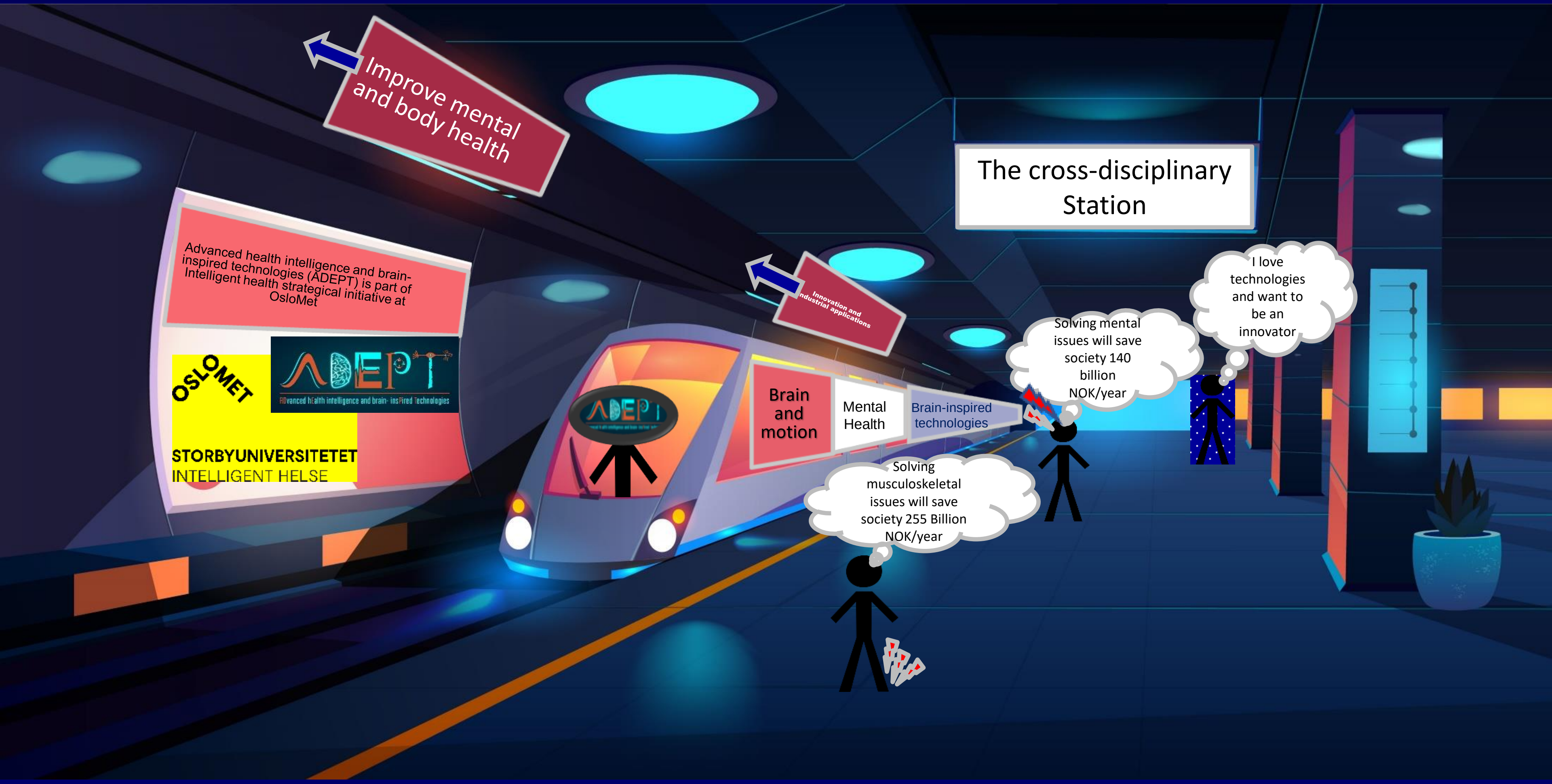
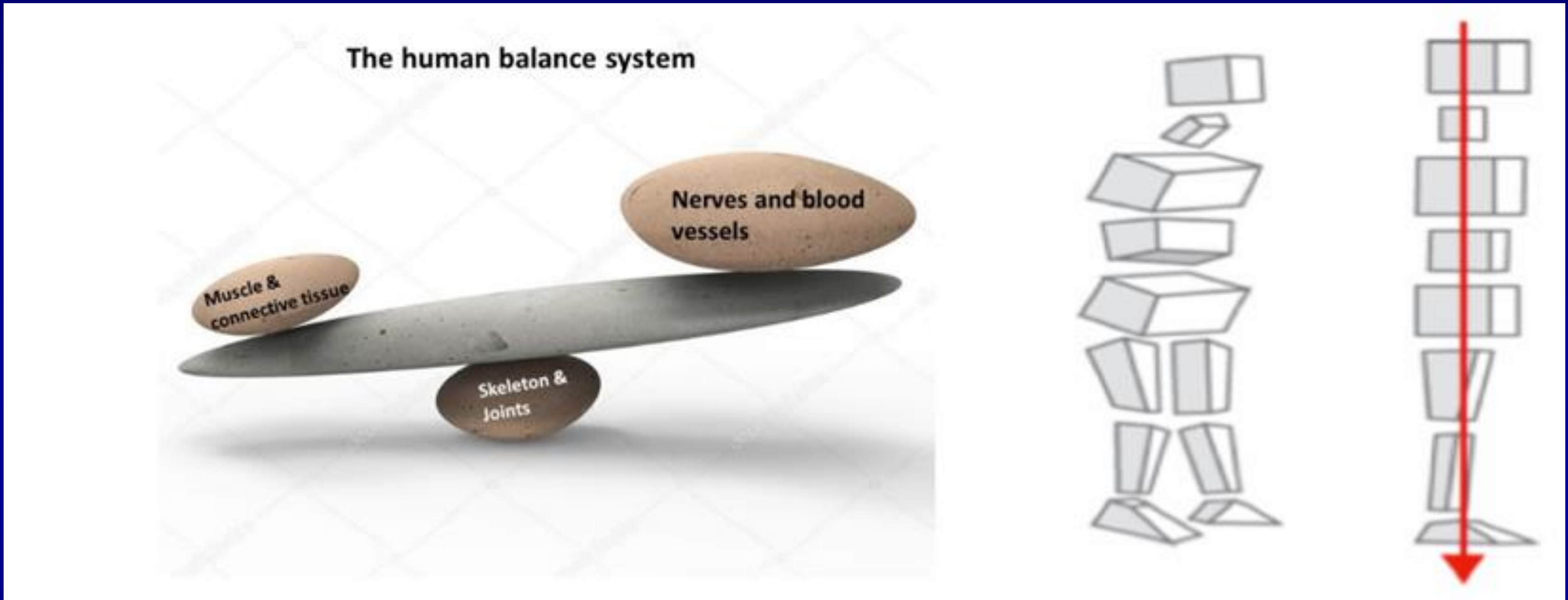
Walking the Path to Wellness: Foot Position, Brain, and Musculoskeletal Health

ADvanced hEalth intelligence and brain- insPired Technologies

Peyman Mirtaheri, Dr. Scient.
Professor of Biomedical Engineering
Leader of Optical/NIRS lab & ADEPT research group
Oslo Metropolitan University (OsloMet)

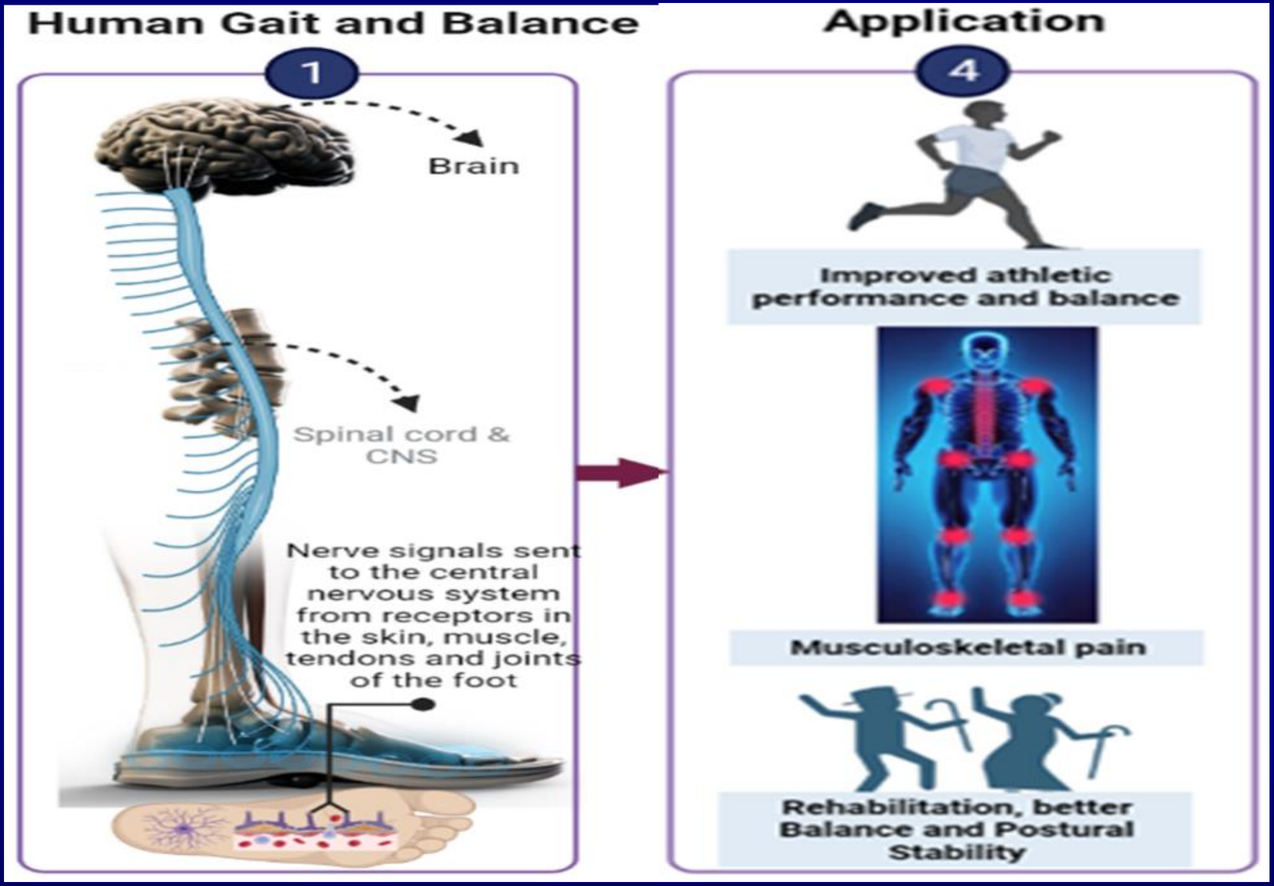

Improve mental and body health
The cross-disciplinary Station
Advanced health intelligence and brain-inspired technologies (ADEPT) is part of Intelligent health strategical initiative at OsloMet
Innovation and industrial applications
OSLOMET
STORBYUNIVERSITETET
INTELLIGENT HELSE
ADEPT
ADvanced hEalth intelligence and brain- insPired Technologies
Brain and motion
Mental Health
Brain-inspired technologies
Solving mental issues will save society 140 billion NOK/year
I love technologies and want to be an innovator
Solving musculoskeletal issues will save society 255 Billion NOK/year

Human gait is a complex interaction

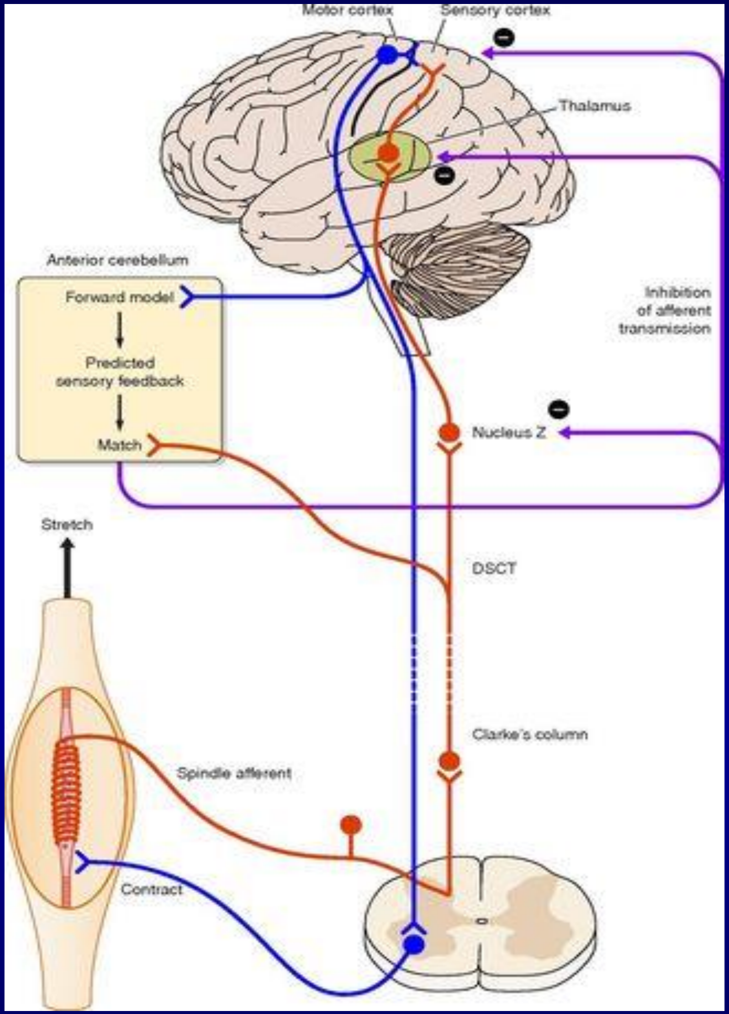


Gait and balance involves interactions between segments of the body that are stacked on top of each other

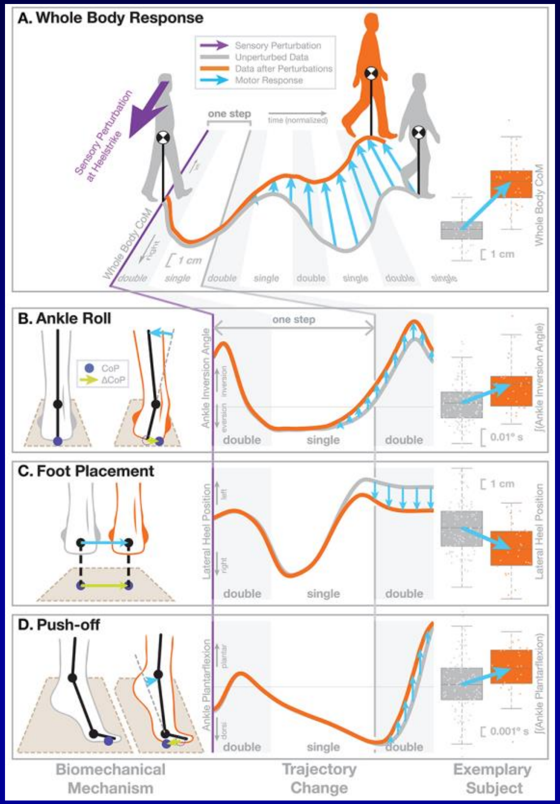
Understanding the role of the Brain and mobility



Proprioception

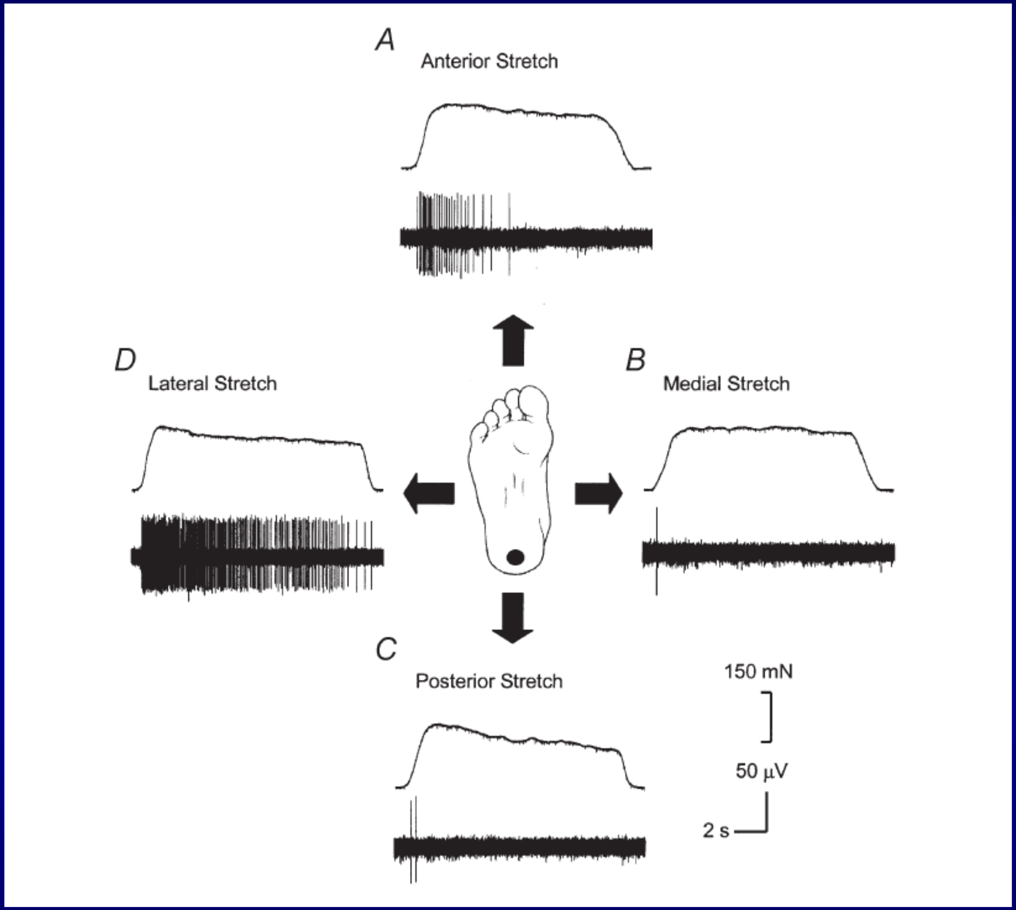


Somatosensory input weighted with 70% compared to vestibular(20%) and visual (10%) [Horak 2006]



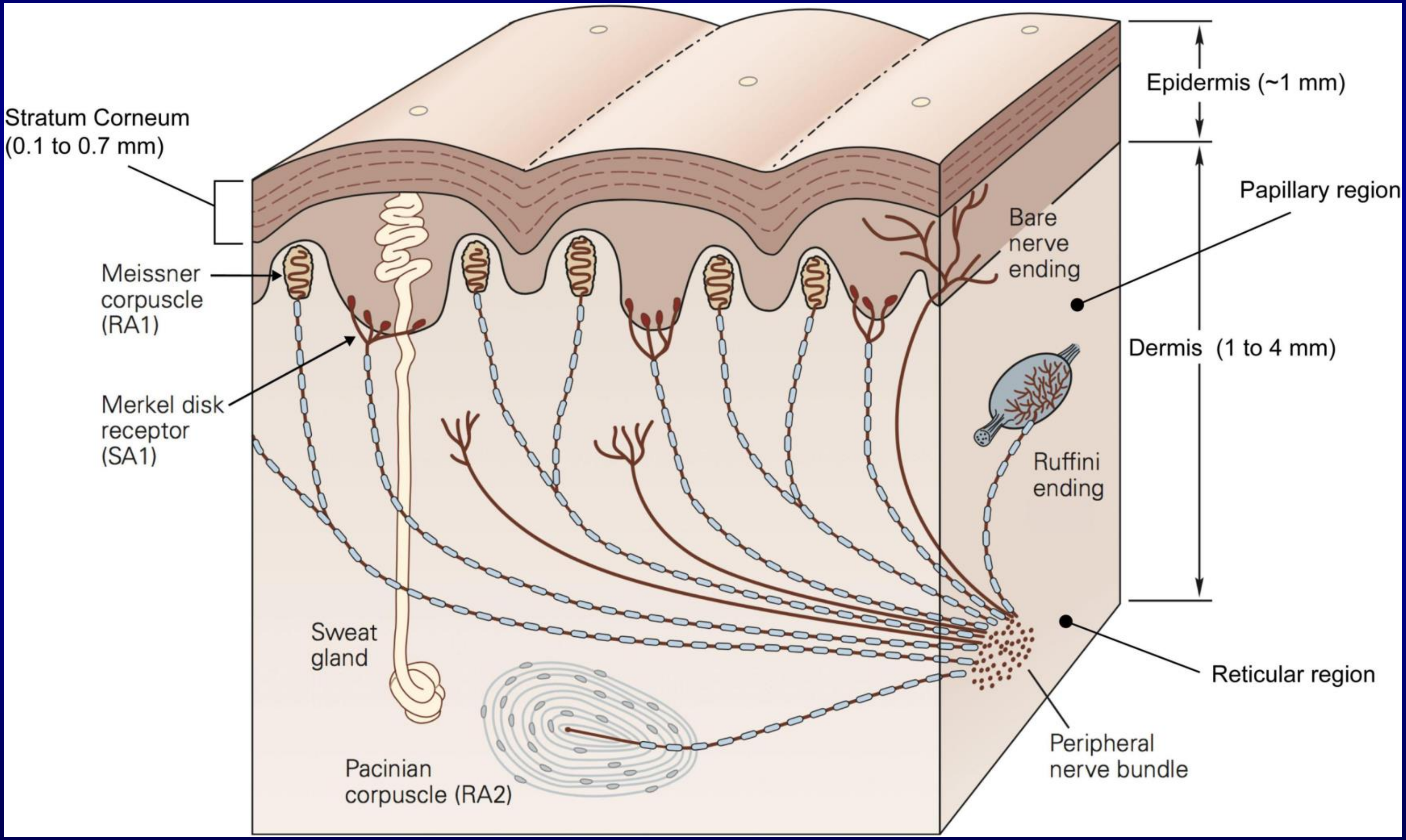
The first contact point to the ground is the foot

Stimulation of the heel

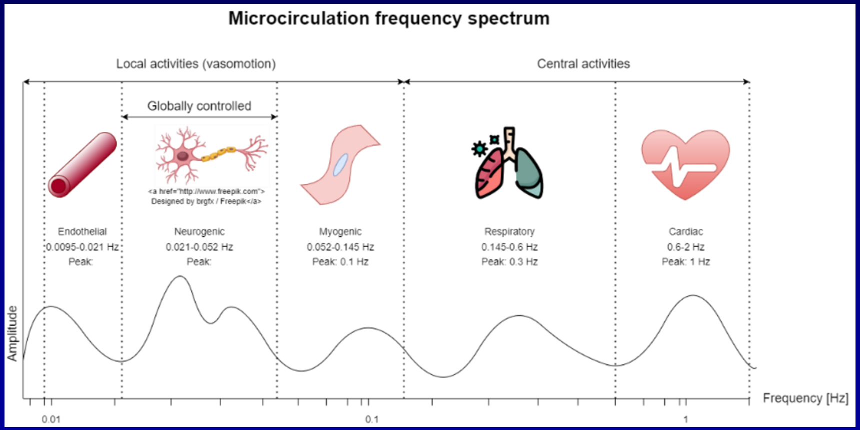


Kennedy and Inglis 2002

The arrangement of mechanoreceptors in the skin



Sensory stimulation and skin perfusion



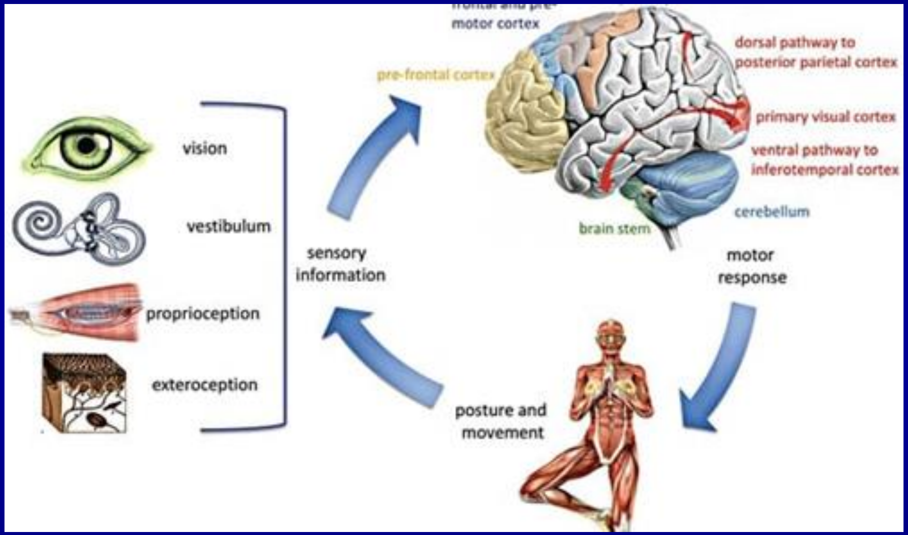
Measurement unit: PU	Lateral probe position	Medial probe position	Supinated foot	Overpronated foot	Lateral skin stretch	Medial skin stretch
Mean perfusion value (trial number)	1.4 (1)	1.4 (3)	1.4 (1)	0.6 (2)	1.4 (1)	0.8 (5)
	0.6 (2)	0.9 (4)	1.4 (3)	0.9 (4)	0.6 (2)	0.6 (6)
	0.8 (5)	0.5 (7)	0.8 (5)	0.6 (6)	1.4 (3)	0.5 (7)
	0.6 (6)	0.5 (8)	0.5 (7)	0.5 (8)	0.9 (4)	0.5 (8)
Sum	3.4	3.3	4.1	2.6	4.3	2.4
Mean of all trials	0.85	0.825	1.025	0.65	1.075	0.6

The perfusion (microcirculation in the skin) is a reflection of activities in the region

A platform to stimulate the heel and balance

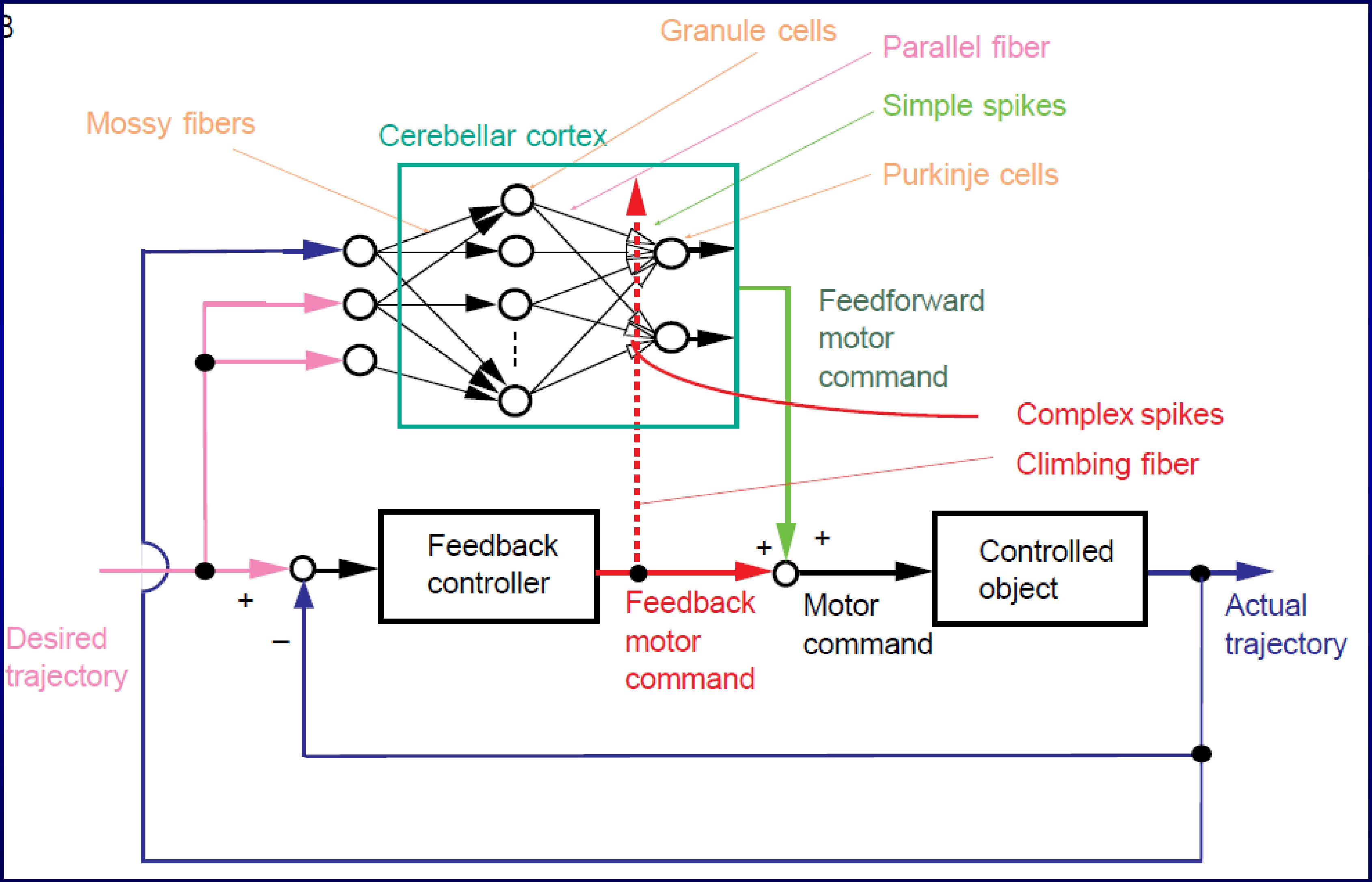
The platform has pressure sensors to adjust the stimulation values and timings.

The incredible human brain

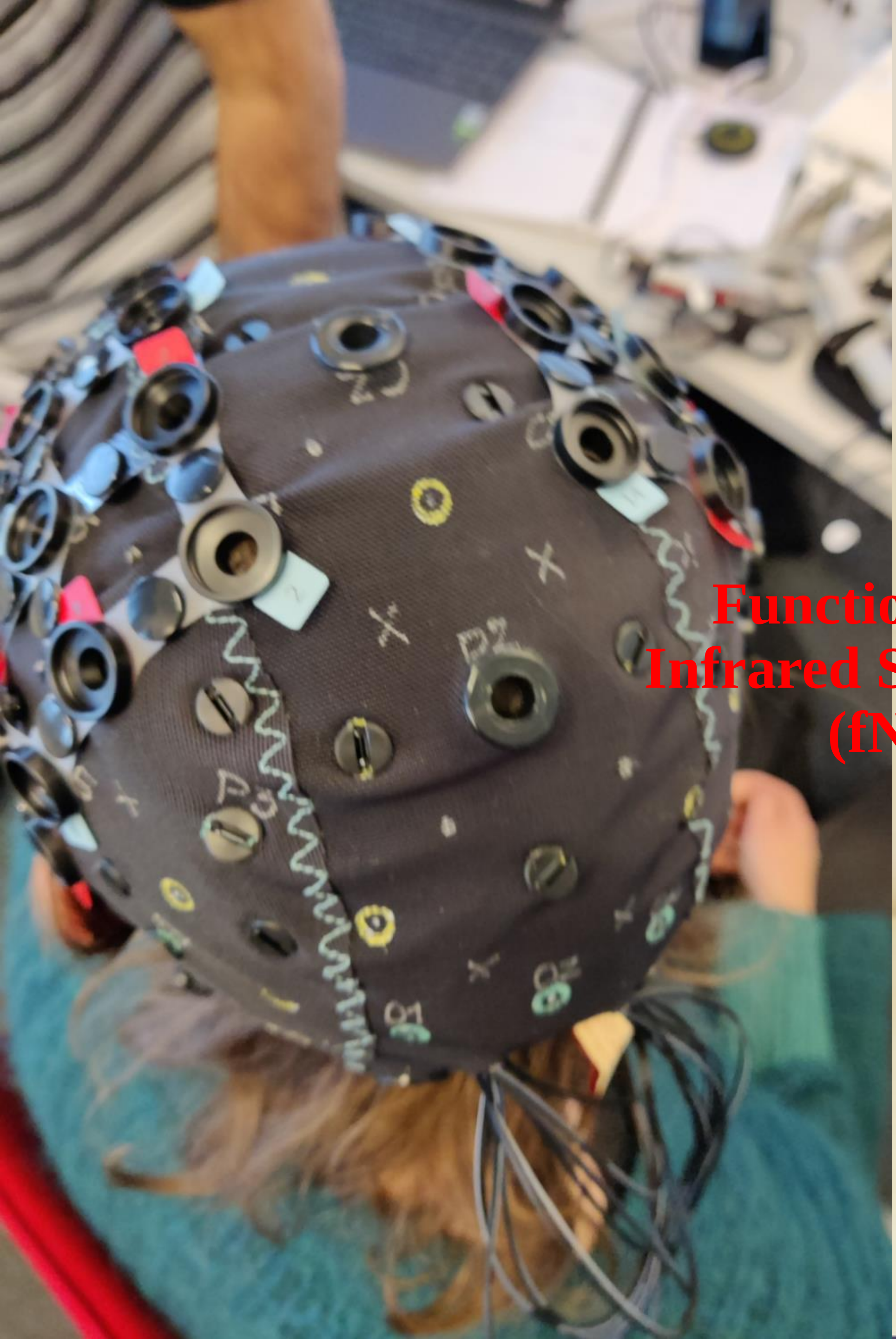


Human brain is capable to process complex tasks with optimized energy consumption. A better understanding will facilitate better diagnostic and rehabilitation of mind and body

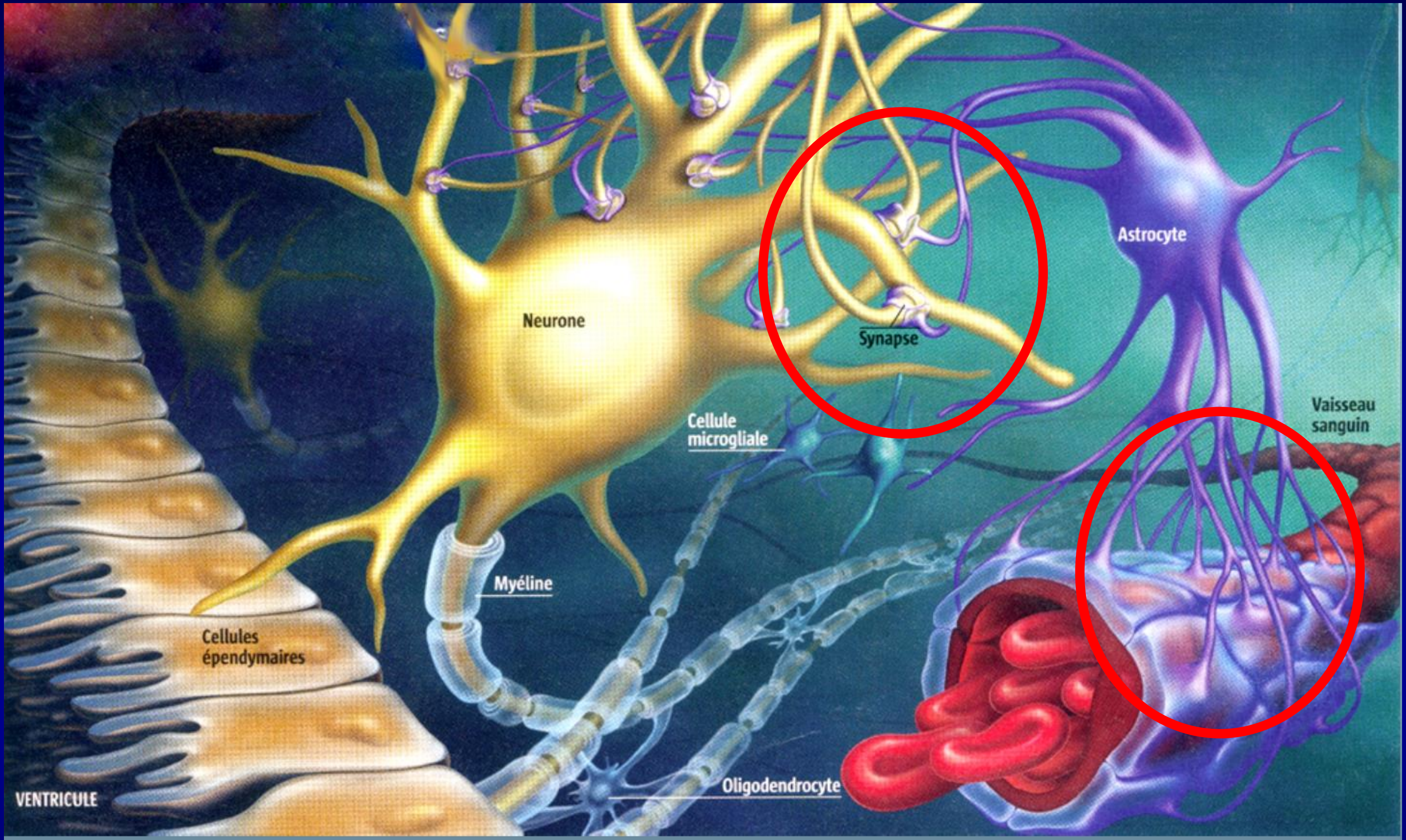
Feed forward control system



Functional Near-Infrared Spectroscopy (fNIRS)



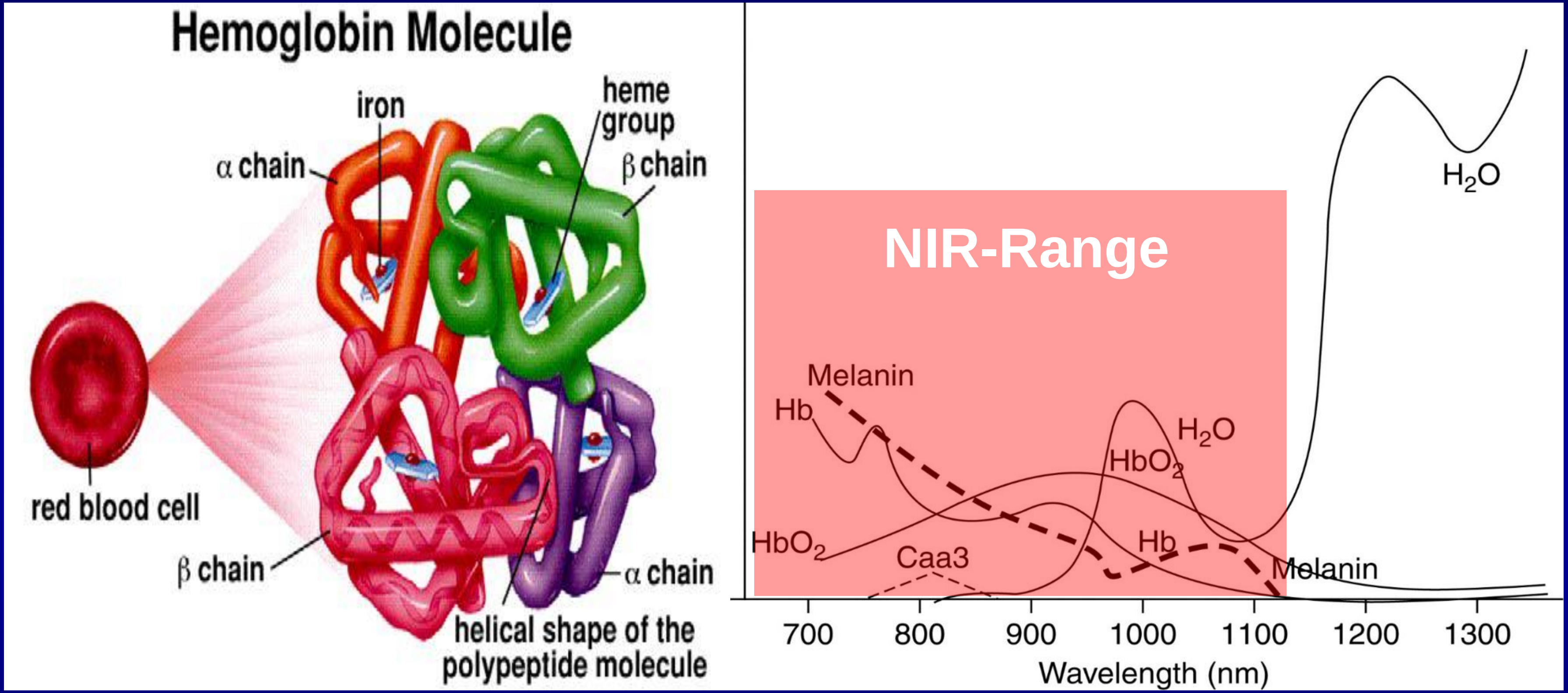
Neuro-activation and Neuro-vascular coupling



from F. Pfrieger and C. Steinmetz, La recherche, 2003 (361)

Changes of blood perfusion due to neuroactivation, while there are no potential changes of Glia cells

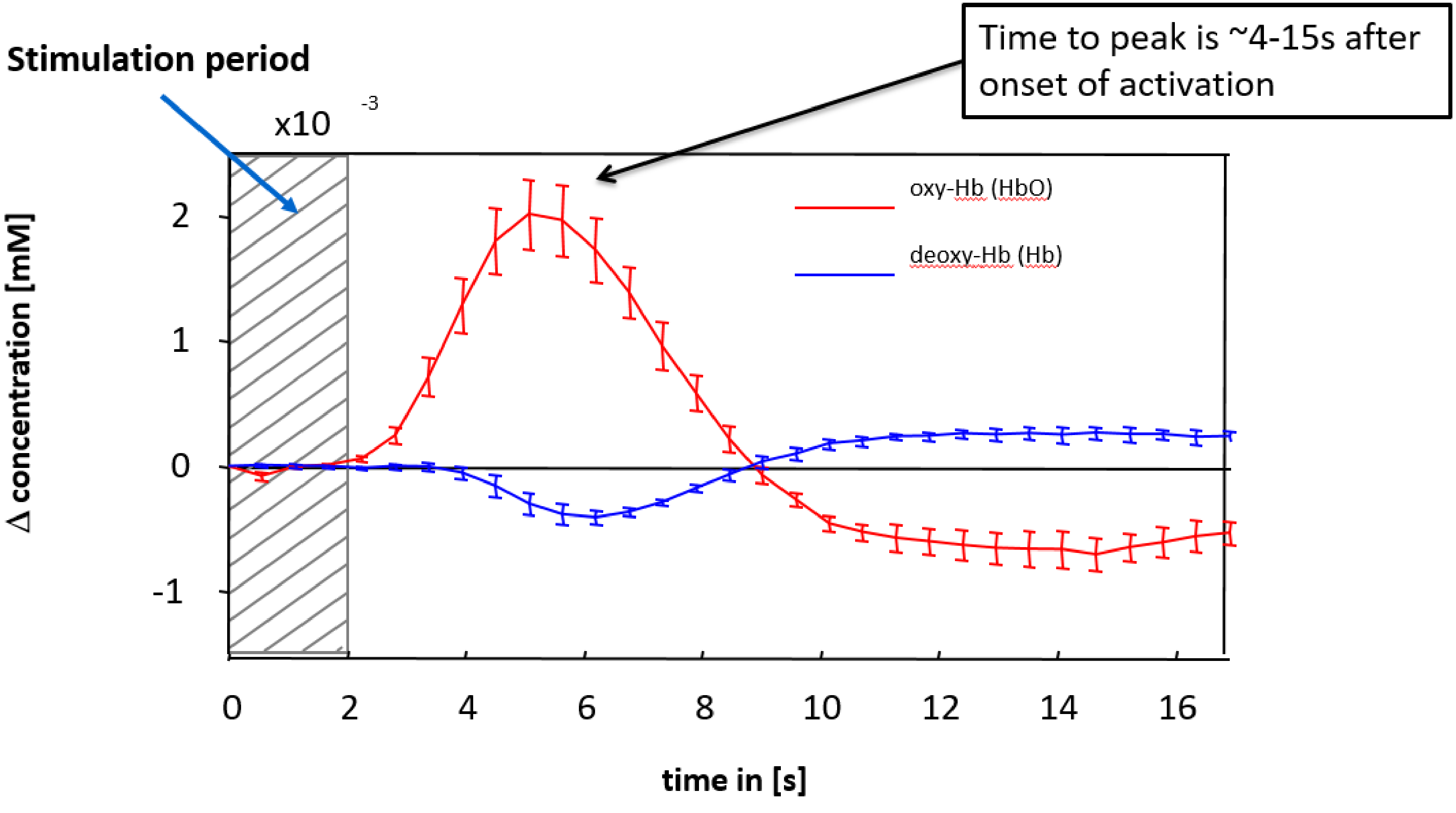
Absorption spectra of hemoglobin



Pansare et al. 2013

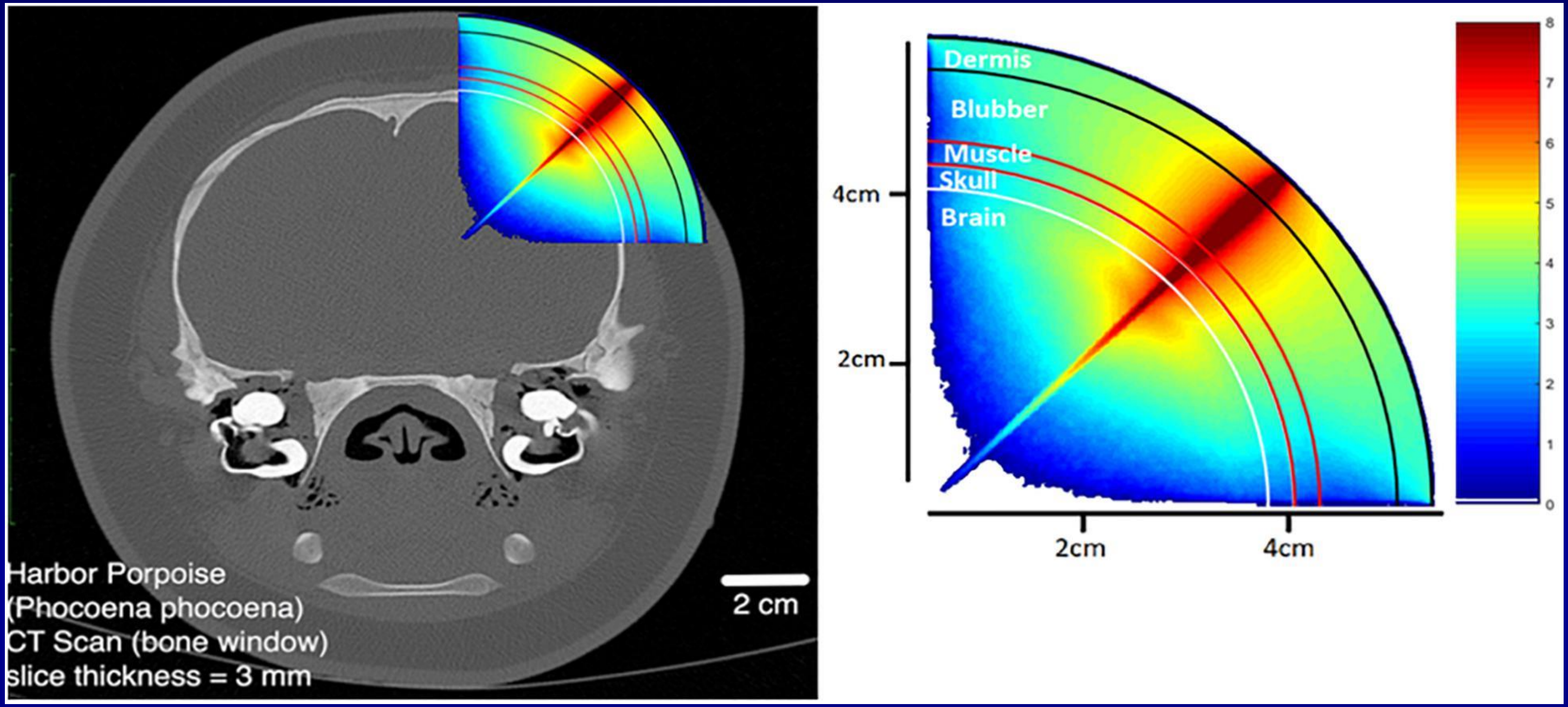
Hemoglobin (Hb) is the protein contained in red blood cells that is responsible for delivery of oxygen to the tissues

Oxy and deoxy response from fNIRS



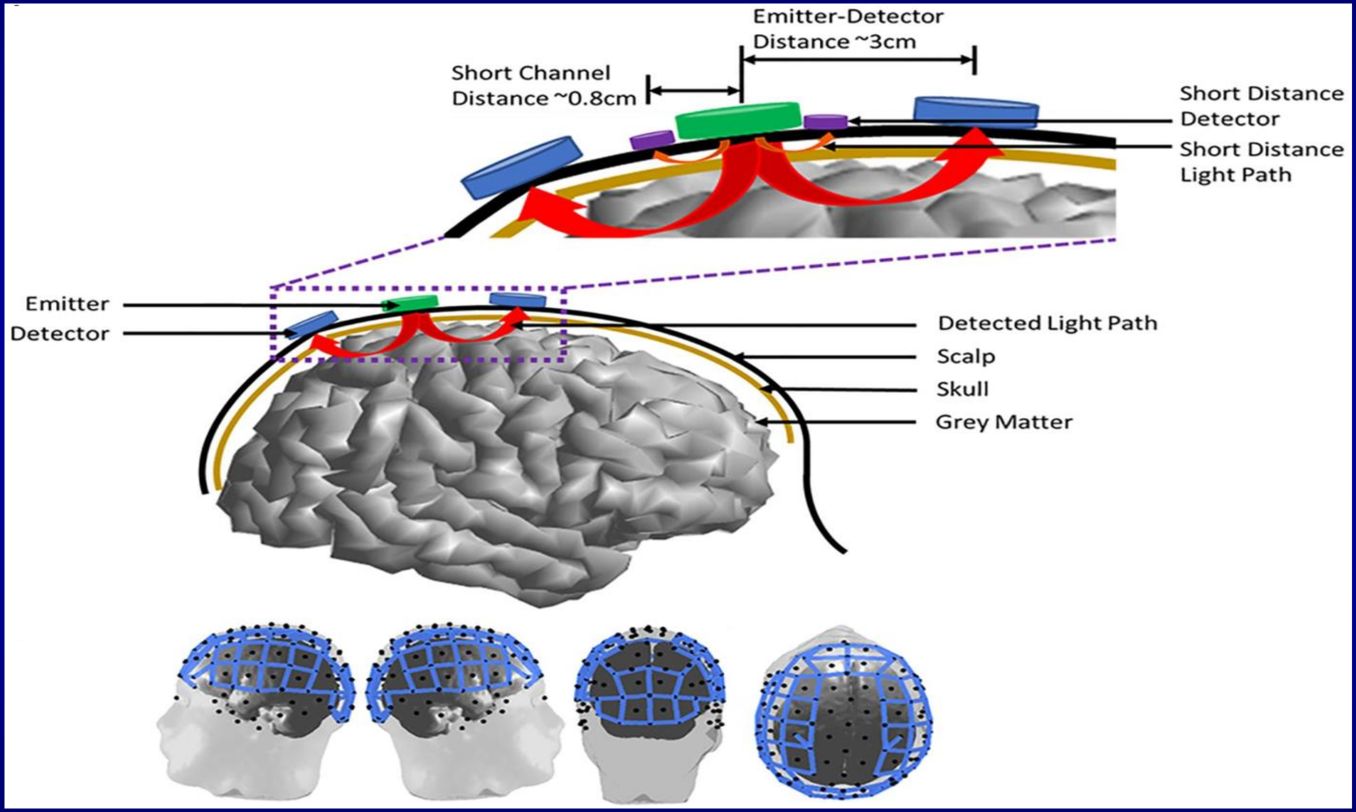
Kohl M ,.. , Dirnagl U. Phys. Med. Bio. 2000
http://www.ncbi.nlm.nih.gov/pubmed/11131197

Photon penetration in tissue



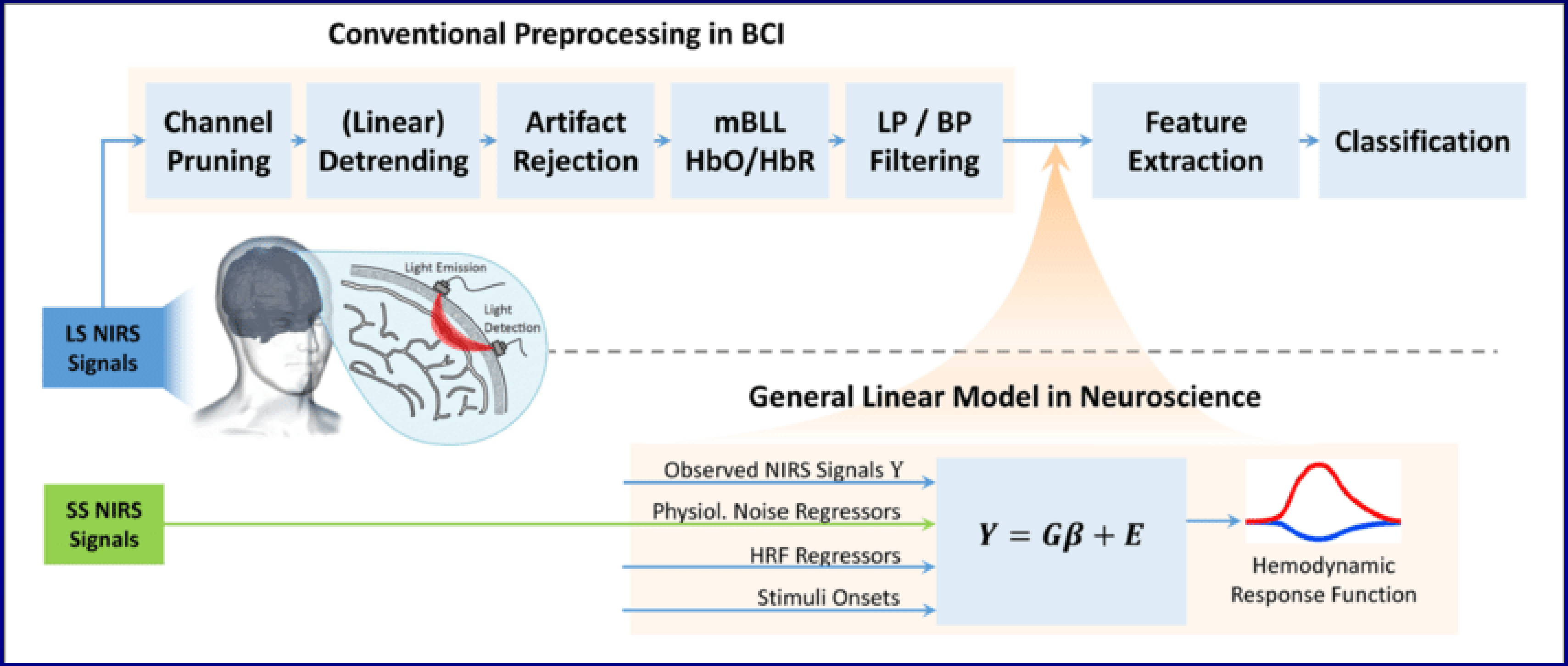
We may not get more that a few mm depth into the cerebral cortex (4-7 mm)

Superficial tissue affects functional NIR-Spectroscopy



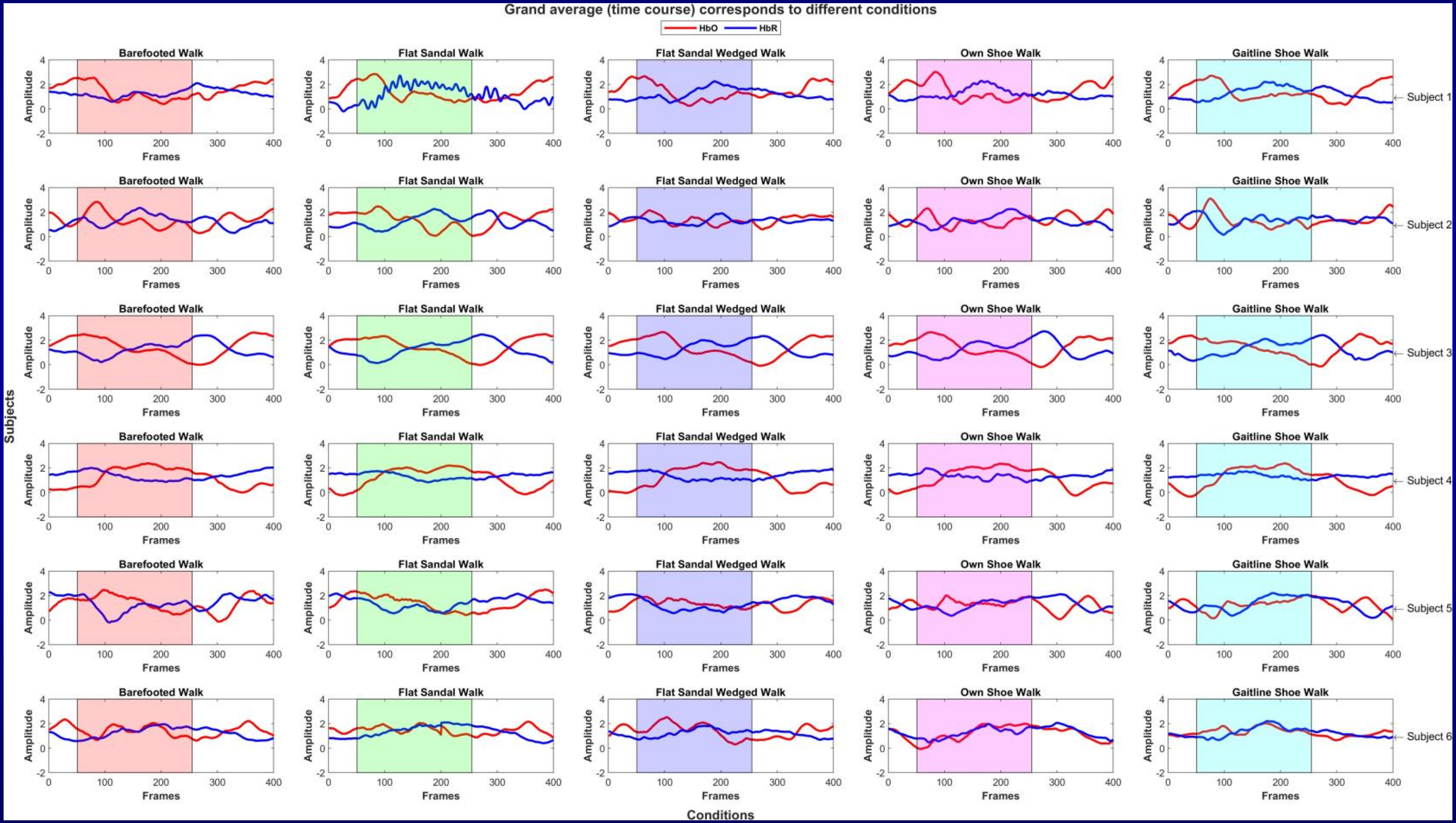
Short channels are needed to separate data from the superficial tissue from the data of interest

Pipeline for data processing



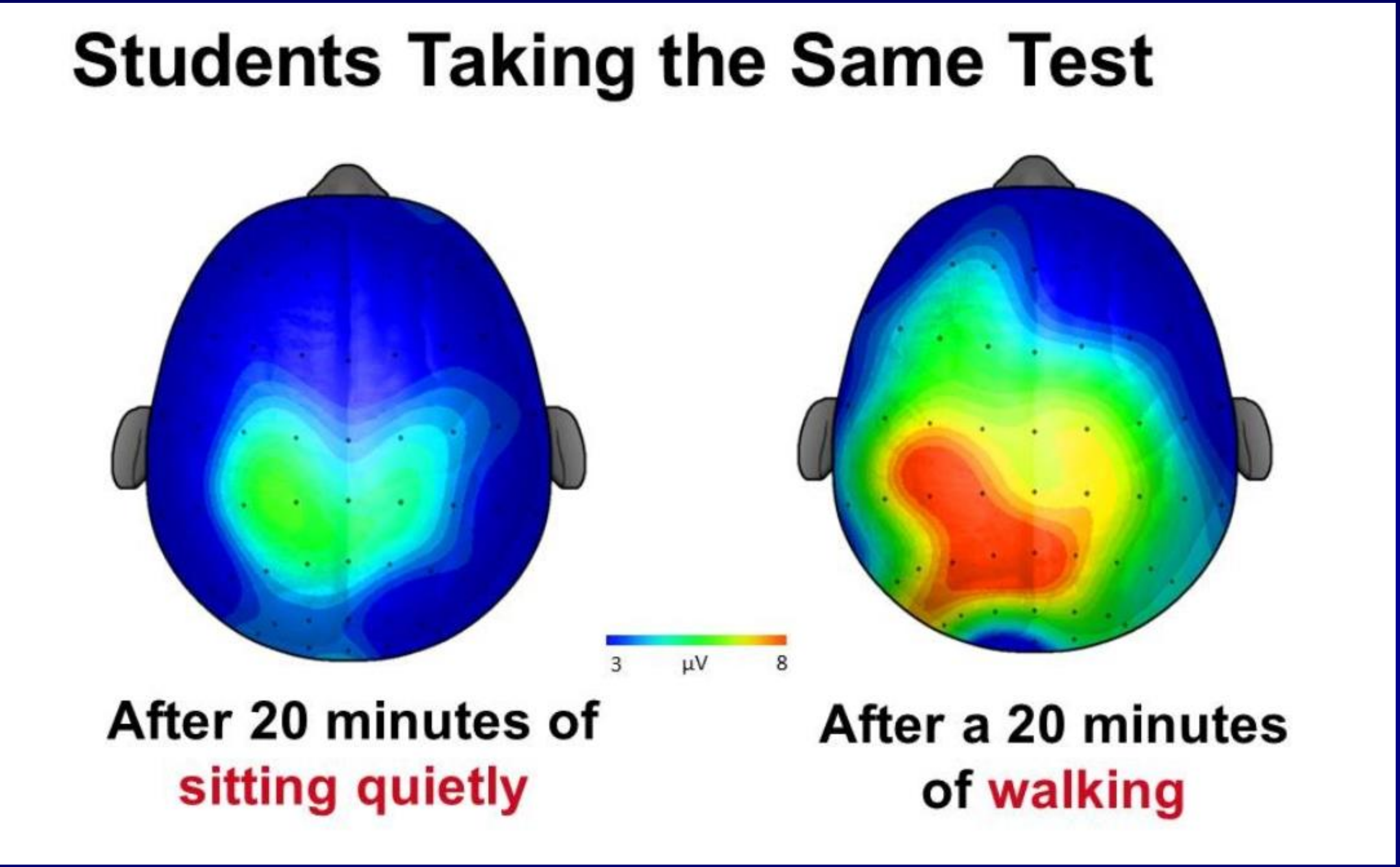
Extraction of the signals to some physiological responses is important [von Lühmann et al. 2020]

Examples of the brain activation with different gait conditions



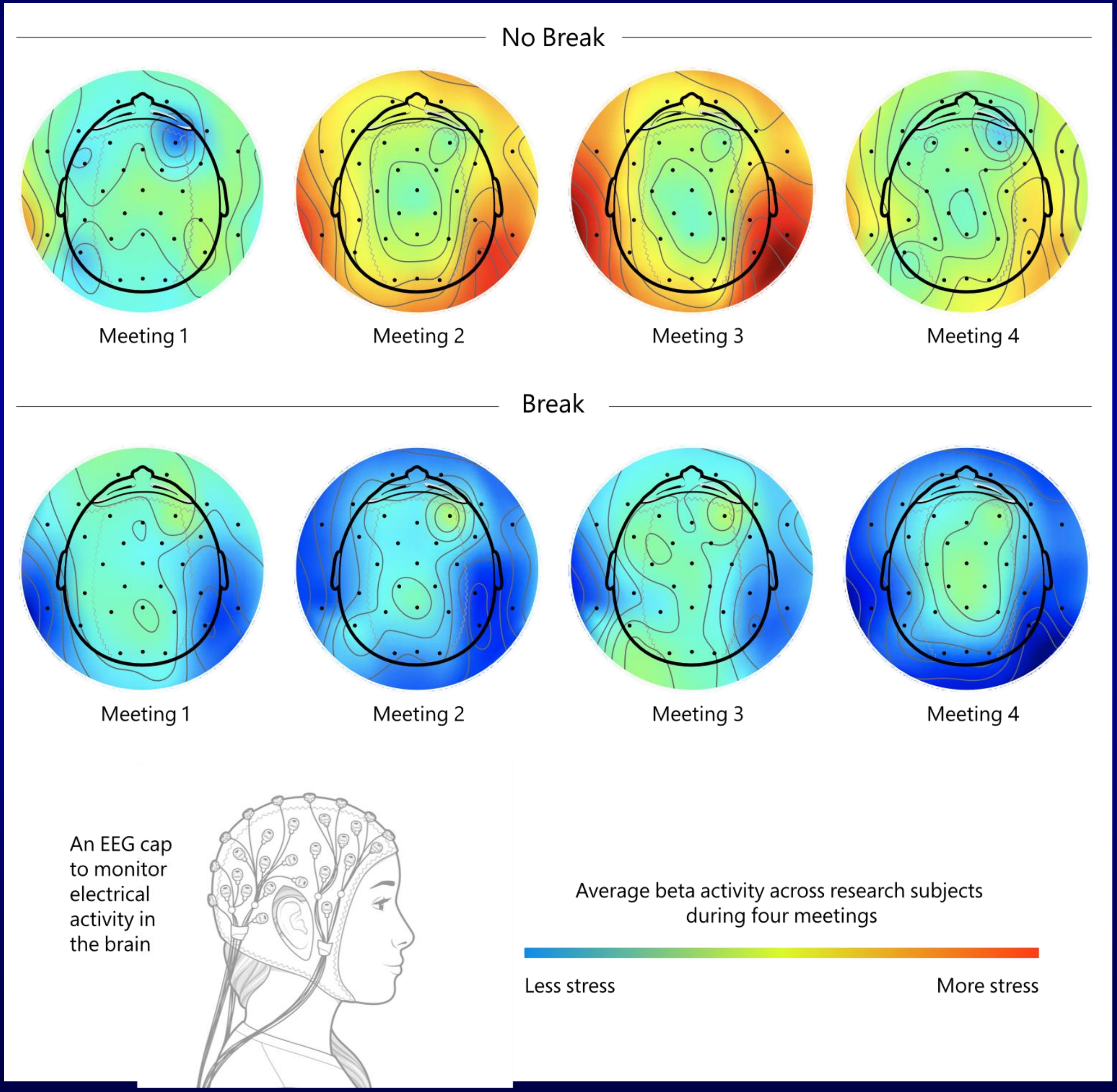
Hbo reflects the arterial and HbR the venous information

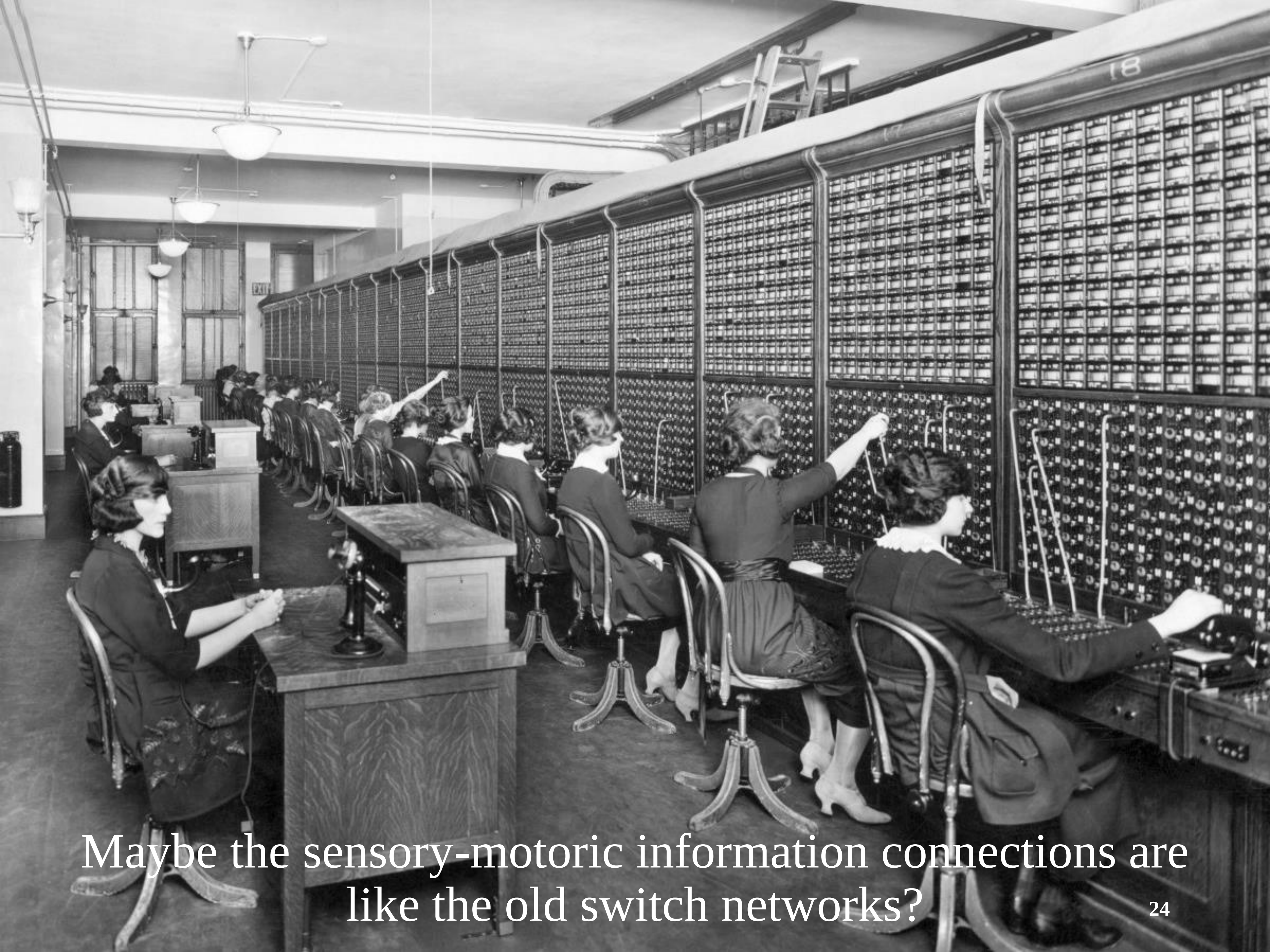
Is activation a good or bad thing?



The results shows that the brain is activated when walking

Too many meetings without break





Maybe the sensory-motoric information connections are like the old switch networks?

Connectivity model

Time series $Y(t) \in \mathbb{R}^M$ with ch channels and T time points.
Each channel k, associated with a 3D coordinate $c_k = (x_k, y_k, z_k)$.
Low-rank projection matrix $\Psi \in \mathbb{R}^{L \times M}$.

$$\Psi Y(t) = \sum_{\ell=1}^{p} \Phi^{(\ell)} \Psi Y(t-\ell) + \varepsilon(t)$$

$$\Phi^{(\ell)} = \Phi_0^{(\ell)} + \Phi_1^{(\ell)} C_1 + \ldots + \Phi_6^{(\ell)} C_6$$

$$\varepsilon(t) \sim \mathcal{WN}(0, \Sigma_\varepsilon)$$

$$\mathrm{vec}(\hat{\Phi}) \to \mathcal{N}(0, \Sigma_\Phi)$$

$$C_0 = \begin{cases} 1 & \text{Baseline (barefoot)} \\ 0 & \text{other} \end{cases}$$

$$C_1 = \begin{cases} 1 & \text{Flat sole} \\ 0 & \text{other} \end{cases}$$

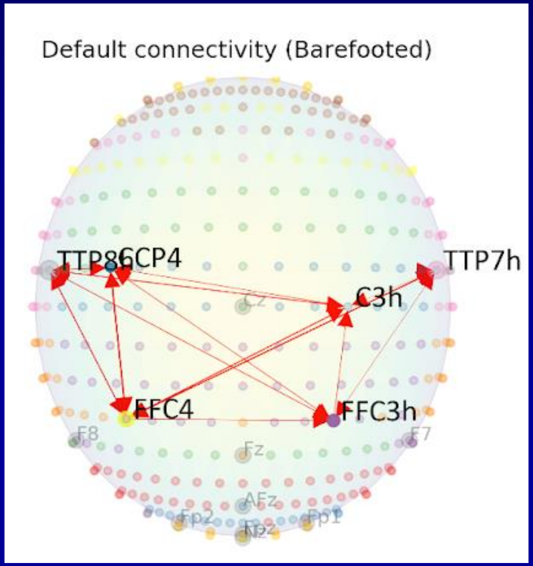
$$C_2 = \begin{cases} 1 & \text{Flat wedged} \\ 0 & \text{other} \end{cases}$$

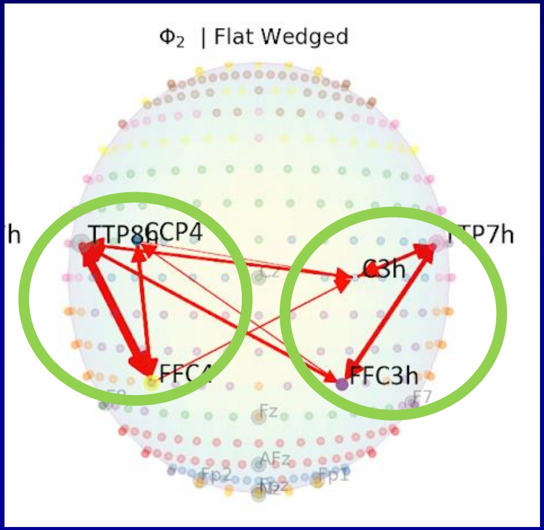
$$C_3 = \begin{cases} 1 & \text{Personal shoes} \\ 0 & \text{other} \end{cases}$$

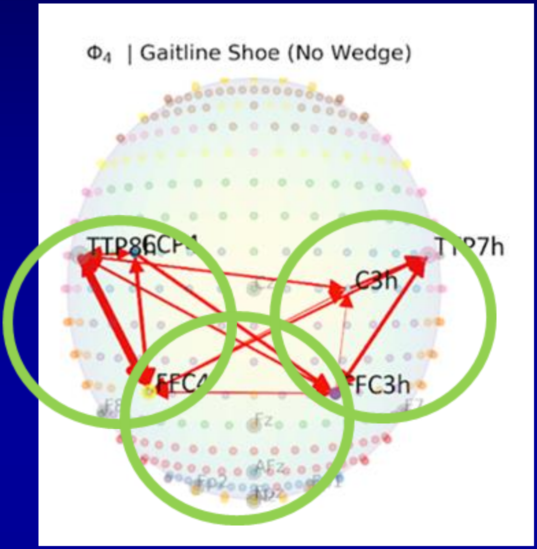
$$C_4 = \begin{cases} 1 & \text{Gaitline shoes} \\ 0 & \text{other} \end{cases}$$

Model is based on fNIRS signals filtered by a FIR bandpass 10-400mHz

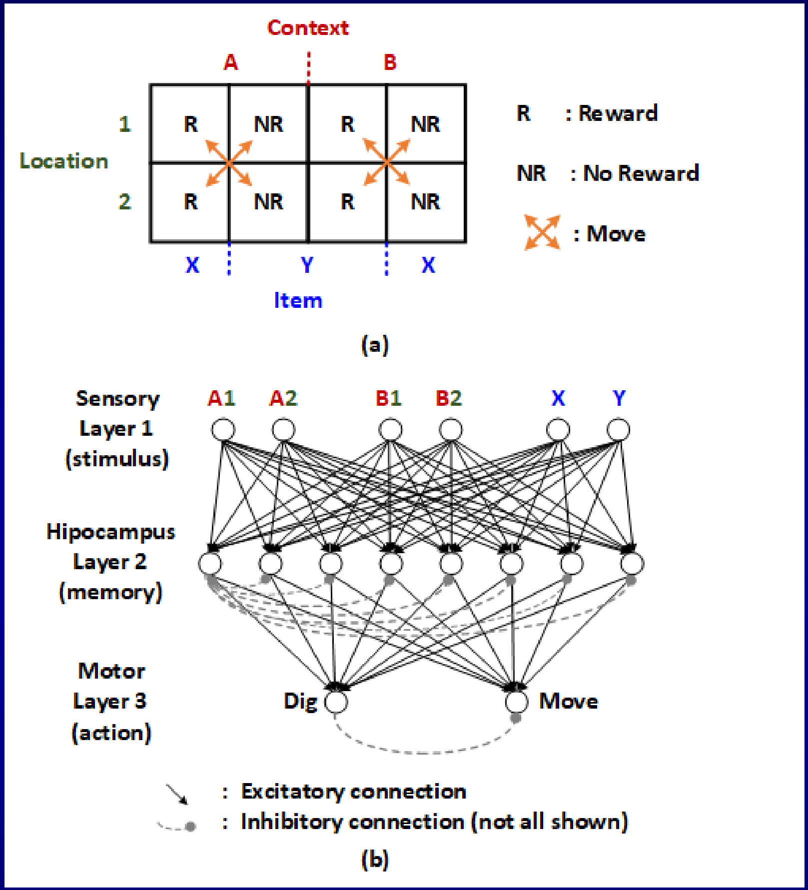
Connectivity patterns with ML model

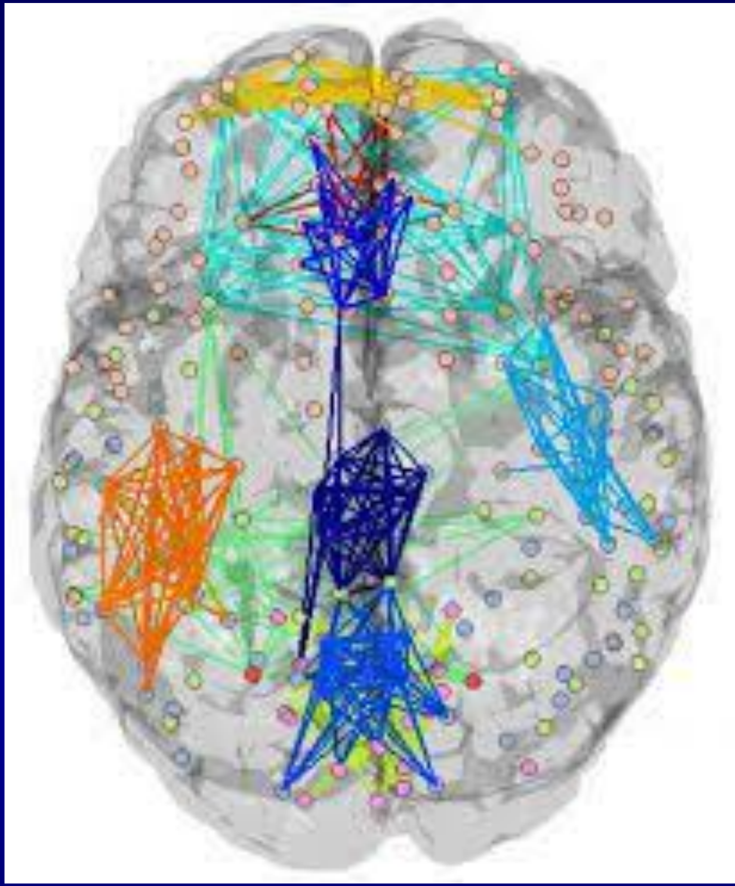






A simplified brain model





Using the engineering to replicate the brain connectivities in a small electronic circuit using FPGA(Field Programmable Gate-Array), Ref. Prof. Muhtaroglu' s projects at ADEPT

In conclusion: Understanding the sensory-motoric controls involving the brain connectivities will be a game changer for diagnostic and rehabilitaiton

- The first contact with the ground is our feet containing sensory information
- The fNIRS (functional near-infrared spectroscopy) is an important tool to look at the brain activities
- Functional and effective connectivties are interesting tools to understand the brain functions

Questions?

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