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Emotion classification with EEG

Neuro-Usability WiSe 2018/19

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Motivation / Goals

- Design and conduct an experiment in order to generate emotional responses (in Virtual Reality) and analyse the corresponding physiological signals

- Model and train a classifier, which is able to predict an emotional state (self-assessment) through EEG signal data, using current machine learning techniques

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Related literature

- Affect generation
  - **DEAP**: “A **D**atabase for **E**motion **A**nalysis Using **P**hysiological Signals “ (Koelstra et al., 2012) [3]
- Affect detection / analysis
  - “Classification of Human Emotions from Electroencephalogram (EEG) Signal using Deep Neural Network” (Al-Nafjan et al., 2017) [1]

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Experiment design

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Experiment design

- What theoretical emotion model do we use?
- How do we generate a variety of emotional responses?
- How do participants self-assess their emotional state?

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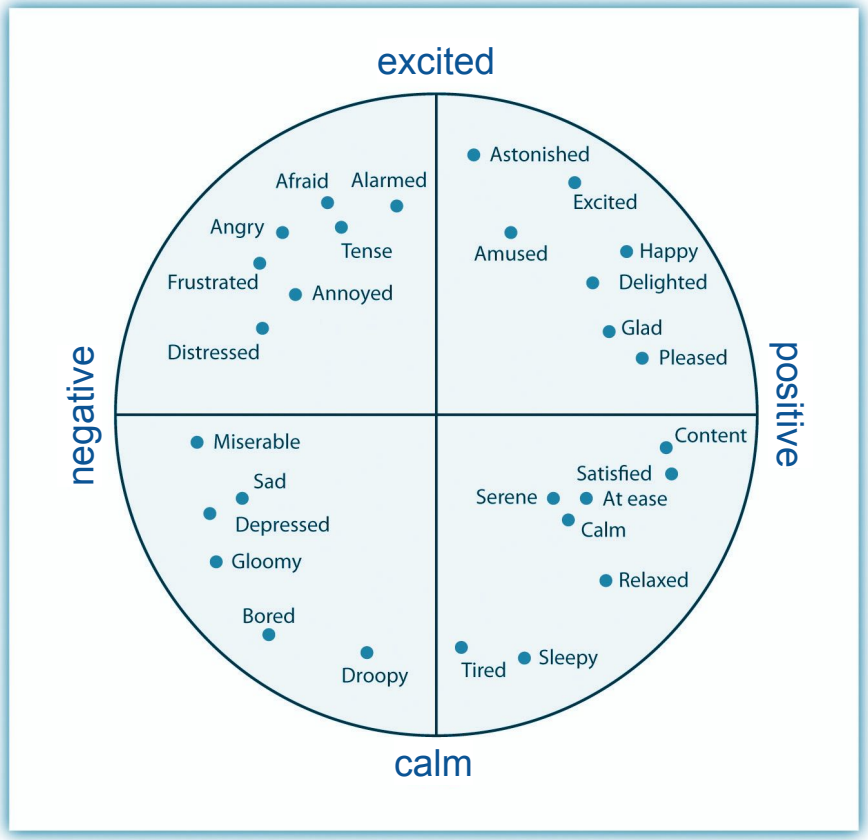
Experiment design

- What theoretical emotion model do we use?
  - ➢ **Dimensional model (Valence-Arousal space)**
- How do we generate a variety of emotional responses?
  - ➢ **Three different Virtual Reality games**
- How do participants self-assess their emotional state?
  - ➢ **Self-Assessment Manikin**

Experiment design - Emotional model



- Valence <-> Arousal
- three games:
  - positive excited
  - negative excited
  - positive calm

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Experiment design - VR Games

positive excited

*"**Beat Saber** is a VR rhythm game where your goal is to slash the beats which perfectly fit into precisely handcrafted music."* [4]

Experiment design - VR Games

negative excited

*"**Brookhaven** is a VR survival shooter [...]. Players will have to use the weapons and tools provided to survive ever more terrifying waves of horrific monsters."* [5]

Experiment design - VR Games

positive calm

"Explore tropical beaches, underwater oceans and even take to the stars. Relax and immerse yourself into the ***Nature Treks VR*** *experience."* [6]

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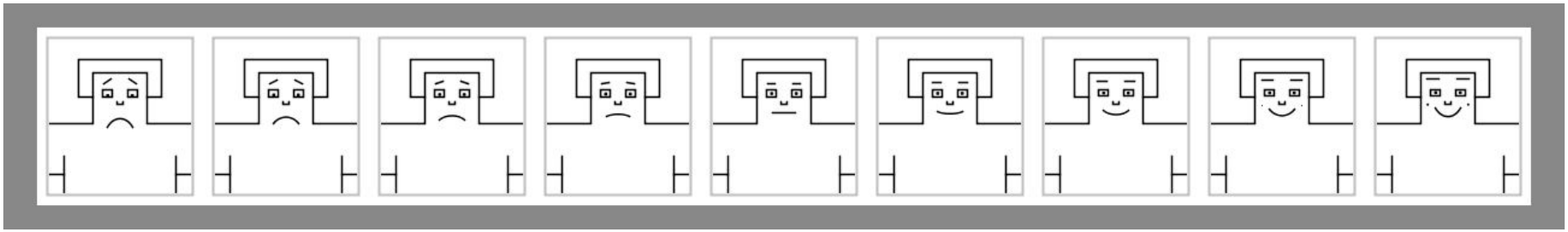
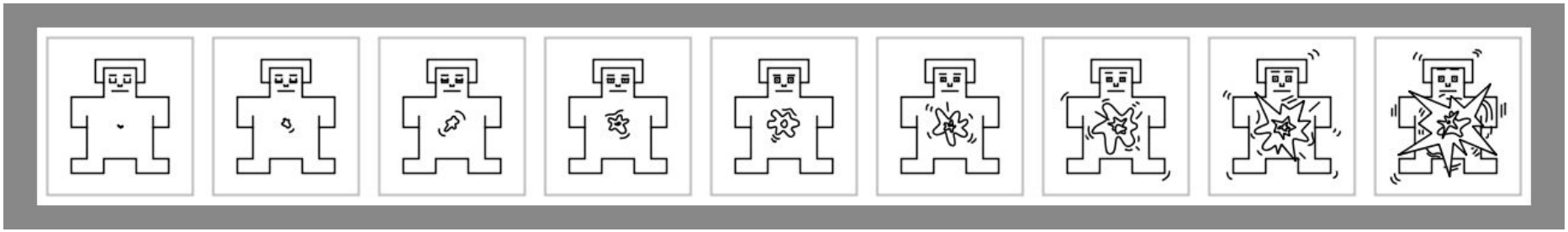
Experiment design - Self-Assessment Manikin

Valence



Arousal



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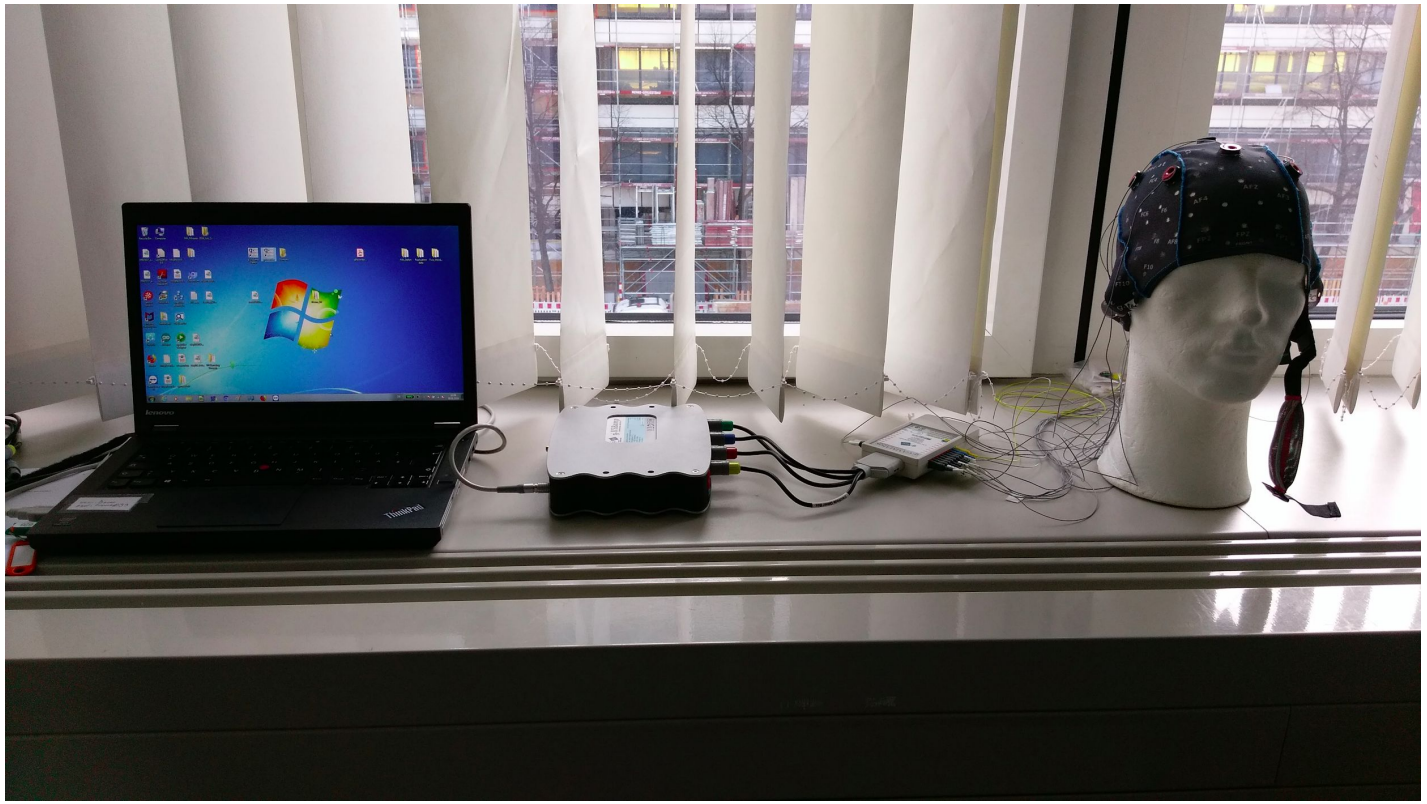
Experiment design - EEG setup



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Experiment design - procedure

- Introduction, signing of consent letter, demographic questionnaire
- EEG preparation, basic explanation of games
- For each game:
  - few minutes to get familiar to the game controls
  - gameplay: about 3 minutes (one song/ one level …)
  - self-assessment rating

➢ ~ 45 minutes

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Data analysis

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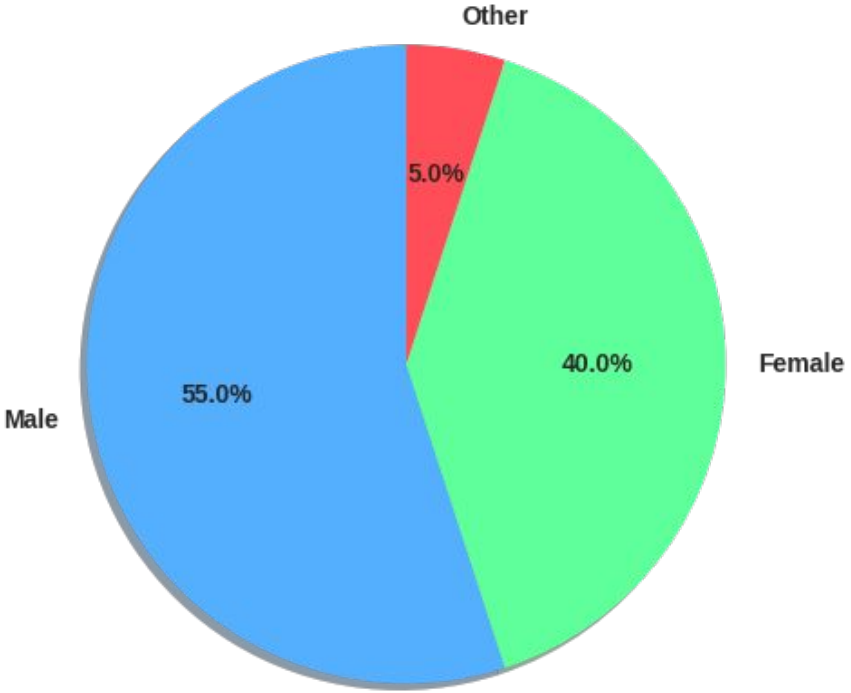
Demographics

- 20 participants
- age: 20-35 years
  - (mean: 25 years)
- little to no Virtual Reality experience (with few exceptions)



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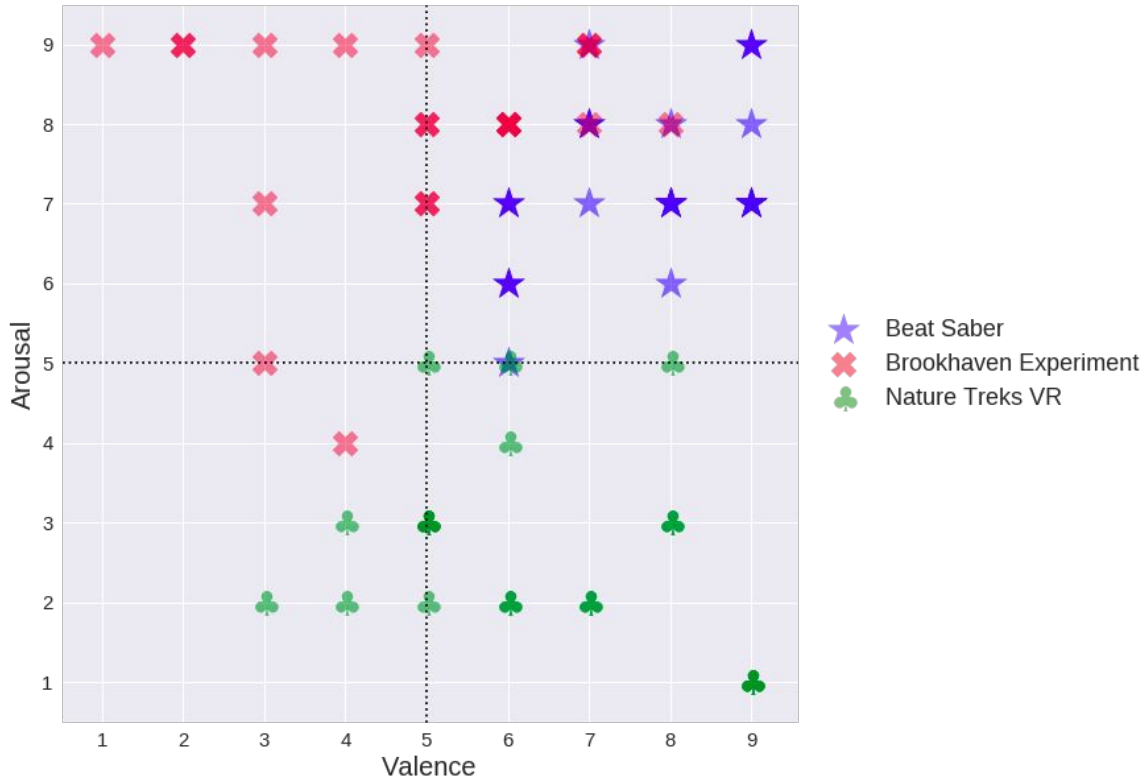
Self-Assessment ratings per game

Valence (mean, std):

- beat: 7.6 (+/- 1.2)
- brook: 4.7 (+/- 1.9)
- nat: 6.3 (+/- 1.8)

Arousal (mean, std):

- beat: 7.3 (+/- 1.1)
- brook: 7.9 (+/- 1.4)
- nat: 2.7 (+/- 1.3)



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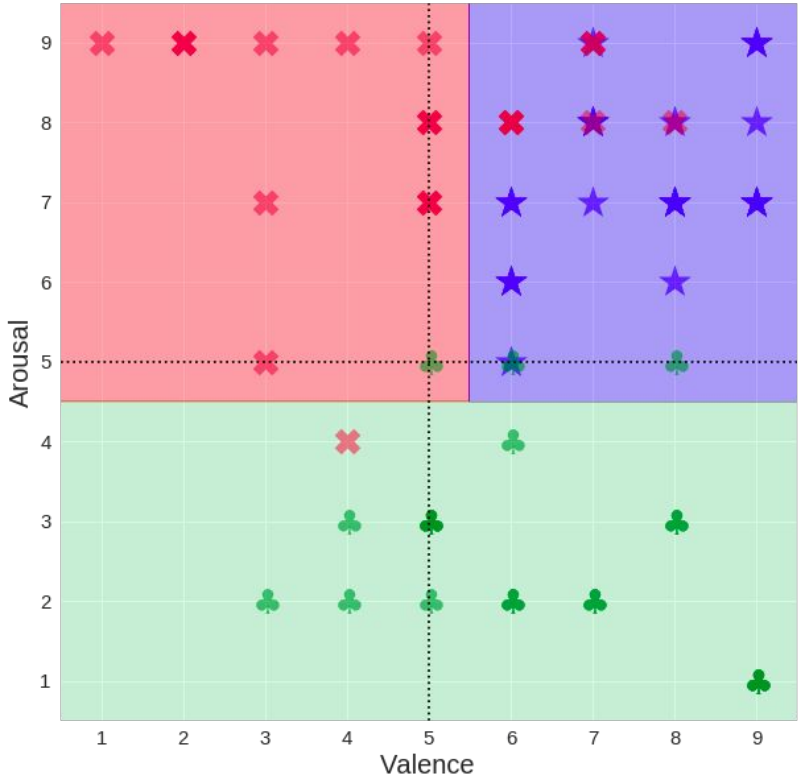
Self-Assessment ratings per game -> labels

- positive excited
  - v>5, a>=5
- negative excited
  - v<=5, a>=5
- calm
  - a<5



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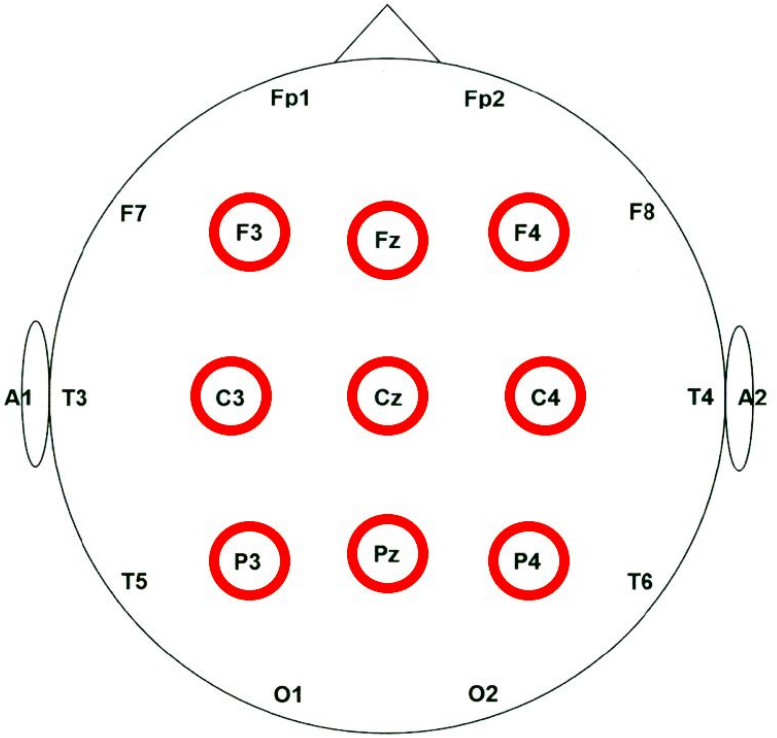
EEG analysis

- 9 channels
- signal preprocessing
- conversion from time domain to frequency domain
- compute average “Power Spectral Density” for four frequency ranges (theta, alpha, beta, gamma)



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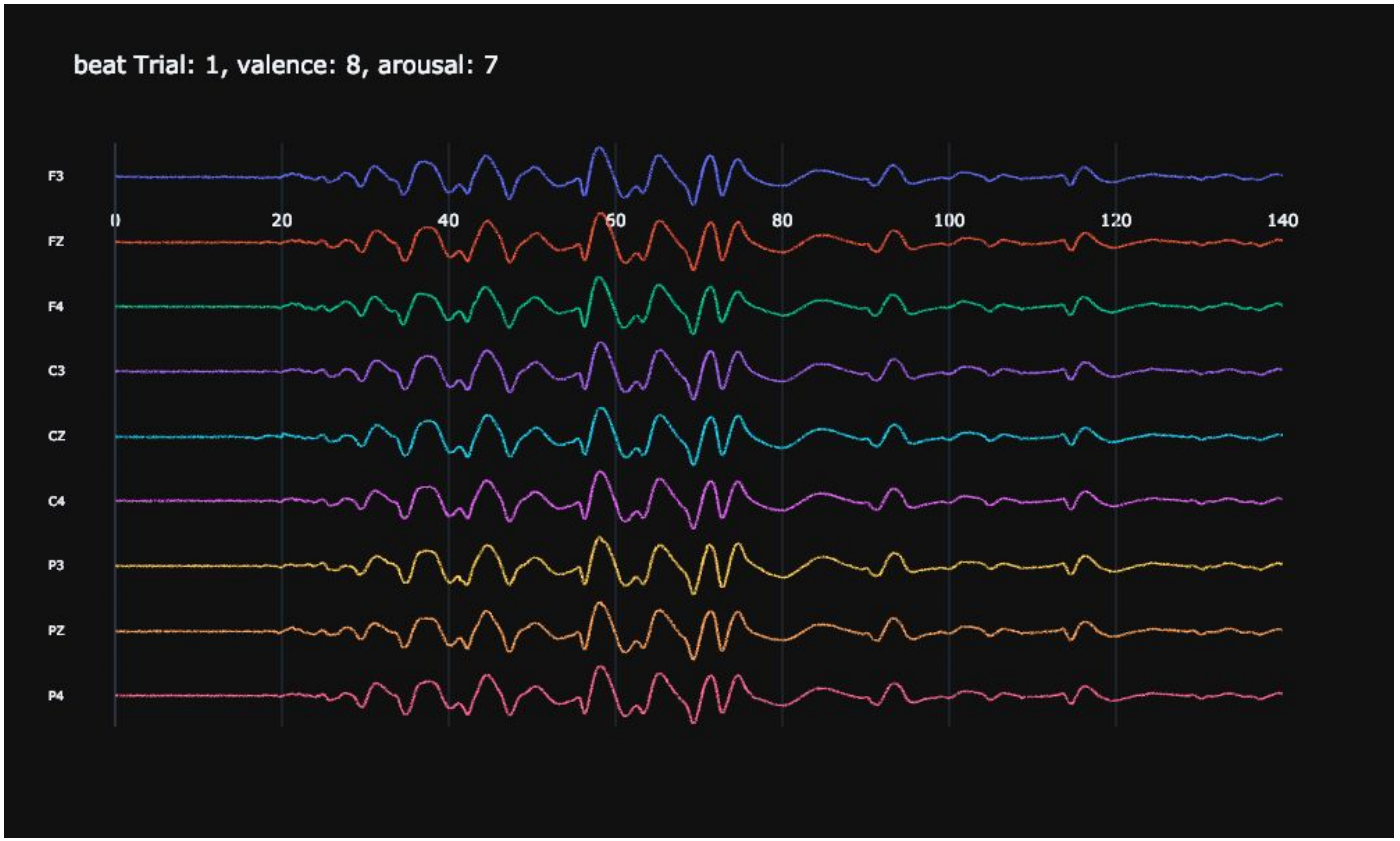
EEG analysis - signal in time domain



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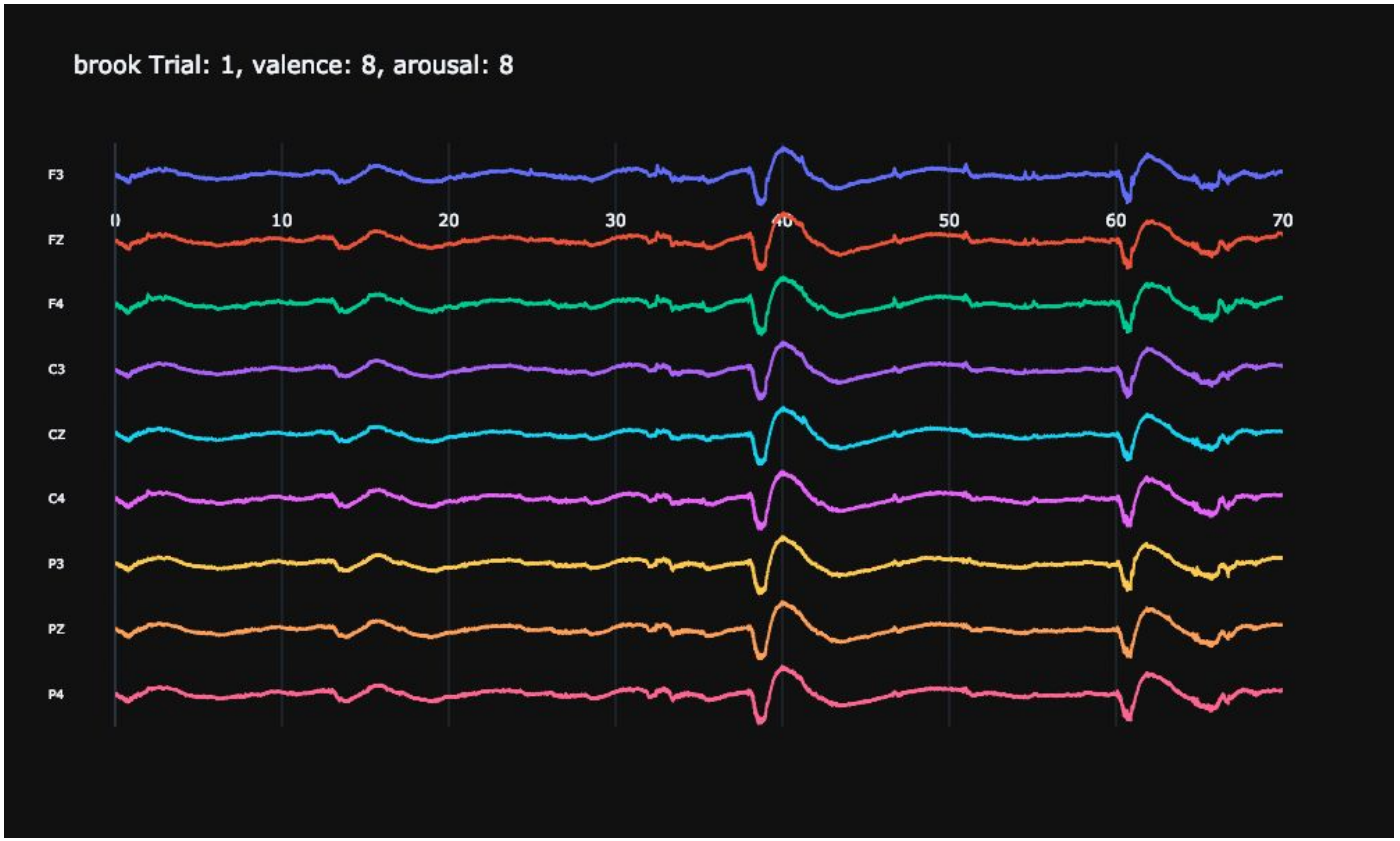
EEG analysis - signal in time domain



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EEG analysis - signal in time domain

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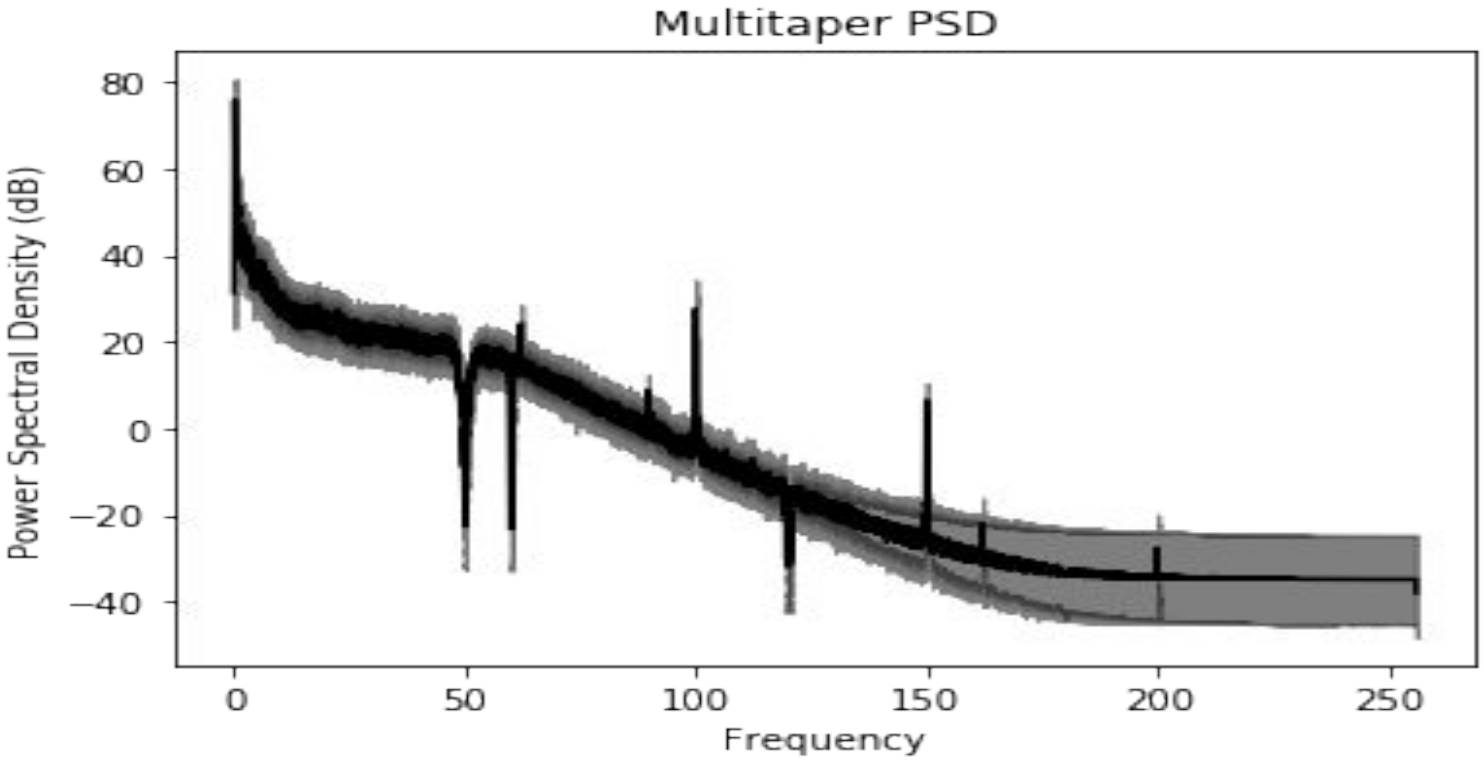
EEG analysis - Frequency domain data



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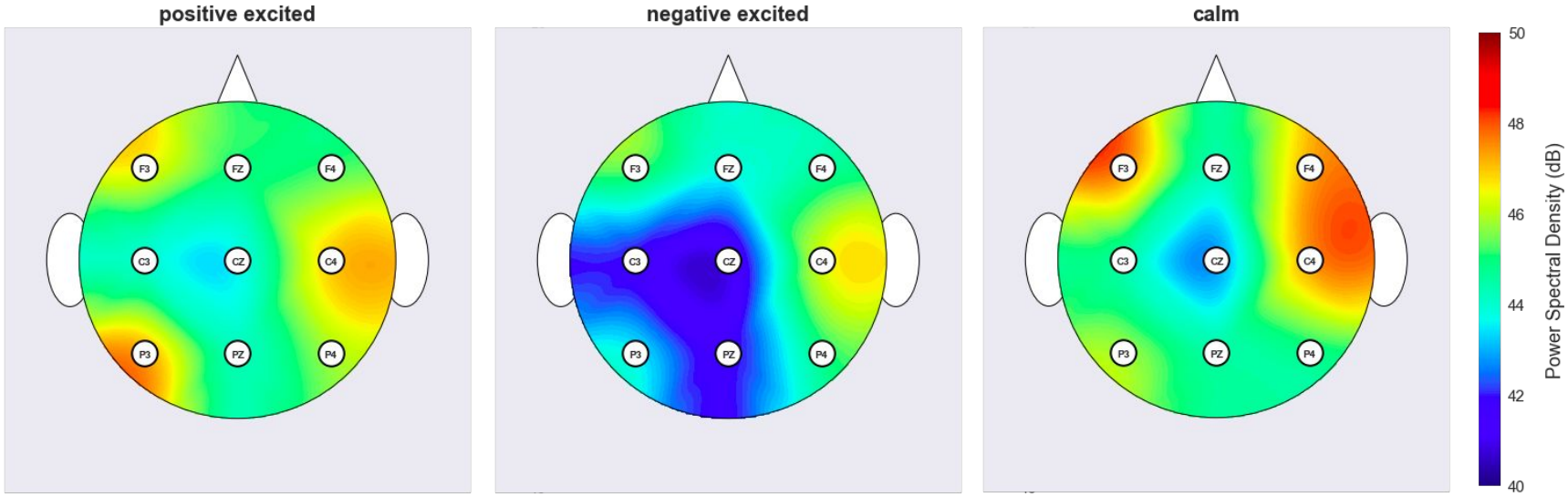
EEG analysis - PSD average (theta: 2-8 Hz)

(averaged again over every record with the same label)



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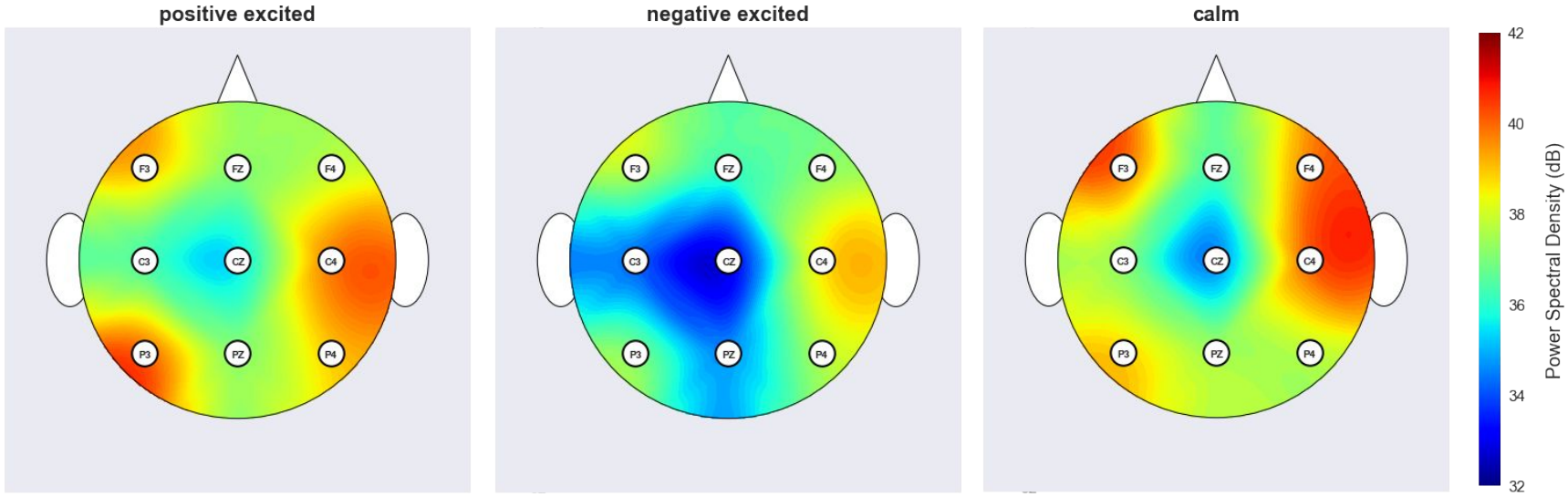
EEG analysis - PSD average (alpha: 8-13 Hz)

(averaged again over every record with the same label)



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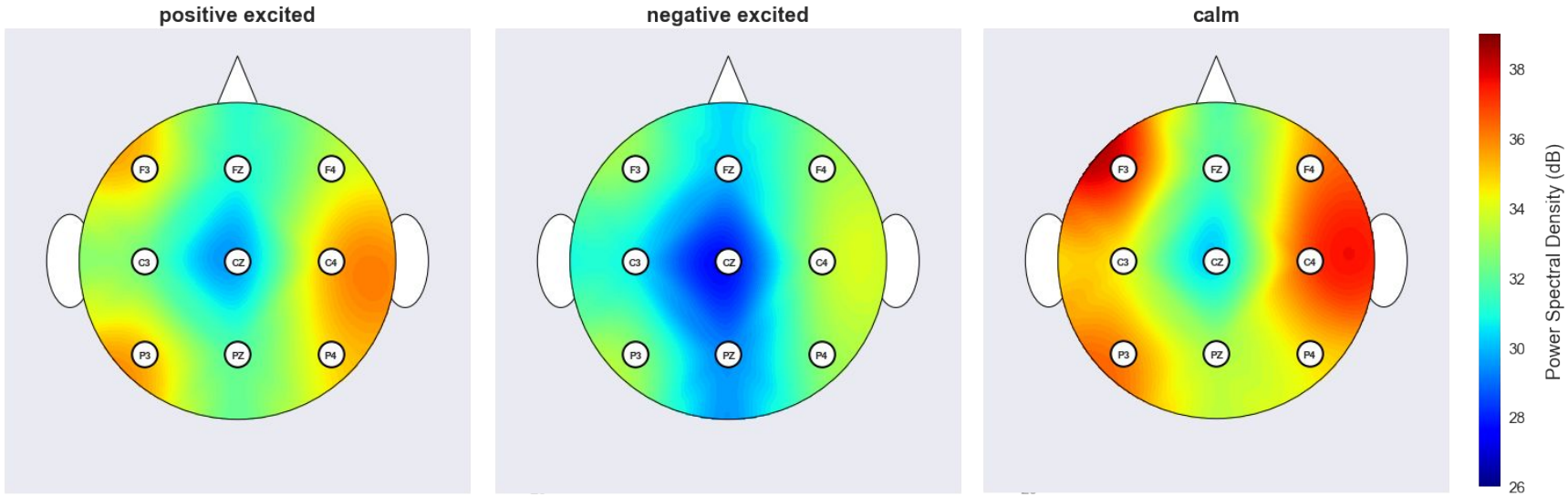
EEG analysis - PSD average (beta: 13-30 Hz)

(averaged again over every record with the same label)



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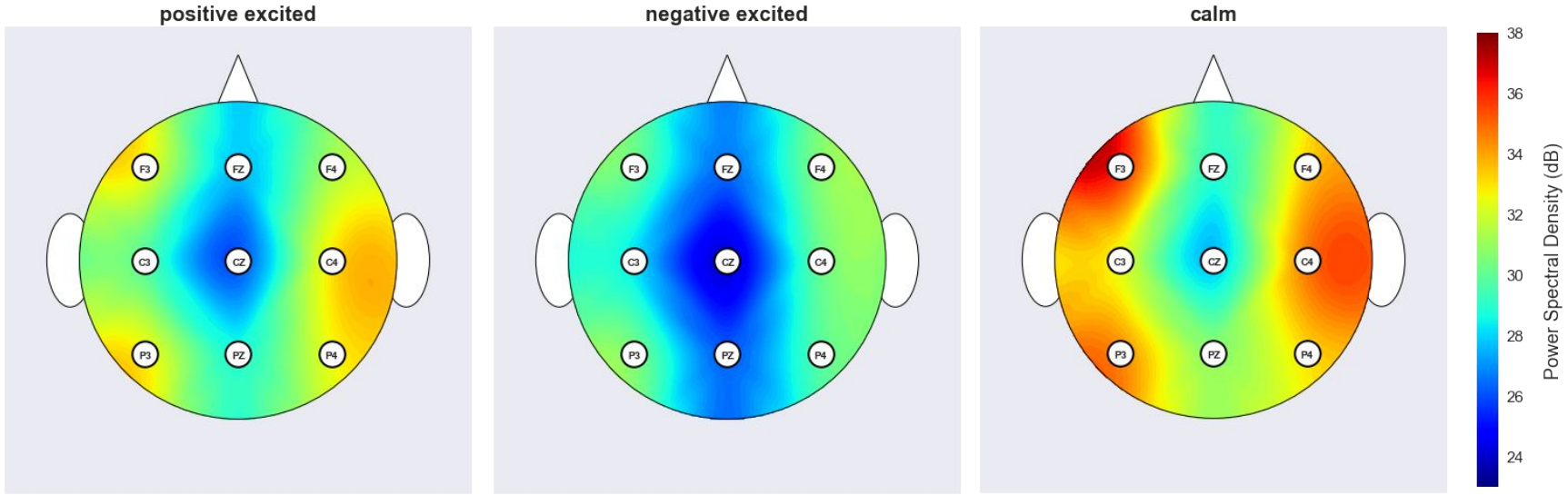
EEG analysis - PSD average (gamma: 30-... Hz)

(averaged again over every record with the same label)



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EEG analysis - Classification

- Evaluation was done by performing a 5-fold cross validation
- Time domain: 3 Deep convolutional networks were trained on trial data

  ➢ **~ 60 % accuracy**

- Frequency domain: Input PSD, standard Multilayer Perceptron

  ➢ **~ 53 % accuracy**

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EEG analysis - Classification

for comparison (using DEAP data set):

- Chung and Yoon, 2012 (four classes) [2]:
  - ➢ 53.4 %
- Koelstra et al., 2012 (valence, arousal separately; two classes each) [3]:
  - ➢ ~ 75.2 % (valence), ~ 81.7 % (arousal)
- Al-Nafjan et al., 2017 (four classes) [1]:
  - ➢ 82.0 %

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Outlook & improvements

- classify valence and arousal separately
- combine with other physiological sensors: heartbeat, skin conductance, etc.
- use more EEG channels, especially in the front area (Frontal EEG Asymmetry used as feature in other papers)
- need to look for better material for ‘negative-exciting’
- better time management -> more participants -> better results

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Thank you!

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References

[1] Al-nafjan, A. & Hosny, M. & Al-Wabil, A. & Al-Ohali, Y.. (2017). Classification of Human Emotions from Electroencephalogram (EEG) Signal using Deep Neural Network. International Journal of Advanced Computer Science and Applications. 8. 10.14569/IJACSA.2017.080955.

[2] S. Y. Chung and H. J. Yoon, “Affective classification using Bayesian classifier and supervised learning”, Control, Automation and Systems (ICCAS), pp. 1768–1771, 2012.

[3] Koelstra, Sander & Mühl, Christian & Soleymani, Mohammad & Lee, Jong-Seok & Yazdani, Ashkan & Ebrahimi, Touradj & Pun, Thierry & Nijholt, Anton & Yiannis) Patras, Ioannis. (2011). DEAP: A Database for Emotion Analysis Using Physiological Signals. *IEEE Transactions on Affective Computing*. 3. 18-31. 10.1109/T-AFFC.2011.15.

[4] Deep learning with convolutional neural networks for EEG decoding and visualization

[5] https://store.steampowered.com/app/620980/Beat_Saber/

[6] https://store.steampowered.com/app/440630/The_Brookhaven_Experiment/

[7] https://store.steampowered.com/app/587580/Nature_Treks_VR/