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Beta Wave Phase Coupling in V4 of a Macaque

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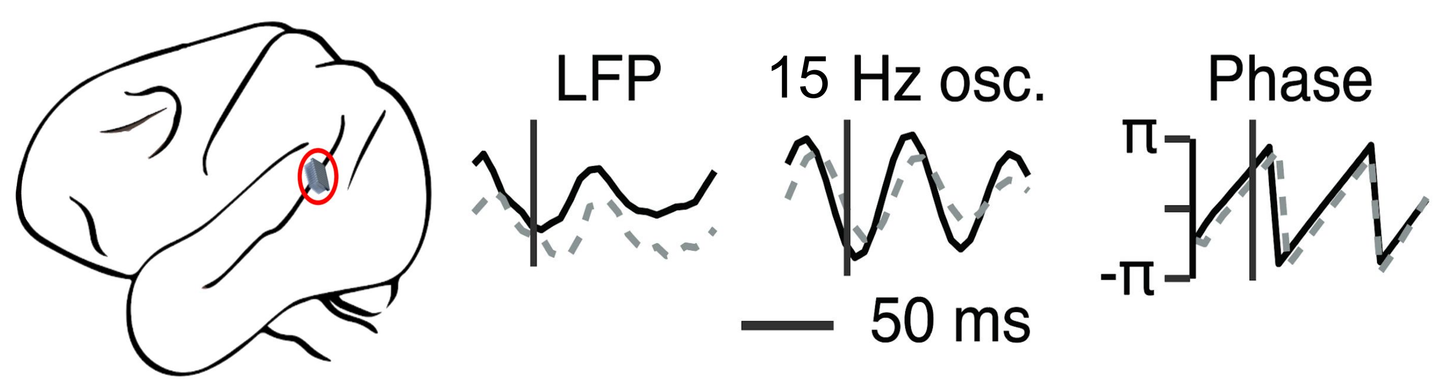
Introduction

- **Goal: To examine the relationship between phase coupling and distance.**
- Phase coupling refers to a consistent lead or lag in neural oscillations between two areas, from which communication between the areas can be inferred.
- Previous research has provided evidence for a relationship between spike count correlations and distance--the present exploration involves a circular analogue to this previous work; as such, circular statistical methods were employed.

Data and the Experiment

Oscillations in the brain can be observed using local field potentials (LFPs). Frequencies of interest can be isolated using a bandpass filter. For the purposes of this inquiry, a filter of 15 Hz (beta wave) was applied to the data which was collected using a Utah array with 96 recording channels in V4 of a macaque monkey performing an orientation change detection task over 1,742 trials. Filtered data was then used to determine the phase of each channel at a single time point over repeated trials.



Phase locking values (PLVs) were calculated using the phases collected from the filtered signal and then used to determine the degree of phase coupling between channels.

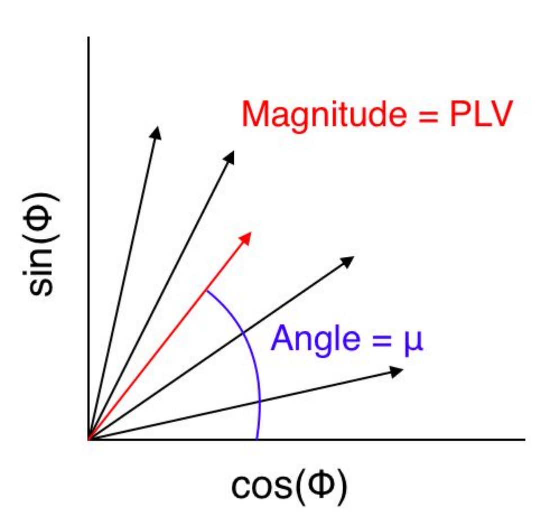
Methods

Given the nature of circular data, standard statistical methods were not sufficient for this analysis. Instead of Pearson's correlation, PLV was calculated to determine the degree of coupling between pairs of channels.

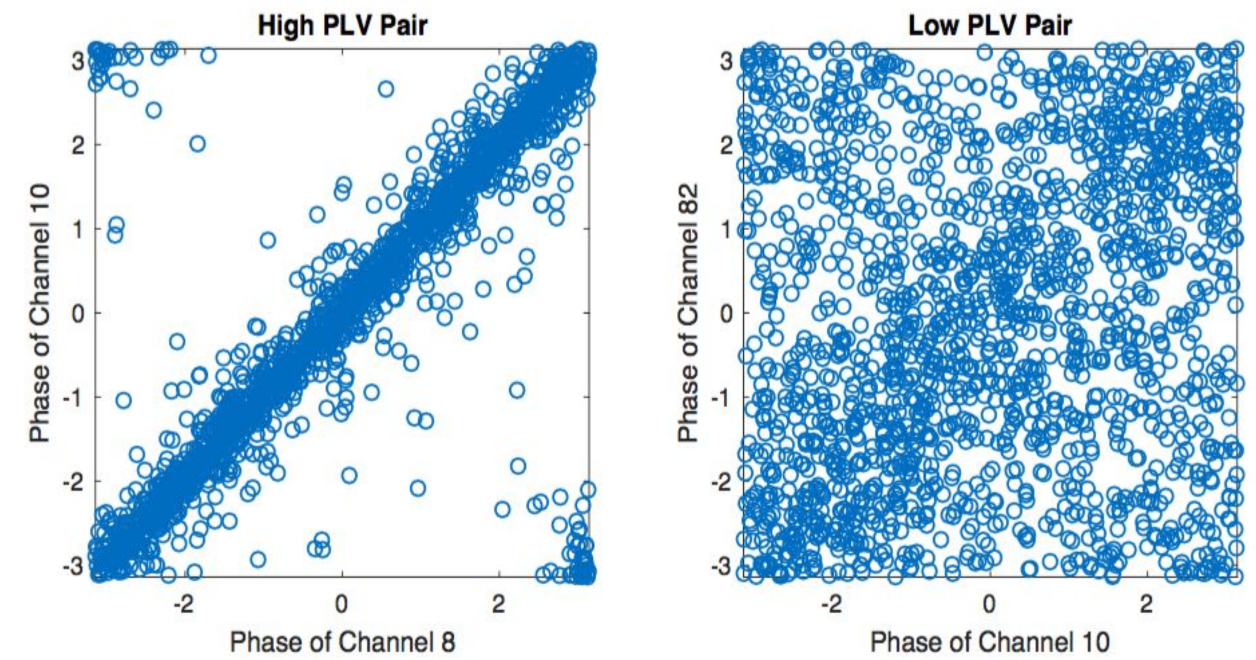
$$\phi_{j,k}^{(t)} = x_j^{(t)} - x_k^{(t)}$$

$$PLV_{j,k} = \frac{1}{N}\left|\sum_{n=1}^{N}(cos(\phi_{j,k}) + isin(\phi_{j,k}))\right|$$

Where *x* is the phase at a single trial *t*, *N* is the total number of trials, *j,k* is a unique pair of channels and *j* does not equal *k*.



PLV is calculated pairwise, across all trials. The difference between the phases of each channel in a single trial (Φ) is broken down into its sine and cosine components to form a vector. All of the vectors (which each represent a single trial) are then averaged into a single vector, the magnitude of which equals the PLV and the direction of which equals the μ value of the pair of channels. **The PLV corresponds to the degree of phase coupling between two channels and μ corresponds to the degree that one channel leads ahead or lags behind the other.**



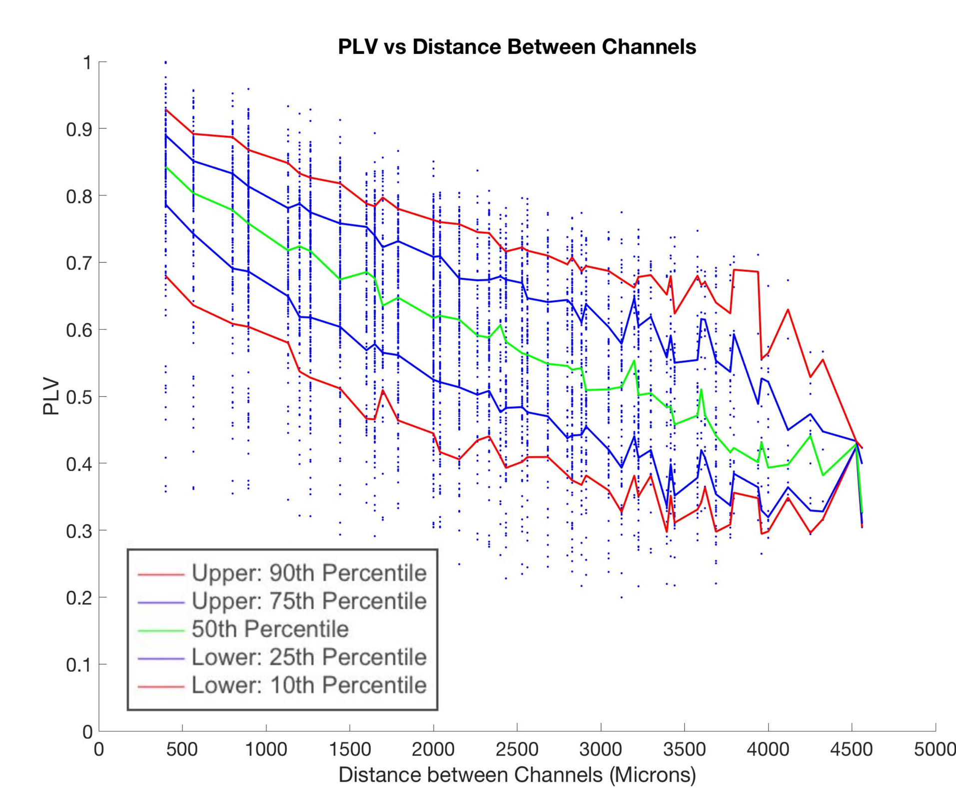
Two sample pairs of channels: It is important to note that PLV is similar to standard correlation, which is exemplified in the two pairs of channels to the left (the pair with a high PLV also has relatively high standard correlation). However, when circular data are plotted on a 2-D graph, some points near the value of pi bleed over onto the opposite end of the axis, which causes problems for Pearson correlation.

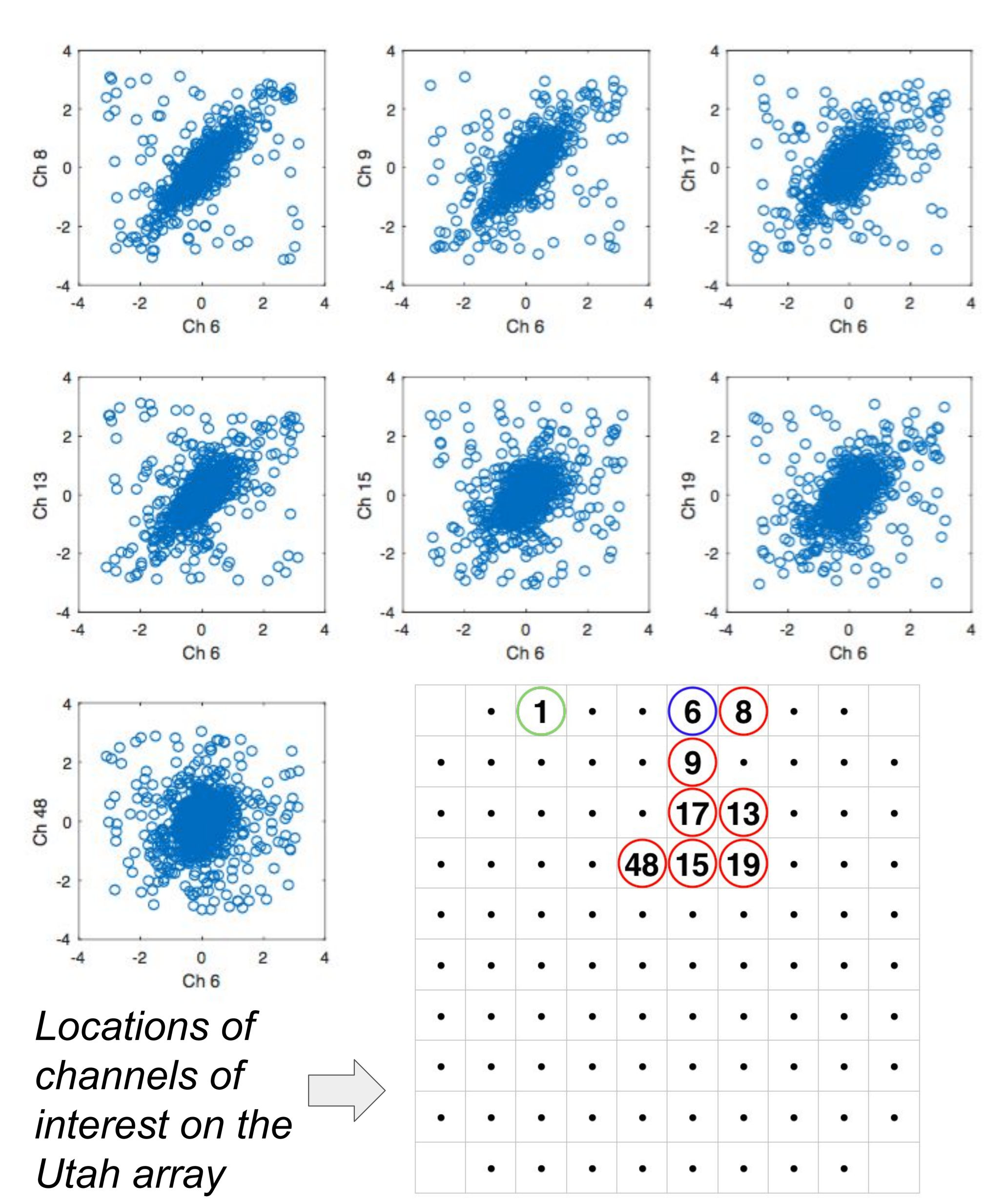
Limitations and Assumptions of PLV

- The calculations for PLV operate under the assumption that the phases of each sample are uniformly distributed
- PLV is a purely bivariate measure, meaning that only two channels can be compared at a time. The implication of this is that multivariate interactions may exist, but PLV does not have the ability to capture such interactions.

Results

- PLV and distance were found for every possible pair of channels in V4
- **General trend of decreasing PLV with increasing distance**





Locations of channels of interest on the Utah array

- Trivariate plots of phase differences: the channels which shared high PLVs with Channel 1 and were relatively distant from Channel 1
- Axes represent the difference in phase for each trial between Channel 1 and the labelled channel
- **Channels near each other share more similar phase differences with an anchor (ex. Channels 6 and 8) than channels farther away from each other (ex. Channels 6 and 48)**

Discussion

- The existence of many high PLVs in pairs of channels very near each other may be due to the proximity of recording channels in the array--it is possible that the same LFP signal was recorded by nearby electrodes.
- Results from trivariate plots support the trend of closer channels displaying higher PLVs; additionally, they may also be evidence for overlapping LFP signals.
- PLV is a more accurate measure of phase locking than simply finding the correlation between raw LFP signals as only specific waveforms are of interest (in this case, the beta wave, 15 Hz), rather than the entire signal.

Main Points

- There exists a relationship between spatial distance and PLV: as the distance between two recording sites increases, PLV decreases.
- Circular statistical analysis methods were necessary due to the circular nature of the filtered data.
- Trivariate relationships between channels support findings of a relationship between PLV and distance.

Future Plans

- Due to the bivariate nature of PLV, it will be necessary moving forward to conduct more in-depth multivariate analysis between channels to remove the effect of possible overlapping signals

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