Default Mode Network Activity Analysis During Self-Contemplating Image Formation

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ABSTRACT

Default mode network (DMN), one of the widely studied resting state functional network, is a distinct network of brain that comprises of actively correlated brain regions while the individual is in a wakeful state but not focused on the outside world. Here, we study and analyze the DMN using Electroencephalography (EEG), the most commonly used electrophysiological monitoring method for recording brain signals in high temporal resolution. In our study, the subjects were asked to sit down quietly on a chair with eyes closed and think about some parts of their own body, such as left and right hands, left and right ears, lips, nose, and the images of faces that they were familiar with as well as perform a simple mathematical calculation. The instance when the image was formed in the subject's mind, was marked in time. Next, the recorded brain activity maps, 300ms prior to the time marked instant, were analyzed for each of the 4 wave bands namely, Delta, Theta, Alpha and Beta waves. We found that for most EEG datasets during this 300ms, Delta wave's activity lied mostly at the frontal lobe or the visual cortex and its movement across these brain regions were slow. On the other hand, theta wave's activity rotated along the edge of cortex in a clockwise and counterclockwise fashion. Furthermore, Beta wave acted as inquiry types of oscillations between any two regions of the cortex. Lastly, Alpha wave's activity looked like a mix of the Theta and Beta wave's activities along similarity with that of the Theta wave's activity. From these observations, we conclude that Beta and high Alpha are playing a role in information inquiry within the brain. Whereas, Theta and Alpha waves are more likely to play the role of developing and binding of imagination in the DMN operations.

BACKGROUND

- Self-Contemplating Image Formation: The **Primary Visual Cortex** is the primary area of the brain responsible for sight -recognition of size, color, light, motion, dimensions, etc. And the **Visual Association Area** interprets information acquired through the primary visual cortex.
- ICA (Independent Component Analysis) was used for EEG Data Processing. It is a method to recover a version of the original sources by multiplying the data by a unmixing matrix, **u=Wx,** where x is our observed signals, a linear mixtures of sources, **x=As.**

OBJECTIVES

To investigate the following:

1. How different brain waves (Delta, Theta, Alpha and Beta) behave during this 300ms from a global view of the cortex?
2. How the brain activities of different rhythms behave on prefrontal lobe and visual cortex?

METHODS

- While EEG of subjects were being recorded, they were required to imagine an image of their body parts, e.g. left and right hands and feet, the faces of the people they hate or love the most, and even doing simple mathematical calculation in mind with eyes closed.
  - 6 subjects: 4 males and 2 females, Aged from 20 to 30
  - Sampling rate was 100Hz: Brain map plots are taken every 10ms.
- Once the image is formed in the mind of the subject, he/she would touch the time marker.
- The decision is made in mind 300ms before subjects realize that they have made a decision.
- Hence, we studied the EEG signals that were 300ms before subjects 'claimed' image formations.
- EEG data (300ms before the time marker was analyzed in EEGlab and sLORETA).
  - 31 spatial maps within 300ms before the time marker using EEG with sLORETA were plotted..
  - Dynamic Brain activity region routes for all Delta, Theta, Alpha and Beta waves were studied

An example of spatial plot example in sLORETA

- X,Y,Z coordinates of the estimated source location in the brain for EEG at a given instance (260 millisecond).
- These coordinate values were used to eventually plot in MATLAB for analyzing brain activity dynamics

METHODS

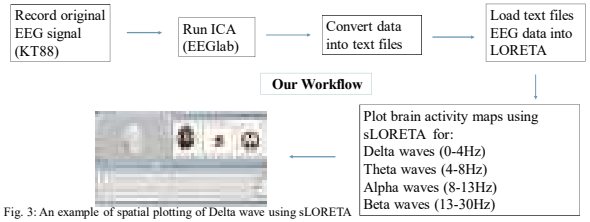
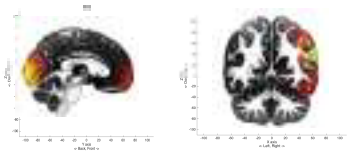


Fig. 3: An example of spatial plotting of Delta wave using sLORETA

RESULTS

Our findings are as follows:

1. Delta rhythms (0-4Hz):

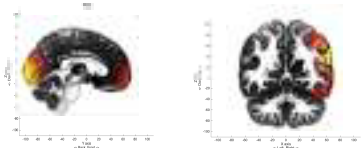


- For most of the time in the 300ms, Delta activities tend to arise at either prefrontal lobe or visual cortex.
- A sudden spatial shift of activity region would occur for most cases, and a duration of about 150ms to 180ms can be observed between two shifts in the analyzed period.

2. Beta rhythms (13-30Hz):

- For one certain activity map in the 300ms sampled time series, the excited region is different from both 10ms before or after itself.
- That is the spatial shifts can be detected very 10ms.
- Beta activities also perform as oscillation between prefrontal lobe and visual cortex, but the spatial shift speed is at least 15 to 18 times faster than that of Delta rhythms.
- During self-contemplating image formation, prefrontal lobe participate in the processing of image formation with visual cortex under both low frequencies (Delta oscillations, 0-4Hz) and Beta oscillations (13-30Hz).

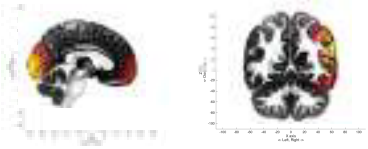
3. Theta rhythms (4-8Hz)



- A detectable annular movement trace can be observed, which is transmitting along the edge of the cortex map from its top view.
- This circulating movement of Theta rhythm activity would be either clockwise or counter clockwise, and the cycle of annular movement varies for different subjects, as well as different tasks of image formation for the same subject.
- For most datasets that we recorded from the six subjects, these cycles are between 60ms and 150ms.

RESULTS

4. Alpha rhythms (8-13Hz)



- A global view of Alpha rhythm activity during the analyzed 300ms presents an anomalous movement trace and the performance properties of Alpha rhythm activity regions mostly falls in between Theta and Beta oscillation behaviour.
- Mu waves also show up on motor cortex, which indicates the mirror neural system is suppressed during the self-contemplating

image formation.

CONCLUSIONS

1. Self-contemplating image formation involves multiple brain regions' activation, and these activation of brain is dynamic during the period from the formation in the mind to the time when subjects realize this image formation.
2. Delta wave activity would mostly locate at the prefrontal lobe or the visual cortex, and the change and movement of activities are slow.
3. Theta wave activity tended to rotate along the edge of cortex either clockwise or counterclockwise.
4. Beta wave behaved like inquiry types of oscillations between any two regions spread over the cortex.
5. Alpha wave activity looks like a mix of the Theta and Beta activities but more close to Theta activity.
6. The higher frequency the rhythm has, the higher the speed of activated region of brain movement would achieve.
7. Beta and high Alpha are playing utility role for information inquiry. Theta and low Alpha are likely playing the role of binding and imagination formation.

REFERENCES

1. Laufs, H., Hamandi, K., Salek-Haddadi, A., Kleinschmidt, A. K., Duncan, J. S., & Lemieux, L. (2007). Temporal lobe interictal epileptic discharges affect cerebral. activity in "default mode" brain regions. *Human brain mapping*, *28*(10), 1023-1032.
2. Jann, K., Dierks, T., Boesch, C., Kottlow, M., Strik, W., & Koenig, T. (2009). BOLD correlates of EEG alpha phase-locking and the fMRI default mode network. *Neuroimage*, *45*(3), 903-916.
3. Whitfield-Gabrieli, S., & Ford, J. M. (2012). Default mode network activity and connectivity in psychopathology. *Annual review of clinical psychology*, *8*, 49-76.
4. Chen, A. C., Feng, W., Zhao, H., Yin, Y., & Wang, P. (2008). EEG default mode network in the human brain: spectral regional field powers. *Neuroimage*, *41*(2), 561-574.
5. Uchida, N., Kepecs, A., & Mainen, Z. F. (2006). Seeing at a glance, smelling in a whiff: rapid forms of perceptual decision making. *Nature Reviews Neuroscience*, *7*(6), 485-491.
6. A. Delorme, T. Mullen, C. Kothe, Z. A. Acar, N. Bigdely-Shamlo, A. Vankov, and S. Makeig, "Eeglab, sift, nft, bcilab, and erica: new tools for advanced eeg processing," Computational intelligence and neuroscience, vol. 2011, p. 10, 2011.
7. Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): technical details. *Methods Find Exp Clin Pharmacol*, *24*(Suppl D), 5-12.
8. Scheeringa, R., Bastiaansen, M. C., Petersson, K. M., Oostenveld, R., Norris, D.G., & Hagoort, P. (2008). Frontal theta EEG activity correlates negatively with thedefault mode network in resting state. International Journal of Psychophysiology,67(3), 242-251.