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Data Article

A dataset of EEG signals from a single-channel SSVEP-based brain computer interface

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A R T I C L E I N F O

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A B S T R A C T

The paper presents a collection of electroencephalography (EEG) data from a portable Steady State Visual Evoked Potentials (SSVEP)-based Brain Computer Interface (BCI). The collection of data was acquired by means of experiments based on repetitive visual stimuli with four different flickering frequencies. The main novelty of the proposed data set is related to the usage of a single-channel dry-sensor acquisition device. Different from conventional BCI helmets, this kind of device strongly improves the users' comfort and, therefore, there is a strong interest in using it to pave the way towards the future generation of Internet of Things (IoT) applications. Consequently, the dataset proposed in this paper aims to act as a key tool to support the research activities in this emerging topic of human-computer interaction.

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Specifications Table

Subject	Neuroscience
Specific subject area	Neuroinformatics, Single channel EEG, BCI, SSVEP
Type of data	Raw data of single channel dry electrodes EEG
How data were acquired	Data were acquired using a BCI headset built on top of the Olimex EEG-SMT, a two-channel differential input 10-bit analogue-digital converter (ADC) with a sampling frequency of 256 Hz. One channel out of two has been used for developing the proposed dataset.
Data format	Raw (.csv)
Parameters for data collection	Subjects were seated on a chair, 70 cm away from a 15.6 inches monitor with a resolution of 1024 × 768 pixels, and a refresh rate of 60 Hz. The visual stimuli displayed on the monitor consisted of 4 alternating black-white squares with frequencies 8.57 Hz, 10 Hz, 12 Hz and 15 Hz respectively. The electrodes were positioned on the midline sagittal plane at the Frontal Parietal area (Fpz) and the Occipital area (Oz), according to the 10–20 system.
Description of data collection	11 volunteers were equipped with the data acquisition headset and asked to focus on the visual stimuli, 16 s each one. Data is stored in eleven .csv files, one for each subject. Each file contains raw EEG data of the four stimuli frequencies.
Data source location	Quantum Computing and Smart Systems (QUASAR) Laboratory, University of Naples Federico II, Naples, Italy
Data accessibility	The dataset can be accessed at the following link: https://data.mendeley.com/datasets/px9dpkssy8/draft?a=7140665d-a0f0–40b2-a9fd-a731d21b6222

Value of the Data

- Collected data was obtained by a single channel dry-electrodes EEG device and can be used to explore the properties of brain signals based on visual evoked potentials.
- Collected data will help the research communities in the development or improvement of algorithms able to recognize useful patterns in SSVEP signals generated by devices featured by few channels. These studies will result in the development of low cost but accurate BCI helmets.
- The proposed dataset, based on data collected by portable BCI devices, will pave the way towards the design and development of future generation of Internet of Things (IoT) applications.
- The dataset can be processed with different feature extraction and selection techniques, such as Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT), and so on.
- The acquired data has been used for a first application related to the use of logistic regression as machine learning technique to classify the SSVEP signals [1]. The mentioned application can be used as starting point for designing new machine learning algorithms for BCI, and as a useful tool to develop applications in the IoT area.

1. Data Description

Steady State Visual Evoked Potentials (SSVEP) are brain signals generated in the visual cortex area when focusing on an intermittent source of light, which is emitted at a specific frequency [2]. Brain Computer Interfaces (BCIs) based on this paradigm are of growing interest in the sci-

Table 1
Stimuli frequencies considered for the design of the proposed dataset.

Frequency band	Range of Frequency (Hz)	Frequencies considered (Hz)
Delta	0–4	–
Theta	4–8	–
Alpha	8–12	8.57 (F1), 10 (F2)
Beta	12–30	12 (F3), 15 (F4)
Gamma	> 30	–

entific community due to the high information transfer rate and few training requirements. In current applications of BCI, SSVEP signals are usually acquired by means of helmets equipped with a collection of wet electrodes, where a saline solution is used to improve the capability of each sensor in capturing brain signals. Both the large number of sensors used in BCI helmets and the annoyance caused by the saline solution make these devices uncomfortable to be used in real world applications. For this reason, recently several research activities are focusing on innovative BCI devices based on few dry electrodes [3–6]. As a consequence, there is a strong need to develop and publish new BCI datasets where aforementioned devices are used to capture brain signals. This paper bridges this gap. Indeed, the proposed dataset contains EEG raw data related to SSVEP signals acquired from eleven volunteers by using an acquisition equipment based on a single-channel dry-sensor recording device. The recorded EEG data from a single volunteer contains the response to an intermittent source of light, which is emitted at four different frequencies, namely 8.57 Hz (F1), 10 Hz (F2), 12 Hz (F3) and 15 Hz (F4). Table 1 reports the considered frequencies that lie in the alpha and low-beta brain frequency bands. Each frequency stimulus has a duration of 16 s and was digitized at a fixed sampling frequency of 256 Hz. The EEG data of each volunteer was stored in a .csv file, represented in the format of "subject*N*", where *N* represents the serial number of volunteers. Each .csv file contains four columns, named F1, F2, F3 and F4, corresponding to the four stimuli frequencies, respectively. Each column is composed of 4096 samples (corresponding to 16 s of signal length sampled at 256 Hz) whose values range from 0 to 1023. Fig. 1 shows eleven plots. Each one of them displays data contained in one of the .csv files. In detail, each plot contains four subplots. Each subplot displays the values for one of the considered frequencies. Hence, each subplot is characterized by the number of samples on the x-axis and the frequency values on y-axis.

2. Experimental Design, Materials and Methods

The hardware architecture of the experiment is shown in Fig. 2 and it is composed of three main parts: the acquisition unit, the processing unit, and the stimulating platform.

The acquisition unit is based on the open source Olimex EEG-SMT device shown in Fig. 3b, a two-channel differential input 10-bit analogue-digital converter (ADC) with 256 Hz sampling rate. In our experimentation, in order to consider a single-channel device, only one of these channels was used. In detail, one channel consists of two active electrodes (CH- and CH+) whose voltage difference is given in input to the ADC. These electrodes (see Fig. 3d-e) were arranged on a self-made 3D printed headset, shown in Fig. 3a, in order to better place them in the Fpz (Frontal Parietal area) and Oz (Occipital area) points according to the international 10–20 system [7]. Moreover, a passive reference electrode was positioned on the earlobe (DRL). It is worth noting that Oz electrode has been modified by adding gold plated pins, shown in Fig. 3e, for a better contact with the scalp through the hair.

The ADC provides the digitized data as an integer number ranging from 0 to 1023 with a dynamic range of ±0.39 mV due to the default internal gain of the device ($G = 6427$). Data is automatically transferred to the processing unit, namely a Raspberry Pi 3 minicomputer (see Fig. 3c), which runs software modules to store data to create the proposed dataset. The Olimex

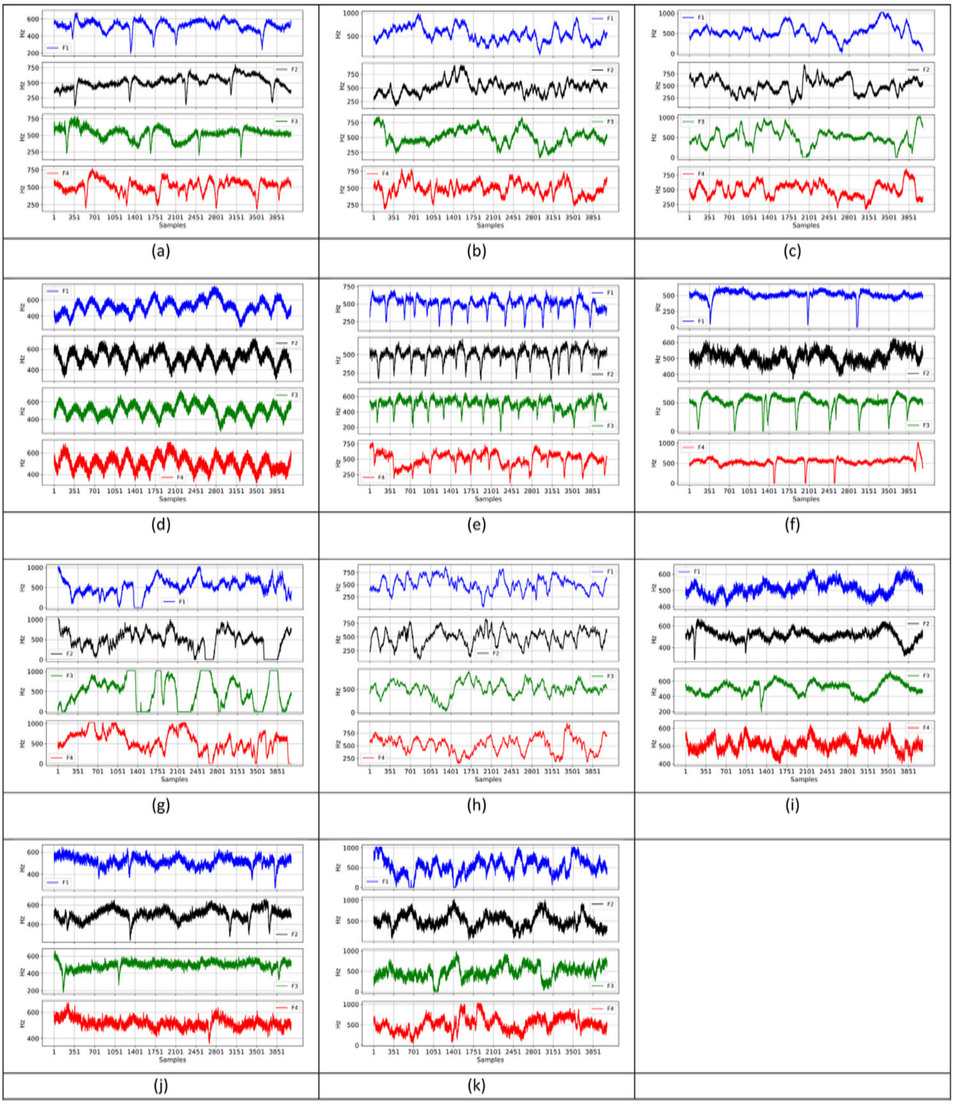

Fig. 1. (a) Data in the file subject1.csv; (b) Data in the file subject2.csv; (c) Data in the file subject3.csv; (d) Data in the file subject4.csv; (e) Data in the file subject5.csv; (f) Data in the file subject6.csv; (g) Data in the file subject7.csv; (h) Data in the file subject8.csv; (i) Data in the file subject9.csv; (j) Data in the file subject10.csv; (k) Data in the file subject11.csv.

device and the Raspberry Pi are packed together with a power bank in a single portable unit characterised by 3 h of battery life.

The stimulating platform was implemented on a 15.6-inch laptop (see Fig. 4). Visual stimuli consist of four alternating black white 80×80 pixel squares on a black background with oscillation frequencies of 8.57 Hz (F1), 10 Hz (F2), 12 Hz (F3) and 15 Hz (F4) respectively, compatible with 60 Hz monitor refresh rate [8]. The stimulating platform runs a software module that guides the user through the experiment.

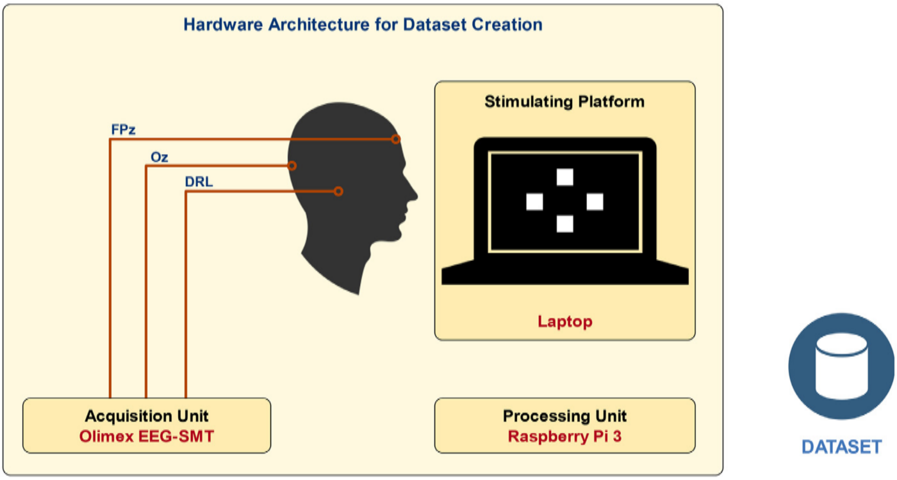

Fig. 2. Architecture of the system [1].

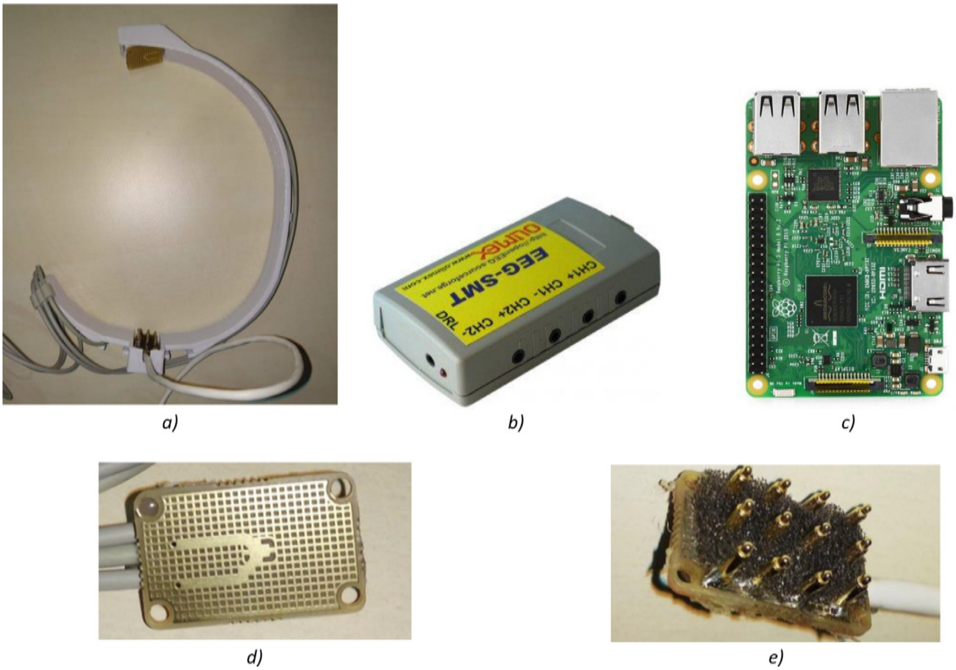

Fig. 3. (a) The 3D-printed headset; (b) the Olimex EEG-SMT device; (c) the Raspberry Pi 3 single-board computer; (d) the Fpz electrode; (e) the Oz electrode improved with gold plated pins.

The experiment was carried out on eleven healthy volunteers, aged from 25 to 50 years. Each volunteer was equipped with the acquisition headset, sat on a chair positioned at 70 cm away from the laptop monitor, and required to follow the steps below:

1. Focus on the stimulus related to the frequency F1 for 16 s;
2. Wait four seconds and relax before focusing on the next stimulus (during the 4 s break no stimuli were projected on the monitor);

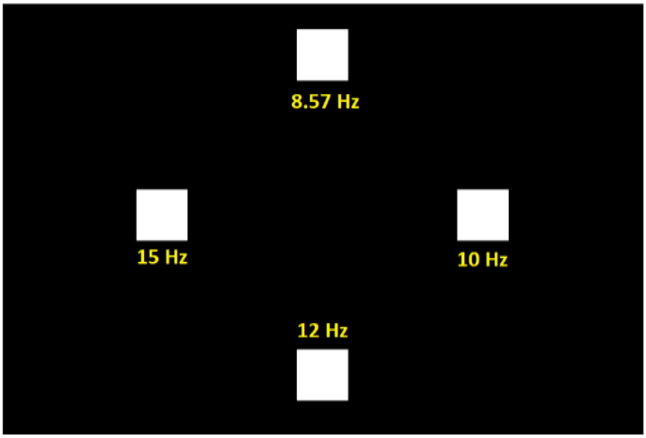

Fig. 4. Visual stimuli window showing the 4 flickering squares [1].

3. The steps 1 and 2 were repeated until data related to the three remaining stimuli (F2, F3, F4) was acquired.

At the end of the experiment, a total of 44 recordings of 16 s each one sampled at 256 Hz, for a total of 180,224 samples was obtained. In the future, the proposed dataset will be extended with more samples from different people in order to make it suitable to be used in both research and ready to market applications.

Ethics Statement

The volunteers were requested to sign a consent form prepared following the guidelines of WHO's (World Health Organisation) informed consent reported at the following link https://www.who.int/ethics/review-committee/informed_consent/en/.

CRediT Author Statement

Giovanni Acampora: Conceptualization, Supervision, Writing; **Pasquale Trinchese:** Software, Writing; **Autilia Vitiello:** Writing, Visualization.

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.

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