NFB Community

The fMRI functional correlates of location were published in the book “Doing Neurofeedback” in 2000 and individually distributed to the leading developers and investigators in the field.

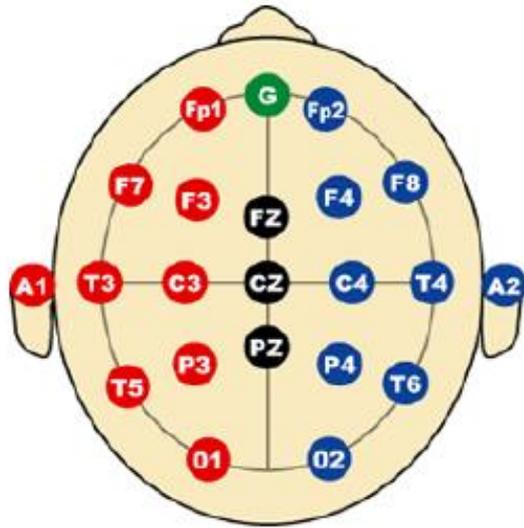
SITE	BRODMANN AREA	FUNCTION
Fpz	10, 11, 32	Emotional Inhibition Oversensitive, Impulsive Motivation & Attention
Fp1	10, 11, 46	Cognitive Emotional <u>Valencing</u> - Lateral Orbital Frontal Irritability, Intrusive, Depression Social Awareness- Approach Behaviors
Fp2	10, 11, 46	Emotional Inhibition- Lateral Orbital Frontal Impulsivity, Tactlessness, Mania Social Awareness- Avoidance Behaviors
F7	45, 47, 46	Working Memory- Visual & Auditory Divided & Selective Attention- Filtering <u>Broca's Area</u> - Semantic Short Term Buffer (Word Retrieval)
F8	45, 47, 46	Prosody Working Memory- Spatial & Visual, Gestalt Facial Emotional Processing Sustained Attention
F3	8, 9, 46	Short Term Memory- Verbal Episodic Retrieval Facial Recognition, Object Processing Planning & Problem Solving- Wisconsin Card Sort (rigidity)
F4	8, 9, 46	Short Term Memory- Spatial/Object Retrieval Vigilance Area- Selective & Sustained <u>Attentional Area</u>
Fz	8, 6, 9	Personality Changes Intention & Motivation- Poverty of Speech, Apathy Possible Anterior <u>Cingulate</u> - Internal vs External Attention Basal Ganglia Output
C3	3, 1, 4	Sensory & Motor Functions
C4	3, 1, 4	Sensory & Motor Functions
Cz	6, 4, 3	Sensory & Motor Functions

Cz	6, 4, 3	Sensory & Motor Functions
T3	42, 22, 21	Language Comprehension- Verbal Understanding <u>Wernicke's Area</u> - Inner Voice Long Term Memory- Declarative & Episodic Processing Event Sequencing- Visualization <u>Amygdala/Hippocampal Area</u>
T4	42, 22, 21	Personality- Emotional Tonality (anger, sadness) Categorization & Organization Visualization Auditory Cortex
T5	39, 37, 19	Meaning Construction- Angular <u>Gyrus</u> <u>Acalcula</u> Short Term Memory
T6	39, 37, 19	Facial Recognition- Emotional Content. <u>Amygdalic connection</u> .
P3	7, 40, 19	Digit Span Problems Information Organization Problems Self- boundaries Excessive Thinking
P4	7, 40, 19	Visual processing- Spatial Sketch Pad, Vigilance Personality- Excessive Self-concern, Victim Mentality <u>Agnosia Apraxia</u> , Context Boundaries, Rumination
Pz	7, 5, 19	<u>Attentional Shifting</u> - Perseverance Self-Awareness, Orientation Association Area <u>Agnosia Apraxia</u>
O1, O2	18, 19, 17	Visual Processing Procedural Memory, Dreaming
Oz	18, 17, 19	Visual Processing, Hallucinations

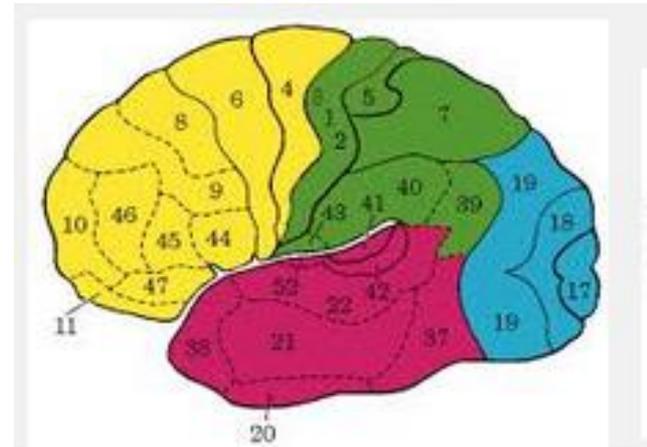
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This was the first document to integrate the 10-20 system and a comprehensive review of the Brodmann area research in the fMRI literature based on the Talairach Atlas for functional brainmapping.

# 10-20 & Brodmann Correlations



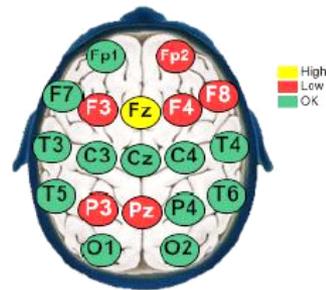
10-20 EEG Coordinate System



Brodman Locations based on cell typology.

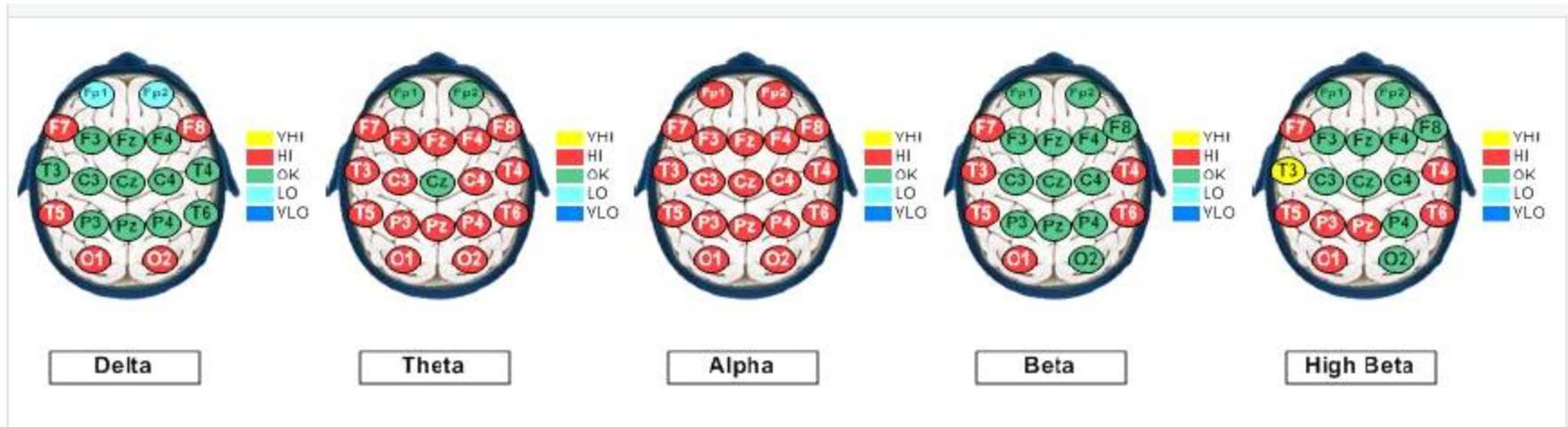
# CEC Compared To qEEG

The level of deviance for each location on the actual qEEG map is rank ordered based on a weighting system that looks at magnitude, dominant frequency, asymmetry, coherence and phase. These weighted values of the deviance of each location are correlated with the CEC hypothesized map.



CEC Response Assessment

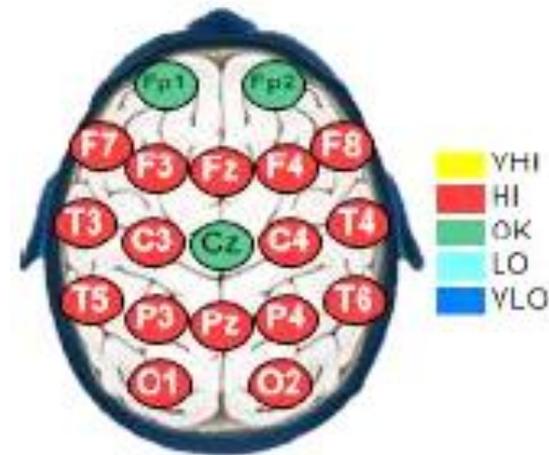
Category	Response Count	Average Response
Anxiety	9	1.78
Depression	4	2.75
Impulsive	4	1.50
Attention	3	1.33
Memory	2	1.50



# qEEG Map Deviance

The qEEG maps by themselves indicate dysregulation or deviance in locations identified in the fMRI literature as being correlated with specific functional deficits.

EEG	Symptom
☀️	Attention
☀️	Categorization
☀️	Decision Making
🌿	Filtering Difficulties
☀️	Motivation
☀️	Problem Solving
☀️	Socio-Emotional Decision Making



Theta

# The CEC and EEG Columns are Compared

The CEC column on the left shows the level of client's acknowledged and endorsed problems and the column on the right shows the level of dysregulation of locations in networks associated with those problems. The EEG dashlight can only indicate a probability level of dysregulation due to the brains complexity and compensation capacity.

CEC	EEG	Symptom	CEC EEG	Symptom
		Attention	 	Attention
		Categorization	 	Categorization
		Decision Making	 	Decision Making
		Filtering Difficulties	 	Filtering Difficulties
		Motivation	 	Motivation
		Problem Solving	 	Problem Solving
		Socio-Emotional Decision Making	 	Socio-Emotional Decision Making

**Note the areas of agreement between the CEC and EEG.**

# Correlations Are Used To Select The Appropriate Test



In this case ST and Working Memory, Decision Making, and Reading Comprehension show correlations

# Appropriate Tests Are Automatically Selected

The screenshot displays a web application interface for Cognitive Performance Testing (CPT). At the top, a navigation bar includes tabs for Profile, Physiology, ISI, CEC, Cognitive (selected), Brain Maps, Training Sessions, Progress Tracking, and Client Login. Below this, a light blue header reads "Cognitive Performance Testing (CPT)".

A row of three action buttons is visible: a green button with a checkmark icon labeled "Select Cognitive Test(s) to Perform", a blue button with a bar chart icon labeled "View All Results", and an orange button with a bar chart icon labeled "Download OLD CPT Version History".

The main content area is organized into five categories, each with a blue header and a list of actions:

- Attention**: Overview, Practice, Start Test, Results
- Short Term Memory**: Overview, Practice, Start Test, Results
- Working Memory**: Overview, Practice, Start Test, Results
- Episodic Memory**: Overview, Practice, Start Test, Results
- Executive Function**: Overview, Practice, Start Test, Results

Each action is represented by a small icon: a list icon for Overview, a circular arrow for Practice, a clock for Start Test, and a bar chart for Results.

# Tests Can Also Be Manually Selected

Profile	Physiology	ISI	CEC	<b>Cognitive</b>	Brain Maps	Training Sessions	Progress Tracking	Client Login
---------	------------	-----	-----	------------------	------------	-------------------	-------------------	--------------

## Cognitive Performance Testing (CPT)

**Select Cognitive Performance Test(s)**  
Select one or many cognitive performance measures below to build a custom view of tests.

**OR**  
Not sure which cognitive measure(s) to pick?  
Select a Brain Map from the list and measure(s) will be automatically chosen based on the selected EEG.

[Optional] Select One ▾

Select	Cognitive Performance Test
<input type="checkbox"/>	Attention
<input type="checkbox"/>	Short Term Memory
<input type="checkbox"/>	Auditory Short Term Memory
<input type="checkbox"/>	Working Memory
<input type="checkbox"/>	Auditory Working Memory
<input type="checkbox"/>	Sequential Memory
<input type="checkbox"/>	List Acquisition
<input type="checkbox"/>	Filtering
<input type="checkbox"/>	Episodic Memory
<input type="checkbox"/>	Executive Function
<input type="checkbox"/>	Spatial Sorting

# Selection Is Quick & Easy

Profile	Physiology	ISI	CEC	<b>Cognitive</b>	Brain Maps	Training Sessions	Progress Tracking	Client Login
---------	------------	-----	-----	------------------	------------	-------------------	-------------------	--------------

## Cognitive Performance Testing (CPT)

**Select Cognitive Performance Test(s)**  
Select one or many cognitive performance measures below to build a custom view of tests.

**OR**  
Not sure which cognitive measure(s) to pick?  
Select a Brain Map from the list and measure(s) will be automatically chosen based on the selected EEG.

[Optional] Select One ▾

Select	Cognitive Performance Test
<input checked="" type="checkbox"/>	Attention
<input checked="" type="checkbox"/>	Short Term Memory
<input type="checkbox"/>	Auditory Short Term Memory
<input checked="" type="checkbox"/>	Working Memory
<input type="checkbox"/>	Auditory Working Memory
<input type="checkbox"/>	Sequential Memory
<input type="checkbox"/>	List Acquisition
<input type="checkbox"/>	Filtering
<input checked="" type="checkbox"/>	Episodic Memory
<input checked="" type="checkbox"/>	Executive Function
<input type="checkbox"/>	Spatial Sorting

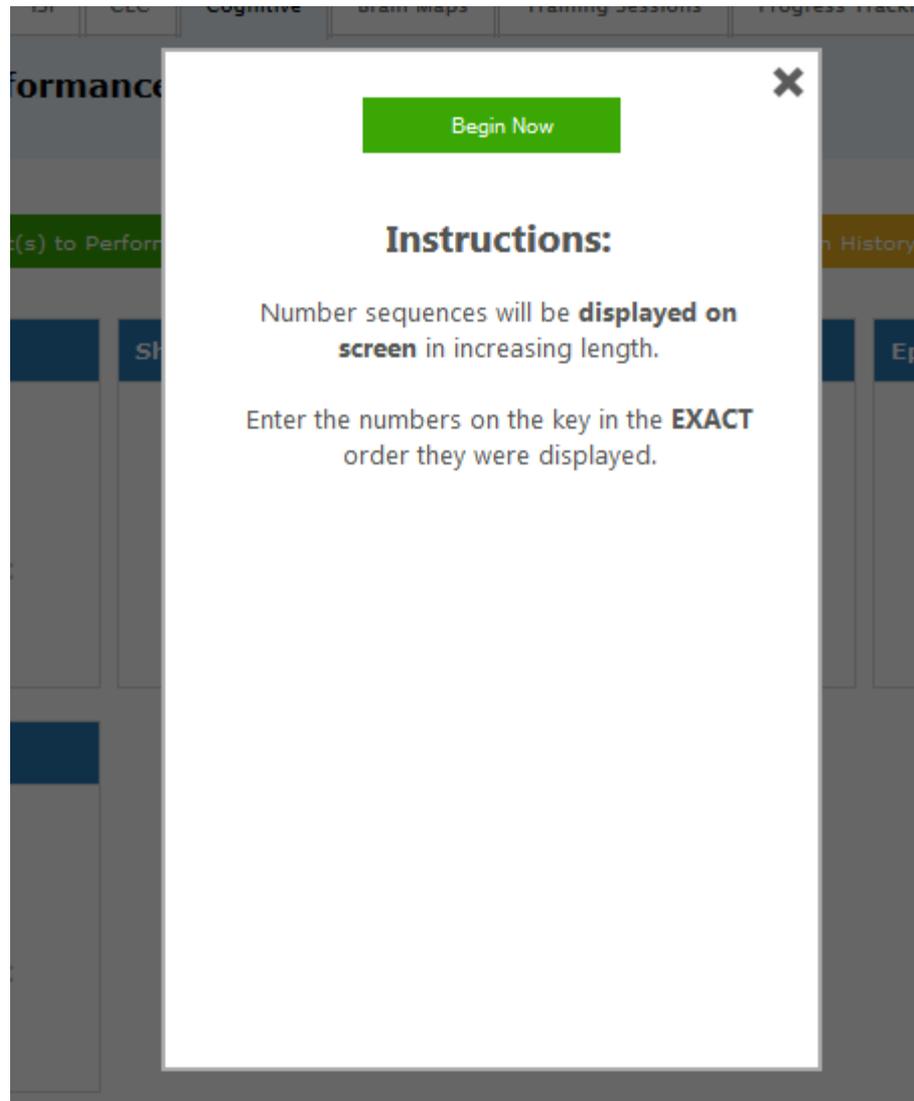
# The Purpose of Each Test Is Explained

The screenshot shows a software interface with a modal window titled "Short Term Memory". The modal window has a blue header with the title and a close button (X). The main content of the modal is a white box with the following text:

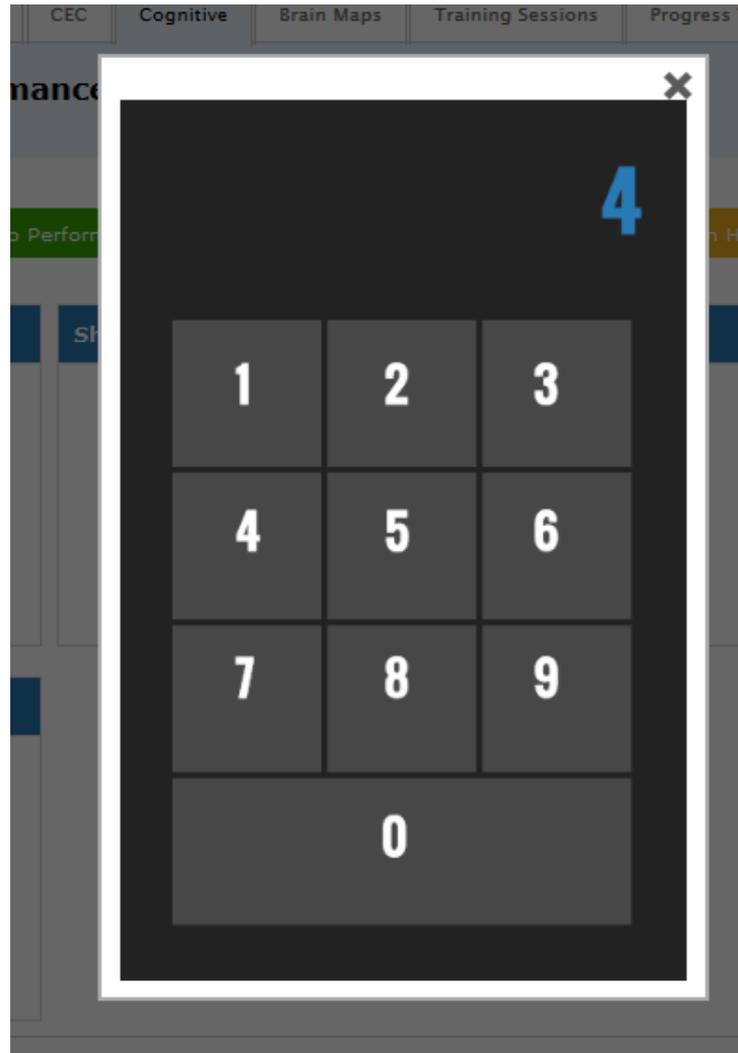
This test measures the capacity for holding a small amount of visual information in mind in an active, readily available state for a short period of time. This ability is crucial to every aspect of social performance. It includes the ability to remember phone numbers, addresses, new rules in a math exercise or aspects of a new task, or what was just said in a conversation. Individuals with problems in this area may notice especially that they have difficulty following conversations and instructions.

The background interface is dimmed and shows a top navigation bar with three buttons: "Cognitive Test(s) to Perform" (green), "View All Results" (blue), and "Download OLD CPT Version History" (brown). Below the navigation bar, there is a sidebar with a menu containing "Overview", "Practice", "Start Test", and "Results". The main content area also has a menu with "Overview", "Practice", and "Start Test".

# Clients Receive Instructions



# A Practice Test Is Provided



# Easy To Interpret Results Immediately Provided

