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Data Article

Motion artifact contaminated multichannel EEG dataset

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A B S T R A C T

Wearable EEG suffers from motion artifact contamination due to the subject's movement in an ambulatory environment. Signal processing techniques pose promising solutions for the detection and removal of motion artifacts from ambulatory EEG, but relevant open-access datasets are not available, which is detrimental to the development of wearable EEG applications. This article showcases open-access electroencephalography (EEG) recordings, while a subject is performing different upper-body, lower-body, and full-body movements. One healthy male subject volunteered to record his EEG data using a 14-channel EMOTIV EPOCH EEG headset device. This device's electrode placement is in accordance with the international 10–20 system, and the data was stored using the EMOTIV Pro application. We used the MATLAB software to visualize the captured brain waveforms. The venue of the data collection was the Biomedical Instrumentation and Signal Processing Laboratory (BISPL) at the Independent University, Bangladesh (IUB). The EMOTIV Pro application extracted the recorded EEG data in the CSV file format, while the MATLAB software converted it to a .mat extension file afterward. The first 14 columns of this file represent the 14-channel EEG data, and the subsequent nine columns are for the motion sensor data. The list of recorded

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movements includes blinking of eyes, eyebrow movement, and also horizontal and vertical eye movements. Afterward, the head shook and nodded. Later, the leg trembled, followed by listening to music, talking, walking, and standing and sitting down. Before the recording ended, the subject relaxed on a chair with both eyes open and closed. This dataset is one of its kind, allowing us to explore further research for wearable EEG while denoising motion artifacts arising from subject movement.

Specifications Table

Subject	*Neuroscience*
Specific subject area	*EEG Artifact Detection*
Type of data	*Raw*
Data collection	*The EMOTIV EPOCH 14-channel EEG Headset was used where a 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer was in-built in the headset.*
Data source location	*Biomedical Instrumentation and Signal Processing Laboratory, Independent University, Bangladesh*
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/42pphfbcdk.1 Direct URL to data: https://data.mendeley.com/datasets/42pphfbcdk/1 Instructions for accessing these data: Please cite: Binte Ahmed, Sheikh Farhana (2024), “Motion Artifact Contaminated Multichannel EEG Dataset”, Mendeley Data, V1, doi: 10.17632/42pphfbcdk.1
Related research article	*Islam, Asma, et al. “Study and Analysis of Motion Artifacts for Ambulatory EEG.” Article in International Journal of Electrical and Computer Engineering 9.4 (2021).*

1. Value of the Data

- The dataset includes both the EEG data and motion sensor data. The 14 channel EEG data is recorded from a human subject and the 3-axis data of each accelerometer, gyroscope, and magnetometer are collected from the three separate motion sensors built within the EMOTIV Epoch EEG headset.
- This multichannel EEG dataset includes 14 channels according to the 10–20 international system. It is promising for applications where single-channel EEG datasets cannot encompass sufficient portions of the brain lobe for target applications.
- The dataset contains artifactual and non-artifactual EEG data recorded during movement and relaxation sessions. The relaxed EEG data can be used as ground truth (in other words, reference data) to gauge the performance of denoising algorithms.
- This data is suitable for designing and testing signal processing algorithms for ambulatory EEG, also known as mobile EEG. Its potential applications in wearable health solutions, including neurological disease diagnosis and brain-computer interface applications, are vast and promising, inspiring future research and innovation.
- The data in this repository are in standardized formats: .csv and .mat, ensuring their compatibility with various tools and platforms. The dataset has potential applications in various domains, including signal-processing techniques such as feature extraction, denoising, and pre-processing.

- This dataset is the sole publicly available multichannel EEG dataset that includes participants with movement artifacts encompassing physiological movements and utilizes a multichannel headset. This uniqueness bestows significant value to the scientific community, offering a rare opportunity for ground-breaking research.

2. Background

EEG is already prone to artifacts, which worsens even further in the case of ambulatory EEG (also known as mobile EEG), where the patient is free to move while recording the brain signals. These artifacts are unavoidable and require sophisticated signal processing techniques and hardware solutions. Researchers and clinicians need to ensure high-quality EEG signals, mainly when used to diagnose brain-related diseases and for brain-computer interface applications in a real-time environment. The literature review reveals that motion artifact-related research primarily used single-channel datasets where cables were regularly perturbed. However, modern neuro-headsets are single-channel and multichannel, ranging from 5 to 64 channels and even more. There is a dearth of standardized and validated open-access datasets on multichannel EEG in existing papers on motion artifact removal. Moreover, motion artifacts cause significant fluctuations in the EEG data where the original properties of the signal are cluttered with noise, which leads to wrong interpretation of the EEG data, causing wrong diagnoses of diseases and false alarms. Thus, motion artifacts contaminate the raw EEG data and make it more complex during daily activities. However, by accurately and automatically detecting and removing the motion artifacts from recorded mobile EEG data, we can significantly enhance the performance of disease diagnosis algorithms and brain-computer interfaces (BCI) applications, inspiring new possibilities and advancements in the field.

3. Data Description

The data folder contains both .csv and .mat files. The file names of the twelve activities are kept relevant for other researchers to understand. That is why the file is named Sub1_'activity' which indicates the corresponding activity of subject no. 01. The file names and their corresponding activities are as follows in Table 1:

The data is arranged in a folder in Mendeley Data Repository [2] as follows in Fig. 1. The CSV and MAT files have the same data in files; only the file formats are different, as found convenient for different software.

Table 1
File name description.

Sl. No.	*File Name*	*Meaning*
01	*Sub1_EB*	*eye blink*
02	*Sub1_EBM*	*eye brow movement*
03	*Sub1_EM*	*eye movement*
04	*Sub1_HS*	*head shaking*
05	*Sub1_HT*	*head tilting*
06	*Sub1_LS*	*leg shaking*
07	*Sub1_Music*	*listening to music with headphones on*
08	*Sub1_SUSD*	*stand up and sit down*
09	*Sub1_Talking*	*speaking or reading out text*
10	*Sub1_Walking*	*freely walking at a slow pace*
11	*Sub1_Relax*	*Relaxed seated with eyes closed*
12	*Sub1_RelaxOpen*	*Relaxed seated with eyes open*

Fig. 1. Data arrangement in the folder.

4. Experimental Design, Materials and Methods

The EEG dataset includes physical movements by human subjects involving both upper body and lower body, along with full body movements. Inspired by a previous research work by the same author [1], we designed the data recording protocol. Different research works in the last ten years have worked with motion artifacts in EEG. Initially, it was only cable movements [3], but the research community realized the importance of handling the artifacts that arose due to subject movement. They generated private datasets due to subject movement [4]. This research addresses the problem of the dearth of open access datasets on electroencephalogram data while the subjects are moving, i.e., motion artifact contaminated dataset. Previous research works included subject movements, such as treadmill walking at different speeds [5]. However, modern neuroscience research requires monitoring brain waves during several other activities, as this dataset addresses. Before starting the recording, the subject was briefed of the overall procedure and written consent was taken from him/her. While recording, the subject first engaged himself/herself in different movements of the eyes, including cued and spontaneous eye-blinking. In the next activity, only eyebrows moved. Then, the eyeballs moved in horizontal and vertical directions. In the talking session, we offered him/her the chance to read any article from a paper. After these facial movements, the head moved upward-downward and left-right directions, i.e., similar to head nodding and head tilting, respectively. Next, the lower body movement included leg shaking, also termed leg trembling. In today's world, listening to music is also a part of daily activities. Thus, in the next session, the subject was offered to listen to music by headphones. Next, whole body movement included standing up and sitting down. Here, the person sat on a chair, stood up, and sat down again in cycles. Finally, the person walked mindfully in a corridor while keeping the headset mounted. The person did not go too far, over-crossing the wireless coverage area. Lastly, the person relaxed and seated on a comfortable chair. After all these twelve activities, we stopped the recording application.

Nowadays, different commercial EEG headsets are gaining rapid popularity in the brain-signal research community. EMOTIV EPOCH PRO company offers three types of headsets: 14-channel, 5-channel, and 64-channel. The five-channel headset may apply to specific regions of the brain. Again, 64 channels might be too many, considering the person might feel uncomfortable wearing them for a long time. So, we chose the 14-channel EEG headset. Also, dry sensors might have more electrode displacement. So, the experiment used a saline solution gel-based electrode placement system. Moreover, the device had three built-in motion sensors: a 3-axis accelerometer, a 3-axis gyroscope, and a 3-axis magnetometer, which allows for more analysis of the subject's timing and intensity of movement. The software for acquiring the data comes as a package with the headset. The device allows wireless connection, making it more suitable for ambulatory EEG. The device needs to set some initial parameters before the onset, such as the sampling frequency of the motion sensors and the electrodes. We set the frequency of both systems to be the same: 128 Hz. The options given by the software were:

Sampling frequency of the 14 channel electrodes: 128 Hz, 256 Hz

Sampling Frequency of the motion sensors: 64 Hz, 128 Hz

We avoided the higher sampling frequency because it would create more data transmission pressure, affecting computational efficiency. Also, as seen from previous literature reviews, they use different sampling frequencies. However, this higher frequency might not be suitable for wearable EEG.

Regarding the 10–20 electrode placement system, it is as follows in Fig. 2:

In the given CSV file, the column-wise electrodes' position and details are shown in Table 2:

The following figures show the waveforms for each activity: (Figs. 3–14).

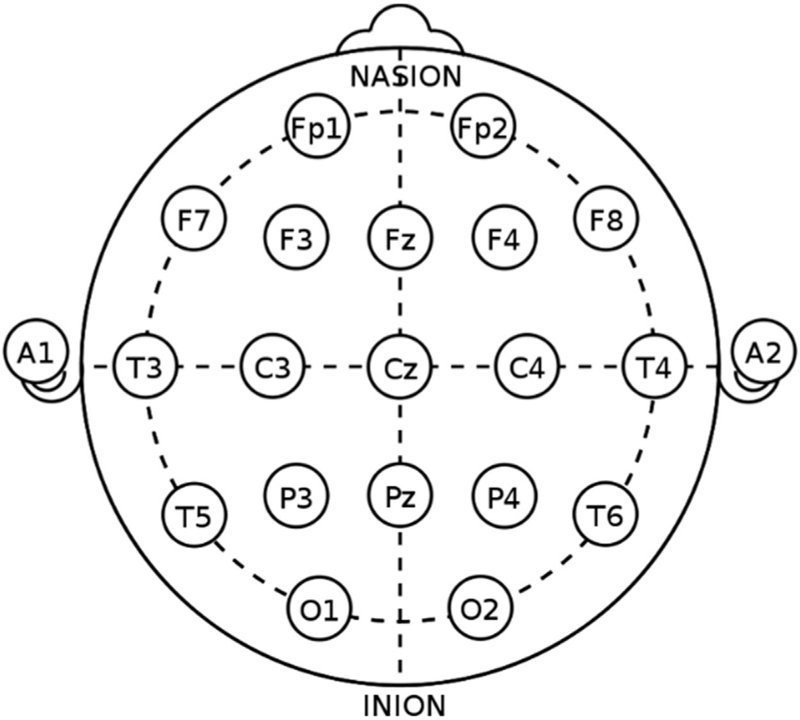

Fig. 2. 10–20 electrode placement system.

Table 2
Electrode position description.

Column	*Electrode Position*	*Electrode Position Details*
01	AF3	between Fp(pre-frontal) and F (Frontal)
02	*F7*	*F=Frontal*
03	*F3*	*F=Frontal*
04	*FC5*	between F (Frontal) and C (Central)
05	*T7*	*T=Temporal*
06	*P7*	*P=Parietal*
07	*O1*	*O=Occipital*
08	*O2*	*O=Occipital*
09	*P8*	*P=Parietal*
10	*T8*	*T=Temporal*
11	*FC6*	between Fp(pre-frontal) and F (Frontal)
12	*F4*	*F=Frontal*
13	*F8*	*F=Frontal*
14	*AF4*	between F (Frontal) and C (Central)

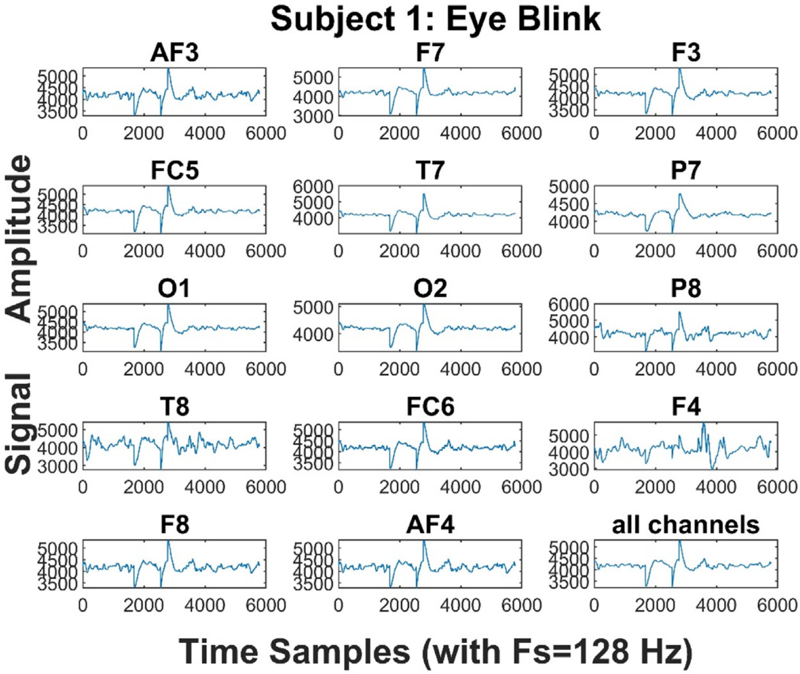

Fig. 3. A sample EEG recording off all 14 channels during Eye Blink (EB) artifacts for Subject-1.

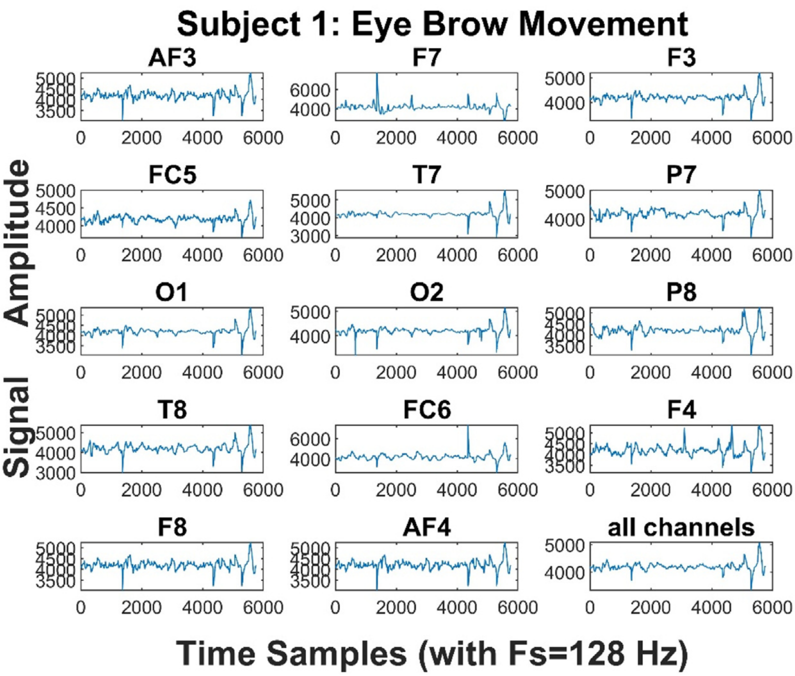

Fig. 4. A sample EEG recording off all 14 channels during Eye Brow Movement (EBM) artifacts for Subject-1.

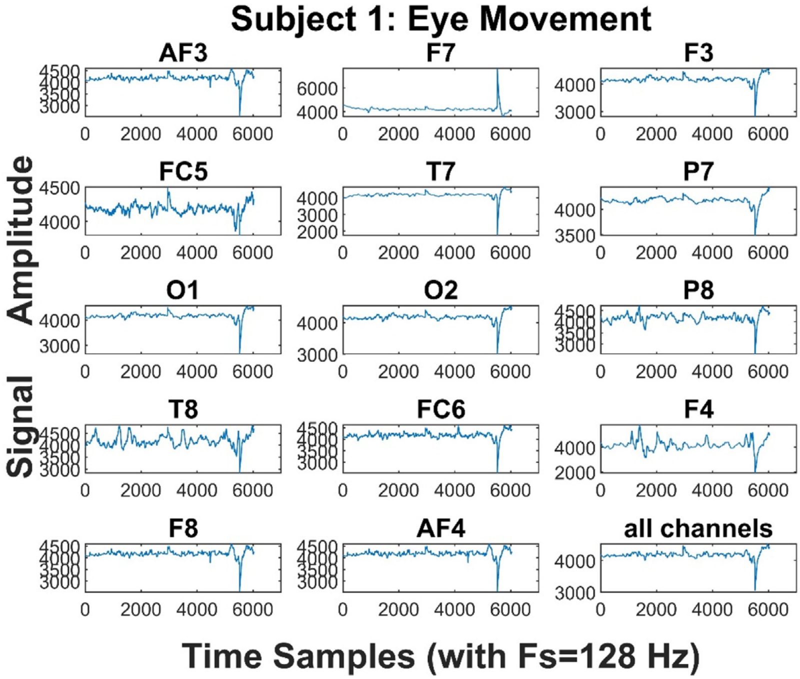

Fig. 5. A sample EEG recording off all 14 channels during Eye Movement (EM) artifacts for Subject-1.

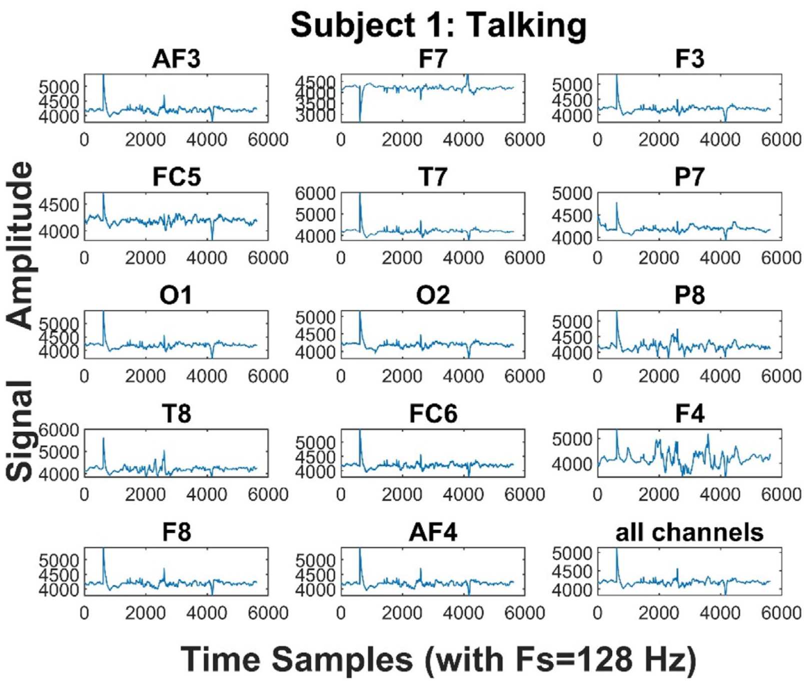

Fig. 6. A sample EEG recording off all 14 channels during Talking artifacts for Subject-1.

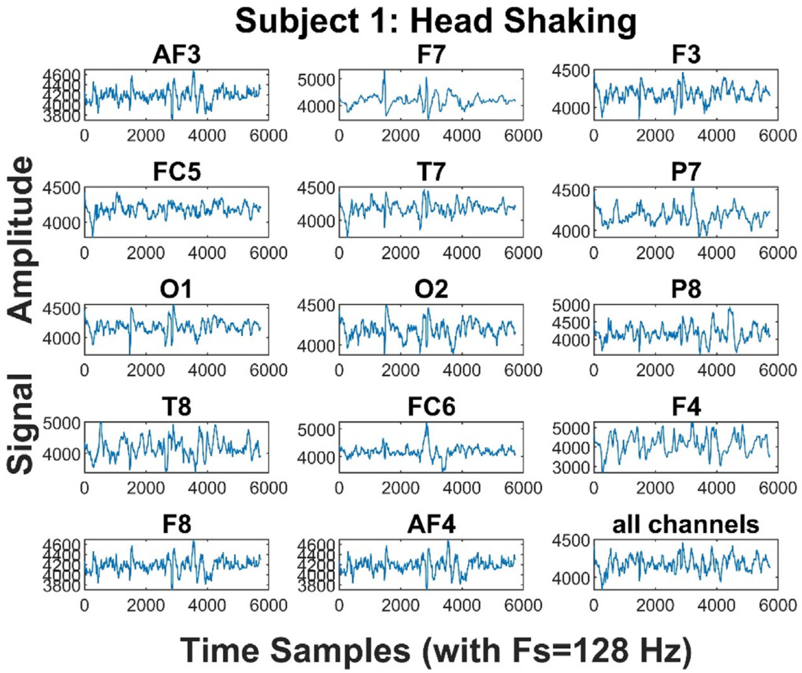

Fig. 7. A sample EEG recording off all 14 channels during Head Shaking (HS) artifacts for Subject-1.

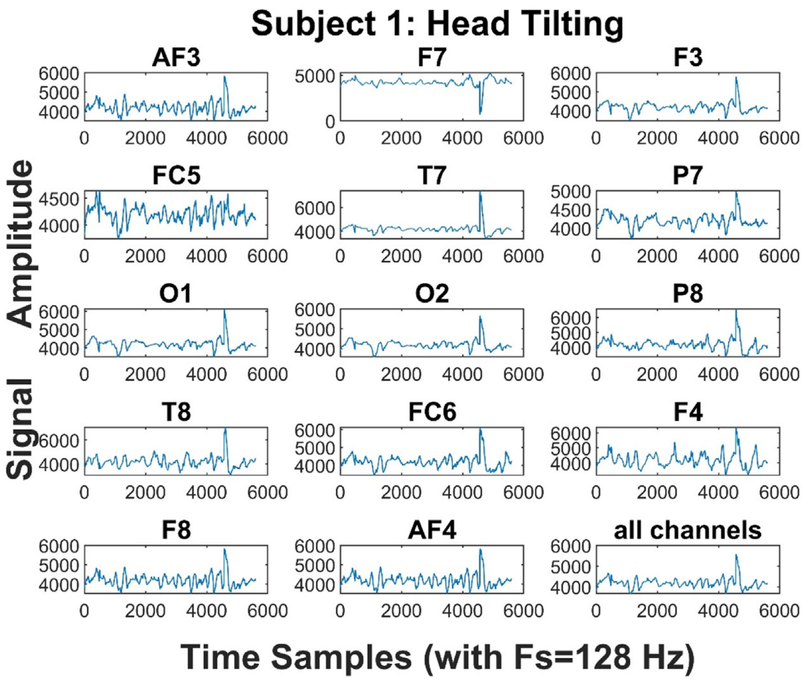

Fig. 8. A sample EEG recording off all 14 channels during Head Tilting (HT) artifacts for Subject-1.

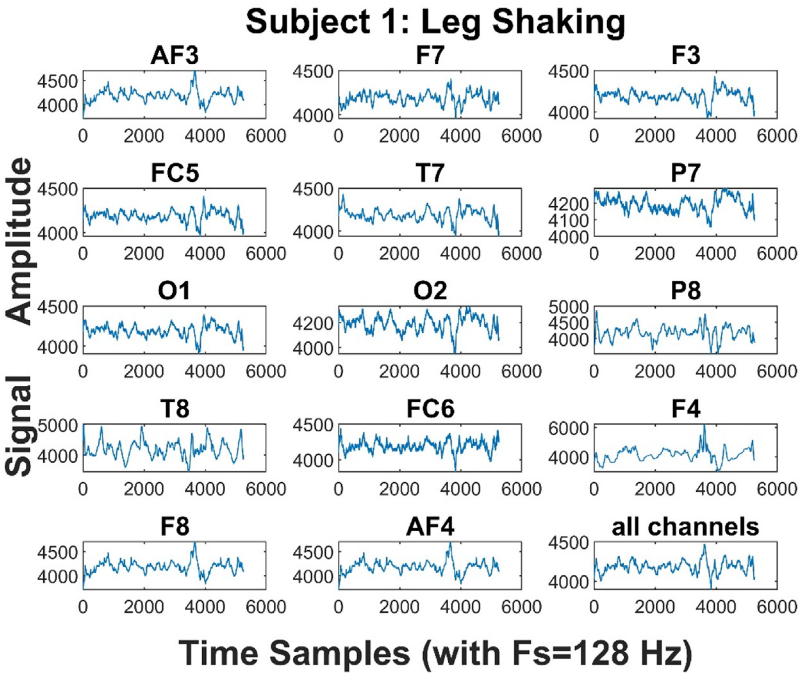

Fig. 9. A sample EEG recording off all 14 channels during Leg Shaking (LS) artifacts for Subject-1.

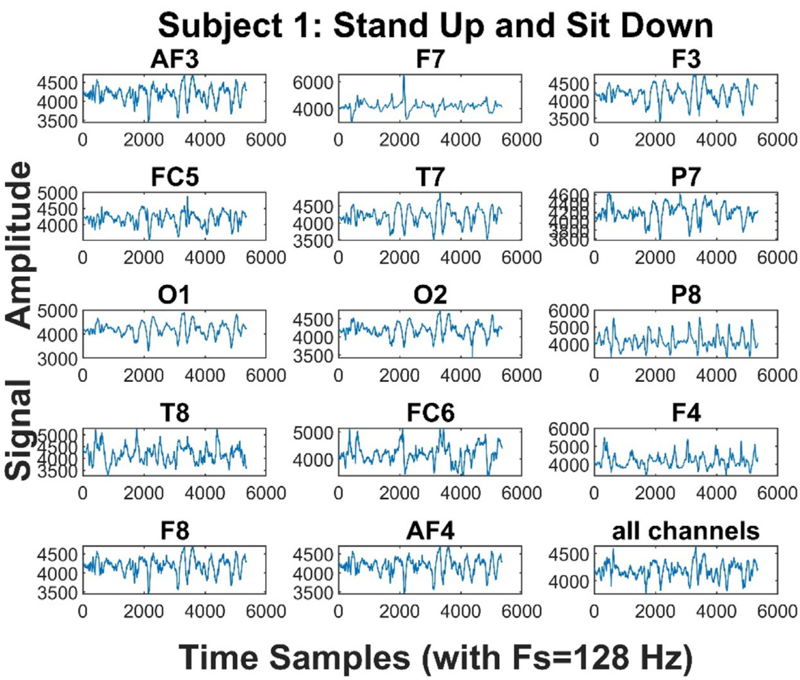

Fig. 10. A sample EEG recording off all 14 channels during Stand Up and Sit Down (SUSD) artifacts for Subject-1.

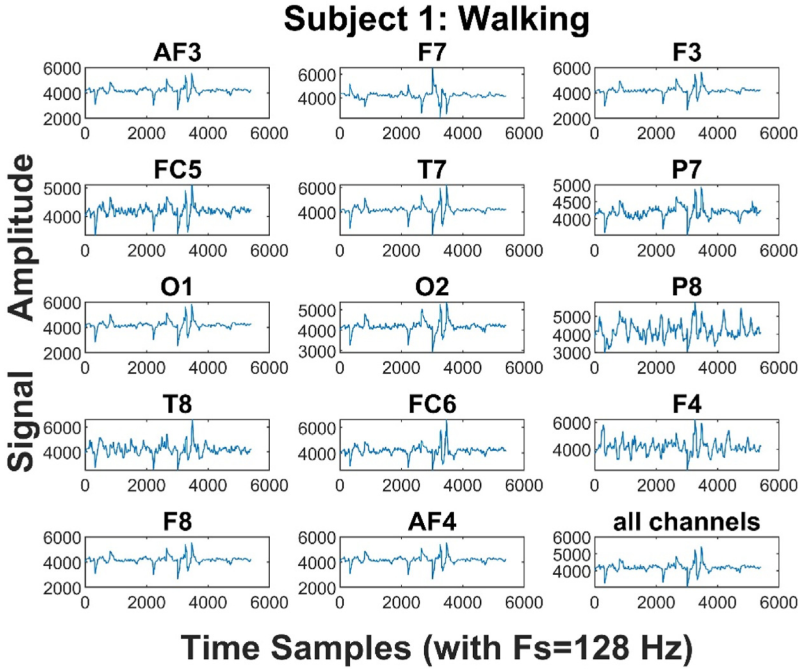

Fig. 11. A sample EEG recording off all 14 channels during Walking artifacts for Subject-1.

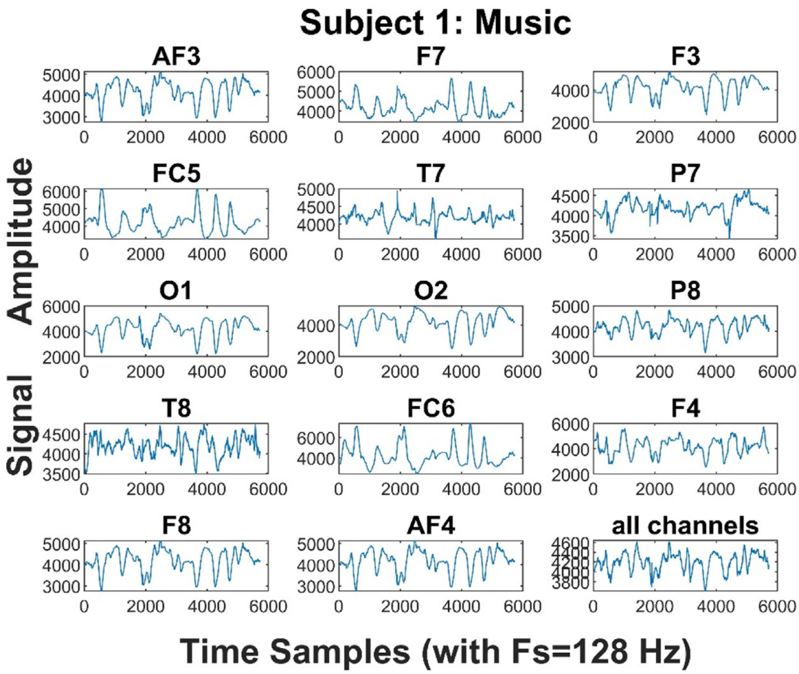

Fig. 12. A sample EEG recording off all 14 channels during Music Listening artifacts for Subject-1.

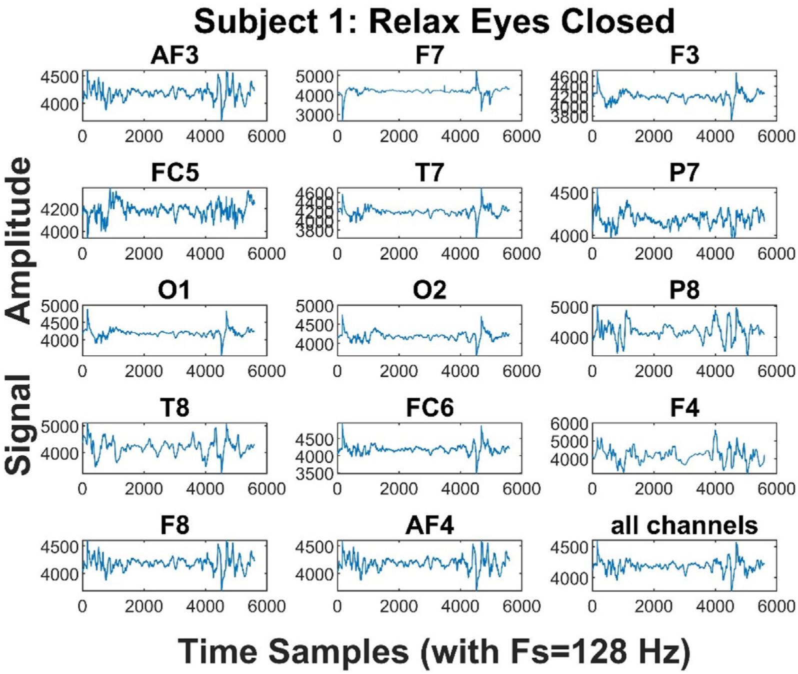

Fig. 13. A sample EEG recording off all 14 channels during Relaxation with closed eyes for Subject-1.

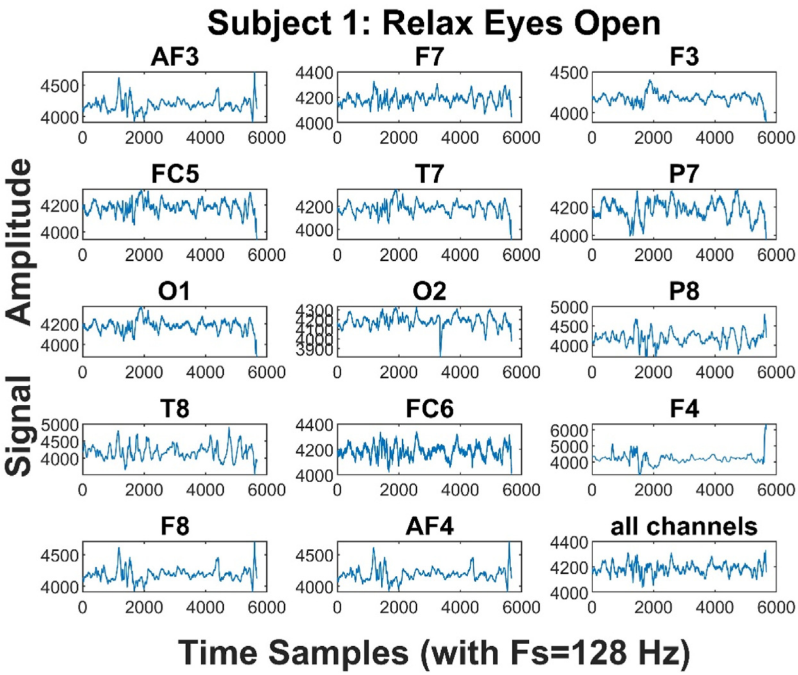

Fig. 14. A sample EEG recording off all 14 channels during Relaxation with open eyes for Subject-1.

Limitations

While recording this dataset, no extra motion sensors captured the subjects' movements. The EMOTIV Epoch EEG headset had built-in sensors within the device, which predominantly capture the upper body and complete body movements compared to feeble lower body motions. Additionally, a video camera setup for the entire recording could have acted as a marker of the subject's movements alongside portraying their intensity. Moreover, more varied movements and subjects of different ages would contribute to a richer dataset.

Ethics Statement

The relevant informed consent was obtained from the subject. The ethical approval was sought and Exempt Review was approved through IRB (Institutional Review Board) of Independent University, Bangladesh (IUB). The ethics protocol no. is '2024-SETS-05'.

Data Availability

Motion Artifact Contaminated Multichannel EEG Dataset (Original data) (Mendeley Data).

CRediT Author Statement

Sheikh Farhana Binte Ahmed: Investigation; **Md. Ruhul Amin:** Conceptualization, Methodology; **Md. Kafiul Islam:** Conceptualization, Methodology.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2024.110994.

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