Using EEG to Decode Subjective Levels of Emotional Arousal during an Immersive VR Roller Coaster Ride

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Background

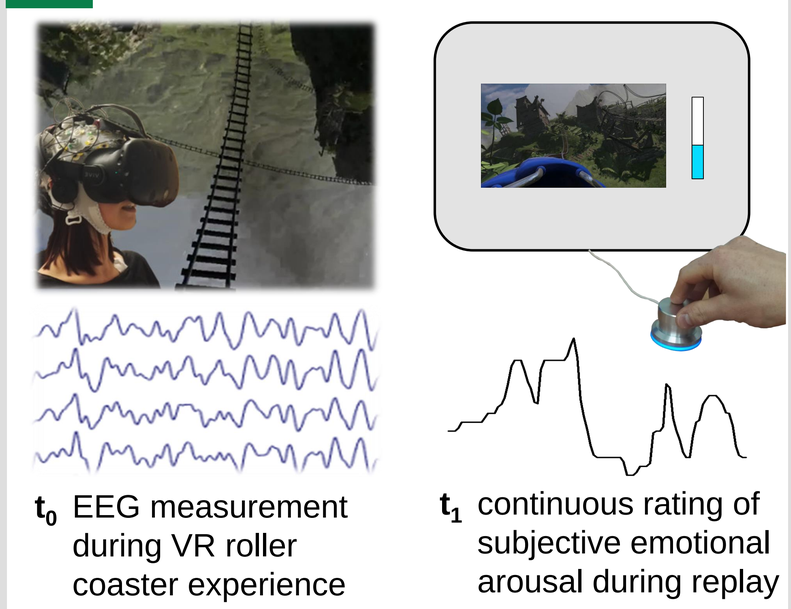
It is of interest for developers and operators of VR applications to **keep track of the user's continuously and individually fluctuating emotional states** to ensure the intended quality of the VR experience and the user's well-being.

Objective measures that correlate with subjective emotional experience **allow monitoring the current (affective) state** of the VR user without interfering with the immersion into the virtual environment.

Emotional arousal—a key component of subjective experience [1]—has recently been associated with changes in **EEG-derived oscillation patterns,** primarily in the alpha frequency range (8-12Hz), measured over parietal cortex areas [2].

Here we examined whether **oscillatory brain signals** can be **used to distinguish states of high and low emotional arousal.** We measured EEG during an immersive VR experience to **predict subjective ratings of emotional arousal**.

1



Methods

Participants
38 (20♀) healthy, young (range: 18-35 years) adults
Stimulation
HTC Vive head-mounted display
Measurement
30 channel EEG (BrainProducts LiveAmp + actiCap)

Task (Fig1)

t_0 passive viewing of two immersive virtual roller coaster rides [3] + intermediate 30s break (stable head-position)

t_1 retrospectively: continuous rating of subjective emotional arousal during the prior VR episode based on a replay of the roller coaster episodes

EEG Analysis

Preprocessing
PREP pipeline [4], EOG activation removal [5]
Dimensionality reduction
Spatio-spectral decomposition [6]:
- optimized signal-to-noise ratio for specified frequency bands (central frequency±2Hz)
- spectral filtering:
  - **narrow band** (only target frequency range)
  - **broad band** (5-35Hz)

Feature extraction (1sec windows)
Common spatial pattern decomposition [7]
- spatial filters to maximize the difference in variance in the signal, comparing two distinct states (here: *high* vs. *low arousal*)

Prediction

Aim
Using the EEG data in order to predict for each single moment (second) whether it was a moment of high or low arousal

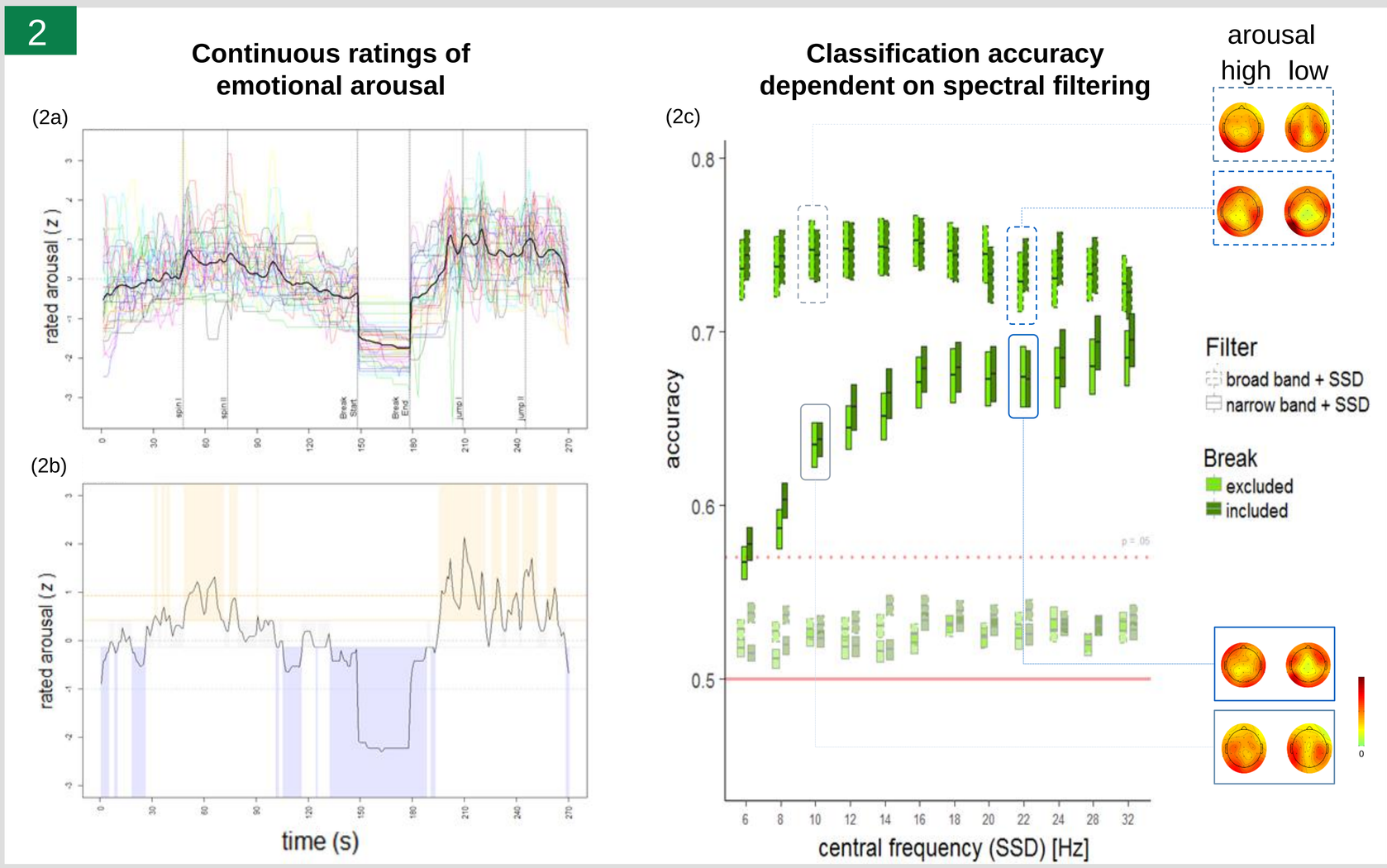
Ground truth
- individual behavioural ratings (Fig2a)
- tertile split of individual time series: we compared high vs. low arousal (Fig2b)

Binary classification of extracted features
Fisher's Linear Discriminant Analysis +
10-fold randomized cross-validation

Results

- prediction accuracies significantly above chance level (red lines) for all frequencies (Fig2c)
- strong contribution of higher frequencies
- low performance in control condition where ground truth had been replaced by randomized values (semi-transparent boxes – Fig2c)

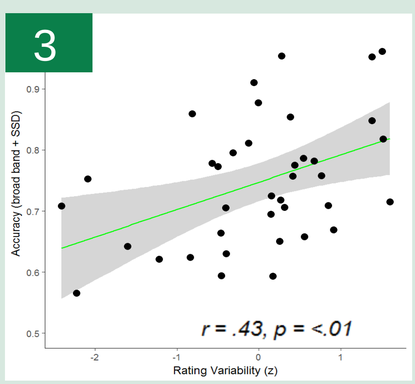
2



Discussion

- Oscillatory patterns in the EEG—acquired during an immersive VR experience—can be a meaningful predictor of subjective states of emotional arousal.
- Signals including higher frequencies led to better classification, but might be contaminated by non-neural sources (see topographies Fig2c).

3



Classification accuracy (y-axis) was higher for participants with more variability in their subjectively reported feelings of arousal (x-axis).

Here:
central freq. = 10Hz
broad band filtered

- Observed desynchronizations in the alpha range are coherent with prior findings in less immersive settings.

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References

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