# BCI under Distraction: Motor Imagery in a Pseudo-Realistic Environment

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## 1 Introduction

We have recorded a motor imagery-based BCI study under 5 types of distractions that mimic out-of-lab environments and a control task. The aim of this study was to investigate the robustness of standard BCI procedures in a more realistic scenario. The distractions/secondary tasks include watching a flickering video, searching the room for a specific number, listening to news, closing the eyes, vibro-tactile stimulation and a control task. We recorded 16 healthy participants (6 female; age range: 22-30 years; mean age: 26.3 years) of which only three had previously participated in another BCI experiment.

## 2 Experiment

The main experiment was divided into 7 runs. Each run lasted about 10 minutes and included 72 trials. Each trial lasted 4.5 s and was defined by one motor imagery task plus one of the 6 secondary tasks. The first run served as a calibration phase where no feedback was given and no distraction task added. The subsequent runs included the control task and the 5 distraction tasks and auditory online feedback. Feedback was based on Laplacian filters of the C3 and C4 electrodes and regularized linear discriminant analysis (RLDA). For further information we refer to [2]

## 3 Secondary Tasks

It follows a brief description of the 6 different tasks, more details can be found in [2]

1. Clean:
   This condition serves as a control task without any distraction.

2. Eyes closed:
   Participants performed motor imagery with their eyes closed.

3. News:
   Sequences of a public newscast were played over the headphones containing current news and news from 1994.

4. Numbers:
   For this task, 26 sheets of paper with a randomly mixed letter-number combination were put up on the wall in front of the participants and also on the left and right side of the room. This means the participants needed to turn their head in order to see the sheets. For each trial a new window appeared on the screen asking the participants to search the room for a particular letter to match with a stated number.

5. Flicker:
   A flickering stimulus with alternating gray shades at a frequency of 10 Hz was presented on the screen.

6. Stimulation:
   We placed two coin vibration motors with a diameter of 3 cm on the insides of both forearms, one over the wrist and another one just below the elbow. Vibrotactile stimulation was carried out with carrier frequencies of 50 and 100 Hz, each modulated at 9, 10 and 11 Hz.

# 4 Data Description

For each participant there are 2 types of variables:
`cnt_orig` contains the continuous raw EEG data and `mrk_orig` contains the markers that indicate when a trial starts, when it ends and what kind of trial it is (i.e. which secondary task and whether left or right).
Both variables are 2-dimensional cell arrays where the first entry contains data from the calibration phase (72 trials, no secondary tasks) and the second entry data from the feedback phase (432 trials with secondary tasks and auditory feedback). For each of the 7 runs we stored a separate file, the 6 files from the feedback phase have been concatenated. The starting points of each file are still visible in `mrk_orig{2}.type` defined by a 'NewSegment' marker. In `mnt` the coordinates of all electrodes are stored and can be used for visualization. The two variables `bands` and `ivals` contain individual frequency bands and time intervals for each participants optimized for CSP analysis.

- `cnt_orig`
  - `x`: array of size [number of samples × number of channels], contains the raw EEG data
  - `clab`: cell array with channel labels
  - `fs`: sampling frequency in Hz.
  - `yUnit`: measurement unit
  - `T`: number of total samples per file that have been concatenated
- `mrk_orig`
  - `y`: array of size [number of classes × number of trials]
  - `event:`
    - `desc` markers
    - `type` type of markers i.e. `New Segment` or `Stimulus`

- time: time of events in ms relative to start of measurement
- className:

| | |
|---|---|
| n/d | for a new segment |
| 5 | stop marker when a trial ends |
| ·1 | a left motor imagery trial |
| | first digit depends on the secondary task, i.e. '51' for flicker left |
| ·2 | a right motor imagery trial |
| 101 | auditory feedback left |
| 102 | auditory feedback right |

- mnt
  - x x-position of electrodes
  - y y-position of electrodes
  - pos_3d coordinates for 3D visualization
  - clab cell array with channel labels
- bands: one frequency band per participant in Hz optimized for CSP analysis
- ivals one time interval per participant in ms optimized for CSP analysis

# 5 Preprocessing

The data is stored in a format that can easily be further processed and analysed with the BBCI toolbox [1]. Typical next steps would be to bandpass-filter the data and cut it into epochs based on a predefined time interval and the corresponding markers. This can e.g. be done by:

```
band = [8 30]; %band for bandpass-filter in Hz
ival = [750 3500]; %interval for the time windows in ms
filtOrder = 3;

%calibration data
%define classes based on markers
mrk{1} = mrk_defineClasses(mrk_orig{1}, {11 12; 'left' 'right'});
%calculate filter paramteres
[filt_b,filt_a]= butter(filtOrder, band/cnt_orig{1}.fs*2);
%filter calibration data with butterworth bandpass filter
cnt{1} =  proc_filtfilt(cnt_orig{1}, filt_b, filt_a);
%cut data into epochs
epo.calibration = proc_segmentation(cnt{1}, mrk{1}, ival);

%filter feedback data
cnt{2} = proc_filtfilt(cnt_orig{2}, filt_b, filt_a);

epo_all = cell(1,6);

%feedback data
for icond= 1:6  %each secondary task has a different marker
    %it is also possible to define classes based on multiple
    markers:
    %mrk_defineClasses(mrk_orig{2}, {[11:10:61] [12:10:62]; 'left'
    'right'});
    mrk_tmp = mrk_defineClasses(mrk_orig{2}, {icond*10+1 icond
    *10+2; 'left' 'right'});
```

```
    %data is stored individually for each secondary task
    epo_all{icond} = proc_segmentation(cnt{2}, mrk_tmp, ival);
end
```

More code can be found on
`https://github.com/stephaniebrandl/BCI-under-distraction`.
Data can also be transformed to a format that is compatible with other toolboxes as e.g. EEGLAB, this however needs to be done manually as there currently is no function to do that.

## References


[1] Benjamin Blankertz, Laura Acqualagna, Sven Dähne, Stefan Haufe, Matthias Schultze-Kraft, Irene Sturm, Marija Ušćumlic, Markus A Wenzel, Gabriel Curio, and Klaus-Robert Müller. The berlin brain-computer interface: progress beyond communication and control. *Frontiers in Neuroscience*, 10:530, 2016.

[2] Stephanie Brandl, Laura Frølich, Johannes Höhne, Klaus-Robert Müller, and Wojciech Samek. Brain–computer interfacing under distraction: an evaluation study. *Journal of neural engineering*, 13(5):056012, 2016.