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Recurrence analysis of brain neurodynamics

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Aim

Analyzing the same states and their transition sequences provides valuable information on frequently occurring states. By combining techniques like Low Resolution Electromagnetic Tomography (LORETA) with Joint Recurrence Quantification Analysis (Marwan et al., 2007), we can generate features that quantify spatiotemporal dynamics within brain networks. These features enable us to differentiate between behaviorally meaningful states, such as emotions.

Data

- SEED V (Liu, et al., 2021): Emotion induction using visual stimuli, subjects were presented images stimulating Happiness, Fear, Sadness, Disgust or showing no emotions: Neutral. Each emotion was induced 3 times and during 3 sessions, resulting in 9 expositions per subject.
- EEG signals were recorded using ESI NeuroScan System with 62 channels and sampling frequency of 1000 Hz (50Hz Notch filter applied) for 20 healthy, right-handed students (10 females).

EEG processing

- The EEG data for each session is preprocessed by cropping (10s), resampling (500Hz), and bandpass filtering (1 - 80Hz).
- The noise covariance matrix is estimated and regularized.
- Forward and inverse solutions are computed to obtain source time courses for regions of interest in the Yeo2011_7Networks_N1000 atlas.

Features

- 14 time series (7 functional networks per each hemisphere).
- Select 10s fragments.
- Calculate power spectra with STFT: win length : 256, n fft: 512.
- Obtain Recurrence Plots (Rawald et al., 2017) from STFT matrices (Furman et al., 2022) with threshold parameter: 25 percentile of distance distribution.
- Calculate Joint Recurrence Plots for both networks from left and right hemisphere.
- Perform RQA on JRP for each network: entropy of diagonal lines (Lentr), trapping time (TT), average diagonal line length (L), laminarity (LAM), determinism (DET), longest vertical line length (Vmax), entropy of vertical line (Ventr), average white vertical line length (W), entropy of white vertical lines (Wentr).
- Normalize features and reduce with the recursive feature elimination with cross validation procedure CV5. Feature matrix: 45 repetitions by 36 CV5 selected RQA features.

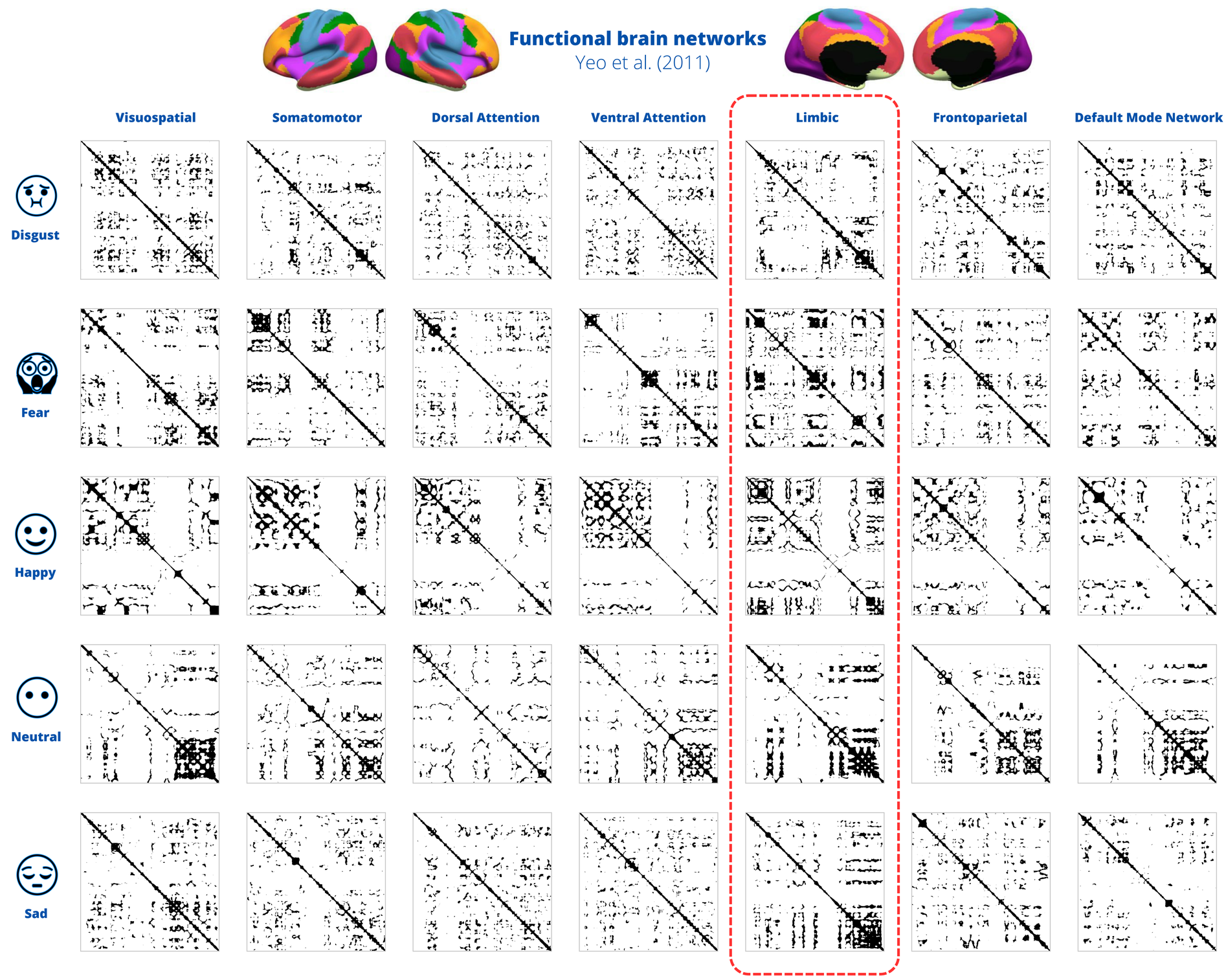

Figure 1: Joint Recurrence Plots for 7 functional networks and 5 emotion conditions calculated from signal averaged over 9 runs per condition, 1st Subject

Results

- Perform dimension reduction using the unsupervised UMAP (Uniform Manifold Approximation and Projection for Dimension Reduction) (McInnes et al., 2018) with following parameter values:
  - number of neighbors: 15,
  - minimum distance: 0.7,
  - metric: hamming.

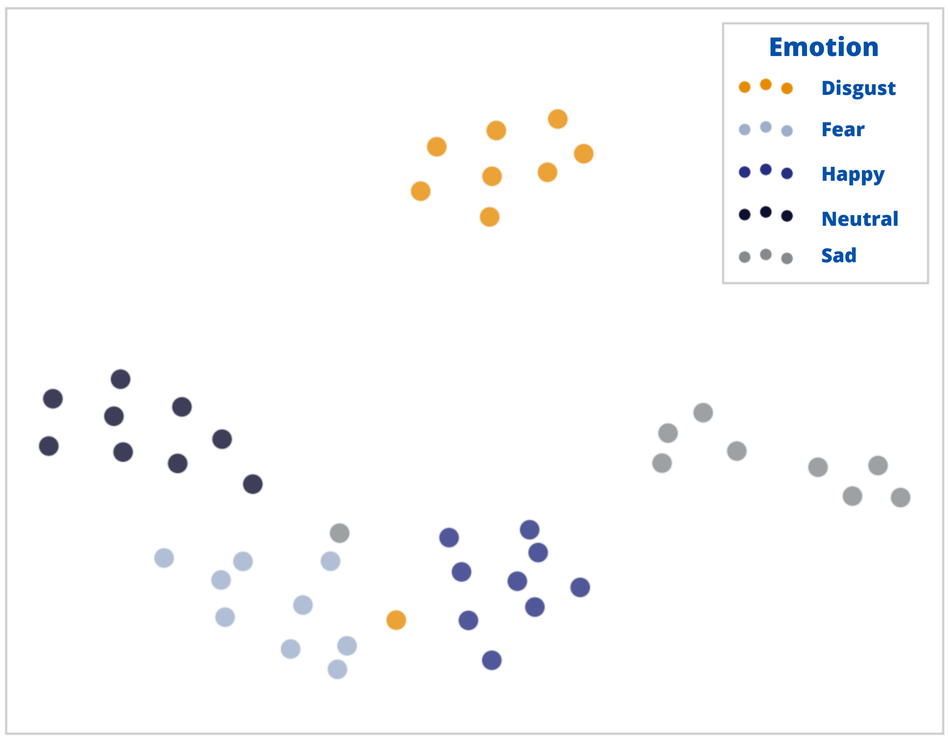

Figure 2: Two embedding dimensions obtained from unsuperived UMAP method

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