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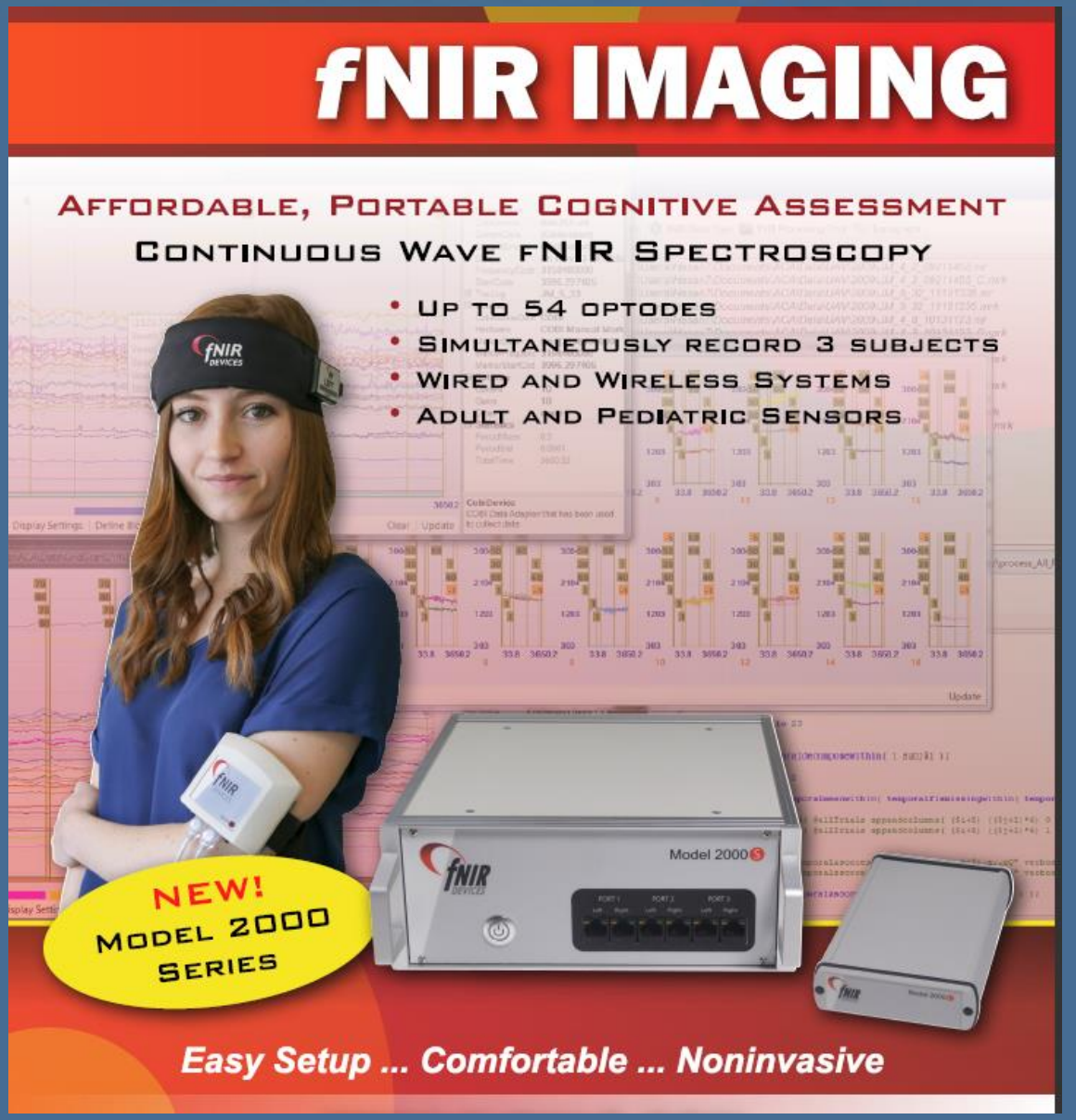
fNIR DEVICES Technology

*f*NIR Devices

Functional Optical Brain Imaging Systems



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fNIR DEVICES Technology

*f*NIR Devices

Functional Optical Brain Imaging Systems

***f*NIR** is an optical imaging technology that measures neural activity and hemodynamic response in the prefrontal cortex. The subject wears a sensor on the forehead that includes four IR light sources and ten detectors that are mounted in a flexible band. The fNIR sensor detects oxygen levels in the prefrontal cortex and provides real-time values for oxy-hemoglobin and deoxygenated hemoglobin. It provides a continuous and real-time display of the oxygen changes as the subject performs different tasks.

The *f*NIR data combines with other physiological variables such as ECG, respiration, cardiac output, blood pressure, electrodermal activity and stimulus response markers. Acq*Knowledge* software provides automated analysis tools for event related potentials and ensemble averaging. Combining the fNIR data with the other physiological signals provides researchers with a detailed subject assessment.

The fNIR100 stand-alone functional brain imaging system for continuous NIR spectroscopy (NIRS) provides an in-lab cognitive function assessment. It eliminates a great many of the drawbacks of a functional MRI. The subject can sit in front of a computer and take a test or perform mobile tasks. The system interfaces with most stimulus presentation systems such as E-Prime, SuperLab, and BIOPAC's range of Virtual Reality systems.

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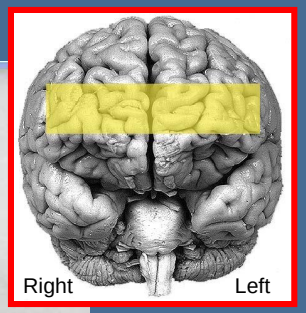
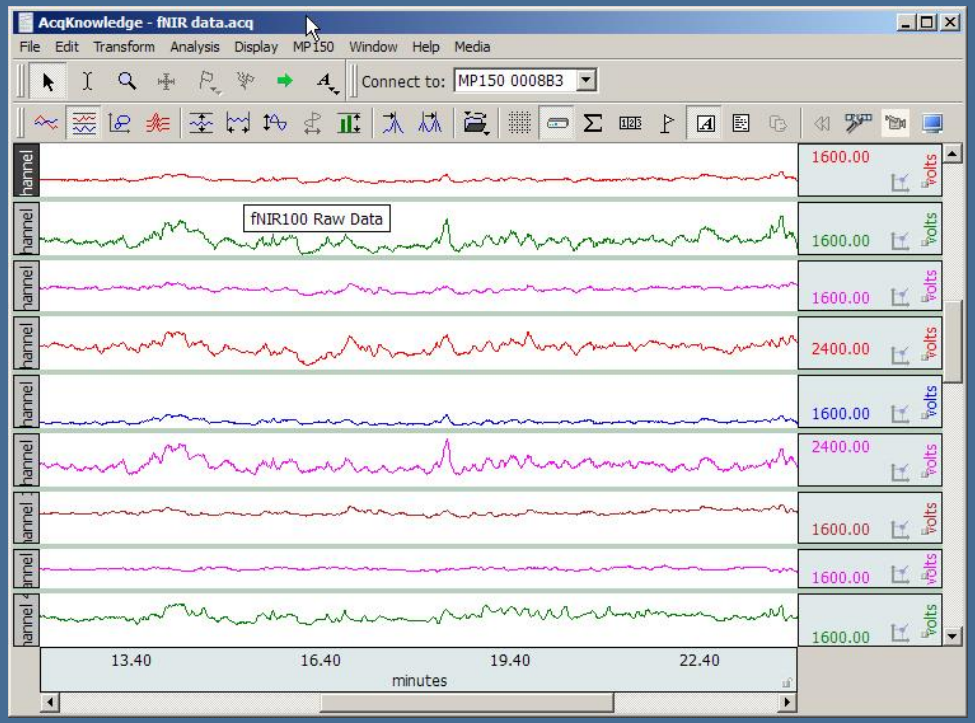
fNIR DEVICES Technology

Functional Near-Infrared Spectroscopy [*f*NIR]

for natural environments & field conditions…





Emerging technology to monitor cortical hemodynamic changes in response to brain activation

- Safe, affordable, portable
- Noninvasive, minimally intrusive, rugged

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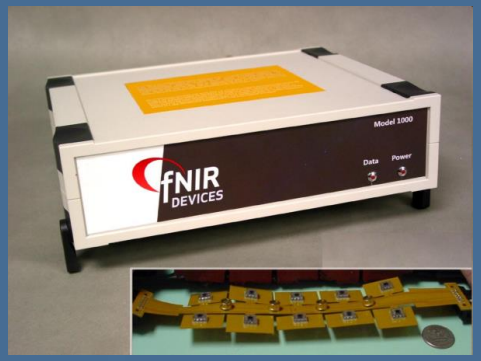
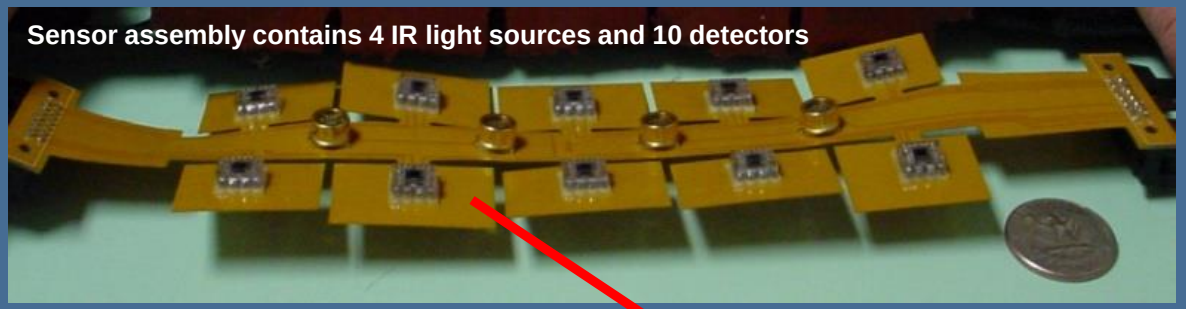
*f*NIR - Overview of the system

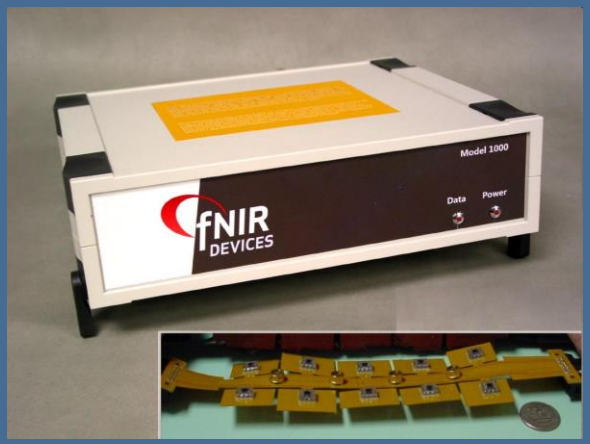


Head Piece



Operator's Monitor

*f*NIR - Overview of the system

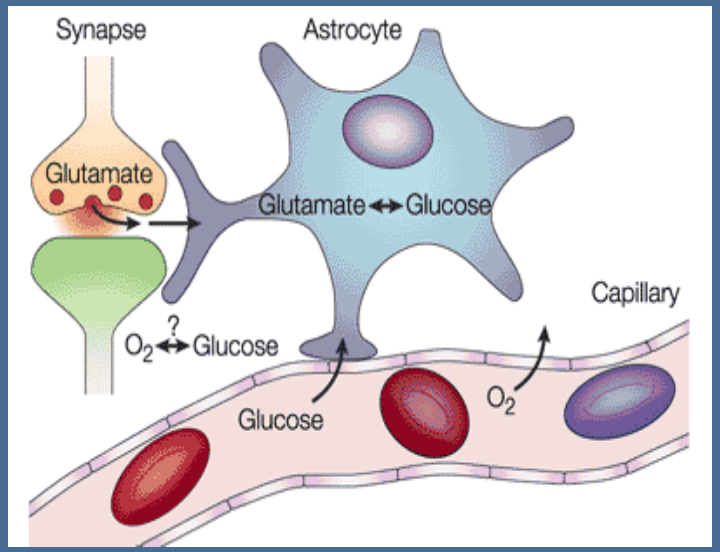


The fNIR device provides relative change in hemoglobin levels, calculated using a modified Beer-Lamber law.

- **Oxygenated hemoglobin change:**
  delta O2Hb (µmol/L)
- **Deoxygenated hemoglobin change:**
  delta HHb (µmol/L)
- **Total hemoglobin change:**
  delta cHb (µmol/L)

Principles of *f*NIR I

Neural Activity & Hemodynamic Response



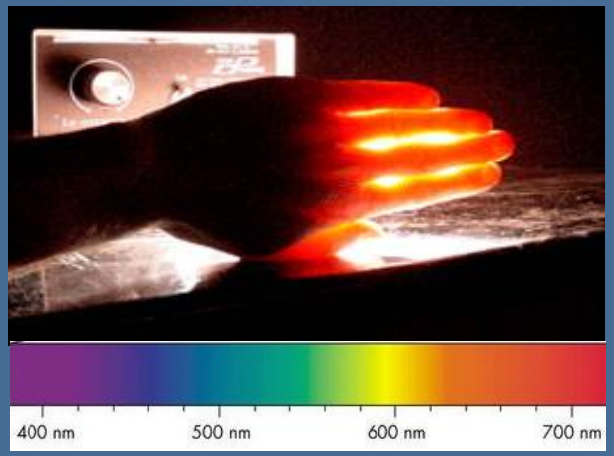
Oxy-Hb and deoxy-Hb are correlates of brain activity through oxygen consumption by neurons

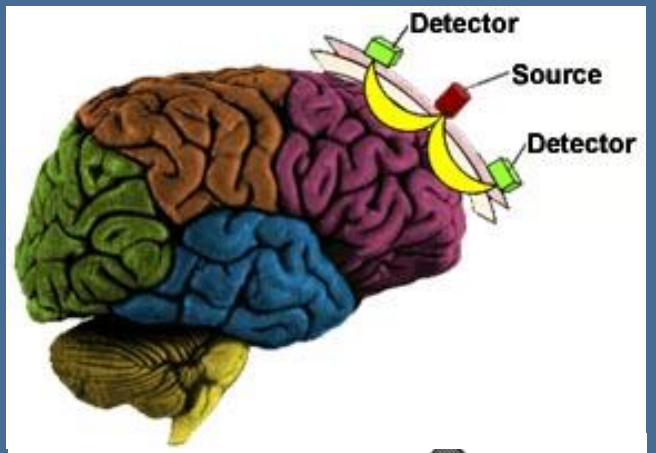
- Neurons consume energy (glucose) when activated
- Oxygen is required to metabolize the glucose
- As clusters of neurons are activated, there is an increased need for oxygen in that area
- Oxygen is transported to neural tissue via oxy-hemoglobin in the blood
- The oxygen exchange occurs in the capillary beds
- As oxy-hemoglobin gives up oxygen to the neural tissue, it is transformed into deoxygenated hemoglobin

David J. Heeger & David Ress. (2002)What does fMRI tell us about neuronal activity? Nature Reviews Neuroscience 3, 142-151

Principles of *f*NIR II

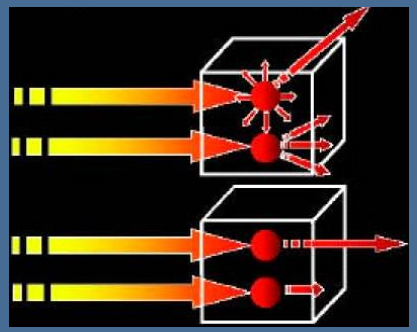
Photon Migration in Tissue

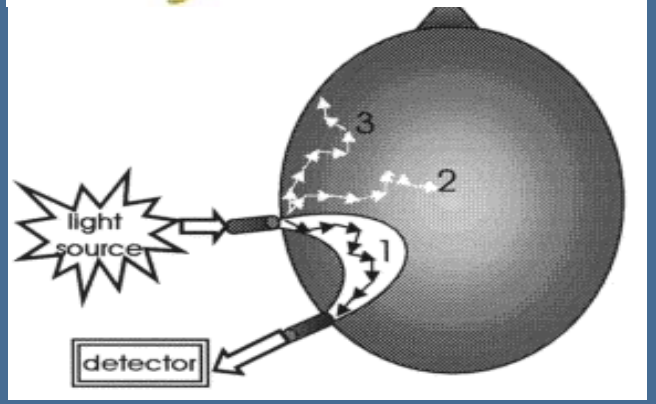




Photons that enter the tissue undergo two types of interaction:

- Scattering (cell membranes)
- Absorption (Hb, HbO_2 water)

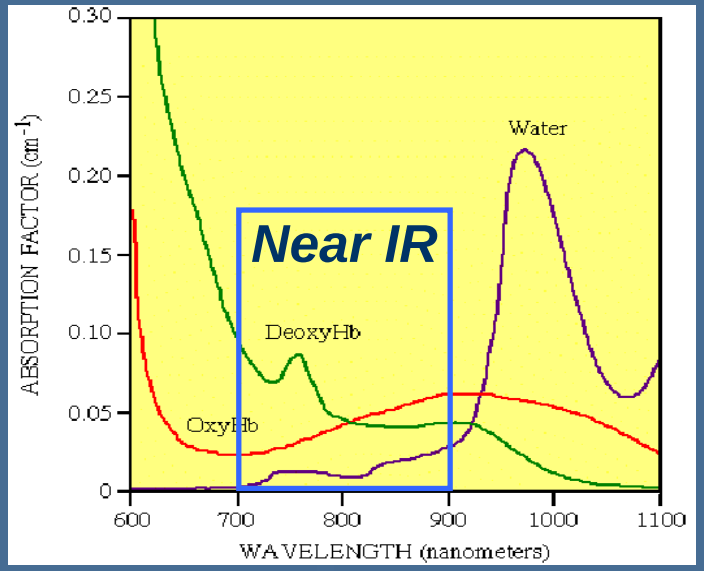


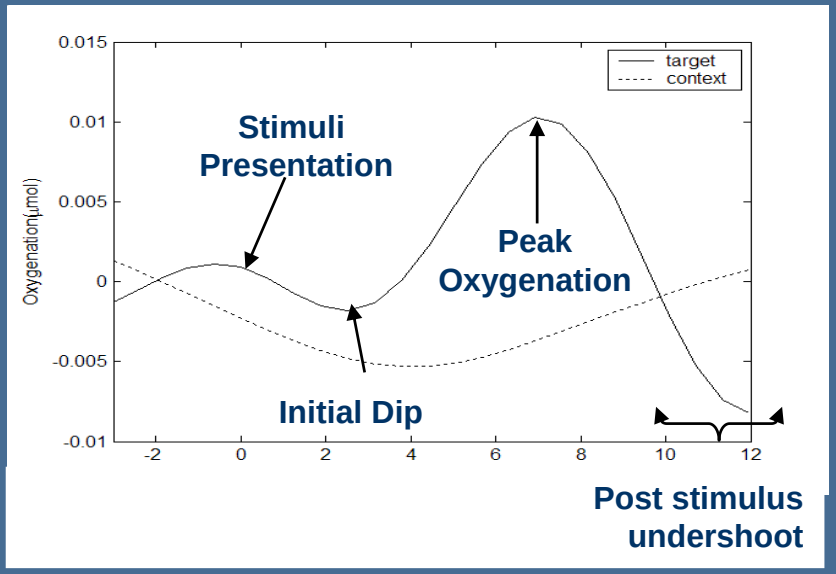


H Obrig , R Wenzel, M Kohl, S Horst, P Wobst, J Steinbrink, F Thomas, A Villringer. Near-infrared spectroscopy: does it function in functional activation studies of the adult brain? International Journal of Psychophysiology 35(2-3):125-142, 2000

Principles of *f*NIR III

Optical Window in Tissue





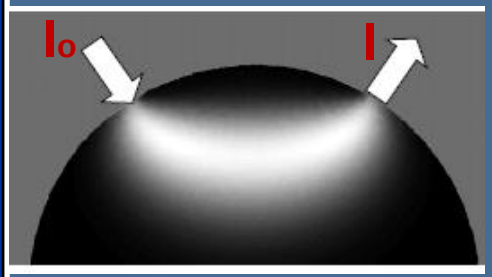
Modified Beer-Lambert Law

$$I = I_0 10^{-(\alpha_{HB}C_{HB} + \alpha_{HBO_2}C_{HBO_2})L} \quad .G$$

$$\Delta OD = \log_{10}\frac{I_B}{I} = (\alpha_{HB}\Delta C_{HB} + \alpha_{HBO_2}\Delta C_{HBO_2})L$$

$$Oxygenation = \Delta C_{HbO2} - \Delta C_{Hb}$$

$$BloodVolume = \Delta C_{HbO2} + \Delta C_{Hb}$$



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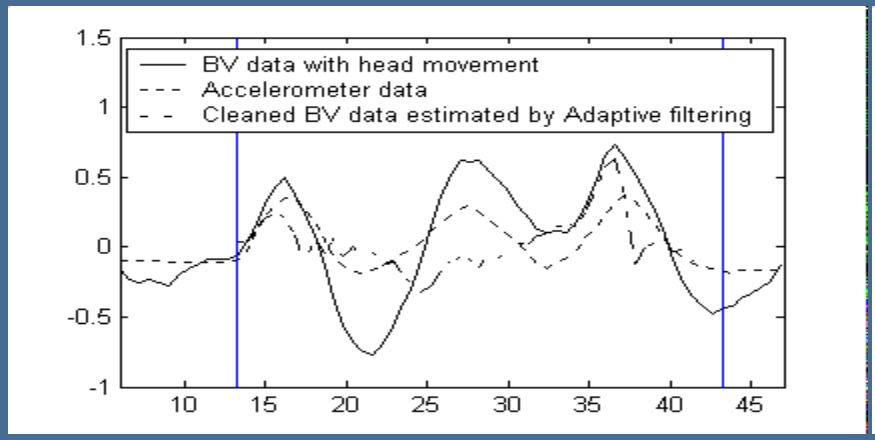
fNIR DEVICES Technology

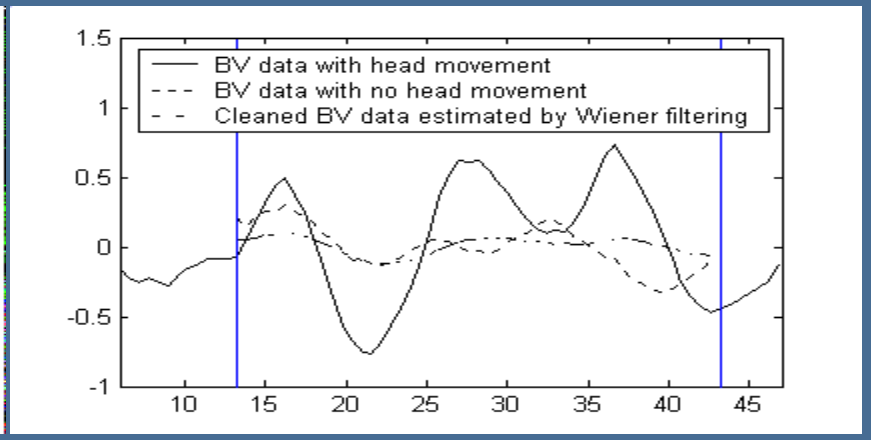
*f*NIR Signal Processing

Artifact Cancellation *(Motion Artifact Removal)*

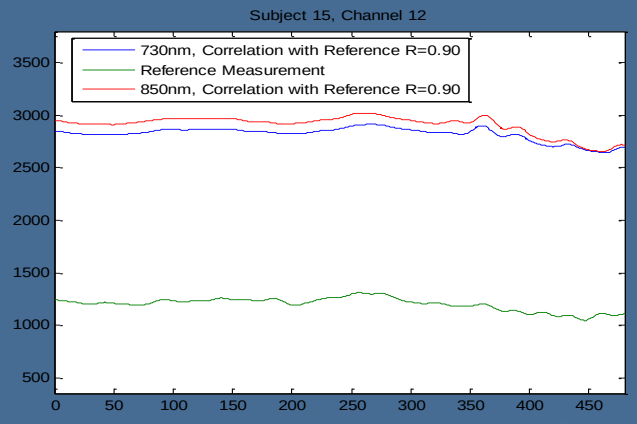
Adaptive Filter *with Accelerometer*

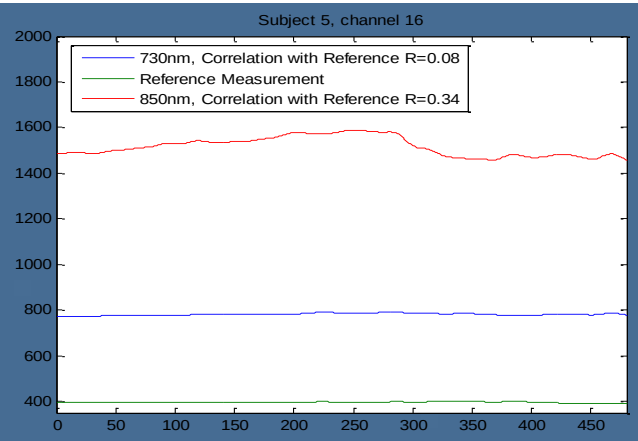


Wiener Filter *without Accelerometer*



Combined ICA & PCA Approach





Izzetoglu M, Devaraj A, Bunce S, Onaral B, "Motion Artifact Cancellation in NIR Spectroscopy Using Wiener Filtering", *Accepted to IEEE Transaction on BME*

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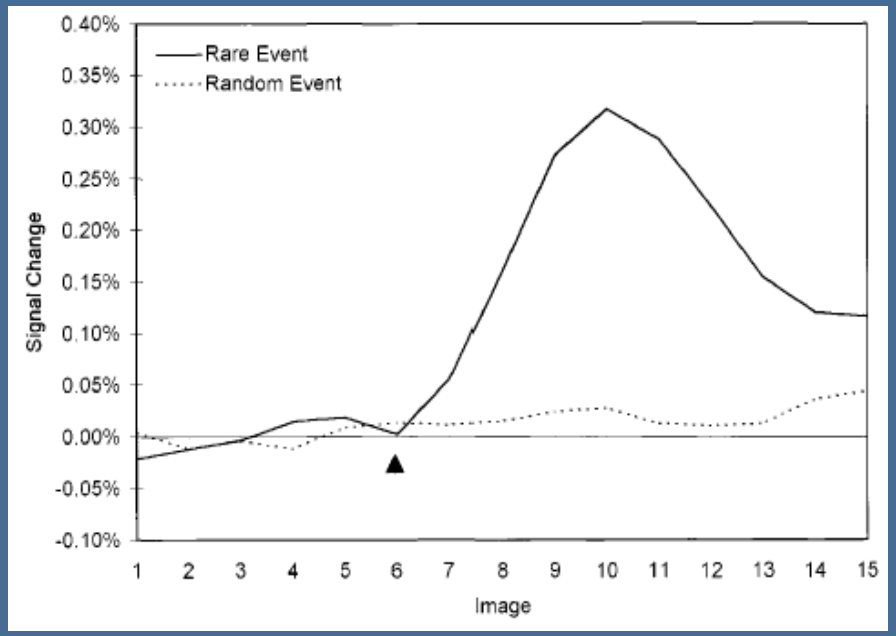
fNIR DEVICES Technology

Assessment of Cognitive Function

ATTENTION **Target Categorization**

Target

O O O X O



*f*MRI Results

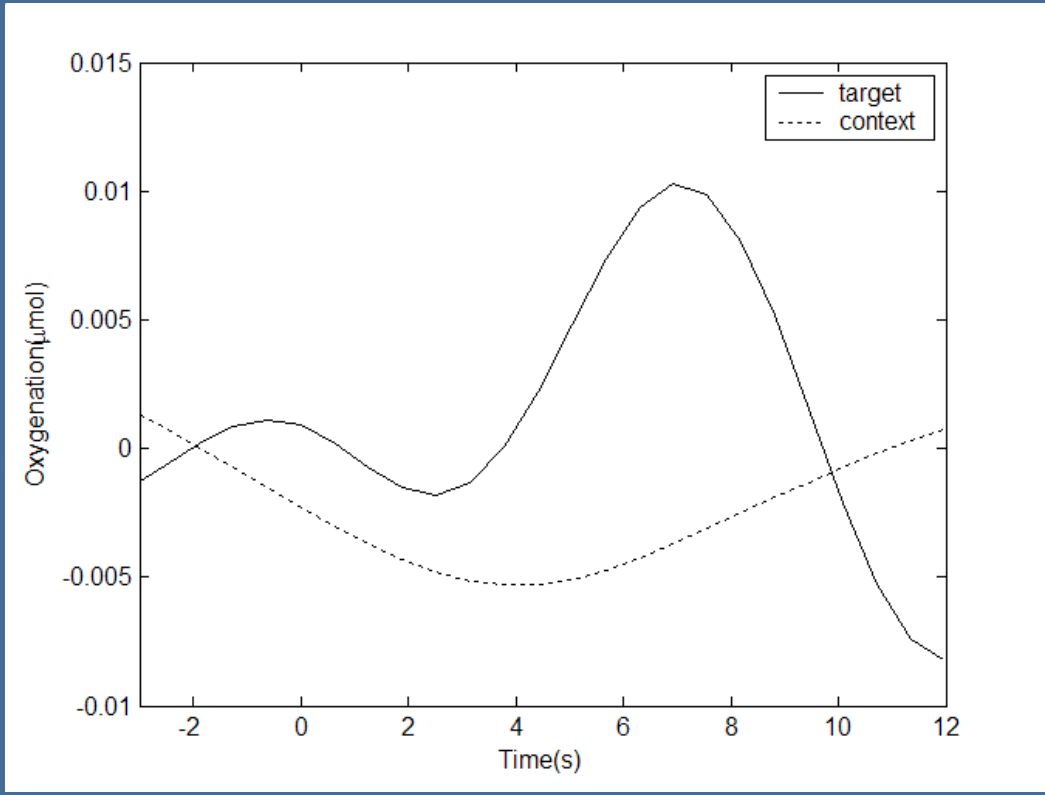
Infrequent Events Transiently Activate Human Prefrontal and Parietal Cortex as Measured by Functional MRI
Gregory Mccarthy, Marie Luby, John Gore, And Patricia Goldman-Rakic. *J. Neurophysiol.* 77: 1630–1634, 1997.

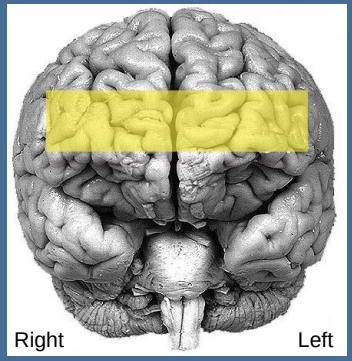
Courtesy of Dr. Scott Bunce

Assessment of Cognitive Function

ATTENTION Target Categorization (Cont'd)

*f*NIR Data





Izzetoglu M, Izzetoglu K, Bunce S, Ayaz, H, Devaraj A, Onaral B, Pourrezaei K "Functional Near Infrared Neuroimaging", *Accepted to IEEE Transaction on Neural Systems and Rehabilitation Engineering – Special Issue on Neural Engineering*

Assessment of Cognitive Function

Working Memory (n-back Task)

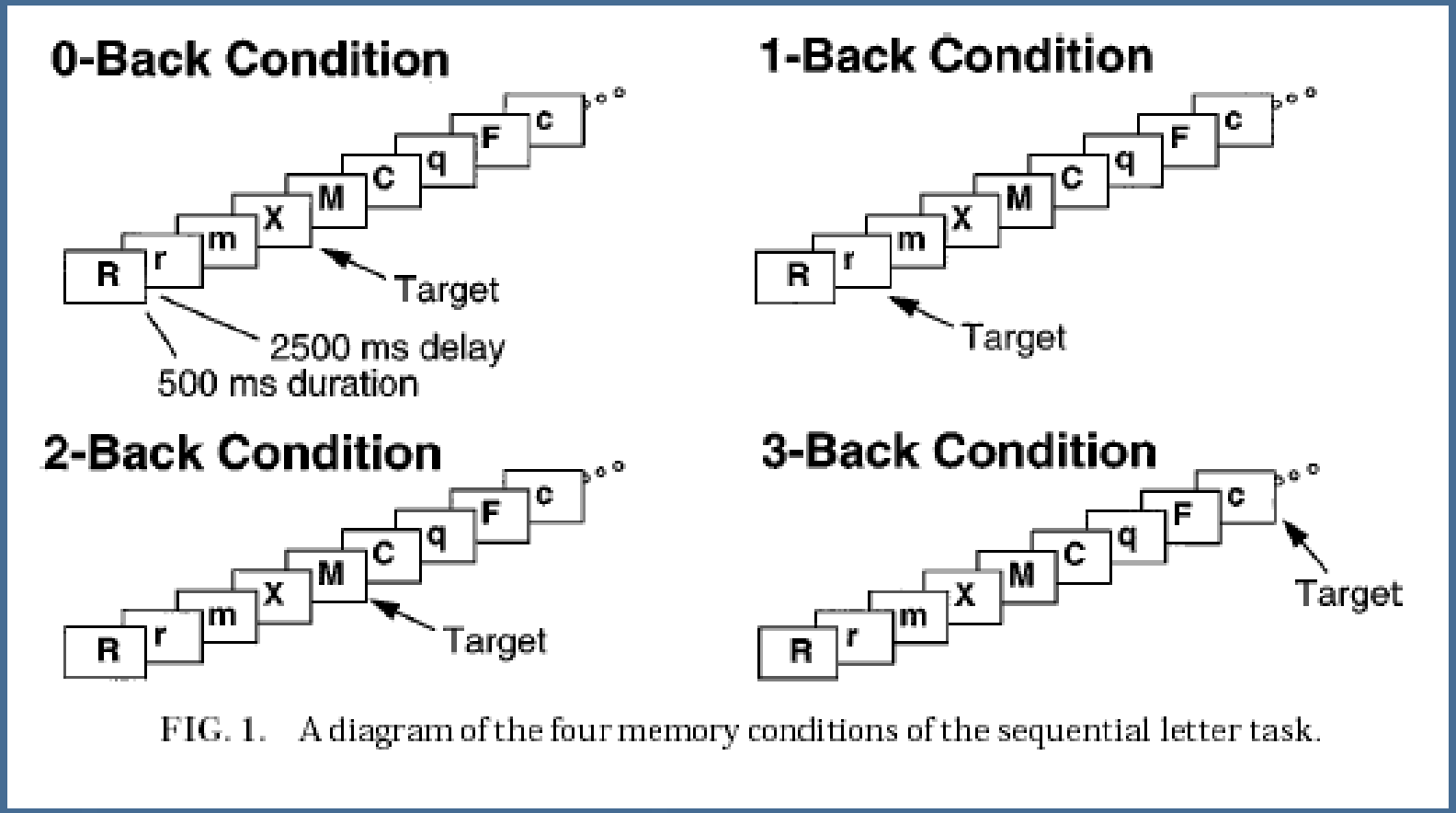
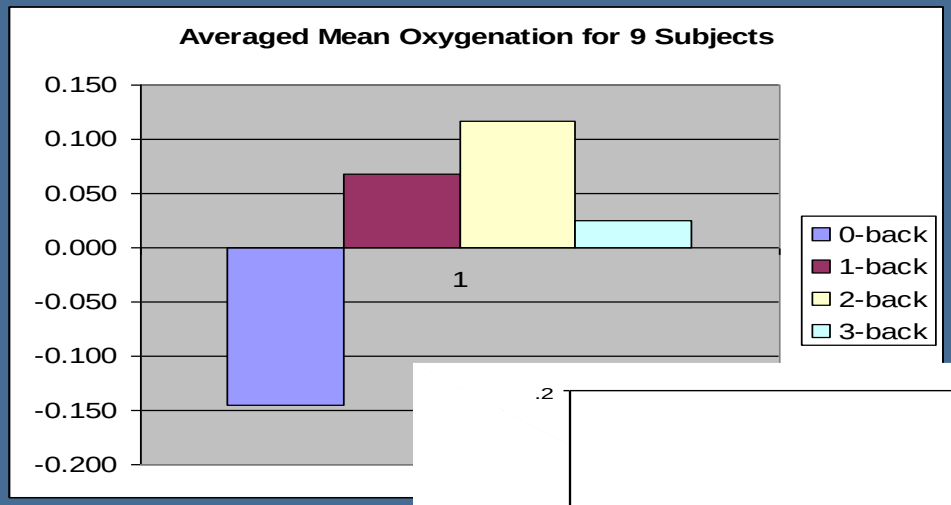
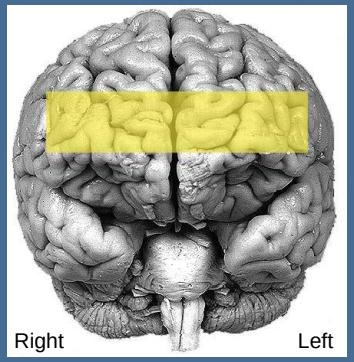


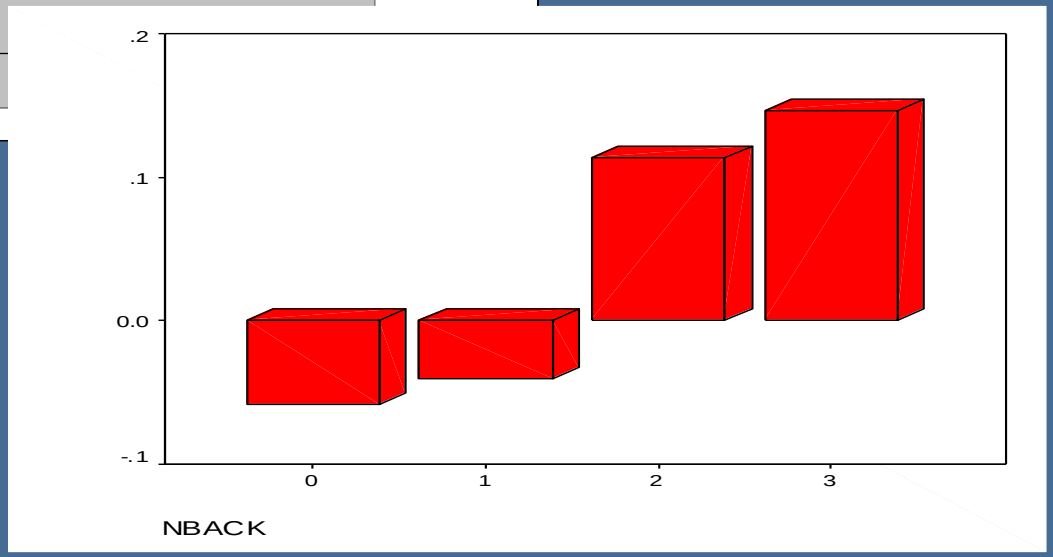
FIG. 1. A diagram of the four memory conditions of the sequential letter task.

Courtesy of Dr. Scott Bunce

Assessment of Cognitive Function Working Memory (n-back Task)







n-back results performance >90%

Results agree with *f*MRI results from Smith & Jonides, 1997.

Izzetoglu M, Bunce S, Onaral B, "Single Trial Hemodynamic Response Estimation in Event Related fNIR Spectroscopy", *Proc. of Optical Society of America Conference, 2003*

*f*NIR APPLICATION AREAS

- Human Performance Assessment
- Depth of Anesthesia Monitoring
- Pain Assessment
- Brain Computer Interface
- Virtual Reality
- Neurorehabilitation
- Autism
- Credibility Assessment (lie detection)

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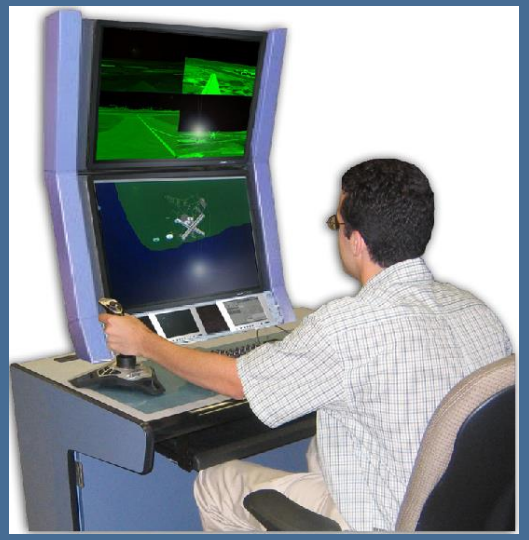
Human Performance Assessment

To use physiological measures based on *f*NIR to predict changes in cognitive workload during a complex cognitive task.



Depth of Anesthesia Monitoring

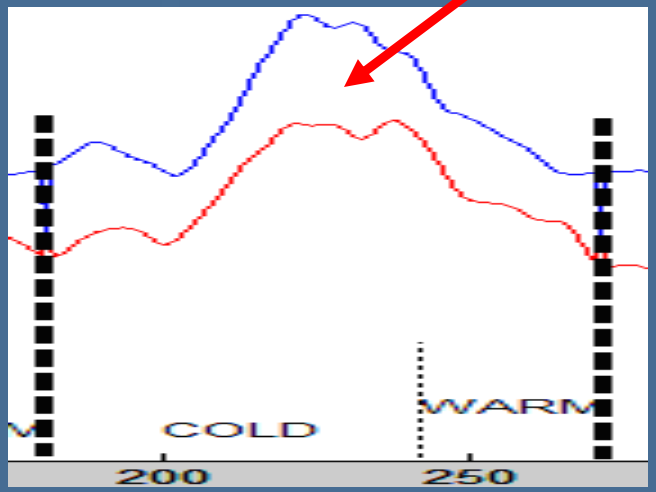
Brain Function Monitor for Intra-operative Awareness During Surgery

Pain Assessment

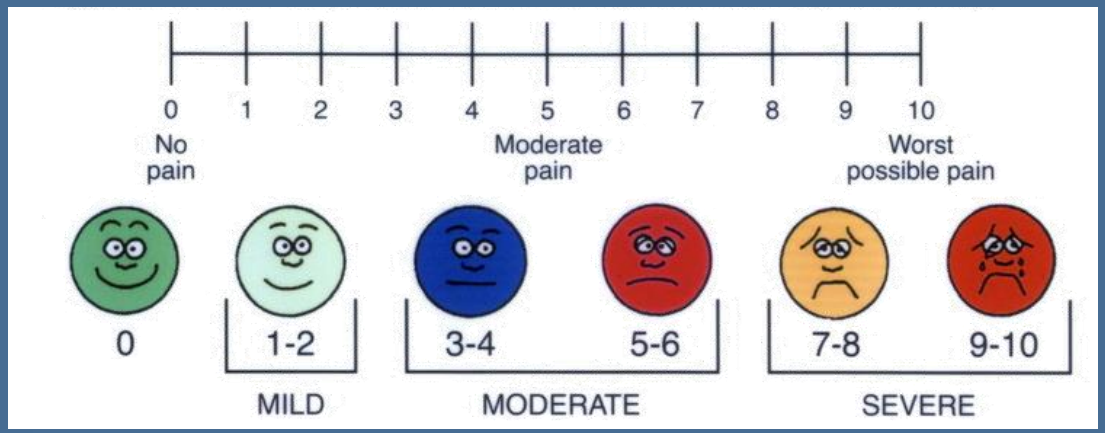
Brain monitoring system to assess:

- Chronic pain
- Response to pain medication

Objective assessment of brain response to pain stimulus



Self Assessment Tool - *Subjective*

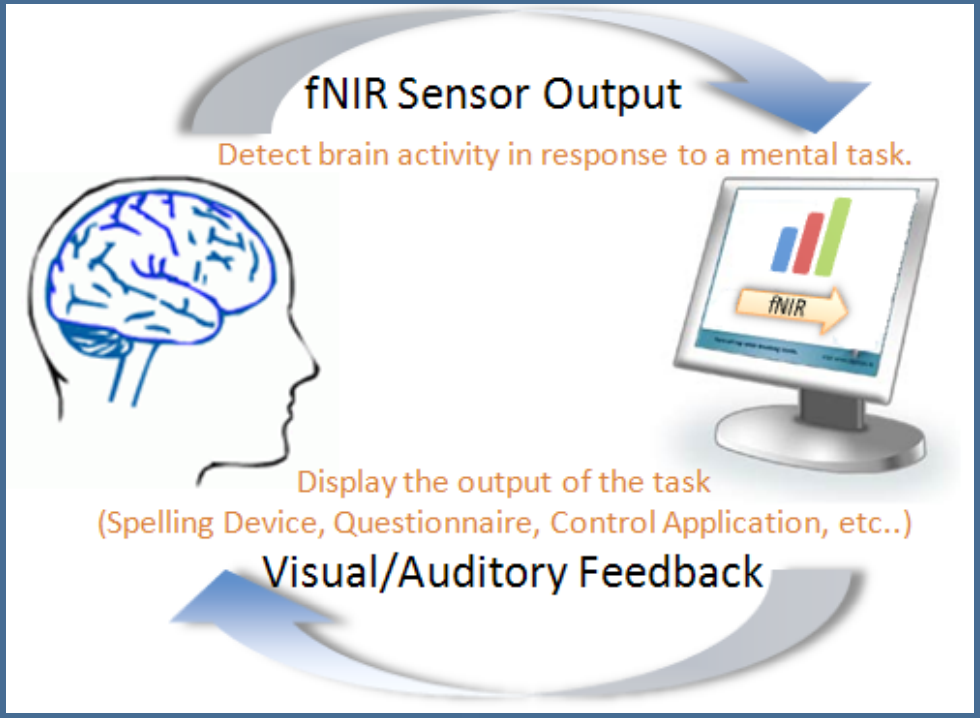


Brain Computer Interface

ALS, Spinal Cord Injury, Paralysis…

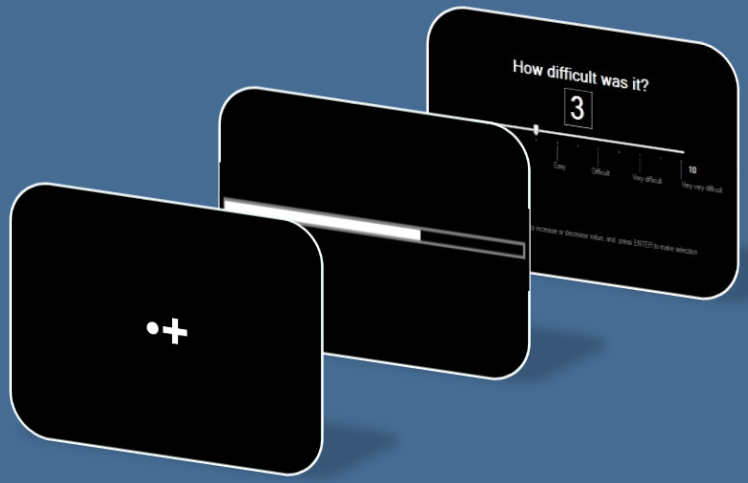
Target Subject Population:

- **Amyotrophic Lateral Sclerosis (ALS)**
- **Spinal Cord Injuries/Paralysis**
- **Cerebral Palsy, Muscular Dystrophy**
- **Brainstem Stroke, and others…**



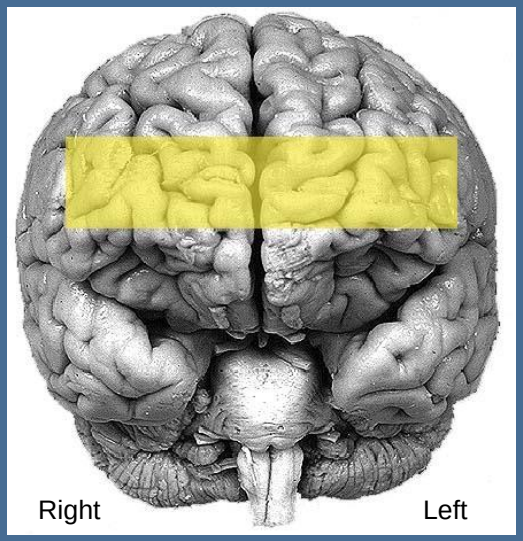
Gaming and Immersive Environments

Enhance 3D experience by enabling users to manipulate and control objects by thought



Neurorehabilitation

Quantitative measure to assess the cognitive impairments of brain injury subjects in their everyday life activities.

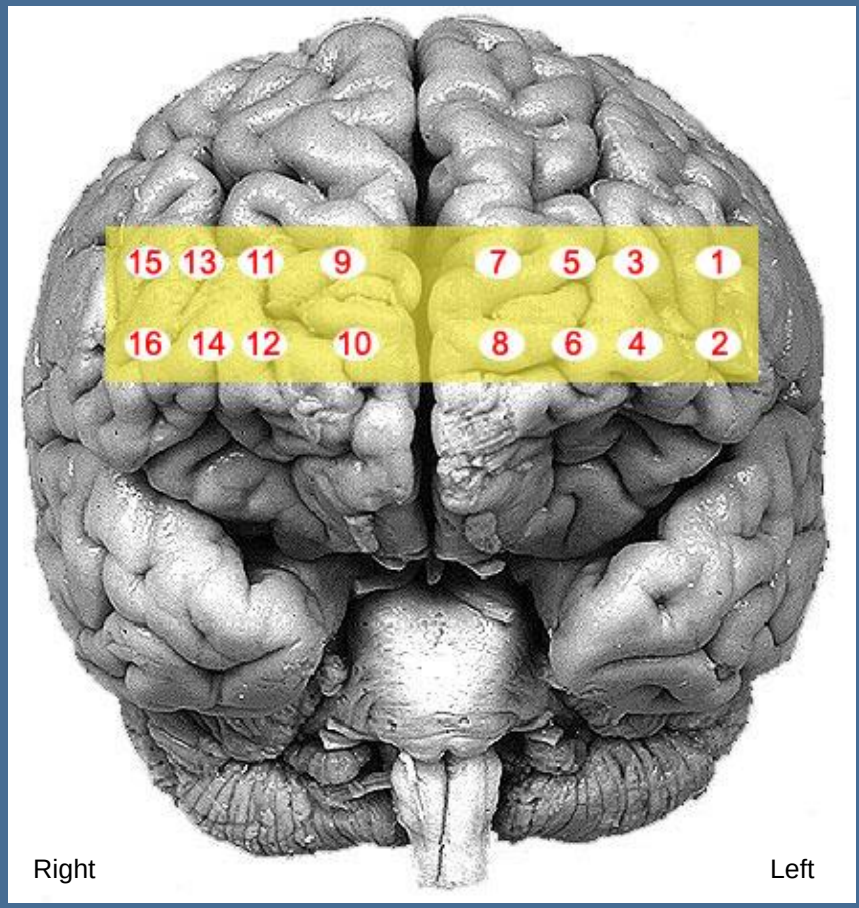


Autism

To understand the neurobiological deficits underlying autism as they relate to early predictors of the disorder as well as optimal treatment options.

The *f*NIR100 system is *suitable* for studies in children and adolescents with autism, because

- *f*NIR100 is not as physically confining as other imaging techniques, such as fMRI, and
- allows for more movement in subjects during imaging

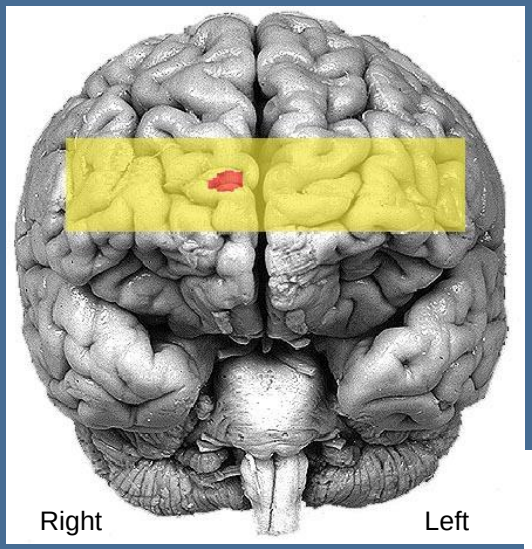


Credibility Assessment

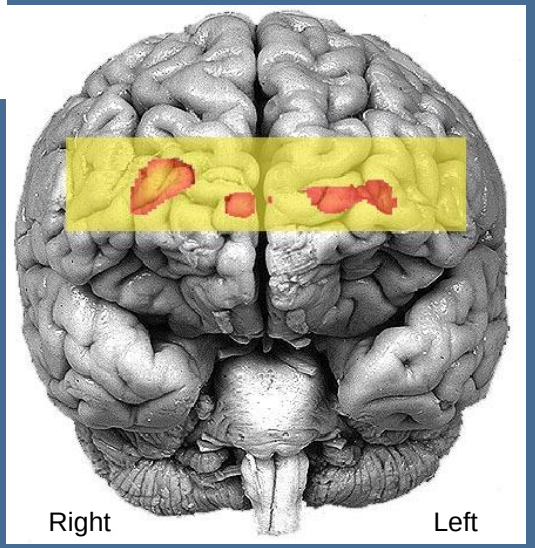
Finding neural correlates of intentional deception

In a modified version of the Guilty Knowledge Task, where participants attempted to conceal the identity of a playing card, results revealed increased activation in bilateral inferior frontal gyri (BA 47/45) and middle frontal gyri (BA 46/10) when participants were lying.

Truth



Lie



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Functional Optical Brain Imaging Systems

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info@biopac.com

(805) 685-0066

8:00AM - 4:30PM PT

fNIR System	Type	Max CH†	Included Sensor	Software (*pre-loaded)	Computer/Stand	TTL	Isolation
fNIR103C	Tethered Imager 2000C	18	1 x RXFNIR-2000-5 + 1 x RXFNIR-CBL-2000L	fNIRSoft Standard and COBI	--	1 TTL	n/a
fNIR203C	Tethered Imager 2000C	18	3 x RXFNIR-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR-CBL-2000R	fNIRSoft Standard and COBI	--	1 TTL	n/a
fNIR303C	Tethered Imager 2000C	18	3 x RXFNIR-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR-CBL-2000R	fNIRSoft Standard and COBI	Tablet Style Computer + Caddy	1 TTL	n/a
fNIR103S	Tethered Imager 2000S	54†	3 x RXFNIR-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR-CBL-2000R	fNIRSoft Pro and COBI	--	1 TTL	n/a
fNIR203S	Tethered Imager 2000S	54†	3 x RX-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR-CBL-2000R	fNIRSoft Pro and COBI	Laptop + Caddy	3 TTL	n/a
fNIR303S	Tethered Imager 2000S	54†	3 x RX-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR CBL-2000R 2 X RX-2000-5 + 2 X RX-2000-6 + FNIR-PHANTOM	fNIRSoft Pro and COBI	Laptop + All-in-one Computer + Pole Cart with Shelf	3 TTL, 1 Serial, 1 Parallel	n/a
fNIR103M	Wireless Imager 2000M	18	3 x RX-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR CBL-2000R + US/EU Power Adapter	fNIRSoft Pro and COBI	--	1 TTL	n/a
fNIR203M	Wireless Imager 2000M	18	3 x RX-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR CBL-2000R + US/EU Power Adapter	fNIRSoft Pro and COBI	Notebook/Tablet Style Computer	1 TTL	n/a
fNIR303M	Wireless Imager 2000M	18	3 x RX-2000-18 + 1 x RXFNIR-CBL-2000L + 1 x RXFNIR CBL-2000R 2 X RX-2000-5 + 2 X RX-2000-6 + FNIR-PHANTOM + US/EU Power Adapter	fNIRSoft Pro and COBI	Notebook/Tablet Style Computer	1 TTL	n/a
fNIR103P	Wireless Pediatric Imager 2000P/1200	4	RXFNIR-PED or RXFNIR-4 for Adults	fNIRSoft Standard and COBI*	--	--	n/a
fNIR103E	Tethered Imager 2000E	6	1 x RXFNIR-2000-6 + 1 x RXFNIR-CBL-2000L	fNIRSoft Education and COBI	--		n/a