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

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Background

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 examine 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.

Methods

Participants
38 (20 f) healthy, young (range: 18-35 years) adults

Stimulation
HTC Vive head-mounted display

Measurement
30 channel EEG (BrainProducts LiveAmp + actiCap)

Task (Fig1)
- Passive viewing of two immersive virtual roller coaster rides [a] + intermediate 30s break (stable head-position)
- Retrospective: 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 [6]

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
Common spatial pattern decomposition [7]
- Spatio-spectral decomposition
- 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- Low performance in control condition where ground truth had been replaced by randomized values (semi-transparent boxes – Fig2c)

Classification accuracy dependent on spectral filtering

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

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-neuronal sources (see topographies Fig2c).
- Observed desynchronizations in the alpha range are coherent with prior findings in less immersive settings.

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References