fNIRS and Gait

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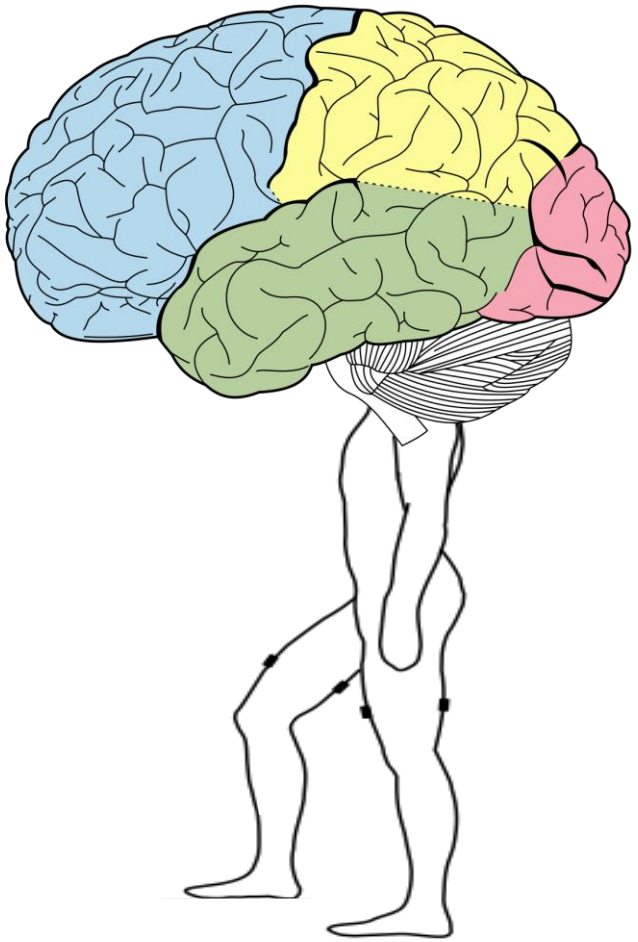
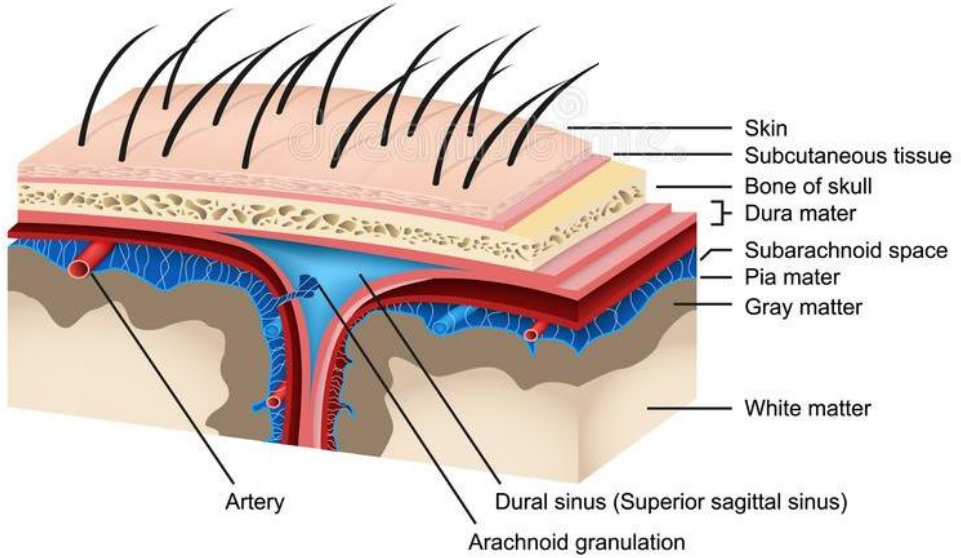
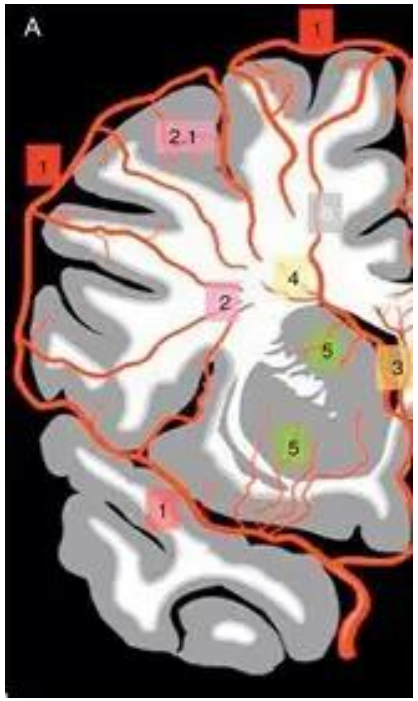
Brain Anatomy







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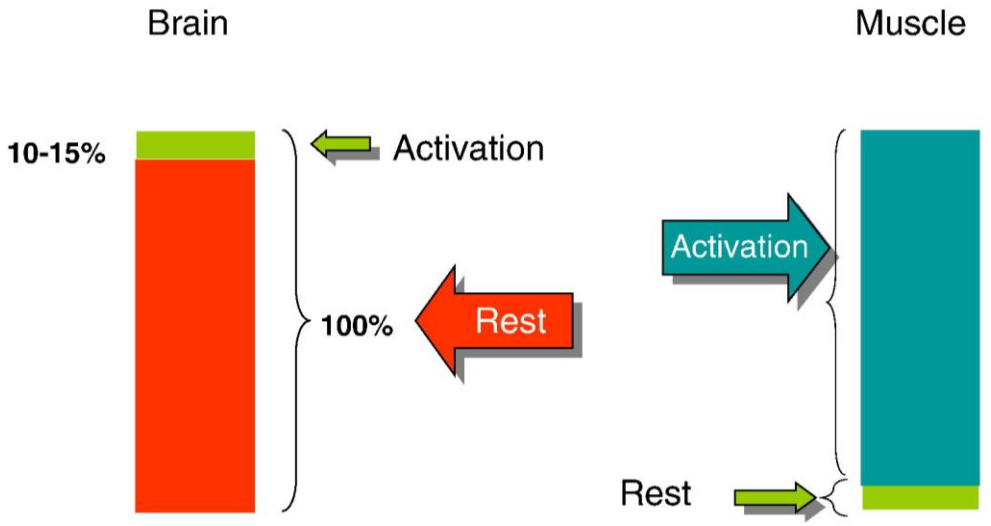
Human Brains at Rest and During a Task

At Rest

- Brain is 2% of body weight, but receives 20% of cardiac output
- Brain blood flow/metabolism are generally constant

During a task

- Increased oxygen consumption and brain blood flow
- Importantly → Increases are brain region specific



(Review: Lauritzen et al Neuroimage. 2012)

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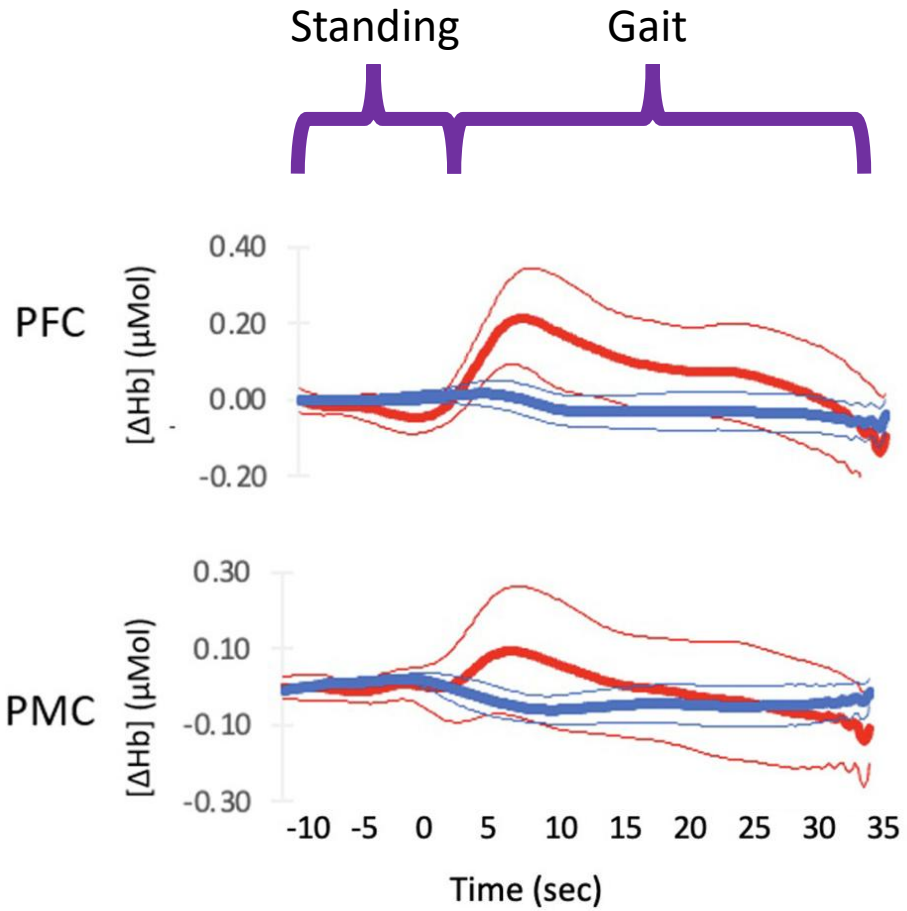
Human Brains at Rest and During a Task

Proposed Mechanisms
- Neurovascular coupling
  - Oxygen metabolism to support neuronal activity
- Overall balance toward excitation or inhibition
  - Generates increase in regional brain blood flow

Hemodynamic response
- Oxy-Hemoglobin (HbO)
- Deoxy-Hemoglobin (HbR)
- Figure → typical to see HbO in red and HbR in blue
  - Here include 2 standard error around the mean



(Lim et al. Front Neurol 2022)

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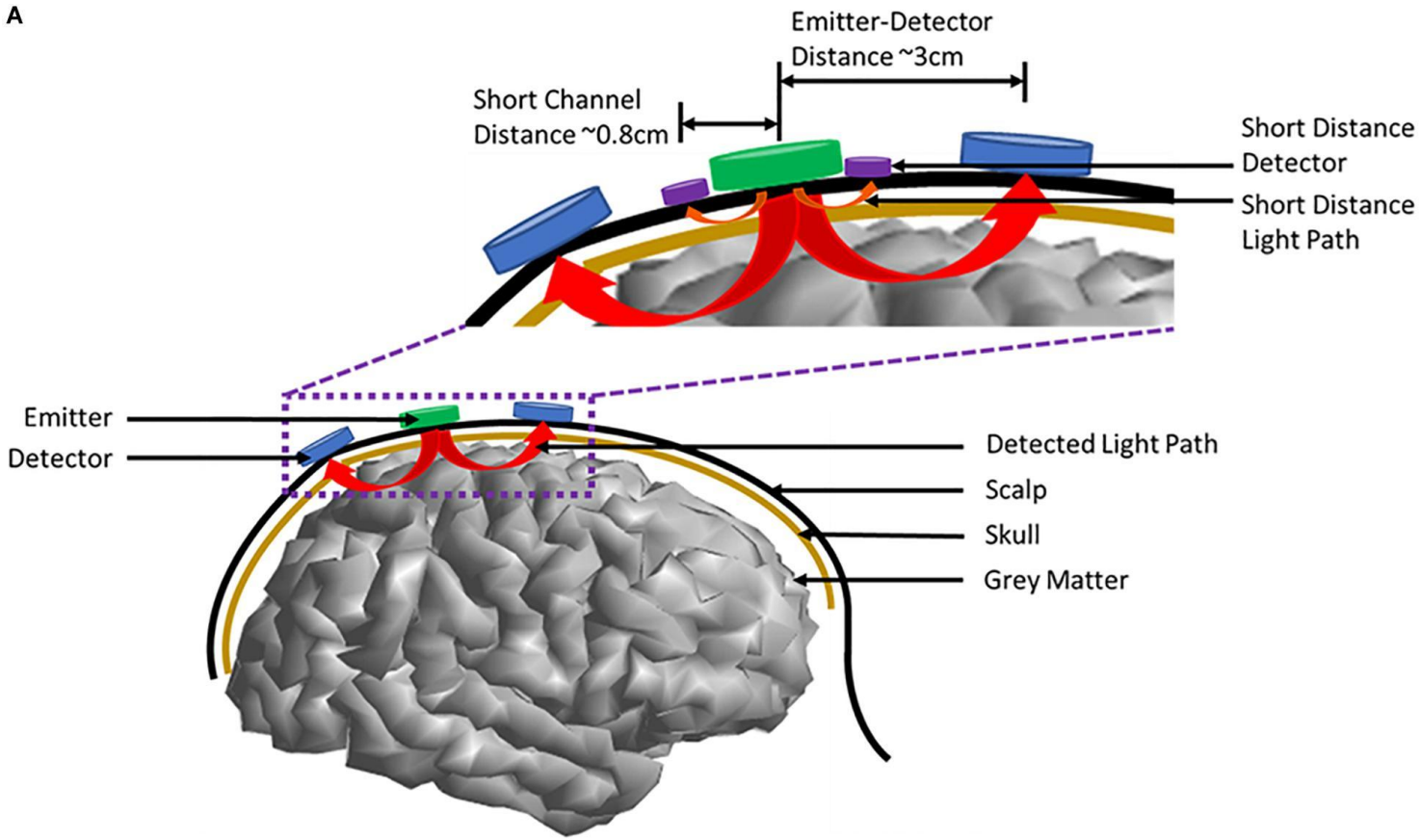
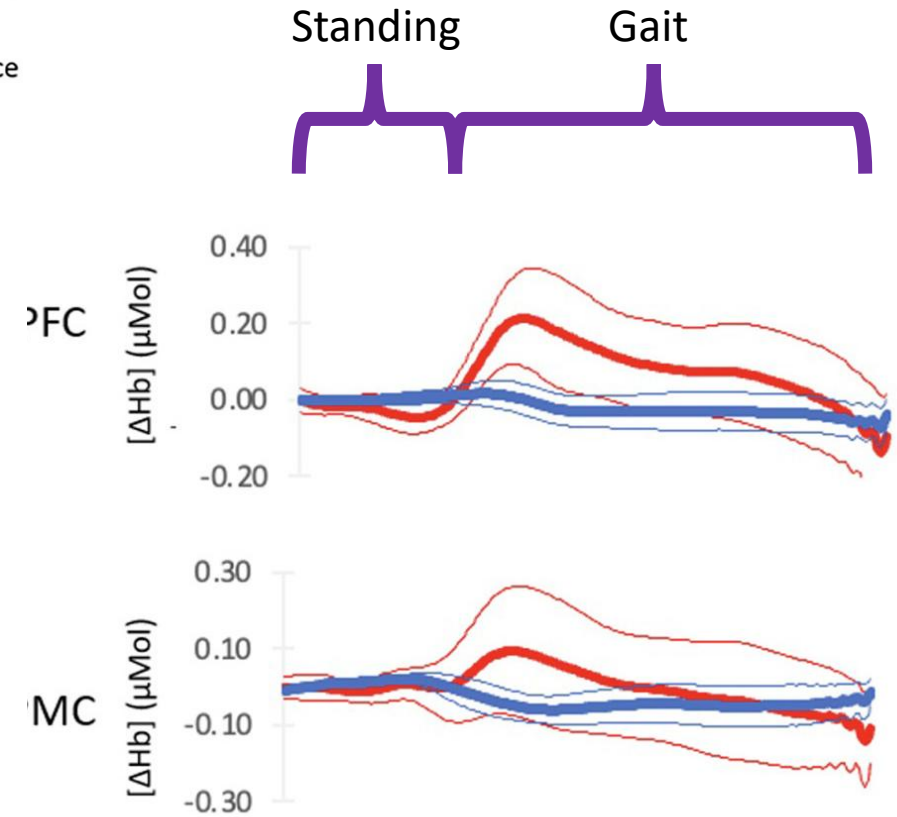
functional Near Infrared Spectroscopy (fNIRS)



Review (Chen et al. Front Neurosci 2020)



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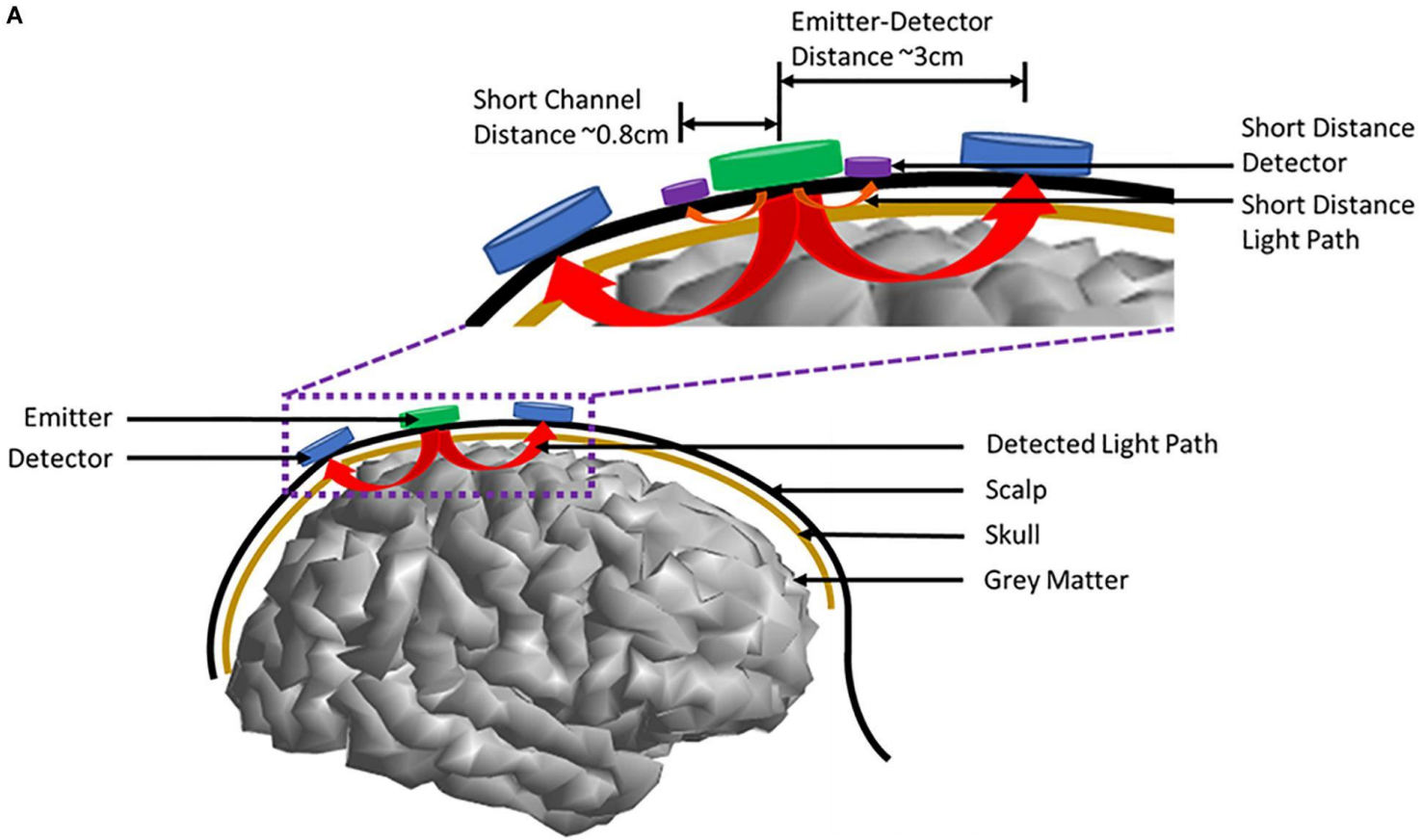

Review (Chen et al. Front Neurosci 2020)

NIRSport 2 system we will use today

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Advantages and Disadvantages of fNIRS

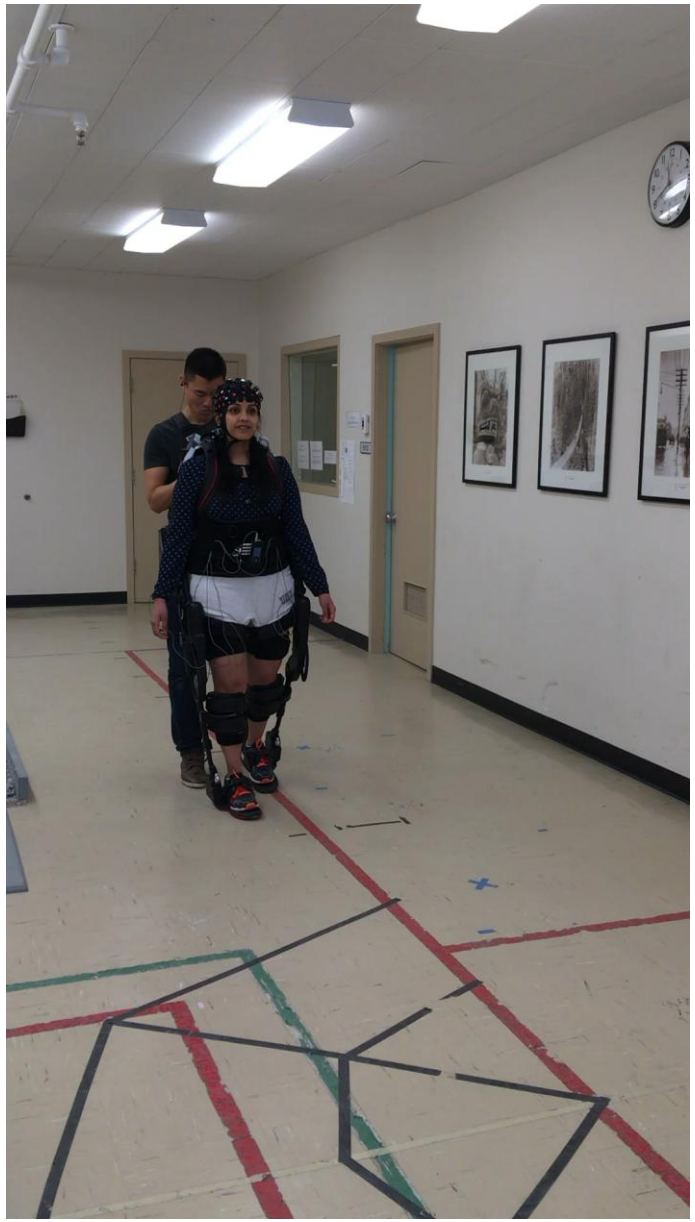
- Advantages
  - Resistant to motion artifact
  - Portable (can be done at bedside, outdoors, etc)
  - Quick set up (~5 minutes) and clean up
  - Low cost to operate (vs MRI)
  - Better temporal resolution than fMRI
  - fNIRS measures oxy- *AND* deoxy- Hb (and total Hb)
  - Better spatial resolution than EEG
  - Easily combined with other modalities
  - **Field is changing very rapidly**
- Disadvantages
  - Worse temporal resolution than EEG
  - Worse spatial resolution then fMRI
  - **Field is changing very rapidly**

NIRSport 2 system we will use today

EEG vs fNIRS

- Both are mobile + can be multi-modal
- Spatial resolution → EEG 5-9cm, fNIRS 1-3cm
- Temporal resolution → EEG >1000Hz, fNIRS 10Hz
- EEG can be time locked to each step
- fNIRS can be time locked to blocks of steps
- EEG is sensitive to electrical noise in environment
- Both modalities susceptible to movement artifacts → fNIRS may have better resistance to movement artifact
- ***Which modality to choose? Depends on your research question***

(Herold et al. *J Clin Med.* 2018)



Example Experiment

- Aim → use fNIRS to delineate brain activation differences between ‘Active’ and ‘Passive’ overground gait in a robotic exoskeleton
- Multimodal → fNIRS + EMG + Xsens + robotic exoskeleton (Ekso)

Sharable link to article: https://rdcu.be/esed3

(Peters et al. *J Neuroeng & Rehab 2020*)

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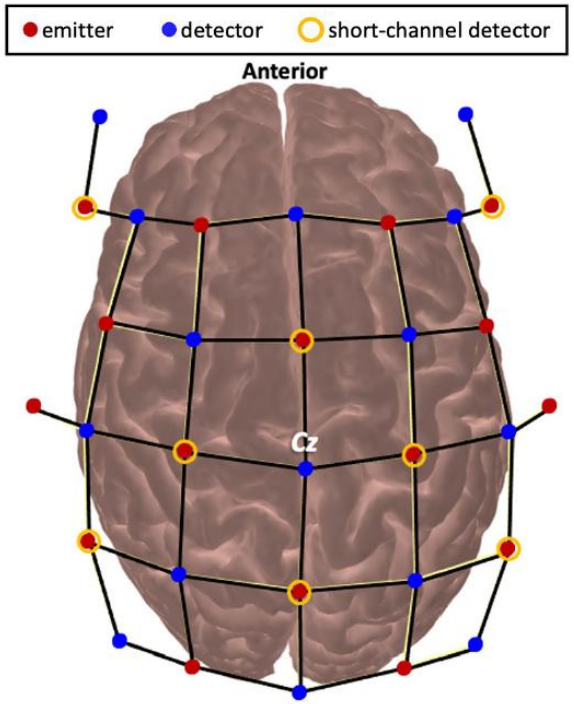
Example Experiment

- Montage → coverage of brain regions that relate to your research question. In Ekso study, wanted broad coverage of frontal and parietal regions bilaterally



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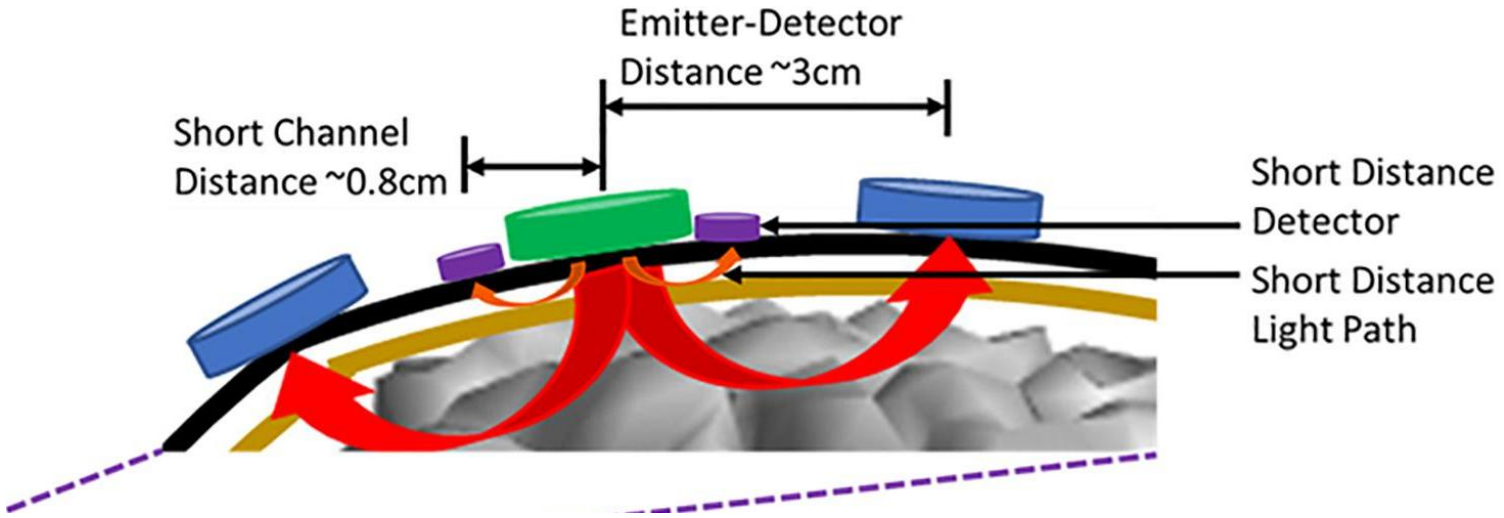
Example Experiment

- Montage → include short channels



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Example Experiment

- Multimodal synchronization with fNIRS
  - EMG, IMU (Xsens)
  - Triggers during data collection across modalities are required → LSL or TTL

- Could adapt this multimodal synchronization
  - We will try fNIRS with WINGS today
  - Synchronize fNIRS with ECG, EMG, GSR, etc

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(Peters et al. *J Neuroeng & Rehab 2020*)

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Example Experiment

- Set up tips (i.e., didn't make it into the publication….)
  - fNIRS cap placed AFTER the EMG and IMUs place and measurements completed for fitting the robot
  - Used different gromet tops with low tension ('zero'-low tension springs) on the forehead
  - fNIRS unit worn by trainee triggering the robot
  - Check +++ to ensure the cap/wires secure
- Motion artifact: Tried Wavelet and Spline and Wavelet+Spline….chose Wavelet
- Consecutive gaussian function for HRF estimation

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(Peters et al. *J Neuroeng & Rehab 2020*)

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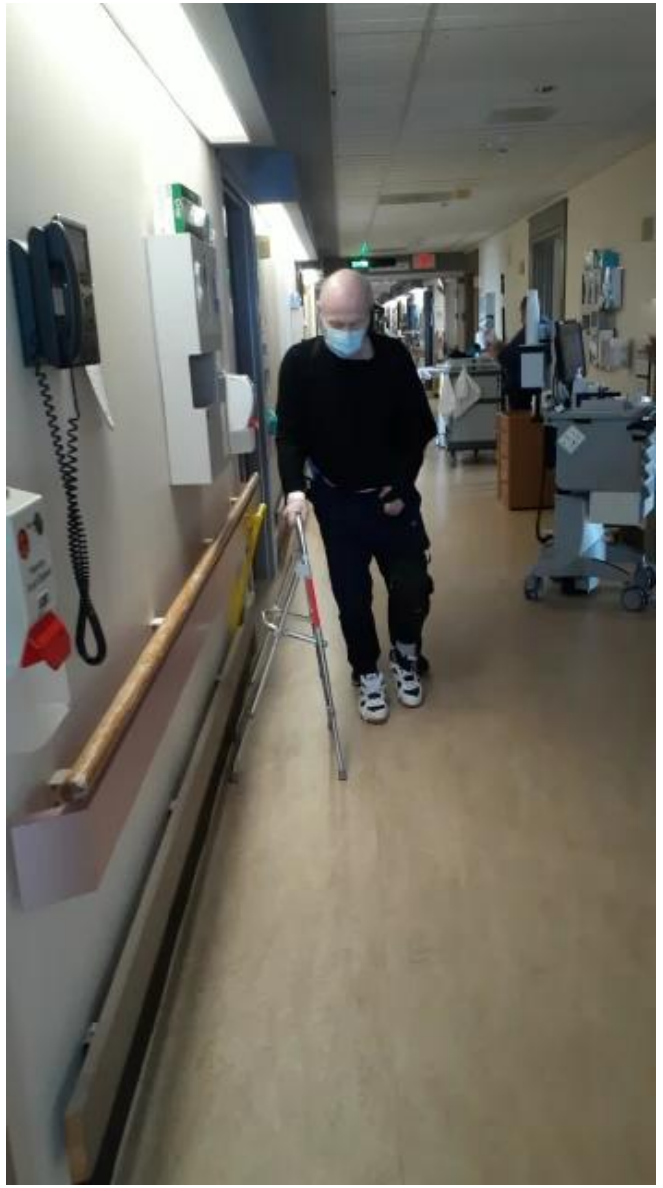
Methods for patient populations

Post-stroke gait

- Reduced velocity
- Decreased step length, coordination
- Is fatiguing → impacts to study design

- Channels grouped into brain regions
  - Option to use 3D digitization
- Need all lesions on the same side for statistics
  - Some brains ‘flipped’
  - Results: ipsilesional & contralesional activation (instead of R and L)



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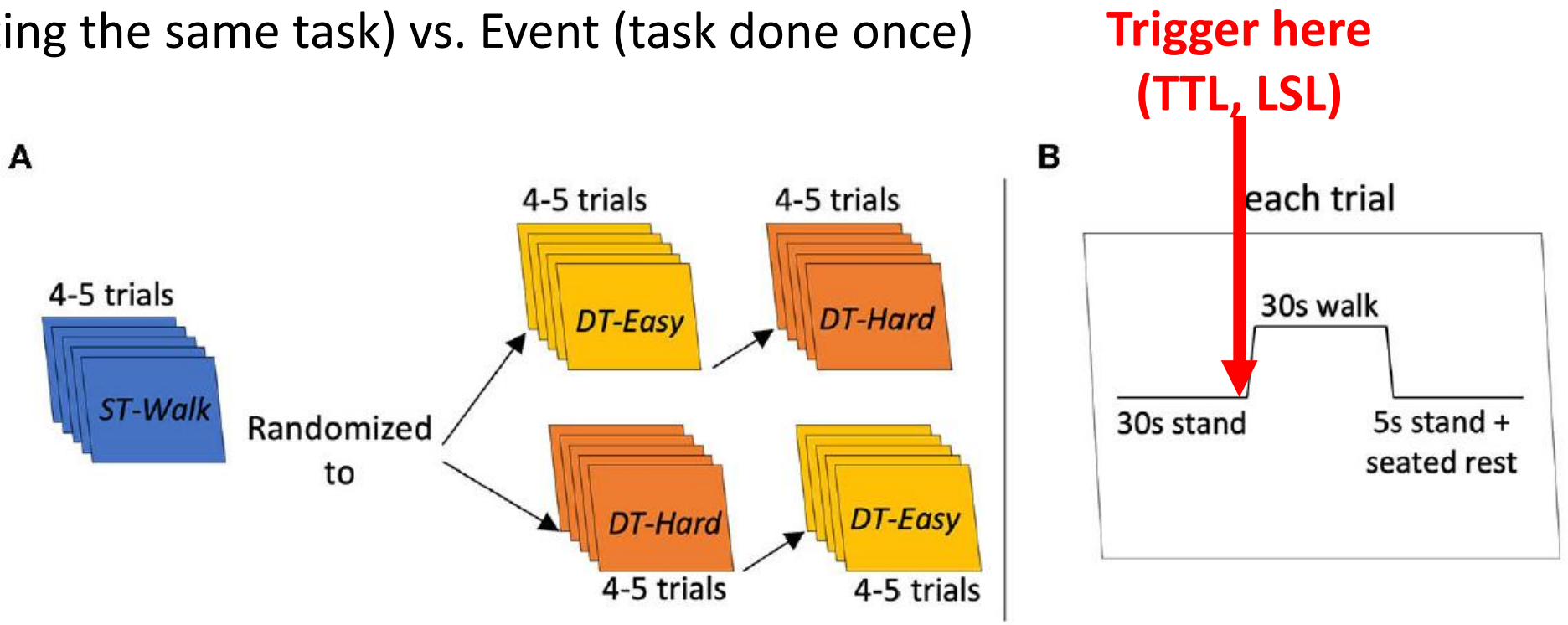
(Lim & Peters et al, 2022; Lim & Peters et al, 2022)

Study design – depends on research question

- Design
  - Block (repeating the same task) vs. Event (task done once)



ST = single task, DT = dual task

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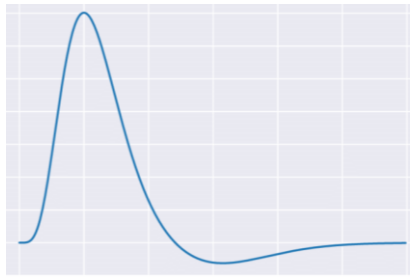
(Lim & Peters et al, 2022; Lim & Peters et al, 2022)

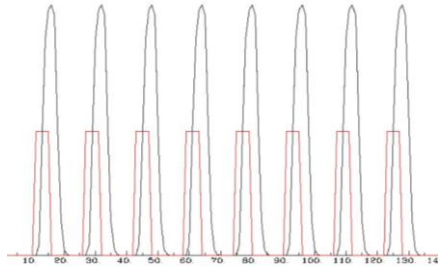
Study design – depends on research question

- Analysis methods
  - GLM
    - Makes assumptions about the shape of the HRF
    - Common to assume the shape is fixed
    - Canonical, boxcar, gaussian (consecutive sequence)
  - Correlations
    - Between brain regions
    - Common in resting state
  - Deconvolution
    - Allows the shape of the HRF to vary
    - Pros: Allows participant/brain region variability
    - Cons: need lots of data, freedom in HRF shape makes interpretation more difficult (may be okay if underlying neural and hemodynamics of population well understood)
  - Other?

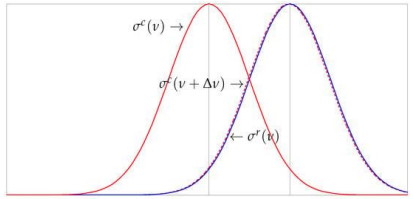
Canonical



Boxcar



Gaussian



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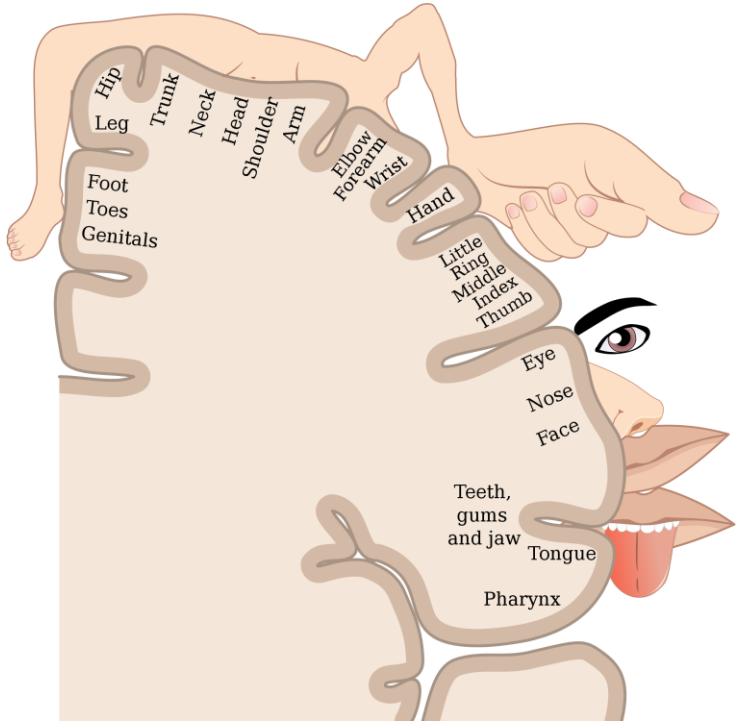
Study design - considerations for balance and gait research questions

Location of leg region in M1

- Motor homunculus
  - Leg, foot, etc located in the midline/ longitudinal fissure
- Gait is a whole-body task
  - postural control, arm swing
  - +/- cognitive aspects of gait
- Consider a control condition in standing
  - Examples
    - Quiet standing
    - Standing with a cognitive task
    - Standing with button press



Tips & Tricks for using fNIRS during Gait

- Use timing and live observation of signal to determine when to start gait trial
- Gait
  - Long hallway (measure the distance), Treadmill, Outdoors?
- Quiet environment
  - (unless studying auditory or cognitive effects of distraction?)
- Cannot clean data that is very noisy → physical set up is key!!
  - Observe heart rate
  - Wires that 'bounce' during gait generate noise
    - Use multiple holders + Velcro + tighten
- Short channels
  - Use multiple holders to secure so these wires don't overlap with holes for optodes

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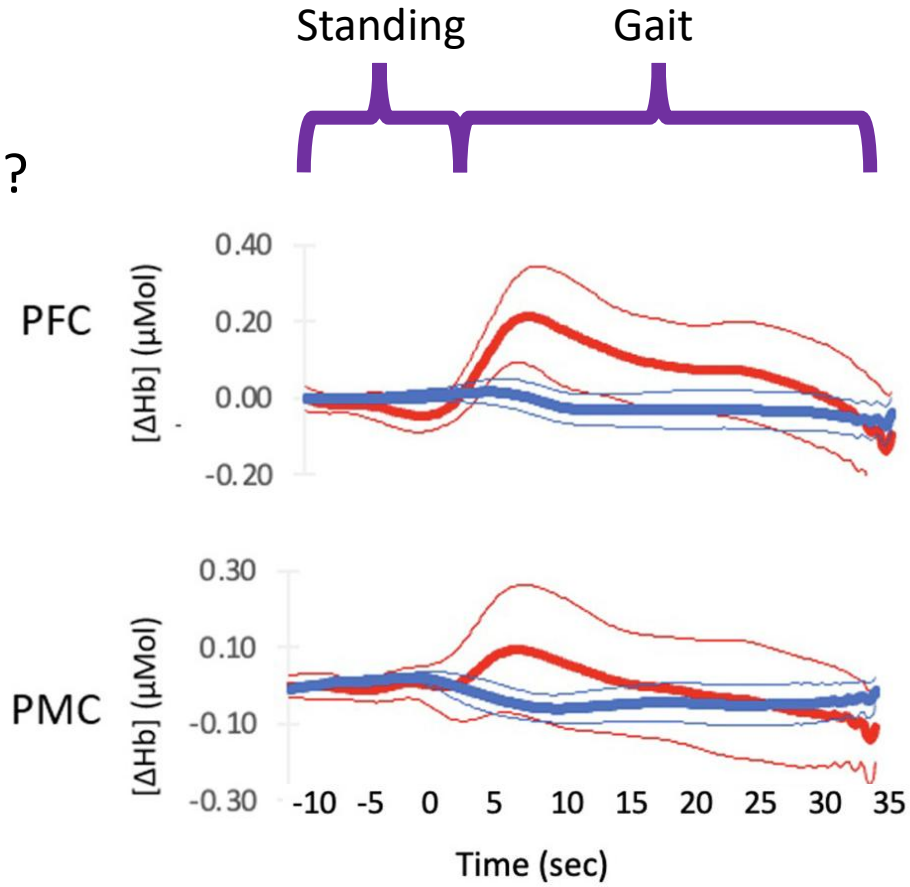
Hands on

Wrap up: fNIRS tips for setting up multimodal research projects

- Study design
  - Consider your participants → what can they tolerate? How much data can you reasonably collect in a session?
    - Number of blocks, signal to noise, etc
  - Patients → what other measures do you want to consider (kinematics? physiology including ECG, respiration rate etc, EMG?)
- Analysis
  - Measure a time window around the HRF peak? Or the whole block?
  - GLM vs correlation vs other?



(Lim et al. Front Neurol 2022)

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Wrap up: fNIRS tips for setting up multimodal research projects

- Collaborators can help – consider researchers and industry
- Lots of piloting of data collection and analysis
- Start with replication - gait vs rest, finger tapping vs rest
- Read recommendation publications → these are not specific to multimodal data collection but a good place to start
  - Menant et al. 2020: A consensus guide to using functional near-infrared spectroscopy in posture and gait research
  - Yücel et al. 2021: Best practices for fNIRS publications
- Field is evolving very quickly!
- Expect more recommendations/guideline papers and updates to current ones

Wrap up: EEG tips for setting up multimodal research projects

- Many similarities with fNIRS tips
- Consider ways to minimize noise, use noise reference channels
- Consider what system to use
  - If your own system isn't possible – online data sets
    - https://openneuro.org
    - https://nemar.org
- Include MOBI in your research!

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Thank you

Questions?

Website with all slides + additional materials

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