Comparison of Emotional States by Time Series Connectivity Analysis of Brain Activity Data

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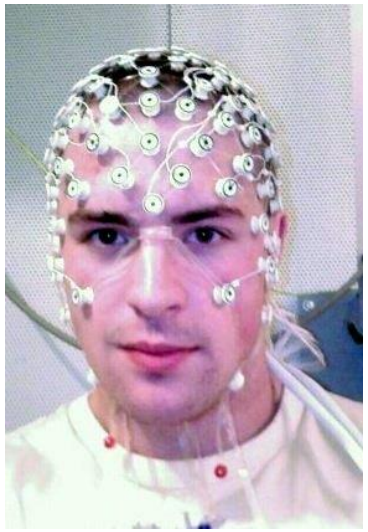
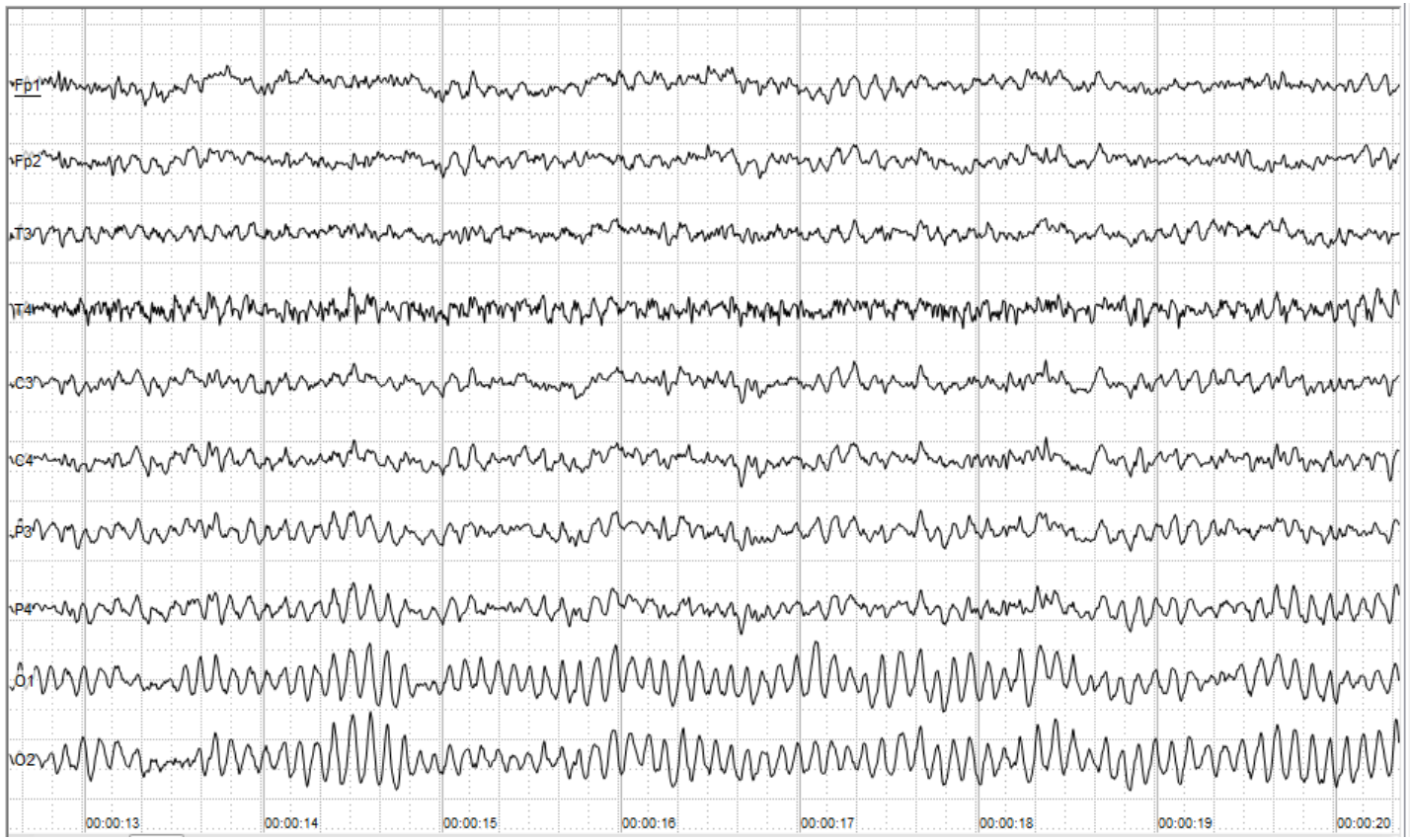
Overview

- Background and objectives
- Methodology and materials
- Results and conclusion

Background

EEG records brain local electrical activity with respect to time
It reflects the state of a person (e.g. sleep, awake, disease)

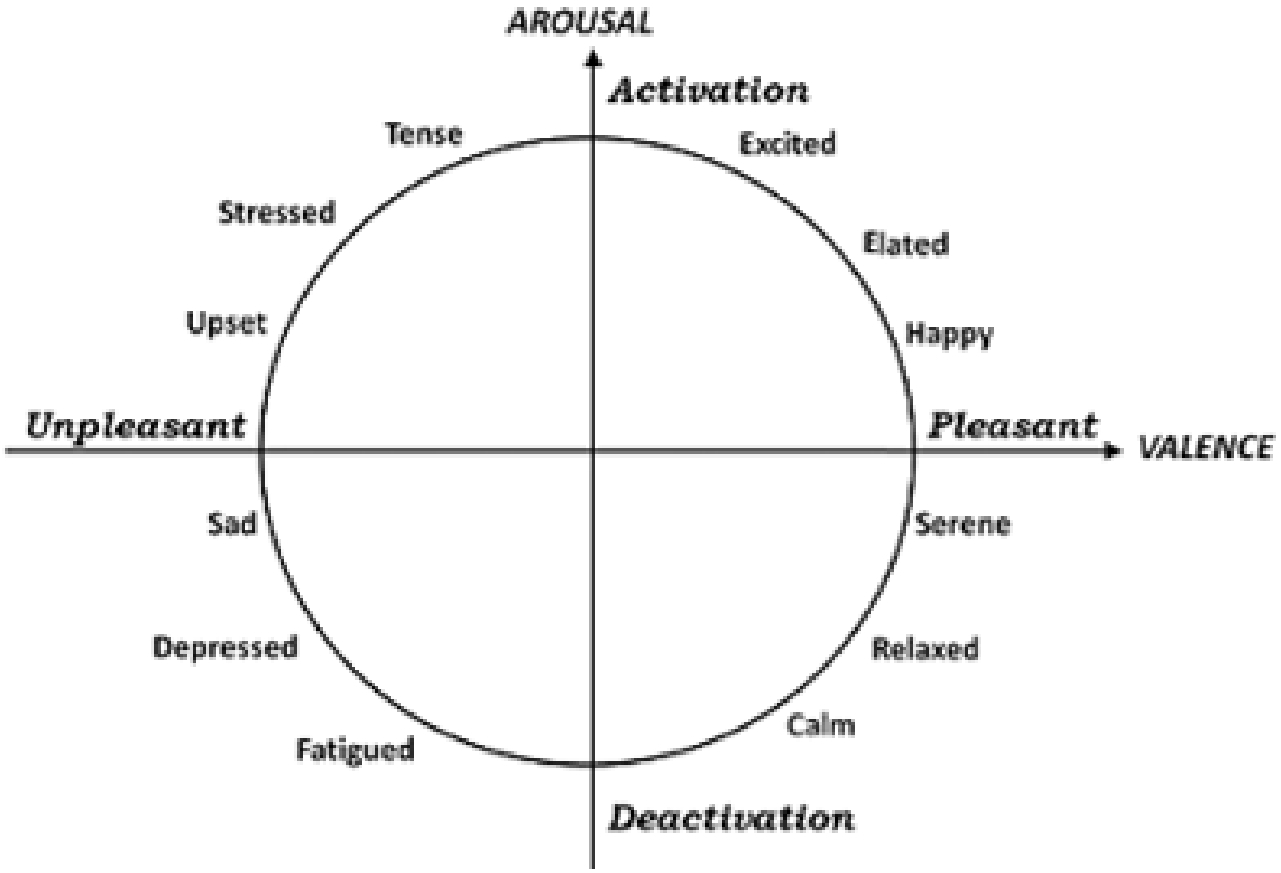




Objectives

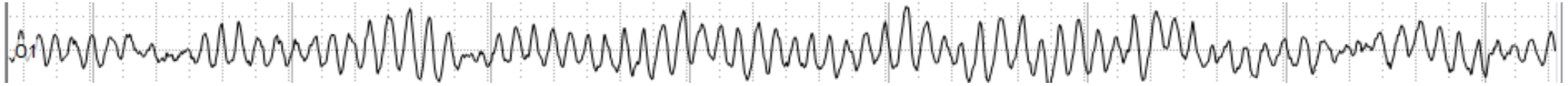
- Question: Can analysis of brain activity differentiate between **emotional states**?

- Investigate the difference(s) in brain functional connectivity during emotional processing by a linear measure in the **frequency domain**



Background

- EEG time series exhibit oscillations that hold broad bands in the frequency domain



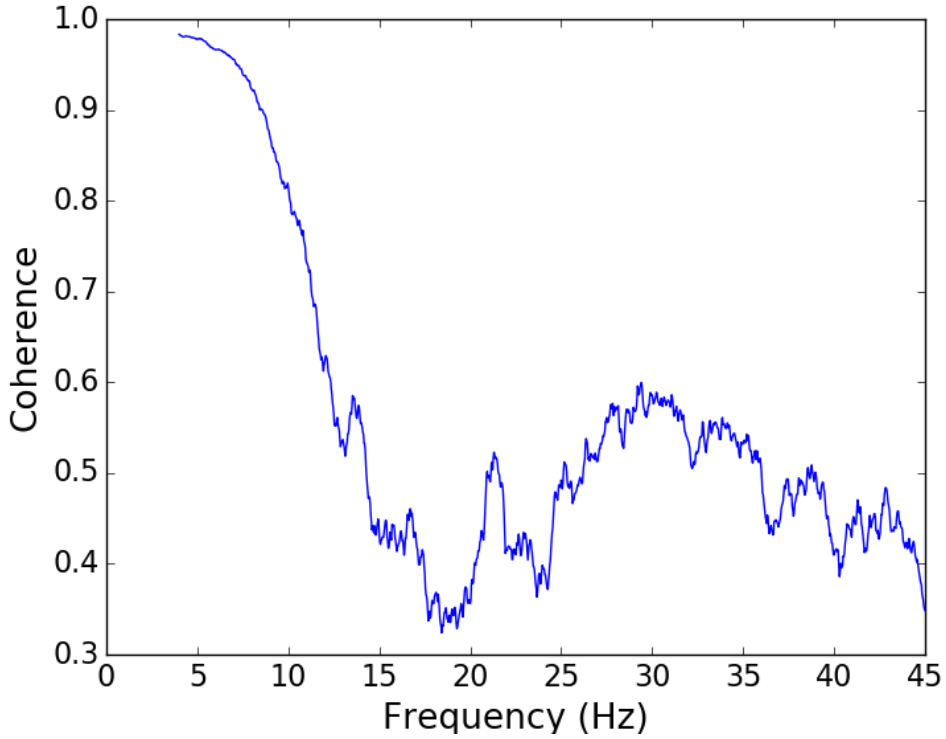
- Multivariate time series analysis of EEG in the frequency domain can be used to study the brain network and reveal characteristics of brain connectivity at different frequencies

Methodology

Coherence: linear dependency between two time series $x(t)$ and $y(t)$ per frequency f

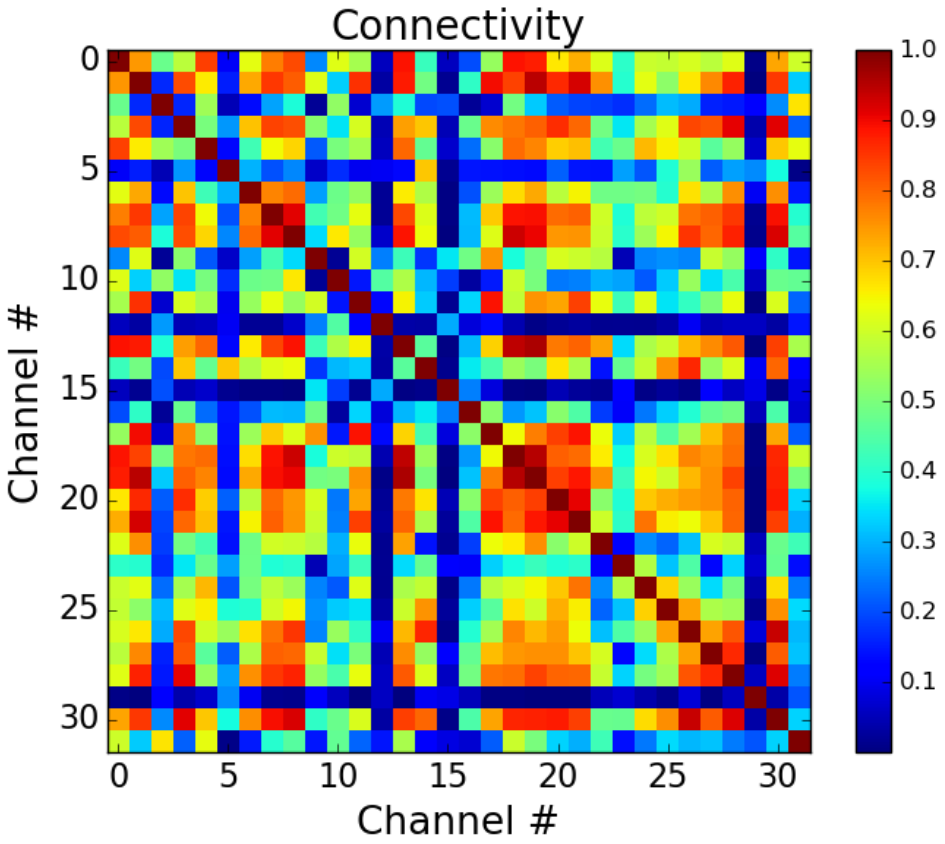
$$C_{XY}(f) = \frac{|P_{XY}(f)|^2}{P_{XX}(f)P_{YY}(f)}$$

- $P_{XY}(f)$ is the cross-spectral density between $x(t)$ and $y(t)$
- $P_{XX}(f)$ and $P_{YY}(f)$ are the auto-spectral densities



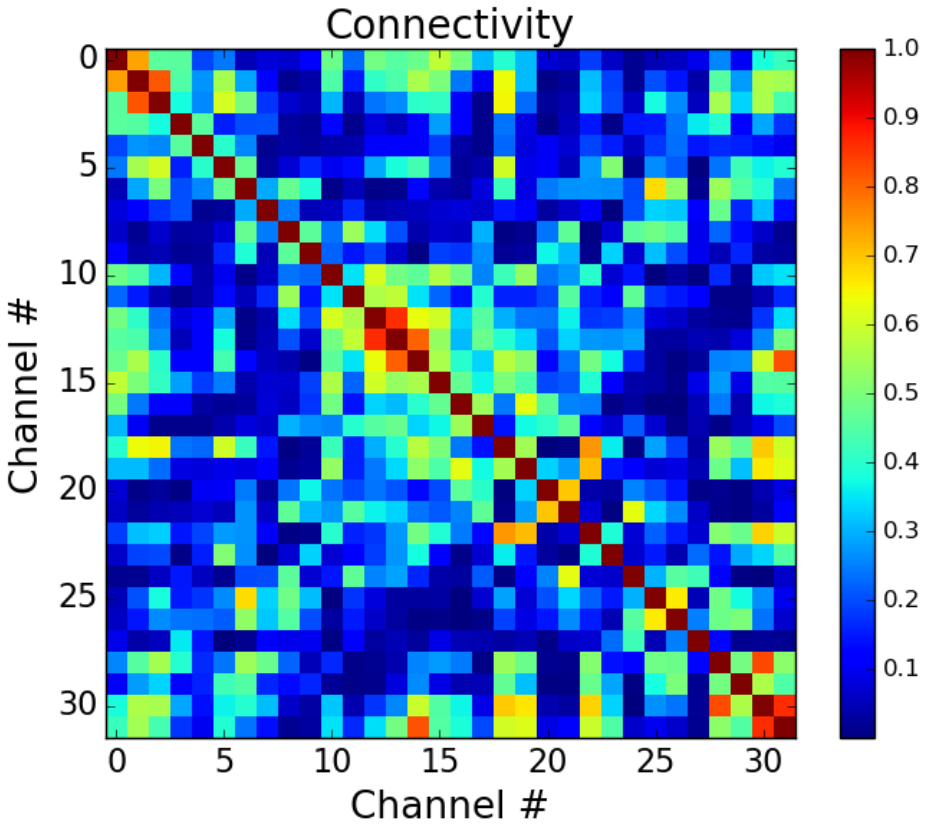
Methodology

- Estimate coherence to construct a weighted network for each distinct frequency value
- The Coherence-based Connectivity matrix is symmetric, each entry corresponds to a pair of time series and the diagonal are all equal to 1

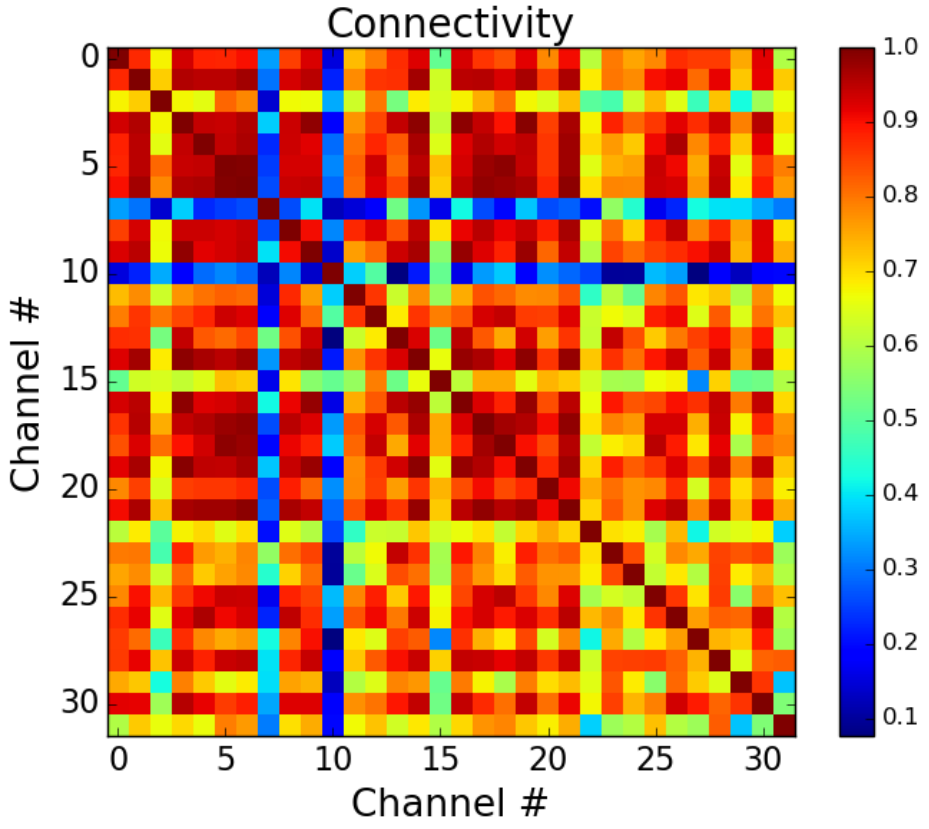


Methodology

- The largest eigenvalue of the coherence matrix quantifies the strength of the overall connectivity within the network



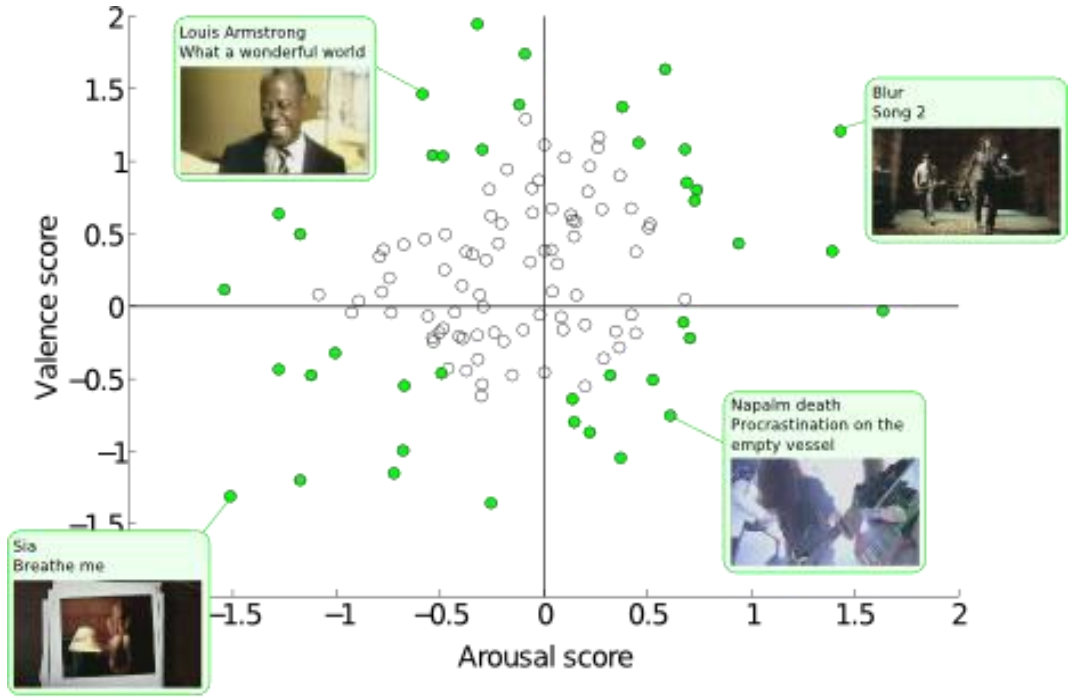
$\lambda_{max} = 9.17$



$\lambda_{max} = 24.79$

Dataset

- 40 music video clips
- 32 participants provide
  - 32-channel EEG recordings
  - Rating score per trial



"DEAP: A Database for Emotion Analysis using Physiological Signals", S. Koelstra, C. Muehl, M. Soleymani, J.-S. Lee, A. Yazdani, T. Ebrahimi, T. Pun, A. Nijholt, I. Patras, *IEEE Transaction on Affective Computing*, 3:18-31, 2011.

Methodology

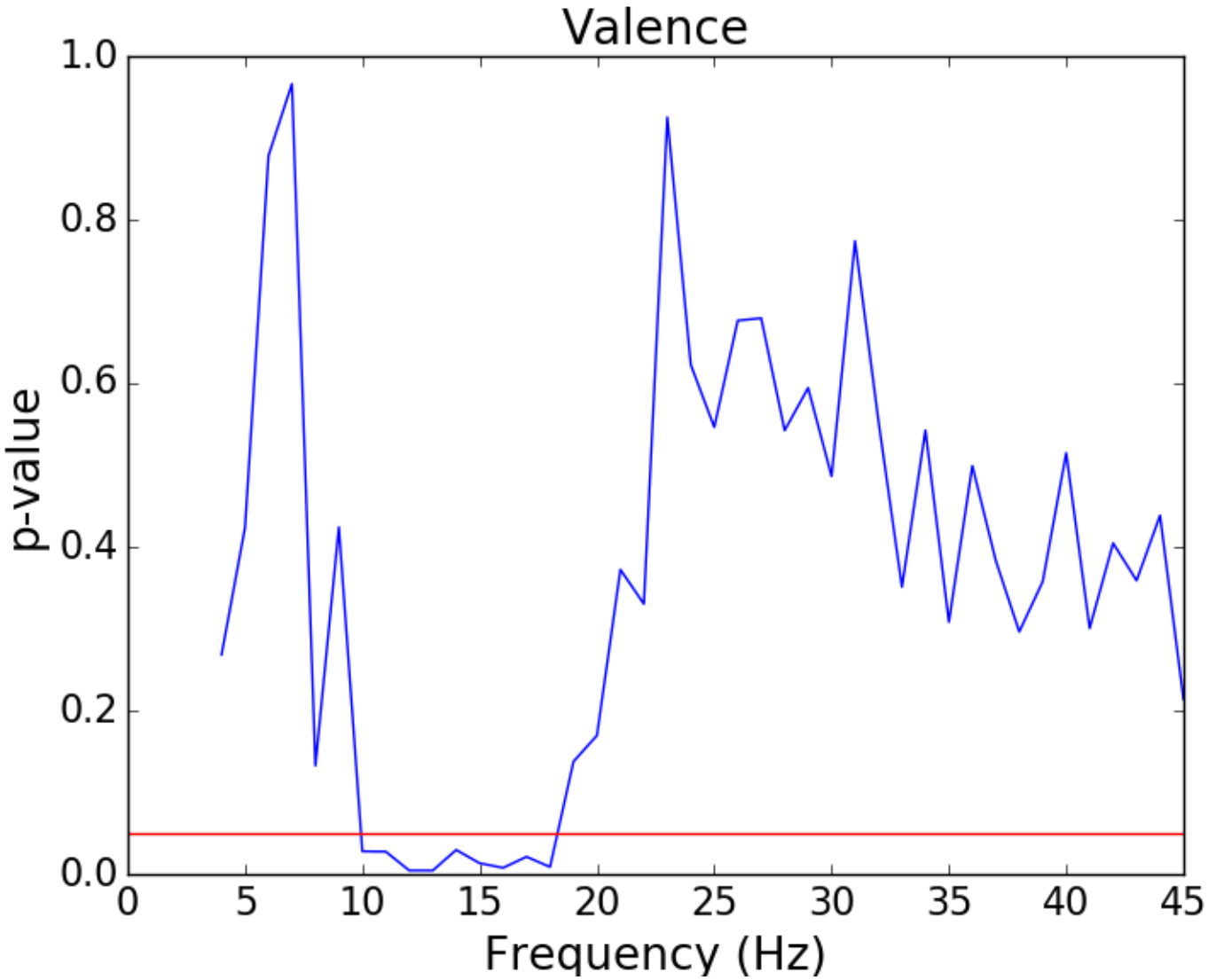
1. Divide trials of each subject into positive/negative emotional state categories based on the median of rating score
2. Estimate Coherence of each state per subject and construct connectivity matrices
3. Estimate strength of connectivity per frequency value by λ_{max}

4. Paired sample t-test between λ_{max} values for positive vs. negative states across frequencies

Results

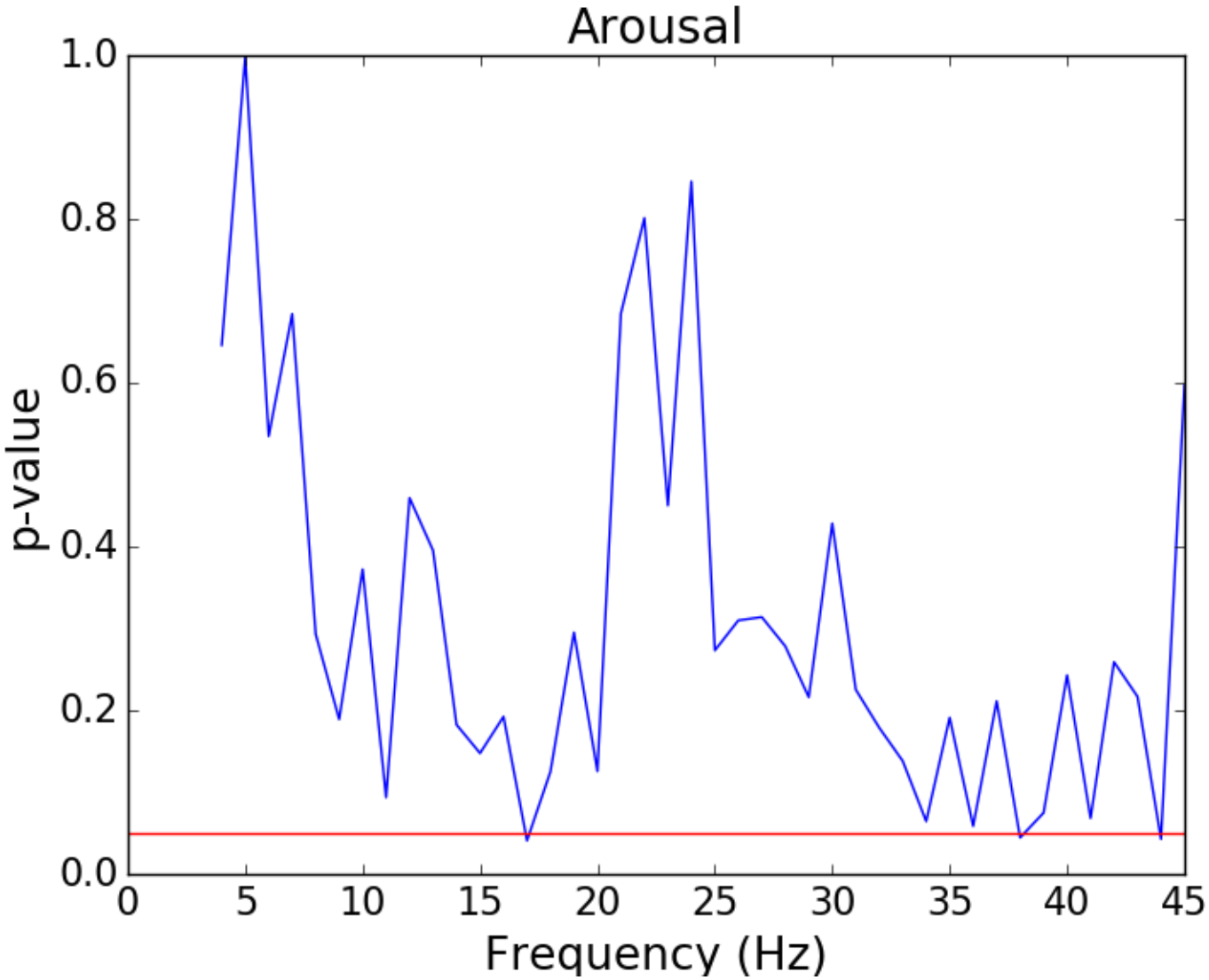
Statistically significant difference of the brain connectivity between the two states at a specific range of frequencies ($p < 0.05$)

$\lambda_{max} \sim 0.4$ larger in value for positive state



Results

Marginal results for some distinct frequency values



Conclusions

- Brain connectivity estimated by means of coherence is capable of differentiating between positive and negative valence states, but not between high and low arousal.

- The emotional state of positive valence (level of pleasure) is associated with higher connectivity in the brain

Q&A

Thank you for your attention!

Notice

Nonlinear dependency and an application in brain functional connectivity study

JSM speed presentation on *July, 30th*