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研究論文

Spatiotemporal Human Brain Activities on Recalling 4-Legged Mammal and Fruit Names

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Abstract

The authors have measured electroencephalograms (EEGs) from subjects observing images of 4-legged mammal and/or fruit, and recalling their name silently. The equivalent current dipole source localization (ECDL) method has been applied to the induced event related potentials (ERPs): averaged EEGs. The equivalent current dipoles (ECDs) were localized to the primary visual area V1 around 100 ms, to the ventral pathway (TE) around 270 ms, to the parahippocampal gyrus (ParaHip) around 380 ms. Then ECDs were localized to the Broca's area around 450 ms, to the fusiform gyrus (FuG) around 600 ms, and again to the Broca's area around 760 ms. According to the previous researches, the process of search and preservation in the memory is presumed to be done in the ParaHip. From the results of the present experiment, the authors supposed that both long shape and round shape visual stimuli are processes by Wernicke's area, but only long shape pass through angular gyrus (AnG) before arriving at Wernicke's area.

Keywords— equivalent current dipole source localization; recalling; 4-legged mammal names; fruit names; spatiotemporal brain activities

I. Introduction

From recent researches on the human brain, it is known that the primary process of visual stimulus is processed at first in the primary visual cortex area V1 in the occipital lobe, and that 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 in the early stage. Then the process goes to the parietal associative area [1].

Higher order process of the human brain thereafter has 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]. However, when one considers language recognition tasks, various parts of the brain associate. The associate activity not only involves the so called language area including Wernicke's area and Broca's, area, but also various part of the brain. There are some precedent studies on the sight agnosia [4], [5]. Regarding to these, one of the present authors has been investigating clinical studies for the sight stimulation [6], [7].

By presenting written words to the subjects using Japanese language typographic symbols of Kanji and Hiragana, some of the present authors

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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). Then to these ERPs, the equivalent current dipole source localization (ECDL) method [8] was applied to analyze spatiotemporal activities of the subjects. In both cases of Kanji and Hiragana recognition, they localized equivalent current dipole (ECD) nodes from early components of ERPs 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 [9]. These results agree with the precedent results on MEG, PET or fMRI.

The symptom, which is called category-specific disorders [6], is now in the clinical lesion studies. It is known that the lesions causing disabilities of naming and comprehension of objects are dissociate depending on the target categories, e.g. artificial or biological things.

Using the same methodology as the preceding research [10] – [13], some of the present authors had cleared human brain activities during language recognition or during image recognition.

In the present study, we had measured EEGs, in order to investigate the brain activity during subject watching the line drawings of 4-legged mammal and fruit and recalling a name of presented image. And each data was summed and averaged according to the type of the stimuli in order to get ERPs. Each peak of ERPs was detected and analyzed by the ECDL method [8].

II. EEG Measurement Experiments

One subject YY is a 22-year-old female and has normal visual acuity. She is right handed. The other subject KS is a 22-year-old male and also has normal visual acuity. He is right handed (TABLE I). The subjects put on 19 active electrodes and watched the 21-inch CRT 30 cm in front of them. Their heads were fixed on the table on a chin rest.

Each image was displayed on the CRT. Stimuli are simple monochrome image (line drawings). Presented images of four 4-legged mammals were giraffe, dog, bear and lion (Fig. 1). Those of fruits were cherry, watermelon, banana, persimmon, and apple (Fig. 2). First, a fixation point was presented, then a stimulus image was presented, both of them were during 3000 ms (Fig. 3). The subjects were directed to look at the object and memorize the image (B in Fig. 3), then recall the name of the object silently in their mind (D in Fig. 3). EEGs were measured on the multi-purpose portable bio-amplifier recording device (Polymate AP 1524, TEAC) by way of the electrodes and the frequency band is between 1.0 and 2000 Hz. Outputs were transmitted to a recording PC.

TABLE I. Data of Subjects

Subject	Dominant Hand	Age	Sex	Image
Y.Y.	R	22	Female	4-legged mammal, Fruit
K.S.	R	22	Male	Fruit
H.T.	R	22	Male	Fruit
Y.K.	R	22	Male	Fruit

We have measured EEGs on each visual

From the right, giraffe, dog, bear, and lion

Fig. 1. Presented images of 4-legged mammal.

From the right, banana, persimmon, cherry, watermelon, and apple

Fig. 2. Presented images of fruit.

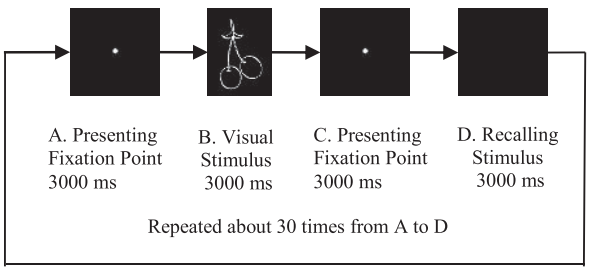

Fig. 3. Time chart of the present experiment

stimulus. So as to effectively execute the ECDL method, both data were summed and averaged according to the type of parts to get event-related potentials (ERPs).

Then the ECDL method was applied to each ERP. Because of the number of the recording electrodes was 19, theoretically, at most three ECDs could be estimated by use of the PC-based ECDL analysis software "SynaCenterPro [8]" (NEC Corporation). The goodness of fit (GOF) of ECDL was more than 99%.

III. Results of ECDL Analysis

After the latency around 400 ms, the ECDs were localized to the right ParaHip (R ParaHip) (Fig. 4), the right fusiform gyrus (FuG), the Broca's area (Fig. 5), the R ParaHip, the Broca's area, and the right fusiform gyrus (FuG).

Above mentioned spatiotemporal pathway accords with so called the ventral pathway which is said to be related with the primitive process of visual recognition. These areas are also related to the integrated process of visual recognition of picture and the recalling of word. Especially, the angular gyrus is said to integrate information of some modalities, so there might have recalled a word already at this stage. On the right inferior temporal white matter, a process progresses from recognition of a picture to recalling of a word.

These ventral and dorsal processes are done in series or in parallel. The relationship is resumed in TABLE II and III. Moreover, there is a possibility that these areas are also the language areas because these subject's dominant language areas were considered to be located in the right hemisphere from the precedent research.

According to TABLE II, we found the spatiotemporal pathway of the human brain activities as follows.

(Input pathway) V1 → R TE → R ParaHip → R FuG → R ParaHip → Broca

(Output pathway) Broca → L Insula → R ParaHip → Broca → R FuG → Broca → R AnG → R FuG → Wernicke → R Broca

In this study, we have estimated the human brain activities during the subject watching a line drawing of cherry. Some of the present authors have applied the same methodology to EEGs on watching a line drawing of persimmon (subject YK) and banana (subject HT). The results are resumed in TABLE IV.

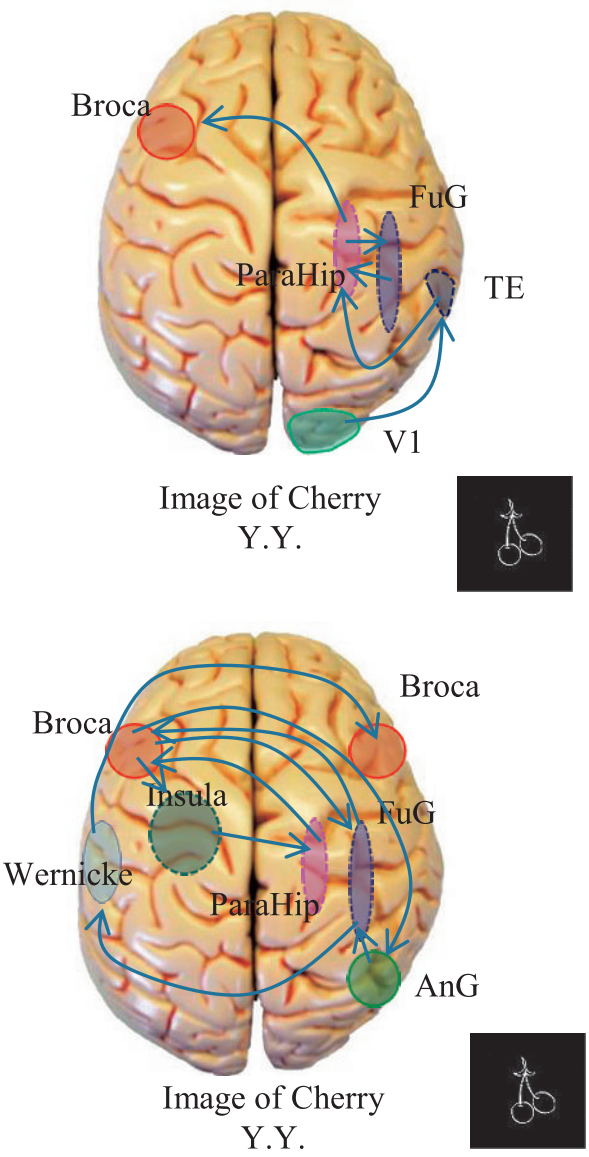

Fig. 4. Spatiotemporal Pathways on Recalling Name of Cherry
(Upper: Input Pathway, Lower: Output Pathway)

IV. Conclusion and Discussion

We have detected a pathway regarding with the recalling 4-legged mammal and fruit names. By use of ECDL method, ECDs were localized to

TABLE II. Relationship between Estimated ECDs and Its Latencies (4-legged mammal)

Subject	Y.Y.	Y.Y.	Y.Y.	Y.Y.
Image	Giraffe	Dog	Bear	Lion
V1	100	94	66	86
R TE	287	290	227	231
R ParaHip	362	332	336	313
R FuG	371	365	350	417
R ParaHip	464	470	470	464
Broca	506	537	501	530
R FuG	522	543	539	546
R ParaHip	548	569	553	557
R AnG	575			
Broca	609	634	593	588
R FuG	655	660	640	629
Wernicke	679	673	724	701
Broca	749	797	765	755

TABLE III. Relationship between Estimated ECDs and Its Latencies (Fruit)

Subject	Y.Y.	K.S.	K.S.	K.S.
Image	Cherry	Cherry	Water-melon	Apple
V1	88	119	84	114
R TE	276	277	248	330
R ParaHip	350	334	311	353
R FuG	361	377	337	363
R ParaHip	375 380	380	386	387
Broca	451	387	439	457
L Insula	466	468	500	468
R ParaHip	485 487	430 470	504	535
Broca	540	477 530		575
R FuG	606	585		602 630
Broca	645	601		
R AnG	652 655	683	648	
R FuG	678	754		
Wernicke	729	764	759	778
Broca	760(R)	828	784	792

the right angular gyrus (R AnG), the Broca's area and the Wenicke's area. These areas are related to the integrated process of visual recognition of picture and the recalling of word. Some of these areas are also related to the image recognition and word generation.

According to the brain activities of subjects KS and YY, we can confirm that most of activities

TABLE IV. Relationship between Estimated ECDs and Its Latencies (Precedent Research on Fruit)

Subject	Y.K.	H.T.
Image	Persimmon	Banana
V1	87	146
R TE	316	291
R ParaHip	384	387
R FuG	401	391
R ParaHip	416	401
Broca	512	436
L Insula	522	442
R ParaHip	548	508 534
Broca		569
R FuG		584
R AnG		626
R FuG		655
Wernicke	680(R)	662(R)
Broca	711	

on the Broca's area and the Wernicke's area are considered to be the language area, and these are concentrated on the left cerebral predominated in the left hemisphere. But, in the case of YY, the activity on the right Broca's homologue area is also located to 760 ms. From this, it might note that the activity on the right hemisphere is occasionally happened to her.

Also, according to the hippocampus, the ParaHip, and the fusiform gyrus, known as memory area, it is said that the memory areas in the left hemisphere mainly relate to language memory, and that of in the right hemisphere relate to non-language memory.

Regarding to the input pathway, the activities with the right ParaHip were estimated multiple times in the study, some kind of processing for the non-language memory is performed in recalling names, and it is thought that a searching, rearranging, and maintaining of the memory is always performed there. These results agree with the precedent our study on subjects YK and HT (Table IV).

Further, there was a case that ECDs were found to the FuG prior to the Wernicke's area. In the case of 4-legged mammal, the ECDs were estimated to the FuG for all of four stimuli. However, in the case of fruit, no activity was found on the FuG except cherry and banana. In

the case of watermelon, apple, and persimmon, their shapes are evident, on the other hand, shapes of cherry and banana are ambiguous, so searching, rearranging, and maintaining of the memory might be repeated.

And also activities are found to the left insula. The insula is said to be related to the taste of the food, and we think that both cases are related to conscious greed of the taste in fruit stimulus. No activities to the insula were found in the cases of 4-legged mammal. These facts were also observed in the previous research on persimmon and banana (TABLE IV).

Regarding to the output pathway, in the case of "giraffe", "cherry", and "banana", the activity on the angular gyrus, the Broca's area, and the Wernicke's area are found. The angular gyrus is also said to be concerned with a language. The ECDs, which is priory estimated on the angular gyrus, then estimated on the Wernicke's area. It is thought that integration of input information was carried out in this area.

However, in the case of "dog", "bear", "lion", and "persimmon", no ECD was localized to the AnG. We think that a factor which is common to those stimuli relates the AnG, but that "giraffe" is different from those. From this, we can assume as follows. A long shape visual stimulus and/or a not normal shape has complex shape compared to a round shape. It was processed through the AnG before the Wernicke's area. However, that a round shape visual stimulus and/or a normal shape is relatively simple, and it was processed the Wernicke's not passed through the AnG.

Back to the case of "watermelon", ECD was located to the AnG. But it has round shape visual stimulus. However, we can suppose that when the stimulus of "watermelon" was displayed, almost all the subjects noticed not the shape itself, but the vertical stripe of the watermelon. The vertical stripe is the long shape stimulus, so we can conclude that it does not run in contradiction.

One of the present authors Otsuki examined the patients who are difficult to recall the name of things. They were presented pictures and requested to name them. As a result, the patients couldn't recall the name of the round shape fruits, but they could recall the name of "watermelon" in spite of the round shape fruits. That result closely relates to the result of the present study [7].

As an application of the present study to the medical field, it may help to determine the cause of a patient's aphasia, and also, to provide a means of new communication to/from the people handicapped. It is also interesting that our results localized by the ECDL analysis accords with the lesion part that is seen in a patient having difficulty in remembering a word. In addition, it is not known too much on the diachronic change in the clinical studies. Further, as the ability for a name, it is known that there exist differences for a shape. The study may be related to the difference of the shape. And biometric data as the EEG is said to be one of the complex systems that interact strongly non-linear element. This may help to understand the complex system.

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