EEG spectral modulations during emotional imagery

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Outline

- Emotional imagery experiment
- Unmixing power modulations with ICA
- Broadband high frequency modulations
- Power modulations during emotional imagery
- Emotion classification using power modulations
Emotional imagery experiment
Unmixing power modulations with ICA
Broadband high frequency modulations
Power modulations during emotional imagery
Emotion classification using power modulations
Experimental procedure

- Pre-session eyes closed baseline
- Guided relaxation (~5 min)
- 15 emotions
  - balanced positive and negative valence
  - introduced verbally via headphones
  - self-paced emotional experience
- Subject pressed a button when feeling became intense
- Instructed to image for ~4 min
- Post-session eyes closed baseline
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Independent component analysis (ICA) separates mixed EEG signals at the scalp into temporally independent time courses.
Independent component analysis (ICA)

\[ x = \text{scalp EEG} \]
\[ W = \text{unmixing matrix} \]
\[ u = \text{sources} \]

\[ W^*x = u \]

ICA

\[ u = \text{sources} \]
\[ x = W^{-1}u \]

Components

W^{-1} (scalp projections)
Dynamic changes in frequency power over time
Complexity of on-going EEG spectral power
Independent (Co-)Modulators of EEG Source Activities
What causes dynamic spectral changes?

- Norepinephrine
- Serotonin
- Dopamine
- Acetylcholine
Log-spectral decomposition

1s window FFTs

Remove mean spectrum

Concatenate spectral modulations from all ICs

PCA/ICA

Independent Modulators

Spectral Windows

Independent Modulators (IMs)

Spectra x ICs
Example IM templates + mean power spectrum
Clusters of spectral modulators (33 Ss)

A. IM Templates

At alpha peak

Example IM

B. Below alpha peak

C. Above alpha peak

Template Strength

Adj. Freq. (Hz)

1x 2x 3x 4x

IM Comodulation

stronger weaker

B. Broadband EEG

32 Ss 112 IMs 156 ICs

10 30 60 100

A. IM Templates

Low beta IMs

Example IM

B. High beta IMs

Template-strength

Frequency (Hz)

10 20 30 40

stronger weaker

frequency (Hz)
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Broadband gamma modulator clusters

**Broadband EEG**
- 32 Ss
- 112 IMs
- 156 ICs

**Broadband EMG**
- 31 Ss
- 106 IMs
- 108 ICs

**Ocular motor tremor**
- 23 Ss
- 28 IMs
- 28 ICs
Muscle is not co-modulated with brain
Muscle is not co-modulated with brain
Gamma power up to 250 Hz
Sorted broadband IM weights
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IM distribution shifts with emotional state changes

IMx weight distribution

Trial Weights (IMx)

Number of Trials

COMPASSION

ANGER

Spectral Windows

Independent Modulators
IM weights for different emotions
IM weights for different emotions
Momentary and mean IM weights
IM weights during emotional imagery

![Graph showing power in dB against frequency (Hz) for jealousy.

- The y-axis represents power in dB, ranging from -45 to 6 dB.
- The x-axis represents frequency in Hz, ranging from 4 to 100 Hz.
- The graph displays multiple lines of data, with the label "jealousy" indicating the emotional state.

The graph illustrates the power distribution across different frequencies for jealousy.
Broadband gamma modulator clusters

Broadband EEG
- 32 Ss
- 112 IMs
- 156 ICs

Broadband EMG
- 31 Ss
- 106 IMs
- 108 ICs

Ocular motor tremor
- 23 Ss
- 28 IMs
- 28 ICs

Frequency (Hz)

Template strength
Inter-subject emotion space

EEG "Emotion Space"

 Independently-rated "Emotion Space"

Spectral Windows

Mean IM Weights

Subject IMs

γ IMs only

γ IMs (all subjects)

Multi-dimensional scaling

Spectral Windows

Matrix

Spectral Windows

Mean IM Weights
Valence-correlation-weighted dipole density of γ IMs
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Emotion classification procedure

1) ANOVA across columns of $W^{-1}$ (IMs)
2) Sort IMs by ANOVA F-score
3) Select IMs with highest F-scores for classification (bet. 3-17)
4) Remove 10% of each emotion period as ‘test’ data
5) Classify each non-overlapping 1-sec of ‘test’ data with SVM
6) Calculate % correct classification across all 1-sec ‘test’ epochs
7) Separate classification IMs into theta, alpha, beta, gamma categories

Yuan-Pin Lin, National Taiwan University
Classification accuracy (1-sec, non-overlapping epochs)

chance = 7%
Brain sources with emotion-related IMs

F-score standard deviation-weighted dipoles

Low Theta F-std: 0.2
Low Beta F-std: 0.3
High Theta F-std: 0.2
High Beta F-std: 0.5
Alpha F-std: 0.3
Gamma F-std: 2.1

Highest F-score IM/IC
Lowest F-score IM/IC

Broadband gamma IMs used for classification
Summary

- ICA isolates independent brain activity from scalp EEG
  - separates high frequency brain from scalp muscle
- IC power is affected by independent modulator processes
  - possibly neuromodulatory influences
- High frequency IM strength is related to emotional valence
- IM strengths can differentiate between subjective states
  - high freq. IMs are more likely to differentiate between emotions
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