

FMRI Correlates of Dynamic Low Frequency Photoplethysmography (PPG) and Arterial Pressure Measures

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INTRODUCTION

- Photoplethysmography (PPG) measures light absorption from blood at the fingertip and exhibits temporal patterns that resemble fMRI signals¹²³.
- The PPG waveform contains a **non-pulsatile component** below 0.1 Hz, associated with **sympathetic nervous activity** and **Mayer waves**⁴³.
- Non pulsatile component is often referred as **low frequency oscillations (LFO)**.
- **Mean Arterial Pressure (MAP)**, derived from tissue displacement via a finger cuff, contains signal features that are distinct yet physiologically linked to PPG.
- This study compares LFO and MAP signals producing **delay and correlation maps** to explore their cerebral influence.

METHODS

→ Participants

11 healthy adults
(mean age: 26.4 ± 3.0 years; 5 females)

→ MRI Acquisition

7T multiband fMRI
Resting-state scan duration: 14.8 ± 2.0 minutes
Parameters: TR = 0.75s, TE = 25ms, voxel size = 2mm isotropic, 68 slices (whole-brain coverage)

→ fMRI Preprocessing (afni_proc.py)

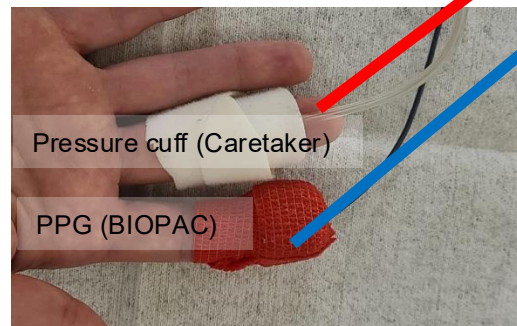
Motion correction, Bandpass filtering (0.01–0.1 Hz), Normalization to MNI space

→ Physiological Signal Recording

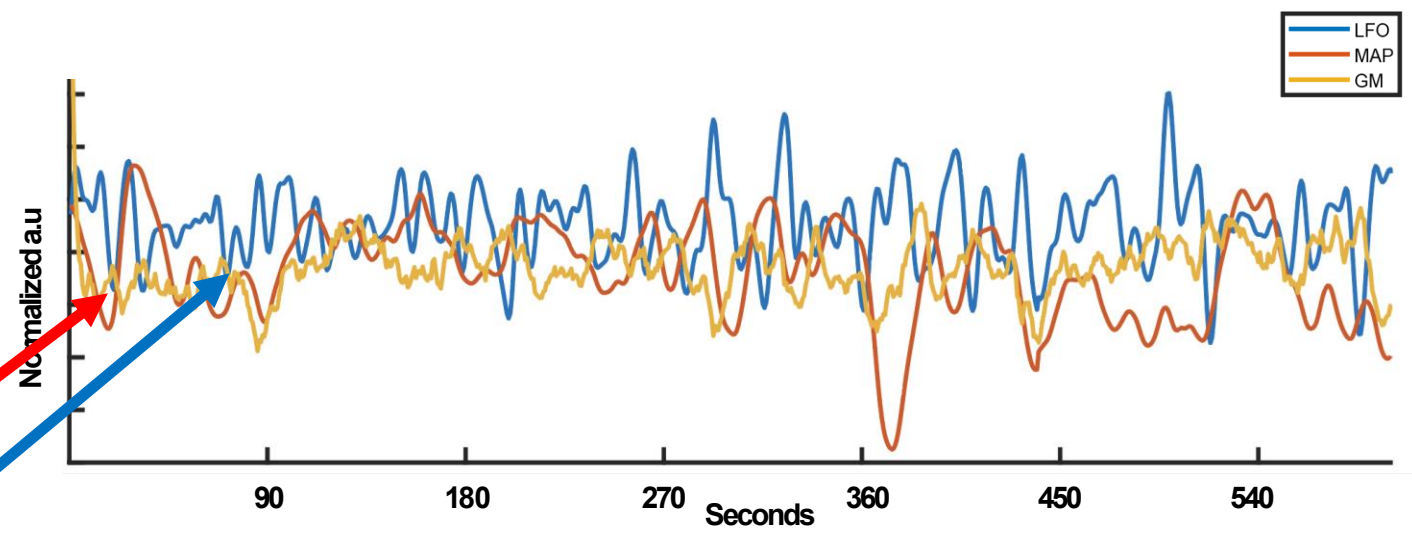
PPG: Acquired via BIOPAC MP160 pulse oximeter
Processed with 4th order Chebyshev filter (cutoff = 0.1 Hz) to derive LFO regressor
MAP: Measured concurrently using CareTaker continuous BP monitor
Validated against invasive BP measurements⁵⁶

→ Voxel-wise delay and correlation analysis using Raptitude software⁷

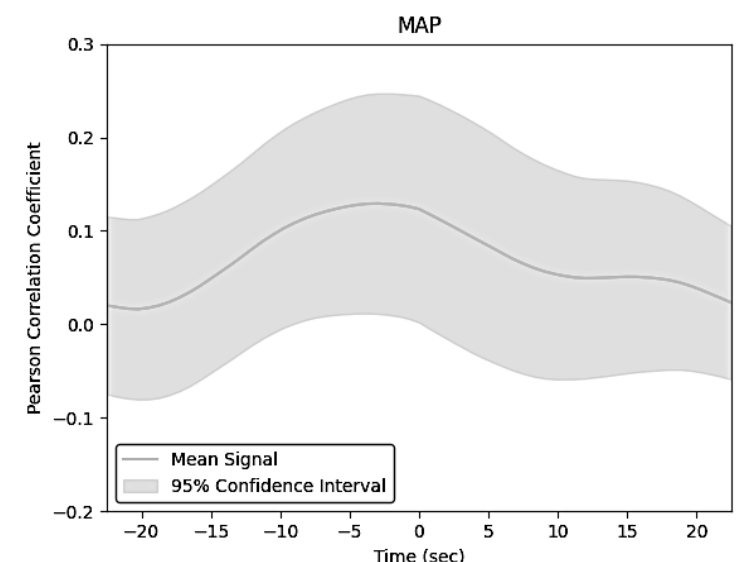
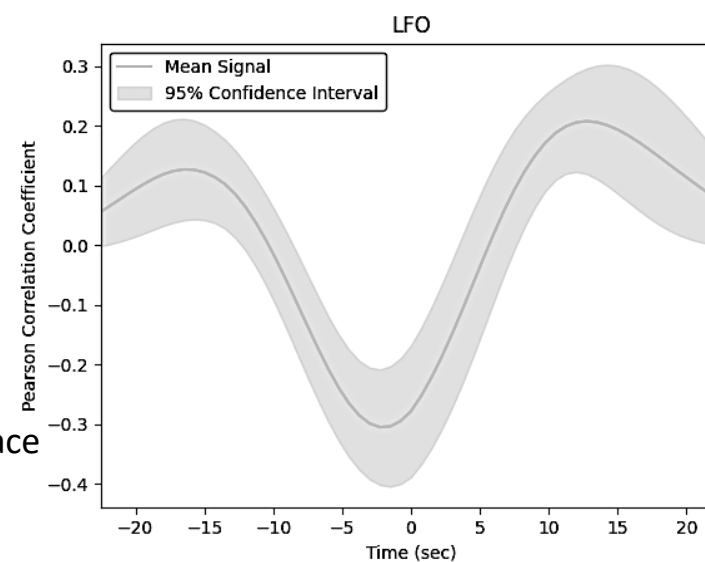
Temporal shifting of physiological regressors in 0.15s steps across a range of -10s to +30s



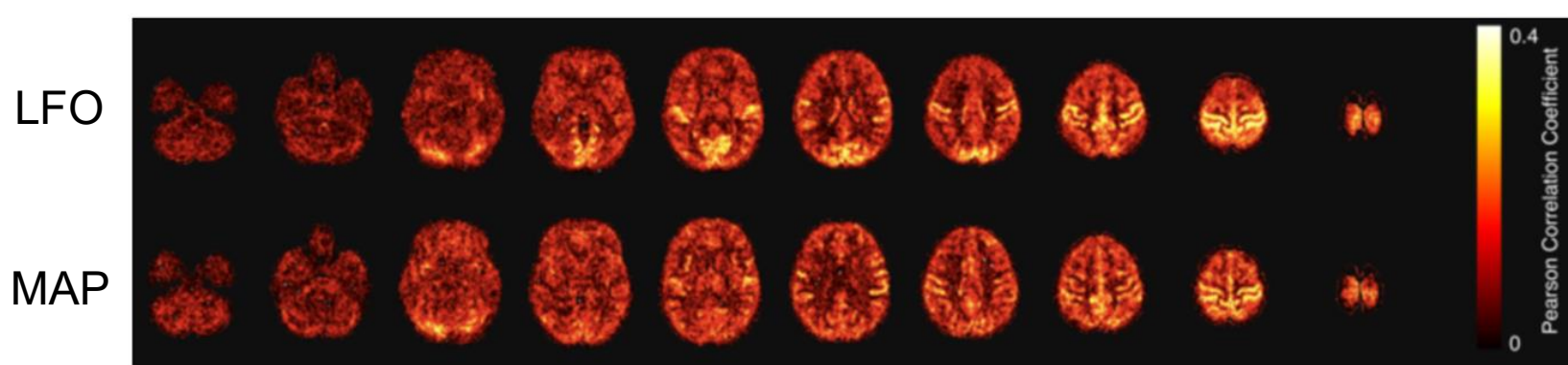
Physio recordings from two fingers: White pressure cuff is recording arterial blood pressure and optical sensor fixated with red tape is PPG sensor from BIOPAC



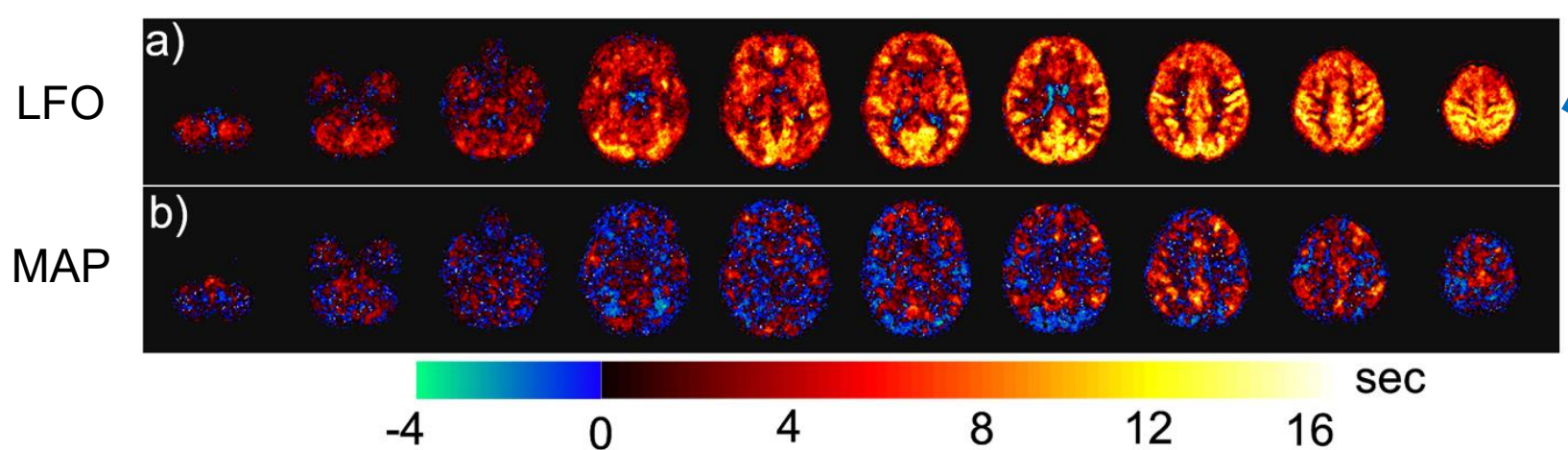
Sample physi traces: Blue one is recorded by PPG and low pass filtered 0.1Hz, red one is mean arterial pressure, and yellow one is averaged gray matter signal from same subject



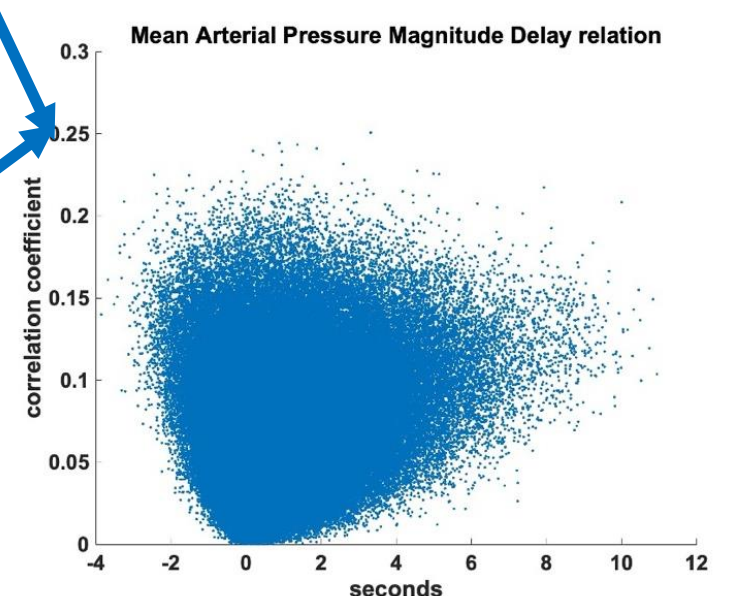
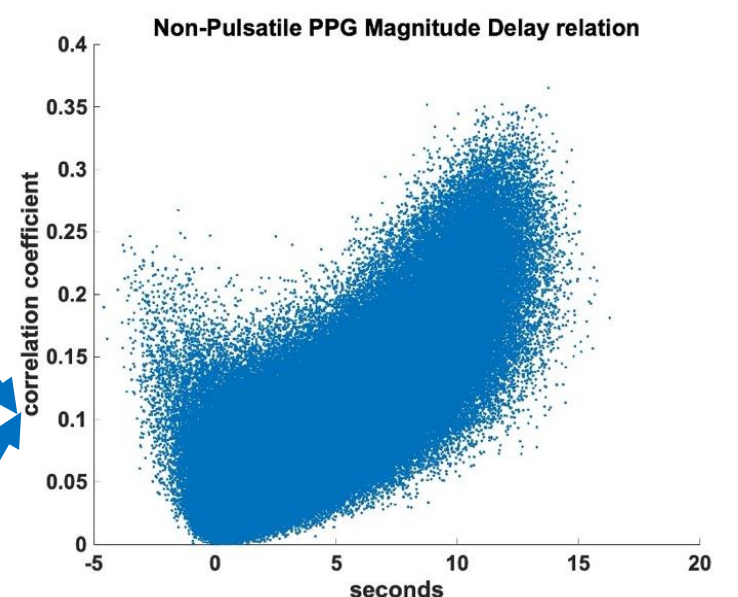
Group averaged cross correlation: The left one shows cross correlation between low frequency part of PPG and average gray matter signal. On the right, cross correlation between mean arterial pressure and average gray matter signal. Highest correlation of LFO corresponds to 12.5 seconds, while dip was around 2 seconds. MAP has peak at -3 seconds. All these measures are relative to finger sensors.



Group level maximum correlation maps: On top, correlation map of non pulsatile part of PPG is shown, bottom one is for mean arterial pressure, these maps are calculated based on optimal delay that maximizes the correlation value between voxel and physiological traces recorded from finger.



Group level delay maps: a), delay map of non pulsatile part of PPG is shown, b) is for mean arterial pressure, these maps are calculated based on optimal delay that maximizes the correlation value between voxel and physiological traces recorded from finger.



Magnitude Delay relation: Top one is for LFO in other words non pulsatile PPG, it shows long lasting delays with increasing correlation, bottom one is for MAP its magnitude is not much time dependent

CONCLUSIONS

- **LFO and MAP exhibit distinct spatiotemporal signatures**, each reflecting unique physiological mechanisms.
- These fluctuations may relate to:
 - **Vascular density and patency**
 - **Flow velocity and sympathetic tone**
 - **Cerebral autoregulation** and broader **homeostatic processes**
- Their spatial distributions align with **major brain networks** such as:
 - **Default mode network (DMN)**
 - **Dorsal attention network**
 - **Visual and sensorimotor networks**

→ This differentiation suggests complementary roles for LFO and MAP in understanding fMRI signals.

→ Future work will modulate these signals to explore causality, potentially providing deeper insight into BOLD signal fluctuations enhancing clinical applications and improving functional connectivity analysis by more effectively removing nuisance signals

RESULTS

- LFO and MAP are mildly anti-correlated ($r \approx -0.15$)
- LFO produces **wider, stronger and long lasting** delay maps than MAP
- MAP delays are **narrow, weak and short** aligned with rapid perfusion zones
- LFO and MAP has two different spatiotemporal propagation patterns.

REFERENCES

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