Bradley Voytek, Ph.D.

UC San Diego

Department of Cognitive Science
Halıcıoğlu Data Science Institute
Neurosciences Graduate Program

bvoytek@ucsd.edu
@bradleyvoytek

WAITLIST

- I can't manipulate the list to let anyone in, even if you're a graduating senior, etc. I'm sorry!

OTHER QUESTIONS

- Piazza: Not listed there? Let me know!

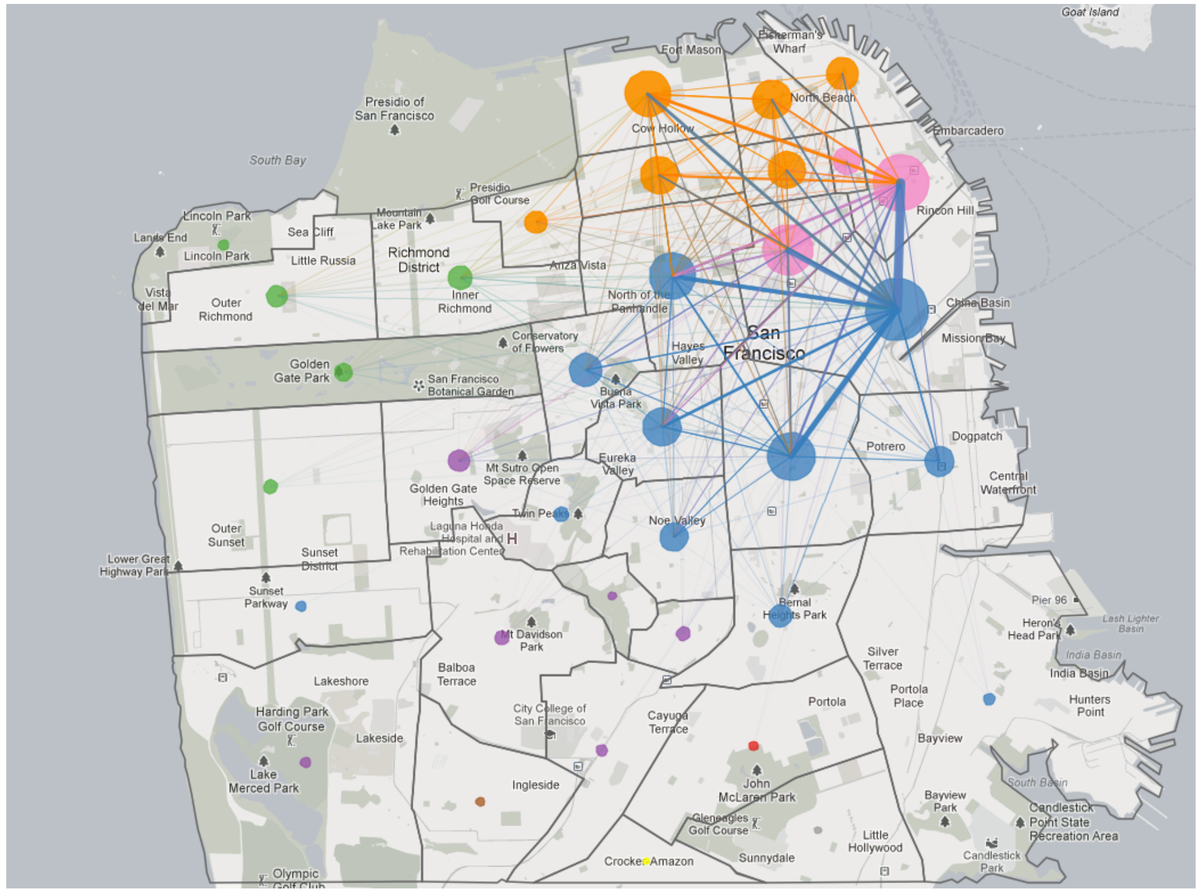
- Groups: ONLY for Final Project, *not* home works!
  - 4-6 people
  - You get to pick 1-2 people to be in your group
  - Each such sub-group of 2-3 will be *randomly* paired with another

Sections and homeworks

- Sections are *not* mandatory
- But bring a computer if you can
- Python, Jupyter, and git *before sections*! (We'll post instructions)
- Sections: intend to go to the section for which you're registered, but you can attend another if needed
- Sections are a great place for assignment guidance
- TA and IA office hours will give you more time to work on assignments
- Assignments will be released Monday mornings
- Assignments will be due Sunday nights
- Assignment solutions will be posted one week after deadline
- Late assignments graded at 50% penalty, not late assignments allowed once solutions are posted

A + B
Data
Science
Student Society

City dynamics



- Aggregating data into arbitrary geographical units: here neighborhoods, but under the hood you'd use e.g., hexagonal tiling.
- Turns lat/lng pairs and time into temporal profiles of demand between parts of a city.

Source: Voytek, *Uber, Inc.*

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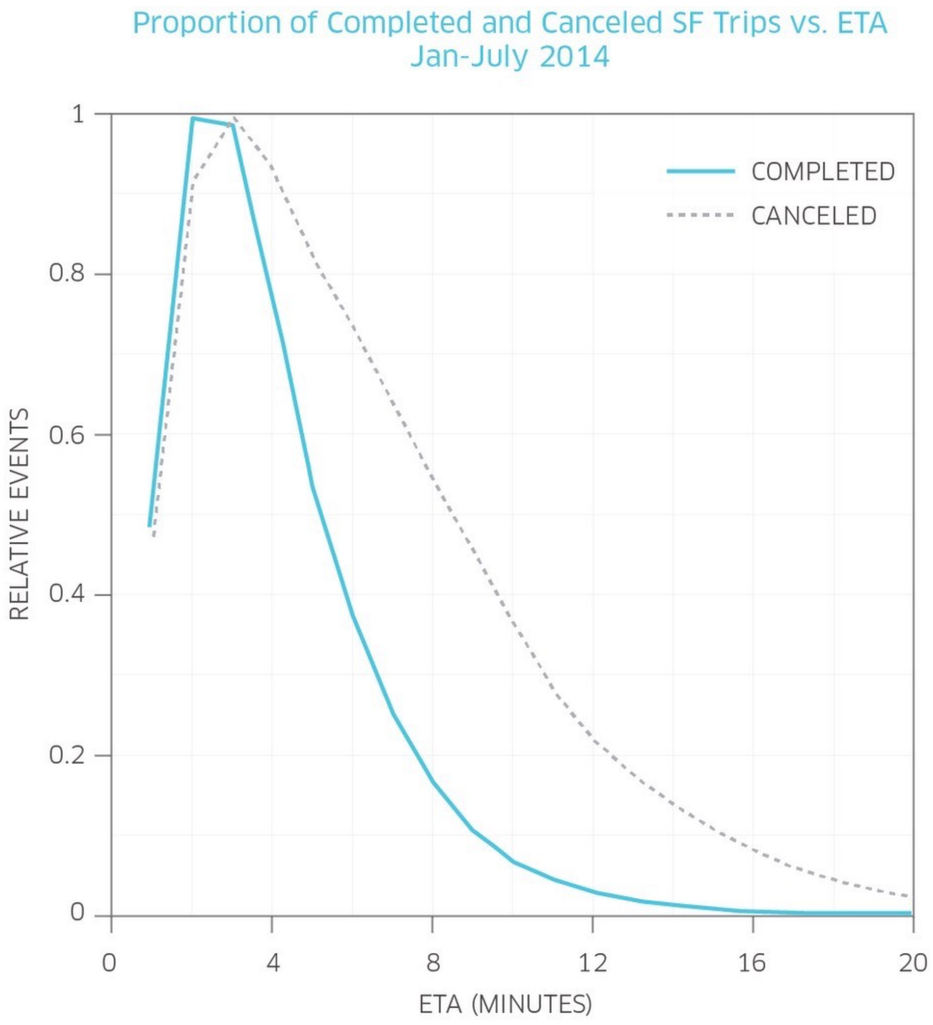
Rider patience



- Plot histograms of ride completion rates as a function of the ETA of the nearest available car.

- This reveals how "patient" riders are in each country, city, or neighborhood: how long they're willing to wait for a car.

Source: Voytek, *Uber, Inc.*

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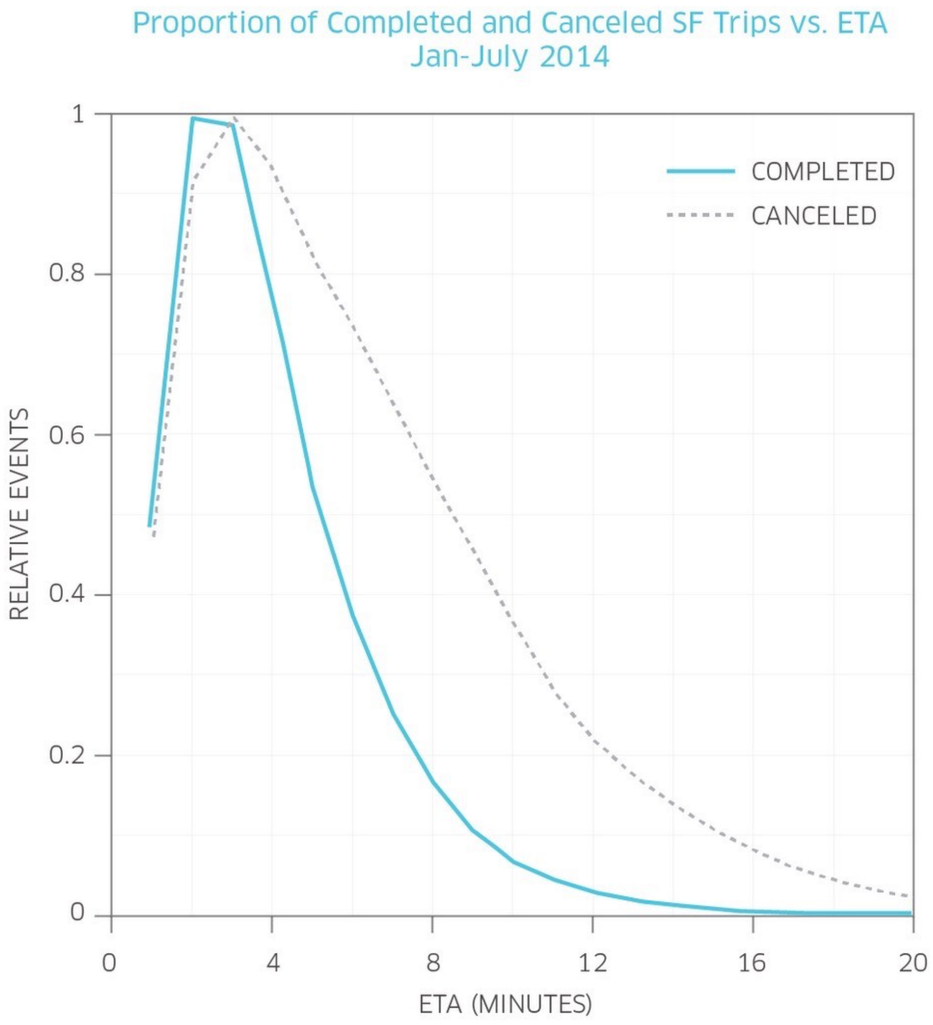
Rider patience



- The decay rate can be inferred to be a proxy for "patience".
- How do we teach this kind of parameterization?
- It's different from modeling, which is the mathematical part.

Source: Voytek, *Uber, Inc.*

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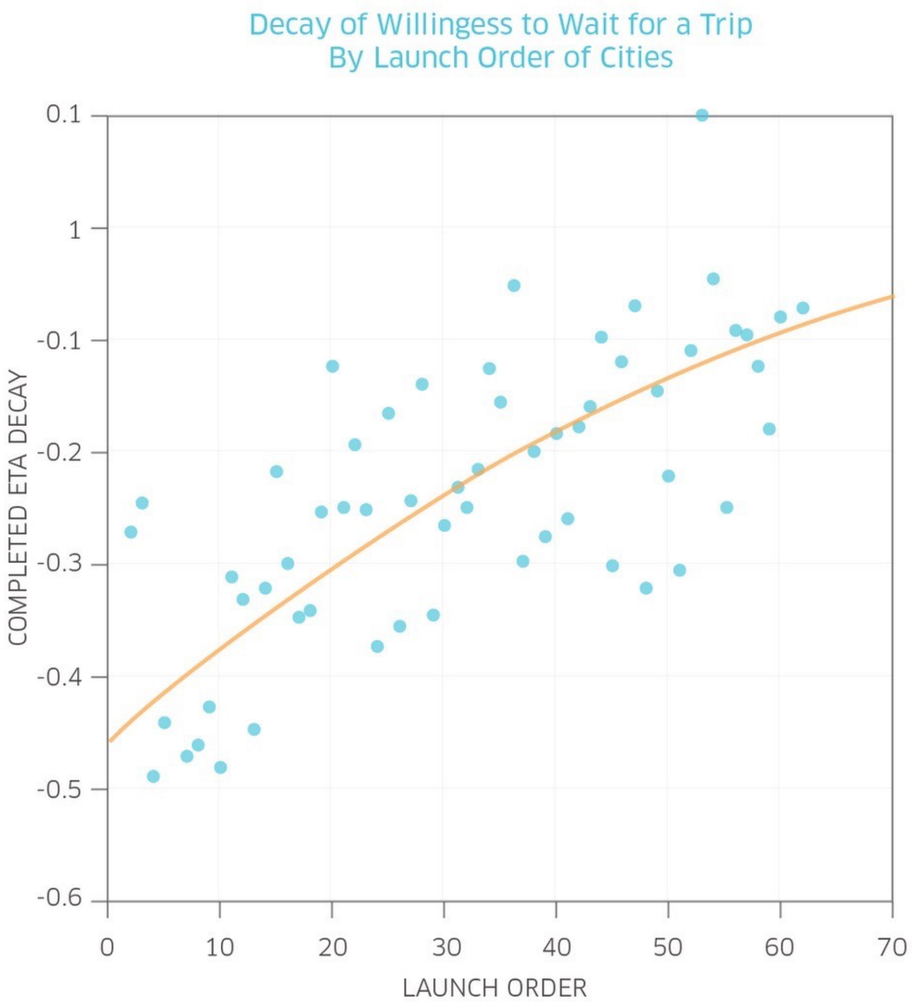
Rider patience



- We saw that this decay rate increased (patience decreased) with each successive city in which Uber launched.

Source: Voytek, *Uber, Inc.*

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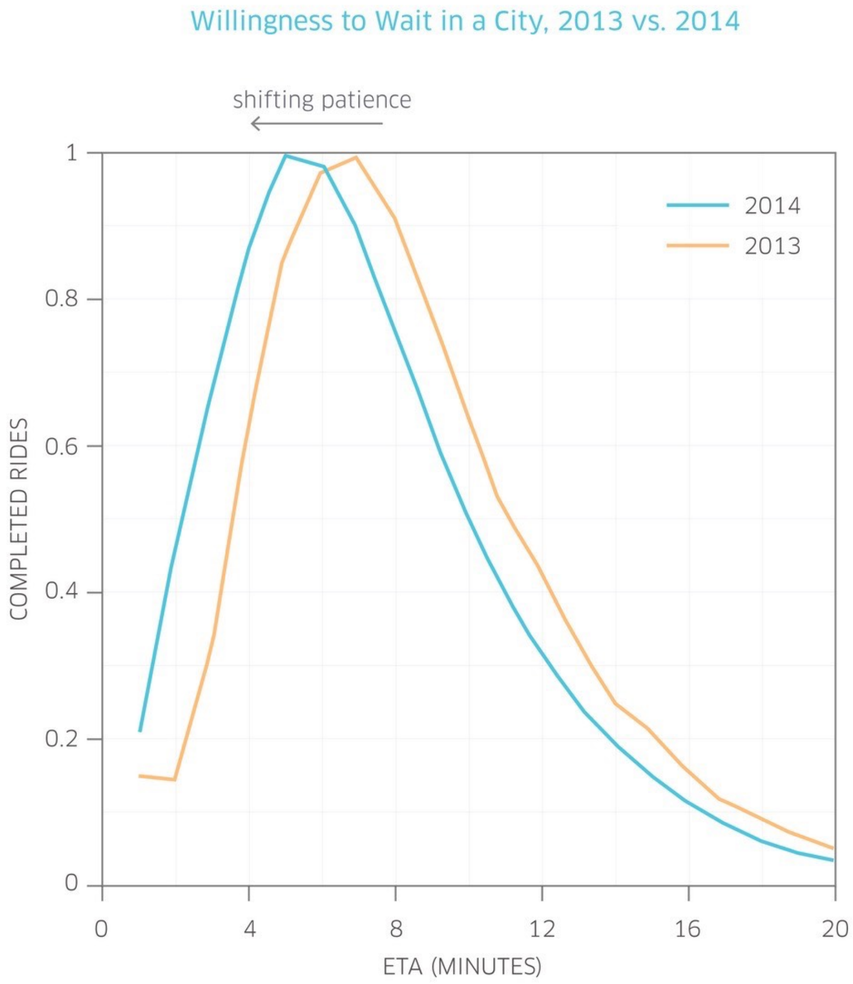
Rider patience



- Additionally the entire curve moves backward with each year Uber is in a city.
- From this we can infer that people are getting more accustomed to the service and expect more of it over time.

Source: Voytek, *Uber, Inc.*

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So what does a professor do?

Teaching

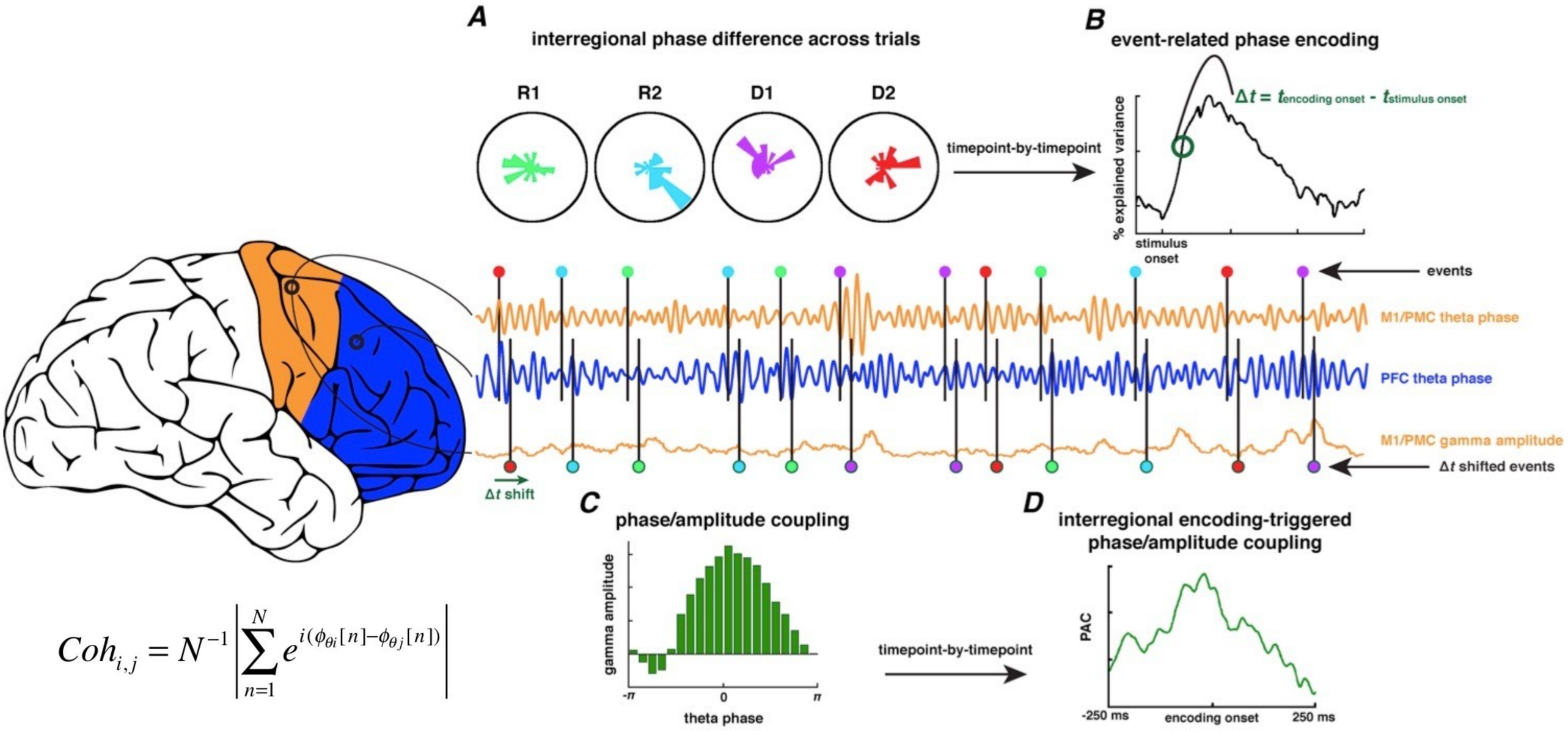
Teaching

Research

What does research look like?

Parametrization

Now I'll show examples of where explicit parameterization has played an important role in our neuroscience research, and what *more* can be done once you have careful parameterization.



$$Coh_{i,j} = N^{-1}\left|\sum_{n=1}^{N} e^{i(\phi_{\theta i}[n]-\phi_{\theta j}[n])}\right|$$

Source: Voytek *et al.*, *Nature Neurosci* 2015

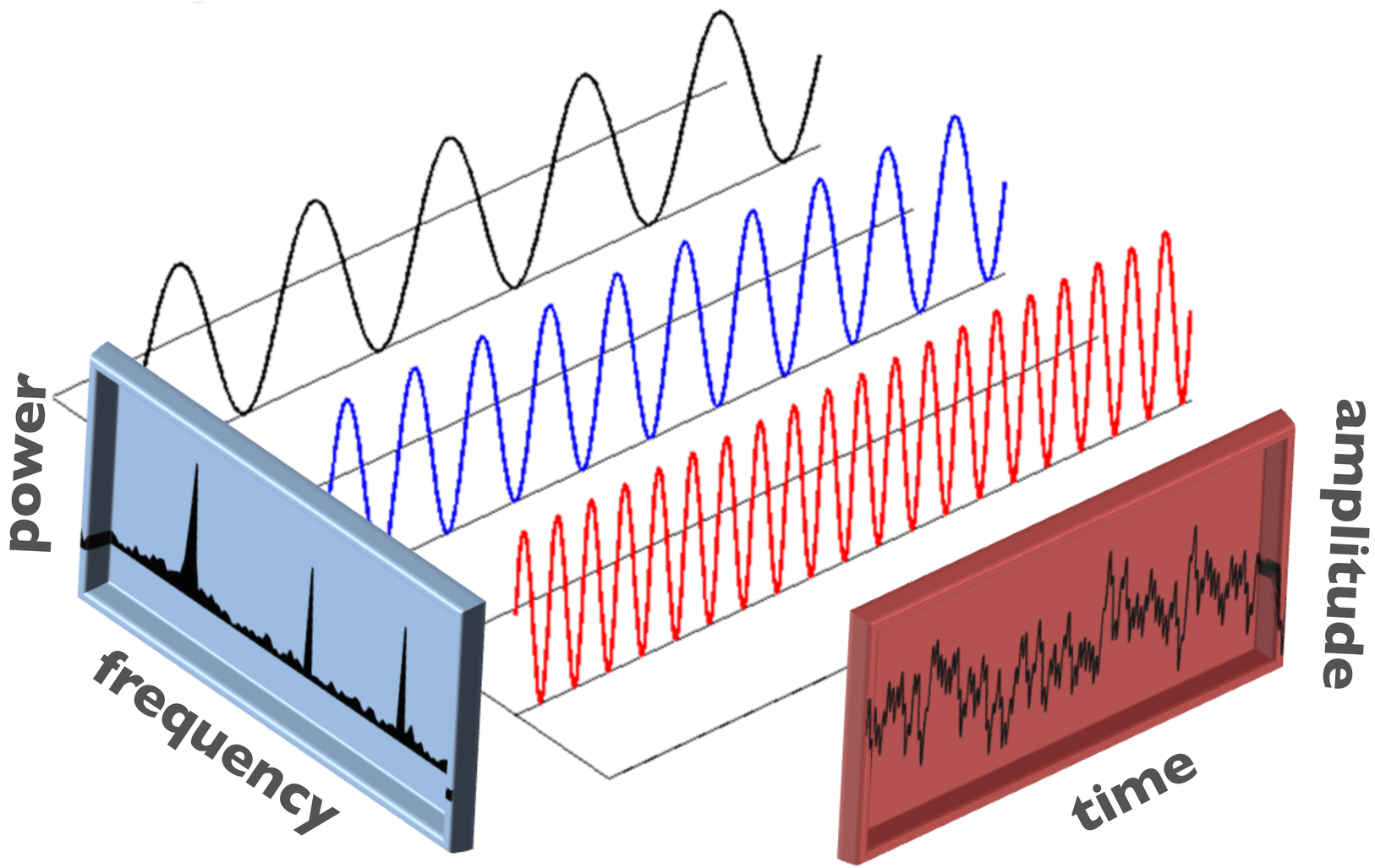
So what’s an oscillation?

Python packages

pip install:

- neurodsp (Cole *et al.*, *J Open Source Softw* 2019)
- fooof (Donoghue, Haller *et al.*, *in revision*)
- bycycle (Cole & Voytek, *J Neurophysiol* 2019)

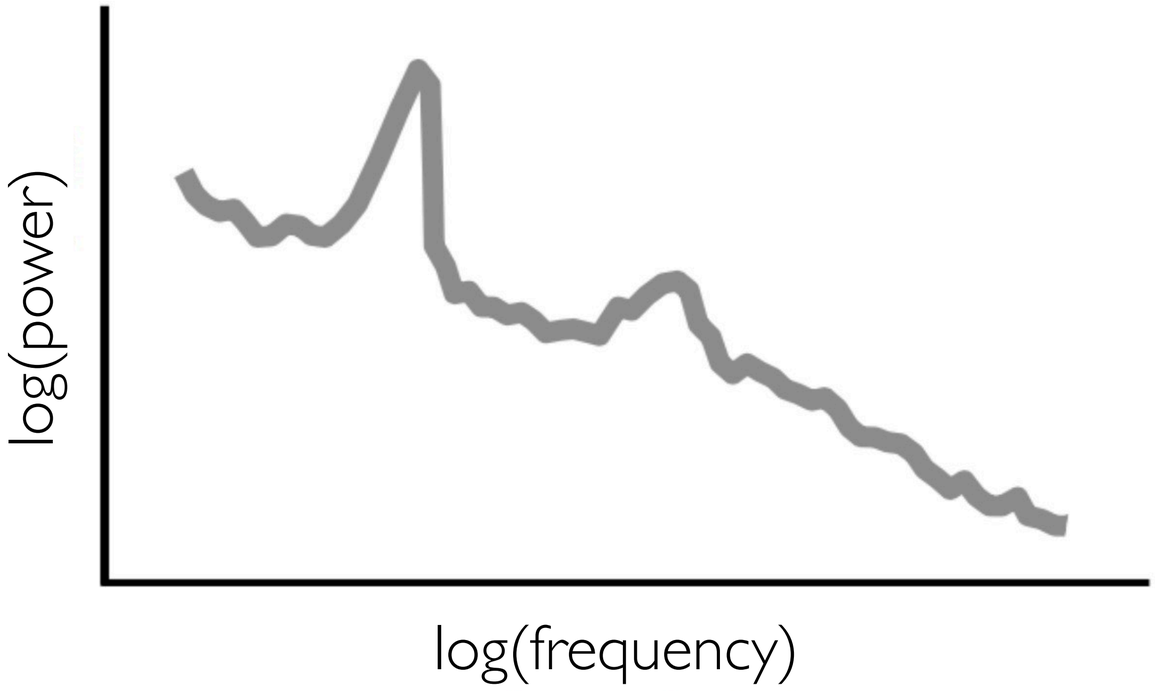
Fourier transform



Oscillations are *bumps*

"In a power spectrum, brain oscillations appear as **bumps** on top of this 1/f slope…" - He B, *Trends Cogn Sci* 2014

"[when] particular oscillation frequencies become dominant… a peak (**bump**) appears in the respective frequency band." - Buzsáki *el al.*, *Neuron* 2013



Oscillations are correlated with *everything*

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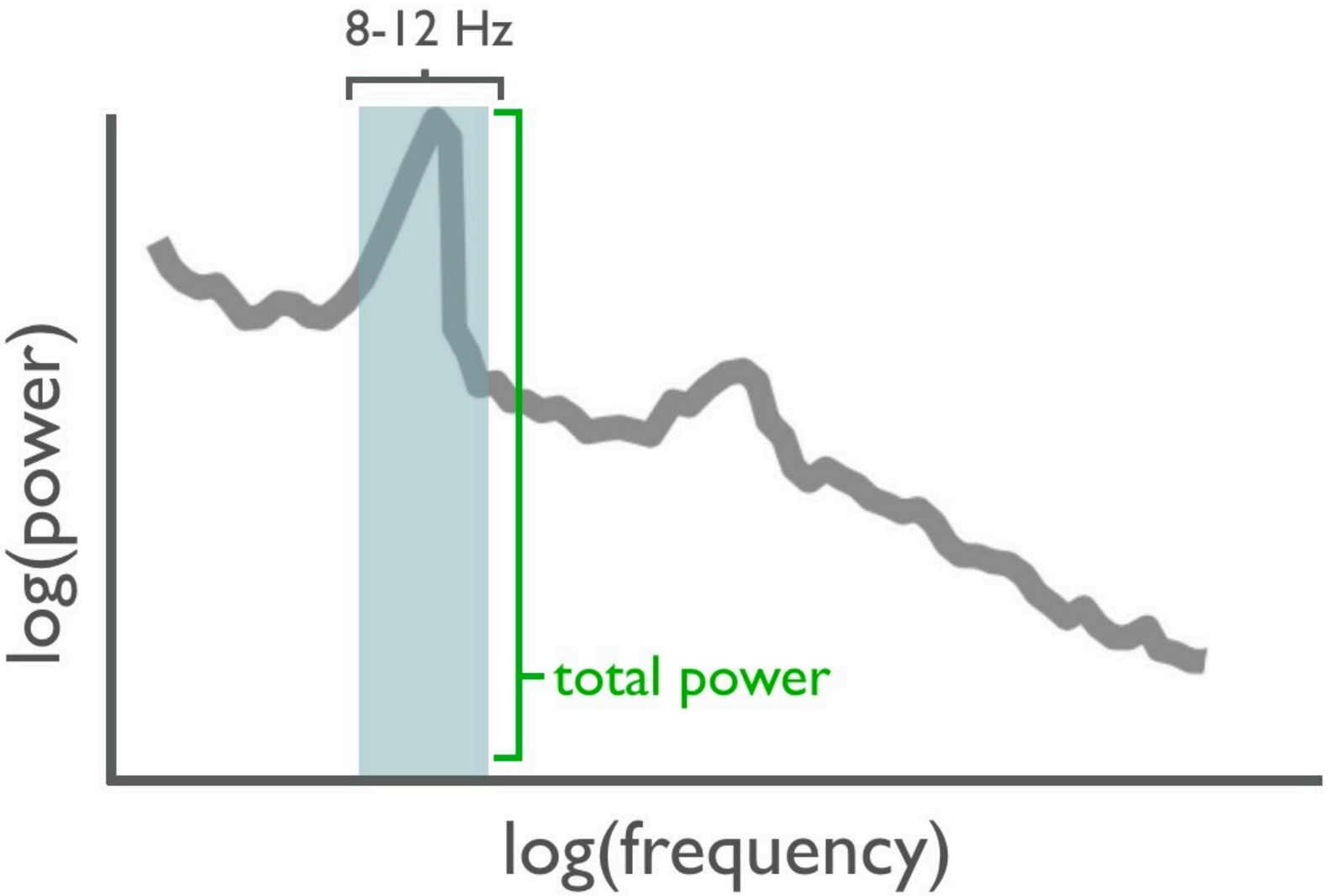
Tens-of-thousands of oscillation papers

Oscillations are correlated with *everything*

Tens-of-thousands of oscillation papers

How do we measure oscillations?

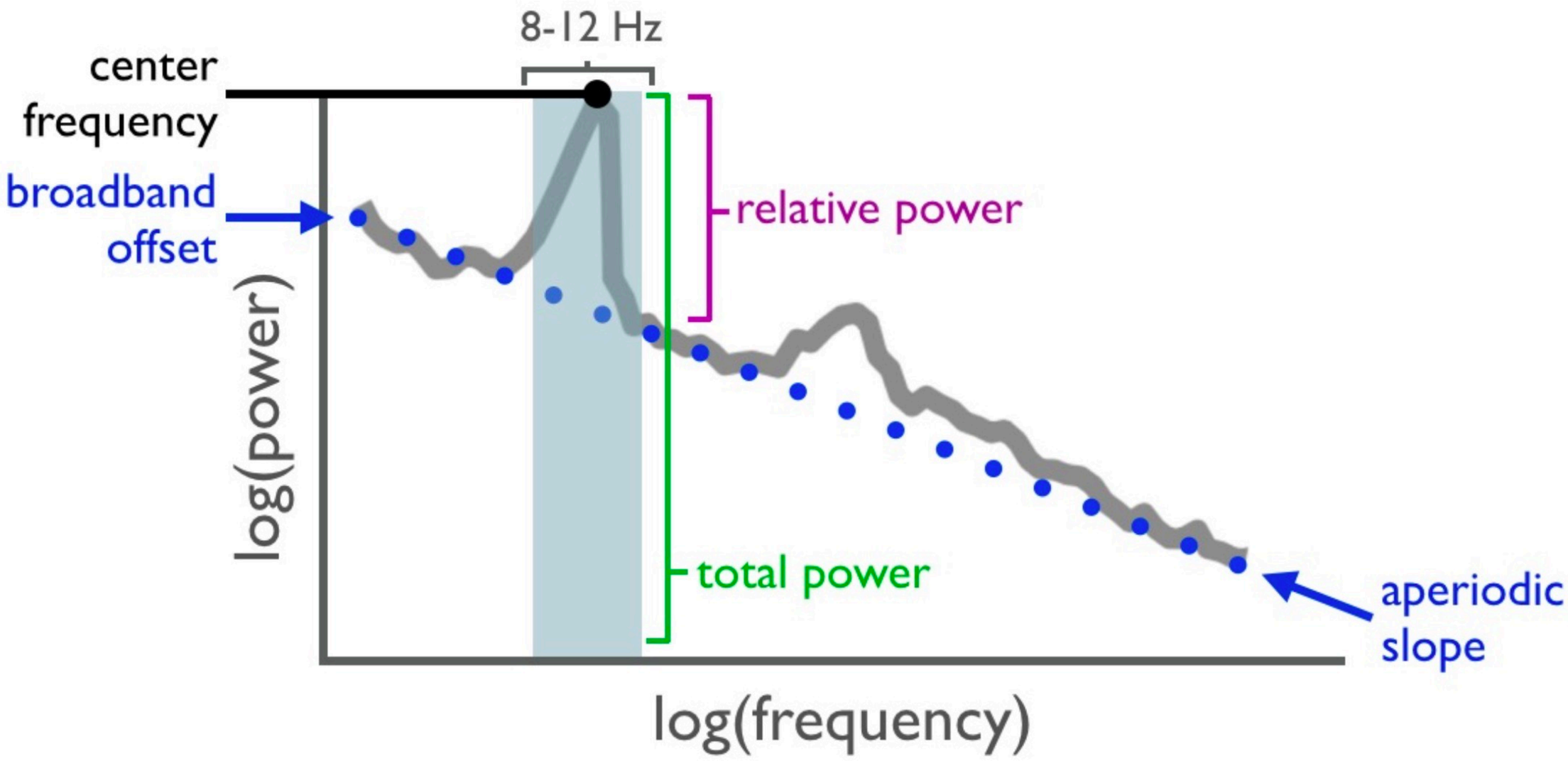
Alpha oscillation



Source: Donoghue, Haller, Peterson, *et al.* (in revision)

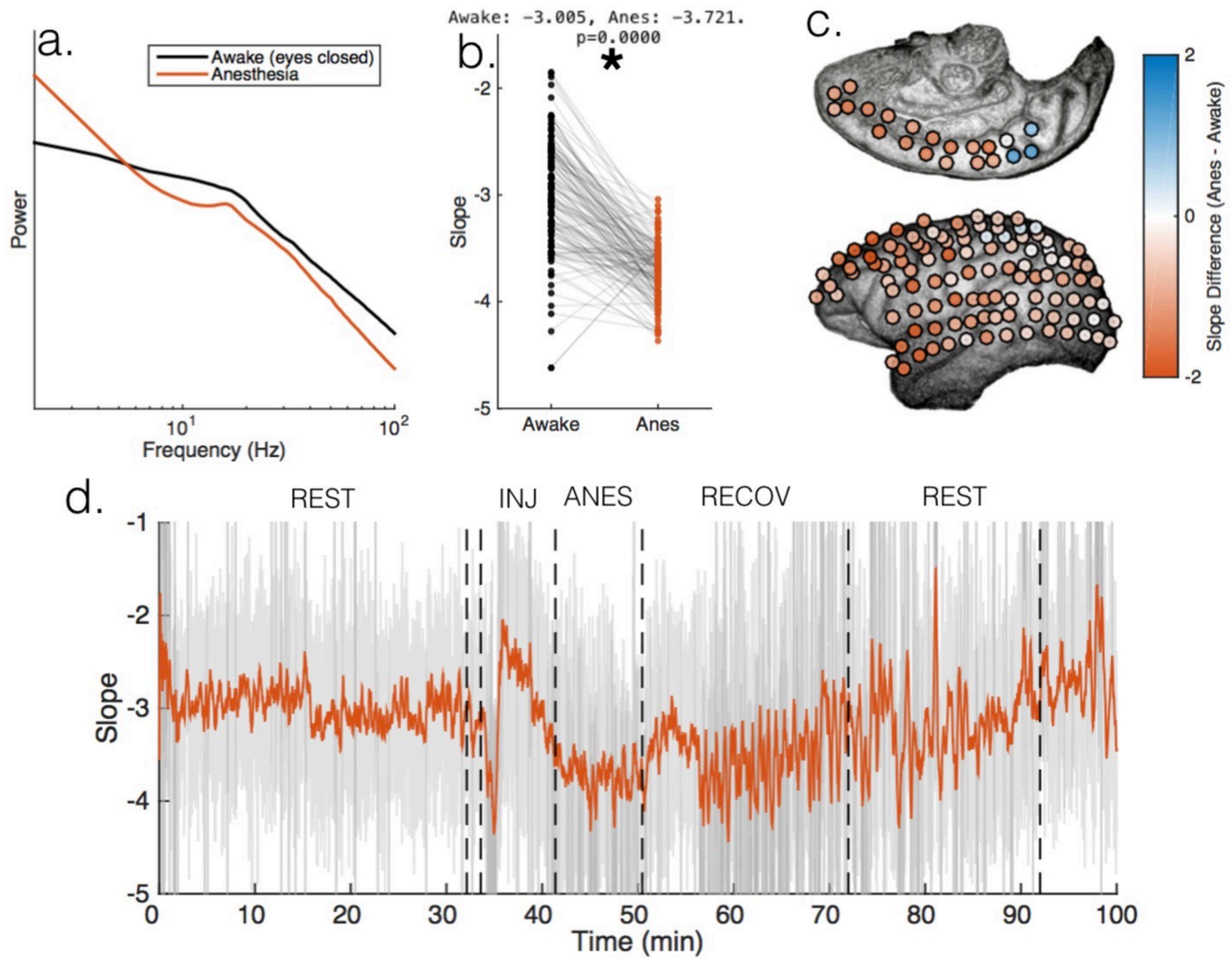
But there’s a problem

Alpha oscillation



Source: Donoghue, Haller, Peterson, *et al.* (in revision)

Aperiodic slope tracks consciousness



Source: Gao *et al.*, *NeuroImage* 2017

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EI imbalance

Implicated in nearly every major neurological and psychiatric disorder

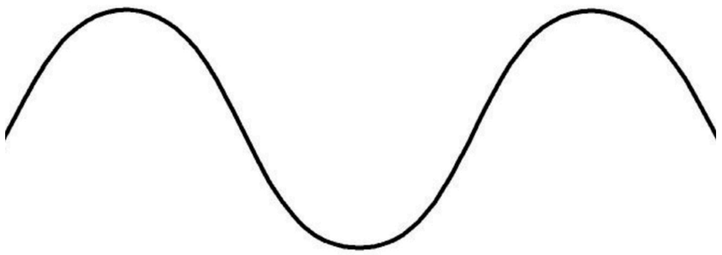
Source: Voytek & Knight, *Biol Psychiatry* 2015

Aperiodic slope effects:

- DBD in depression (Veerakumar *et al.*, *J Neurophysiol* 2019)
- Auditory attention (Waschke, Wöstmann, Obleser, *Sci Reports* 2017)
- Sleep (Miskovic *et al.*, *Human Brain Mapping* 2019)
- Schizophrenia (Peterson *et al.*, *bioRxiv* 2018)

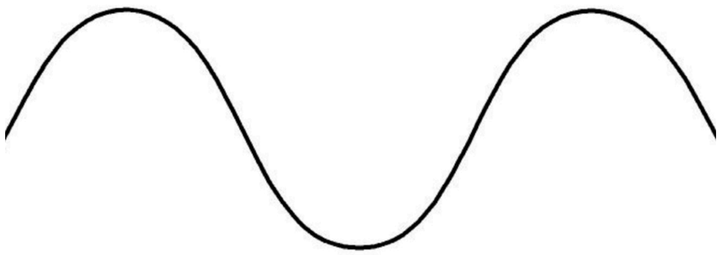
But wait, there’s more!

Meet *sin*

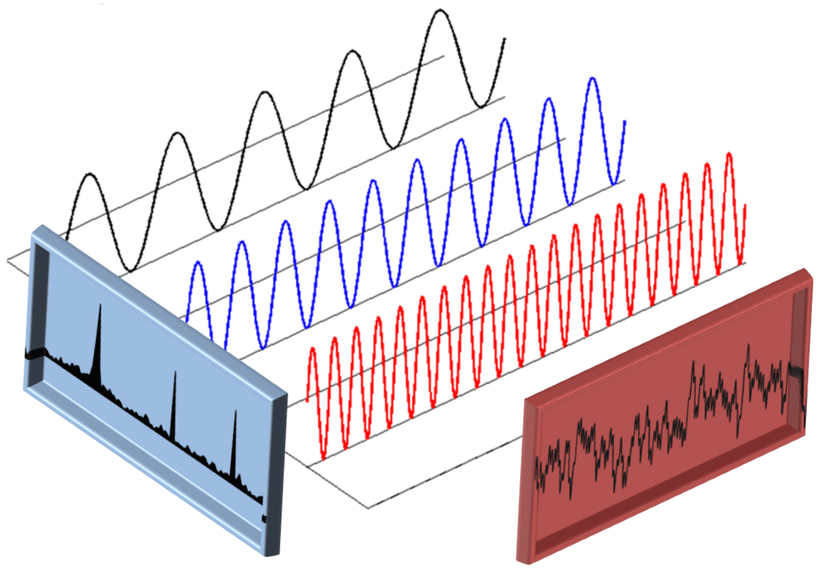


sinusoid

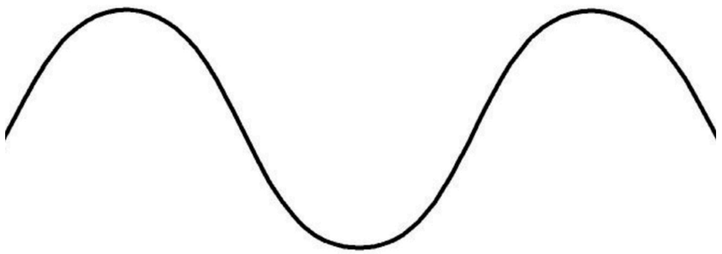
Meet *sin*



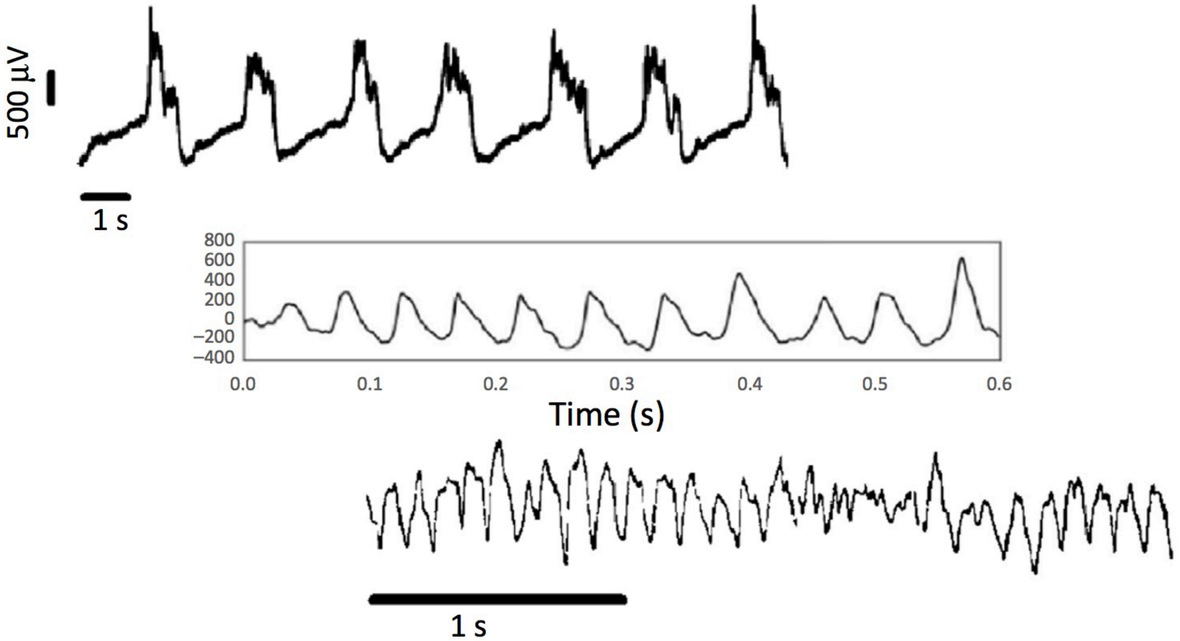
sinusoid

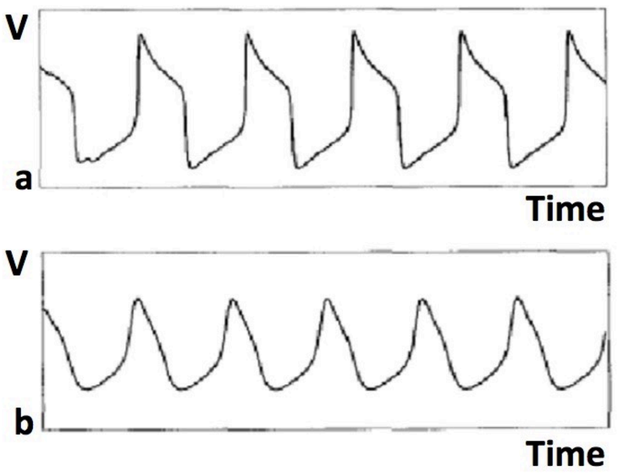


Neural oscillations are *not* sinusoidal



sinusoid





not sinusoids

Source: Cole & Voytek *Trends Cogn Sci* 2017

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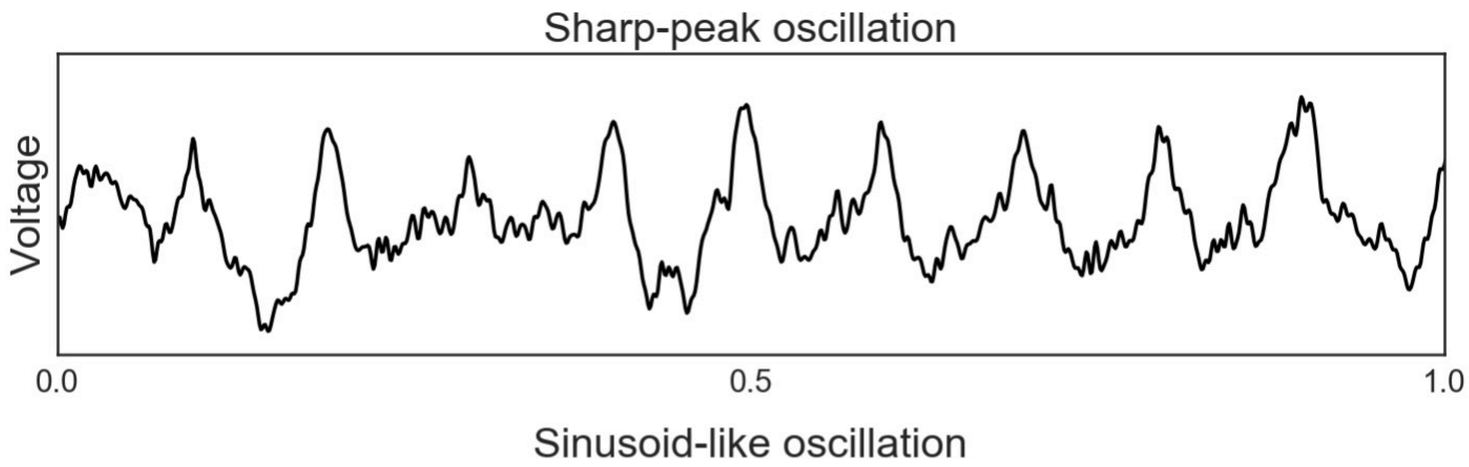
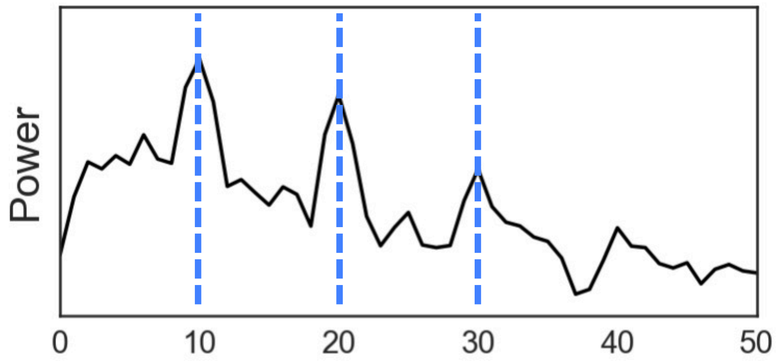
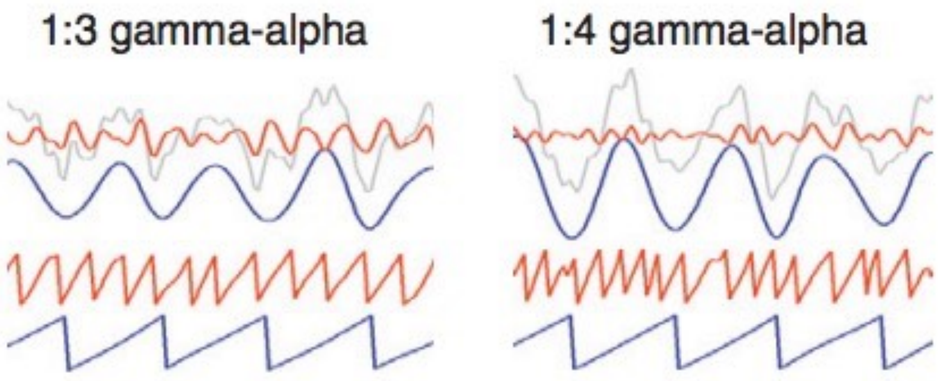
Nonsinusoidality is deceiving







n:m synchrony
(*cf* Palva & Palva, *Trends Cogn Sci* 2012)

Source: Cole & Voytek *J Neurophysiol* 2019

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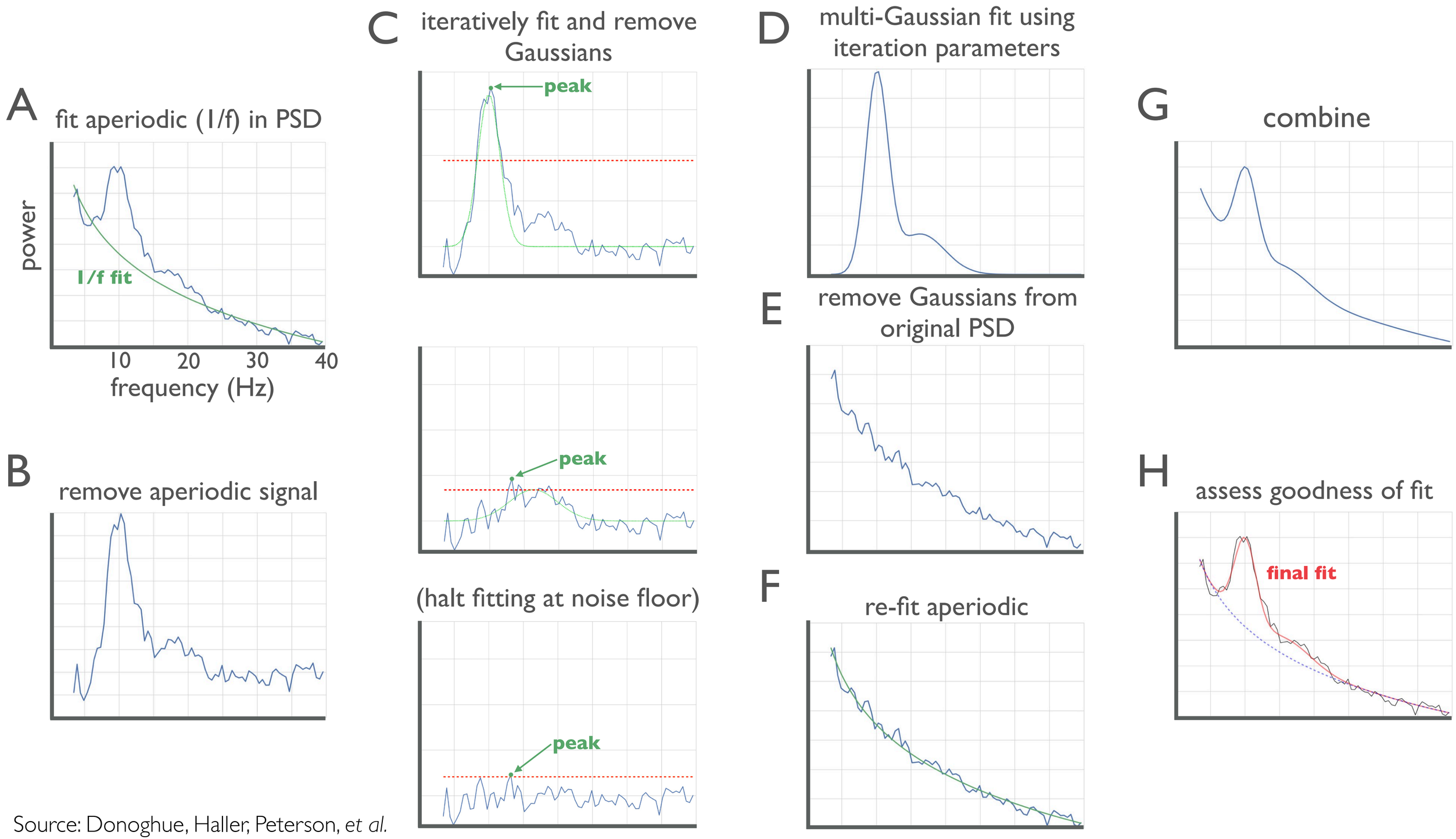
We can’t adjudicate between these without careful parameterization

This is actually a problem...

...and problems are fun!

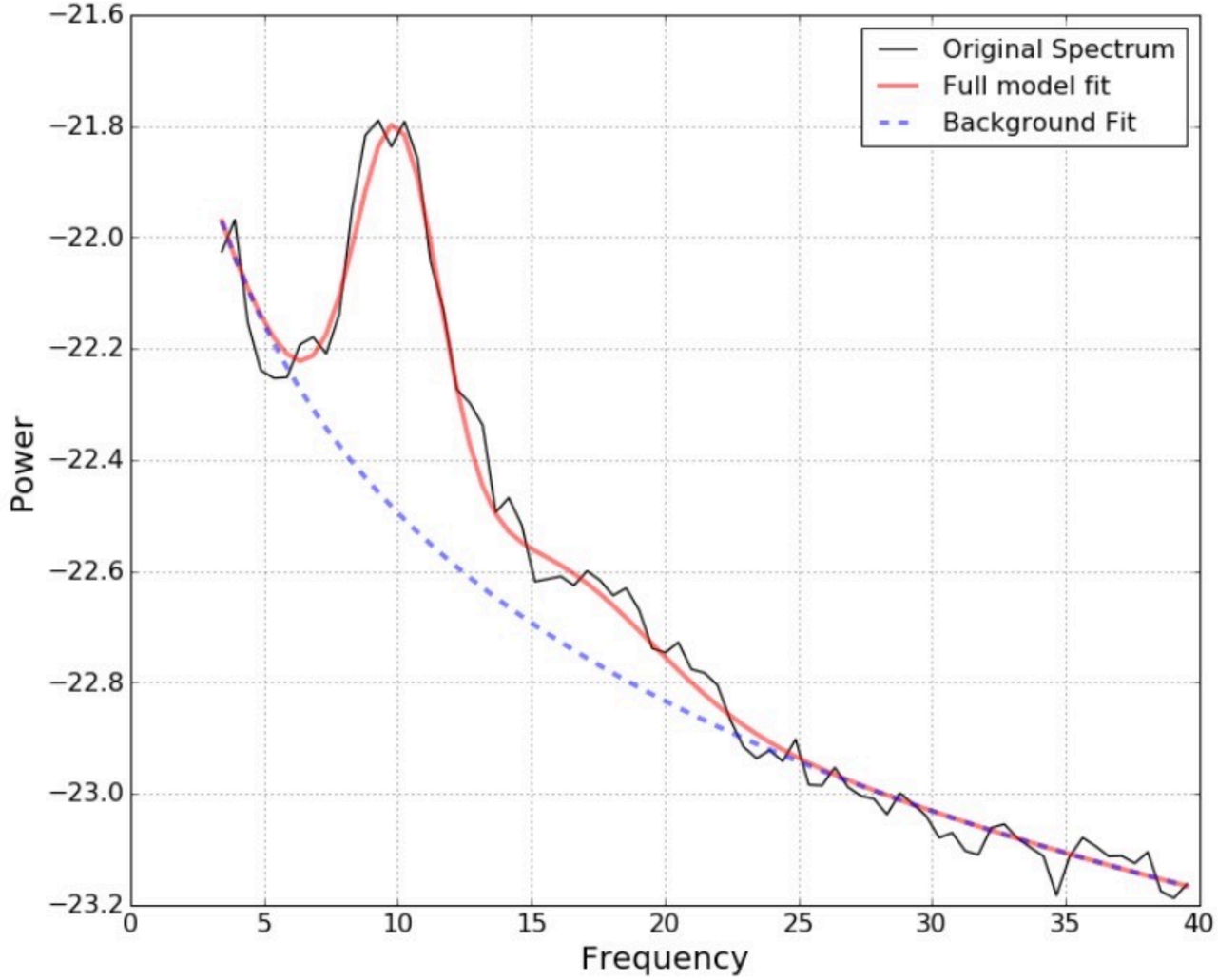
What’s a solution?

Parameterize our spectra!



Source: Donoghue, Haller, Peterson, *et al.*

Parameterizing neural power spectra




```
FOOOF - POWER SPECTRUM MODEL

The model was run on the frequency range 3 - 40 Hz
Frequency Resolution is 0.49 Hz

Background Parameters (offset, slope):
-21.3713, 1.1239

2 peaks were found:
CF:  10.00, Amp:  0.685, BW:  3.18
CF:  16.32, Amp:  0.138, BW:  7.03

Goodness of fit metrics:
R^2 of model fit is 0.9909
Root mean squared error is 0.0332
```

Source: Haller, Donoghue, Haller, Peterson, *et al.* (in revision)

Code: https://github.com/fooof-tools/fooof

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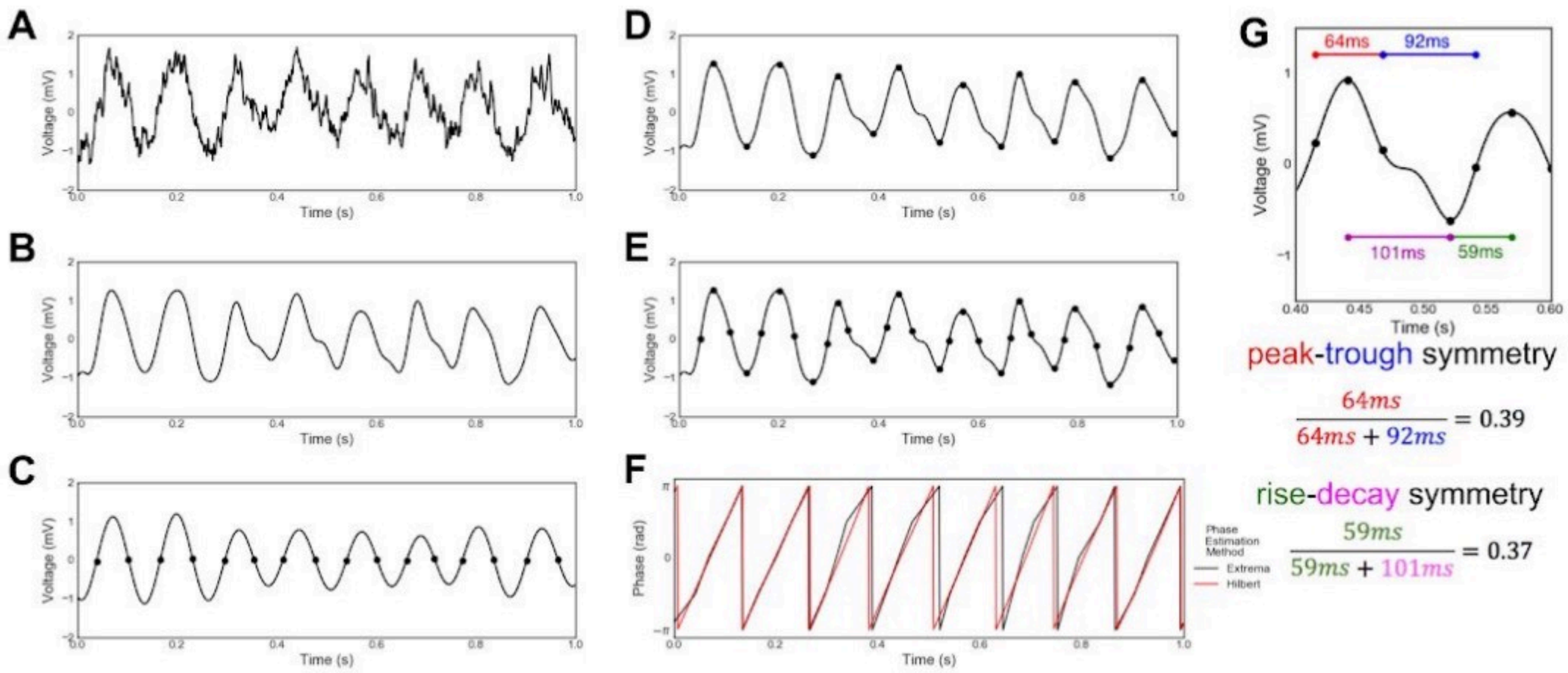
Cycle-by-cycle waveform analyses



Source: Cole & Voytek *J Neurophysiol* 2019

Code: https://github.com/bycycle-tools/bycycle

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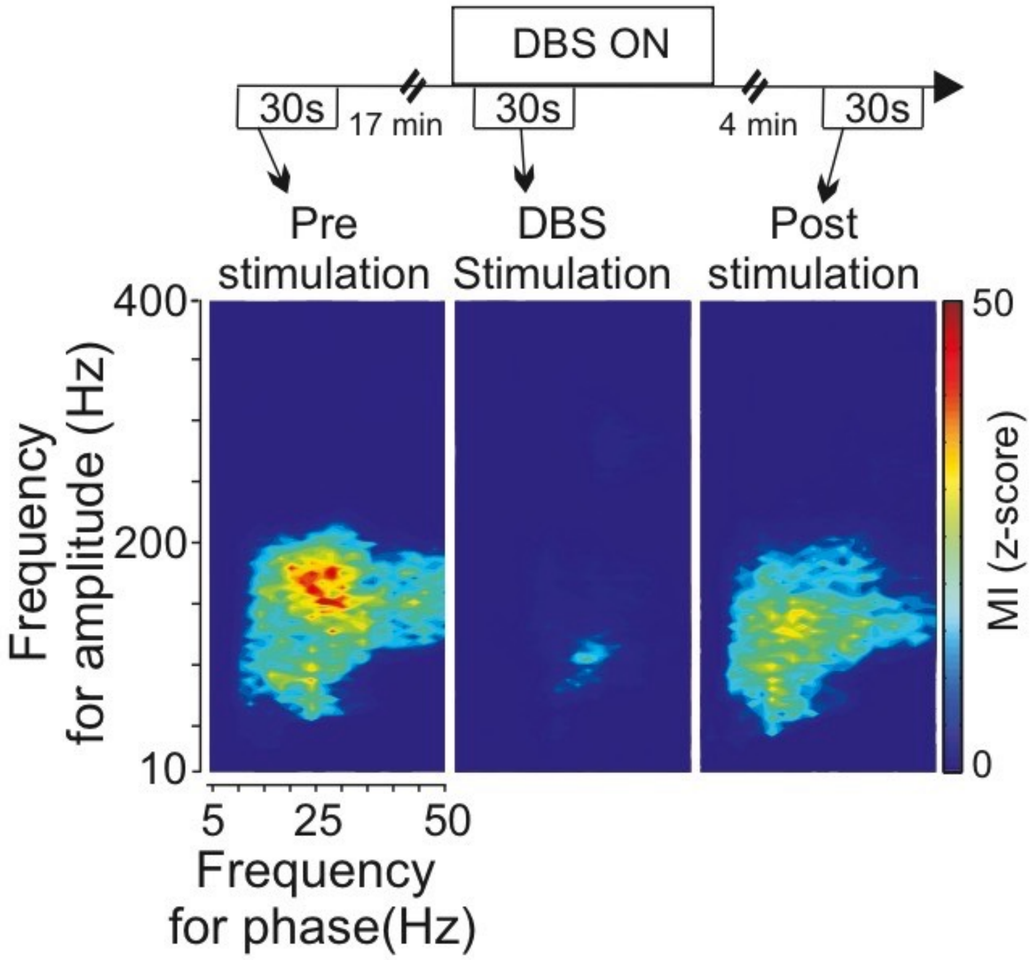
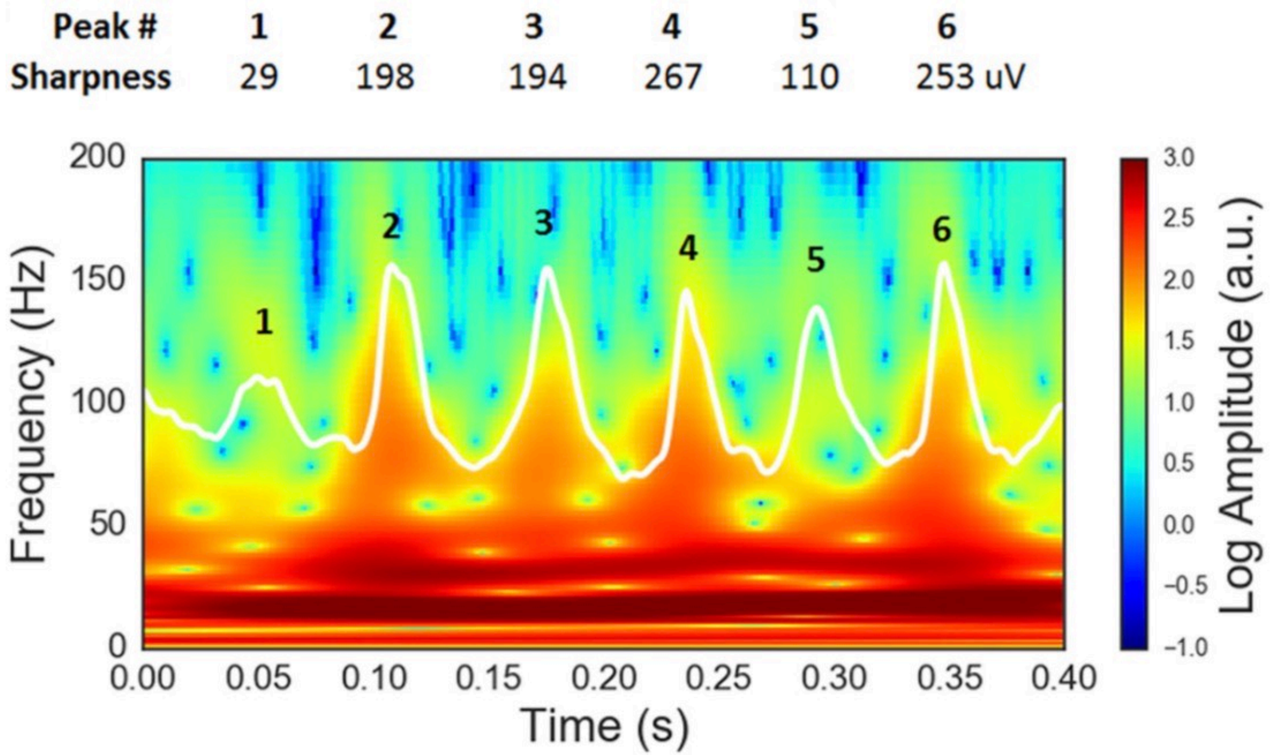
This matters

Deep brain stimulation

Deep brain stimulation

Oscillations in Parkinson's disease





Source: Cole *et al.*, *J Neurosci* 2017

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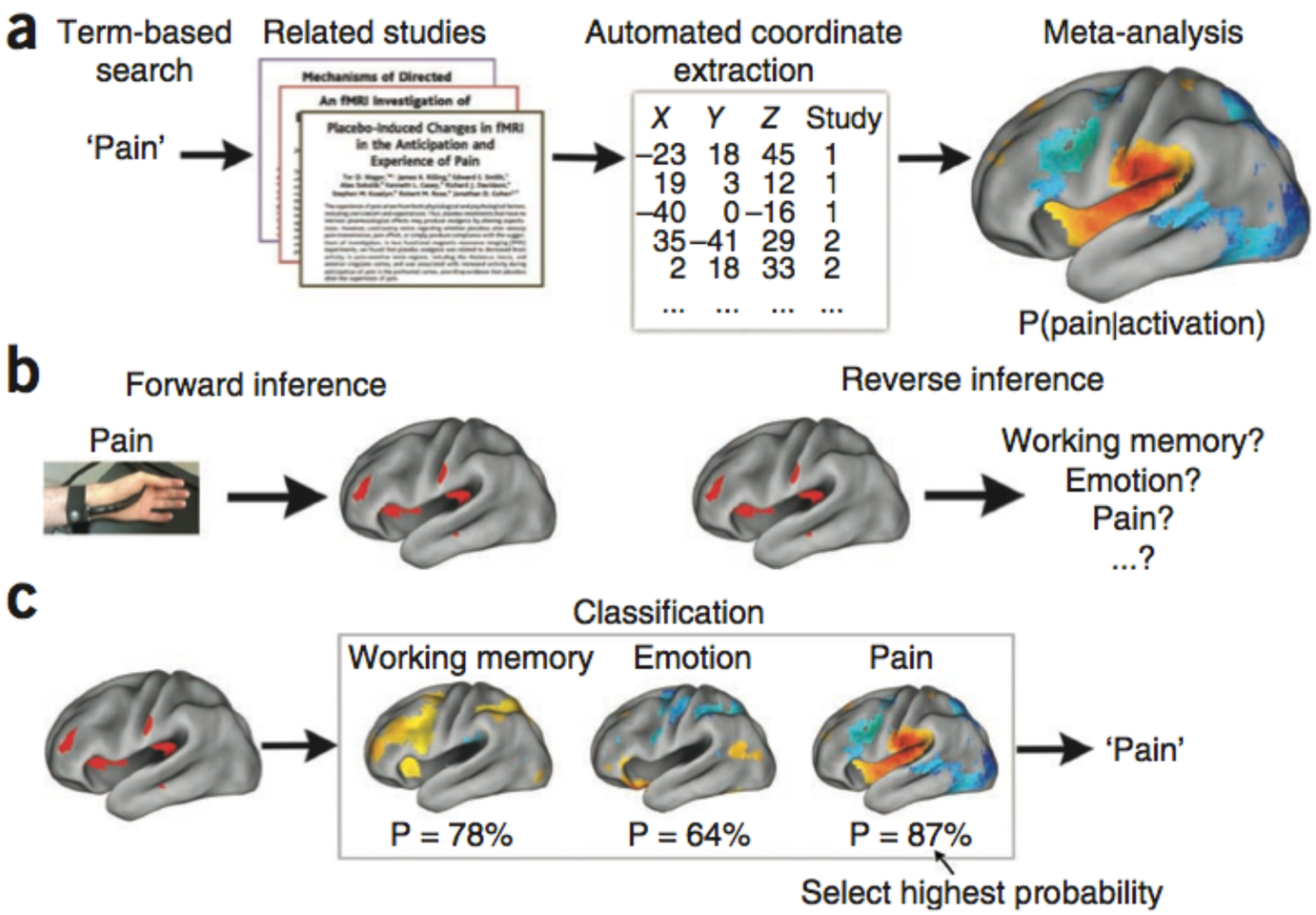
With parameterization, we can then run large scale analyses that were not possible without it.

Such as?

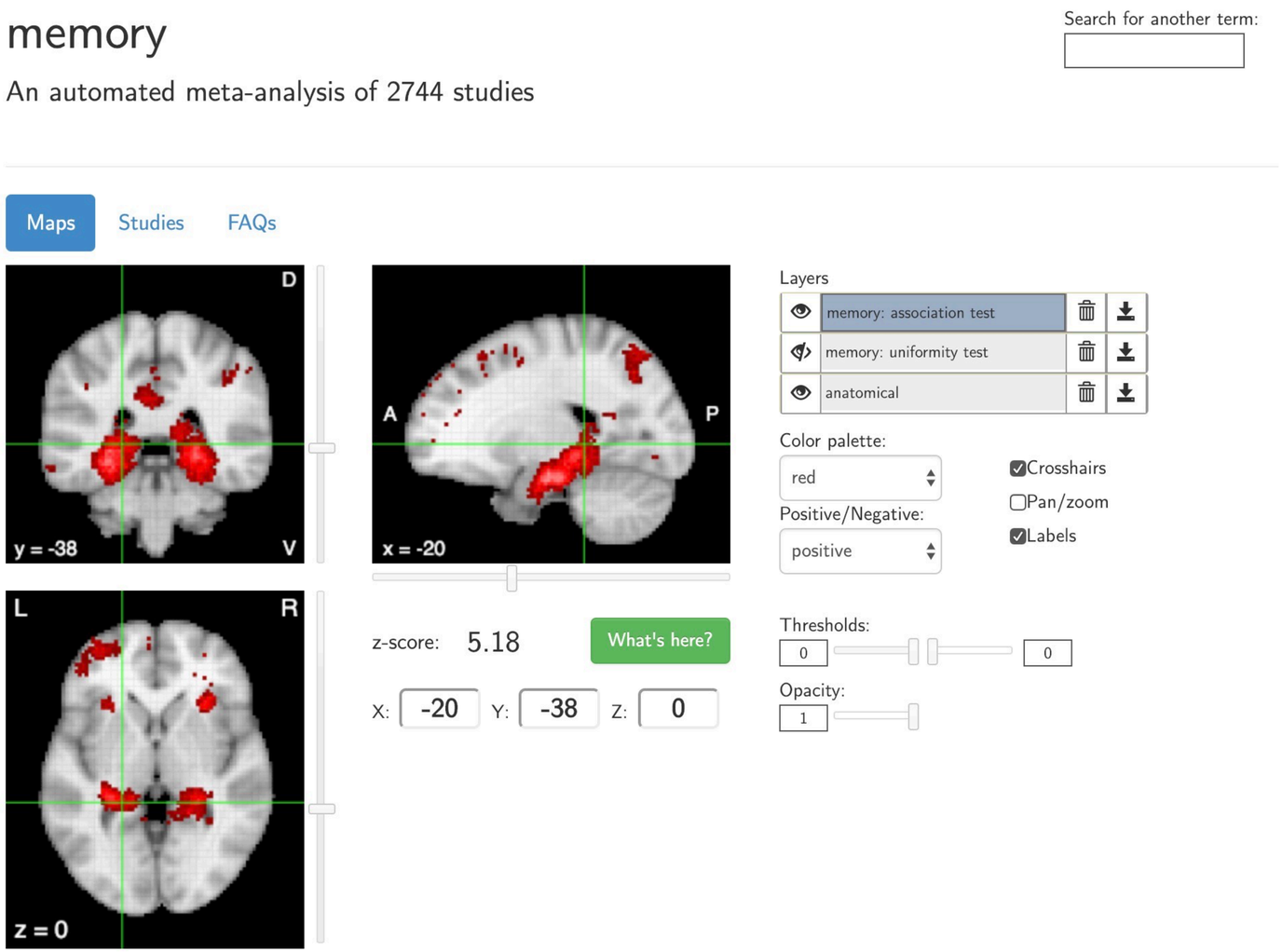
Large-scale data mining

NeuroSynth



Source: Yarkoni *et al.*, Nature Methods 2011

NeuroSynth



Source: Yarkoni *et al.*, Nature Methods 2011

Example: http://neurosynth.org/analyses/terms/memory/

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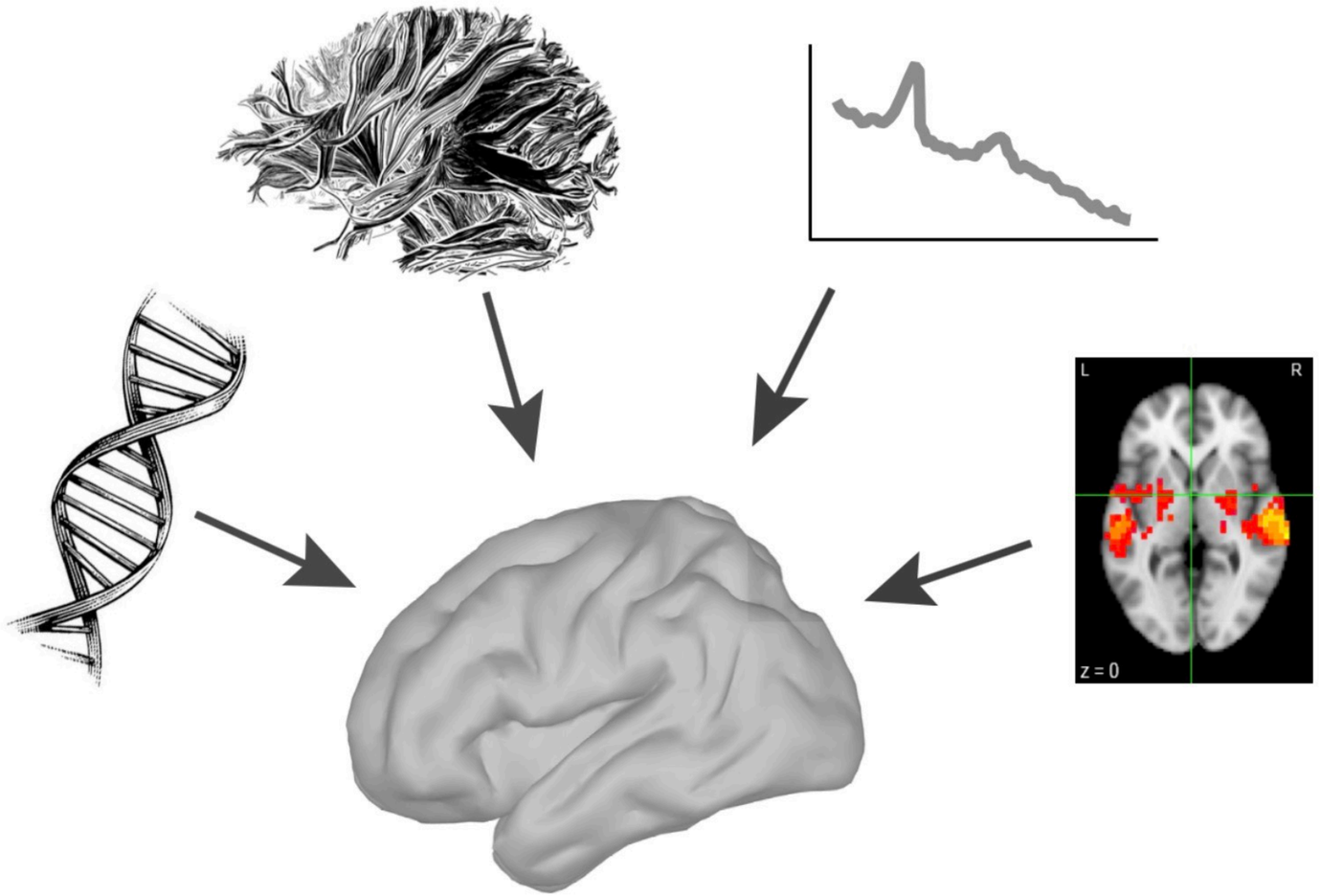
Multimodal comparisons



- cell types?
- gene expression (ABA)
- WM connectivity (HCP)
- functional terms (NeuroSynth)
- waveforms (shape)
- oscillations (FOOOF)

We can integrate diverse datasets:

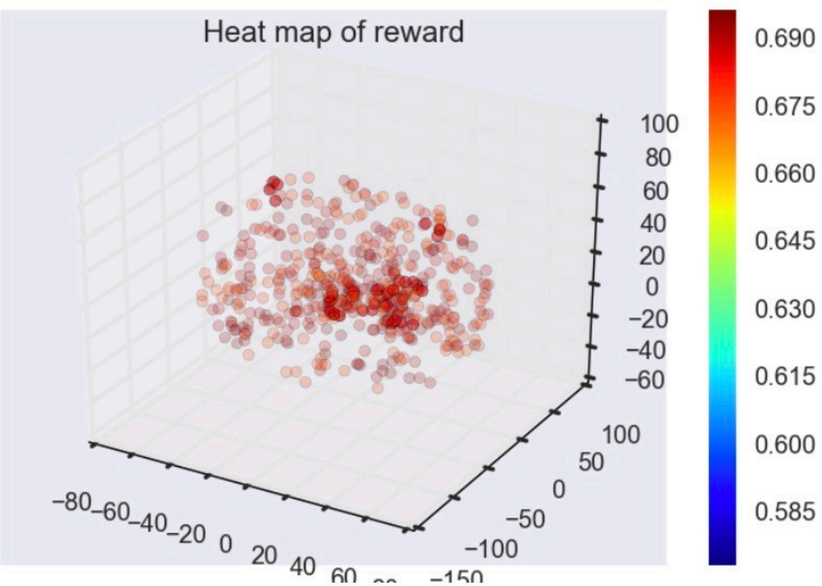
cell type, gene expression, WM, function, waveform, oscillations, aperiodic signal

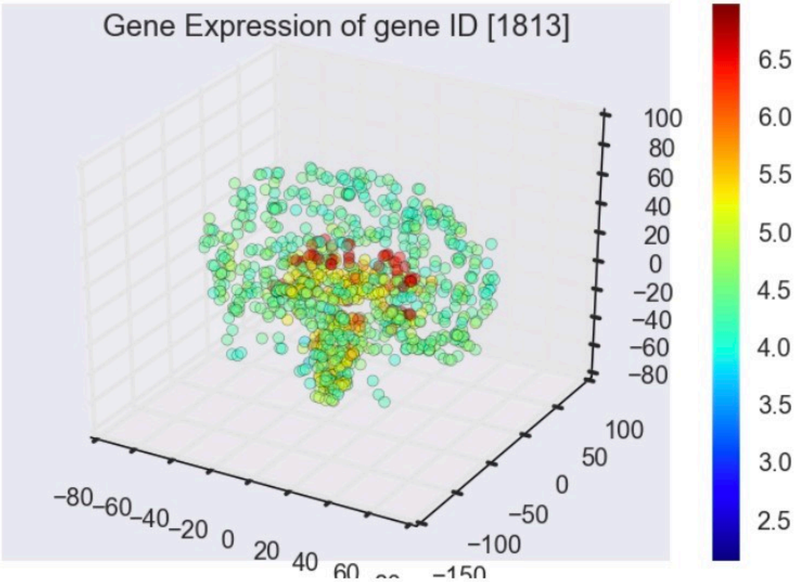
Putting them into the same space —“brain space”—allows us to ask new questions:

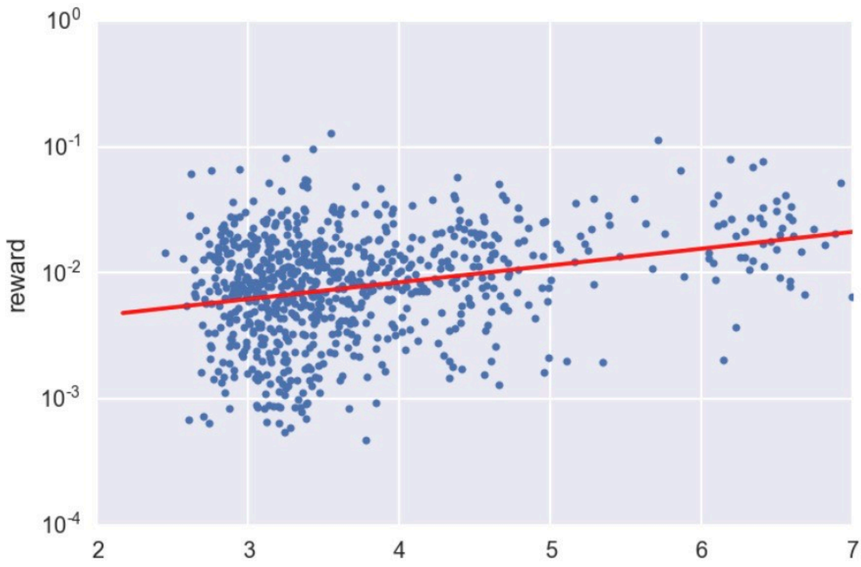
Are there genes statistically over/ under-expressed in “reward” regions of the brain?

Function~gene associations

dopamine receptor D2







Source: Donoghue *et al.* (in preparation)

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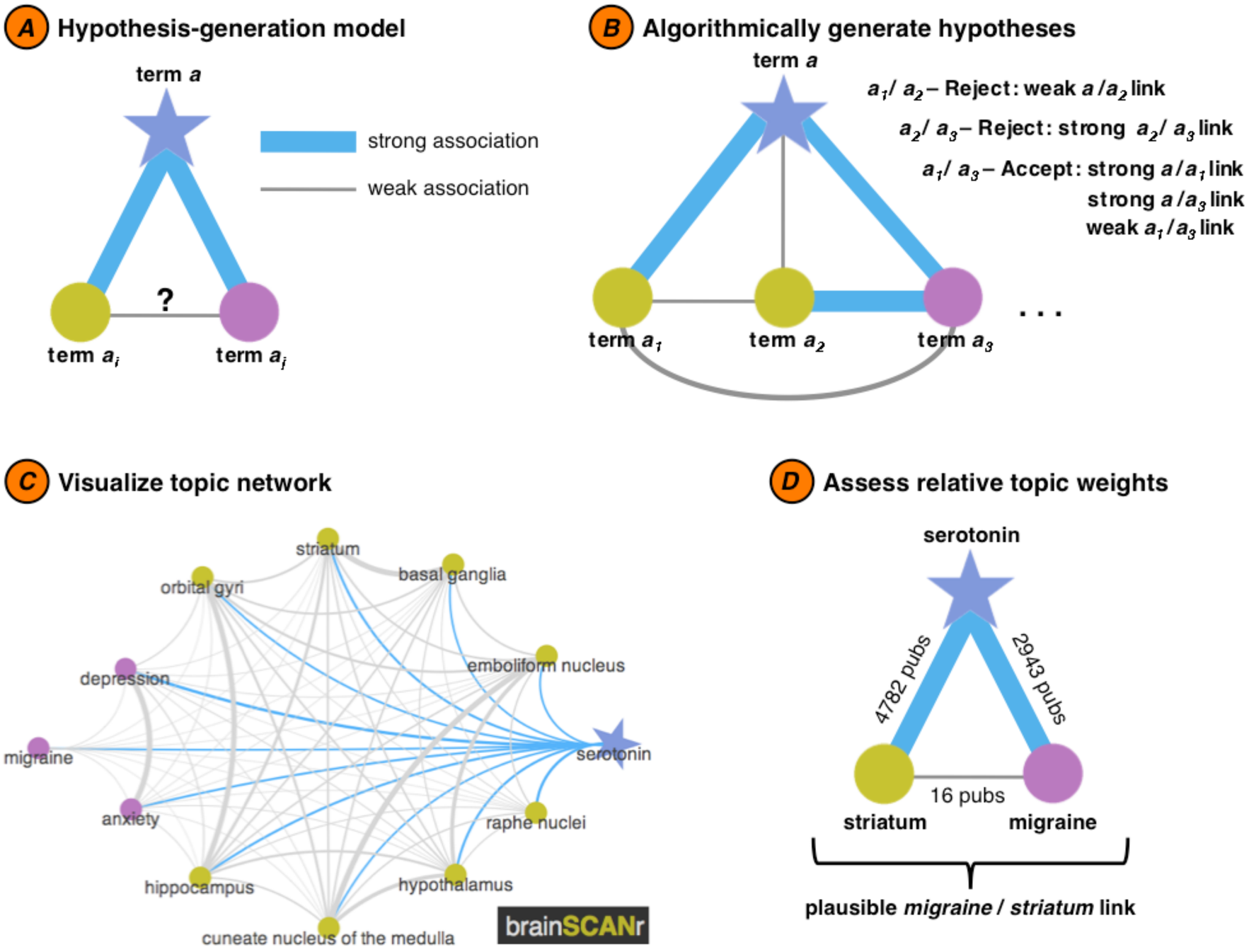
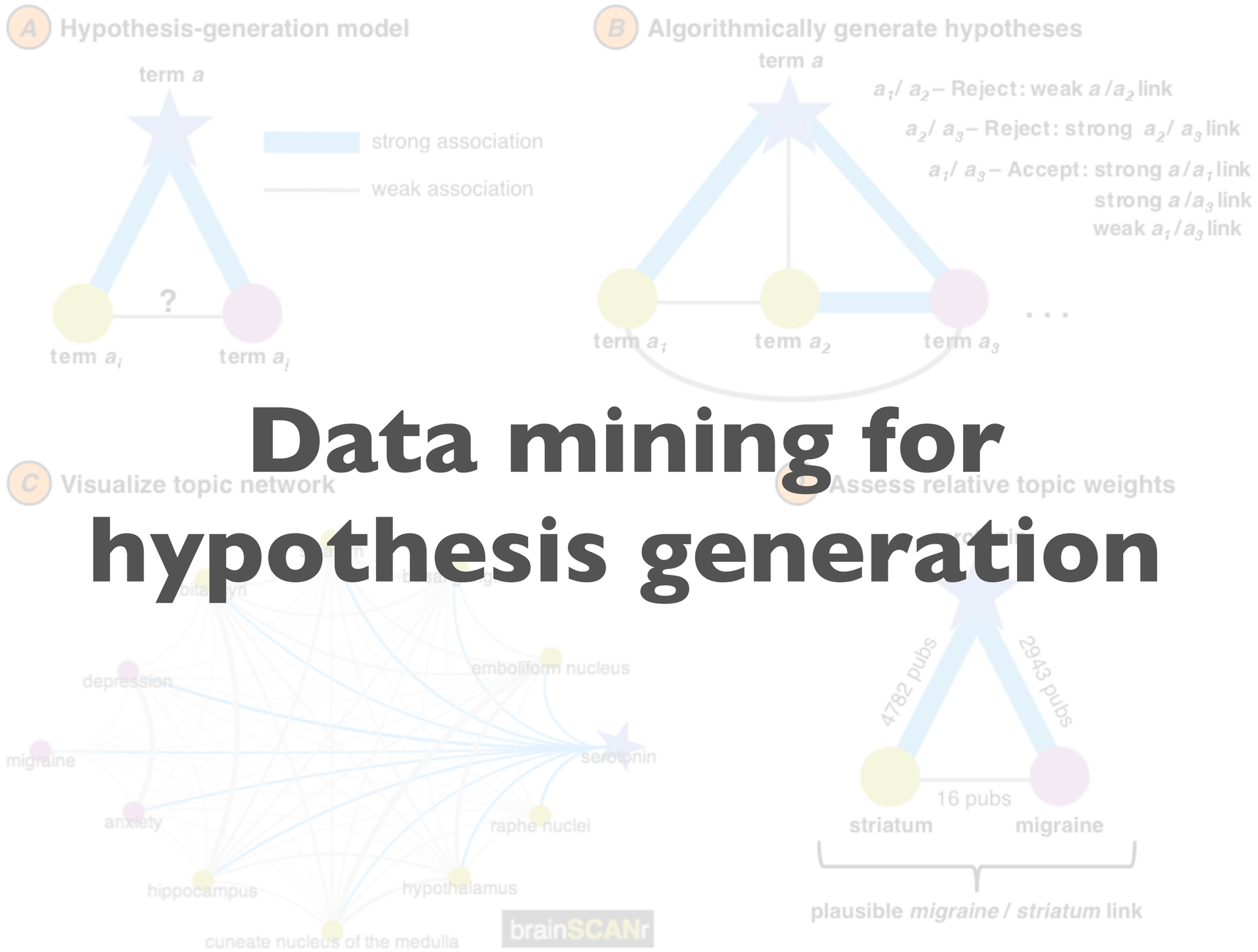
Are distant brain regions that oscillate at similar frequencies more likely to be connected by WM tracts?

Are there certain cell densities across lamina that give rise to particular waveform shapes?

But we can go further.

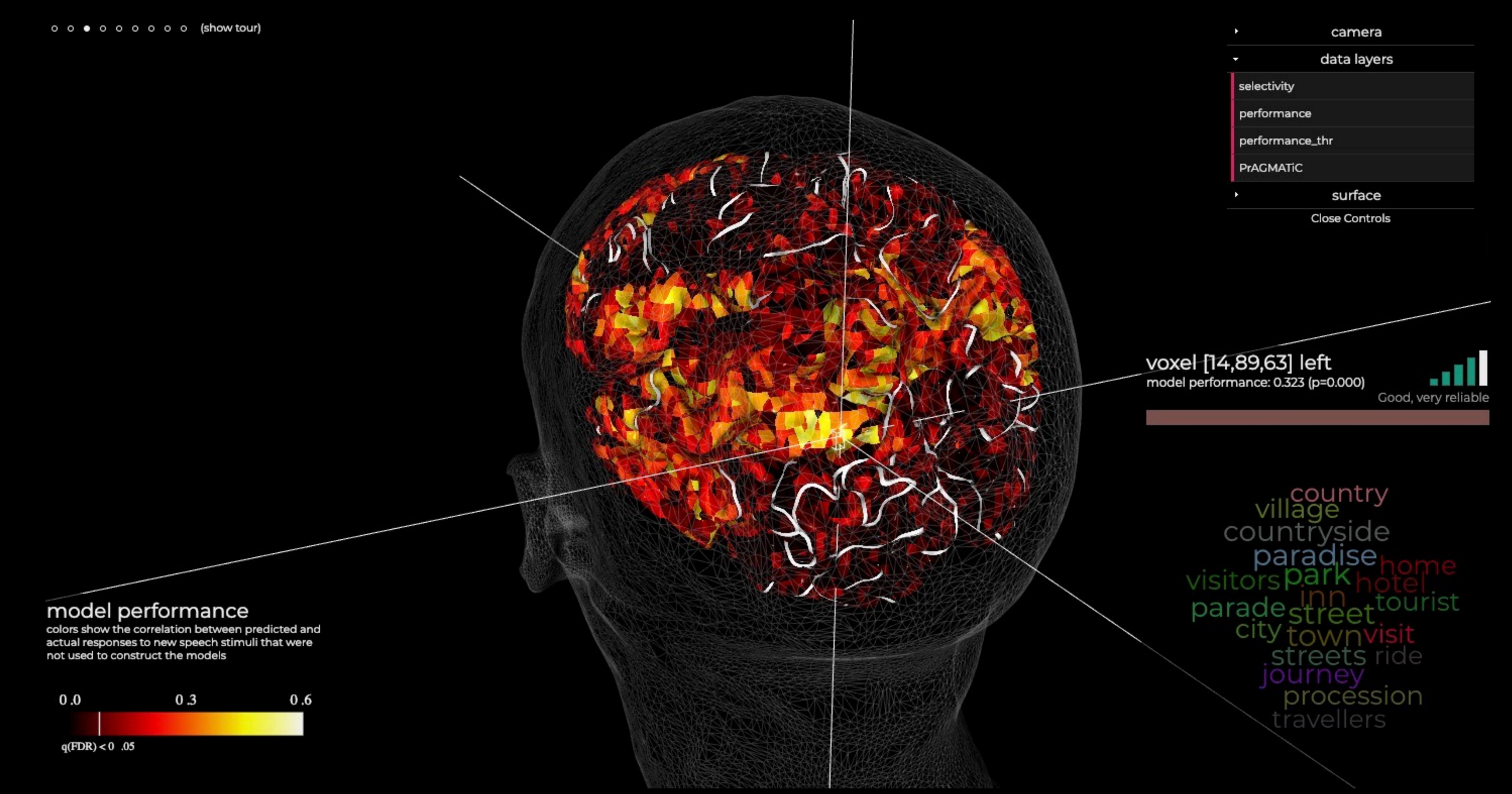


Source: Voytek & Voytek, *J Neurosci Methods* 2012



Data mining for hypothesis generation

Source: Voytek & Voytek, *J Neurosci Methods* 2012



Source: Huth *et al.*, *Nature* 2016

We can look for connections between all of these—cell types, gene expression, function, oscillations, connectivity—to see how they all interrelate.

And we can find *gaps*—missing connections where topics *should be* related but aren't.

We can mine through these connections to find potential *missing links*.

That is, we can use the data themselves to generate new hypotheses *for us*.