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Theta Neurofeedback of the Parahippocampal Gyrus for Memory Enhancement: A Preliminary Study

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***Abstract*— Resective surgery for mesial temporal lobe epilepsy (MTLE) carries the potential risk of memory decline. Neurofeedback (NF) which regulates brain activity and function, may be a promising solution for improving memory function. We constructed a memory-NF system using theta band power of electrocorticograms from the parahippocampal gyrus (PHG) and evaluated it with a preliminary study. As a result, we observed changes in theta-range oscillatory activity in PHG during NF training, and gained important insights for further developing the memory-NF system for memory enhancement.**

I. INTRODUCTION

Removal of mesial temporal lobe (MTL) is an established surgical procedure leading to seizure freedom in patients with intractable MTL epilepsy (MTLE), but it carries the potential risk of damaging memory. In recent years, neurofeedback (NF) has been established to improve brain function through cognitive learning using information of one's own brain activity. However, to our knowledge, no NF solution has been proposed to improve memory function of hippocampus so far.

Therefore, we developed a memory-NF system using theta band power of parahippocampal gyrus (PHG). In this paper, we present the result of changes in theta-range oscillatory activity in PHG through NF training and discuss the prospect.

II. METHODS

Subjects: This study included two patients (subject 1: 57-year-old male; subject 2: 26-year-old female) with intractable epilepsy who underwent implantation of subdural electrodes for diagnostic purposes. This study was approved by the institutional review board of the University of Tokyo Hospital. An informed consent was obtained from patients.

Data acquisition: We used trapezoid-shaped electrode sheets on which eight platinum electrodes were arranged in a "T" shape (Unique Medical, Tokyo, Japan). We inserted the sheet so that the four electrodes were aligned longitudinally along the left PHG. Electrocorticogram was recorded at 512 Hz.

Memory-NF training: In our NF system, one session consisted of 20 trials, and each trial consisted of a memory task and a NF. In the memory task, subjects memorized five words, each presented for 1.6 s at 2.6 s intervals. After that, one word was presented, and subjects were asked whether they saw it and what number they saw it. In the following NF, theta (4-8 Hz) band power of PHG during word memorization was visualized as the height of a new bar with those of all previous trials for 10 s. Subjects were asked to raise the bar. Subject 1 underwent 6 sessions and subject 2 underwent 5 sessions. In session 2 of subject 2, only 17 trials were conducted due to a technical error. In this study, no control condition was included.

Data Analysis: After reducing the epileptic activity, the ratio of theta band power to total (0.5-32 Hz) band power were extracted. A total of 20 trial band power ratios were added and averaged. One-way repeated measured ANOVA was used to statistically compare the band power ratios for the sessions.

III. RESULTS

In the case of subject 1, theta band power ratio gradually increased from session 2 along with the progress in the NF training, and the effect of the number of sessions was significant ($F(5,95) = 13.41$, $p < 0.001$) (Fig. 1). However, in the case of subject 2, there was no rising trend and significant difference across sessions.

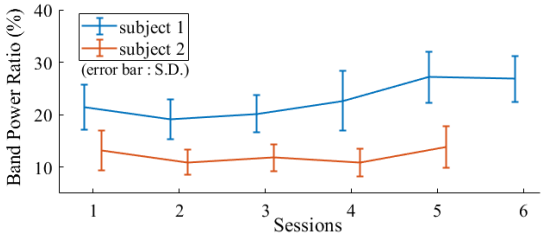

Figure 1. Changes in mean theta band power ratio throughout NF training.

IV. DISCUSSION & CONCLUSION

The result of subject 1 showed that NF training could activate neural activity related to memory encoding in the PHG. On the other hand, in subject 2, upward trend in theta band power was not observed. However, theta band power ratio of subject 2 was generally lower in all sessions than in subject 1, suggesting that the lower frequency (~ 4Hz) band power ratio was higher than in subject 1. In other words, for subject 2, the lower frequency band power (~ 4Hz) may have been more important for memorization and more suitable for neurofeedback. A previous study [1] also reported the importance of 3Hz "slow-theta" oscillation in memory encoding. In future studies, we would like to expand the NF target range to lower frequencies and compare the effects of NF with the control condition.

REFERENCES

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