Simultaneous Acquisition of EEG and NIRS during Cognitive Tasks for an Open Access Dataset

We provide an open access multimodal brain-imaging dataset of simultaneous electroencephalography (EEG) and near-infrared spectroscopy (NIRS) recordings. Twenty-six healthy participants performed three cognitive tasks: 1) n-back (0-, 2- and 3-back), 2) discrimination/selection response task (DSR) and 3) word generation (WG) tasks. The data provided includes: 1) measured data, 2) demographic data, and 3) basic analysis results. For n-back (dataset A) and DSR tasks (dataset B), event-related potential (ERP) analysis was performed, and spatiotemporal characteristics and classification results for "target" vs. "non-target" (dataset A) and symbol "O" vs. symbol "X" (dataset B) are provided. Time-frequency analysis was performed to show the EEG spectral power to differentiate the task-relevant activations. Spatiotemporal characteristics of hemodynamic responses are also shown. For the WG task (dataset C), the EEG spectral power and spatiotemporal characteristics of hemodynamic responses are analyzed, and the potential merit of hybrid EEG-NIRS BCIs was validated with respect to classification accuracy. We expect that the dataset provided will facilitate performance evaluation and comparison of many neuroimaging analysis techniques.

Data Acquisition

All EEG and NIRS signals were recorded simultaneously. For timing synchronization, triggers were sent to both EEG and NIRS equipment simultaneously via a parallel port using MATLAB.

EEG data was recorded using a multichannel BrainAmp EEG amplifier (Brain Products GmbH, Gilching, Germany) at a sampling rate of 1000 Hz. Thirty EEG active electrodes were placed on a stretchy fabric cap (EASYCAP GmbH, Herrsching am Ammersee, Germany) according to the international 10-5 system (Fp1, Fp2, AFF5h, AFF6h, AFz, F1, F2, FC1, FC2, FC5, FC6, Cz, C3, C4, T7, T8, CP1, CP2, CP5, CP6, Pz, P3, P4, P7, P8, POz, O1, O2, TP9 (reference) and TP10 (ground)). The EEG amplifier was also used to measure the electrooculogram (EOG). EOG was recorded using two vertical (above and below the right eye) and two horizontal (outer canthus of each eye) disposable electrodes at the same sampling rate as the EEG data.

NIRS data was acquired with a NIRScout (NIRx Medizintechnik GmbH, Berlin, Germany) at a sampling rate of 10.4 Hz. Sixteen sources and sixteen detectors were placed at frontal (sixteen channels around AFz, AF3, AF4, AF7 and AF8), motor (four channels each around C3 and C4), parietal (four channels each around P3 and P4), and occipital (four channels around POz) areas. An adjacent source-detector pair configures a NIRS channel; 36 channels were configured. The NIRS channels, each of which was composed of a pair of a source and a detector, were created around AFpz, AFp3, AFp4, AFp7, AFp8, AF1, AF2, AF5h, AF6h, AF7, AF8, AFFz, AFF3h, AFF4h, AFF5h, AFF6, FCC3, FCC4, C3h, C4h, C5h, C6h, CCP3, CCP4, CPP3, CPP4, P3h, P4h, P5h, P6h, PPOz, PPO3, PPO4, PO1, PO2, and POOz according to the international 10-5 system. The source-detector distance was set to 30 mm for all the channels. NIRS optodes were fixed on the same cap as the EEG electrodes. Figure 2 shows the locations of the EEG and NIRS channels. Yellow and red circles denote the location of the EEG and NIRS channels, respectively. EEG electrodes are relatively uniform in their distribution over the whole head. Reference and ground electrodes are located at TP9 and TP10, respectively. NIRS channels are located on (pre)frontal (sixteen channels), motor (four channels around C3 and C4 each), parietal (four channels around P3 and P4 each), and occipital areas (four channels around POz).

Structural information

- Locations of EEG channels in Cartesian coordinate system

clab	X	Y	Z
Fp1	-0.3090	0.9511	0.0001
AFF5h	-0.5417	0.7777	0.3163
AFz	0.0000	0.9230	0.3824
F1	-0.2888	0.6979	0.6542
FC5	-0.8709	0.3373	0.3549
FC1	-0.3581	0.3770	0.8532
T7	-1.0000	0.0000	0.0000
C3	-0.7066	0.0001	0.7066
Cz	0.0000	0.0002	1.0000
CP5	-0.8712	-0.3372	0.3552
CP1	-0.3580	-0.3767	0.8534
P7	-0.8090	-0.5878	-0.0001
P3	-0.5401	-0.6724	0.5045
Pz	0.0000	-0.7063	0.7065
POz	0.0000	-0.9230	0.3824
O1	-0.3090	-0.9511	0.0000
Fp2	0.3091	0.9511	0.0000
AFF6h	0.5417	0.7777	0.3163
F2	0.2888	0.6979	0.6542
FC2	0.3581	0.3770	0.8532
FC6	0.8709	0.3373	0.3549
C4	0.7066	0.0001	0.7066
T8	1.0000	0.0000	0.0000
CP2	0.3580	-0.3767	0.8534
CP6	0.8712	-0.3372	0.3552
P4	0.5401	-0.6724	0.5045
P8	0.8090	-0.5878	-0.0001
O2	0.3090	-0.9511	0.0000
TP9	-0.8777	-0.2852	-0.3826
TP10	0.8777	-0.2853	-0.3826

- Locations of NIRS channels in Cartesian coordinate system

clab	X	Y	Z
AF7	-0.5878	0.809	0
AFF5	-0.6149	0.7564	0.2206
AFp7	-0.454	0.891	0
AF5h	-0.4284	0.875	0.2213
AFp3	-0.2508	0.9565	0.1438
AFF3h	-0.352	0.8111	0.4658
AF1	-0.1857	0.915	0.3558
AFFz	0	0.8312	0.5554
AFpz	0	0.9799	0.1949
AF2	0.1857	0.915	0.3558
AFp4	0.2508	0.9565	0.1437
FCC3	-0.6957	0.1838	0.6933
C3h	-0.555	0.0002	0.8306
C5h	-0.8311	0.0001	0.5552
CCP3	-0.6959	-0.1836	0.6936
CPP3	-0.6109	-0.5259	0.5904
P3h	-0.4217	-0.6869	0.5912
P5h	-0.6411	-0.6546	0.3985
PPO3	-0.4537	-0.796	0.3995
AFF4h	0.352	0.8111	0.4658
AF6h	0.4284	0.875	0.2212
AFF6	0.6149	0.7564	0.2206
AFp8	0.454	0.891	0
AF8	0.5878	0.809	0
FCC4	0.6957	0.1838	0.6933
C6h	0.8311	0.0001	0.5552
C4h	0.555	0.0002	0.8306
CCP4	0.6959	-0.1836	0.6936
CPP4	0.6109	-0.5258	0.5904
P6h	0.6411	-0.6546	0.3985
P4h	0.4216	-0.687	0.5912
PPO4	0.4537	-0.796	0.3995
PPOz	0	-0.8306	0.5551
PO1	-0.1858	-0.9151	0.3559
PO2	0.1859	-0.9151	0.3559
POOz	0	-0.9797	0.1949

Data Organization

Data Structure

Please refer to basic data structures of the BBCI Toolbox.

EEG data

- **cnt**: continuous EEG data including EOG

cnt_nback: cnt for n-back task (3 sessions are concatenated)

cnt_dsr: cnt for Go/No-go task (3 sessions are concatenated)

cnt_wg: cnt for word generation task (3 sessions are concatenated)

- **mrk**: task onset markers

mrk_nback: mrk for n-back task.

Number	Description	Number	Description
16	0-back target	96	3-back non-target
48	2-back target	112	0-back session
64	2-back non-target	128	2-back session
80	3-back target	144	3-back session

mrk_dsr: mrk for discrimination/selection response task.

Number	Description
16	Go
32	No-go
48	session

mrk_wg: mrk for word generation task.

Number	Description
16	verbal fluency
32	baseline

NIRS data

- **cnt**: continuous NIRS data

cnt_nback: cnt for n-back task (3 sessions are concatenated)

- **.deoxy**: deoxy hemoglobin data

- **.oxy**: oxy hemoglobin data

cnt_dsr: cnt for discrimination/selection response task (3 sessions are concatenated)

- **.deoxy**: deoxy hemoglobin data

- **.oxy**: oxy hemoglobin data

cnt_wg cnt for word generation task (3 sessions are concatenated)

- **.deoxy**: deoxy hemoglobin data

- **.oxy**: oxy hemoglobin data

- **mrk_nback**: mrk for n-back task

Number	Description
7	0-back session
8	2-back session
9	3-back session

- **mrk_dsr**: mrk for discrimination/selection response task

Number	Description
3	DSR session

- **mrk_wg**: mrk for word generation task

Number	Description
1	word generation
2	baseline

Preprocessing

Data was downsampled to 200 Hz (EEG) and 10 Hz (NIRS). Any signal processing method was not applied to the raw data except the methods described below:

EEG: data conversion to MATLAB compatible format

NIRS: data conversion to MATLAB compatible format

Metadata

Demographic data is provided in the supplementary information[2]. Other related metadata could be provided in the rawdata in vendor-specific format.

Citation

We would be grateful if you cite following articles:

1. Shin, Jaeyoung et al. "Simultaneous Acquisition of EEG and NIRS during Cognitive Tasks for an Open Access Dataset." *Scientific Data,* submitted.

2. Shin, Jaeyoung, et al. "Open Access Dataset for EEG+ NIRS Single-Trial Classification." *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 25(10), (2017).

3. Blankertz, Benjamin, et al. "The Berlin brain–computer interface: non-medical uses of BCI technology." *Frontiers in neuroscience* 4 (2010).