V1.1

# Dataset Description

*Attempted Arm and Hand Movements can be Decoded from Low-Frequency EEG from Persons with Spinal Cord Injury*

## Associated Publication

Ofner, P., Schwarz, A., Pereira, J., Wyss, D., Wildburger, R. & Müller-Putz, G. R. Attempted Arm and Hand Movements can be Decoded from Low-Frequency EEG from Persons with Spinal Cord Injury. *Scientific Reports*, 9, 7134 (2019)

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## Paradigm

This data set consists of electroencephalography (EEG) data from 10 participants with cervical spinal cord injury (SCI) aged between 20 and 69 years. All participants but P04 were male. The right hand was tested in all participants except P07 where we tested the left hand. All participants were originally right-handed.

We applied two paradigms. First, an offline paradigm comprising 9 participants (P01 - P09), and one session per participant. Second, we recorded with an online paradigm and used a movement-related cortical potentials (MRCPs) classifier to provide feedback. The online paradigm was recorded with participant P09 and comprises two sessions.

### *Offline Paradigm*

Each of the participants sat in front of a computer screen with an arm resting on a pillow on their lap or on a table and they carried out the instructions given on the computer screen. At the trial start, a fixation cross and a beep sound were presented. We asked the participants to focus their gaze on the cross which was displayed during the whole trial period of 5s to avoid eye movements, see Fig. 1. Furthermore, we instructed participants to avoid swallowing and eye blinking during the trial period. The class cue was displayed 2s after the trial start for 3s (i.e. until the end of the trial) and corresponded to one of 5 classes: pronation, supination, palmar grasp, lateral grasp or hand open. Based on the participants' residual motor abilities, they were asked to execute or attempt the corresponding movement immediately when the class cue appeared. Furthermore, they were asked to avoid any other movement. If the participants were able to execute a movement, they went back to their initial position after the trial period. Between trials, a break with a random period of 1s to 3s followed. We recorded 9 runs with 40 trials per run, i.e. 72 trials per class in total. Additionally, we recorded 3 runs each comprising one trial in which participants were instructed to move their eyes and to blink, and 3 runs each comprising one trial in which participants were instructed to rest (i.e. avoid any movement). Trials in the eye movement and rest condition lasted 65s and 70s, respectively.

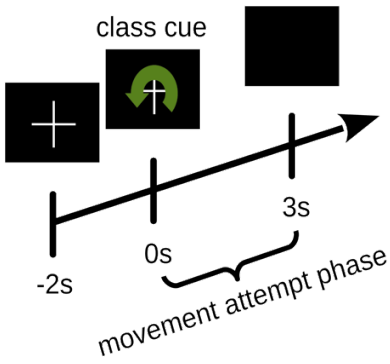


**Figure 1: Trial sequence. At second -2 a cross appeared together with a beep sound; at second 0 the class cue was presented, and participants executed/attempted the respective movement. After the trial, a break with a random duration of 1s to 3s followed.**

### *Online Paradigm*

We employed two separate paradigms in the online classification, one to train the classifier (training paradigm), and one to evaluate the performance (test paradigm).

The *training paradigm* comprises two different trial types: movement trials and rest trials. In a movement trial, a class cue together with a cross and a beep were displayed in the beginning of a trial (c.f. Fig. 2a). The class cue represented either hand open or palmar grasp. After 2s, the class cue was replaced by the ready cue, a filled green circle with a smaller inner white circle. After a random time interval of 0.5s to 1s, the filled green circle started to shrink with a random speed to the size of the inner white circle in 2s to 4s. The participant was instructed to attempt the movement corresponding to the class cue when the filled green circle hit the inner white circle, i.e. the go cue. In the first online session, we instructed the participant to attempt to open or grasp, and deliberately hold the position until the end of the trial, i.e. attempt a sustained movement. In the second online session, we gave the instruction not to hold the position, but to make a short single movement attempt. In both sessions, the experimenter demonstrated the participant a hand open and a palmar grasp movement executed at a regular speed and asked the participant to attempt to imitate these movements. The screen was then cleared 2s later at the end of the trial. A break of 2s to 3s was between trials. The other trial type was a rest trial, where a cross was shown for 70s and the participant was instructed to avoid any movement during this period. We recorded 5 movement runs, each comprised 30 movement trials, and 4 rest runs each comprised 1 rest trial. Thus, in total we recorded 150 movement trials (75 trials per movement class) and 4 rest trials.

In the *test paradigm*, the class cue (hand open, palmar grasp, rest), a fixation cross, and a beep were presented at the beginning of a trial, see Fig. 2b. The class cue was then removed at second 5 and a 60s long period of movement or rest, followed. In the case of a rest class cue, we instructed the participant to avoid any movement during this period. In the case of a movement related class cue, we instructed the participant to attempt multiple self-paced movements of the requested movement class during the 60s period. Furthermore, we instructed the participant to report any movement attempt 2s afterwards by a soft speech sound. The experimenter then promptly pressed a button on the computer to mark the time point of a movement event. However, due to a misunderstanding, the participant reported movement attempts immediately afterwards in the first online session. Moreover, the participant was instructed to wait at least 3s after reporting before attempting the next movement. The online classifier was constantly

active and showed the corresponding movement icon (hand open or palmar grasp) for 2s whenever a movement attempt was detected. We then recorded 6 runs in session 1 and 5 runs in session 2. Each run comprised 4 movement trials and 1 rest trial.

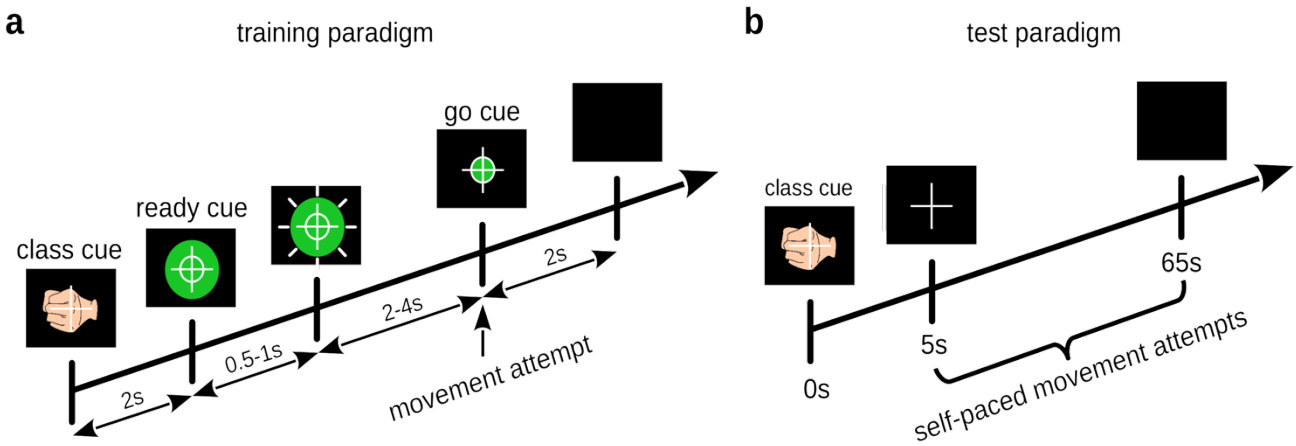


**Figure 2: Training and test paradigms for online classification. a: Training paradigm. A green filled circle shrunk with a random speed. The participant attempted a movement (hand open or palmar grasp) when it hit the inner white circle, i.e. the go cue.**

## Data Acquisition

We measured the EEG with 61 electrodes covering frontal, central, parietal and temporal areas. Additionally, we measured the electrooculogram (EOG) with 3 electrodes placed above the nasion and below the outer canthi of the eyes. Reference was placed on the left earlobe and ground on AFF2h. Signals were recorded using four 16-channel g.USBamps biosignal amplifiers and a g.GAMMAsys/g.LADYbird active electrode system (g.tec medical engineering GmbH, Austria). We sampled signals with 256 Hz and applied a band-pass filter from 0.01 Hz to 100 Hz ($8^{th}$ order Chebyshev filter). Power line interference was suppressed with a notch filter at 50 Hz.

## Data Set

The recorded data are stored in the GDF Format (General Data Format for Biosignals). GDF files can be read with, e.g. BioSig[1] or EEGlab[2].

### *Offline Paradigm*

The data set comprises 15 runs per participant: 9 attempted movement runs, 3 eye movement runs, and 3 rest runs, see Table 1. Every run is stored in a separate GDF file named according to the participant's code name and run number. The cues and other events are encoded with event codes, see Table 2 for the event codes and their descriptions. Table 3 shows the channel labels of the channels stored in the GDF

[1] http://biosig.sourceforge.net
[2] https://sccn.ucsd.edu/eeglab

files. The channel labels indicate the positions of the EEG electrodes according to the 10-5 system, and the positions of the EOG electrodes.

**Table 1: Run number and types in the offline paradigm.**

| *run number* | *run type* |
|---|---|
| 1 | eye movements |
| 2 | rest |
| 3 | attempted movement |
| 4 | attempted movement |
| 5 | attempted movement |
| 6 | attempted movement |
| 7 | attempted movement |
| 8 | eye movements |
| 9 | rest |
| 10 | attempted movement |
| 11 | attempted movement |
| 12 | attempted movement |
| 13 | attempted movement |
| 14 | eye movements |
| 15 | rest |

**Table 2: Event codes in hexadecimal numbers in the offline paradigm.**

| *event code* | *event description* |
|---|---|
| 0x300 | trial start |
| 0x311 | beep |
| 0x312 | fixation cross |
| 0x308 | supination class cue |
| 0x309 | pronation class cue |
| 0x30B | hand open class cue |
| 0x39D | palmar grasp class cue |
| 0x39E | lateral grasp class cue |

**Table 3: Channel labels in the offline paradigm.**

| *channel* | *label* | *channel* | *label* | *channel* | *label* |
|---|---|---|---|---|---|
| 1 | AFz | 25 | FCC6h | 49 | CPP2h |
| 2 | F3 | 26 | C5 | 50 | CPP4h |
| 3 | F1 | 27 | C3 | 51 | CPP6h |
| 4 | Fz | 28 | C1 | 52 | P5 |
| 5 | F2 | 29 | Cz | 53 | P3 |
| 6 | F4 | 30 | C2 | 54 | P1 |
| 7 | FFC5h | 31 | C4 | 55 | Pz |
| 8 | FFC3h | 32 | C6 | 56 | P2 |
| 9 | FFC1h | 33 | CCP5h | 57 | P4 |
| 10 | FFC2h | 34 | CCP3h | 58 | P6 |
| 11 | FFC4h | 35 | CCP1h | 59 | PPO1h |
| 12 | FFC6h | 36 | CCP2h | 60 | PPO2h |
| 13 | FC5 | 37 | CCP4h | 61 | POz |

| | | | | | |
|---|---|---|---|---|---|
| 14 | FC3 | 38 | CCP6h | 62 | EOG left |
| 15 | FC1 | 39 | CP5 | 63 | EOG middle |
| 16 | FCz | 40 | CP3 | 64 | EOG right |
| 17 | FC2 | 41 | CP1 | | |
| 18 | FC4 | 42 | CPz | | |
| 19 | FC6 | 43 | CP2 | | |
| 20 | FCC5h | 44 | CP4 | | |
| 21 | FCC3h | 45 | CP6 | | |
| 22 | FCC1h | 46 | CPP5h | | |
| 23 | FCC2h | 47 | CPP3h | | |
| 24 | FCC4h | 48 | CPP1h | | |

## *Online Paradigm*

The data set contains GDF files for two online sessions of participant P09. The first online session includes 9 training runs and 6 test runs; the second online session includes also 9 training runs but 5 test runs. The 9 training runs comprise 5 attempted movement runs and 4 rest runs, see Table 4. Table 5 shows the event code descriptions. The EEG and EOG channels are the same as in the offline paradigm. Additional to the EEG and EOG data, also data glove data, classifier output data, and button press data (i.e. when the experimenter pressed a button after the participant reported a movement attempt) are available for the test runs, see Table 6.

**Table 4: Run numbers and types in the online training paradigm.**

| *run number* | *run type* |
|---|---|
| 1 | rest |
| 2 | attempted movement |
| 3 | attempted movement |
| 4 | rest |
| 5 | attempted movement |
| 6 | attempted movement |
| 7 | rest |
| 8 | attempted movement |
| 9 | rest |

**Table 5: Event codes in hexadecimal numbers in the online paradigm**

| *event code* | *event description* |
|---|---|
| 0x300 | trial start |
| 0x311 | beep |
| 0x312 | fixation cross |
| 0x30A | palmar grasp class cue |
| 0x30B | hand open class cue |
| 0x600 | ready cue |
| 0x601 | countdown start |
| 0x602 | go cue |

**Table 6: Channel labels in the online paradigm**

| *channel* | *label* | *channel* | *label* | *channel* | *label* | *channel* | *label* |
|---|---|---|---|---|---|---|---|
| 1 | AFz | 25 | FCC6h | 49 | CPP2h | 73 | middle ring |
| 2 | F3 | 26 | C5 | 50 | CPP4h | 74 | ring near |
| 3 | F1 | 27 | C3 | 51 | CPP6h | 75 | ring far |
| 4 | Fz | 28 | C1 | 52 | P5 | 76 | ring little |
| 5 | F2 | 29 | Cz | 53 | P3 | 77 | little near |
| 6 | F4 | 30 | C2 | 54 | P1 | 78 | little far |
| 7 | FFC5h | 31 | C4 | 55 | Pz | 79 | thumb palm |
| 8 | FFC3h | 32 | C6 | 56 | P2 | 80 | - |
| 9 | FFC1h | 33 | CCP5h | 57 | P4 | 81 | - |
| 10 | FFC2h | 34 | CCP3h | 58 | P6 | 82 | - |
| 11 | FFC4h | 35 | CCP1h | 59 | PPO1h | 83 | - |
| 12 | FFC6h | 36 | CCP2h | 60 | PPO2h | 84 | - |
| 13 | FC5 | 37 | CCP4h | 61 | POz | 85 | classifier probability zero-class 1 |
| 14 | FC3 | 38 | CCP6h | 62 | EOG left | 86 | classifier probability zero-class 2 |
| 15 | FC1 | 39 | CP5 | 63 | EOG middle | 87 | classifier probability palmar grasp |
| 16 | FCz | 40 | CP3 | 64 | EOG right | 88 | classifier probability hand open |
| 17 | FC2 | 41 | CP1 | 65 | thumb near | 89 | classifier probability rest |
| 18 | FC4 | 42 | CPz | 66 | thumb far | 90 | detected class (1 = grasp, 2 = open) |
| 19 | FC6 | 43 | CP2 | 67 | thumb index | 91 | button press |
| 20 | FCC5h | 44 | CP4 | 68 | index near | | |
| 21 | FCC3h | 45 | CP6 | 69 | index far | | |
| 22 | FCC1h | 46 | CPP5h | 70 | index middle | | |
| 23 | FCC2h | 47 | CPP3h | 71 | middle near | | |
| 24 | FCC4h | 48 | CPP1h | 72 | middle far | | |