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Data in Brief

Data Article

A motor imagery vs. rest dataset with low-cost consumer grade EEG hardware☆

Victoria Peterson [a,*], Catalina Galván [a,b], Hugo Hernández [c], María Paula Saavedra [a], Ruben Spies [a,d]

[a] *Instituto de Matemática Aplicada del Litoral IMAL, CONICET-UNL, Santa Fe 3000, Argentina*
[b] *Facultad de Ingeniería, Universidad Nacional de Entre Ríos, FIUNER, Oro Verde, Entre Ríos 3100, Argentina*
[c] *Instituto de Investigación en Señales, Sistemas e Inteligencia Computacional, CONICET, UNL, Santa Fe 3000, Argentina*
[d] *Departamento de Matemática, Facultad de Ingeniería Química, Universidad Nacional del Litoral, Santa Fe 3000, Argentina*

A R T I C L E   I N F O

A B S T R A C T

The data consist of electroencephalography (EEG) signals acquired by means of low-cost consumer-grade devices from 10 participants (four females, right-handed, mean age $\pm$ SD = 26.1 $\pm$ 4.0 years) without any previous experience in Brain-Computer Interfaces (BCIs) usage. The BCI protocol consisted of two conditions, namely the kinesthetic imagination of grasping movement (motor imagery, MI) of the dominant hand and a rest/idle condition. Five protocol runs were required to be performed by each participant in a single-day session, of about 1.5 h. The first run, called RUN0, involved 5 trials together with the same number of trials in a rest condition. This first run was done to both better explain the protocol and to encourage the participant to focus on the sensation of executing the movement. The rest of the runs (RUN1-RUN4) were identical, consisting of 20 trials for each condition presented in a random order. The electrical brain activity was registered from 15 electrodes covering the sensorimotor area, at a sam-

pling frequency of 125 Hz. Muscle activity of the dominant hand was controlled via the electromyography (EMG) activity by two electrodes placed at two antagonist muscles involved in the flexion/extension of the wrist. The recordings were performed in a non-shielded office, by means of low-cost consumer grade devices and free multi-platform open source software. The EMG corruption level was analyzed and EEG trials for which the EMG activity was higher than a prescribed threshold value, were discarded. During acquisition, EEG data was digitally band-pass filtered between 0.5 and 45 Hz. These data provide a motor imagery vs. rest EEG dataset, relevant for BCI for motor rehabilitation applications. Since the recordings were performed by means of low-cost consumer grade devices in a non-controlled environment, this dataset provides an excellent source for exploring robust brain decoding techniques for future in-home BCI usage.

Specifications Table

Subject	Neuroscience (General)
Specific subject area	Human-computer interaction, Motor imagery, Low-cost brain computer interface.
Type of data	Continuous raw EEG data.
How data were acquired	The EEG signals were acquired by using an Electro-Cap System II (Electrocap, USA) connected to an OpenBCI Cyton + Daisy board (OpenBCI, USA). The sampling frequency of the OpenBCI amplifier was 125 Hz. The number of electrodes was 15. OpenViBE was used for both protocol presentation and data saving.
Data format	BIDs format, one subfolder per participant ID 'edf' files with the continuous raw EEG signal 'tsv' files with participants and channel information 'json' files with description of the dataset, and events. The dataset is available here: https://openneuro.org/datasets/ds003810.
Parameters for data collection	Participants were over 18 years old, did not have any previous experience with brain-computer interfaces commanding, they had no motor disabilities nor central nervous system pathologies. They were cognitively capable and able to give informed consent. People with addiction to alcohol and/or drugs were excluded.
Description of data collection	The data were acquired in a non-shielded office, with a room divider between the technical personnel and the participant. At the beginning of the session each subject was clearly instructed about the mental tasks to be performed. During the experiment, the subject was comfortably seated in front of a computer screen with both arms resting on a desk. In order to ensure kinesthetic (and no visual) MI, the dominant hand was placed inside an opaque cardboard box. Five experimental runs were conducted. During the first one (called RUN0), real hand grasping movements were asked to be performed by the participant. The rest of the runs (RUN1-RUN4) consisted of motor imagery vs. rest conditions.
Data source location	Institution: Instituto de Matemática Aplicada del Litoral, IMAL, CONICET, UNL City/Town/Region: Santa Fe Country: Argentina
Data accessibility	Repository name: OpenNeuro Data identification number: ds003810 Direct URL to data: https://openneuro.org/datasets/ds003810.
Related research article	V. Peterson, C. Galván, H. Hernández, R. Spies, A feasibility study of a complete low-cost consumer-grade brain-computer interface system, Heliyon, 6(3), 2020, https://doi.org/10.1016/j.heliyon.2020.e03425

- Collected data were obtained by means of low-cost EEG acquisition devices in a non-controlled environment, and can be used by machine learning developers willing to test robust methods for natural environment-registered signals.
- Data comprise motor imagery vs. rest tasks from 10 subjects, and it can be used for testing brain decoding models in the context of BCI for hand motor rehabilitation.
- The signal-to-noise ratio varied across the session of each participant, as it can be observed in Fig. 1. This opens an opportunity to evaluate noise artifactual denoising methods.

1. Data Description

This dataset consists of motor imagery vs. rest electroencephalography (EEG) signals acquired in the context of a feasibility study of low-cost Brain Computer Interfaces (BCIs) with applications in motor rehabilitation [1].

The BCI protocol consisted of two conditions, namely the kinesthetic imagination of grasping movement of the dominant hand and rest/idle condition. The recordings were made in one single session, of about 1.5 h, comprising five (5) runs. The first run (RUN0) accounted for five (5) real grasping movement trials and five (5) rest trials. The rest of the runs (RUN1-RUN4) were
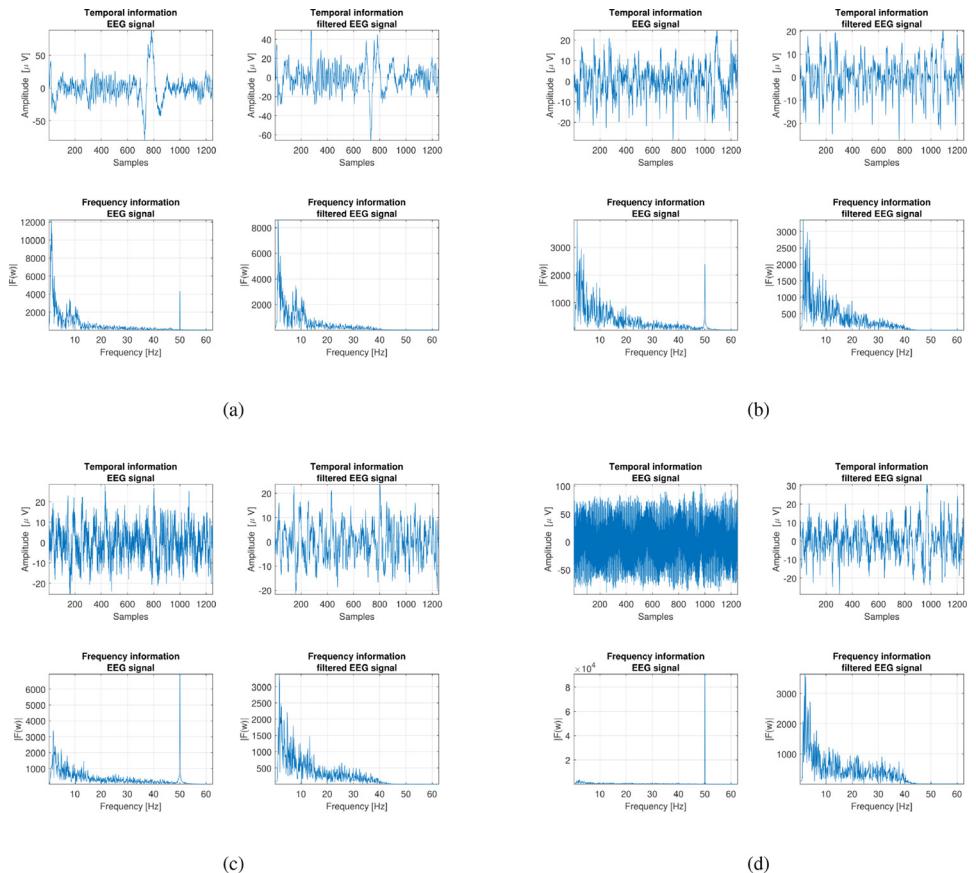

Fig. 1. Time and frequency domain information of four subject's EEG signal showing four different levels of noise artifacts during acquisition. Taken from [1].

Table 1
Demographic information of the participants included in this dataset.

ID	Sex	Age	Dominant hand
S02	Male	28	Right
S03	Female	29	Right
S04	Male	30	Right
S05	Male	29	Right
S06	Male	30	Right
S07	Female	20	Right
S08	Male	25	Right
S09	Female	28	Right
S10	Male	26	Right
S12	Female	22	Right

motor imagery vs. rest runs and contained twenty (20) trials of each class. Thus, each session comprised a total of 160 MI vs. rest trials (80 per each class). The EEG activity was recorded via low-cost devices and open source software. Fifteen (15) electrodes covering the sensorimotor area were used. The sampling frequency was set to 125 Hz. A band-pass digital filter from 0.5 to 45 Hz was used during signal acquisition.

The data storage format follows the BIDs standard [2], thus for each participant three files per run are provided within the subfolder called eeg: a '.tsv' file with the channel information, a '.json' file with information about the recording, like power line, EEG electrodes reference, and sampling frequency, and an '.edf' file containing the raw continuous EEG data. The participants's list and other general information about the dataset can be found in the main folder. Given that for EEG acquisition we used a modified version of the Graz protocol [3] implemented in OpenViBE (see *Experimental Design, Material and Method* section), the events markers for motor imagery and rest appear under the name OVTK_GDF_Right and OVTK_GDF_Tongue, respectively. This information can be found in the file named task_MIvsRest_events.json.

A demo showing how to load and work with the data in MNE-Python [4] is also provided in the /code/ subfolder.

2. Experimental Design, Materials and Methods

2.1. Participants

In total, 12 participants were recruited via email. All of them signed and gave informed consent. Only adults (> 18 years old) with no motor impairments, with the ability to understand and follow simple commands and give informed consent were included. People with previous BCI experience, of known drug or/and alcohol abuse, cognitive impairment or (neuro)motor disabilities were excluded. After signal quality assessment, data from two participants were discarded (see *Trial rejection due to EMG activity*). Thus, this dataset comprises recording from 10 naive BCI users without any motor impairment (four females, right-handed, mean age $\pm$ SD = 26.1 ± 4.0 years). Table 1 shows a complete description of the dataset's demographic information.

2.2. Registered Signals

For the assessment and quality control of the recorded brain activity (EEG), the electrical activity of two antagonistic muscles (EMG) involved in the wrist flexion/extension movement (flexor digitorum superficialis and extensor digitorum) were also registered during the experimental session. This was done to ensure that the observed brain (de)synchronizations within
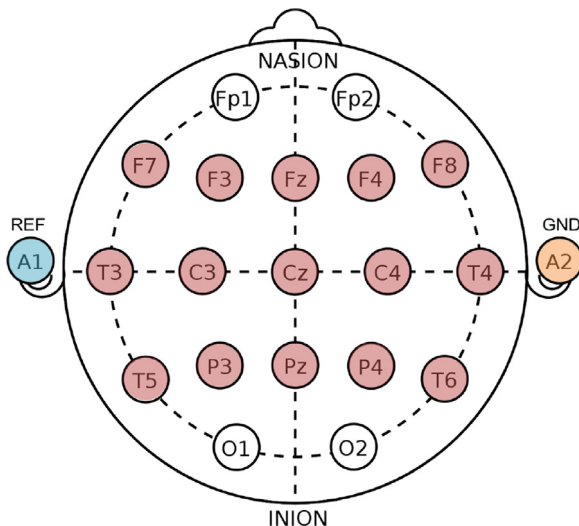
Fig. 2. Electrode configuration used during EEG acquisition. Red colored circles illustrate the position of the EEG electrodes. The A1 (left ear lobe) and the A2 (right ear lobe) electrodes were used as reference and ground, respectively. Taken from [1].

the MI period were not a consequence of voluntary or involuntary movements of the participant's hand.

2.3. Hardware and Software

Low-cost amplifiers and free multi-platform software were used for the data recording. The EEG signals were acquired by using an Electro-Cap System II (Electrocap, USA) connected to an OpenBCI Cyton + Daisy board (OpenBCI, USA). The cap followed a 10-20 international electrode placement montage. Fifteen (15) electrodes covering the sensorimotor cortex (Fz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, Pz, P3, P4, T5, T6) were selected. The reference and ground electrodes were placed at the left and right ear lobes, respectively (see Fig. 2). The sampling frequency of the OpenBCI amplifier was 125 Hz. The OpenBCI board was wirelessly connected to a dedicated PC (OS Linux, Intel® Core^{TM} i7-6700K CPU @ 4.00GHz $\times$ 8) by a USB Dongle. The OpenViBE platform, acquisition server and designer, was used for the protocol presentation, visualization and storage of both the EEG signals and the time mark stamps sent by the OpenViBE scenario. During acquisition, the EEG signals were filtered between 0.5 and 45 Hz with a 3rd order Butterworth bandpass-filter.

For the EMG monitoring an Open-BCI Ganglion board (OpenBCI, USA) connected to two MyoWare sensors (Advancer Technologies, USA) were used. The sampling frequency of the amplifier was 200 Hz. The MyoWare sensors were located at two forearm antagonist muscles, compromised in wrist flexion and extension movement. Disposable pre-gelled Ag-AgCl foam electrodes were employed. Due to stability problems for simultaneous acquisition of both EEG and EMG, the Ganglion board was wirelessly connected to another dedicated laptop (OS Windows 10, Intel® Core^{TM} i7-6500U CPU @ 2.50GHz $\times$ 2), where the OpenBCI GUI was running for visualization and storage of the EMG signals. Care was taken in manually synchronizing the EMG and EEG data recording.
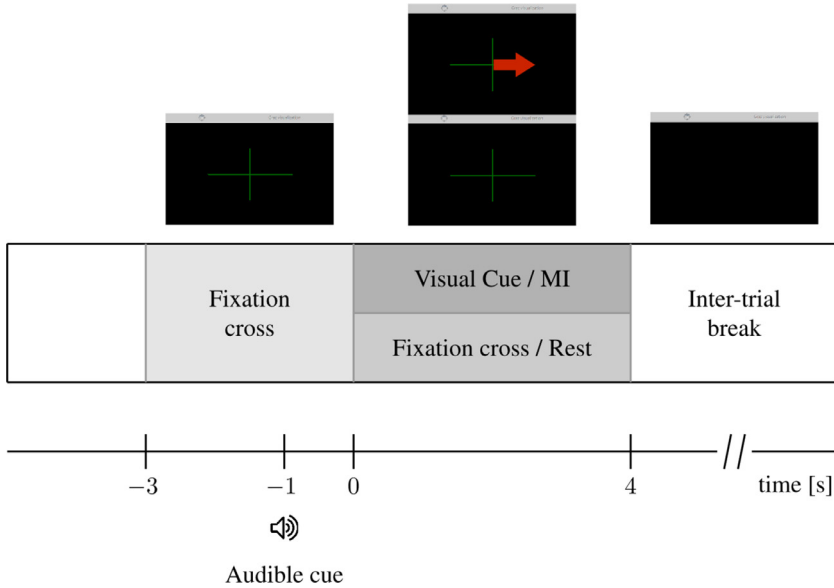
Fig. 3. Schematic representation of experimental protocol. Timing references are in seconds, and referred to the trial onset ($t = 0$). Figure taken from [1].

2.4. Stimuli

The OpenViBE software was used to present the experimental paradigm to the participants. The exemplary scenario *motor-imagery-bci-1-acquisition.xml* of OpenViBE was modified by changing the parameters of the LUA stimulator[1]. Auditory cues were used to get the participants attention before the beginning of a new trial. A red right arrow was used as visual cue to indicate that a mental imagery of the hand movement should be performed by the participant, while a no appearance of any visual cue indicated a rest trial. Due to these modifications, markers were sent as `OVTK_GDF_Right` and `OVTK_GDF_Tongue`, for MI and Rest, respectively.

2.5. Trials and Experimental Protocol

Each trial of the stimulation protocol began with a fixation cross ($t = -3$ s), followed by an audible beep cue two seconds later ($t = -1$ s). At $t = 0$ s, the subjects were asked to imagine either grasping movements of the dominant hand or just to relax for a period of 4 s. The visual cue, a red arrow pointing to the right, was presented only for the MI trials. The subjects were asked to carry out the MI task until the red arrow disappeared from the screen. No feedback whatsoever was provided at any stage. Between trials, a break of random duration (between 2.5 and 4.5 s) followed. At the end of each run, the subject was allowed to distend and relax for a longer period of time (> 2 min), until he/she felt comfortable to continue. An schematic representation of a trial, with time references, is shown in Fig. 3.

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[1] see http://openvibe.inria.fr/documentation/2.0.0/Doc_BoxAlgorithm_LuaStimulator.html

Procedure

The participants were contacted via email. Once the experiment date was established, a digital copy of the protocol description and informed consent was sent to them for being read beforehand. On the day of the experiment, the participants were asked to read the informed consent again. Private time was given to them to do so. Questions about the protocol were answered, if any. Only once the consent was signed and given by the participants, the experiment followed.

Seated on a comfortable chair, the participants were instructed about the different runs that the protocol comprised. The importance of performing a kinesthetic and not a visual motor imagery task was stressed. A questionnaire for assessing the motor imagery ability of the participant was performed. This questionnaire comprised five kinesthetic mental exercises of the KVIQ-10 questionnaire [5], which movements were previously explained and shown by the experimenter.

Once the questionnaire was completed, the EMG signal preparation followed. The skin of the forearm was prepared by rubbing it with alcohol. Then, in order to place the electrodes as accurateñy as possible, the participant was asked to make the wrist flexion/extension movement in a dramatic manner. This helped the experimenter to better find the center of the agonist and antagonist muscle involved in the hand movement. Two electrodes were placed per muscle. The ground electrode per each measured muscle was placed as far as possible from it. The OpenBCI GUI was used in this stage to visually inspect the quality of the EMG signals. If at this point the EMG activity was not properly captured, this procedure was started over from the beginning.

In order to know which EEG cap size (M or L) the participant corresponded to, the head diameter was measured by a flexible tape measure. Heads whose diameter were lower than 58 cm corresponded to an M cap size. Once the cap was placed on the head, the experimenter checked if the Cz electrode was placed on the vertex of the head. Clip electrodes were used for the reference and ground electrodes, placed on the ear lobes, after the zone was cleaned with alcohol. The electrode gelling followed. A syringe with the electrolyte conductive gel was utilized for this procedure. At this stage, the OpenBCI GUI was used for checking the impedance level of each electrode. Care was taken to get impedance values below $5k\Omega$ before starting any data recording. In addition, a visual inspection of the quality of the EEG signals was done by using also the OpenBCI GUI.

When both EMG and EEG electrodes were correctly placed, we asked the participant to seat facing a computer screen, with both arms resting on a desk. His/her dominant hand was placed inside of a cartoon box. This was done to help the participant to avoid performing visual MI, instead of kinesthetic. The EMG signal was registered with the OpenBCI GUI in a dedicated laptop. In a second PC, the OpenViBE *acquisition server* together with the *designer module* were running for capturing the EEG signals while presenting the experimental protocol.

Before the protocol presentation started, the EMG rest signal was measured for a period of 20 s. The first run followed (RUN0), in which 5 trials of real grasping movements of the dominant hand and 5 rest trials were performed. This run was done with the purpose of better explaining the protocol to the participants and for them to recall the movement sensation in the incoming MI runs. The rest of the runs (RUN1-RUN4) were identical, in which 40 MI vs rest trials were performed.

Once the five experimental runs were acquired, the experiment was concluded. Electrode disconnection and cleaning followed, as well as data storage.

2.6. Trial Rejection Due to EMG Activity

The data provided here are free of EMG artifacts. A movement detection based on a single threshold method was used. The envelope of the EMG signal was estimated by means of a low-pass 3rd order zero-phase Butterworth filter with 40 Hz cut-off frequency applied to the zero-

mean rectified EMG signals. EMG segments of 5 s lengths were extracted, with a starting and ending buffer of 0.5 s from the beginning to the end of the EEG trials. The threshold used for hand movement detection, was calculated as the standard deviation of the envelope of a rest segment of 0.25 s extracted from RUN0. A sliding window of 0.05 s was considered as having EMG activity if its mean value was greater than 5 times the prescribed threshold. An EEG trial was considered contaminated with EMG activity if 50% or more of the sliding windows detected muscle activity. The source codes, written in Matlab, can be found in GitHub. One participant's data presented more than 50% of the trials contaminated with EMG activation, while for another participant the EMG data was lost during the session. For this reason, these participants were excluded of the database.

2.7. Code and Data Availability

OpenViBE was used for both protocol presentation and EEG data saving and storage. We used a modified version of the Graz protocol for MI [3]. Customized Matlab functions for analyzing both the EMG and EEG data were created. The scripts together with additional information for running the protocol in OpenViBE as well as the source codes for data analysis can be found in GitHub (https://github.com/vpeterson/MI-OpenBCI) [6].

The raw EMG and EEG data, as.txt and.mat files, respectively, can be found in the original GitHub repository (https://github.com/vpeterson/MI-OpenBCI) [6]. The EEG epoched data, saved as Matlab files, ready for running machine learning algorithms, can be found in the lab GitHub repository (https://github.com/ProMABLab/Database-MIOpenBCI). In addition, the raw continuous data, in.edf format following BIDs standards, are available in OpenNeuro [7] (https://openneuro.org/datasets/ds003810).

Ethics Statement

The study was approved in Feb. 2018 by the "Comité Asesor de Ética y Seguridad en el Trabajo Experimental" (Advisory Committee on Ethics and Safety in the Experimental Work, CEySTE, CCT-CONICET, Santa Fe, Argentina) and conformed to the principles of the Declaration of Helsinki. Twelve healthy subjects (four females, right-handed, mean age $\pm$ SD = 25.9 $\pm$ 3.7 years) without any previous BCI experience participated in the experiment and gave their informed consent.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Data Availability

Motor Imagery vs Rest - Low-Cost EEG System (Original data) (ResearchData).

CRediT Author Statement

Victoria Peterson: Conceptualization, Software, Validation, Data curation, Writing – original draft, Formal analysis, Methodology; **Catalina Galván:** Software, Investigation, Data curation, Writing – review & editing, Visualization; **Hugo Hernández:** Software, Investigation, Data curation, Writing – review & editing, Visualization; **María Paula Saavedra:** Software, Data curation,

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