A Bayesian approach to phases for frequency-tagged EEG for the cognitive neuroscience of language

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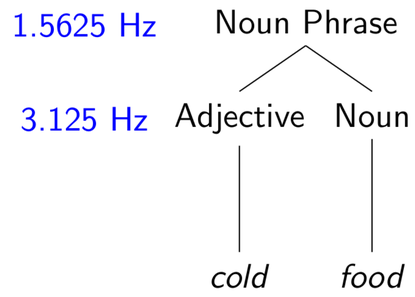
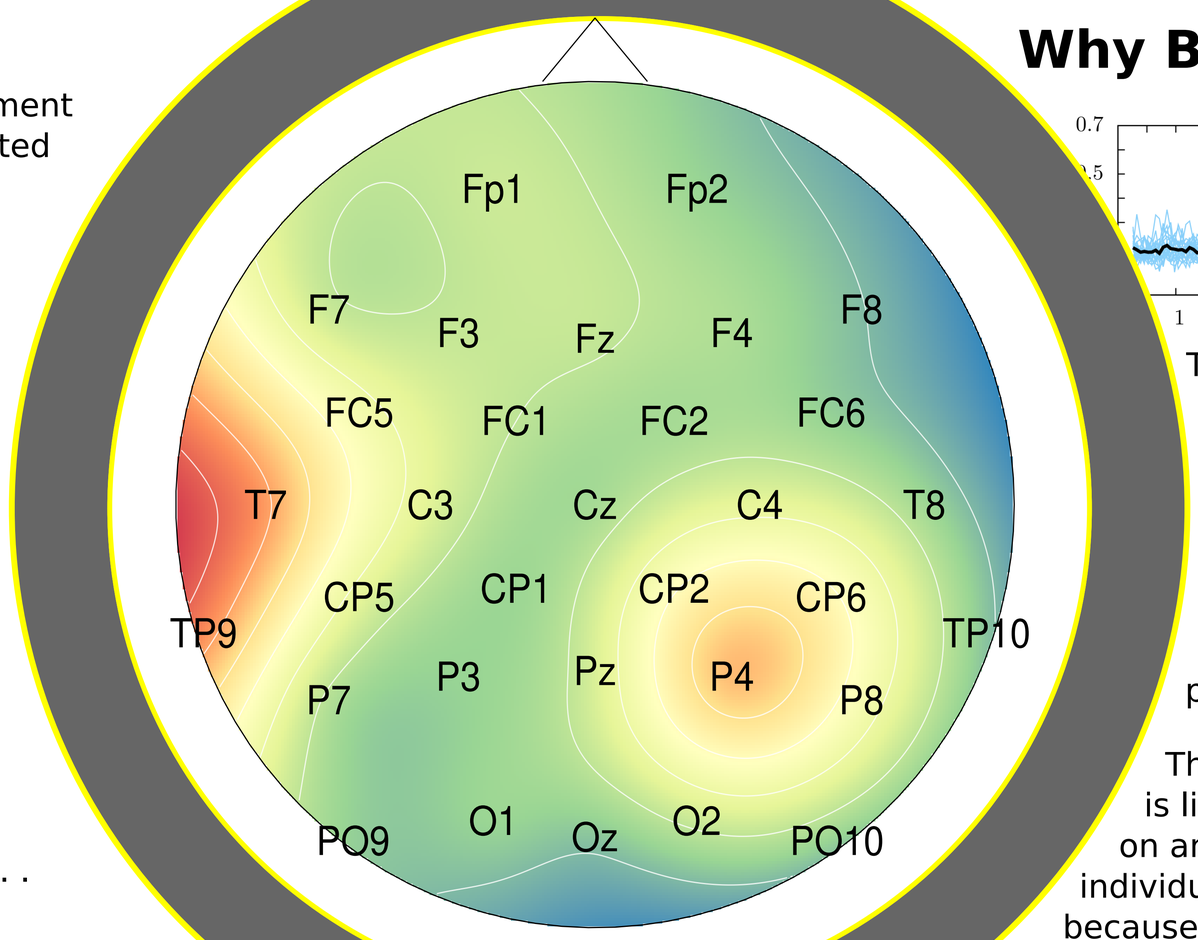
Phase Data

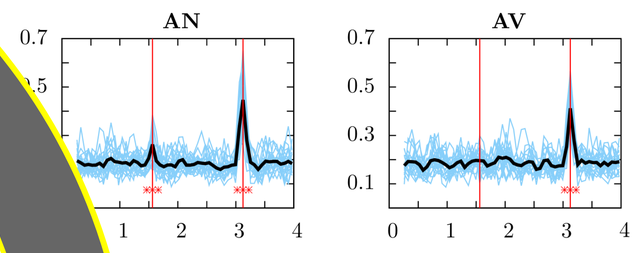
In a frequency-tagged experiment a linguistic stimulus is presented at a fixed frequency. You will note we are making a complicated claim here: frequency tagging is more robust than ERPs, but still not robust enough without our fancy Bayesian approach!



AN - adjective noun
cold food loud room tall girl . . .
AV - adjective verb
ill tell thin chew rough give . . .
RR - random
from solve good him ask an . . .



Why Bayes?



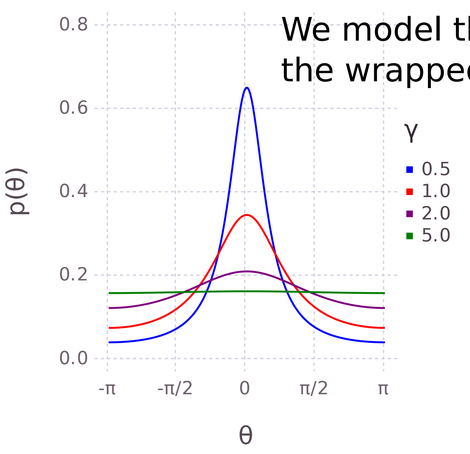
The effect in frequency-tagged experiments is usually measured using inter-trial phase coherence (ITPC):

$$r = \left| \left\langle e^{i\theta} \right\rangle \right|$$

where the average is over all phase for condition and so on.

The **problem** is that the ITPC is like a variance: it doesn't exist on an item-by-item basis. The individual phases can't be compared because there are uninteresting phases differences between different electrodes and participants. **This makes the statistics inefficient and complex**.

Our Model

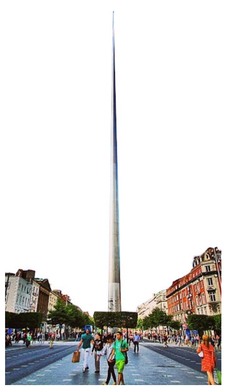


We model the **phase angles** as coming from the wrapped Cauchy distribution, this has a mean and a gamma parameter which is related to variance.

For **priors** we use a "Bundt distribution" this is axially symmetric to allow any mean phase. The radial profile encodes our expectations about the gamma parameter.

The radial profile of the Bundt distribution, effectively the prior for gamma, is given a **slab and spike** distribution.

v ~ x spike + (1-x) slab

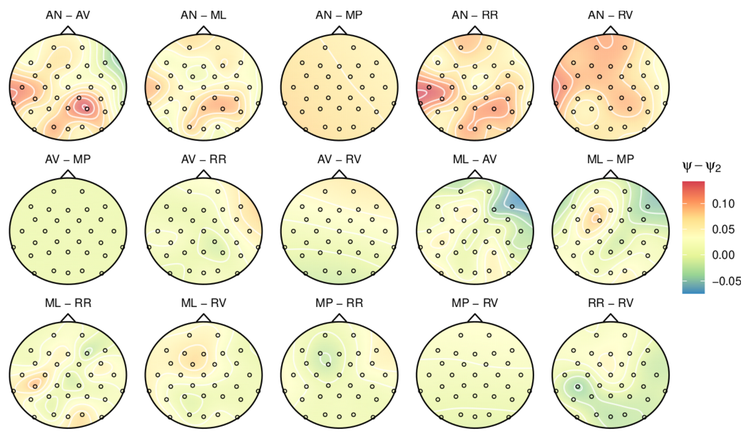


The spike corresponds to values of gamma where the wrapped Cauchy distribution has high variance, that means there is little phase coherence. This allows us to include in the model **our knowledge** that many electrodes and some participant (*) don't respond to the stimulus.
(*) as anyone who has done EEG experiments will know some participants fall asleep.

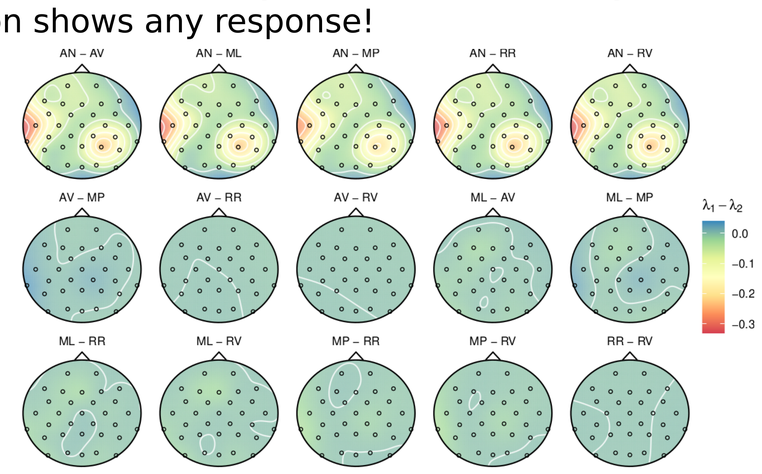
Results

Our approach was tested on an existing EEG data set which compared frequency-tagged responses to six different grammatical conditions including the AN, AV and RR described above, (Burroughs et al. 2021)

ITPC results - very noisy, hypothesis testing difficult, prone to frustratingly non-significant but visually beguiling results.



Bayesian results - very clean but shows only the AN condition shows any response!



Summary: Bayesian modelling gives results that are clean, it is very data efficient when effects are real and less likely to fool you with noise that looks like an effect but isn't! It allows you to arrange the model around the experiment and describes the data in terms of a clear model and posterior probabilities instead of the often confusing picture presented by hypothesis testing and frequentist statistics.

Data: Burroughs, Amelia, Nina Kazanina, and Conor Houghton. "Grammatical category and the neural processing of phrases." Scientific reports 11, no. 1 (2021): 1-10.

Poster format: intended as a tribute to the art of Patrick Scott.

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