Brain Invaders calibration-less P300-based BCI using dry EEG electrodes Dataset (bi2014a)

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Abstract - We describe the experimental procedures for the ***bi2014a*** dataset that we have made publicly available at https://doi.org/10.5281/zenodo.3266223 in *mat* and *csv* formats. This dataset contains electroencephalographic (EEG) recordings of 71 subjects playing to a visual P300 Brain-Computer Interface (BCI) videogame named *Brain Invaders*. The interface uses the oddball paradigm on a grid of 36 symbols (1 Target, 35 Non-Target) that are flashed pseudo-randomly to elicit the P300 response. EEG data were recorded using 16 active dry electrodes with up to three game sessions. The experiment took place at GIPSA-lab, Grenoble, France, in 2014. Python code for manipulating the data is available at https://github.com/plcrodrigues/py.BI.EEG.2014a-GIPSA.

Résumé - Dans ce document, nous décrivons une expérimentation pour les données ***bi2014a*** qui ont été publiées sur https://doi.org/10.5281/zenodo.3266223 aux formats *mat* et *csv*. Ce jeu de donnée contient les enregistrements électroencéphalographiques (EEG) de 71 sujets jouant à une interface-cerveau ordinateur (ICO) basée sur la détection des P300 visuels nommée Brain Invaders. L'interface utilise le paradigme oddball (ou stimuli discordant) sur une grille de 36 symboles (1 cible, 35 non-cibles) qui sont flashés de façon pseudo-aléatoires afin de générer un potentiel évoqué P300. L'EEG de chaque sujet a été enregistré grâce à 16 électrodes sèches pendant une à trois sessions de jeu. L'expérience a été menée au GIPSA-lab (Université de Grenoble-Alpes, CNRS, Grenoble-INP) en 2014. Nous fournissons également une implémentation python pour manipuler les données à https://github.com/plcrodrigues/py.BI.EEG.2014a-GIPSA.

Introduction

The experiment was designed to study the viability of a calibration-less P300-based BCI system with dry electrodes and as a screening session for potential candidates for a broader multi-user BCI study (1). The visual P300 is an event-related potential (ERP) elicited by an expected but unpredictable target visual stimulation (i.e., oddball paradigm (2)), with peaking amplitude 240-600 ms after stimulus onset. In this experiment, there were two event-related stimuli: Target (P300 expected) and Non-Target (no P300). The experiment used *Brain Invaders, a* P300-based BCI open-source software (3). During the experiment, the output of a real-time adaptive Riemannian Minimum Distance to Mean (RMDM) classifier was used for assessing the participants' command (4,5). This scheme allows to have a calibration-free procedure (6). This experiment is part of a collective effort to develop plug and play open-source BCI software at GIPSA-lab (1). An example of application of this dataset can be seen in (7).

Participants

71 subjects (49M, 22F) with mean (sd) age 23.55 (3.13) were recruited for this experiment and randomly paired (see **Table 1** in the annex). The recruited participants were mostly students and young researchers. Among them, 57 were naïve BCI participants. At the end of the experiment one ticket of cinema was offered to each subject, for a value of 7.5 euros per subject. All participants provided written informed consent confirming the notification of the experimental process, the notification of the data management procedures and the right to withdraw from the experiment at any moment. The study was approved by the Ethical Committee of the University of Grenoble Alpes (Comité d'Ethique pour la Recherche Non-Interventionnelle).

Data of 10 participants have been rejected from the study for the following reasons:

- Participant 62 and 64: vision not perfectly corrected.
- Participant 63: dry electrodes had poor contact with the scalp due to thick hair.
- Participant 65-71: issue with tagging or experience aborted.

Data of these subjects are not provided. Data for subjects 62, 63 and 64 are provided as they can be of general interest, but are very noisy and should not be used for P300 data analysis.

Note also that the ERPs of subjects 36, 46, 52 and 57 are inconsistent as compared to the others subjects in the database. As we did not report any issues during the recording of these subjects, these data are still provided - see **Table 1** for details.

Material

EEG signals were acquired by means of a research-grade amplifier (g.USBamp, g.tec, Schiedlberg, Austria) equipped with 16 dry 8-pins gold-alloy electrodes g.Sahara (g.tec, Schiedlberg, Austria), placed according to the 10-10 international system (Fp1, Fp2, F5, AFZ, F6, T7, Cz, T8, P7, P3 , PZ, P4 , P8, O1, Oz, O2) with reference electrode on the right earlobe and ground electrode at the FZ scalp location (**Figure 1**). The g.USBamp amplifier was linked by USB connection to the PC where the data were acquired by means of the software OpenVibe (8,9). The data were stored with no digital filter applied and a sampling frequency of 512 samples per second. In order to reduce the jitter, the experimental tags produced by Brain Invaders were synchronized with the EEG signals using an USB digital-to-analog converter connected to the g.USBamp trigger channel. The same tagging procedure is used in all Brain Invaders databases (bi2012a (10), bi2013a (11), bi2014b, bi2015a, bi2015b[1]). This allows comparing the resulting ERP between the experimental conditions thanks to a consistent tagging latency (12).

[1] https://sites.google.com/site/marcocongedo/science/eeg-data

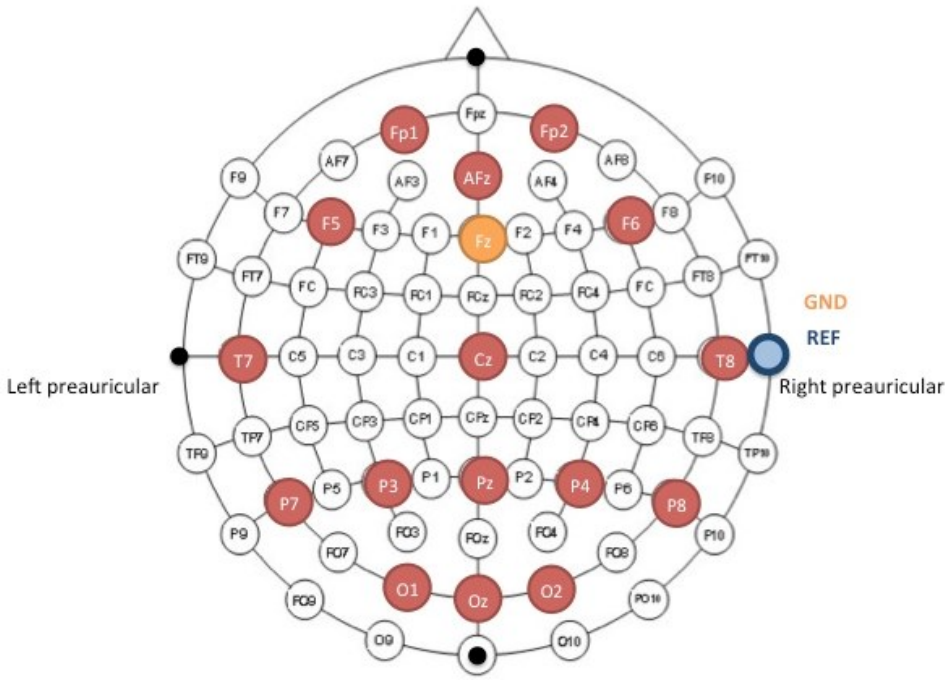

Figure 1. The 16 electrodes placed according to the 10-10 international system. In yellow: Ground (GRN) FZ. In blue: Reference (REF) left earlobe.

Procedures

For all subjects, the experiment took place in a small room with a surface of four meters square, containing a 24' screen and all the required hardware materials for acquiring the EEG data. After the EEG headset was placed, the integrity of the recording pipeline was checked by performing preliminary tests, consisting in inspecting visible signals such as eye blinks and the occipital dominant rhythm. The experimenter controlled the session from an adjacent room equipped with a one-way glass window.

The experiment consisted of up to three game sessions of Brain Invaders, composed of 9 levels of the game each. The experimenter could stop before three game sessions for the following reason: (a) no control was attain on the BCI system after 10 minutes, (b) a very high score was reached (120 000 in game points).

Brain Invaders Interface

The interface of Brain Invaders is compounded by 36 symbols flashing in 12 groups of six aliens. In the Brain Invaders P300 paradigm, a *repetition* is composed of 12 flashes (*i.e.*, one for each group), of which two include the Target symbol (*Target* flashes) and 10 do not (*non-*

Target flashes) - **Figure 2**. A detailed description of this paradigm is available in (3,13,14). The ratio of Target versus non-Target epochs in the whole datasets is therefore one-to-five.

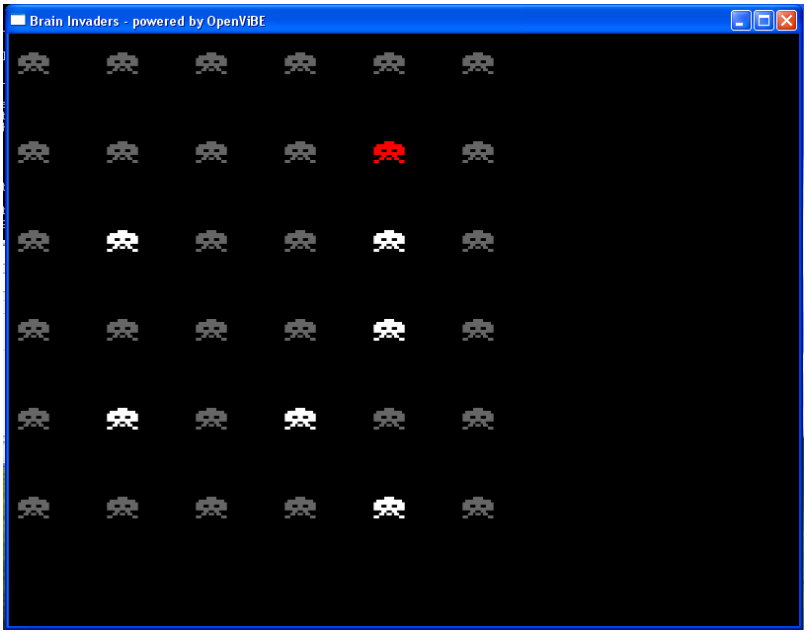

Figure 2. Interface of Brain Invaders at the moment where a group of six non-Target symbols flash (in white). The red symbol is the Target. The non-Targets which are not flashing are in grey.

A game session was compounded by nine levels, consisting in a unique and predefined configuration of the 36 symbols of the interface. Symbols were slowly and regularly moving according to a predefined path keeping constant the inter-distance of the aliens on the screen. We found that this level of animation suffice to maintain the player's attention during the whole experiment.

Once the target symbol destroyed the level ended, a reward screen was shown and the next level was generated (if available). The player had up to eight attempts to destroy the target symbol (a counter was always shown in the bottom part of the interface). If the player missed all eight attempts, the level was started once again from the beginning. As a consequence, the duration for the nine levels was variable, with an average of five minutes and the experimenter could end the experiment if no control over the BCI system was gained after 10 minutes to avoid the raising of a frustration's feeling for the player.

Organization of the Dataset

The EEG recording of 64 out of the 71 subjects are provided in *mat* and *csv* formats. Each file is a 2D-matrix where the rows contain the observations at each time sample. Columns 2 to 17 contain the recordings on each of the 16 EEG electrodes. The first column of the matrix represents the timestamp of each observation and column 18 contains the experimental events (see below). For ease of use, we provide columns 19 which are filled with zeros, except at the timestamp corresponding to the onset of a non-Target (Target) flash where it gets the value of one (two).

The rows in column 18 (Events) are filled with zeros, except at the timestamp corresponding to the beginning of an event, when the row gets one of the following values:

- 102 for the end of a repetition.
- 100 for the onset of a new block.
- 20-25 and 40-45 when a group containing the target flashes. The twelve groups are separated in six "rows" and six "columns", in such way that a symbol is included in exactly one "row" and one "column" (3). Note that the naming of "row" and "column" group do not refers to the physical rows and columns in the matrix of symbols, although it was the case in the first implementation of the protocol (15). The first digit of the values indicates whether the group is a "row" (digit *2*) or a "column" (digit *4*). The second digit indicates the number of the flashed "row" or "column" in the range [0, 5]. Note that the groups are constructed randomly at each repetition, thus a physical symbol in the matrix does not belong to the same "row" or "column" group across repetitions.
- 60-65 and 80-85 when a group containing the target flashes. The first digit of the values indicates whether the group is a row (digit *6*) or a column (digit *8*). The second digit indicates the number of the flashed row or column in the range [0, 5].

The *Header.mat* (or *Header.csv*) file contains the column names, sorted by ascending column number, including the name of the EEG channels.

We supply an online and open-source example working with Python (7) and using the analysis framework MNE (16,17) and MOABB (18,19), a comprehensive benchmark framework for testing popular BCI classification algorithms. This example shows how to download the data and classify 1s non-Target and Target epochs using the Riemannian MDM algorithm (5).

Annex

Table 1. Age and Gender of the bi2014a participants.

#	Age	Gender	Notes
1	24	h	
2	22	f	
3	25	f	
4	22	h	
5	22	h	
6	23	f	
7	24	h	
8	24	h	
9	31	h	
10	24	f	
11	25	h	
12	19	f	
13	26	f	
14	22	h	
15	22	h	
16	23	h	
17	25	h	
18	23	h	
19	26	f	
20	29	h	
21	23	h	
22	20	f	
23	23	h	
24	26	f	
25	20	h	
26	22	f	
27	25	h	
28	35	h	
29	21	f	
30	27	f	
31	25	h	
32	25	h	
33	23	f	
34	23	h	
35	29	h	
36	23	h	Inconsistant ERP

#	Age	Gender	Notes
37	30	h	
38	22	h	
39	20	f	
40	26	h	
41	20	h	
42	26	h	
43	22	h	
44	24	h	
45	22	h	
46	29	h	Inconsistant ERP
47	27	h	
48	23	f	
49	27	h	
50	20	h	
51	25	f	
52	27	h	Inconsistant ERP
53	25	h	
54	19	f	
55	23	h	
56	24	h	
57	22	h	Inconsistant ERP
58	21	f	
59	20	f	
60	21	f	
61	25	h	
62	19	h	Rejected
63	19	f	Rejected
64	20	h	Rejected
65	26	h	Data not included
66	23	h	Data not included
67	21	h	Data not included
68	22	h	Data not included
69	22	h	Data not included
70	21	h	Data not included
71	18	f	Data not included

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