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著者	Toyoshima, Hisashi; Yamanoi, Takahiro; Yamazaki, Toshimasa; Ohnishi, Shin-ichi
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研究論文

SPATIOTEMPORAL BRAIN ACTIVITIES DURING HIRAGANA RECOGNITION TASK

Hisashi Toyoshima†, Takahiro Yamanoi*, Toshimasa Yamazaki** and Shin-ichi Ohnishi*

Abstract

The authors recorded nineteen-channel event related potentials (ERPs) during recognition of Japanese characters; Hiragana (one type of phonetic characters). By field-sequential stereoscopic 3D display with liquid crystal shutters, a real word and a non-word were simultaneously and independently presented to the left (right) and the right (left) eyes, respectively. Each word consists of three Hiragana characters. Three subjects were instructed to press a button 3000 ms post stimulus when they understood the meaning of the visual stimulus. Equivalent current dipole source localization (ECDL) with three unconstrained ECD was applied to the ERPs. The ECDs were localized to the Wernicke's area at around 600 ms. The ECD for one left-handed subject was localized at the Wernicke's homologue. After that ECDs were localized to the prefrontal area, the superior frontal gyrus and the middle frontal gyrus. Then at around 800 ms, the ECDs were localized to the Broca's area and after that ECDs were localized again to the Wernicke's area and then to Broca's area.

1. INTRODUCTION

According to researches on the human brain, the primer process of visual stimulus is processed at first on V1 in the occipital robe. In the early stage, a stimulus from the right visual field is processed on the left hemisphere and a stimulus from the left visual field is processed on the right hemisphere. Then the process goes to the parietal associative area [1].

Higher order process of the brain thereafter has its laterality, for instance, 99% of right-handed and 70% of left-handed have their language area on the left hemisphere as the Wernicke's area and the Broca's area [2], [3].

Some of the present authors have used the same methodology as the preceding research [4]. By presenting Kanji and Hiragana word to the subjects, they measured electroencephalograms (EEGs) under those stimuli and both data were summed and averaged according to the type of the stimuli and the subjects in order to get event related potentials (ERPs). Each peak of ERPs were detected and analyzed by the equivalent current dipole source localization (ECDL) [5] at that latency by use of two dipole model. In both cases of Kanji and Hiragana recognitions, from the early components of ERPs, ECDs were localized to the V1, V2 and the inferior temporal gyrus (ITG), after then ECDs are localized to the Wernicke's area and the Broca's area. These results agree with the results on MEG, PET or fMRI.

In the present paper, we have used the same methodology as used in the preceding our research. We have estimated spatiotemporal brain activity during Hiragana recognition task by using the ECDL of three dipole model.

† Japan Technical Software Co.,Ltd.
* Department of Electronics and Information Engineering, Graduate School of Engineering, Hokkai-Gakuen University
** Department of Bioscience and Bioinformatics, Kyusyu Institute of Technology

2. EEG MEASUREMENT EXPERIMENTS ON MENTAL TRASLATION

2.1 Experimental apparatus and method

A. Experimental Apparatus and Method

Two subjects are from 21 to 22 year-old and have normal visual acuity. One is the right dominant hand and the other is left. The subjects put on an electrode cap (ECI, Electrocap International) and watched the 21inch CRT 30cm in front of them. Their heads were fixed on the table on a chin rest. Each word was displayed on the CRT stereoscopic display system with field-sequential liquid crystal glasses. The system consists of a personal computer, vertical synchronizer (Solidlay) and field-sequential liquid crystal glasses. This enables to control the simultaneous signals by infrared. With the system, a word (or non-word) to the left eye and a non-word (or word) to the right eye are displayed independently.

Words to be displayed had been stored on the disk of PC as a file and they were presented at random. Electrodes on the cap were followed to the International 10-20 system (Fig. 1) and two electrodes were fixed on the upper and lower eyelids for eye movement monitoring. Impedances were adjusted to the range from 2 to 5kΩ. Reference electrodes were put on both earlobes and the ground electrode was on the base of the nose. Electroencephalograms (EEGs) were recorded on the digital EEG measuring system (NEC Corporation, Synafit EE2500); the amplitude was 5 μV/V, the frequency band was between 0.15 and 100 Hz. Analog outputs were sampled at a rate of 1kHz and stored on a hard disk in a PC (Fig. 2).

B. Stimulus conditions and presentations

Words composed of Hiragana characters were presented to the subjects. We gave two types of words simultaneously to a subject's eyes.

One type is a real word composed of Hiragana. The other is a non-word that has no meaning and in a random order of a real word. By field-sequential stereoscopic 3D display with liquid crystal shutter, a word and a non-word were simultaneously and independently presented to the left (right) eye and right (left) eye, respectively. All the words are presented in vertical writing (Fig. 3).

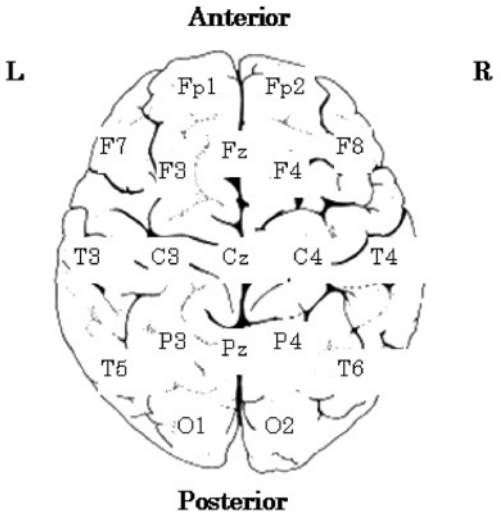

Figure 1. Positions of electrode in International 10-20 system

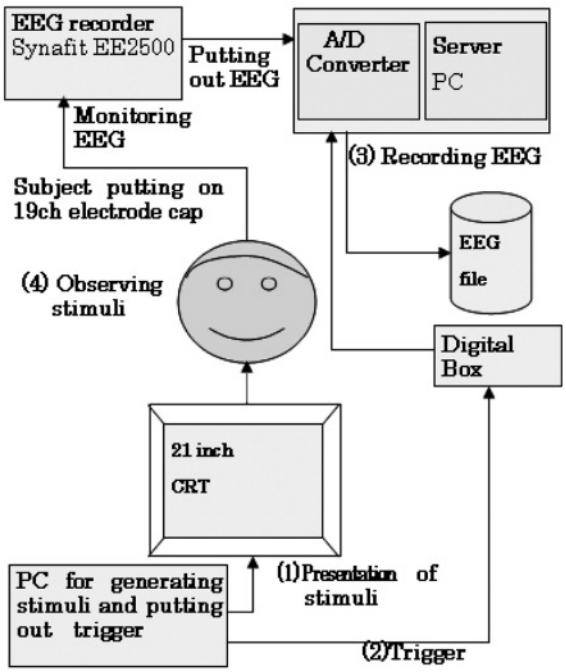

Figure 2. Experimental apparatus

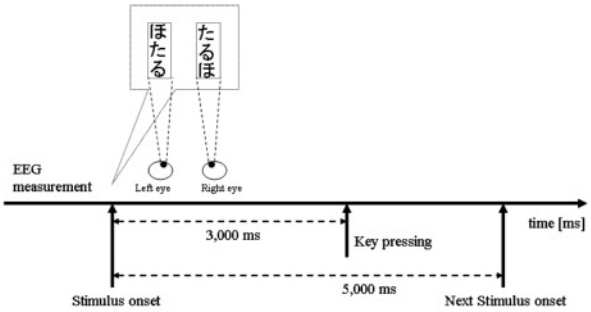

Figure 3. Time chart of experiment

C. Analysis by equivalent current dipole source localization

We have measured EEGs of each visual stimulus. In order to effectively execute the ECDL method, both data were summed and averaged according to the type of directions and the subjects in order to get event-related potentials (ERPs). Summing these ERPs of the types respectively, then the ECDL method was applied to each ERP by each subject. Because the number of the recording electrodes was 19, three ECDs at most were estimated by use of the PC-based ECDL analysis software "SynaCenterPro [5]" (NEC Corporation). The goodness of fit (GOF) of ECDL was more than 99 %.

3. RESULT OF ECDL ANALYSIS

A. Result of ECDL analysis before the Broca's area

Same as the preceding research [4], process of the Hiragana recognition is mainly through the left hemisphere. The ECDs were localized to the middle temporal gyrus (MTG) called the Wernicke's area at around 600 ms (Fig. 4). After that ECDs were localized to the prefrontal area (PFA) (Fig. 5, 7), the superior frontal gyrus (SFG) and the middle frontal gyrus (MFG) (Fig. 6). Then at around 800 ms, the ECDs were localized to the Broca's area (Fig. 8).

B. Result of ECDL analysis after the Broca's area

In the latency after the Broca's area, ECDs were localized again to the Wernicke's area (Fig. 9), the PFA (Fig. 10, 12), the left inferior frontal gyrus (IFG), the left MFG (Fig. 11). And then ECDs were localized again to the Broca's area at around 970 ms (Fig. 13).

4. DISCUSSION

In the case of Hiragana recognition, ECDs were localized to the language area; the Wernicke's area at around 600 ms, to the PFA, and

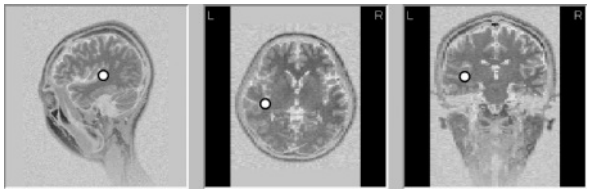

Figure 4. Example of ECD localized to the Wernicke's area at 586 ms (Subject NS)

Figure 5. Example of ECD localized to the PFA at 638 ms (Subject NS)

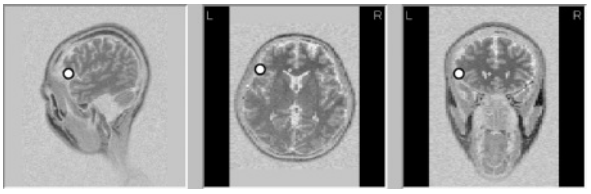

Figure 6. Example of ECD localized to the left MFG at 741 ms (Subject NS)

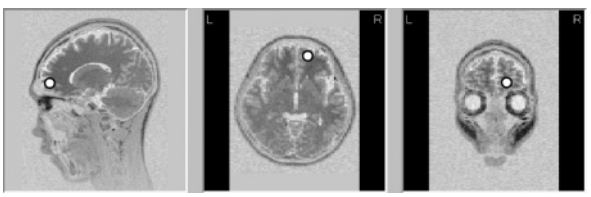

Figure 7. Example of ECD localized to the PFA at 766 ms (Subject NS)

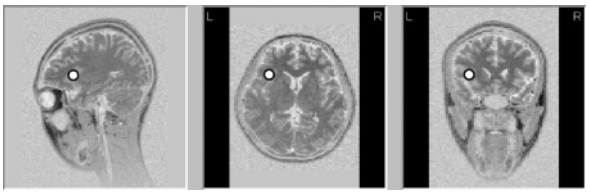

Figure 8. Example of ECD localized to the Broca's area at 807 ms (Subject NS)

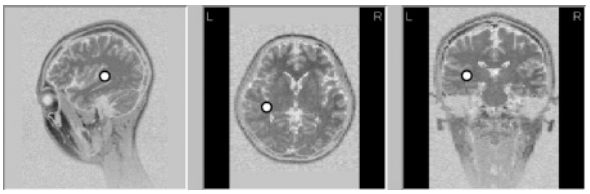

Figure 9. Example of ECD localized to the Wernicke's area at 809 ms (Subject NS)

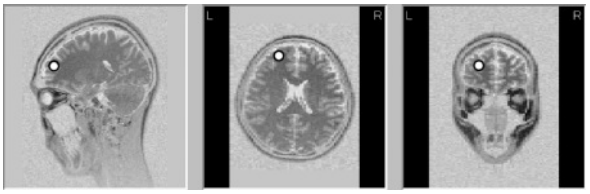

Figure 10. Example of ECD localized to the PFA at 881 ms (Subject NS)

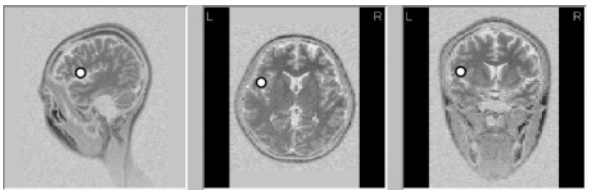

Figure 11. Example of ECD localized to the left MFG at 914 ms (Subject NS)

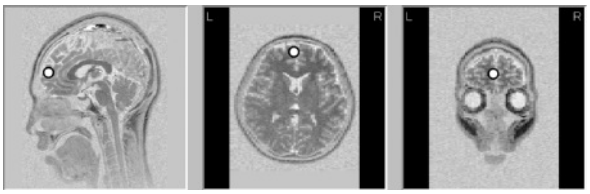

Figure 12. Example of ECD localized to the PFA at 953 ms (Subject NS)

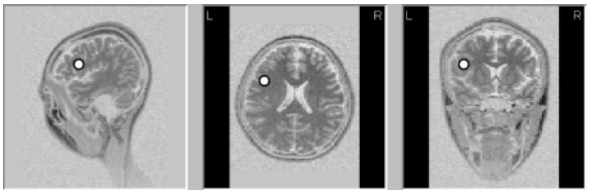

Figure 13. Example of ECD localized to the Broca's area at 977 ms (Subject NS)

to the left MFG. Then the ECDs were localized to the Broca's area around 800 ms, (Table I, Fig. 14). After the Broca's area, ECDs were localized again to the Wernicke's area, the PFA and the left MFG, and then again to Broca's area around 970 ms (Table II, Fig. 15).

The first cycle of spatiotemporal brain activity is also the same process in the case of directional Kanji recognition using three dipole models [6]. And these repeated cycles in spatiotemporal brain activity are also the same in the case of recalling sentences task by loci mnemonic system [7]. In the case of recalling sentences task, spatiotemporal brain activities are divided into some tasks; the language recognition task, the recalling task related locations and recalling task corresponding to the contents of sentences.

Presented stimuli in the present research were Hiragana characters which are one of phonetic words. So these spatiotemporal brain activities are supposed to be divided into

TABLE I. RELATIONSHIP BETWEEN LOCALIZED SOURCE AND ITS LATENCY BEFORE THE BROCA'S AREA Unit: [ms]

Subject	Wernicke	PFA	MFG	PFA	Broca
MY	593	677	712	749	810
NS	586	638	741	766	807
MT	615	634	711	758	822

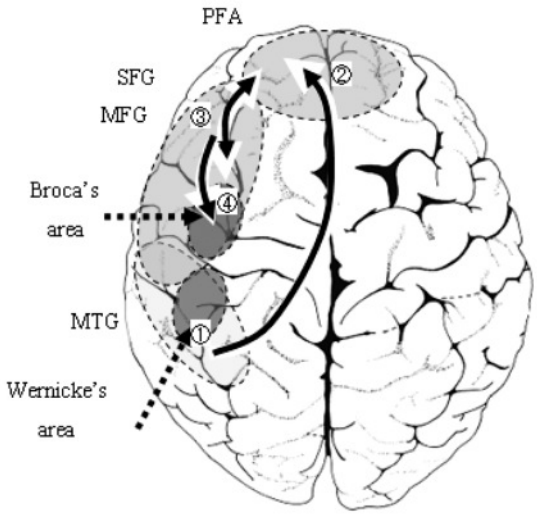

Figure 14. Spatiotemporal pathways before the Broca's area

TABLE II. RELATIONSHIP BETWEEN LOCALIZED SOURCE AND ITS LATENCY AFTER THE BROCA'S AREA Unit: [ms]

Subject	Wernicke	PFA	MFG	PFA	Broca
MY	830	861	903	941	973
NS	809	881	914	953	977
MT	825	873	910	953	972

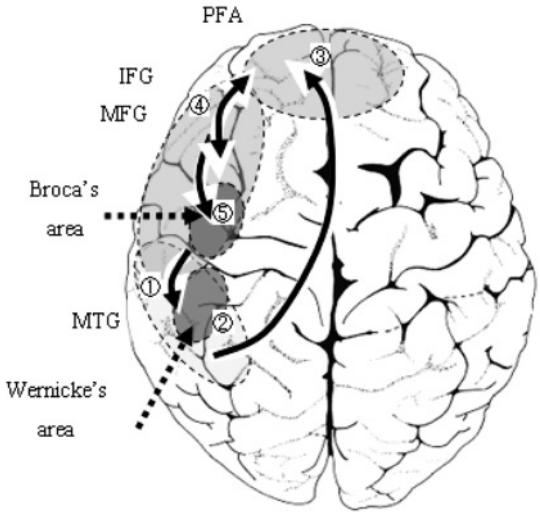

Figure 15. Spatiotemporal pathways after the Broca's area

two parts; a task for pronunciation recognition and a task for meaning recognition. This hypothesis is strengthened because this tendency was not observed in the case of Kanji recognition.

5. ACKNOWLEDGEMENT

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