

*High frequency EEG power during
vivid emotional imagery*

Julie Onton, PhD

*Naval Health Research Center, San Diego, CA
University of California, San Diego
Swartz Center for Computational Neuroscience*

Outline

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

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Experimental procedure

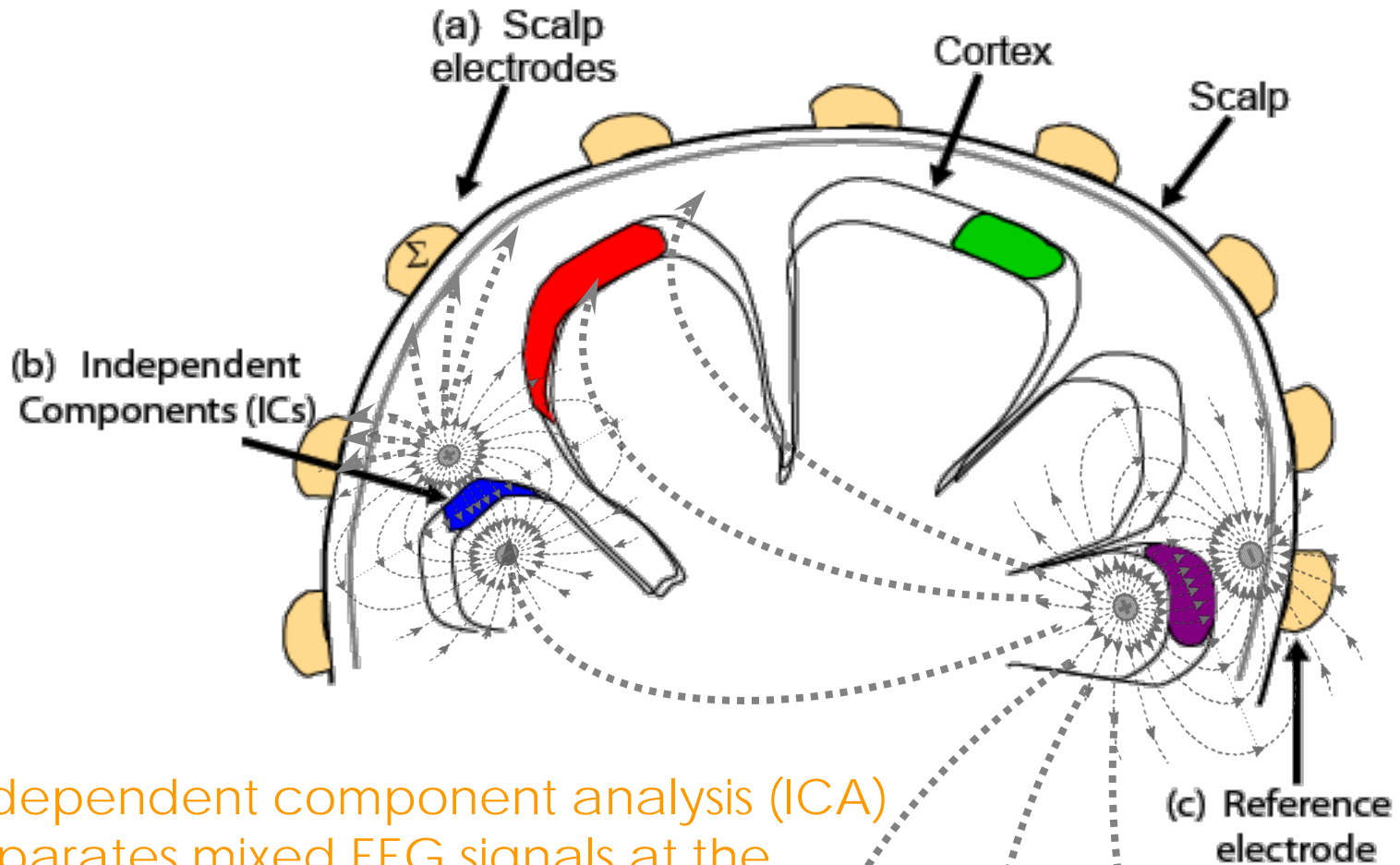
- Pre-session eyes closed baseline
- Guided relaxation (~5 min)
- 15 emotions
 - balanced positive and negative valence
 - introduced verbally via headphones
 - self-paced emotional experience
- Subject pressed a button when feeling became intense
- Instructed to image for ~4 min
- Post-session eyes closed baseline



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Separate mixed source activities



Independent component analysis (ICA) separates mixed EEG signals at the scalp into **temporally** independent time courses

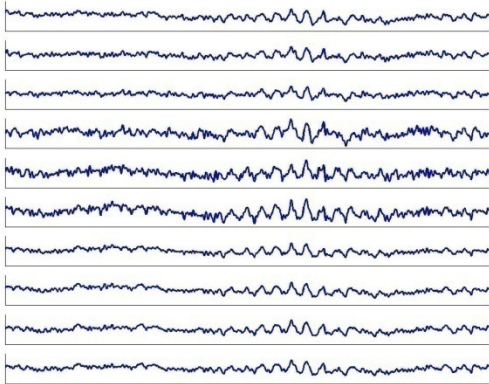
Independent component analysis (ICA)

$x = \text{scalp EEG}$

$W = \text{unmixing matrix}$

$u = \text{sources}$

Channels

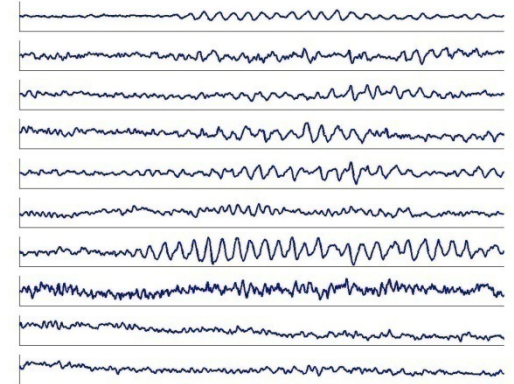


Time

$$W^*x = u$$

ICA

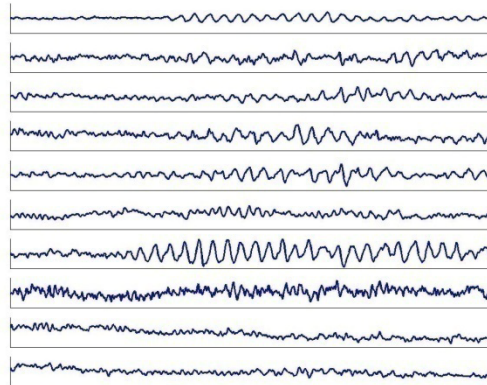
Components



Time

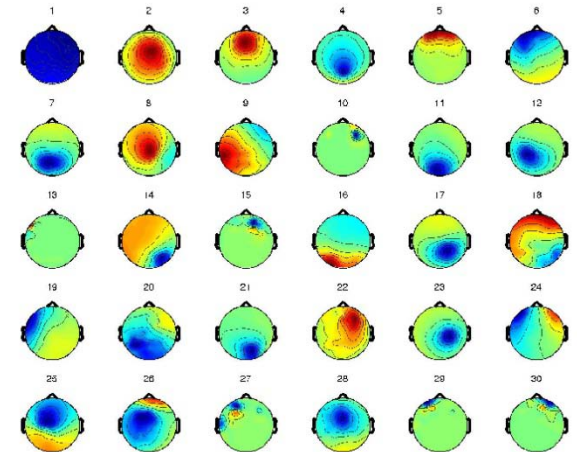
$u = \text{sources}$

$$x = W^{-1} * u$$

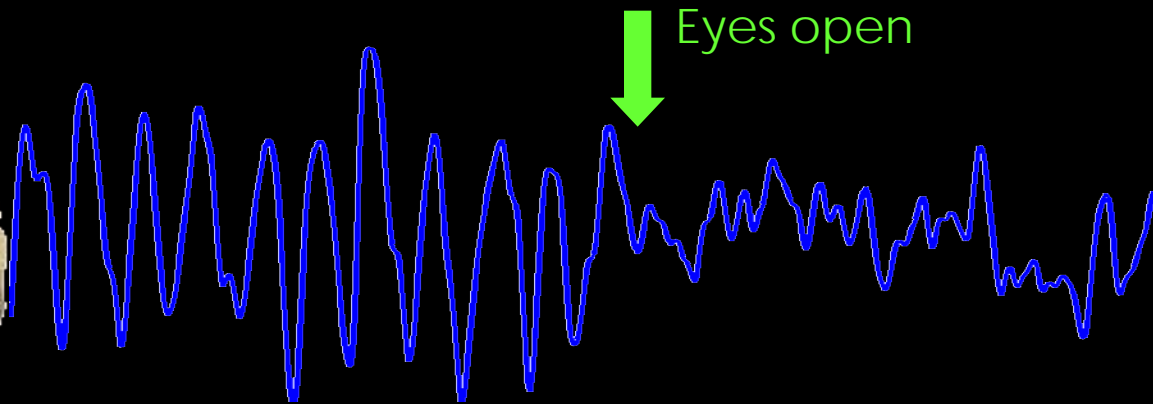


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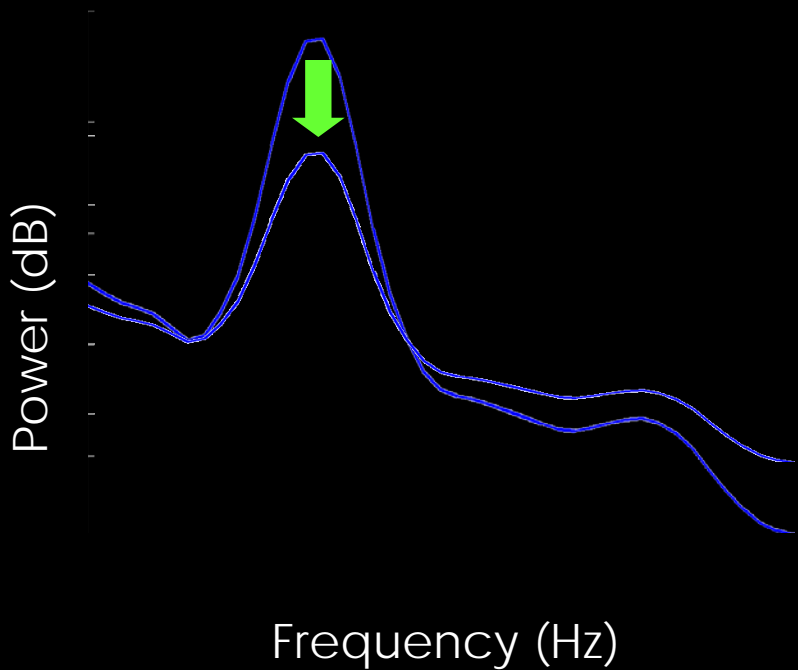
W^{-1} (scalp projections)



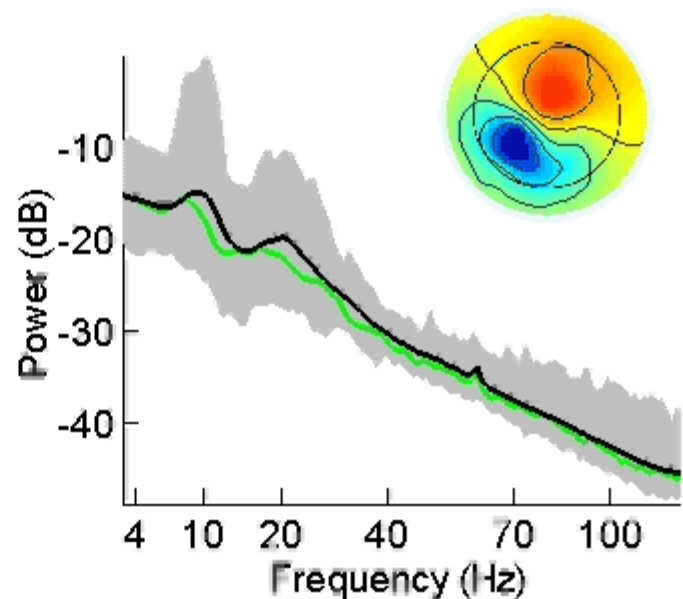
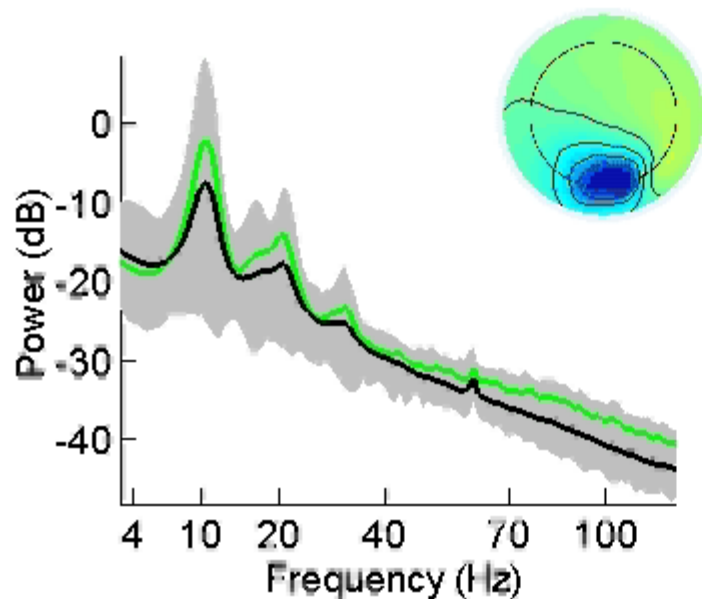
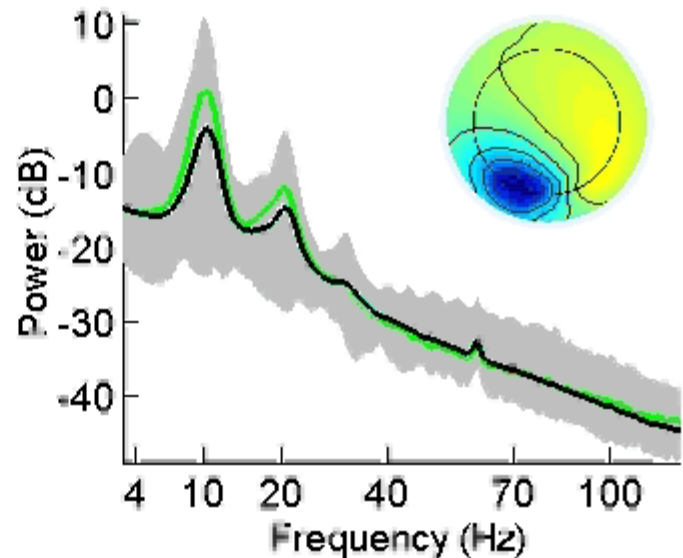
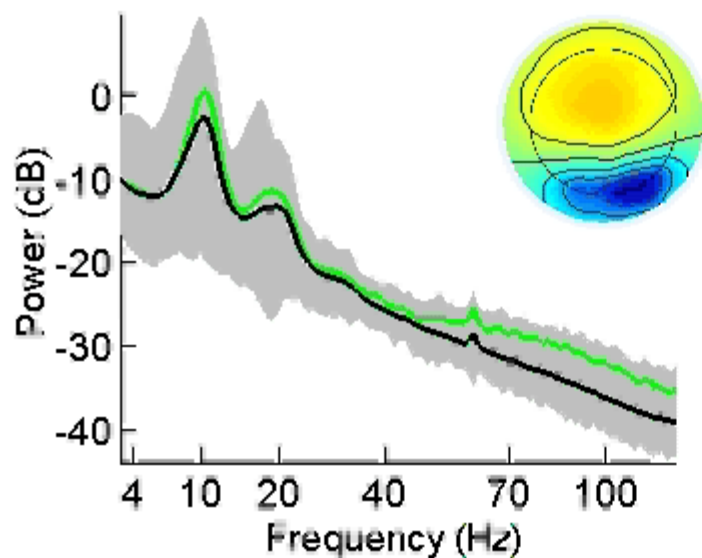
ICA Components



**Dynamic changes
in frequency
power over time**



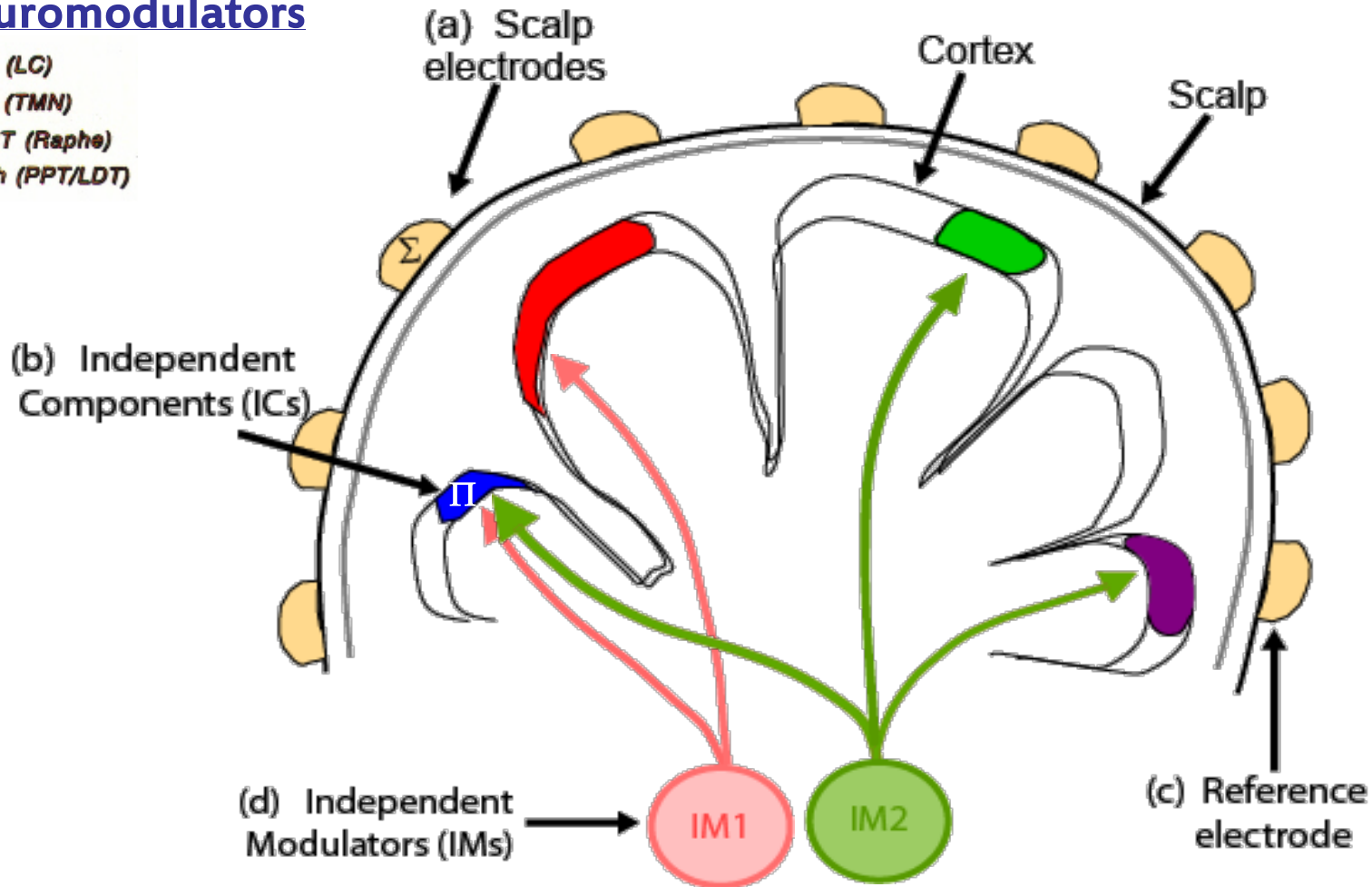
Complexity of on-going EEG spectral power



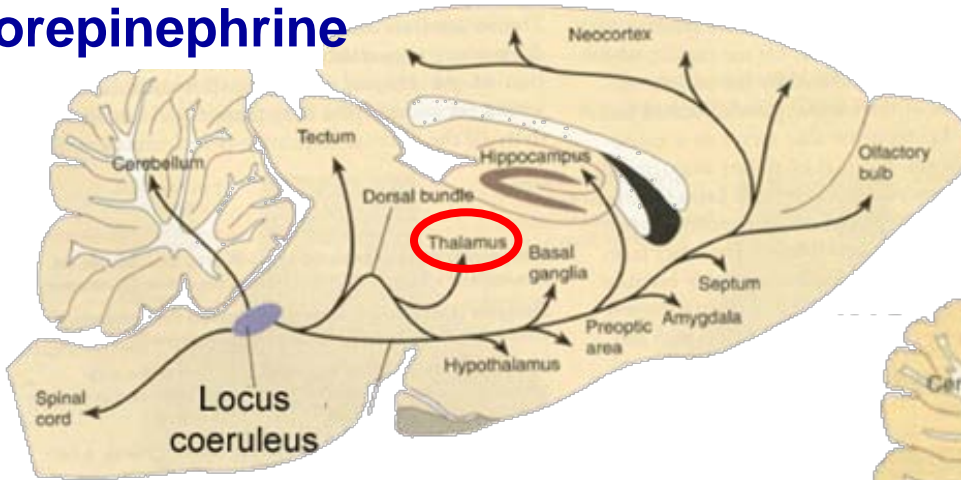
Independent (Co-)Modulators of EEG Source Activities

Neuromodulators

NE (LC)
HA (TMN)
5-HT (Raphe)
ACh (PPT/LDT)

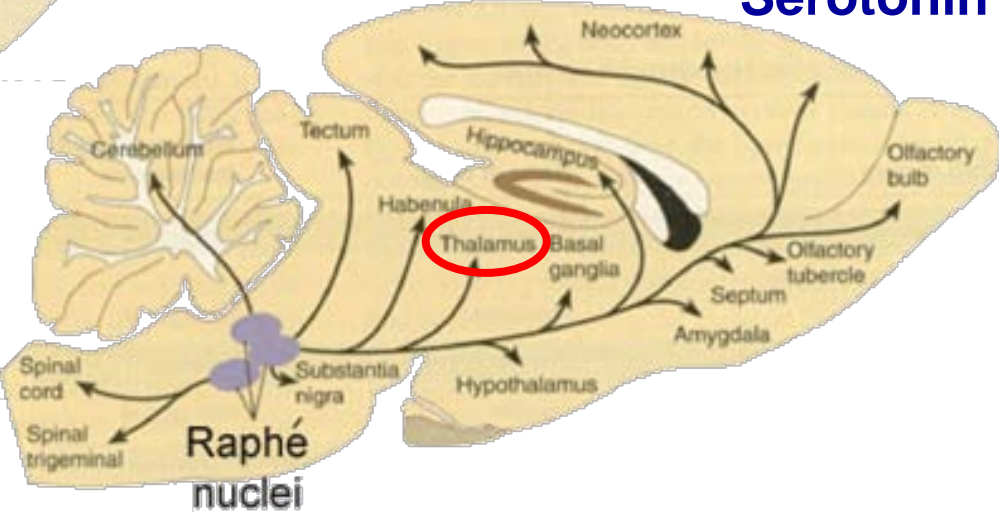


Norepinephrine

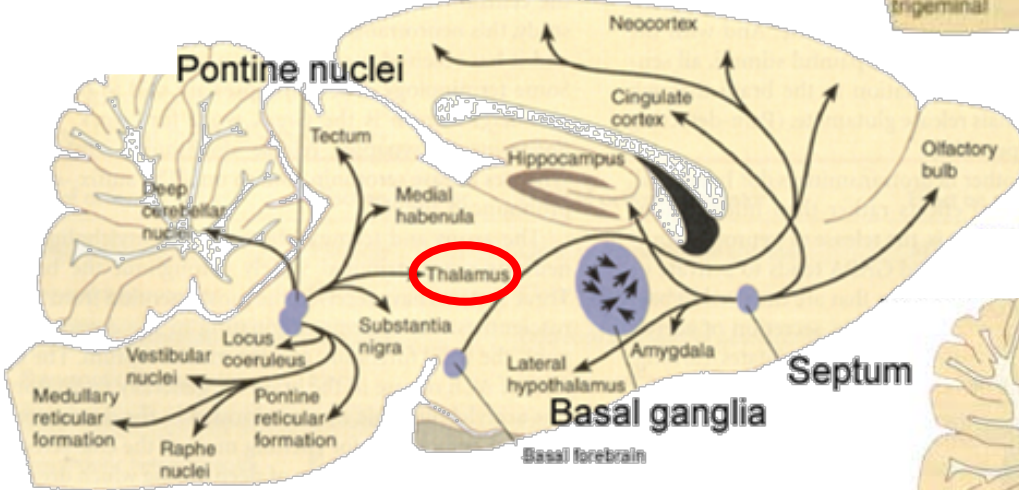


What causes dynamic spectral changes?

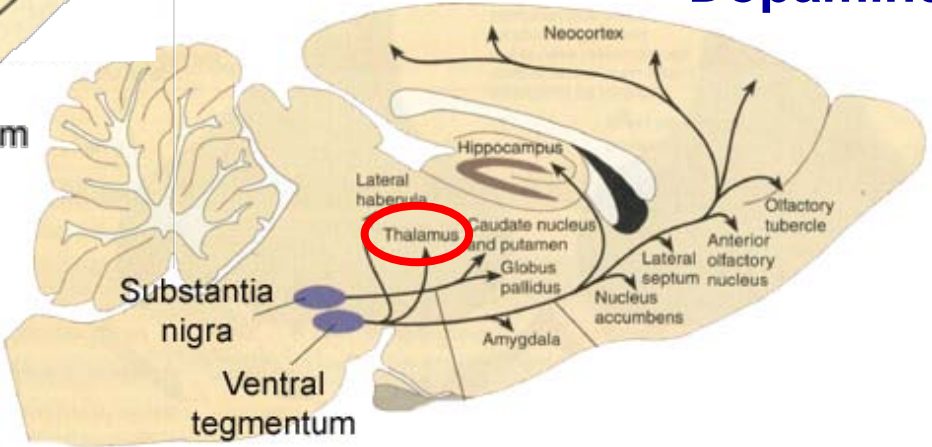
Serotonin



Acetylcholine

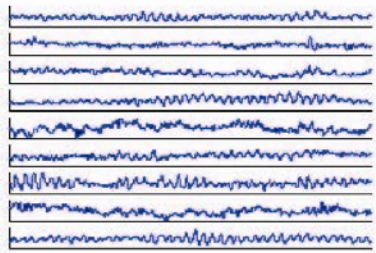


Dopamine

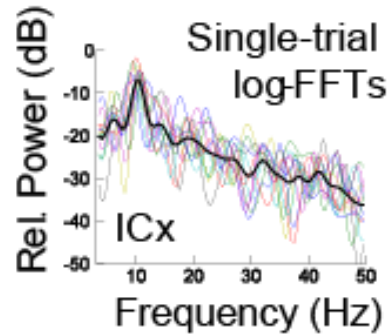


Log-spectral decomposition

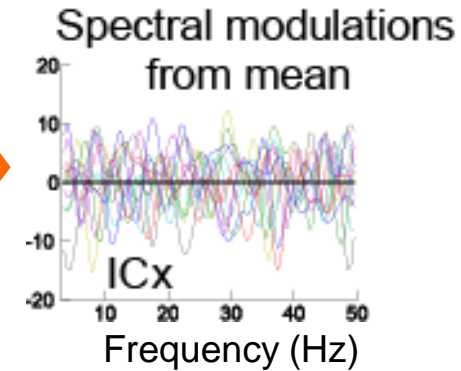
Selected ICA Components



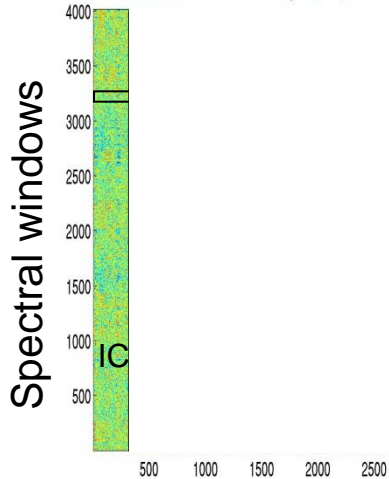
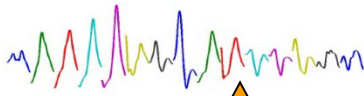
1s window
FFTs



Remove
mean spectrum



Concatenate spectral modulations from all ICs



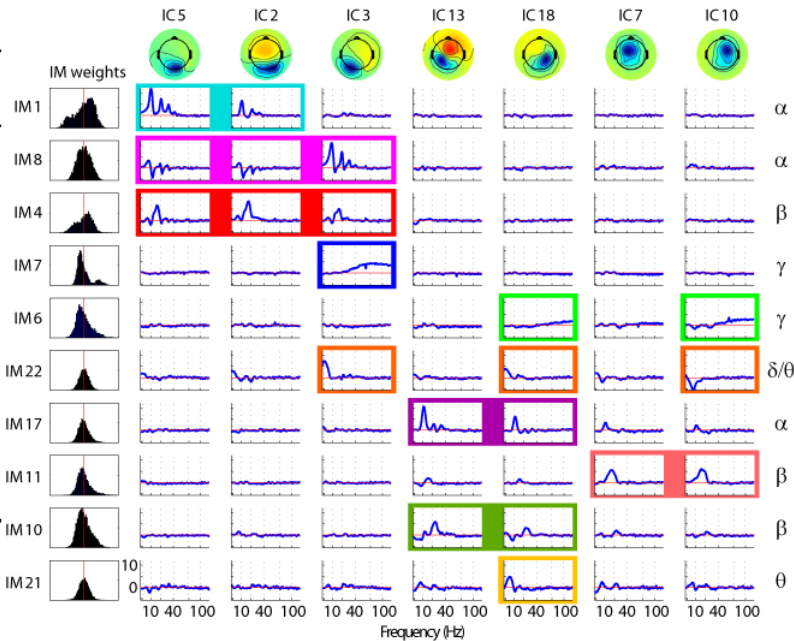
PCA/ICA

Independent Modulators

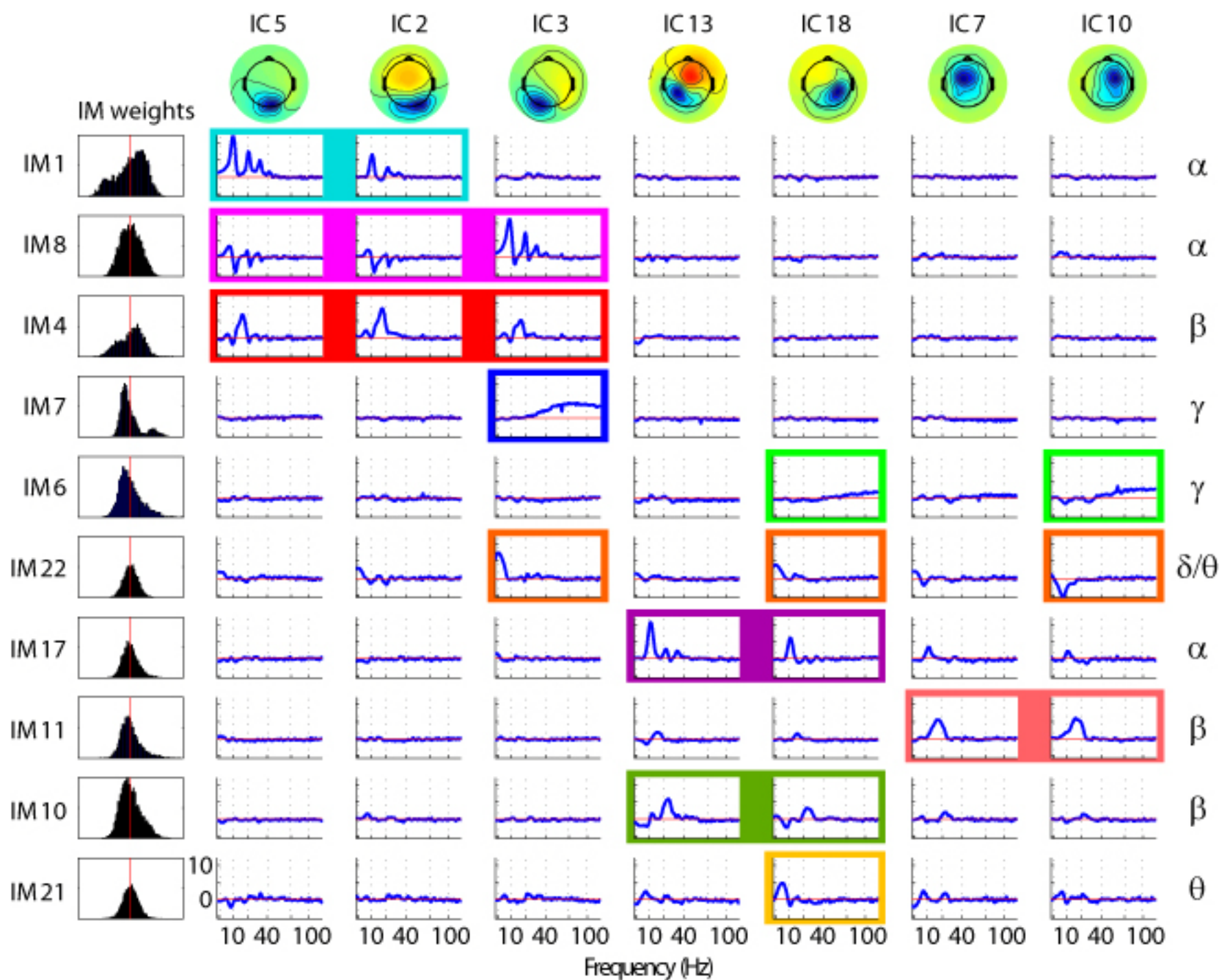


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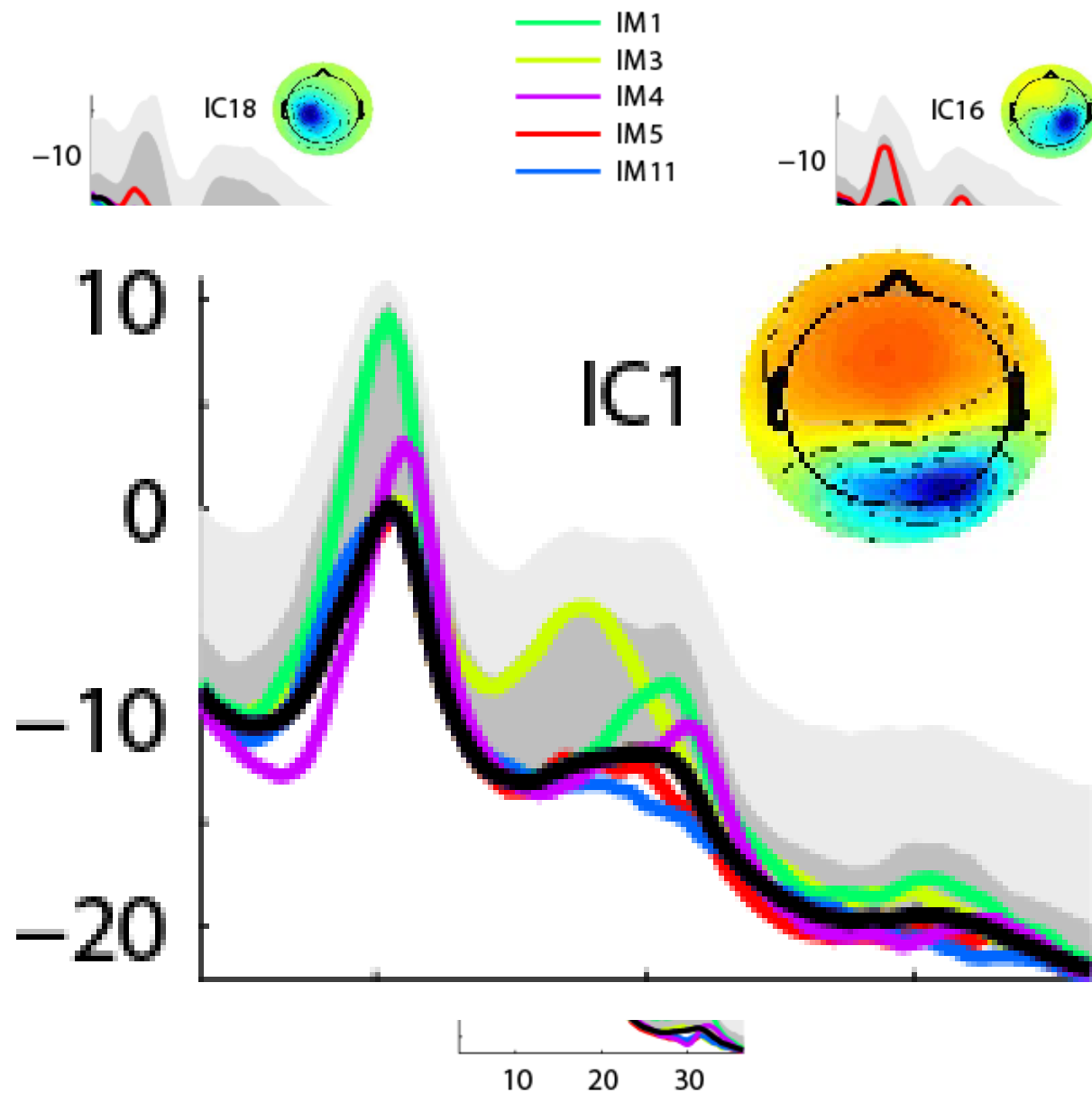
Independent Modulators (IMs)



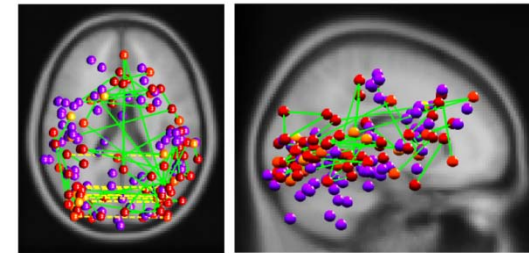
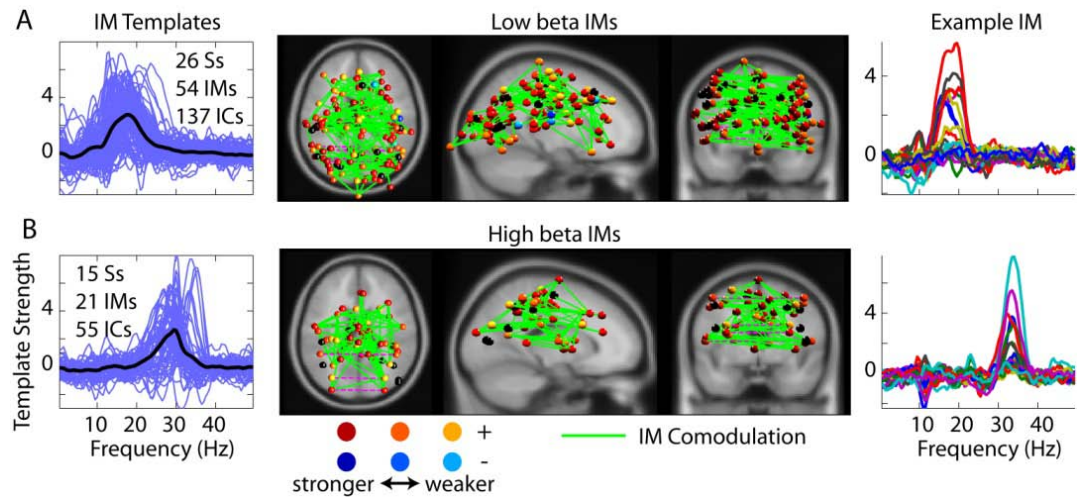
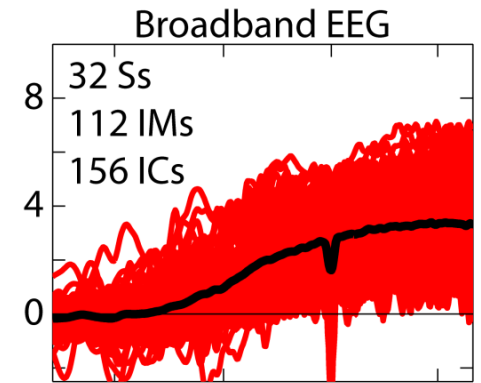
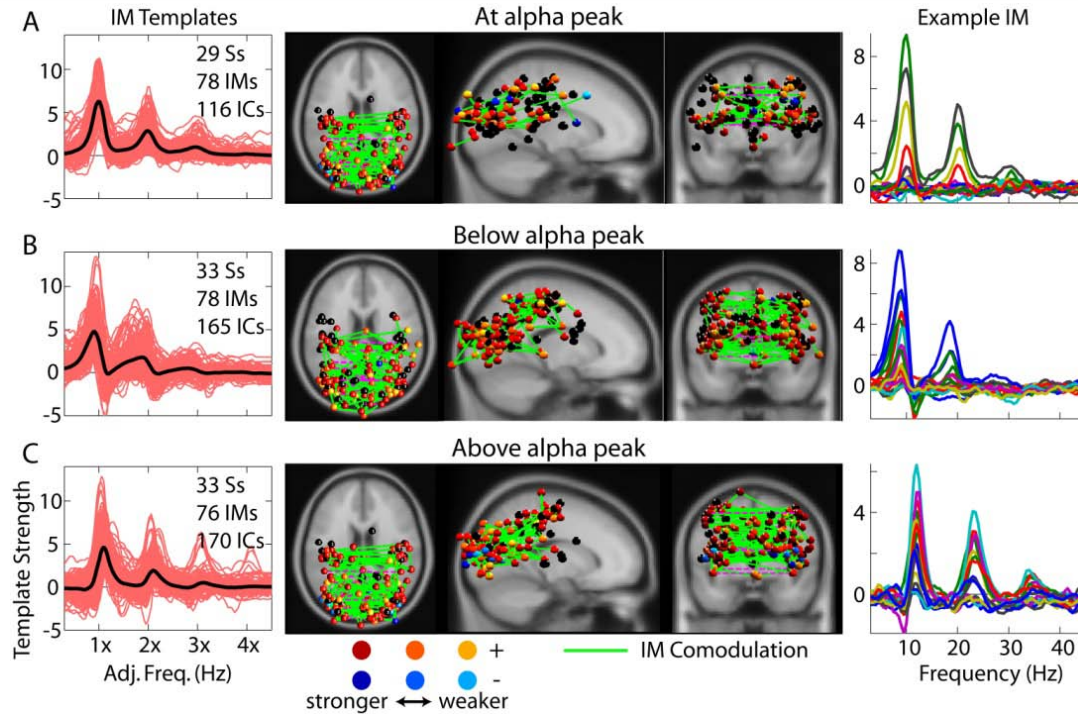
Spectra x ICs



Example IM templates + mean power spectrum



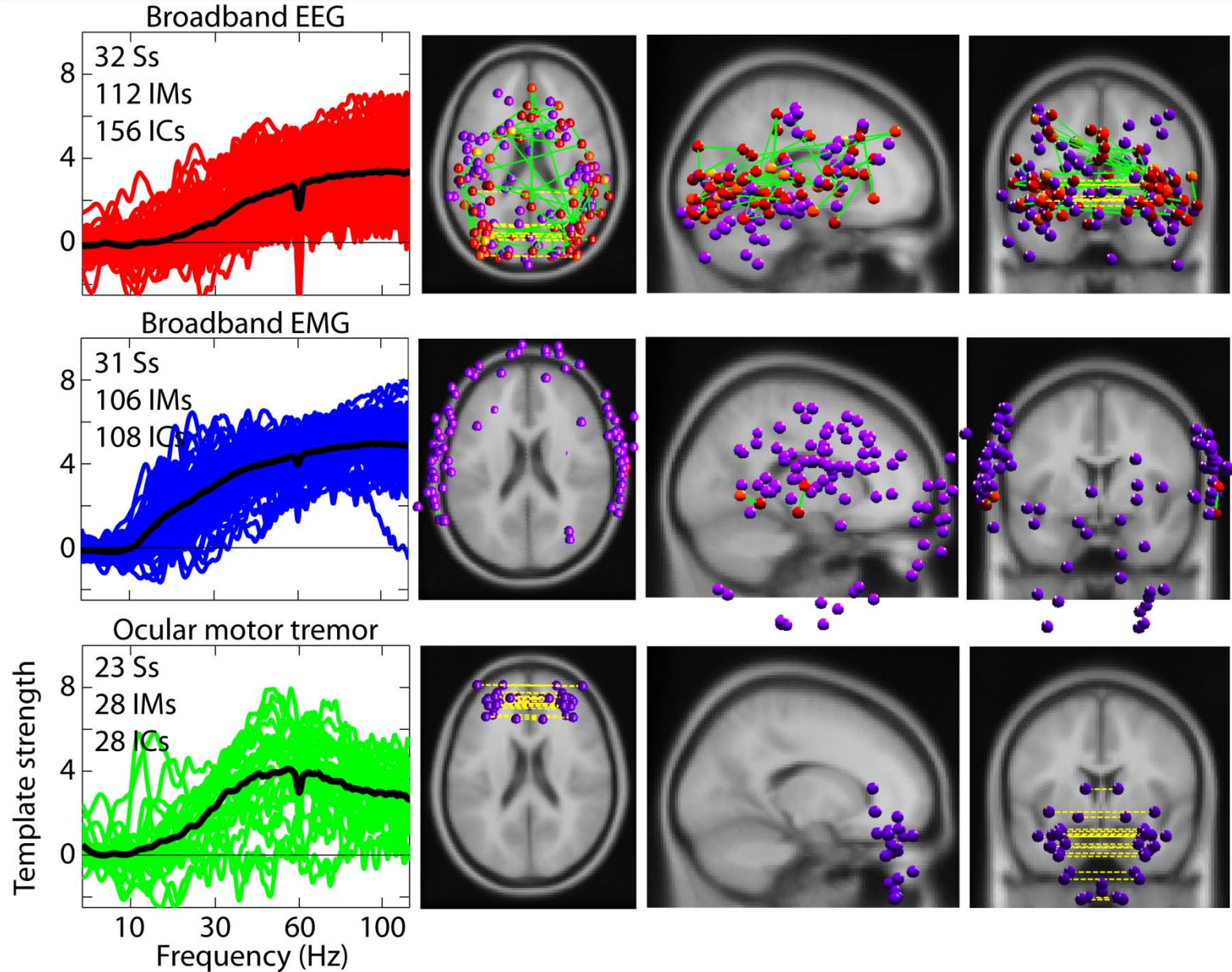
Clusters of spectral modulators (33 Ss)



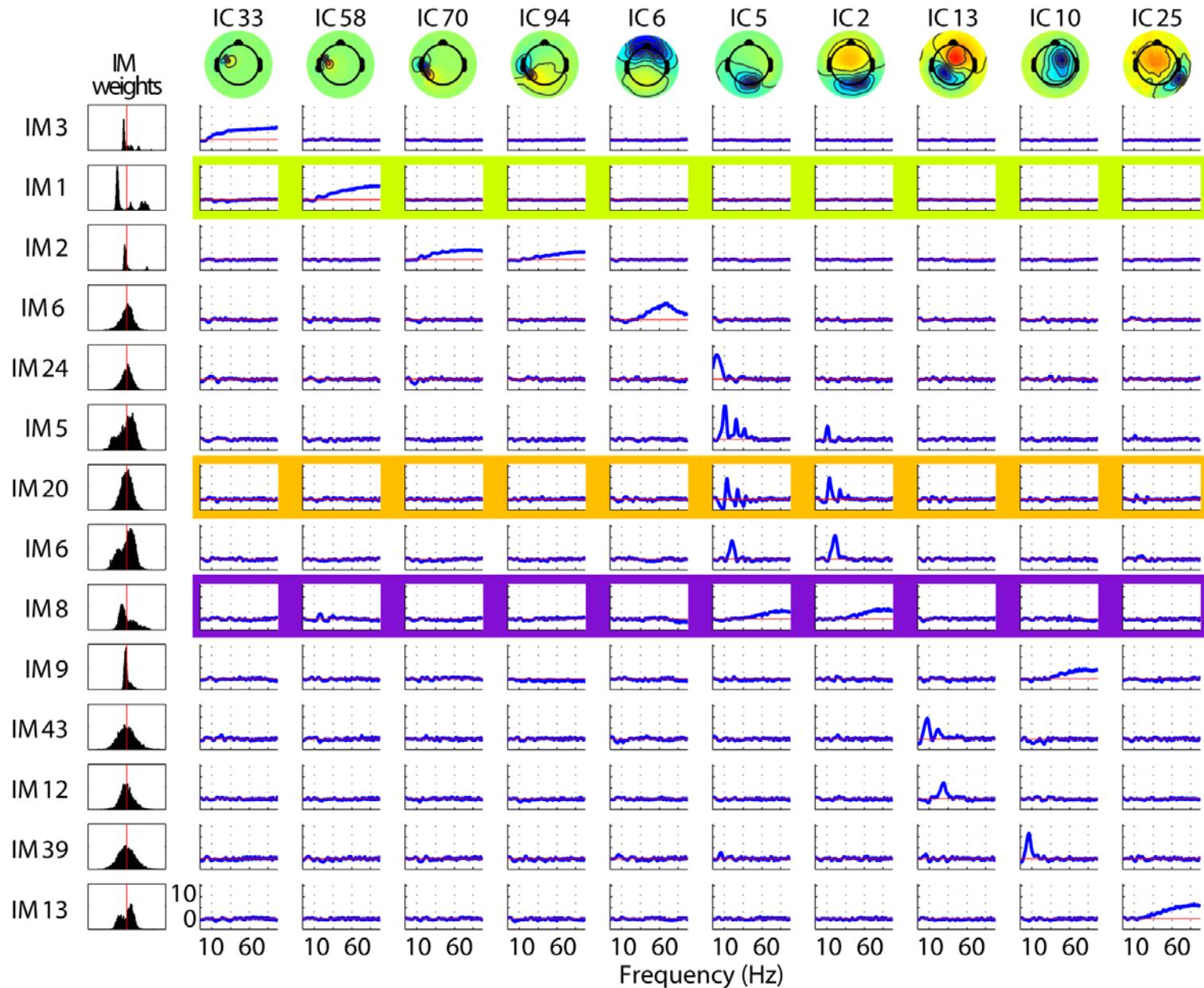
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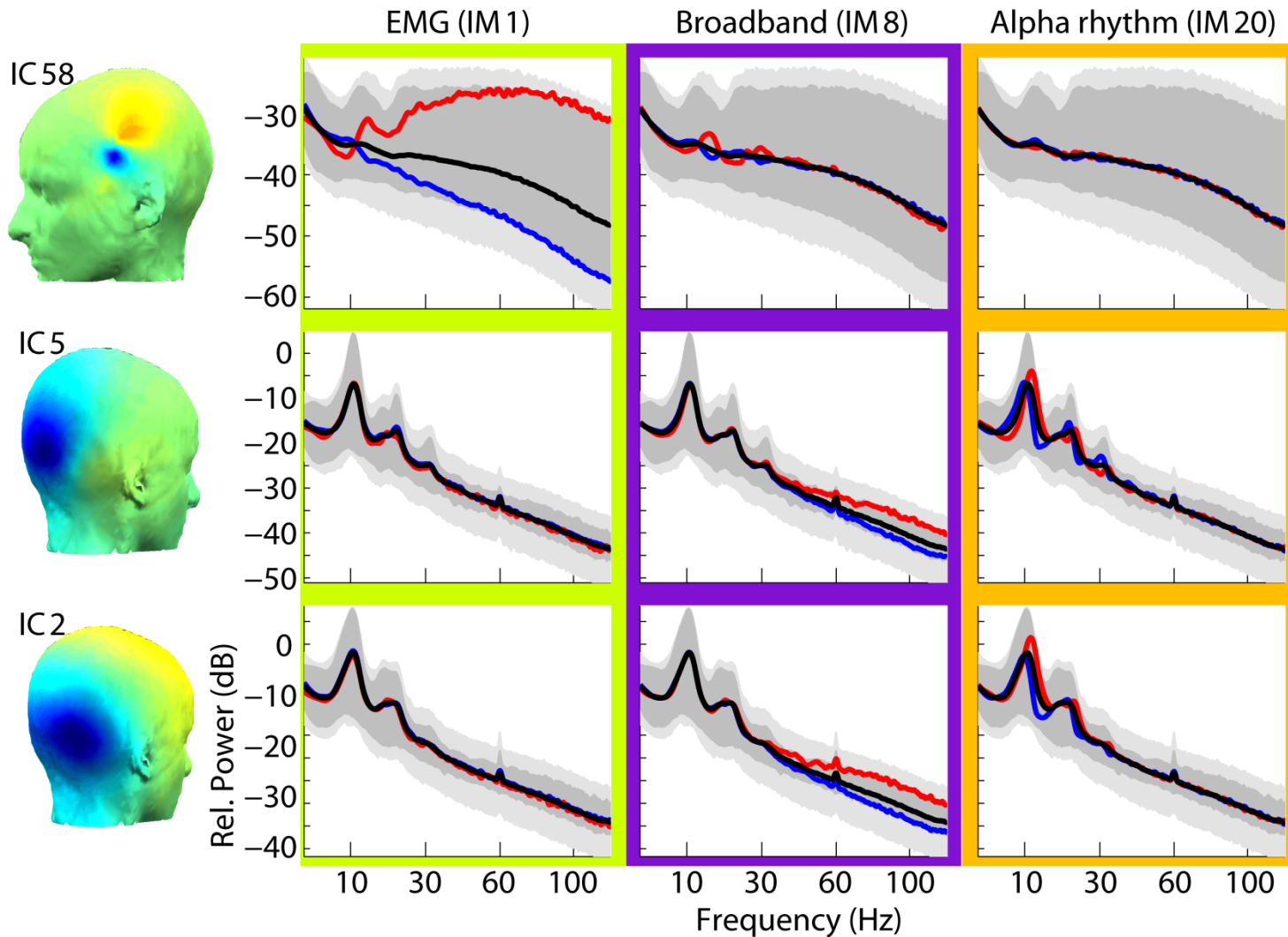
Broadband gamma modulator clusters



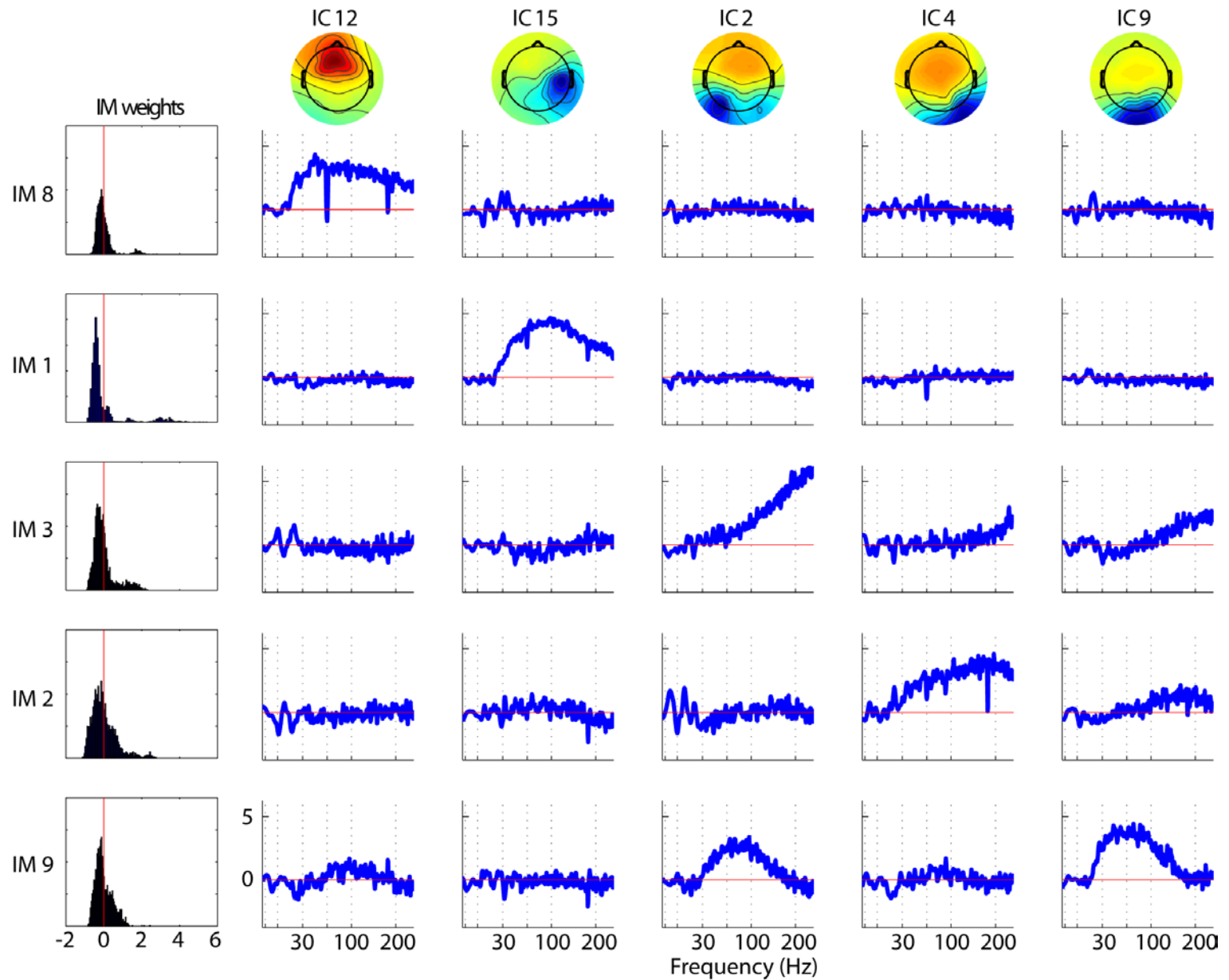
Muscle is not co-modulated with brain



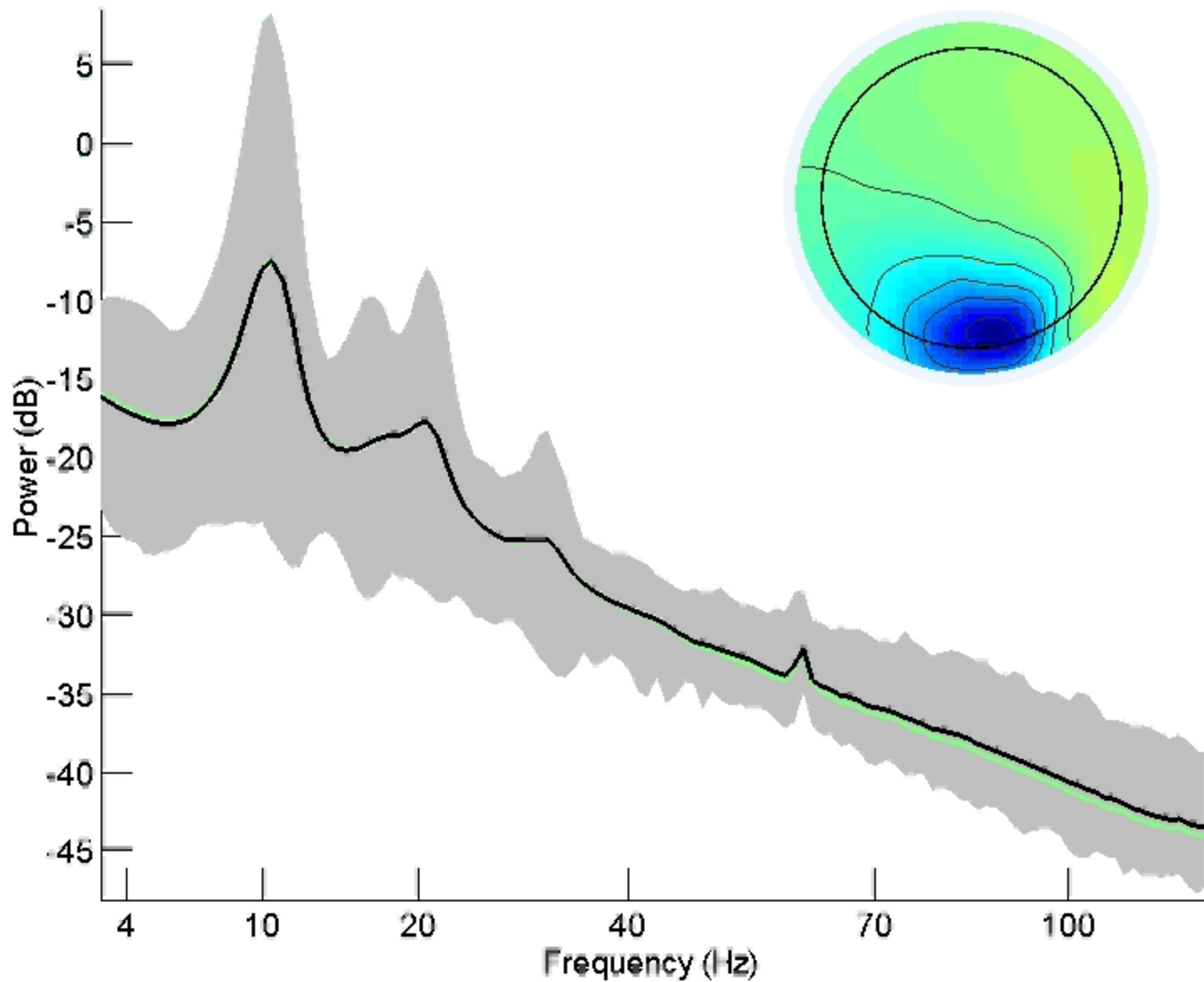
Muscle is not co-modulated with brain



Gamma power up to 250 Hz



Sorted broadband IM weights

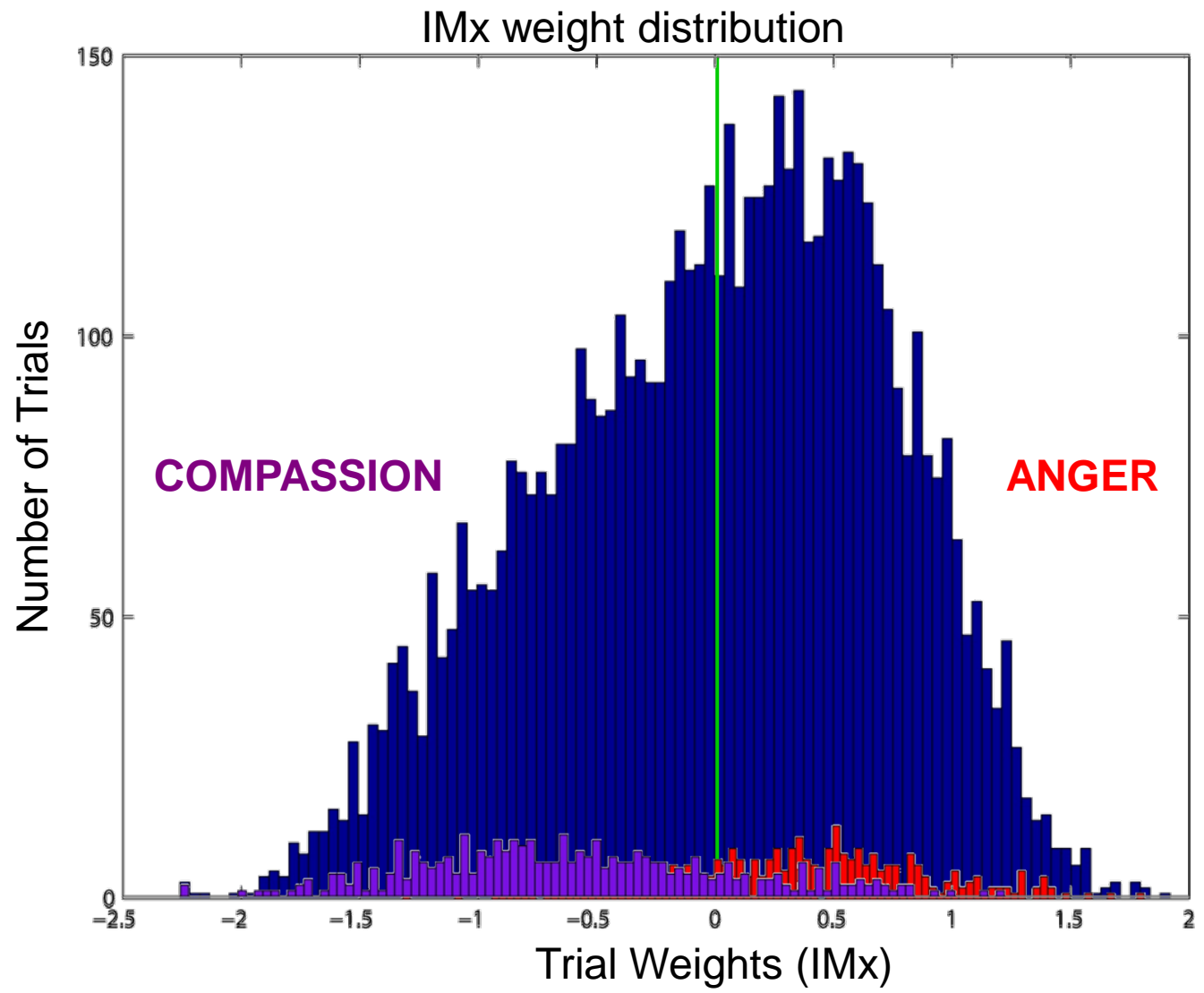
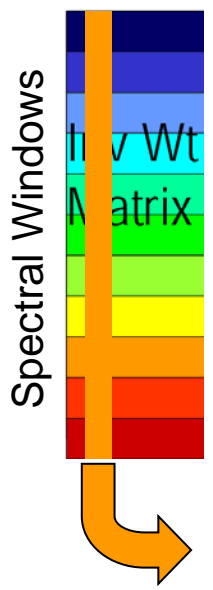


Outline

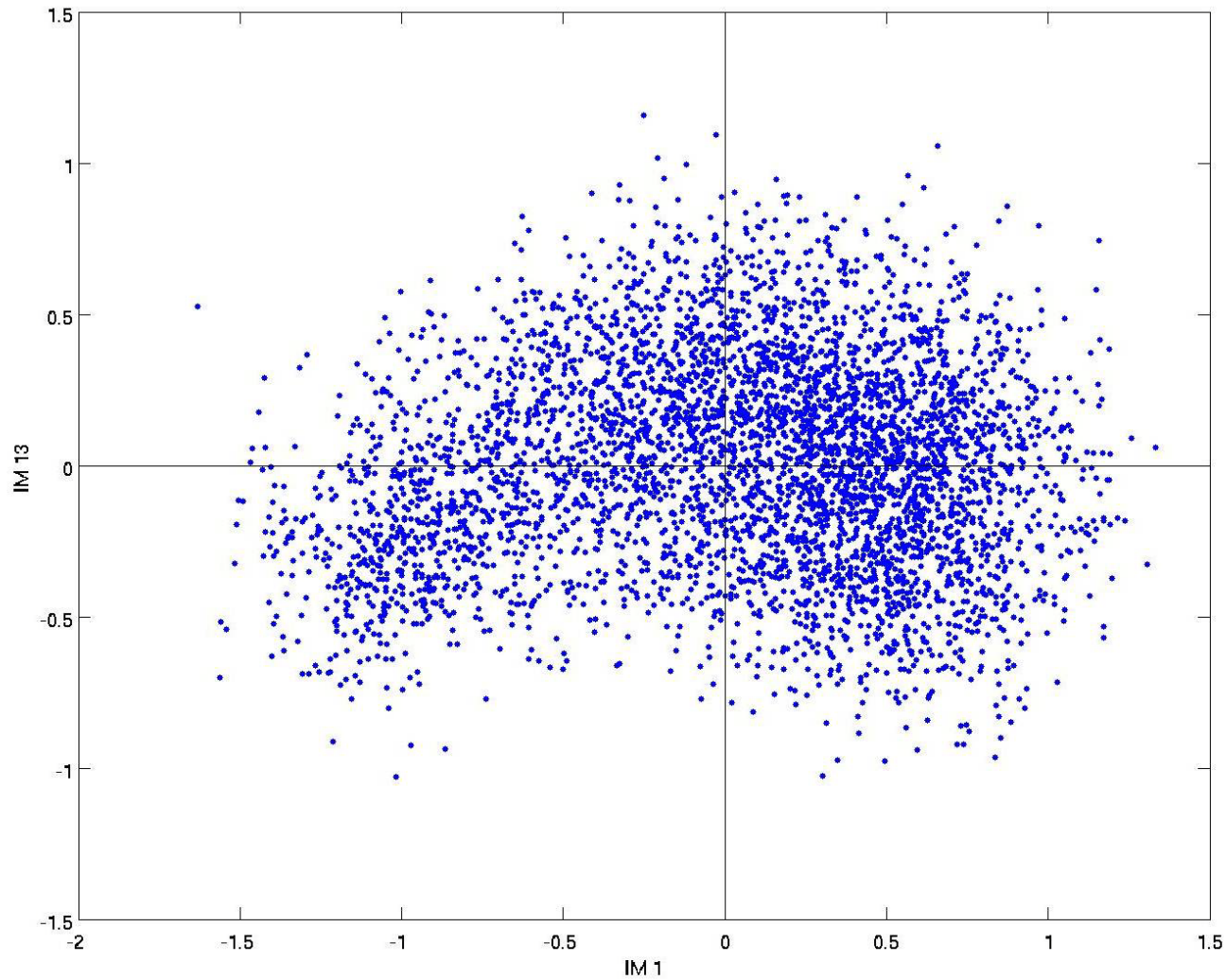
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IM distribution shifts with emotional state changes

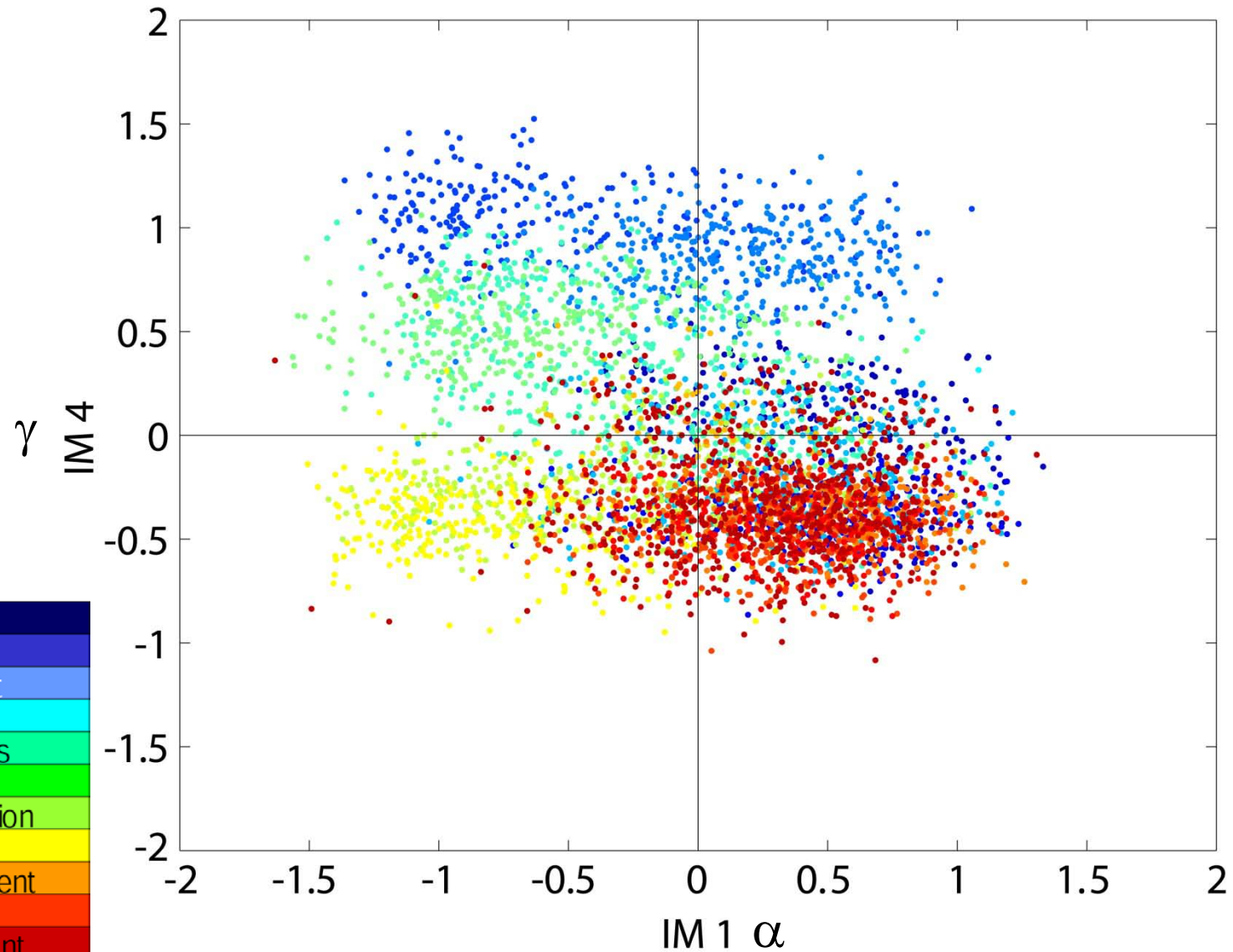
Independent Modulators



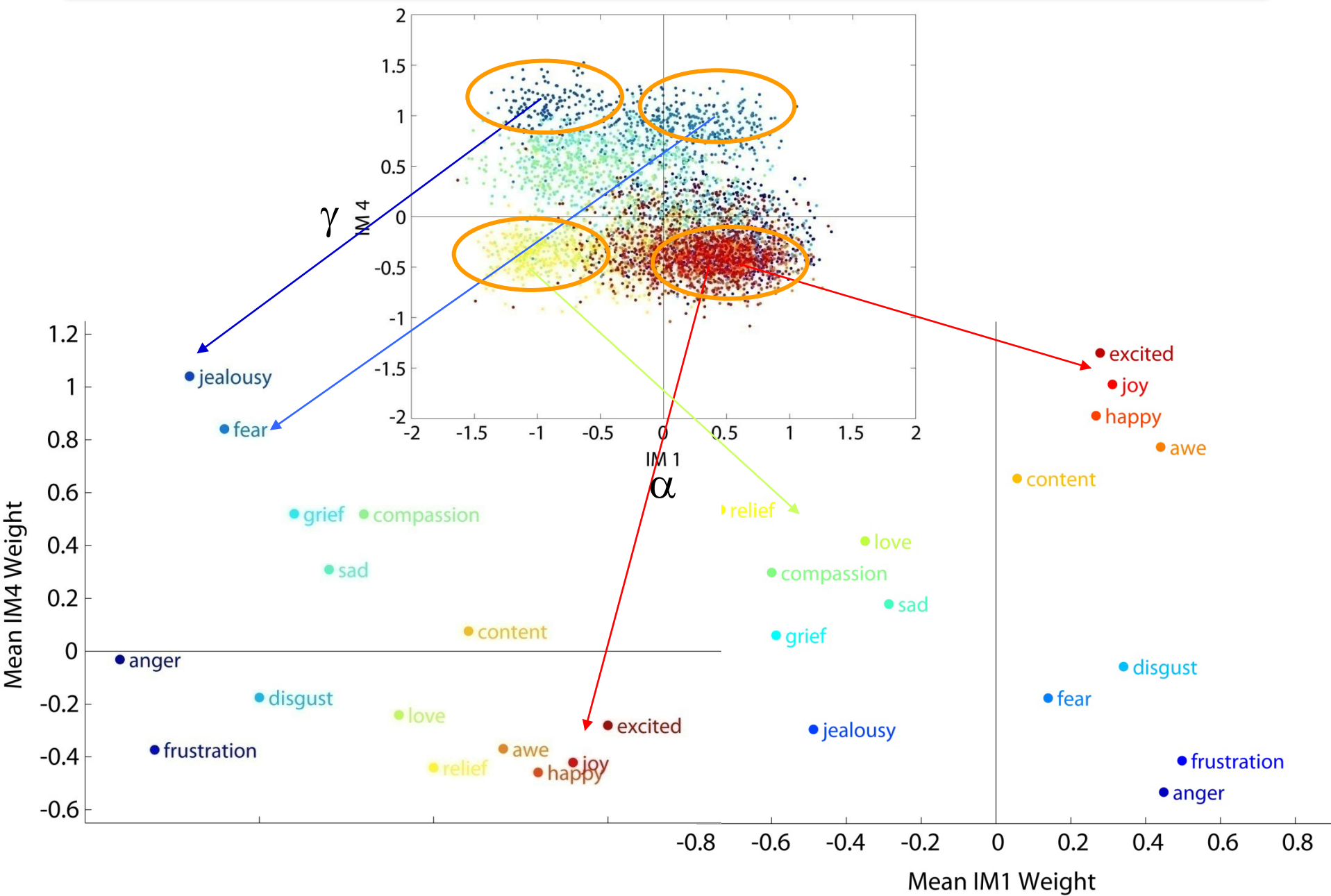
IM weights for different emotions



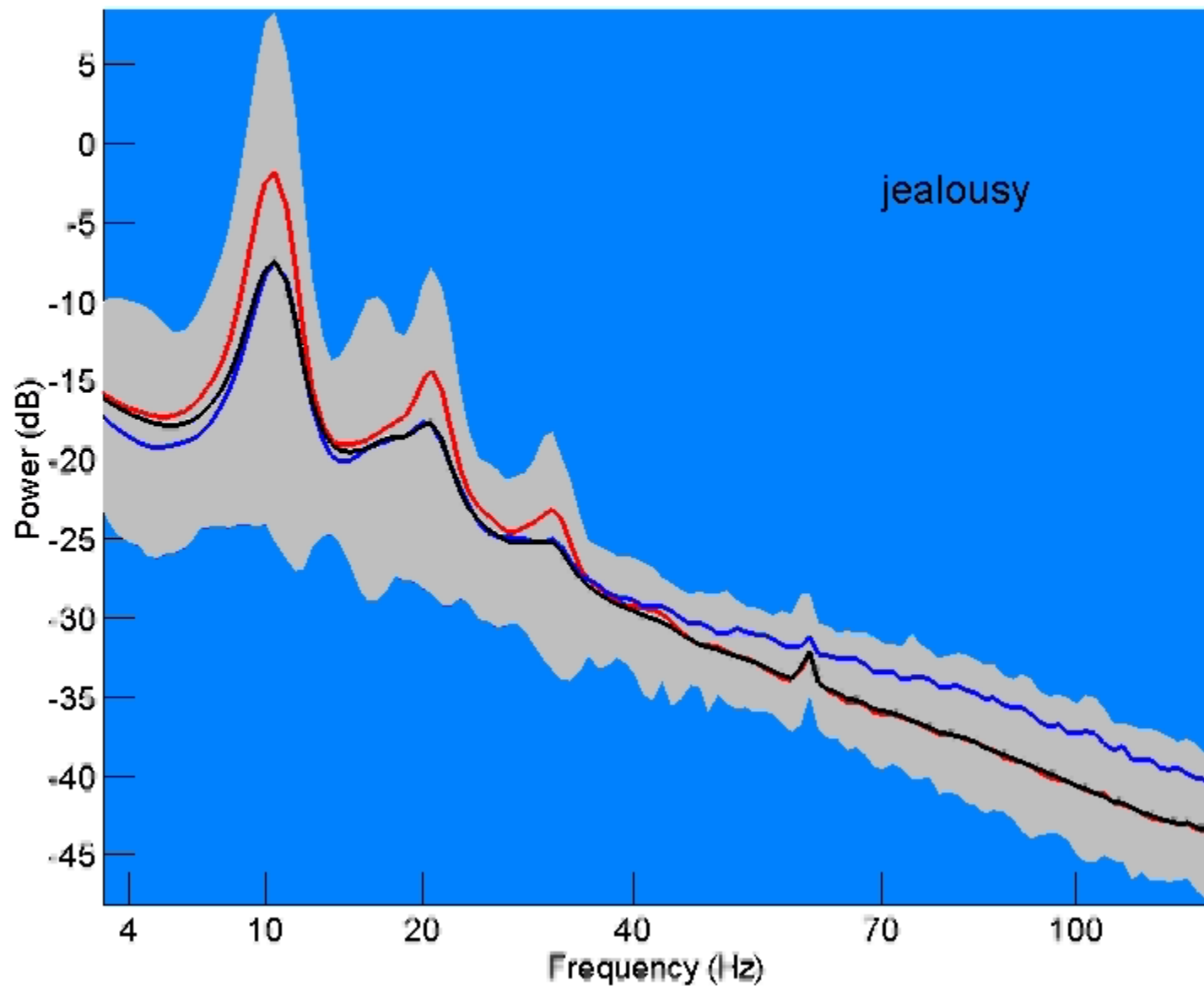
IM weights for different emotions



Momentary and mean IM weights

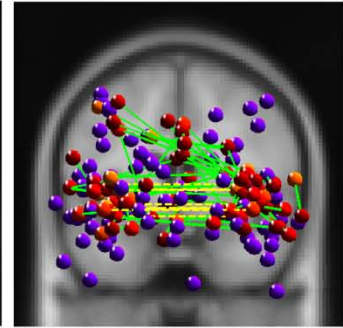
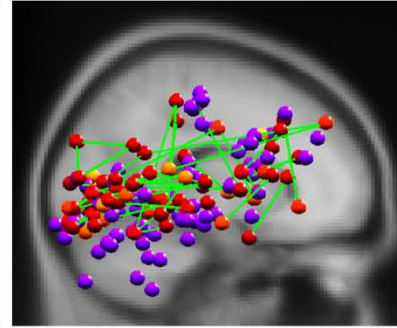
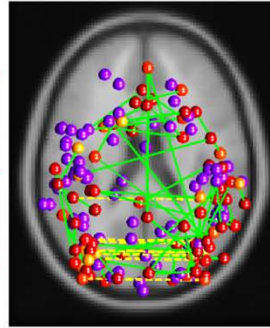
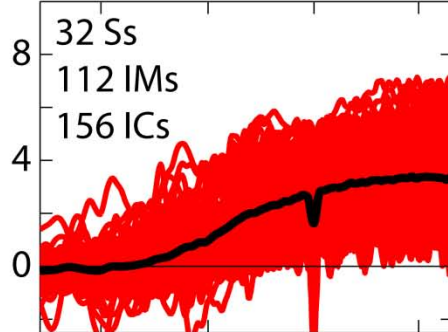


IM weights during emotional imagery

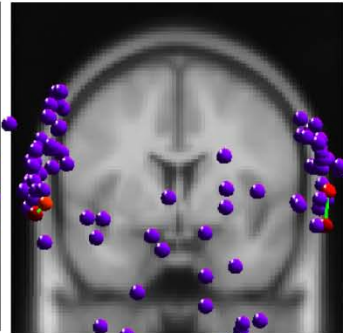
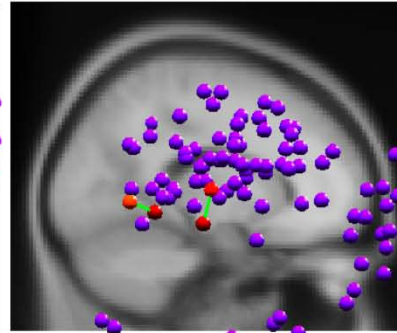
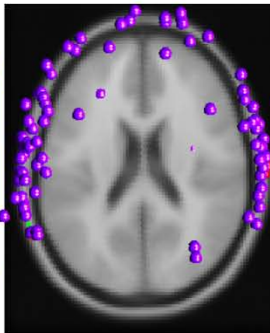
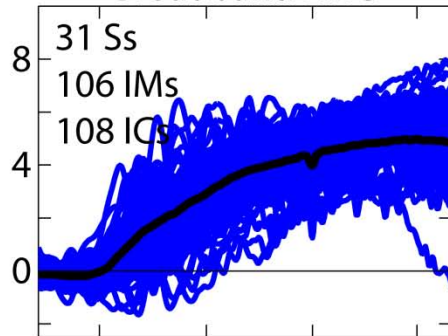


Broadband gamma modulator clusters

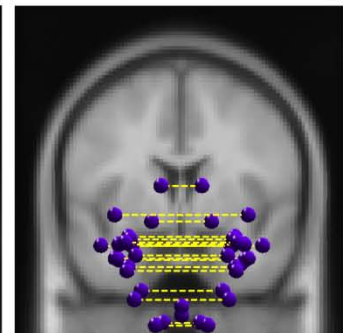
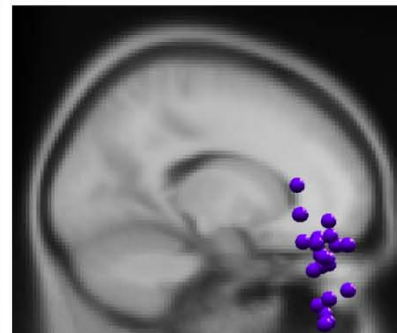
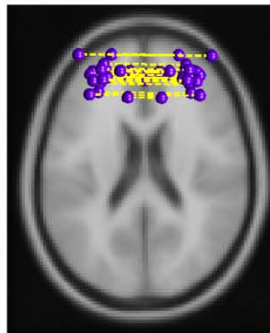
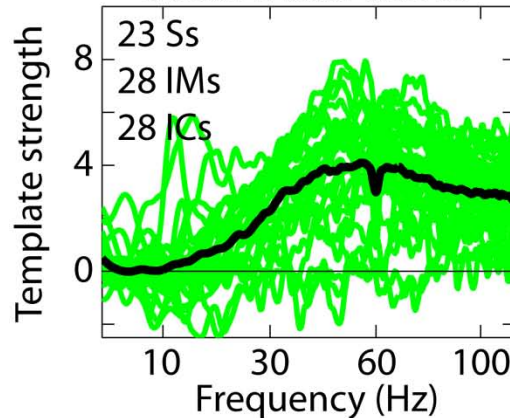
Broadband EEG



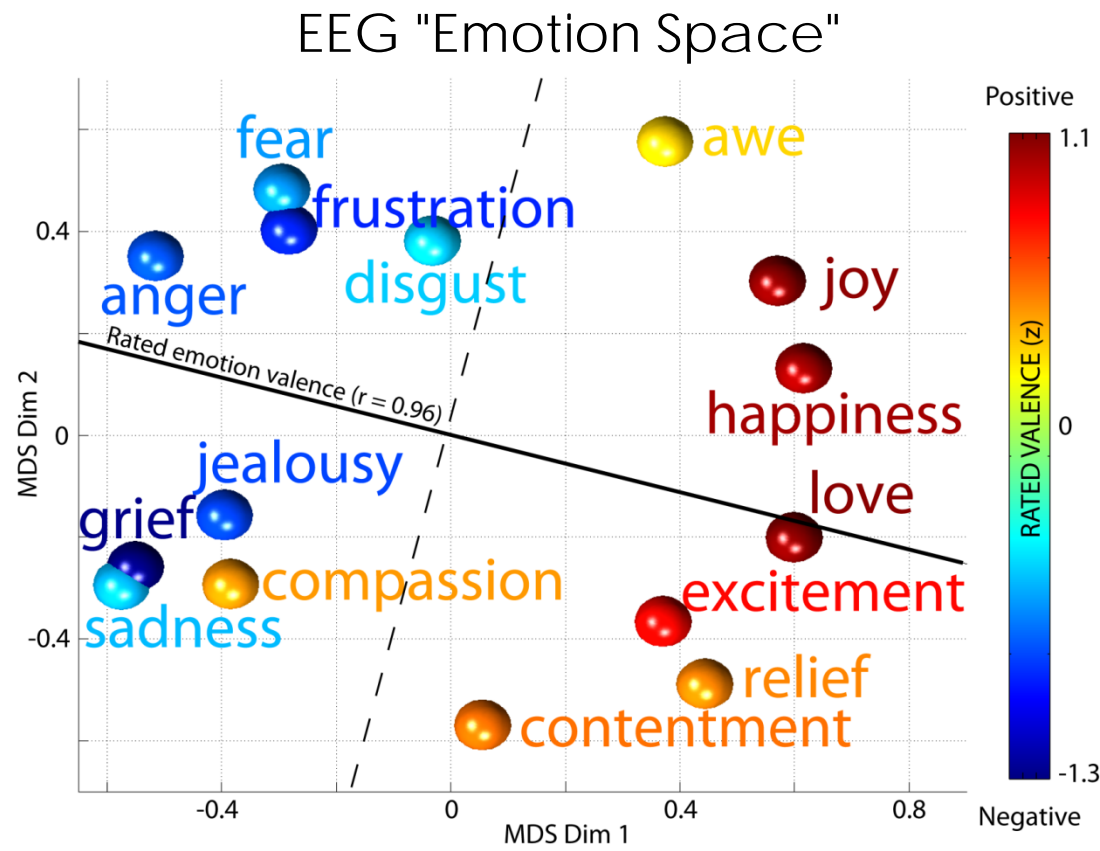
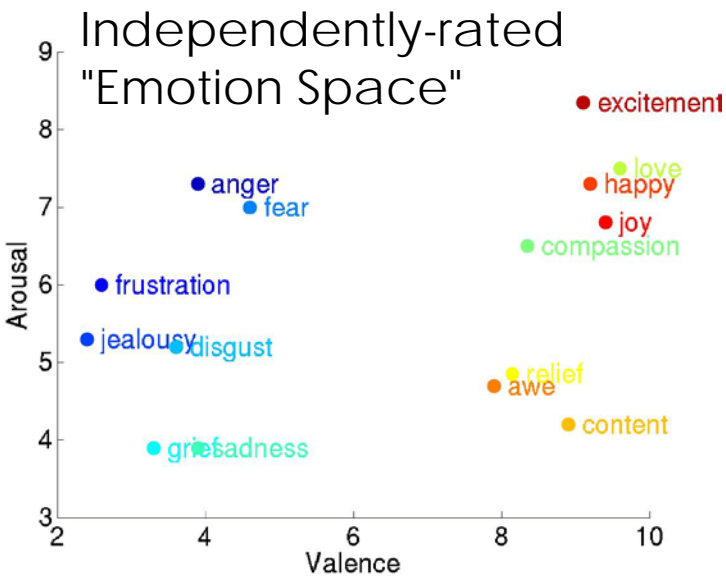
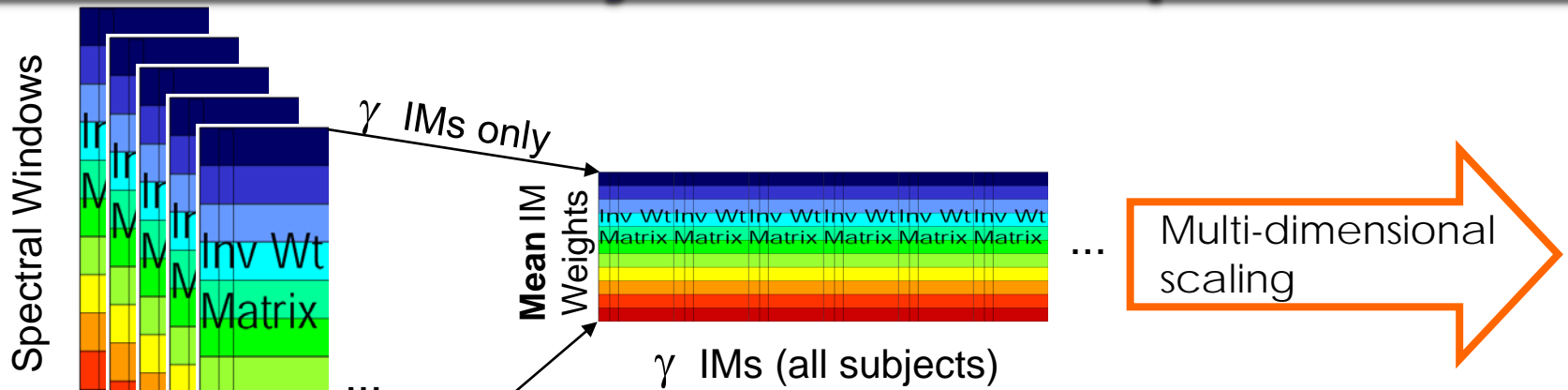
Broadband EMG



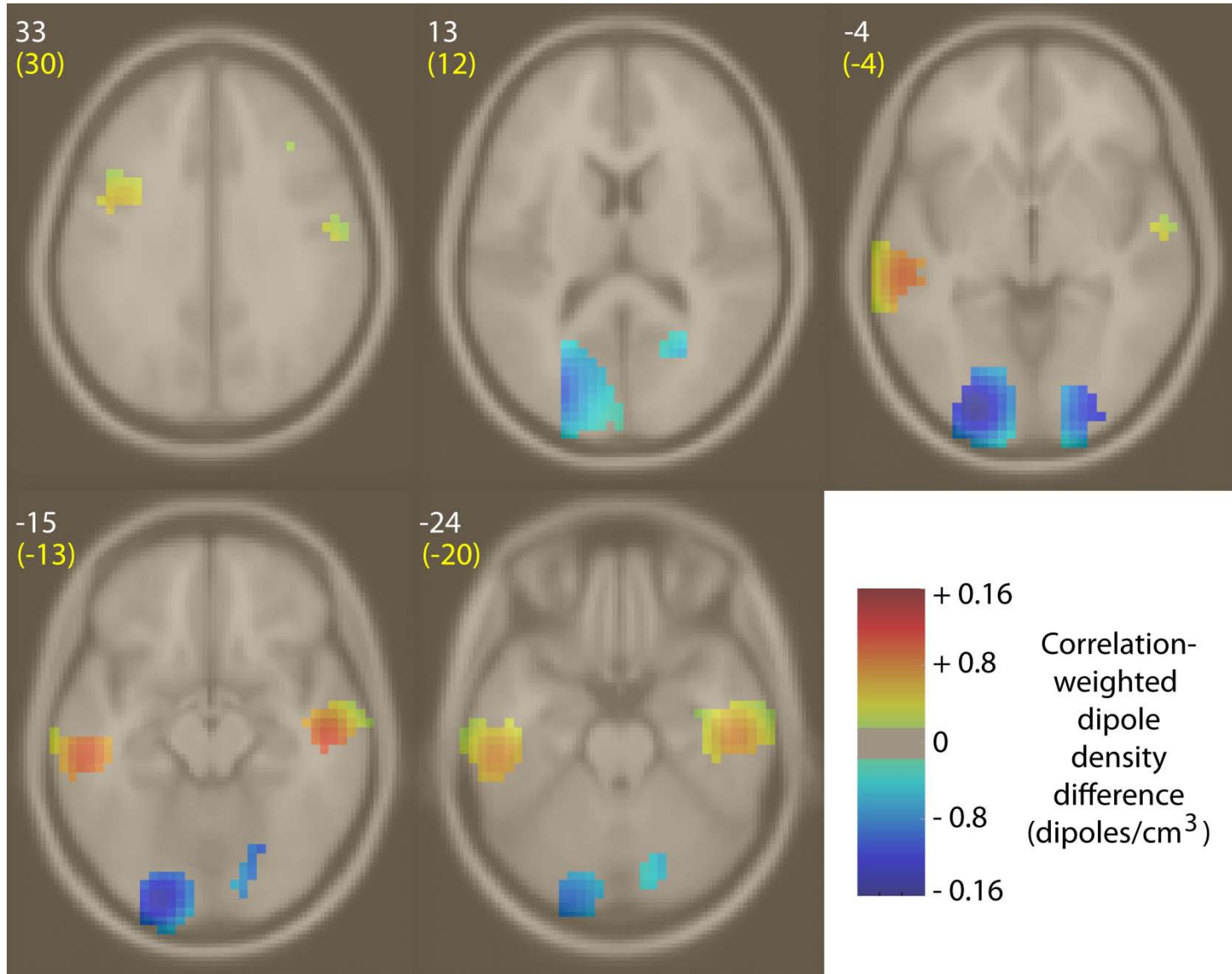
Ocular motor tremor



Inter-subject emotion space



Valence-correlation-weighted dipole density of γ IMs

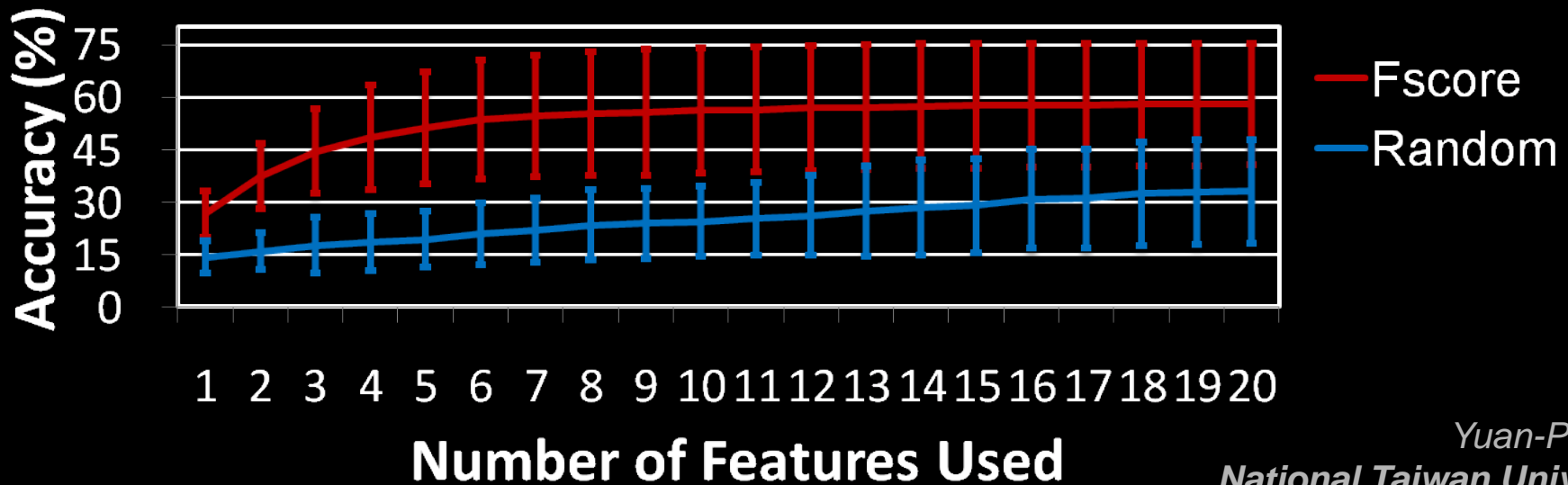


Outline

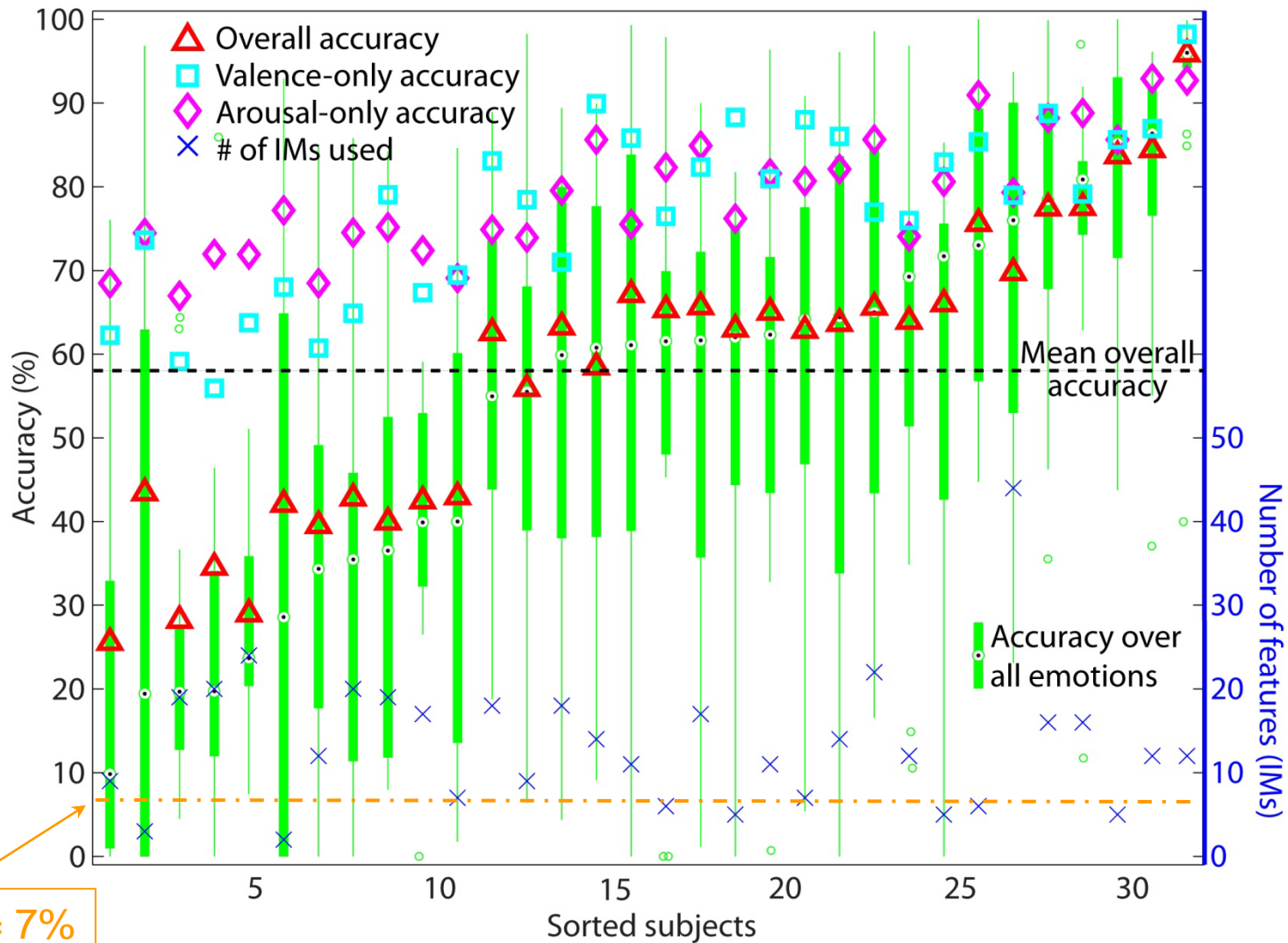
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Emotion classification procedure

- 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

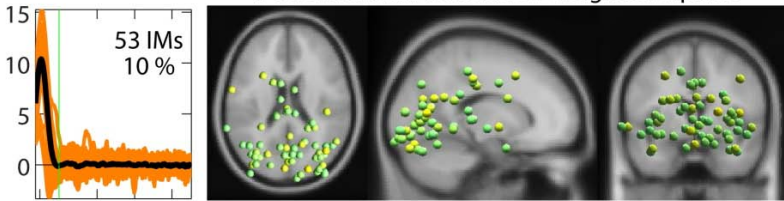


Classification accuracy (1-sec, non-overlapping epochs)

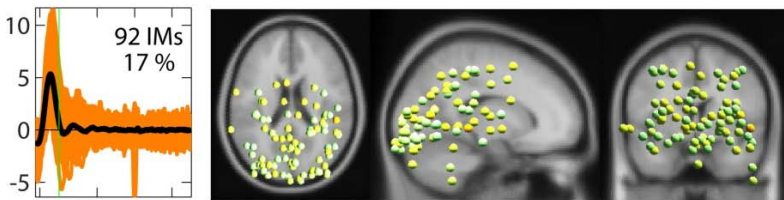


Brain sources with emotion-related IMs

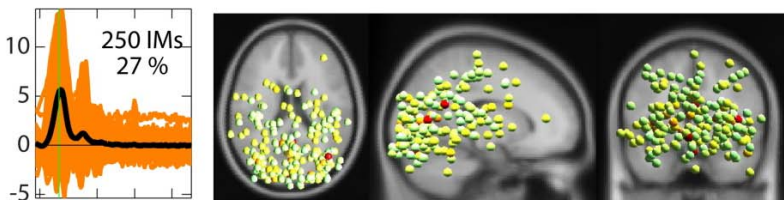
F-score standard deviation-weighted dipoles



Low
Theta
F-std: 0.2

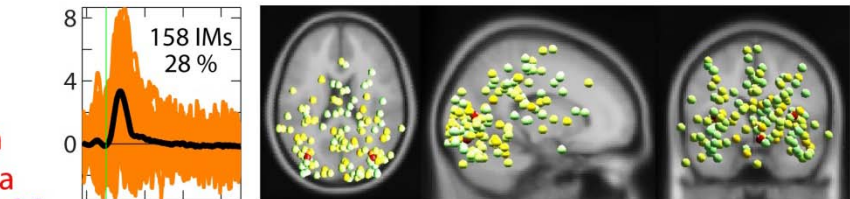
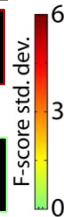


High
Theta
F-std: 0.2

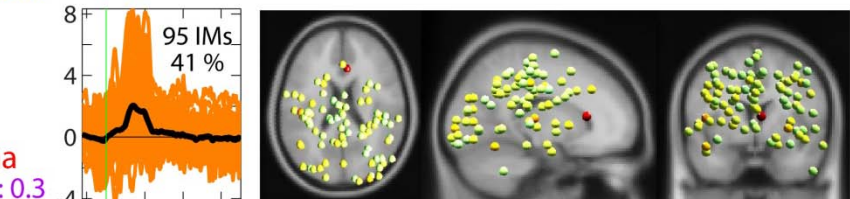


● Highest F-score IM/IC

● Lowest F-score IM/IC

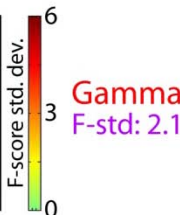
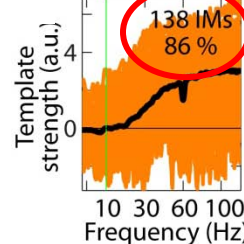
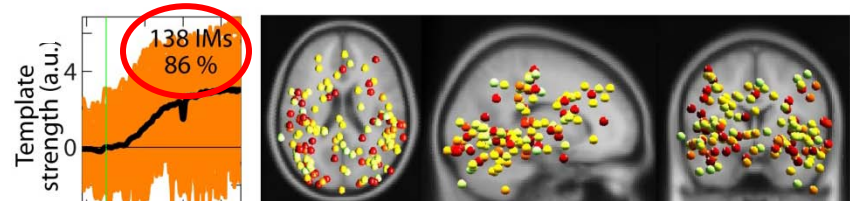


Low
Beta
F-std: 0.3

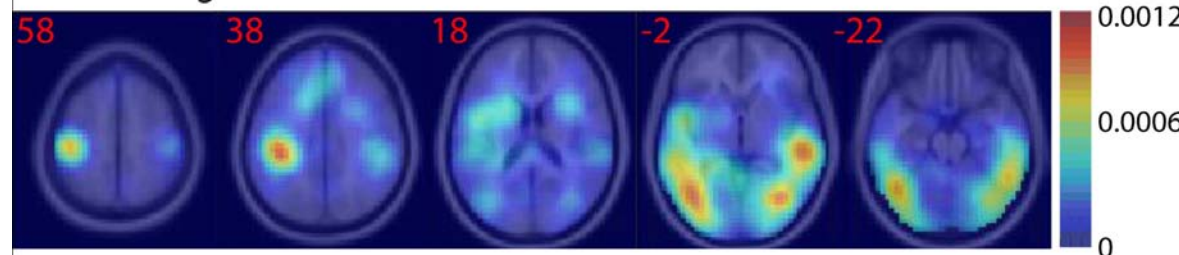


Alpha
F-std: 0.3

High
Beta
F-std: 0.5



Broadband gamma IMs used for classification



Summary

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

*Thank you to
Jerry Swartz,
Scott Makeig,
and
thank you
for your attention*