ACT-R Parameters from (Resting State) Neuroimaging Data

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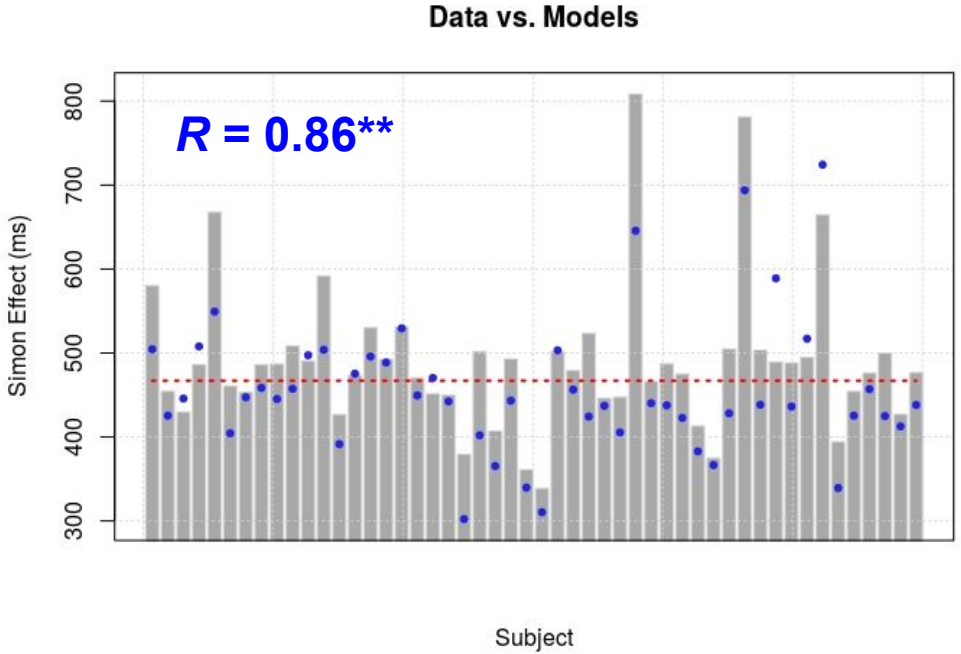
Individual differences in modeling

- Individual differences ~ different model parameters
- Individual parameters stable across tasks
- Parameters would predict future behavior
- Many interesting efforts:
  - Christian Lebiere, Marsha Lovett, Glenn Gunzelmann, Niels Taatgen…

In-House Example

- Max likelihood to fit four parameters in a DM task
  - PSS task
- Plugged parameters in model of different task
  - Simon task
- Parameters predicted response times in incongruent trials



Limits of Behavioral Inference of Params

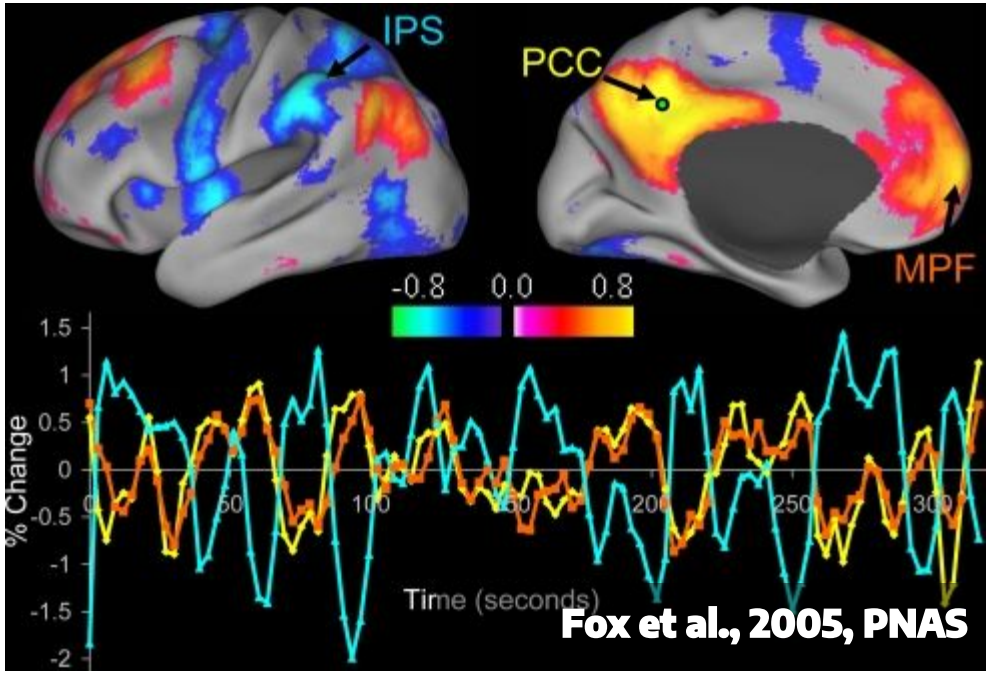
- Depends on behavioral testing
  - can be long and complicated
  - Many many trials to get reliable measures
- Requires reasonable models of a task
  - Garbage in, garbage out
- Parameters should be the same across tasks
  - “Cognitive supermodels”, à la Salvucci

What if we Could Bypass Behavior?

- Parameters should reflect basic neural activity
- Individual differences in parameters could and should be measurable somehow.
- Many task-free neural measures exist
  - Anatomical MRI, DTI, SPECT/PET…

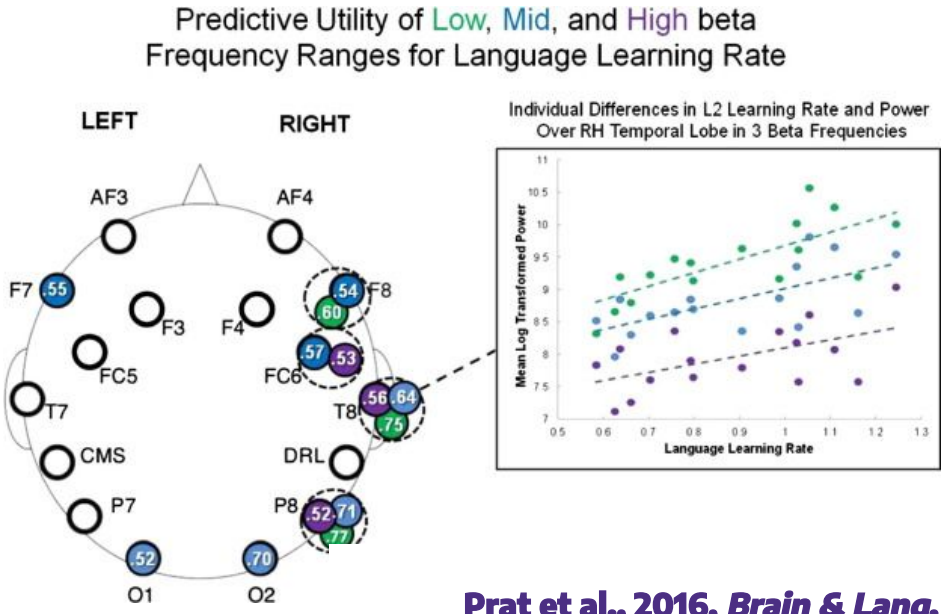
Resting State fMRI

- Most popular method
- Participants rest or “mind-wander” for ~8 mins
- Slow (0.1 - 0.01 Hz) fluctuations in activity identify networks of stably connected regions
- Connectivity measures predict individual variables (Age, IQ).

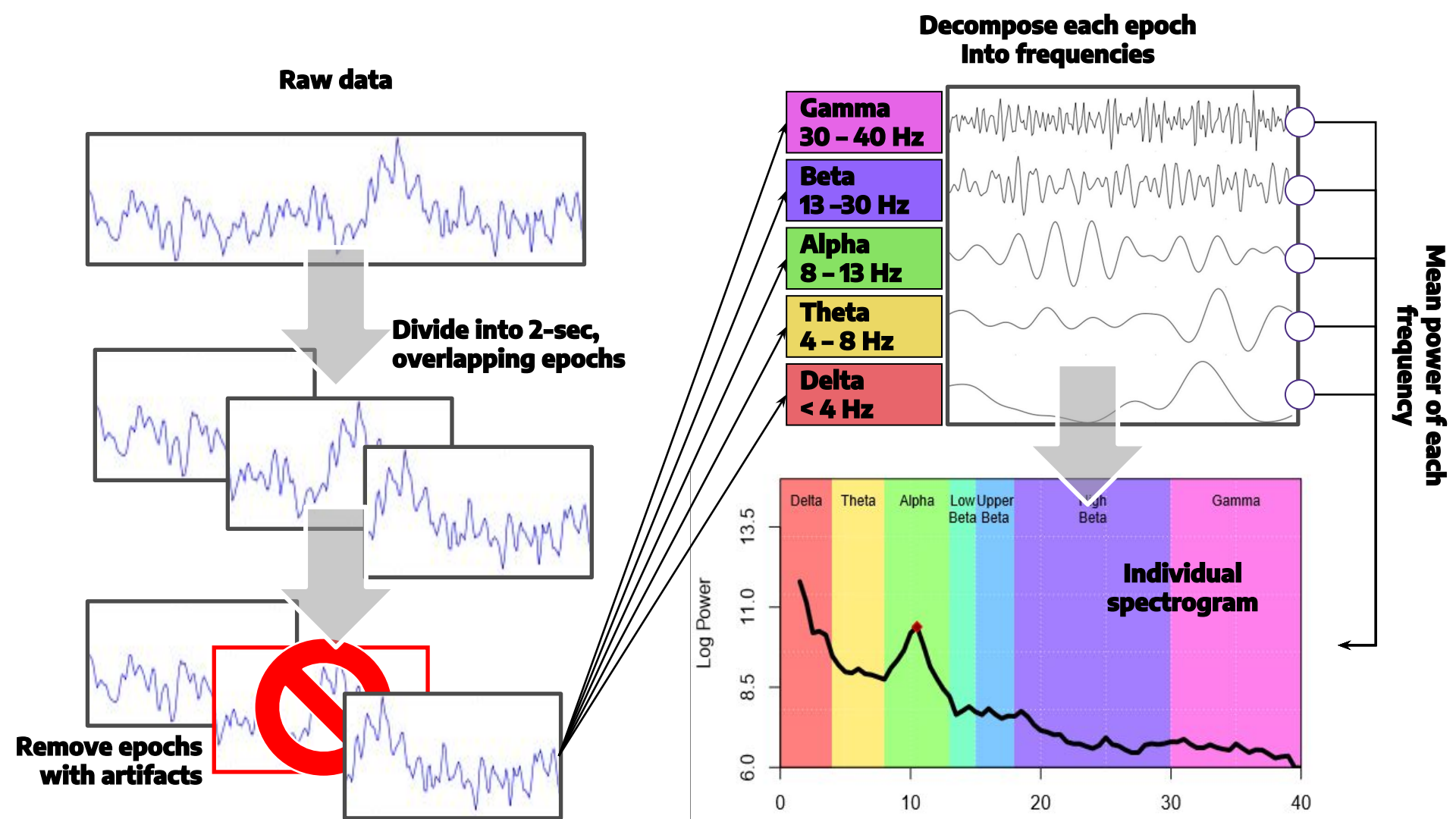


Resting State EEG

- Decades-long use in clinical practice
- Very stable across age
- Reliably associated to individual traits
  - E.g., intelligence (Klimesh, 2003)
  - Second language aptitude (Prat et al., 2016)



Prat et al., 2016, *Brain & Lang.*


Raw data
Divide into 2-sec, overlapping epochs
Remove epochs with artifacts
Decompose each epoch Into frequencies
Gamma 30 – 40 Hz
Beta 13 –30 Hz
Alpha 8 – 13 Hz
Theta 4 – 8 Hz
Delta < 4 Hz
Mean power of each frequency
Delta
Theta
Alpha
Low Beta
Upper Beta
Gamma
Individual spectrogram
Log Power
13.5
11.0
8.5
6.0
0
10
20
30
40

Emotiv EPOC Headsets

- Reasonable price (< 1K)
- Decent characteristics
  - 14 channels @ 128 Hz
  - Frequently used for BCIs
- Easy:
  - Portable, wireless systems
  - Saline-based electrodes
  - ~15 mins for correct application
  - Minimal training required
  - Great for individual difference studies

Target: Long-Term Memory Decay

- Perhaps the cornerstone of ACT-R
- Likely reflects nature of temporal lobe processing
- Activation is controlled by decay parameter *d*

$$A = \sum_j t_j^{-d}$$

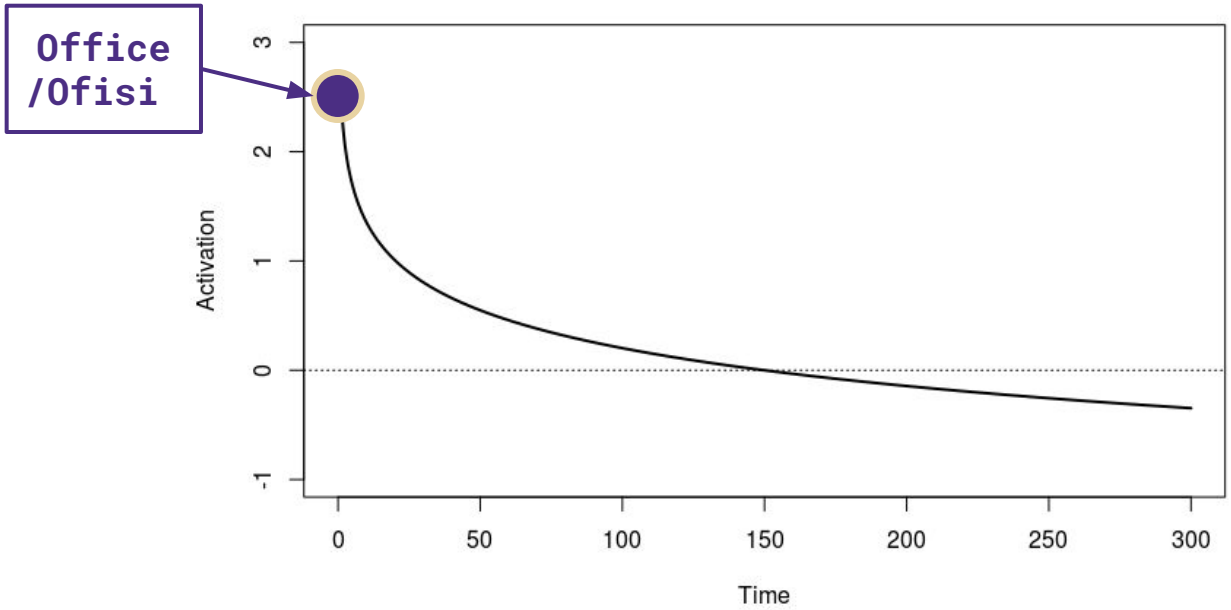
- Used Pavlik & Anderson's equation

$$A = \sum_j t_j^{-d}$$

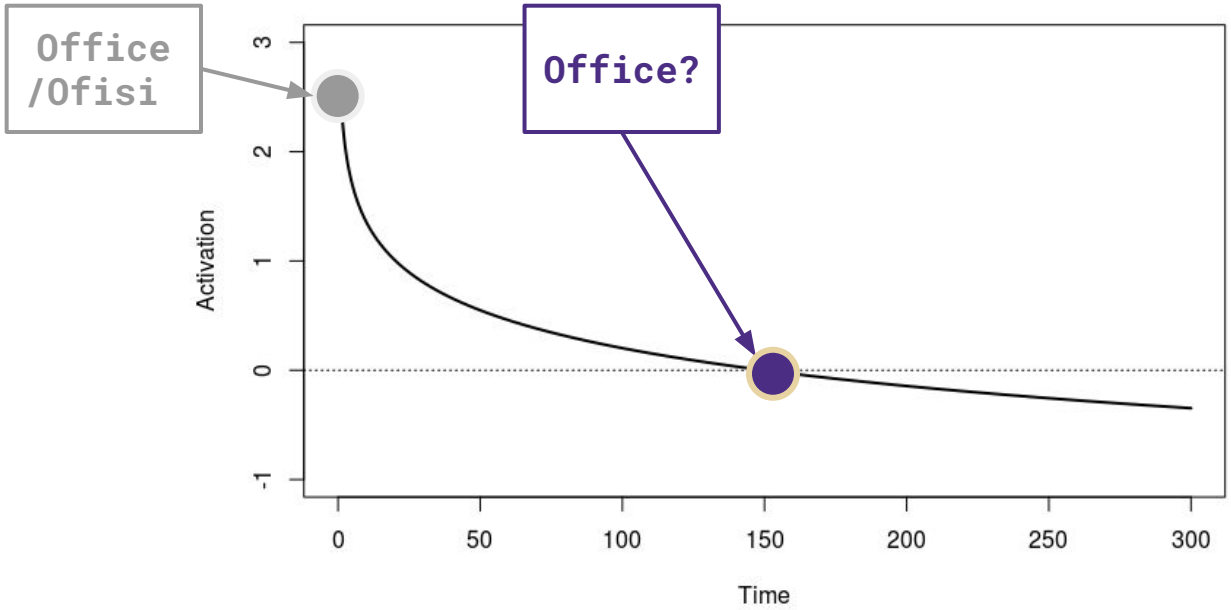
$$d = ce^{A} + \alpha$$

  - Consistent across very short and very long intervals
  - Accounts for spacing effects
- Florian and Hedderik devised a method to estimate α

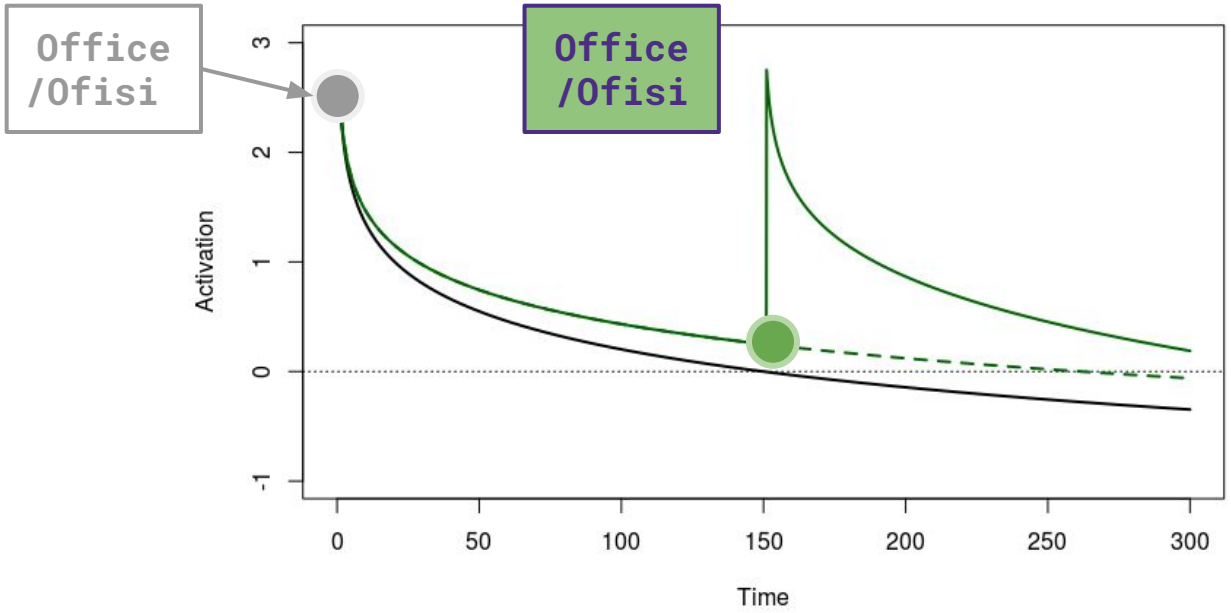
How is α Measured?



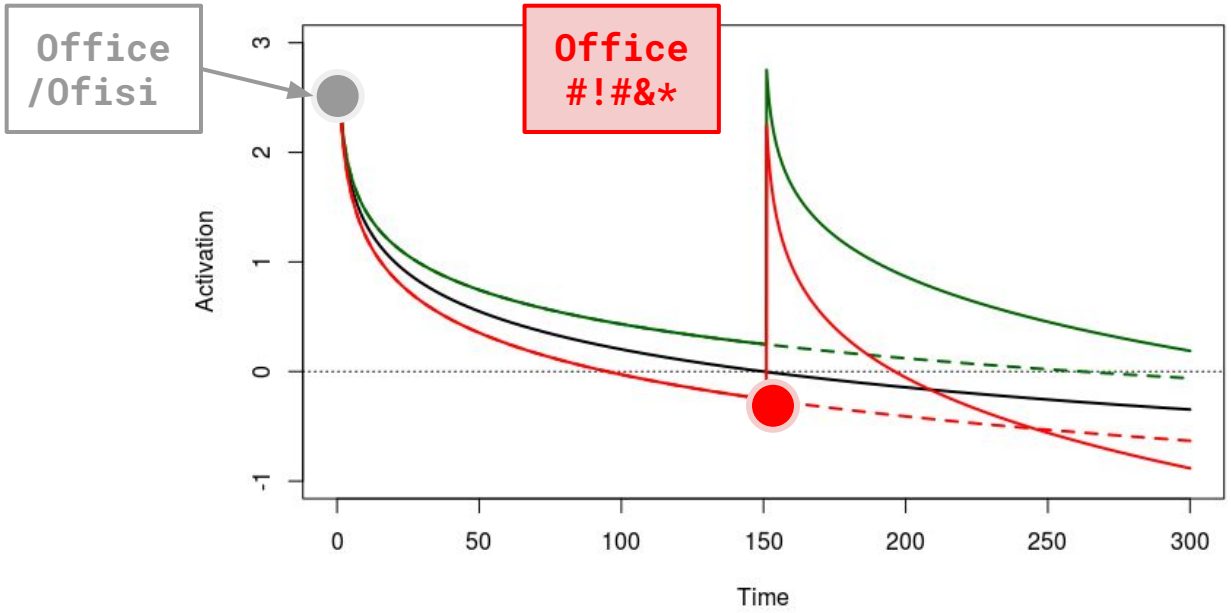
Predict when the chunk is forgotten



If the chunk is remembered, reduce α



If the chunk was forgotten, increase α



Reliability of estimates

- Sense et al., 2016, *TopiCS*
- Reliability between 0.5 and 0.8
- In essence, α is psychological “trait”.

Does QEEG Predict Forgetting Rate?

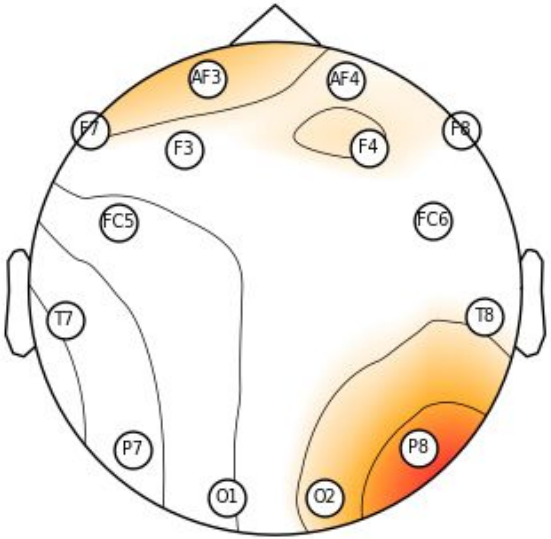
- *N* = 50 UW undergraduates
- All native English speakers
  - This is important!
- Collected 5 minutes of resting state, eyes closed EEG
- Learned 25 pairs of English-Swahili words
  - Same paradigm as Sense et al., 2016

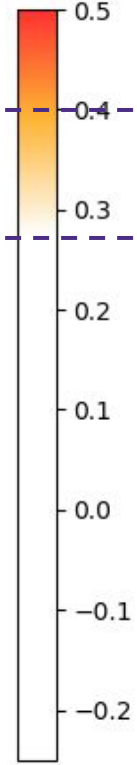
What Should We Expect?

- Correlation with power in beta band (13-30 Hz)
  - Changes in beta power linked to memory formation
- Location: likely around temporal lobe
  - Previous studies show greater correlations in the right hemisphere (greater variability)
- Precise source localization not possible
  - Signal not up to par for task
  - (I tried, results are awful)

Results: Topographical correlations

Low Beta (13-15 Hz)



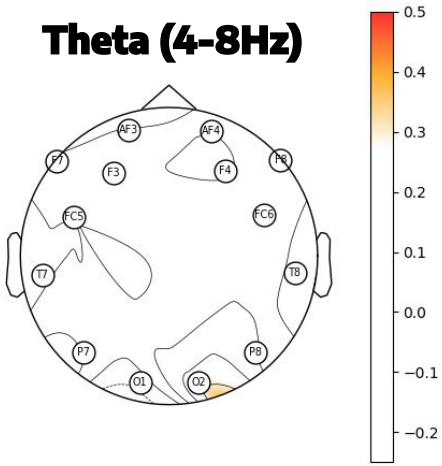


q **< 0.05 (FDR)**

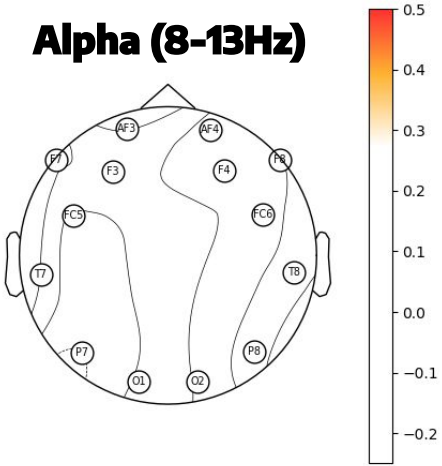
p **< 0.05 (uncorrected)**

Specific to Beta Band

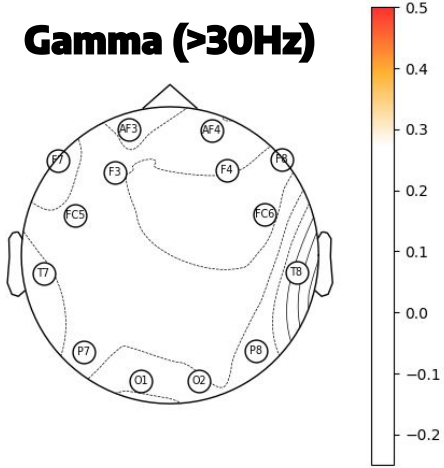
Theta (4-8Hz)



Alpha (8-13Hz)

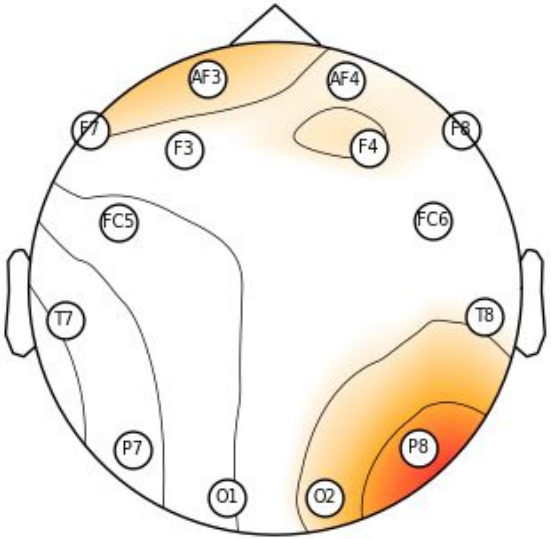


Gamma (>30Hz)



What does it mean?

Low Beta (13-15 Hz)

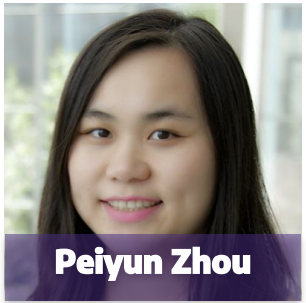


- Power reflects synchronized neural activity
  - *H1*: Greater power = less specialization = more expensive encoding of memories
  - *H2*: Greater power = greater effort in retrieving

Discussion

- Forgetting rate is reflected in basic neural characteristics
- Other ACT-R parameters might be measurable in a similar way
  - Procedural learning rate (also α!) might be reflected in frontal theta power

Credits



university of groningen