Spatiotemporal Activities in Human Brain during Recognizing Ambiguous Figure

Takahiro Yamanoi,
Faculty of Engineering,
Hokkai-Gakuen University,
Sapporo, Japan,
e-m ail: yamanoi@hgu.jp,

Tomoko Yonemura,
Integrated Education Center,
Meikai University,
Chiba, Japan,
e-mail: yonemura@meikai.ac.jp,

Hisashi Toyoshima,
Sapporo Branch,
Japan Technical Software,
Sapporo, Japan,
e-mail: toyoshima@jtsnet.co.jp,

Yahachiro Tsukamoto,
Emeritus Professor,
Meijo University,
Nagoya Japan,
e-mail: yytsukamoto@ac.auone-net.jp,

Shin-ich Ohnishi
Faculty of Engineering
Hokkai-Gakuen University
Sapporo, Japan
e-mail: ohnishi@hgu.jp

***Abstract*—To treat higher order brain dysfunction, it is necessary to identify the location of each function. In Japan, a super-aging society is progressing, and many dysfunctions such as cerebral infarction have occurred. The fMRI analysis is not enough to identify the position of dysfunction in detail. The authors had tried to elucidate higher order brain functions. In the paper, the authors have measured electroencephalograms (EEGs) from subjects (MK and RE) who were observing four images of ambiguous monochrome line pictures. The equivalent current dipole source localization (ECDL) method has been applied to those Event Related Potentials (ERPs): averaged EEGs by each figures and trials. The paper reports the comparison results of "Saxophone player and Girl's face." In the case of the Saxophone player, the process was done over a latency from 400ms to 1000ms, however for the Girl's face image, the corresponding process was completed relatively quickly and ended the latency around 800ms. Especially in the case of Girl's face, ECDs were localized to the right and the left angular gyrus (AnG) around 370ms and to the right post central gyrus (PstCG) around 415ms, then by way of language areas, ECDs were localized again to the right and the left AnG around 520ms. It has been clarified in our previous study that activities on the angular gyrus (AnG) are important to discriminate the unusual shape of presented images. This fact is confirmed also in this work.**

Keywords-Electro-encephalogram; Electro-encephalogram; Equivalent Current Dipole Localization Method; Ambiguous Pictures; Brain Activity.

I. INTRODUCTION

To elucidate brain function, many instruments have been used nowadays, however, to detect activities in milli second order was nothing sufficient but using EEGs. The authors compare the results of an attempt to analyze EEG from two subjects M K and R E during recognizing an ambiguous image of a saxophone player and/or a girl's face among four types of images. First, the authors compared each latency of EEGs between in cases of the saxophone player and the girl's face. EEGs were averaged and summed by each 19channel for each image and the event related potentials (ERPs) were obtained. The authors analyzed spatiotemporal activities and pathways in the brain by using the equivalent current dipole localization (ECDL) method [1], as our previous EEGs experiments. To elucidate brain function, many instruments have been using nowadays, however, to detect activities in milli second order was not sufficient but using EEGs.

Figure 1. Presented Ambiguous Images (Grey dots are introducing points to one of them.)

Ambiguous figures are often used to elucidate the mechanism of perceptual alternation and attention (cf. [2]), which are concerned with the multi stable perceptual phenomena. Some of the present authors had tried an experiment by using the eye mark camera EMR-9 (NAC Co.), to see if imposing the introducing point in the figure is helpful to recognize each image. The insert of introducing point proved to be effective, because obtained results had differences in locus of each eye movement, however, that could not elucidate activities in the brain. The previous researches using fMRI to examine the brain information processing suggested that the activities on the frontal lobe [3] and the right parietal lobe [4] are largely involved in processing images. However, the results of eye mark camera were not able to point at the area. In this study, it is examined that the activity of the AnG can be seen where the previous research elucidated. In section II, procedure of the experiment and the analysis of EEG data are explained. In section III, the results of ECDL method are summarized. Section IV presents a discussion of the results and the future work.

II. EEG MEARSUREMENT EXPERIMENT AND ANALYSIS

Two subjects M. K. and R. E. are 22-year-old females and have normal visual acuity. They are right-handed. The subjects put on 19 active electrodes and watched the 21inch PC monitor screen 30 cm in front of them. Their heads were fixed on the table on a chin rest.

Stimuli are simple monochrome figures of ambiguous picture (Figure 1). First, a fixation point was presented, then a stimulus was presented, both of them were during 3000ms (Figure 2). EEGs were measured on the multi-purpose portable bio-amplifier recording device (Polymate AP1524, TEAC) by way of the electrodes and the frequency band is between 1.0Hz and 2000Hz. Outputs were transmitted to a recording PC. Each position of electrode was measured in the three dimensional coordinate on each experiment by the subjects. These electrode positions were used in applying ECDL method with MRI of the subject.

By use of the equipment, the authors have measured

 ISBN: 978-1-61208-759-7

EEGs on each visual stimulus. So as to effectively execute the ECDL method, both data were summed and averaged according to each channel of EEGs, each type of figure, and each subject to get ERPs. Then, the ECDL method was applied to each ERPs. 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 [2]" (NEC Corpo- ration). Selected results of the goodness of fit (GOF) of ECDL were more than 99 %. Estimated EEGs were super im- posed on MRIs from the subject.

The authors presented four types of monochrome images (Figure 1) to the subjects and measured EEGs during recognizing presented images. Among four images, the authors will report compared results between the saxophone player and the girl's face by estimated latency. One extra channel

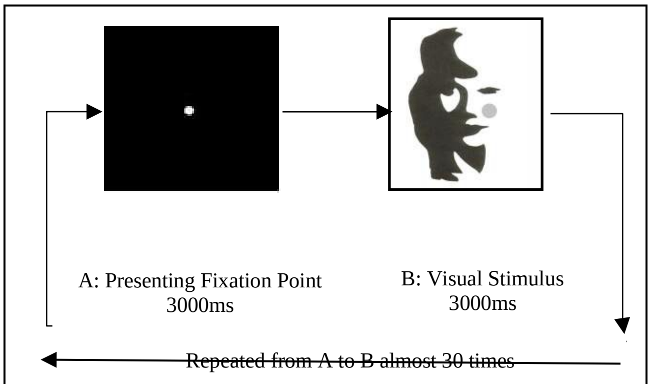

Figure 2 Time Chart of Present Experiment (In Case of Girl's Face)

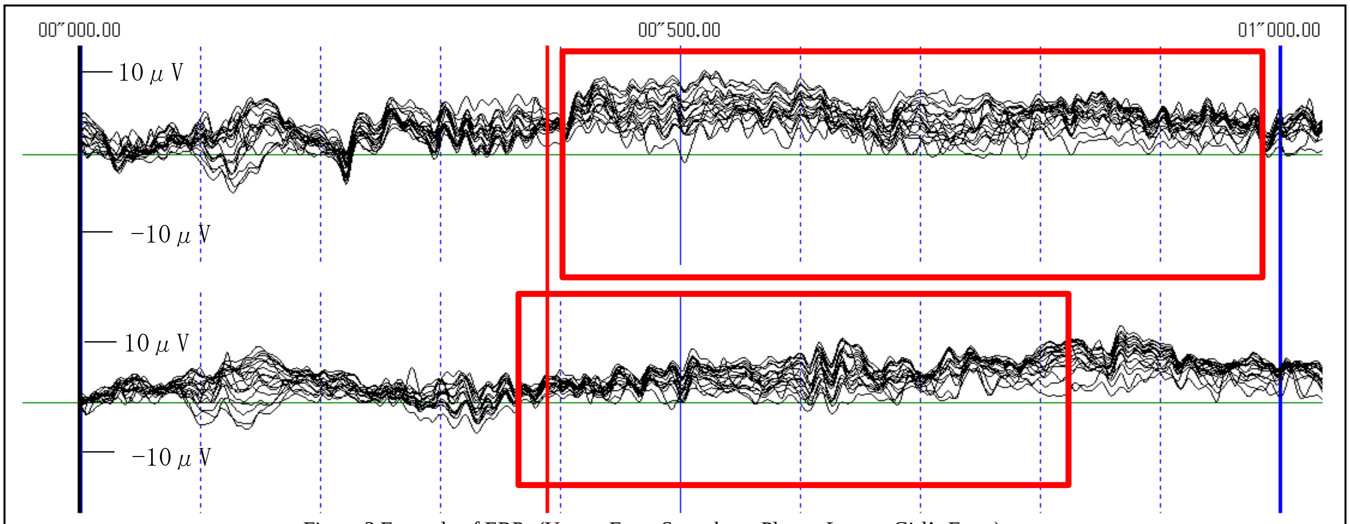

Figure 3 Example of ERPs (Upper: From Saxophone Player, Lower: Girl's Face.)

TABLE 1. RELATIONSHIP BETWEEN ESTIMATED ECD AND LATENCY IN EVENT RELATED POTENTIALS FOR SAXIOPHONE PLAYER (SUBJECT: M. K.)

Brain Part	L MFG	L PrCG	L ParaHip
Latency	336	339	406
R FuG	R PrCG	Broca	Wernicke
446	501	586	646
R ITG	R ParaHip	R ITG	Broca
653	672	676	687
R ParaHip	L AnG	Broca	
771	814	890	

TABLE III. RELATIONSHIP BETWEEN ESTIMATED ECD AND LATENCY IN EVENT RELATED POTENTIALS FOR SAXIOPHONE PLAYER (SUBJECT: R.E.)

Brain Part	L PrCG	Wernicke	R ParaHip
Latency	408	417	468
Broca	L AnG	R PrCG	L ParaHip
473	513	519	535
Broca	Wernicke	R FuG	L AnG
560	621	690	733
Wernicke	Broca	L AnG	
737	744	762	

TABLE II RELATIONSHIP BETWEEN ESTIMATED ECD AND LATENCY IN EVENT RELATED POTENTIALS FOR GIRL'S FACE (SUBJECT: M. K.)

Brain Part	L AnG	R AnG	L AnG
Latency	387	388	397
R PstCG	R SFG	Broca	L AnG
416	427	433	434
L AnG	R FuG	R FuG	R FuG
439	440	455	483
L AnG	R AnG	R Hip	
514	579	587	

TABLE IV. RELATIONSHIP BETWEEN ESTIMATED ECD AND LATENCY IN EVENT RELATED POTENTIALS FOR GIRL'S FACE (SUBJECT: R. E.)

Brain Part	L AnG	R AnG	R PstCG
Latency	362	369	415
L SFG	Wernicke	R ParaHip	R MFG
424	430	457	475
R Hip	R MFG	R MFG	L PrCG
482	489	495	517
L AnG	L AnG	R Hip	
525	527	574	

was used as trigger of the beginning of presentation of figure, and was recoded as a pulse. This pulse timing was used as a marking index, and summed by figure type and by recognizing result individually, to obtain ERPs.

In the experiment, a gazing point was presented for 4 seconds at the center of the screen to the subjects, and this was used as the screen masking, after that, a visual stimulus was presented for 3 seconds at the center of the screen. The above cycle was repeated 40 times, and these were put together as one course, and the measurement of two courses were made into one set. The visual stimuli were presented at random.

The authors applied the equivalent current dipole estimation (ECDL) method [1] as same as the previous researches. In general, ECDL method places ECD in the head model and calculates the theoretical value of electric potential distribution on the scalp "forward problem" and optimizes the ECD parameter so that the error between theoretical value and measured value is minimized. To solve so called "inverse problem" analytically result in solving the defect optimization problem, and is solved using a numerical analysis method in which initial values are set at grid points. The head model was modeled as three layers of concentric spheres of different conductivity: scalp, skull and cortex.

MRI of brain from each subject was used to set up the concentric sphere model of the head. In addition, the accuracy and reliability of the estimation results were evaluated by the values of Goodness of fit (GOF) and statistical confidence limits, respectively. The authors used PC version dipole estimation software (SynaCenterPro: NEC) for these analyses. Among the estimation results, the results with a GOF value of 99% or more and a 95% confidence limit of 1mm or less were adopted. In the dipole estimation software SynCenterPro used by the authors, the dipole of the estimated result is superimposed and displayed on the subject's MRI.

III. RESULTS OF ECDL ANALYSIS

After the latency around 400 ms, the ECDs were localized to the right ParaHip (R ParaHip) (Figure 4), the right fusiform gyrus (FuG), the Broca’s area (Figure 5), the R ParaHip or Hip, the Broca’s area, and the right fusiform gyrus (FuG) (Tables). Above mentioned spatiotemporal pathway accords with so called the ventral pathway which is 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, the authors found the spatiotemporal pathway of the human brain activities as follows. The authors call a pathway A until the first activity on the Broca’s area and after the first activity on the Brocas’s area then again activity.

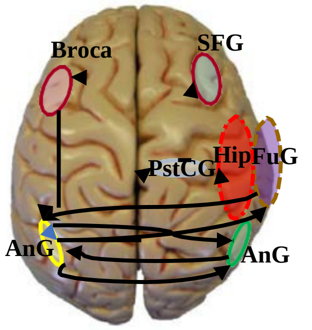

Figure 4 Spatiotemporal brain activity before R ParaHip.

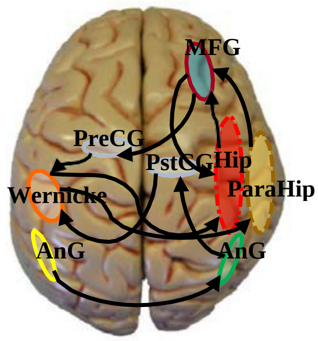

Figure 5 Spatiotemporal brain activity after R ParaHip.

Presented figures are shown in Figure 1. An example of gray introducing point is placed on each image. Figure 3 shows thee ERP of the subject M.K. In this result, the potentials so called as P300 and N400 could also be seen slightly. N400 is said to appear as a result of processing which involves semantic conflict. Although the presented images and their experimental situations are different, the authors analyzed the ECDs and compared the estimated latencies with the results from the precedent experiment on recalling of the fruit name [8]. It can be seen from Figure 2 that the response latency of the saxophone player's is slightly delayed from that of the girl’s face image, and the potential of saxophone shows a relatively high negative potential.

As shown in Figure 3, P300 was faintly observed with similar latency. The same is true for N400. The para hippocampus (ParaHip) was estimated as the processing site at this latency. As for the whole process, in the case of the saxophone player, the process can be seen over a latency of 400ms to 1000ms, but for female face images, it can be confirmed that the corresponding process is completed relatively quickly and the latency is around 800ms.

As shown at the beginning, regarding the recognition of language, the path in the first half and the second half of processing is assumed. From this, in the subject MK, in the estimation from the ERP regarding to the saxophone player, a pathway obtained is:

L MFG → L PrCG → L ParaHip → R FuG →R PrCG → Broca → Wernicke →R ITG →R ParaHip → RITG → Broca →R Hip → L AnG → Broca,

the processing route in the second half after L MFG was obtained and shown in Figure 5.

It was relatively difficult to estimate the position due to the early response of the initial visual processing, however, result pathway,

L AnG → R AnG →L AnG → R Pst CG →R SFG →Broca → L AnG → R FuG → L AnG ⟶R AnG →R Hip

was obtained. Furthermore, within a short latency, several loop responses have been observed. These results were shown in Figure 4 of the first half pathway and Figure 5 of the second half. Although this result was roughly confirmed in the case of subject RE, it is considered that in addition to the comparison between the presented images, a detailed comparison and examination between the subjects is required

IV. Conclusion and Futurework

From the results from previous studies on fruits and animals [8], according to the difference between normal shapes (round ones) and non-normal shapes (long ones or angled ones), in the former case, no ECD was estimated on the right AnG. The presented figures in this study are ambiguous figures, on considering these as well as the previous study, it is apparently not ordinary shape, so it is thought that ECD is estimated to R AnG. If processing in 700ms just before the high potential in Figure 2 was reaction from the FuG, the AnG, and the TE in the right hemisphere, the shape pro- cessing is clearly performed in that period. In particular, the right AnG is supposed to be the shape processing area, that has been clarified in the previous studies by Yamanoi et al. It is interesting that the ECD on this area was also estimated for the ambiguous figure. Furthermore, the authors would further investigate and clarify in more detail what role the N700 component plays in shape processing, including the results of previous studies. The authors had recorded EEGs for the other ambiguous figures, so it will be hoped to continue analysis on the other cases and will compare the results each other. Although, the EEG experiment needs much time for preparation and for measure, it will be necessary to increase the number of subjects.

Acknowledgments

This research was partially supported by a grant from the Ministry of Education, Culture, Sports, Science and Technology for the national project of the High-tech Research Center of Hokkai-Gakuen University ended in March 2013. And also, this work was partly supported by JSPS KAKENHI Grant Number 16H02852.

The experiment was approved by the ethical review board of Hokkaido University.

References

[1] T. Yamazaki, K. Kamijo, and A. Kenmochi: “Accuracy of Multiple Equivalent Current Dipole Source Localization from EEG in Terms of Confidence Limits for Radial Distances”, Bio Medical Engineering, vol. 37, no. 4, pp. 336-341, 1999.

[2] J. Brascamp, P. Sterzer, R. Blake, and T. Knapen: “Multistable Perception and the Role of the Frontoparietal Cortex in Perceptual Inference”, Annual Review of Psychology, vol.69, pp.77-103, 2018.

[3] P. Sterzer and A. Kleinschmidt: “A neural basis for inference in perceptual ambiguity”, Proceedings of the National Academy of Sciences, vol.104, pp.323-328, 2007.

[4] R. Kanai, B. Bahrami, and G. Rees: “Human Parietal Cortex Structure Predicts Individual Differences in Perceptual Rivalry”, Current Biology, vol.20, pp.1626-1630, 2010.

[5] T. Yamanoi, H. Toyoshima, J-L. Vercher, E. Sanchez, and M. Sugeno: “Dominance of recognition of words presented on right or left eye -Comparison of Kanji and Hiragana”, Modern Information Processing from Theory to Applications, pp. 407-416, Elsevier Science B.V., Oxford, 2006.

[6] Y. Tanaka, T. Yamanoi, M. Otsuki, H. Toyoshima, S. Ohnishi, and T. Yamazaki: “Spatiotemporal Brain Activities on Recalling Body Names” (in Japanese), 22th Soft Science Workshop, pp.27-28, 2012.

[7] H. Toyoshima, T. Yamanoi, T. Yamazaki, and S. Ohnishi: “Spatiotemporal Brain Activity during Hiragana Word Recognition Task”, Journal of Advanced Computational Intelligence and Intelligent Informatics, vol. 15, no. 3, pp. 357-361, 2011.

[8] K. Sugimoto, T. Yamanoi, H. Toyoshima, M. Otsuki, S. Ohnishi, and T. Yamazaki: “Spatiotemporal Human Brain Activities on Recalling Tetrapod and Fruit Names”, Engineering Research, Bullutin of Graduate School of Engineering, Hokkai-Gakuen University, pp. 45-50, 2017.