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Technical Report

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Brain Invaders Solo versus Collaboration: Multi-User P300-based Brain-Computer Interface Dataset (bi2014b)

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Abstract - We describe the experimental procedures for a dataset that we have made publicly available at <https://doi.org/10.5281/zenodo.3267301> in *mat* and *csv* formats. This dataset contains electroencephalographic (EEG) recordings of 38 subjects playing in pair to the multi-user version of a visual P300-based Brain-Computer Interface (BCI) named *Brain Invaders* (1). The interface uses the oddball paradigm on a grid of 36 symbols (1 Target, 35 Non-Target) that are flashed pseudo-randomly to elicit a P300 response, an evoked-potential appearing about 300ms after stimulation onset. EEG data were recorded using 32 active wet electrodes per subjects (total: 64 electrodes) during three randomised conditions (Solo1, Solo2, Collaboration). 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.2014b-GIPSA>. The id of this database is *bi2014b*.

Résumé - Dans ce document, nous décrivons une expérimentation dont les données ont été publiées sur <https://doi.org/10.5281/zenodo.3267301> aux formats *mat* et *csv*. Ce jeu de donnée contient les enregistrements électroencéphalographiques (EEG) de 38 sujets jouant par pair à une version multi-user du jeu *Brain Invaders* (1), une interface cerveau-ordinateur de type 'P300 visuel'. L'interface repose sur le paradigme oddball avec une grille de 36 symboles (1 Target, 35 Non-Target) qui clignotent de façon pseudo-aléatoire afin de produire un P300, un potentiel évoqué apparaissant environ 300ms après le début d'une stimulation. L'EEG de chaque sujet a été enregistré grâce à 32 électrodes humides réparties sur la surface du scalp (total : 64 électrodes par pair), au cours de trois session expérimentales randomisé (Solo1, Solo2, Collaboration). 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.2014b-GIPSA>. L'identifiant de cette base de données est *bi2014b*.

Introduction

The experiment was designed to study the inter-brain synchrony of two participants engaged in collaborative Brain-Computer Interface (BCI) as compared to the same participants playing alone (2). The visual P300 is an event-related potential (ERP) elicited by an expected but unpredictable target visual stimulation (i.e., oddball paradigm (3)), peaking 240-600 ms after stimulus onset. In this experiment, there are two visual stimuli: Target (P300 expected) and Non-Target (no P300 expected). The experiment used the multi-player version of *Brain Invaders*, a P300-based BCI open-source software (1) creatively called *Brain Invaders 2* (4). During the experiment, the output of a real-time adaptive Riemannian Minimum Distance to Mean (RMDM) classifier was used for assessing the participants' command (5,6). This classifier allows a calibration-free procedure (7). The RMDM was extended to the multi-user setting in (8). This experiment is part of a collective effort to develop *plug and play* open-source BCI software at GIPSA-lab while assessing their usability for hyperscanning studies (2). An example of analysis of this dataset can be retrieved at (9).

Participants

38 subjects (24M, 14F) with mean (sd) age 24.10 (3.09) were recruited for this experiment and randomly paired (see Table 1). The participants were selected on the basis of their individual score during a preliminary session of *Brain Invaders* (10) and therefore were not naïve users. At the end of the experiment two tickets of cinema were offered to each subject, for a total value of 15 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).

<i>pair #</i>	<i>GENDER</i>	<i>AGE1</i>	<i>AGE2</i>	<i>info</i>
1	FH	24	22	
2	FH	25	22	
3	FH	22	23	
4	HH	24	24	
5	FH	31	24	
6	FH	25	19	
7	FH	26	22	
8	HH	22	23	
9	HH	25	23	
10	FH	26	29	
11	FH	23	20	
12	FH	24	21	rejected
13	HH	29	23	rejected
14	FH	23	26	
15	FH	20	22	
16	HH	25	35	
17	FF	21	27	
18	HH	25	25	
19	FH	23	23	

Table 1. Age and Gender of the participants

Material

EEG signals were acquired by means of a research-grade amplifier (g.USBamp, g.tec, Schiedlberg, Austria) and the g.GAMMAcap (g.tec, Schiedlberg, Austria) equipped with 32 wet Silver/Silver Chloride electrodes per subject, placed according to the 10-10 international system at locations FP1, FP2, AFz, F7, F3, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO7, O1, Oz, O2, PO8, PO9 and PO10. The reference electrode was placed on the right earlobe and the 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 open-source software OpenVibe (11,12). 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 2* were synchronized with EEG signals using an USB analog-to-digital converter connected to the g.USBamp trigger channel. The same tagging procedure is used for all Brain Invaders databases¹. This allows

¹ <https://sites.google.com/site/marcocongedo/science/eeg-data>

comparing the resulting ERP between the experimental conditions thanks to a consistent tagging latency and jitter (13).

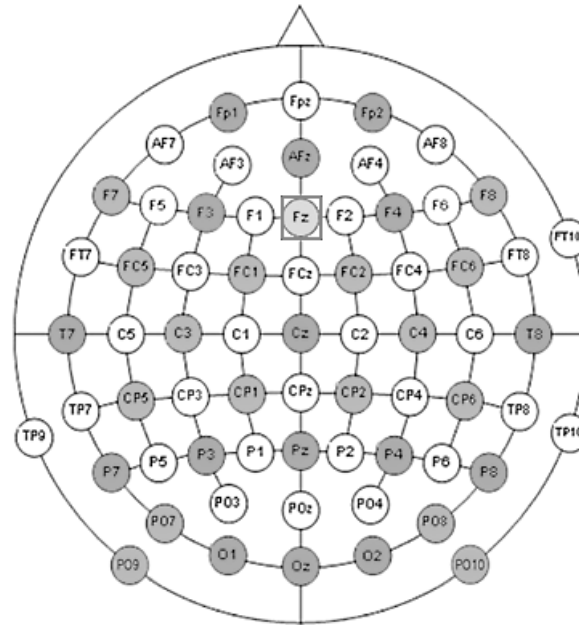


Figure 1. In grey the 32 electrodes placed on the scalp to each subjects according to the 10-10 international system. The ground (GRN) was placed at Fz (squared). The reference (REF) was placed on the left earlobe (not shown on the figure).

Procedures

For all subjects, the experiment took place in a small room containing a 24' screen and all the required hardware materials for acquiring the EEG data. The two subjects were sitting side by side at a distance of approximately 125cm from the same screen. The EEG headset was placed on all subjects, and the integrity of the incoming data was checked by inspecting visible signals such as eye blinks and the posterior occipital dominant rhythm. The experimenter controlled the session from an adjacent room equipped with a one-way glass window (**Figure 2**).

The experiment consisted of three conditions: one game session of the Player1 playing solo (*Solo1*), one game session of the Player2 playing solo (*Solo2*) and four game sessions of *Collaboration*. The order of the three conditions were pseudo-randomly sorted for each pair controlling for order balance through the 17 pairs.

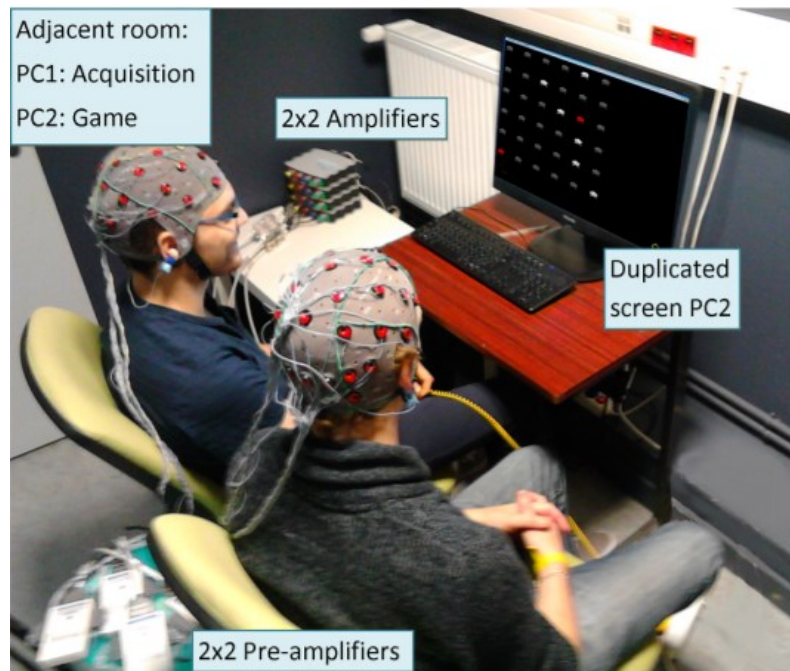


Figure 2. Experimental setup.

Brain Invaders Interface

The interface of Brain Invaders is composed of 36 aliens. In the Brain Invaders P300 paradigm, a *repetition* is composed of 12 flashes of pseudo-random groups of six symbols chosen in such a way that after each repetition each symbol has flashed exactly two times. Thus in each repetition the target symbol flashes twice, whereas the remaining 10 flashes do not concern the target (non-target). The ratio of Target versus non-Target is therefore one-to-five (**Figure 3**). A detailed description of this paradigm is available in (1,14,15).

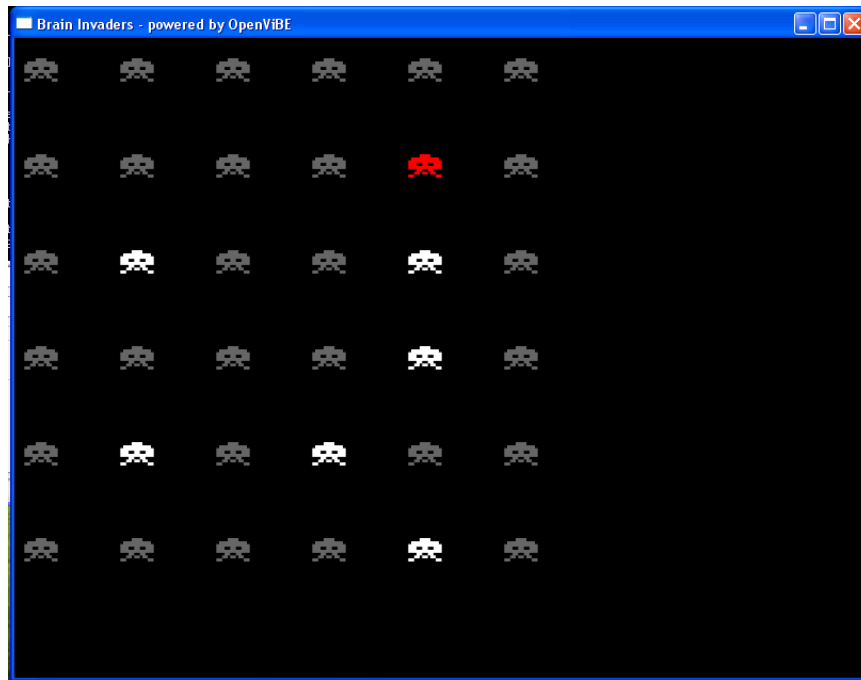


Figure 3. Interface of Brain Invaders during the first level at the moment where a group of six non-Target symbols flash (in white). The red symbol is the Target. The non-Targets which are not flashing are in grey.

A game session was compounded by nine levels, consisting in a unique and predefined spatial configuration of the 36 aliens. Aliens slowly and regularly moved according to a predefined path keeping constant the inter-distance between adjacent aliens. We found that this level of animation suffice to maintain high the player's attention during the whole experiment.

Once the target symbol had been destroyed, the level ended, a reward screen was displayed and the next level was generated (if available). The player(s) 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(s) 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.

Solo conditions (Solo1 and Solo2)

The two subjects in a pair were sitting side by side in front of a single computer screen. In the solo condition one of the subjects played a game session of Brain Invaders while the other did not interact. Instead, the non-playing participant focused on an unanimated cross with the game screen out of his/her field of view to prevent him/her from observing the stimuli (**Figure 4**). The

EEG data of the two subjects were always recorded. This experimental design allows to correct for *fake* inter-brain synchrony (control condition) (7).

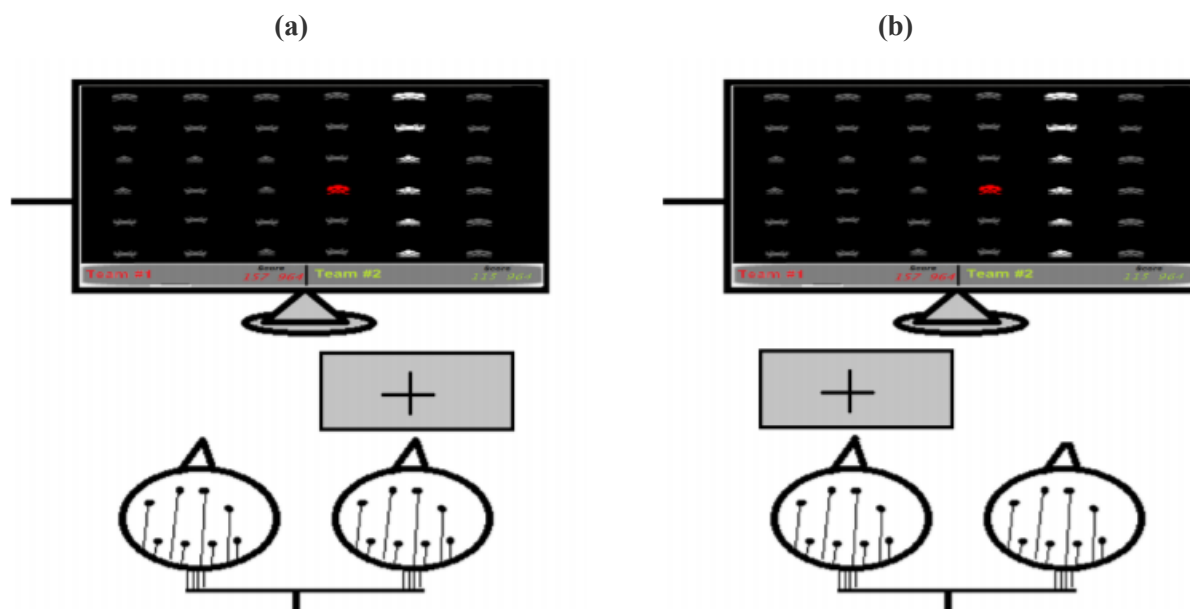


Figure 4. A pair of subjects during the Solo phase. (a) the subject to the left (player1) is playing. (b) roles are inverted, player2 is playing. The non-player activity is still recorded simultaneously during solo condition. The non-player gaze is fixed on an unanimated cross on the wall localized at the same distance as the screen. The non-player cannot see the screen as his/her field of view is blocked.

Collaboration condition

The two participants played four game sessions of Brain Invaders with the same objective, which is to destroy the target as fast as possible for each level of the game. The nine levels of each game session were always displayed in the same order, and this order was the same in the Solo and Collaboration condition. A rest break was interleaved between levels and between blocks. During these pauses, the subjects were encouraged to interact together by sharing feelings about the game. In the Collaboration condition the score was the same for the two subjects.

Organization of the Dataset

The EEG recording of the 17 pairs are provided in *mat* and *csv* formats. There are three files (in both formats) for each pair corresponding to the number of experimental condition (*Solo1*, *Solo2* and *Collaboration*). Each file is a 2D matrix containing the concurrent EEG recording of the two subjects. Columns 2 to 33 contain the recordings on each of the 32 EEG electrodes for the first player. Columns 34 to 65 contains the EEG recordings on each of the 32 EEG electrodes for the second player. The first column of the matrix represents the timestamp of each observation and column 66 contains the experimental events. The rows in column 66 (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 of aliens not containing the target flashes. The twelve groups are separated in six “rows” and six “columns”, in such a way that a symbol is included in exactly one “row” and one “column” (1). Note that the naming of “rows” and “columns” do not refers to the physical rows and columns in the matrix, although it was the case in the first implementation of the protocol (16); those are simply group created pseudo-randomly as we have reported. 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 randomized between the repetitions, thus a physical symbol in the matrix does not corresponds to the same “row” or “column”.
- 60-65 and 80-85 when a group of aliens 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].

For ease of use, we provide column 67 which is 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 *Header.mat* (or *Header.csv*) file contains the column names, sorted by ascending column number, including the name of the EEG channels. The age and genre of the subjects are provided in Table 1. Other subjective variables, collected by means of a questionnaire, such as the preference for the experimental condition and the feeling of fatigue, will be published later.

We supply an online and open-source example working with Python (9) and using the analysis framework MNE (17,18) and MOABB (19,20), 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 of signals.

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