Sharif University of Technology

Advance Neuroscience

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Traveling Waves Assignment

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In this assignment we are going to analyze the activity of local field potential (LFP) recorded with multi electrode array in motor cortex. The task (Figure 1) is designed to study the encoding of working memory in Premotor Area F5.

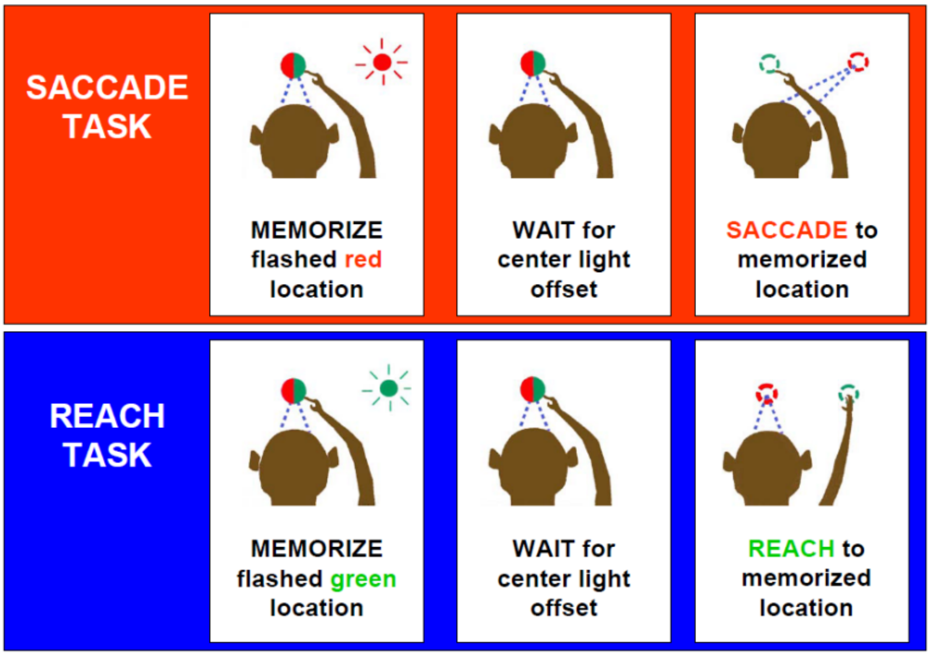
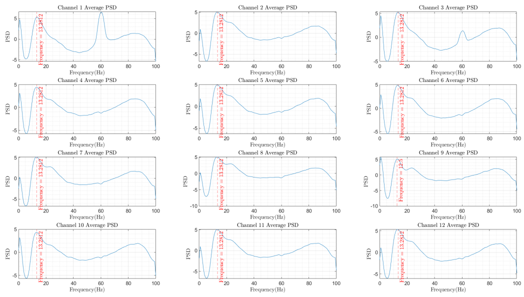
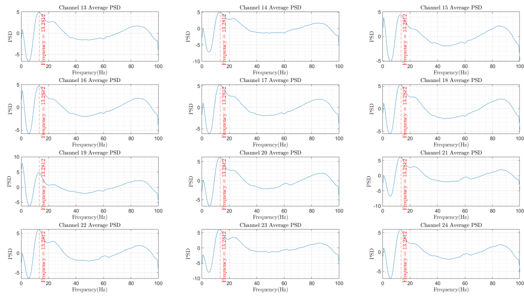


Figure 1: Delayed Response Task.

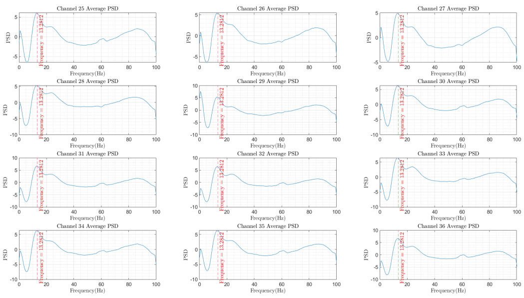
1. For traveling Waves, the data that we want to analyze should have the same(near) dominant frequency and filtered on that frequency to see traveling waves. As we know the LFP data have pink noise in them and must have been removed from the data. As we can see in Figure 2, the data are filtered and pink noise is removed. Also, in each electrode, the dominant frequency is shown. As we can see in Figure 3, the electrodes have an almost the same dominant frequency so we can use this data to see the traveling waves.



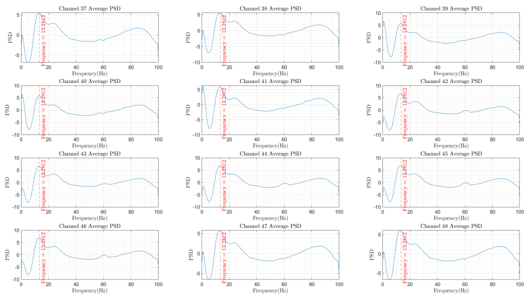
(a) Channels 1 to 12



(b) Channels 13 to 24



(c) Channels 25 to 36



(d) Channels 37 to 48

Figure 2: Denoised Channel Signals

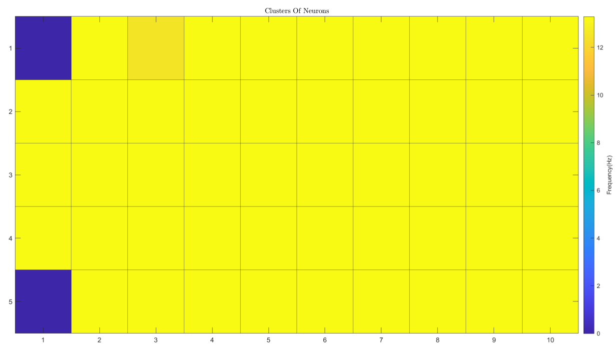


Figure 3: Dominant Frequency Clusters.

Also, another analysis is done to see in what band the signals have the most power. As we can see in Figure 4, the most power is in β band and as we seen before, the dominant frequency was in that range.

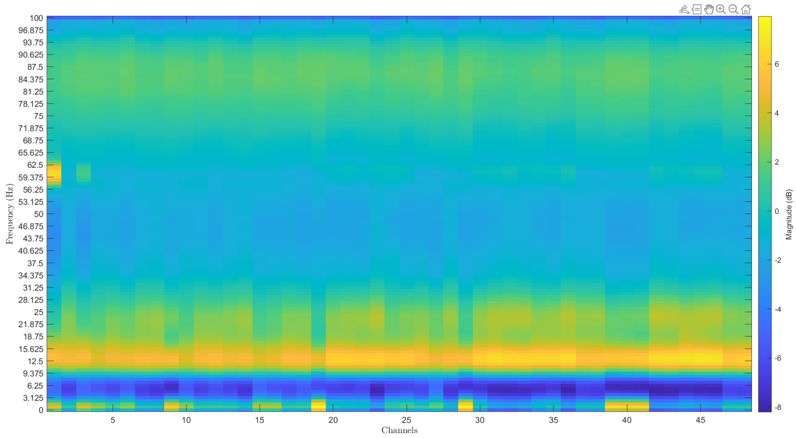


Figure 4: Channels Power Spectral Density.

2. To see the changes in Power Spectral Density over time, we can look at Figure 6. As we can see, after the cue onset, there is a rise in PSD. But there is a question that all over the trial, the signal has a meaningful power. It might come up to mind that from the start to the end of the trial we have traveling waves or this wave doesn't depend on the task and it always can be seen.

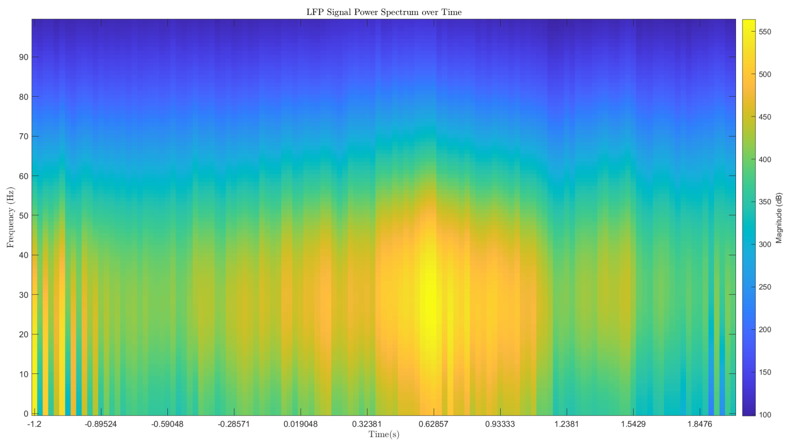


Figure 5: Power Spectral Density Over Time.

3. The traveling wave can be seen over time. So in https://drive.google.com/file/d/1HaEwA4JkzuG9B1Dn02nSkwiZOGp6 , you can find the video of one of trials traveling wave. To reach this, first of all the raw data was filtered on their dominant frequency. Then, with help of Hilbert transform, I calculate the instant phase of the signals. After that, as what Zhang et al.[**1**] done, in every time step, a plane was fit to the phases in electrodes dimension. In every time step, we can estimate the phase by:

$$\hat{\theta}_i = (ax_i + by_i + \vartheta) mod 360$$

We have:

$$\alpha = atan2(b, a)$$

where α is The angle of wave propagation. Also:

$$\zeta = \sqrt{a^2 + b^2}$$

where ζ is spatial frequency.

We have to find a and b to maximize r:

$$r = \sqrt{\left[\frac{1}{n}\sum_{i=1}^{n} cos(\theta_i - \hat{\theta}_i)\right]^2 + \left[\frac{1}{n}\sum_{i=1}^{n} sin(\theta_i - \hat{\theta}_i)\right]^2}$$

To find the best a and b, as what Zhang et al. [**1**] did, I do a greedy search for parameters α and ζ. If we have α and ζ:

$$a = \zeta \times cos(\alpha)$$

and:

$$b = \zeta \times sin(\alpha)$$

.

With that, we can find the best a a,d b to maximum r. r is also a good scale of how powerful or how a wave is in a linear direction way. We can see the r in Figure **??**. As we can see, we have a good wave after beginning of trial and before end of trial. It may show that the wave is because of the trial (we can not be sure it may be the regular wave in brain).

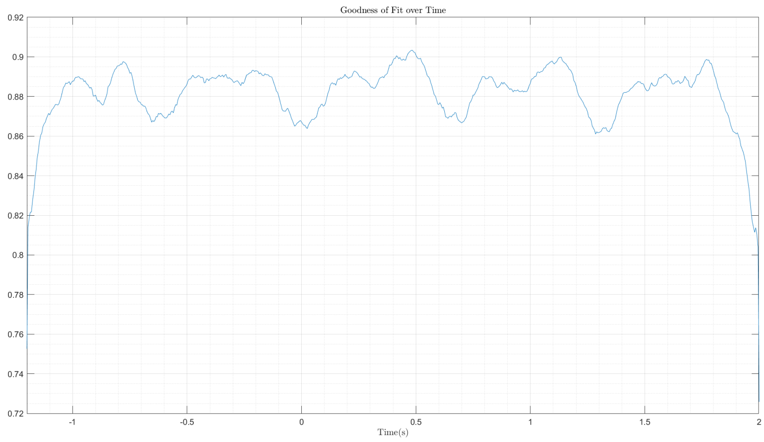


Figure 6: The Goodness of Fit Over Time.

We can also find the speed of wave from:

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

We can see the speed of wave in Figure 7. We can see that during the trial, the speed was around 20 cm/s.

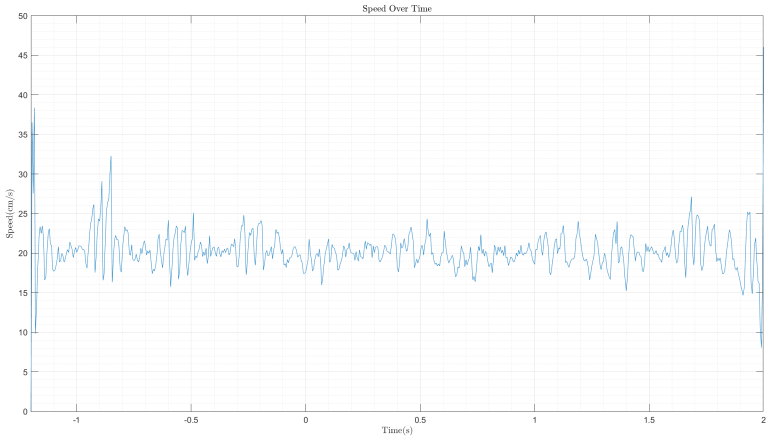


Figure 7: The Speed Over Time.

References

[1] Zhang H, Watrous AJ, Patel A, Jacobs J. Theta and Alpha Oscillations Are Traveling Waves in the Human Neocortex. Neuron. 2018 Jun 27;98(6):1269-1281.e4. doi: 10.1016/j.neuron.2018.05.019. Epub 2018 Jun 7. PMID: 29887341; PMCID: PMC6534129.