Dataset Documentation

Regulation of arousal via online neurofeedback improves human performance in a demanding sensory-motor task

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(1) Reference

We hope you find this data useful. Please reference the following paper, when using the data:

Faller, J., Cummings, J., Saproo, S. & Sajda, P. (2019) Regulation of arousal via online neurofeedback improves human performance in a demanding sensory-motor task. Proceedings of the National Academy of Sciences (PNAS).

If you have any questions about the data or the paper, please find the contact information of the corresponding authors at the end of this document.

(2) Aim

Test whether auditory neurofeedback intervention mitigates effect of Pilot Induced Oscillations (PIO) during boundary avoidance task (BAT).

(3) Hypothesis

Down-regulating arousal via auditory neurofeedback improves time-on-task in BAT.

(4) Subject inclusion criteria

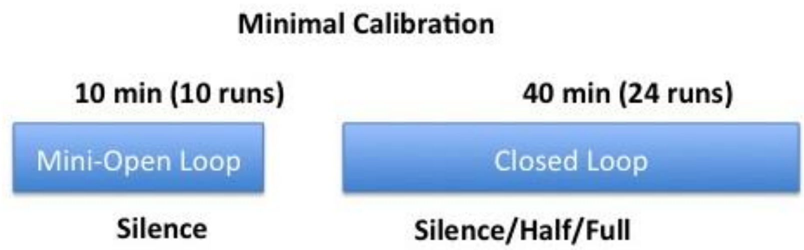
o > 18 years
o Normal or contact lens corrected to normal vision
o Neurologically normal and no (potentially interfering) medical condition
o Not on any medication (self reporting)
o Novice to the task
o Right handed
o Balanced, male/female

(5) Paradigm

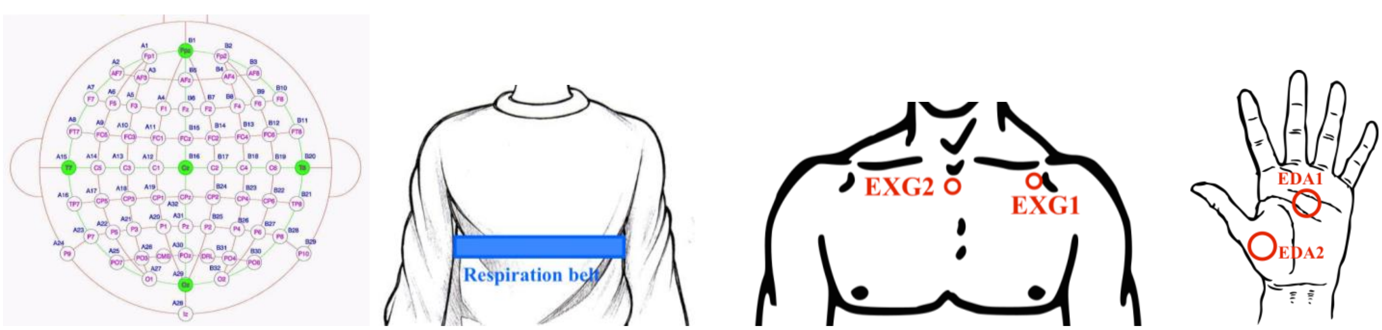
(5.a) Screening session

o Subjects come in on a separate day prior to participating in experiment.
  o No biophysiological signals but behavior, like eyetracking, head-, joystick & plane movement
o We train them in flying in the measurement cabin
  o Max 2 practice runs for them to get acquainted with Joystick
  o Non-practice runs until 3 of 4 consecutive runs are above 60 seconds / 66%
    o We record every run with number and path length in percentage in our measurement report.
  o Max duration around 40 minutes.
  o Subjects that reach proficiency within the 40 minutes are enrolled in the Experimental session
o Subjects receive flat monetary reimbursement for travel and time
o Subjects are told to be well rested and not intoxicated for the experiment.

(5.b) Experimental session



	Rec-Name	Total (minutes)
BEFORE subject arrives: Preparation (syringes, sensors, battery, materials)		20
Explanation + PPTs + subject signs previously received CONSENT		10
PPTs + Mount (1) Respiration (2) ECG (3) EDA (4) 64 x EEG		20+10
Put on Oculus rift.		
Run demo scene to calib & 9 point eye-tracker calibration		2+3
Record relaxed state with eyes open wearing Oculus.	**RWEO**	1 + 1
Max 2 practice runs		2
Open Loop RUNS (SILENCE ONLY, Bose NOISE CANCELLING ON)	**OLoop**	10 (10 x [1 + 1])
Record relaxed state with eyes open wearing Oculus.	**RWEO**	
Take off Oculus rift.		
Train classifier		10
Put on Oculus. Demo scene. Again 9 pt ET-calib.		
Record relax with eyes open wearing Oculus.	**RWEO**	
Closed Loop RUNS (Silence / Half / Full random! / 2 path difficulties alternated!)	**CLoop**	40 (24 x [1 + 1])
Record relax with eyes open wearing Oculus.	**RWEO**	
Take off Oculus rift.		
Debriefing		5
Subject signs payment receipt, receive monetary reimbursement, subject goes home		5
MAXIMUM TOTAL		**2.5 h**



Montage of the sensors.

o “Trial” structure
- o 3 x 15 Rings (large, medium and small size), 2 seconds between rings, ~500 m/s
- o max. 90 seconds per trial
- o Safety critical boundaries => failure to pass through ends trial abruptly

- o INSTRUCTION to participant:
  - o For Flying
    - “Please fly the virtual plane through this course of red boxes.”
    - “The boxes are about 2 seconds apart and get smaller every 30 seconds.”
    - “Make sure you go through every box. Missing a box ends the paradigm immediately.”
    - “The real world equivalent of missing a box can be thought of as crashing a plane.”
  - “Joystick control works only AFTER the first box. Do not move the joystick before.”
    - “Joystick control is delayed and less direct to more closely resemble flying a real plane.”
    - “To be successful make slow, small and controlled joystick movements and compensate carefully.”
  - o Additionally for the feedback
    - “If you hear heartbeat feedback, try to bring yourself into a state where the volume of the heartbeat becomes and stays as low as possible”

- o Closed Loop Conditions (sequence random for every subject)
  - o Subjects were kept blind as to the difference between the conditions where heart beat sound was audible (2 & 3).
    - o (1) Silence: No feedback
    - o (2) Half: 50% Sham, 50% real feedback
    - o (3) Full: 100% real feedback

- o Audio feedback
  - o PC volume configured to 50% of max
  - o Artificial heartbeat feedback louder with increasing “PIO-index”
  - o Only volume, not rate of heart beat is modulated
  - o Moving average on BCI output 5 seconds

- o 2 Paths
  - o Alternate between easy and difficult path, as in the pilot study
  - o Length of paths 90 seconds

Filter delay = 0.3
Filter UP Time = 0.6
Filter DOWN Time = 0.8

Relax with eyes open 1 min before and after every part

(6) Setup

- o In farad. cage, conveniently upright in body-contoured seat, airplane joystick, controlled with right hand
- o No light in cabin, shades closed, lights on outside the recording box.
- o Bose, noise cancelling head-phones

(7) Recorded data

(7.a) Signal types, sampling rates and event markers

- o BioSemi 64 Electrodes (fs = 2048 Hz)
- o EKG, bipolar derivation @ thorax (fs = 2048 Hz)
- o EDA (aka. GSR) @ palm of left hand (fs = 2048 Hz)
- o Respiration (fs = 2048 Hz)
- o Pupillometry (fs = 60 Hz)
- o Gaze (fs = 60 Hz)
- o Joystick input

o Flight trajectory
o Location of boundaries
o Tracking of HMD movement and orientation
o Output of autoregressive model (“Shm-raw”, experimental software performed additional scaling)
o BCI result as output by BCILAB (“BCI-raw”, experimental software performed additional scaling)
o Actual feedback (“FB-HB-raw”, mix of sham from autoregressive model and BCI)

o Event Markers
    o Start and end of flights
    o Which size of ring was passed and what was the experimental condition (see COND, below).
    o For present R spike, which ring was last passed
    o ECG R spike
    o Eye blinks

COND 0 = SILENCE (no audio feedback), but specifically in open-loop block that was used for calibration
COND 1 = SILENCE (no audio feedback), closed-loop block
COND 2 = HALF BCI / HALF SHAM, closed-loop block
COND 3 = FULL BCI, closed-loop block

(7.b) Mild preprocessing and data preparation

For convenience, the signals across all modalities were synchronized using Matlab signal processing toolbox, resampled to 256 Hz (including adequate filtering) and data for flight attempts was concatenated separately for the open loop and the closed loop block.

Prior to downsampling, EEG was low-pass filtered with a cut-off at 70 Hz (Butterworth, order 8). After downsampling, the EEG was high-pass filtered at a cut-off at 0.5 Hz (Butterworth, order 5).

(7.c) How to best work with the data

All datasets are stored in Matlab structures inside Matlab .MAT files. The structures adhere to EEGLAB format and can be loaded into Matlab using the command

    BF_Data = load (“…”);

For this example, you would then find the EEGLAB data structure here

    BF_Data.actualVariable.EEG_full

and should then see something similar to the following fields displayed in the Matlab console:

```
       setname: 'Merged datasets'
      filename: ''
      filepath: ''
       subject: ''
         group: ''
     condition: ''
       session: []
      comments: ''
        nbchan: 144
        trials: 1
          pnts: 277761
         srate: 256
```

```
               xmin: 0
               xmax: 1085
              times: [1x277761 double]
               data: [144x277761 single]
             icaact: []
            icawinv: []
          icasphere: []
         icaweights: []
        icachansind: []
           chanlocs: [1x144 struct]
         urchanlocs: []
           chaninfo: [1x1 struct]
                ref: 'common'
              event: [1x10673 struct]
            urevent: [1x10673 struct]
   eventdescription: {''  ''  ''  ''  ''  ''  ''  ''  ''  ''  ''  ''  ''  ''  ''}
              epoch: []
   epochdescription: {}
             reject: [1x1 struct]
              stats: [1x1 struct]
           specdata: []
         specicaact: []
         splinefile: ''
      icasplinefile: ''
             dipfit: []
            history: ''
              saved: 'no'
                etc: []
```

You would be able to visualize the time series for the data with the command

pop_eegplot (BF_Data.actualVariable.EEG_full)

Please feel free to check

https://sccn.ucsd.edu/wiki/EEGLAB_TUTORIAL_OUTLINE

or

https://sccn.ucsd.edu/eeglab/index.php

for further ways to work with the data in EEGLAB or

https://sccn.ucsd.edu/wiki/BCILAB

to learn how to work with the data in BCILAB, for example to do single trial based classification on the data.

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of neuroscience methods*, *134*(1), 9-21.

Kothe, C. A., & Makeig, S. (2013). BCILAB: a platform for brain–computer interface development. *Journal of neural engineering*, *10*(5), 056014.

(7.d) Missing data

The data for subjects 13 and 14 was not analyzed for the study since one of the subjects had to leave in the middle of the recording session and the other subject accidentally introduced strong muscle artifacts into the data for about half of the experiment by changing their posture.

Some of the baseline recordings (relax with eyes open, RWEO, see above) are missing because of technical or logistical problems. These were not analyzed for the study though.

(8) Contact information

For questions please feel free to contact the corresponding authors

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or

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(9) Acknowledgements

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