Integrated Systems & NeuroImaging Lab

How to Co-Position EEG Electrodes and fNIRS Optodes in Multi-Modal Functional Brain Imaging Experiments?

Li Zhu, Ali E. Haddad, Tianjiao Zeng, Yunqi Wang and Laleh Najafizadeh

Integrated Systems and NeuroImaging Laboratory
Department of Electrical and Computer Engineering, Rutgers University

RUTGERS School of Engineering

DARPA

SIEMENS Healthcare

Motivation

- Multi-modal imaging of the human brain function offers a unique opportunity to simultaneously study the brain function across multiple spatial and temporal scales.
- One such approach is to combine *Electroencephalography (EEG)* and *functional Near-Infrared Spectroscopy (fNIRS*). EEG measures the electrical activity related to active neurons, on the scalp, offering high temporal resolution (ms) with relatively modest spatial resolution (cm). fNIRS on the other hand, uses light in the near infrared range, to measure the local changes in the oxyhemoglobin and deoxyhemoglobin concentrations associated with brain activity.
- Combining high-density array EEG with fNIRS in a multi-modal imagin setting, would enable observing the brain function simultaneously from two perspectives, and thus provides an appropriate tool for studying spatio-temporal relationship between neuronal activity and vascular response.
- In this work, through simulations and experiments, we investigate the impact of different arrangements for co-positioning of EEG electrodes and fNIRS optodes on some aspects of multi-modal analysis.

EEG-fNIRS Electrode-Optode Arrangements

- EEG electrodes and fNIRS optodes can be co-positioned in three ways:
  - ***integrated:*** where the EEG electrodes are co-located with fNIRS optodes (Fig. 1-a)
  - ***proximity:*** where the EEG electrodes are placed in the proximit of fNIRS channels and optodes (Fig. 1-b)
  - ***aligned:*** where the EEG electrodes are placed half the distance from the source and detector positions (Fig. 1-c)

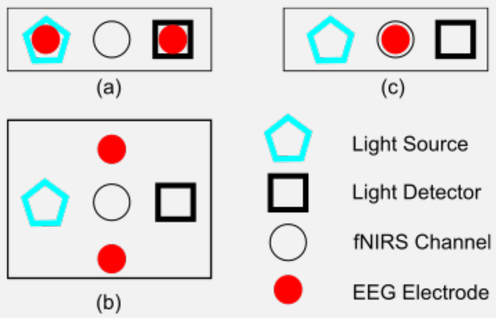

Fig. 1. Possible EEG Electode/fNIRS optode configuration.

Simulation Results

- **Simulation Setup:** assuming the active region is located under the fNIRS channel, we investigate the performance of source localization in detecting activities in the source space from EEG recordings, for two EEG-fNIRS configurations.

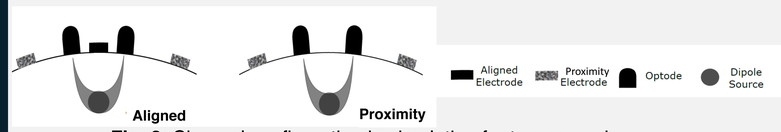

Fig. 2. Channel configuration in simulation for two scenarios.

– **Simulation Result:**

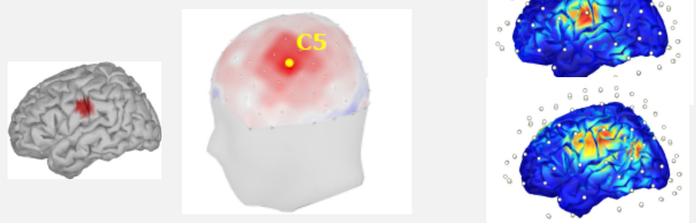

Fig. 3. *Left*: simulated dipole cluster (radius = 1 cm) on the cortex, with its centre located under "C5". *Centre*: Projected topography of the scalp field potential. *Right:* Recovered dipole activation topographies on the cortex, using *aligned* configuration (top) and proximity configuration (bottom).

Experimental Procedure

- 10 healthy male volunteers
- EEG *(Brain Vision)*:
  - 32 channels
  - 5 kHz sampling rate
- fNIRS *(NIRx-NIRScout)*:
  - 8 sources, 8 detectors
  - 14 channels
  - 12.5 Hz sampling rate

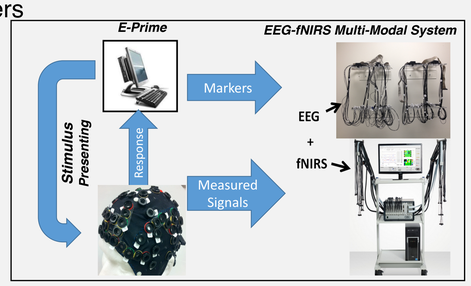

Fig. 4. Experimental setup.

Paradigm

- Event related design
  - 60 "Go", 30 "NoGo" stimuli
  - ITI=11-14 s
  - Mouse click when "Go"
  - Do NOT click when "No-Go"

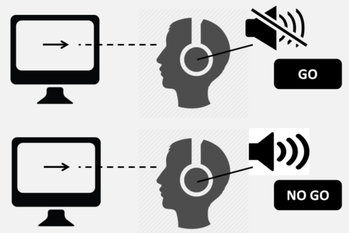

Fig. 5. Go/No-Go task.

Experimental Result

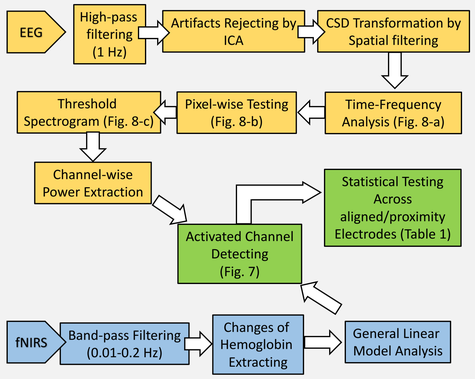

Fig. 6. Overview of data analysis procedure.

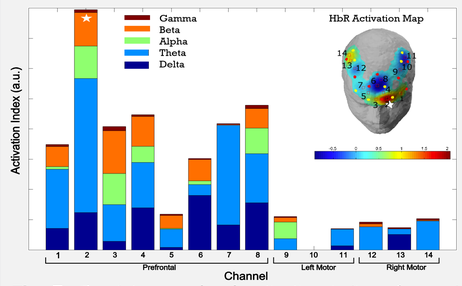

Fig. 7. *Barplot:* group-level activation indices for each frequency band and each EEG electrode, *3D brain activation map:* group-level activation patterns based on GLM using $\Delta[\mathrm{HbR}]$ signals.

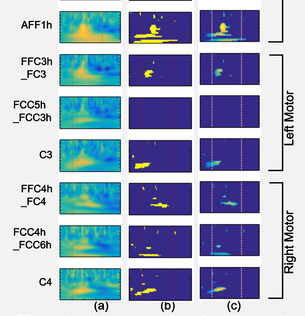

Fig. 8. (a) group-level differential spectrograms, (b) *t*-maps to identify the No-Go-specific power, and (c) thresholded group-level differential spectrograms.

Table 1. Paired-sample one-tail student's *t*-tests (* p<0.05, ** p<0.01)

Channel to Compare	Label	Scalp Distance to Fp1 (cm)	Delta	Theta	Alpha	Beta	Gamma	**Total**
1	AF7	3.5	1.590	**2.641** *	**0.013** *	**2.204** *	1.451	**2.912** **
3	Fpz	3	**2.217** *	**2.930** **	0.219	-1.157	-1.794	**2.576** *
4	AFp1	2.2	0.631	**2.960** **	**2.357** *	0.795	**2.186** *	**2.461** *
5	AFp2	5	**2.441** *	**3.034** **	**2.699** *	**2.699** *	1.806	**3.312** **
6	AFz	4.5	-0.980	**2.932** **	**2.627** *	**2.090** *	**2.203** *	**2.294** *
7	AF4	7	0.966	1.070	**2.696** *	**3.228** **	**2.174** *	**2.121** *
8	AFF1h	5.5	-0.621	**2.682** *	0.823	**2.371** *	-0.478	**2.142** *

Conclusion

- Results from both simulation and experimental studies reveal that overlapping the position of EEG electrodes with the position of fNIRS channels appears to be the best configuration choice, when outcome of fNIRS modality is used for localizing the active regions.
- The outcome of this study can be used as a guideline for designing and planning EEG-fNIRS multi-modal experiments.