Homework 04 – Advanced Neuroscience

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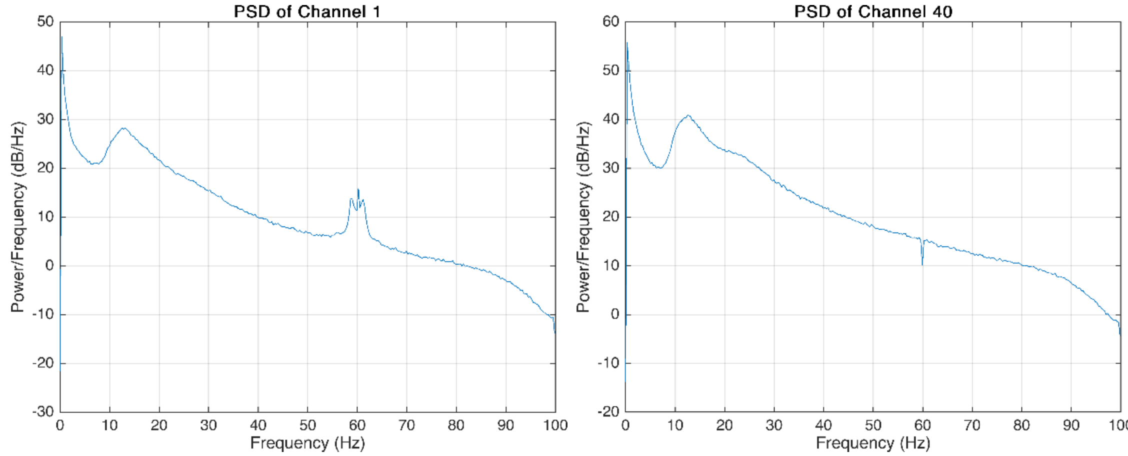
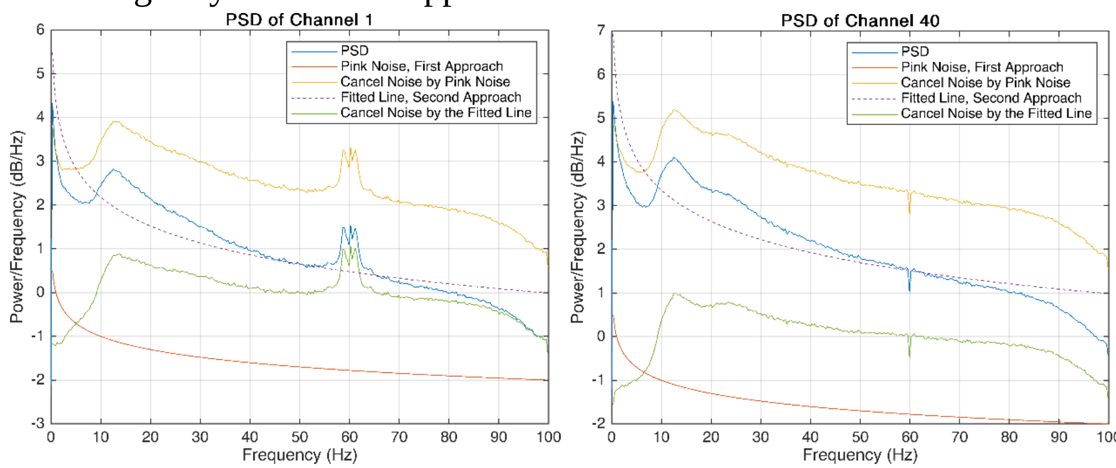
1. All analysis are done only by given clean trials. To find the dominant frequency for each channel, I've used FFT transform to have power spectrum of each channel. To show the below plot, I took average signal of the channel across all clean trials:

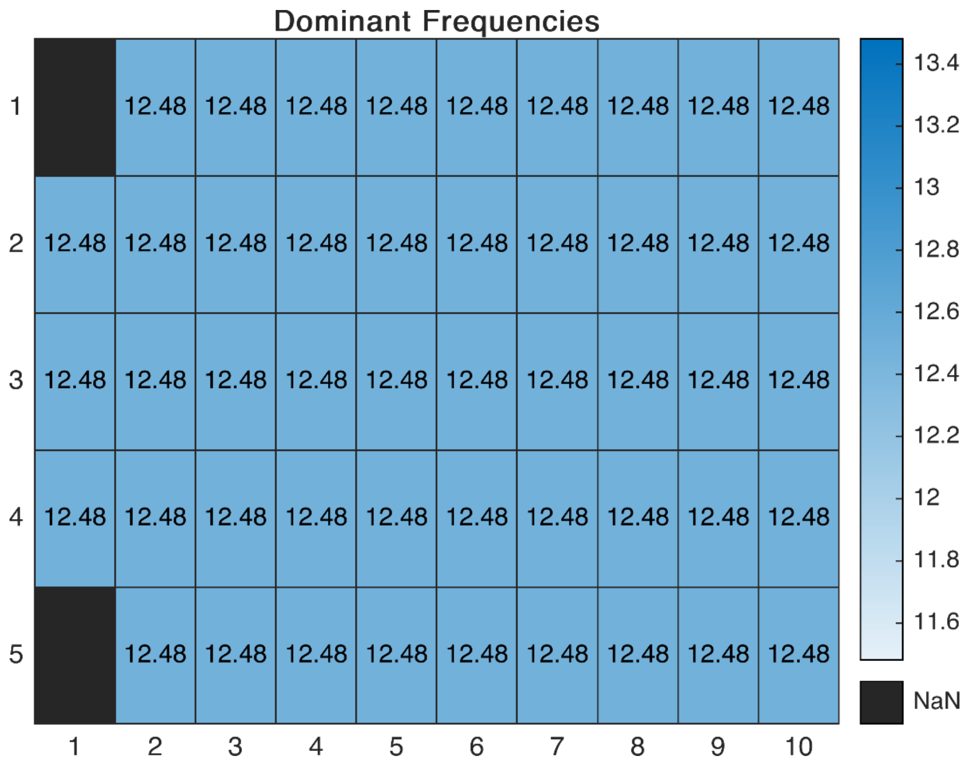


Then I've tried to cancel the pink noise by 2 approaches. The first one was to subtract the line $\frac{1}{f}$ in the log log space of PSD; The second approach is to fit a line in log log space of PSD and subtract the line from the data. In the below figure you see both approaches:

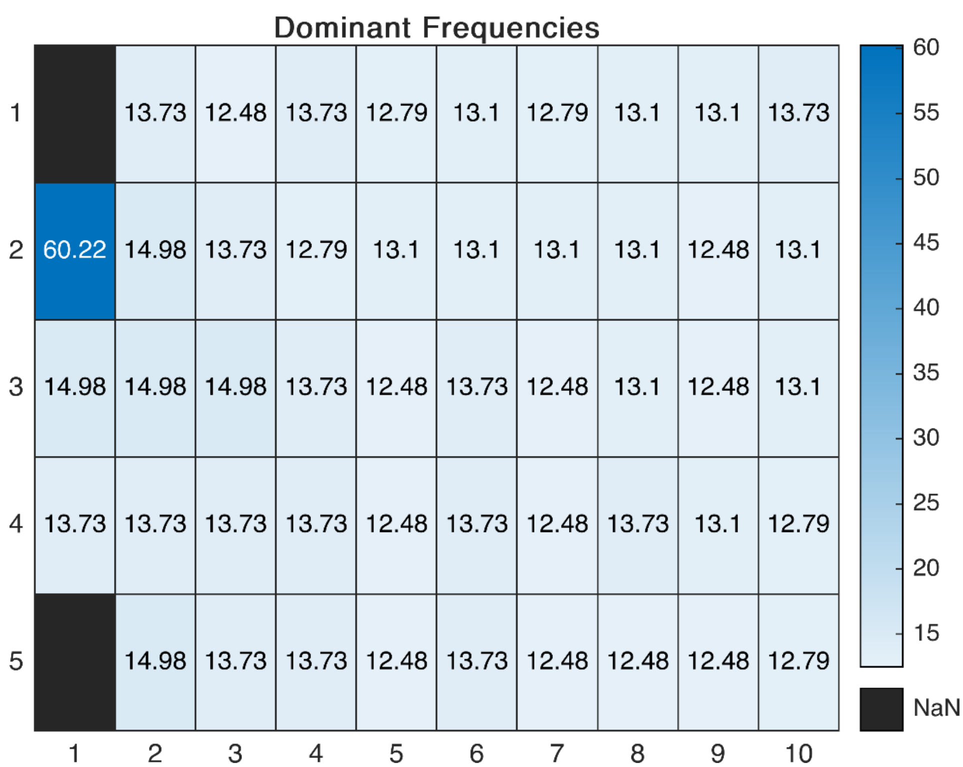


The problem with the second approach was the fact that the fitted line doesn't have slope near -1. Instead, it's about -2 or -3.

After Pink noise cancellation, I've extracted the dominant frequencies by considering the global maximum of the result. Then I plotted the result based on the channels' location for both approaches:



First Approach

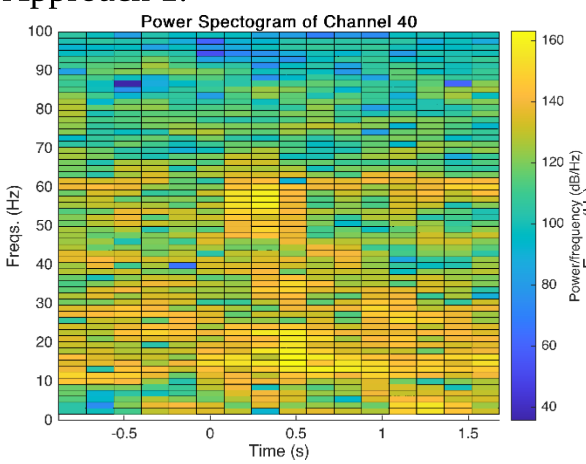


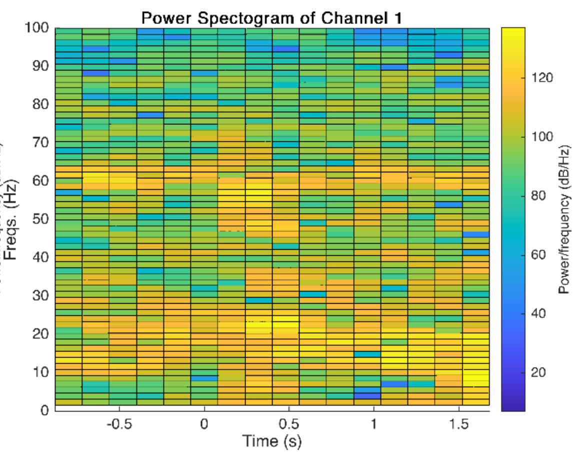
Second Approach

Many channels have a same value in both approaches. It seems that we have dominant frequencies in the range of about 12.5 Hz to 13.75 Hz.

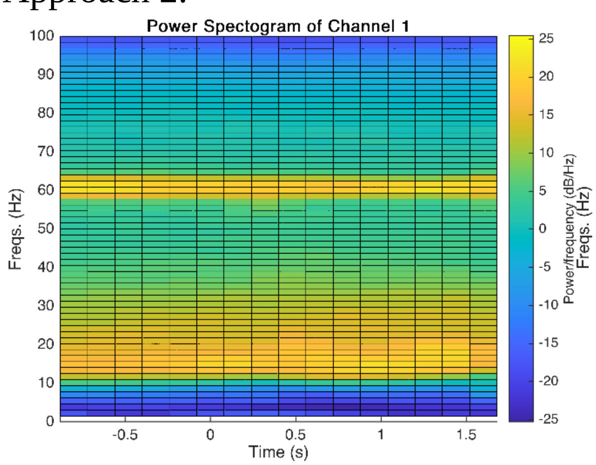
2. Results show that we can cluster almost all the channels except one of them (60.22 Hz) since the obtained frequencies are in a same range.
   There is a topographic arrangement because of the recording a small area in the motor cortex. It is expected for neurons in an area to be connected and have somehow a same behavior. So I think having close dominant frequencies is due to recording LFP signals of neurons of an area and the fact that the LFP signal is the accumulation of the activity of a bunch of neurons in the area.
3. Power spectrum of 2 channels (result of all channels are available at result folder).

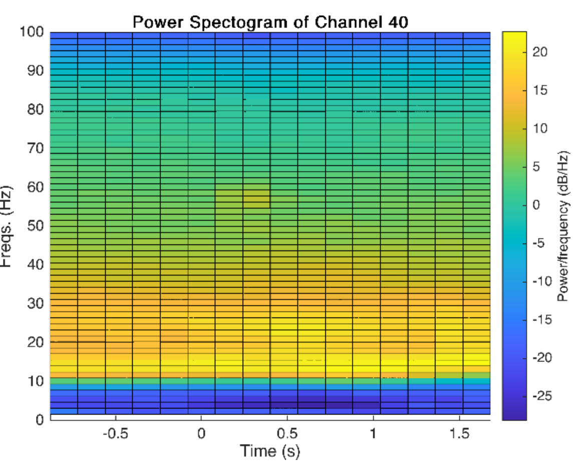
Approach 1:





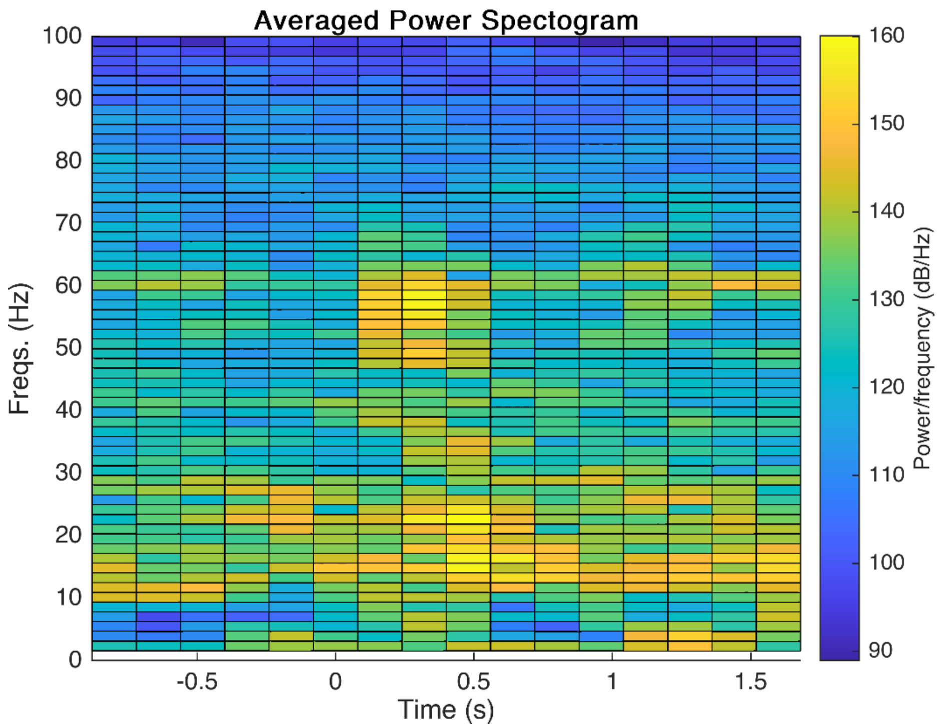
Approach 2:



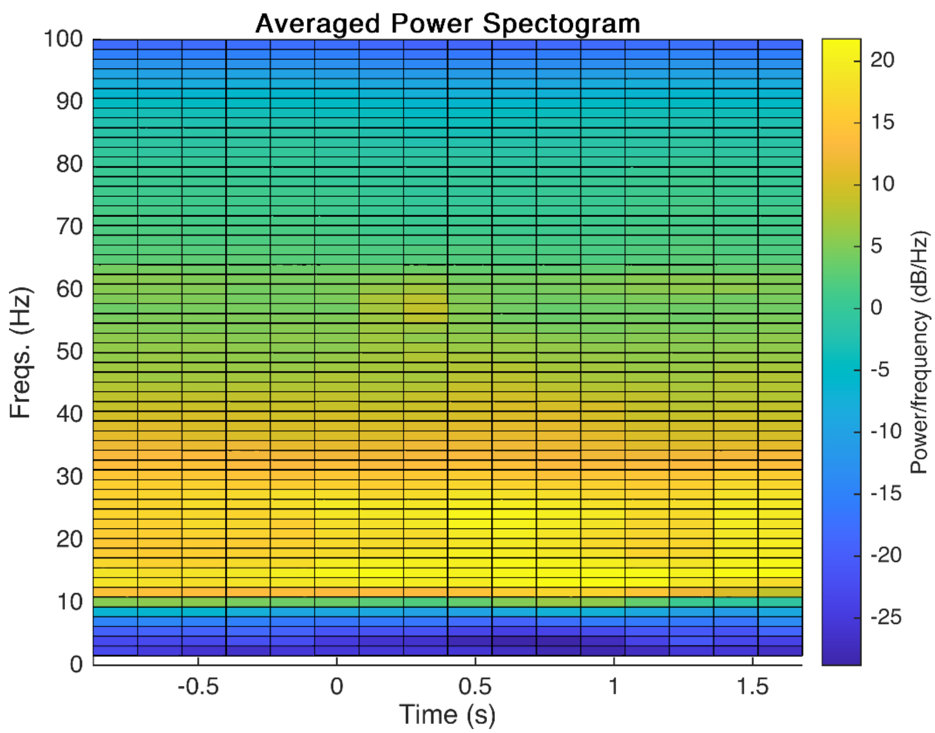


After Averaging across all channels

Approach 1:



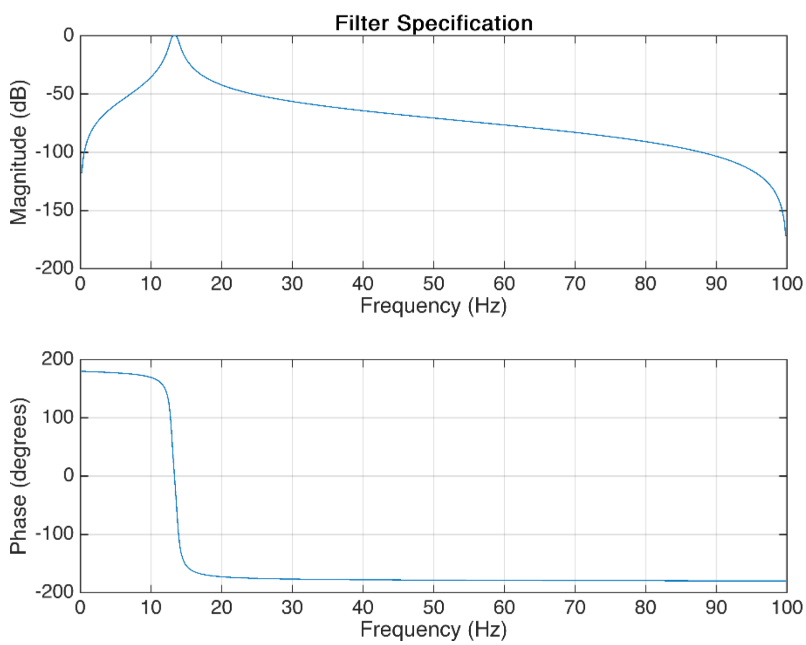
Approach 2:



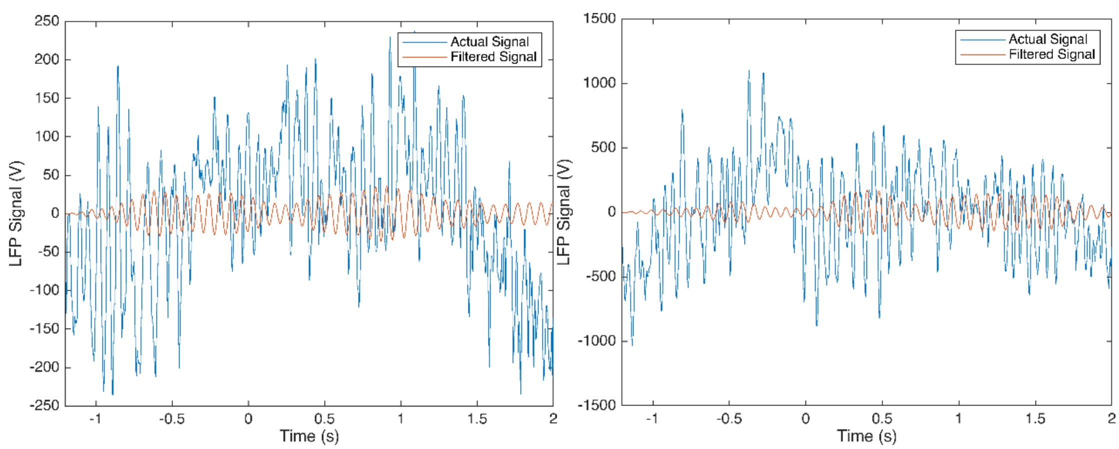
4. Results shows that power of the signal in 10-25 Hz has stronger changes and bigger magnitude compare to other frequencies. Also power in the frequencies near 60 Hz has changes after cue. So we have stronger power in Beta band and Gamma band.

In the figure presented by the Hatsopolous, we can see that same effect can be seen in 10-25 Hz (Beta band). Since the changes in 60 Hz is omitted from their plot it can be infer that the effect seen in 60 Hz is due to the power of the instruments which is consuming electricity on 60 Hz probably.

5. In the Phase propagation part of this homework, I've used the dominant frequencies obtained from the described second approach. So in order to filter the signals, I've used a 2^{nd} order band pass Butterworth filter that pass the content of the signal around the mean of the dominant frequencies (13.32 Hz ,mean is achieved by excluding the 60.22 Hz one):

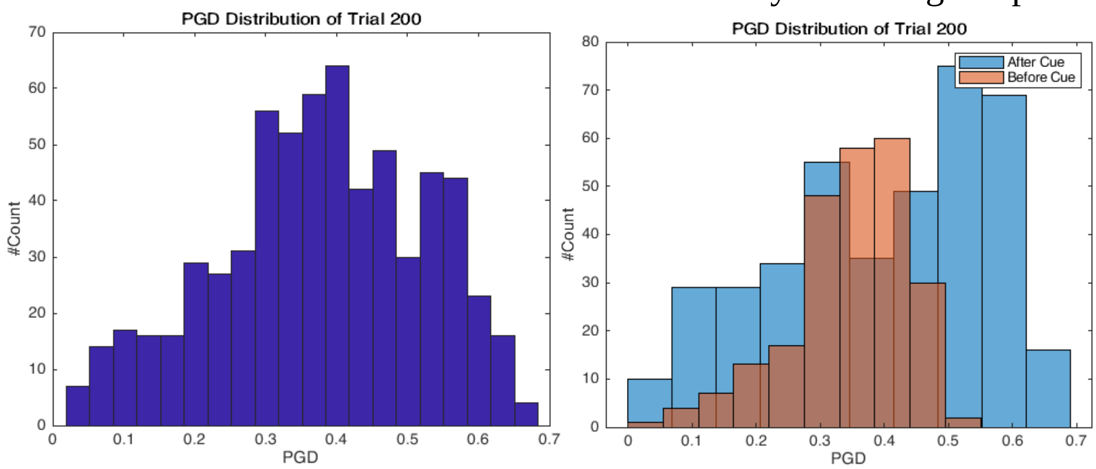


The 10^{th} trial of channels 1 and 10:



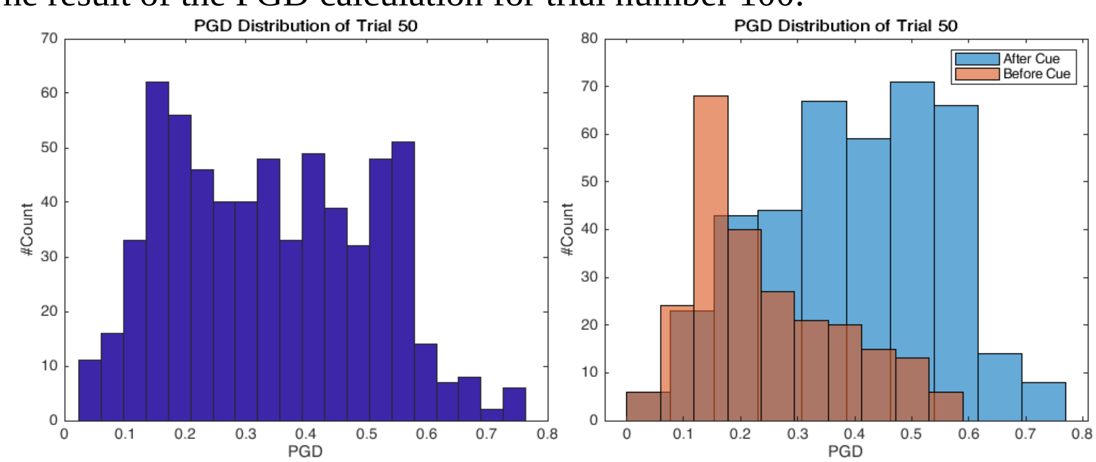
6. I used Hilbert transform to extract the phase of the signals.

7. I have created 2 movies. One of them show the changes of cosine(angle) in time for the trial 1. And the second one for the trial 200. The movies are available in the code folder.
8. For calculating PGD, First of all I extracted the gradient of the cosine(angle) by considering the distance of neighboring electrodes equal to 400 um. Then as the definition of PGD is the ratio of the norm of the mean gradients and mean of the norms, I calculated the norm of the mean gradients and mean of the norms. So after calculation, I have one PGD value for each time point of a trial. Then I tried to show the distribution of PGD by the histogram plots:



By the second plot showing the difference of distribution before and after cue, it's obvious that we have strong travelling wave because most of the PGD values are near 1.

The result of the PGD calculation for trial number 100:



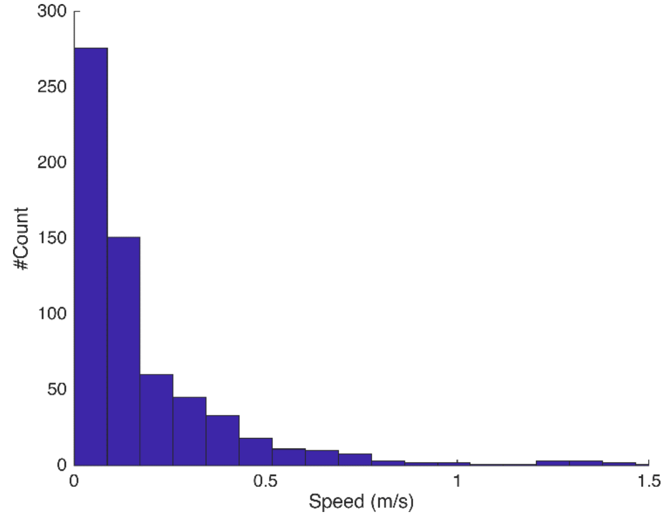
Although most of the trials shows high PGD values after Cue, But some of the trials show the opposite effect.

For direction of propagation, I've plotted the direction of gradient in each channel and like the visualization of the cosine(angle), I've created a movie which shows the direction in time course. This movie is created for trials 200 and 1. They are available in code folder.

For calculating the speed of propagation, since we have the equation below, it's necessary to calculate the derivative of cosine(angle) in time domain and measure the absolute of the mean:

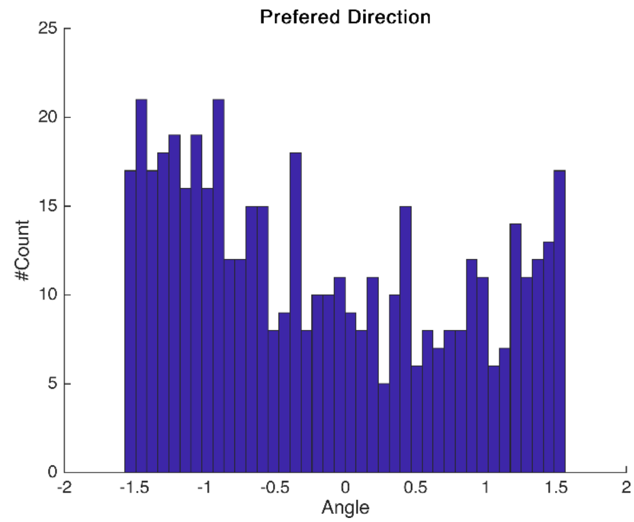
$$speed(t) = \left|\overline{(\partial\varphi/\partial t)}\right| \Big/ \overline{\|\nabla\varphi\|}$$

Histogram of the speed for trial 100:



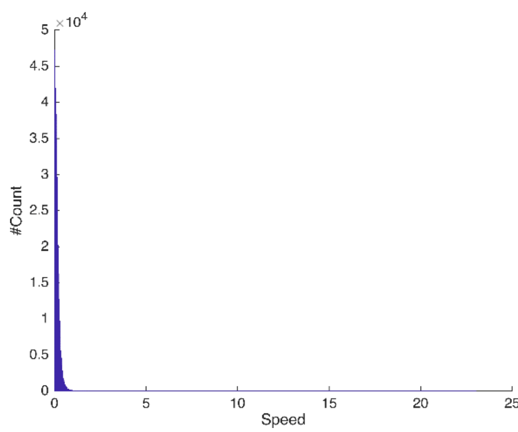
9. I added PGD and Speed of each time point to the movie created on Q7 for trials 100 and 200. The names of the movies start with "Demo".
10. To see whether we have a preferred direction or not, I used the $\overline{\nabla\varphi}$ calculated in PGD part and calculated it's angle. So I have one angle per each trial. Then I've plotted the histogram of these angles for different trials.

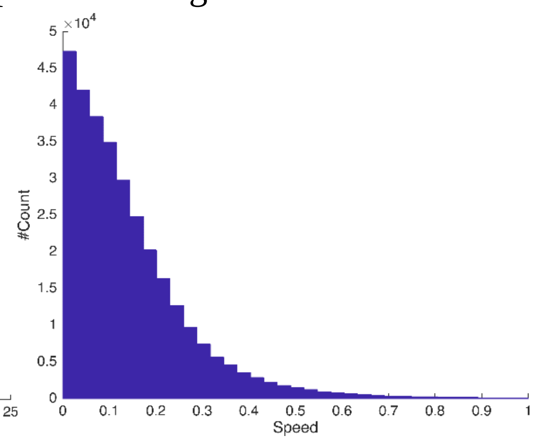
    Also since I see the traveling wave after the cue, I've just used the time of after cue:



This plot shows that the direction of wave is mainly about -1.5 rad or about -90 degree. This means that we mainly have waves that travel from top to bottom.

11. For this question, I've calculated the speed in the way discussed in 8 for each time point and all trials. Then I plot the histogram of the result below:





As you can see most of the measured speed is within the range proposed in paper. In the paper, this range is said to be related to conduction speed of unmyelinated fibers. I have calculated that 0.68% of measured speed have values bigger that 0.8 m/s. And I believe that this is related to so myelinated fibers there or the noise we have. However more that 99% of data is in the 0.1 – 0.8 m/s range and the mean of speeds is 0.15 m/s.