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# Functional Near Infrared Spectroscopy (fNIRS) neuroimaging of the prefrontal lobe: Acquisition and processing protocols

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# 1. Background-Aim

fNIRS is a novel noninvasive optical neuroimaging method frequently used to detect changes of cortical hemodynamic responses to human perceptual, cognitive, and motor functioning

Human tissues are transparent to NIR light (650-950nm): Absorption & Scattering (few cm)

Optical Window: Various substances like lipids, melanin, water

Most dominant absorbing chromophore is Hemoglobin

$HbO_2$: λ>800nm

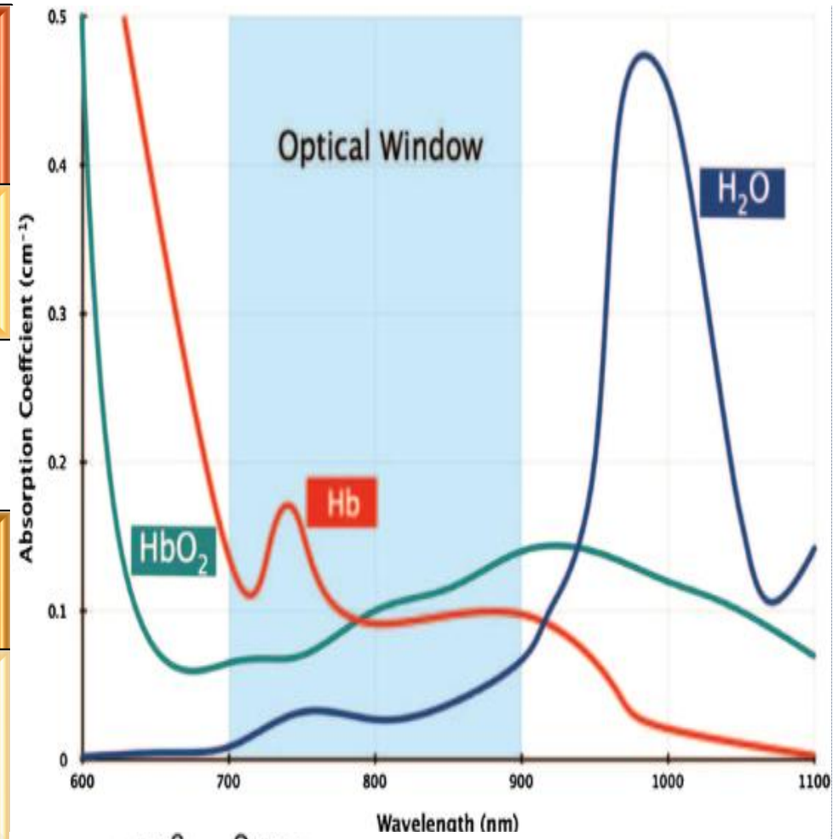
HbR: λ<800nm

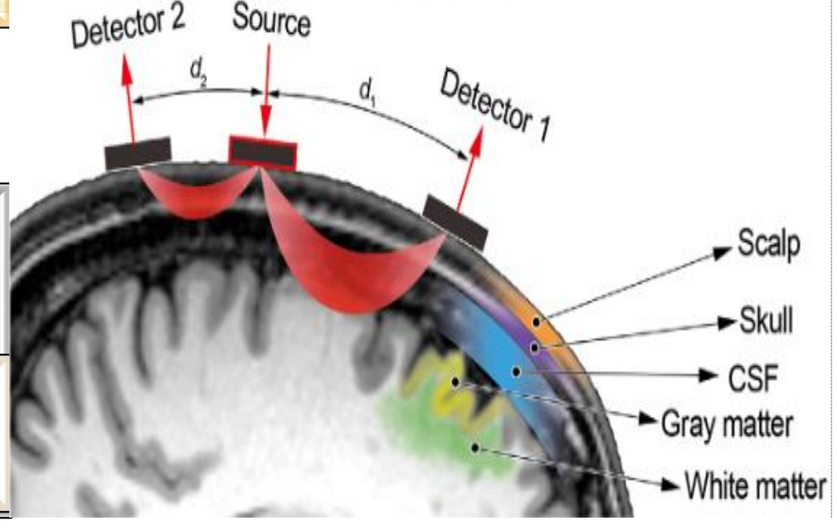
↑ neural activation→ ↑ metabolic demands→ neurovascular coupling/functional hyperemia (↑[$HbO_2$],↓[HbR])

Changes in chromophore concentrations can be quantified via changes in NIR light absorption detected by fNIRS

Indirect measurement of neuronal activity in brain areas of interest

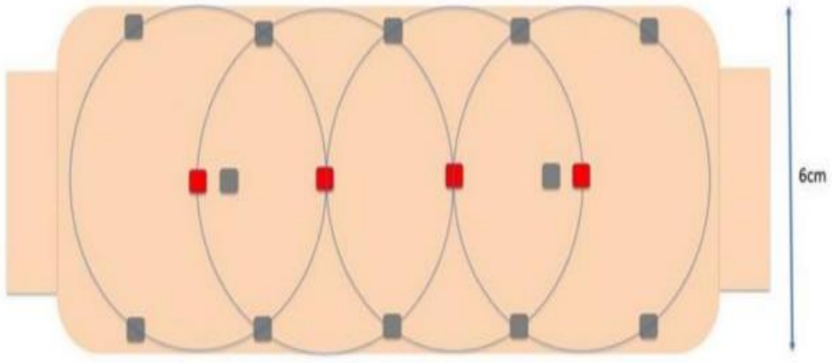
Aim: Extracting and analyzing fNIRS signals from cognitive trial settings and proper protocols



# 2. Materials & Methods






## BIOPAC 2000C Imager Model

- 4 LED CW Emitters, 12 Photodiode detectors, 16 measurement channels
- Two wavelengths of near-IR light: 730 nm & 850 nm
  Sampling Rate: 10 Hz
- 10-25mm Emitter-Detector distance: hemodynamic changes within 1-1,5 cm distance from center of Emitter-Detector arrangement
- All emitters are activated sequentially: The first one activates and performs 5 (or 4) channel measurements at one wavelength then at the other wavelength measurements, and then the second emitter is turned on, etc.

# 3. Materials & Methods

**Cognitive Tasks: Numerous challenges for the evaluation of high – level cognitive processes, executive brain functions etc. → pre-task, task & post-task period**

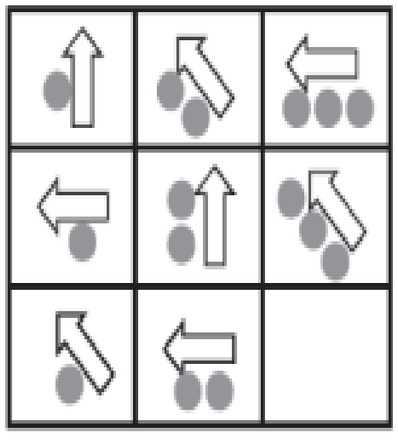
| VFT: Sensitive indicator of frontal lobe activation → LFT (phonological example) & CFT (category example) | RAPM: Assessment of brain behavior in reasoning and problem solving process → cell form patterns |
|---|---|

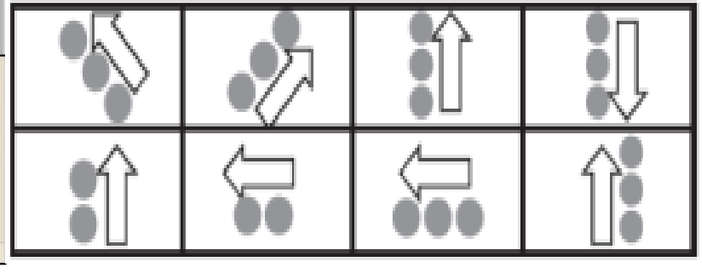
**VFT Acquisition Protocol: 30s pre-task BS1: Participant is asked to verbally count the numbers from 1 to 5 repeatedly**

| 60s LFT period: 3x20s blocks of word generating beginning with a 2 letter syllable→ different in each block | 30s pre-task BS2 : Same as BS1, 60s CFT period: Same as LFT but categories, 5 Participants each 5 sessions |
|---|---|

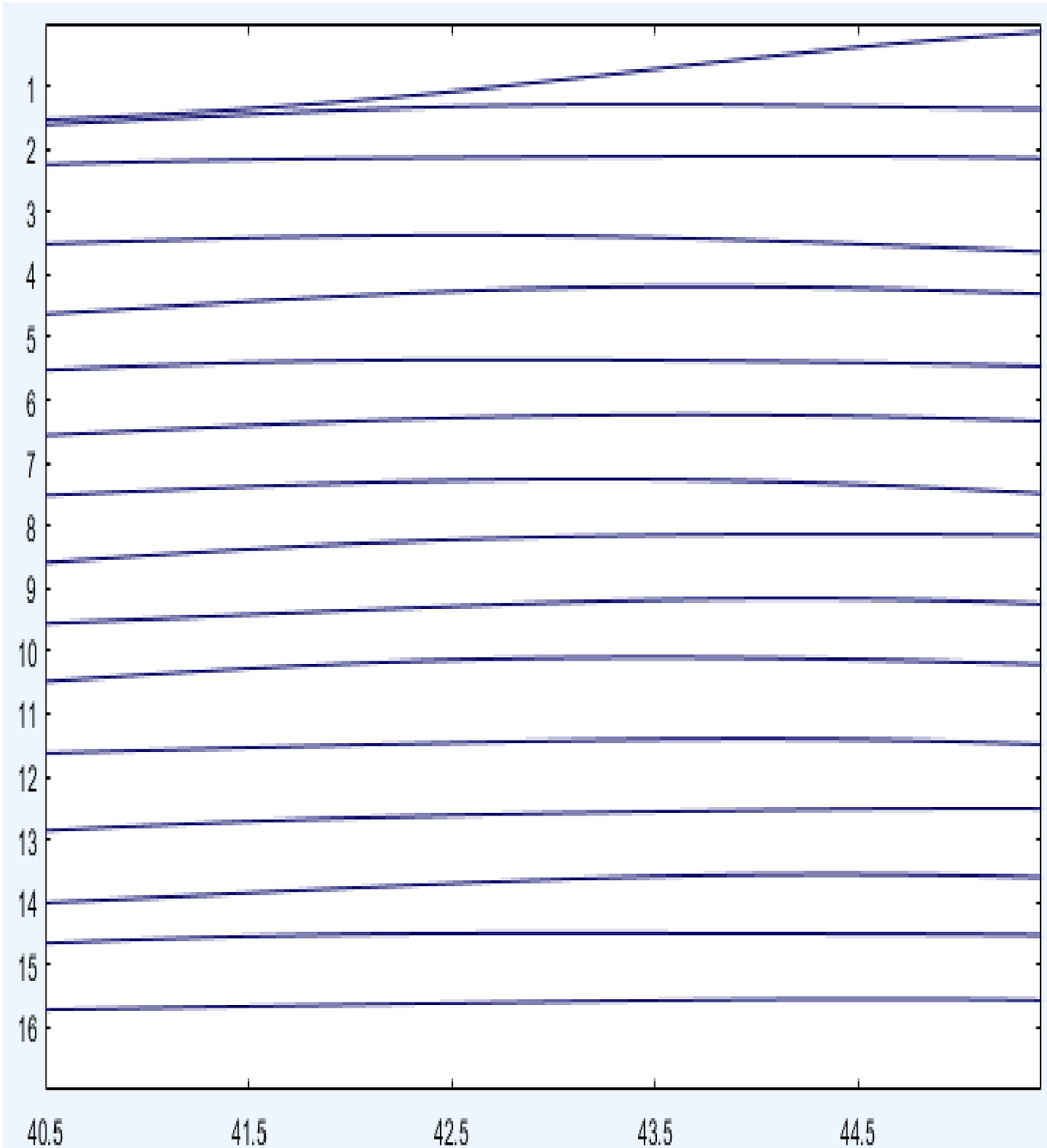
**RAPM Acquisition Protocol: 30s pre-task BS1: Participant is asked to verbally count the numbers from 1 to 5 repeatedly**

| 60s RAPM1 period: Choice of the best available pattern to fill a missing element | 30s pre-task BS2: Same as BS1, 60s RAPM2 period: Same as RAPM1 but other patterns, 5 Participants each 5 sessions |
|---|---|





# 4. Materials & Methods




## fNIRS Data Processing Protocol

FIR Band Pass filter : 0,01 – 0,19 Hz

Detrending

## fNIRS Statistical Analysis

2 Subjects

2 VFTs & 2 RAPMs each

VFT : BS1 & LFT, RAPM : BS1 & RAPM1

One – way ANOVA for each case→ Levene's test for homogeneity of variances→ NOT homogenous

Comparison of the first 8 optode channels through non parametric independent samples Kruskal-Wallis Test

# 5. Results

## Bibliography

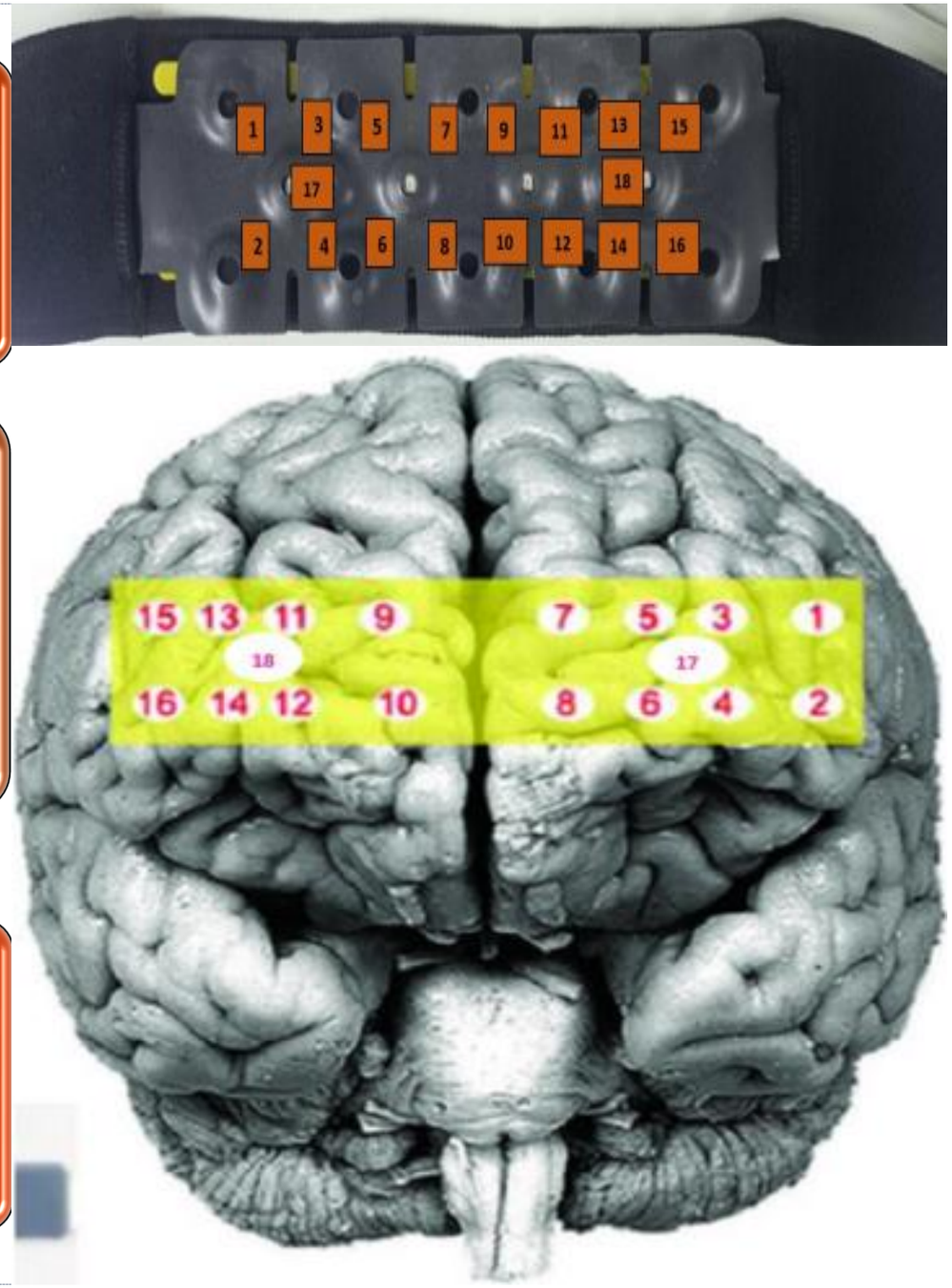
**fNIRS & VFT**: $HbO_2$ & Tot-Hb ↑, HbR ↓, Statistically Significant Difference ( $\rho < 0.05$) between BS – Task period

**fNIRS & RAPM**: $HbO_2$ ↑, HbR ↓, Statistically Significant Difference ( $\rho < 0.05$) between BS – Task period

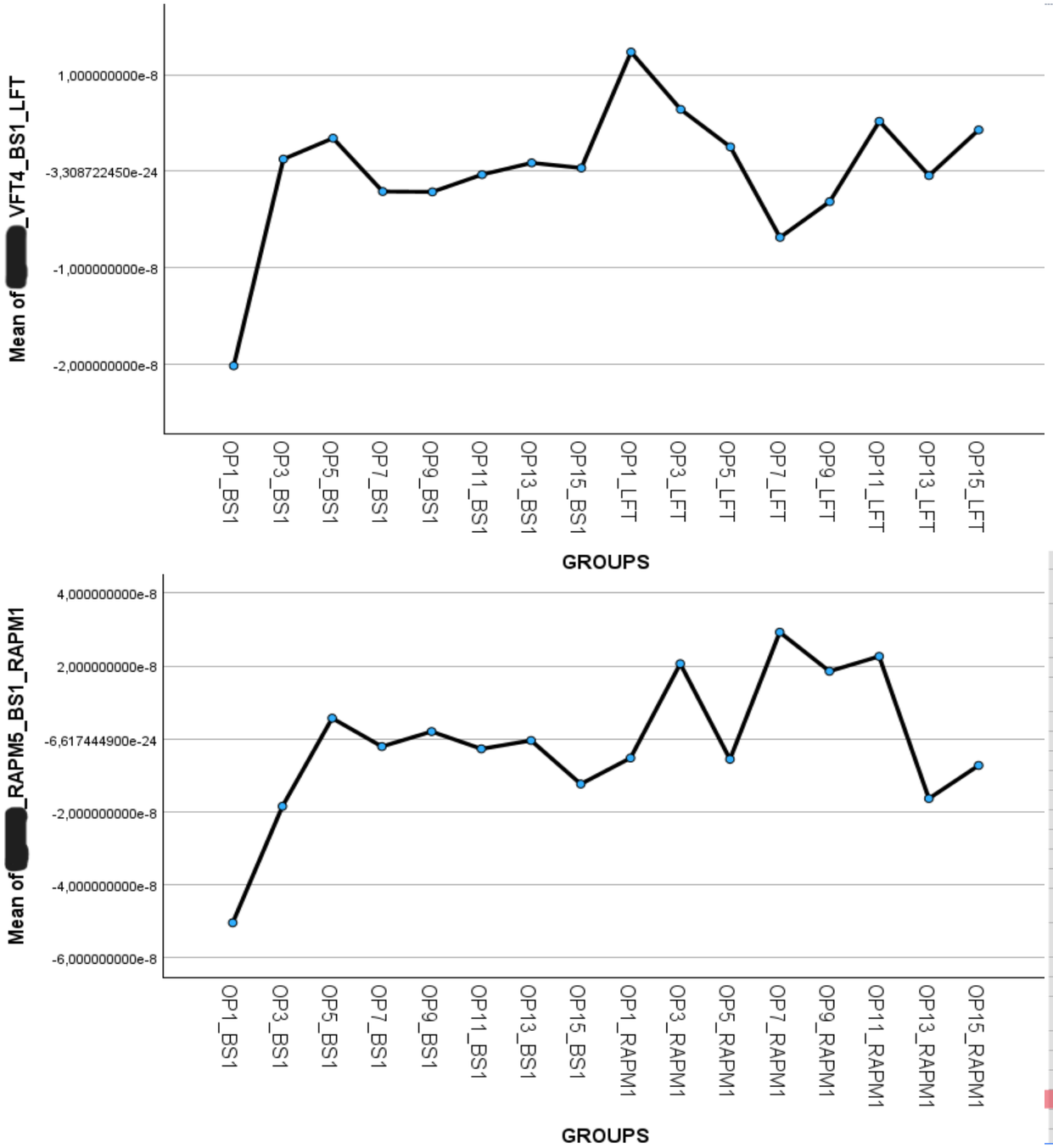
## Experimentation

**fNIRS & VFT**: Most channels' mean $HbO_2$ values confirmed $HbO_2$ ↑, Statistically Significant Differences between BS1 – Task Period

**fNIRS & RAPM**: Same as above



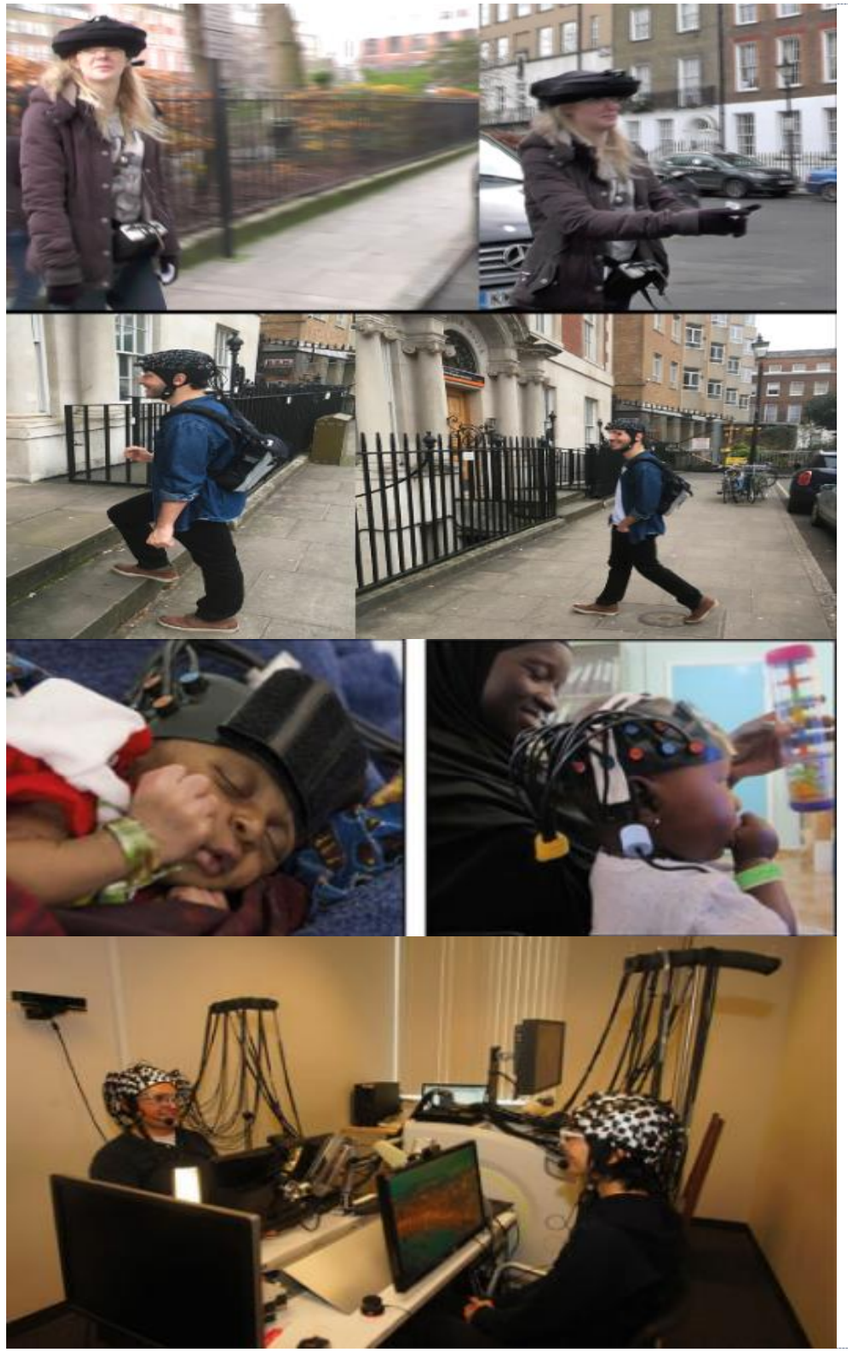
# 7. Results

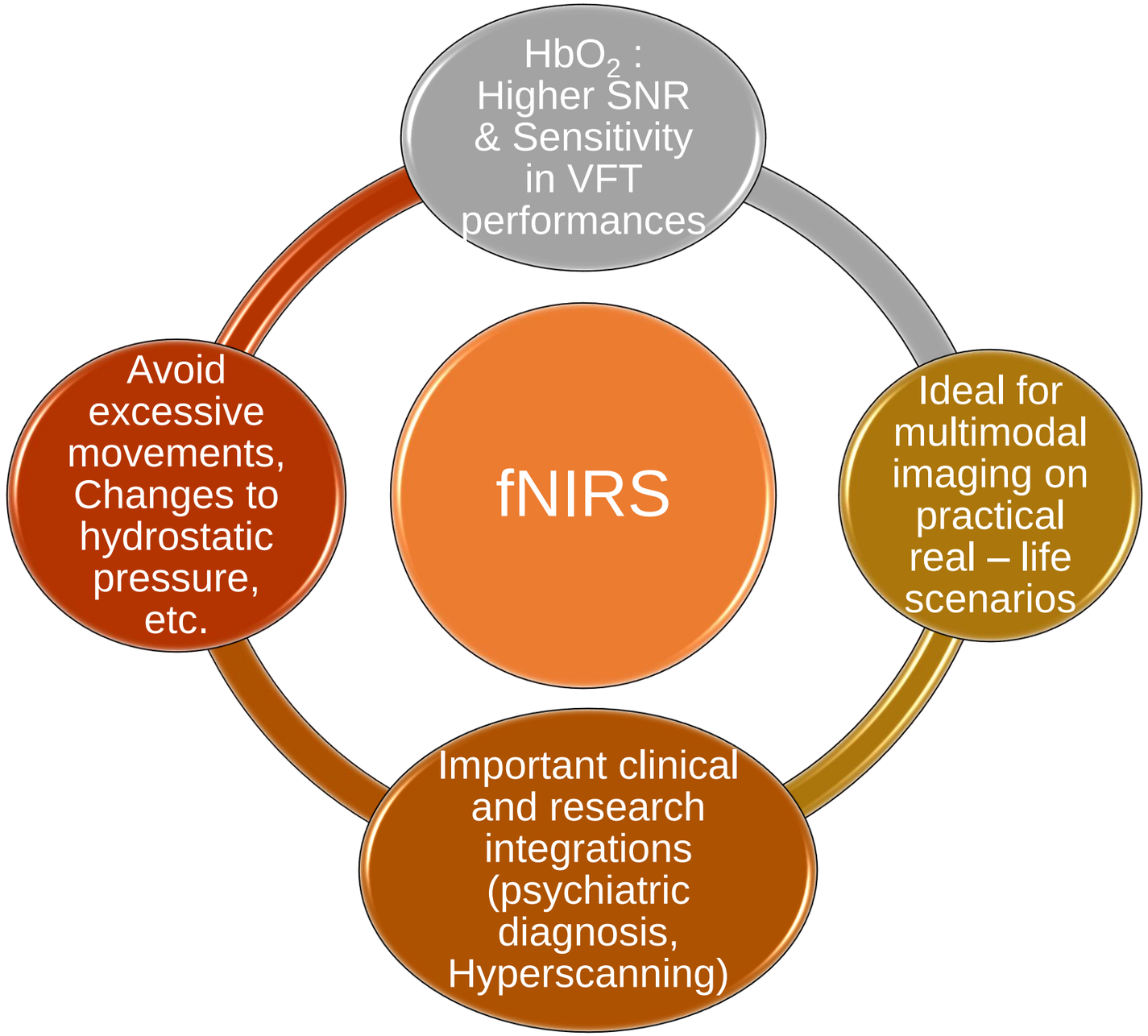



Mean of relative [$HbO_2$] ↑ in dominant majority of recording optodes (OP) between Baseline (BS1) & Task. Statistically significant differences, between BS1 – Task Period, were observed in serious majority of optodes.

| | | | | |
|---|---|---|---|---|
| OP1_RAPM1-OP9_RAPM1 | -1270.962 | 120.008 | -10.591 | <.001 |
| OP1_RAPM1-OP13_RAPM1 | -1286.140 | 120.008 | -10.717 | <.001 |
| OP1_RAPM1-OP11_RAPM1 | -1286.387 | 120.008 | -10.719 | <.001 |
| OP1_RAPM1-OP9_BS1 | 1295.755 | 146.980 | 8.816 | <.001 |
| OP1_RAPM1-OP13_BS1 | 1303.905 | 146.980 | 8.871 | <.001 |
| OP1_RAPM1-OP15_RAPM1 | -1305.868 | 120.008 | -10.881 | <.001 |
| OP1_RAPM1-OP7_BS1 | 1319.545 | 146.980 | 8.978 | <.001 |
| OP1_RAPM1-OP11_BS1 | 1340.508 | 146.980 | 9.120 | <.001 |
| OP1_RAPM1-OP15_BS1 | 1346.105 | 146.980 | 9.158 | <.001 |
| OP1_RAPM1-OP5_BS1 | 1371.248 | 146.980 | 9.330 | <.001 |
| OP1_RAPM1-OP1_BS1 | 1651.855 | 146.980 | 11.239 | <.001 |
| OP5_RAPM1-OP7_RAPM1 | -39.457 | 120.008 | -.329 | .742 |
| OP5_RAPM1-OP3_BS1 | 165.572 | 146.980 | 1.126 | .260 |
| OP5_RAPM1-OP3_RAPM1 | 169.938 | 120.008 | 1.416 | .157 |
| OP5_RAPM1-OP9_RAPM1 | -284.658 | 120.008 | -2.372 | .018 |
| OP5_RAPM1-OP13_RAPM1 | -299.837 | 120.008 | -2.498 | .012 |
| OP5_RAPM1-OP11_RAPM1 | -300.083 | 120.008 | -2.501 | .012 |
| OP5_RAPM1-OP9_BS1 | 309.452 | 146.980 | 2.105 | .035 |
| OP5_RAPM1-OP13_BS1 | 317.602 | 146.980 | 2.161 | .031 |
| OP5_RAPM1-OP15_RAPM1 | -319.565 | 120.008 | -2.663 | .008 |
| OP5_RAPM1-OP7_BS1 | 333.242 | 146.980 | 2.267 | .023 |
| OP5_RAPM1-OP11_BS1 | 354.205 | 146.980 | 2.410 | .016 |
| OP5_RAPM1-OP15_BS1 | 359.802 | 146.980 | 2.448 | .014 |
| OP5_RAPM1-OP5_BS1 | 384.945 | 146.980 | 2.619 | .009 |
| OP5_RAPM1-OP1_BS1 | 665.552 | 146.980 | 4.528 | <.001 |
| OP7_RAPM1-OP3_BS1 | 126.115 | 146.980 | .858 | .391 |

# 8. Conclusions





# 9. References


- fNIR Near Infrared Spectroscopy Prefrontal Cortex Monitoring | Research | BIOPAC, n.d. . BIOPAC Systems, Inc. URL https://www.biopac.com/application/fnir-functional-near-infrared-optical-brain-imaging/ (accessed 6.11.24).
- Kumar, V., Shivakumar, V., Chhabra, H., Bose, A., Venkatasubramanian, G., Gangadhar, B.N., 2017. Functional near infra-red spectroscopy (fNIRS) in schizophrenia: A review. Asian Journal of Psychiatry 27, 18–31. https://doi.org/10.1016/j.ajp.2017.02.009
- Li, R., Yang, D., Fang, F., Hong, K.-S., Reiss, A.L., Zhang, Y., 2022. Concurrent fNIRS and EEG for Brain Function Investigation: A Systematic, Methodology-Focused Review. Sensors 22, 5865. https://doi.org/10.3390/s22155865
- Li, W., Zhang, Z., Li, Z., Gui, Z., Shang, Y., 2023. Correlation and asynchronization of electroencephalogram and cerebral blood flow in active and passive stimulations. J. Neural Eng. 20, 066007. https://doi.org/10.1088/1741-2552/ad0a02
- Pinti, P., Tachtsidis, I., Hamilton, A., Hirsch, J., Aichelburg, C., Gilbert, S., Burgess, P.W., 2020. The present and future use of functional near-infrared spectroscopy (fNIRS) for cognitive neuroscience. Annals of the New York Academy of Sciences 1464, 5–29. https://doi.org/10.1111/nyas.13948
- Toichi, M., Findling, R.L., Kubota, Y., Calabrese, J.R., Wiznitzer, M., McNamara, N.K., Yamamoto, K., 2004. Hemodynamic differences in the activation of the prefrontal cortex: attention vs. higher cognitive processing. Neuropsychologia 42, 698–706. https://doi.org/10.1016/j.neuropsychologia.2003.08.012
- Wei, Y., Chen, Q., Curtin, A., Tu, L., Tang, X., Tang, Y., Xu, L., Qian, Z., Zhou, J., Zhu, C., Zhang, T., Wang, J., 2021. Functional near-infrared spectroscopy (fNIRS) as a tool to assist the diagnosis of major psychiatric disorders in a Chinese population. Eur Arch Psychiatry Clin Neurosci 271, 745–757. https://doi.org/10.1007/s00406-020-01125-y