Imaging Oxygen Consumption with Near-Infrared Spectroscopy and fMRI simultaneously

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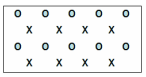
1. INTRODUCTION

The ability to observe functional activation of the human brain with high spatial and temporal resolutions has been advancing with the development of new imaging techniques. Electroencephalography and magnetoencephalography provide information that can be directly related to neuronal activity. On the other hand, functional magnetic resonance and diffuse optical imaging reflect hemodynamic changes. The coupling between neuronal information and hemodynamics is a subject of great interest. For instance, some studies have shown that the hemodynamic response may vary nonlinearly with neuronal activity, but the relative change of the cerebral metabolic rate of oxygen ($rCMRO_2$) may be linearly proportional to neuronal activity. This encourages the development of accurate measures of $rCMRO_2$ with good spatio temporal resolution.

2. EXPERIMENTAL SET-UP

Optical

- Continuous Wave System (CW4, TechEn Inc.)
- 8 sources, 10 detectors = 48 channels
- 3 cm SD distance



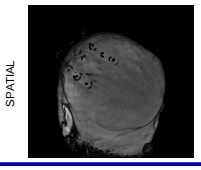
MRI

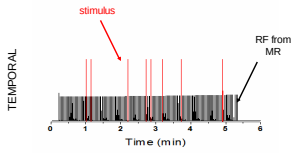
- 3 T Siemens Allegra MR Scanner (Siemens Medical Systems)
- pulsed Arterial Spin Labeling (pASL) sequence
  - PICORE labeling geometry with Q2TIPS saturation (700 ms)
  - 10 slices, 3.5 x 3.5 x 5.0 mm^3, interleaved acquisition
  - TR/TE/α = 2s/20ms/90º

Protocol

- Median nerve stimulation: event-related, 3 Hz, 4 sec, motor-threshold
- 30 – 50 trials into 4 – 7 runs, 6 min each
- 7 subjects, healthy, right-handed, male, mean age (28 ± 4) y.o.

Correlations



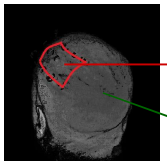


3. DETERMINATION OF $CMRO_2$

Theory

$$\frac{\Delta BOLD}{BOLD_0} \simeq M \cdot \left[1 - \left(\frac{OEF}{OEF_0}\right)^{\beta} \left(\frac{CBF}{CBF_0}\right)^{\alpha}\right]$$

$$\frac{OEF}{OEF_0} = \frac{q}{v} + \frac{\tau_0}{f_{in}(t)}\left[\frac{dq}{dt} - \frac{q}{v}\frac{dv}{dt}\right]$$



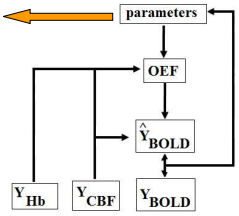
optical + fMRI: estimation of *M*

fMRI only: OEF, then $CMRO_2$

Optical to calibrate BOLD

Pseudo-Bayesian Approach

4 parameters
τ, α, β, M

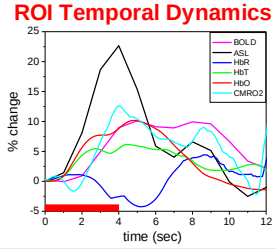


M that best fits data

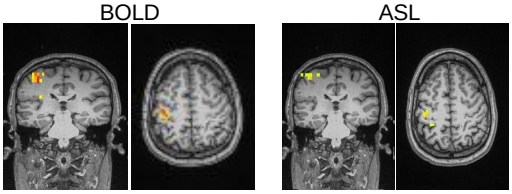
$CMRO_2$ for every voxel

4. RESULTS

ROI Temporal Dynamics



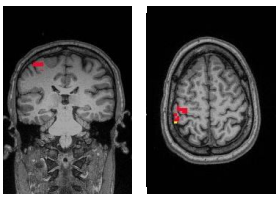
Activation maps



$CMRO_2$ maps

***M* best fit:**
(0.25 ± 0.03)

τ = 0.8
α = 0.38
β = 1.52



5. Conclusions

This study has shown the possibility of getting $CMRO_2$ images from simultaneous measurements of NIRS and fMRI. By using a pseudo Bayesian approach we were able to calibrate fMRI and estimate *M* from combined optical data. We believe metabolic maps will help understanding the physiology of the evoked potential and might be a more robust tool for understanding the neuro vascular metabolic coupling. However, the validation of the technique is needed and we are working on hypercapnia experiments before proceeding with the advantages the present method might bring to the neuroscience field.

Acknowledgments

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