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Measurement of the occipital alpha rhythm and temporal tau rhythm by using magnetoencephalography

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Abstract

Developing Magnetoencephalography (MEG) based on Superconducting Quantum Interference Device (SQUID) facilitates to observe the human brain functions in non-invasively and high temporal and high spatial resolution. By using this MEG, we studied alpha rhythm (8-13 Hz) that is one of the most predominant spontaneous rhythm in human brain. The 8–13 Hz rhythm is observed in several sensory region in the brain. In visual related region of occipital, we call to alpha rhythm, and auditory related region of temporal call to tau rhythm, sensorimotor related region of parietal call to mu rhythm. These rhythms are decreased in task related region and increased in task irrelevant regions. This means that these rhythms play a pivotal role of inhibition in task irrelevant region. It may be helpful to attention to the task. In several literature about the alpha-band inhibition in multi-sensory modality experiment, they observed this effect in the occipital and somatosensory region. In this study, we hypothesized that we can also observe the alpha-band inhibition in the auditory cortex, mediated by the tau rhythm. Before that, we first investigated the existence of the alpha and tau rhythm in occipital and temporal region, respectively. To see these rhythms, we applied the visual and auditory stimulation, in turns, suppressed in task relevant regions, respectively.

Keywords: *SQUID, Magnetoencephalography, Human alpha band rhythm, Inhibition*

1. INTRODUCTION

A Superconducting Quantum Interference Device (SQUID) is a very sensitive magnetometer used to measure extremely weak magnetic fields, based on superconducting loops containing Josephson junctions. Magnetoencephalography (MEG) based on the SQUIDs measurse the magnetic fields generated from above 50,000 synchronized active neurons aligned parallel to the surface of the skull [1]. The synchronized neuronal current induces extremely weak magnetic fields at 10 -1000 fT. Thanks to the development of whole-head helmet MEG system, we can measure the active neurons firing in long distance in the brain simultaneously. These whole-head system requires to have lots of electronic lines and the devices. We used the double relaxation oscillation SQUID (DROS) that designed by using a single reference junction instead of the reference SQUID, so that enable direct readout by a room-temperature dc preamplifier, and consequently uses simple flux-lock loop electronics [2].

In human brain, spontaneous oscillating signals are generated for a period of time in synchronized neurons. The alpha rhythm (8 - 13Hz) generated in occipital region which contains visual cortex is the most predominant rhythm in the human brain [3]. This rhythm can be easily detected in MEG or electroencephalography (EEG) and directly can be seen without averaging procedure. We thought this alpha rhythm may play a pivotal role in brain functions, but also provides an important key of studies of brain mechanism. We found out the alpha rhythm is related to the attention to the sensory stimulations [4, 5, 6]. In the several literature, alpha rhythm increased when concentrate on other sensory stimuli (e.g. auditory, somatosensory and so on), conversely decreased when focus on the visual stimulation than other stimuli.

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In other words, alpha rhythm inhibits the visual stimulation in order to concentrate to the other sensory stimuli.

As well as alpha rhythm, many other rhythms are sharing same frequency range of the alpha. The alpha band rhythm is observed in several sensory regions in the brain. In visual cortex of occipital region, we call to alpha rhythm, and auditory cortex of temporal region to tau rhythm, sensorimotor cortex of parietal region to mu rhythm, and also call to sigma rhythm in second somatosensory cortex. These all rhythms are suppressed when apply the related sensory stimulation.

Rosanne M. et al. studied that alpha wave was suppressed or increased in occipital region depending on the attention to the visual or auditory stimulation. A. Mazaheri et al. also studied the difference between visual and auditory attention. They showed the suppression of alpha rhythm in occipital and the increase of the beta band (14-16 Hz) rhythm in temporal region. The temporal beta rhythm was related to the short-term storage of pitch information. But they do not show the power change of tau rhythm in temporal region, which indicate that the tau rhythm may be also related to the inhibitory system. We now hypothesize that this inhibitory phenomenon of the tau rhythm in the auditory cortex could be observed. Before that, we first want to confirm the existence of tau and alpha rhythm in temporal and occipital region, respectively. In this study, we focused on identifying the existence of these two rhythms in each sensory region.

In sensor space, it is difficult to separate the alpha rhythm and tau rhythm due to overlapping in some channels. To identify these two rhythm separately, we measured the power change (reactivity) after the auditory and visual stimulation in each sensory region, respectively. We calculated the reactivity after the stimuli comparing the previous state by using the Temporal Spectral Evolution method (TSE) [7]. The procedure of the TSE is followed by,

1. Filter the signals in narrowband.
2. Rectify (take absolute value) or Hilbert transform (take envelope of the signals).
3. Average the rectified or Hilbert transformed data across trials [-2s to 3s].
4. Normalize them to baseline (2s pre-stimulus baseline).

In this study, we used the Hilbert transform instead of rectifying in order to see the amplitude variation of the alpha band rhythm maximally. The TSE contains the phase locked and un-locked signals.

The alpha suppression were studied in many literatures by using MEG and EEG. But tau suppression were studied a little. Because the tau rhythm locally exist in the auditory cortex. And EEG is difficult to measure or can measure the spreading signals due to the volume-conduction effect, which can be identified by using the intracranial EEG. There were a little literatures by using MEG [8, 9].

2. METHODS

2.1. Experiments

Two healthy young adults were participated in the study. The alpha and tau rhythms are largely generated in drowsy state. Subjects were requested to be in a drowsiness state. All measurements were recorded with a whole-head helmet system (KRISS MEG system, KRISS, Daejeon, KOREA) within a magnetically shielded room [10]. The data were sampled at 1024 Hz. The system has 152 axial first-order double relaxation oscillation SQUID gradiometers. In visual experiment, full size checkerboard visual stimuli were presented for 400 ms and inter-stimulus-interval (ISI) was 4400 ms. During the ISI, black screen was presented. In auditory experiment, 500 Hz beep sound were presented at left ear for 500 ms and ISI was 5500 ms. Fig. 1 Shows the two experiment paradigm. Participants' eyes were closed during the auditory experiment to see the suppression effect of the tau rhythm maximally. There were 100 trials in visual and auditory experiment, respectively.

2.2. Analysis

Fig. 2 shows the example of data acquisition. After the visual measurements, we first removed the eye blink by using Independent Component analysis (ICA) in fieldtrip in Matlab. In the visual evoked fields (VEF), we filtered the signals from 0.02 Hz to 511 Hz and then averaged the filtered data across trials from -0.5s to 1s. To get a TSE, the data were filtered from 8 Hz to 13 Hz. And then, take a Hilbert transform from filtered signals and normalize them to baseline. In the auditory analysis, we did not remove the eye blink because subjects were eye closed during the experiment. The procedures were same with VEFs and visual TSE, except that the filtering range was 8 Hz to 10 Hz in auditory TSE.

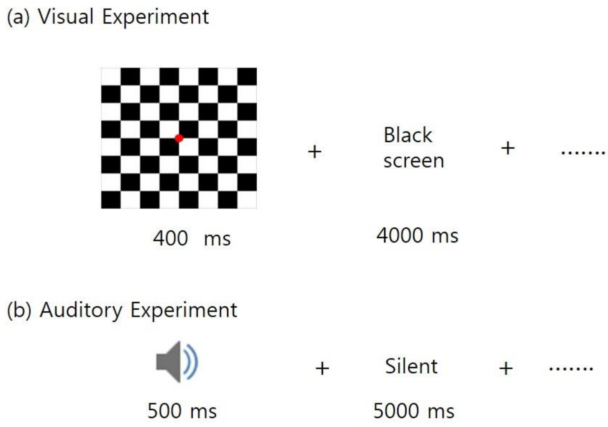

Fig. 1. Two expriment paradigm. (a) Visual experiment. Full size checkerboard visual stimuli were presented for 400 ms and inter-stimulus-interval (ISI) was 4400 ms. (b) Auditory experiment. 500 Hz beep sound were presented at left ear for 500 ms and ISI was 5500 ms.

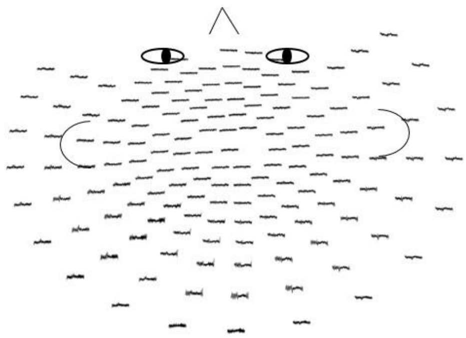

Fig. 2. 152 channel MEG sensor layout and approximate head position. The raw data recorded for 1.5 second on visual experiment was shown as an example for a data acquisition.

3. RESULTS

Alpha suppressions after the visual stimulation were observed in two subject. Fig. 3 shows the visual evoked fields (VEFs) and Temporal Spectral Evolution (TSE) representing the alpha suppression in one subject. We found out the difference between the region of VEF and TSE in sensor space. Alpha suppressions were covered in the almost all channels in occipital region. The VEFs were

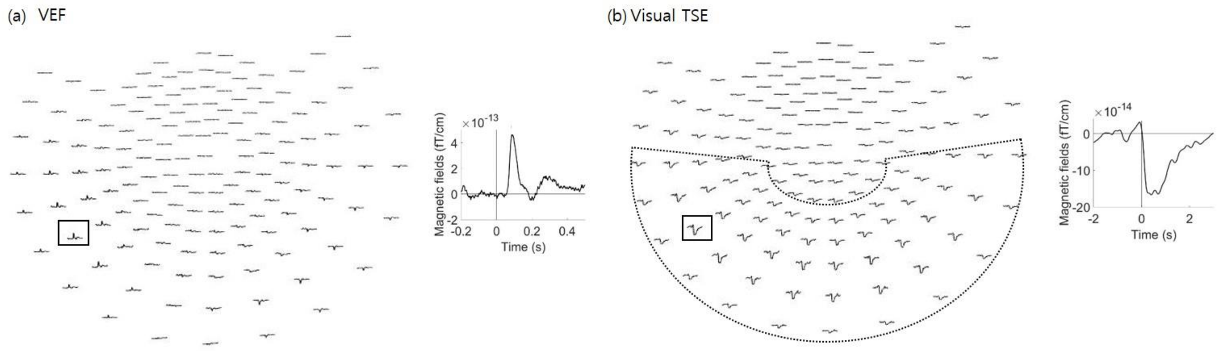

Fig.3. (a) Visual evoked fields (VEF) (averaged over 100 responses). There are VEFs over the occipital region. On the right figure, the enlarged signal show the one of the strong response in left figure. (b) TSE result in alpha band (8 – 13 Hz). The alpha rhythm was suppressed after the visual stimulation and return to baseline in 3 seconds. The dashed line indicates the region related to the ongoing alpha rhythm.

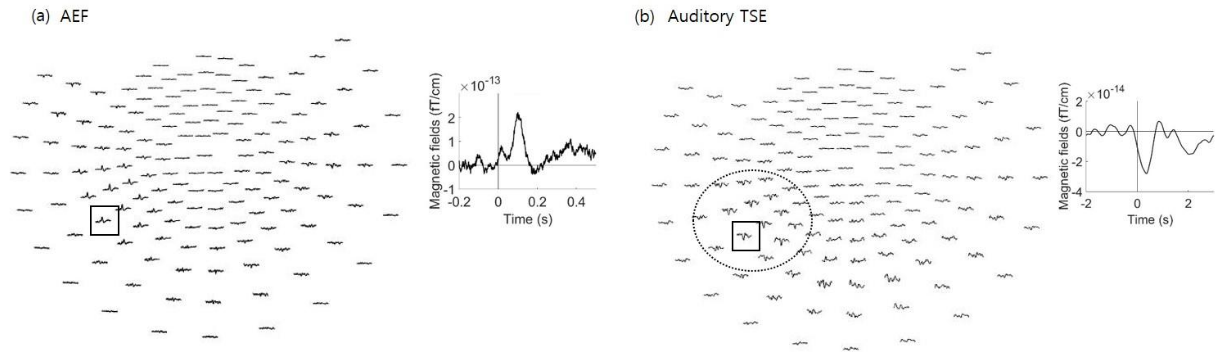

Fig. 4. (a) Auditory evoked fields (AEF) (averaged over 100 responses). There are AEFs over the temporal region. On the right figure, the enlarged signal show the one of the strong response in left figure. (b) TSE result in tau rhythm (8 - 10 Hz). The tau rhythm was suppressed after the auditory stimulation and return to baseline in almost one second. The dashed line indicates the region related to the ongoing tau rhythm.

showed in two hemisphere in occipital region with an opposite polarity. Tau rhythms were also suppressed after the auditory stimulation. Fig. 4 shows the auditory evoked fields (AEFs) and TSE representing the tau suppression in one subject. The result shows that the region of the AEFs and TSE were almost same.

4. CONCLUSION

In this study, we identified the existence of the two ongoing rhythms, alpha and tau rhythm in occipital and temporal region, respectively. The alpha rhythm is related to the visual inhibition. We hypothesized that the tau rhythm also follow the inhibition mechanism. In reference [11], they revealed that neurofeedback training to enhance tau rhythm generated in the auditory cortex can help to reduce auditory sensations in patients suffering from tinnitus, possibly by locally enhancing inhibitory processes. This implies that the tau rhythm plays a role to inhibit the auditory sounds. Although we did not conduct an experiment related to the inhibition mechanism in present study, we plan to do this in the near future.

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