Methods Lunch: Introduction and demo for the fNIRS system

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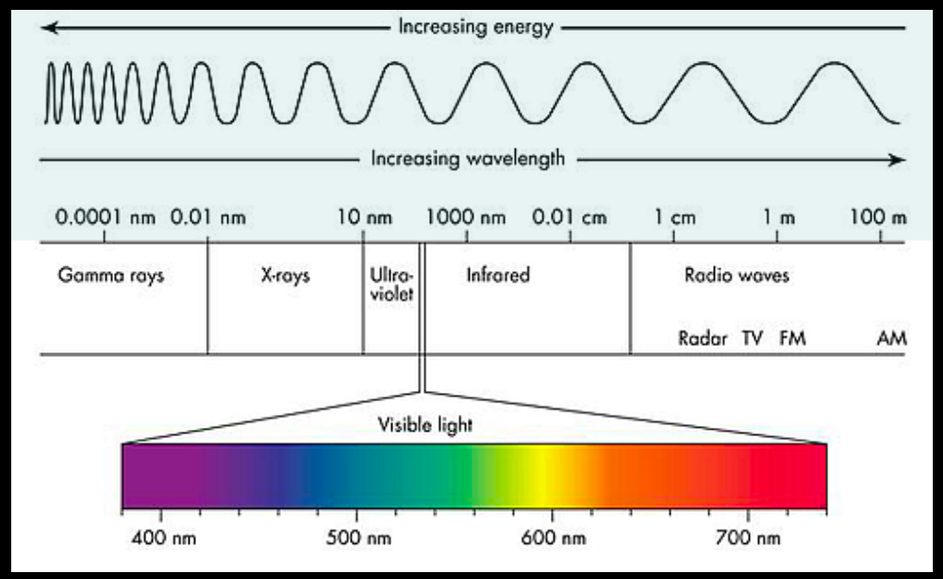
What is fNIRS?

- fNIRS = **F**unctional **N**ear-**I**nfra**R**ed **S**pectroscopy
- Uses low levels of red to near-infrared light (650-950mm)



- Measures changes in the optical absorption of tissue due to **oxy-**, **deoxy- or total hemoglobin**
- Light propagates up to several cm, deep enough to reach cerebral cortex

The Hemodynamic Response

Neural activation

↓

Increased metabolic demand

↓

Increased food flow

↓

Increase in oxy-hemoglobin

+

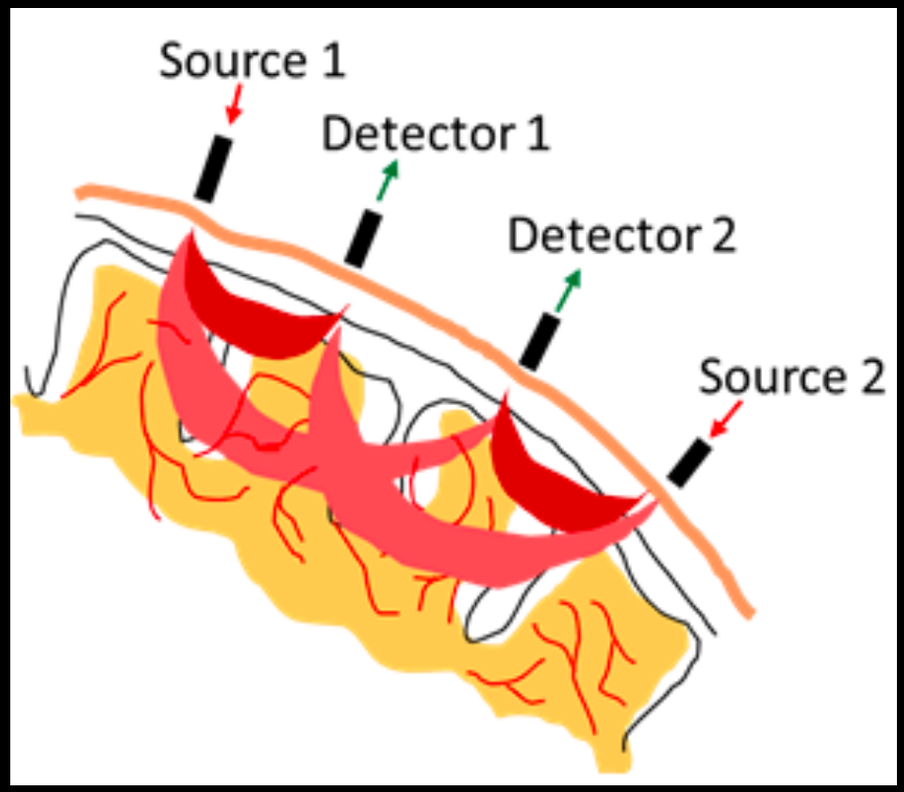
Wash-out of deoxy-hemoglobin

fMRI

Blood-oxygen dependent (BOLD) fMRI measures functional changes in **deoxy** hemoglobin, as well as the head's (brain, skull, etc) structure

fNIRS

fNIRS measure relative changes in **oxy, deoxy, and total** hemoglobin, but does not measure structural characteristics


Source 1
Detector 1
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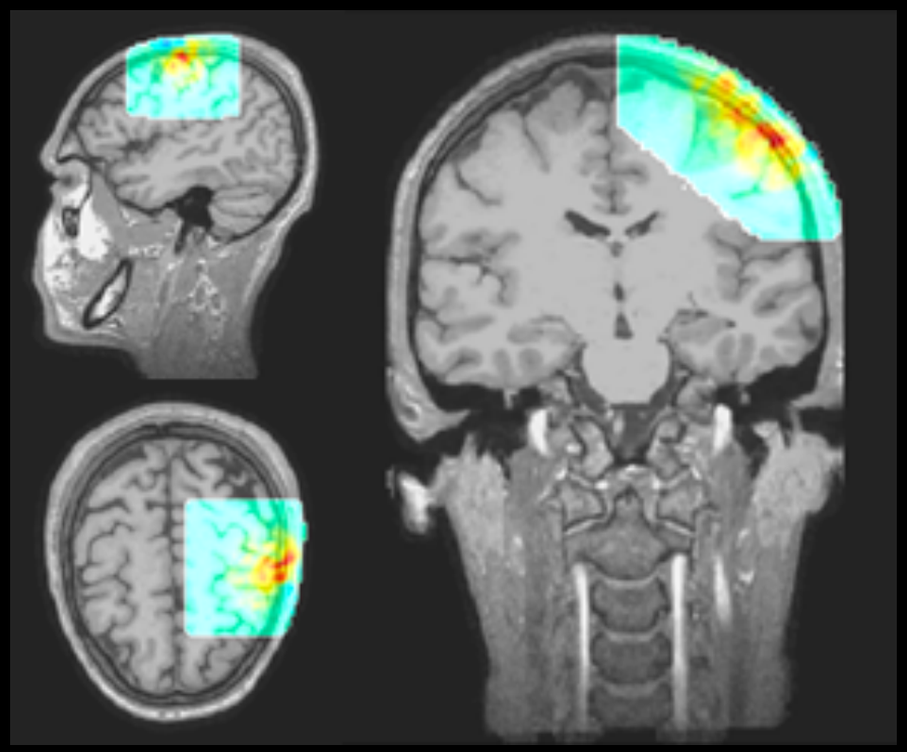


Measuring the hemodynamic response with fNIRS

- The “standard” 3 cm channel measures both **event-evoked** and **non-evoked** responses (neural and systematic) from both cerebral and extra cerebral tissues

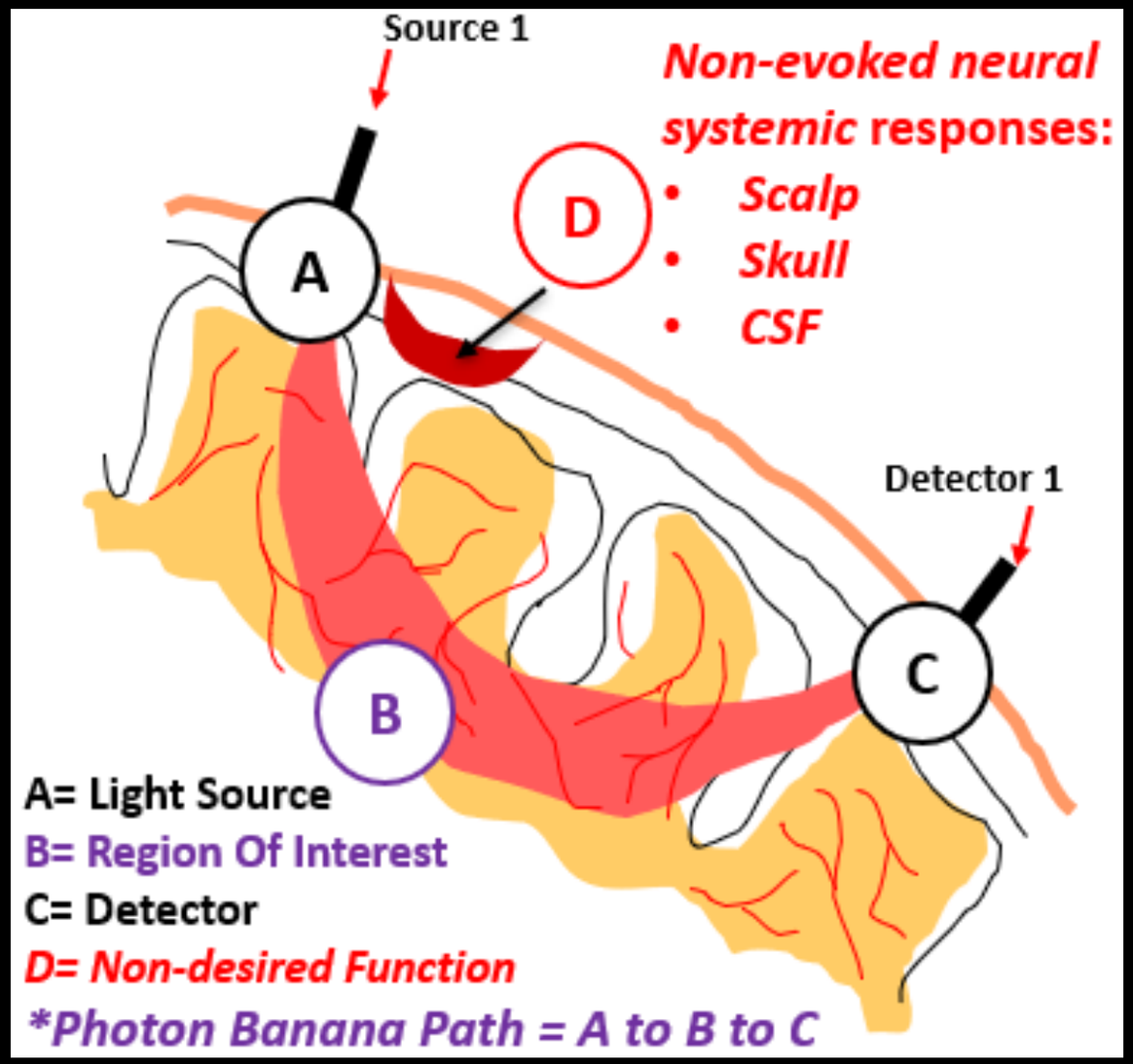
- Shorter channels (<1 cm) are used to measure *only* extra cerebral responses

- The shorter-channel measurements are regressed out, leaving the event-evoked responses

Measuring the hemodynamic response with fNIRS

Non-evoked responses (or noise) include:

- Arousal changes
    - Excitement, boredom
- Emotional state changes
    - Stress, frustration, anger, sadness, etc.
- Other non-evoked neural responses:
    - Respiration
    - Mayer Waves
    - Scalp blood flow
    - CSF, skull thickness
    - Skin/hair pigment



Practical considerations

Light penetration depends greatly on:

- Thickness of scalp, skull, and CSF
    - The forehead and temporal cortices are easiest to measure
- Density and colour of hair
    - Darker and thicker is more difficult
    - The roots of the hair can be problematic (denser or spikier hair)
    - Red-dyed hair can be problematic (due to the light absorption properties of red colour molecules)

It is important to be aware of the challenges to obtain a good signal quality!

Gendered variability in skull and CSF thickness (in children)

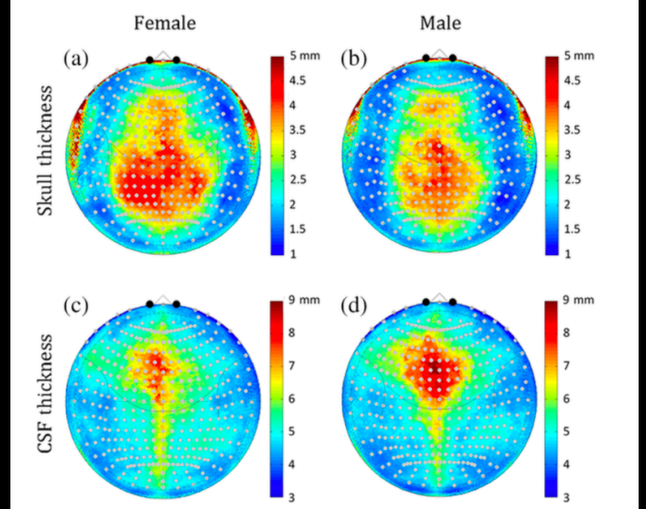


Fig. 2 Gender differences in skull CSF layer thickness. (a) and (b) The median skull and (c) and (d) CSF thickness for the male and female subjects is shown in the normalized polar (10-5 coordinate) space. The color scales show the thickness of these layers in millimeters.

Gendered variability in scalp-to-brain depth (in children)

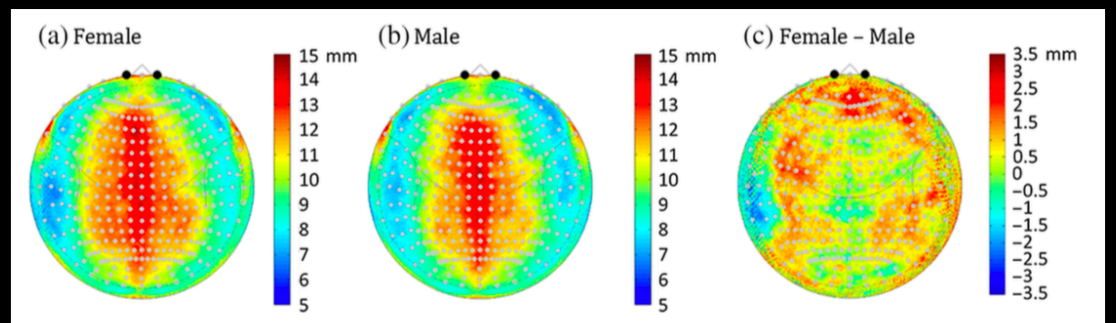


Fig. 3 Gender differences in the scalp-to-brain depth. (a) and (b) The median distance normal to the surface from the scalp to the nearest position on the pial cortical surface in the subject normalized polar (10-5 coordinate) space. (c) The difference between the depth of the females compared to the males. In most regions, the brain of the female subjects up to 3-mm deeper.

Correlation of scalp-to-brain depth with (a) head circumference and (b) age (in children)

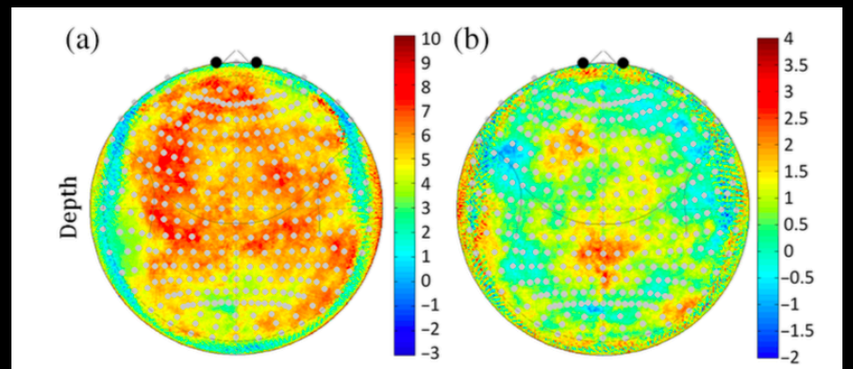


Fig. 5 Correlation of scalp-to-brain depth with head circumference and age. This figure shows *t*-statistic maps (89 degrees of freedom) from the pooled data across both genders for a regression model against (a) head circumference and (b) age at time of MRI scan in months. Red indicates a positive correlation and increasing depth with circumference or age.

Greater depth of cortex means that fNIRS will be less sensitive to changes in brain activation

females < males
larger heads < smaller

Whiteman et al., (2017). Investigation of the sensitivity of function near-infrared spectroscopy brain imaging to anatomical variations in 5- to 11-year-old children. *Neurophoton, 5*(1).

Benefits over fMRI

- Portable and low-cost
- Can be performed in a naturalistic environment without sedation or restraint
- Ability to record from paediatric or other special populations for whom MRI is difficult or contraindicated
- Noiseless (beneficial for auditory paradigms)
- Quick set-up
- Hyperscanning capabilities

More benefits to fNIRS

- NIRS is optical, does not cause or receive interference
- Compatible with:
  - EEG
  - MEG
  - fMRI
  - TMS
- Relatively stable signal despite movement-related noise

Limitations of fNIRS

- Cannot measure hemodynamic responses involving “deep” brain regions (eg, basal ganglia, amygdala)
    - fNIRS measurements are restricted to outer cortex
- Precise identification of brain areas is improved, but not perfected, with 3D MRI
    - Exact position of source/detector, optical properties of localized tissue
- But, being able to measure most of the brain surface greatly improves our interpretation of NIRS results

What's "hot" in the world of fNIRS:

Skimming some of the most-cited fNIRS papers

Schroeder et al. (2004). **Prefrontal activation due to Stroop interference increases during development - an event-related fNIRS study.** NeuroImage, 23(4), 1317-1325.

Holtzer et al. (2011). **fNIRS study of walking and walking while talking in young and old individuals.** Journals of Gerontology Series A, 66(8), 879-887.

Ehlis et al. (2008). **Reduced lateral prefrontal activation in adult patients with attention-deficit/hyperactivity disorder (ADHD) during a working memory task: a functional near-infrared spectroscopy (fNIRS) study.** Journal of Psychiatric Research, 42(13), 1060-1067.

Tsuzuki et al. (2007). **Virtual spatial registration of stand-alone fNIRS data to MNI space.** NeuroImage, 34(4), 1506-1518.

Interested in doing an fNIRS study?

Interested in being added to the fNIRS mailing list?

Contact me (Nicolette): nnoonan3@uwo.ca

Questions?