Spatio-temporal Analysis of Brain Activities on Aperture Problem

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***Abstract*— The aperture problem is a motion perception through a small window involved ambiguity both in a speed and a direction of the motion. It has been analyzed in various experimental approaches with knowledge about the early motion process in visual pathways of the human brain. Some of the present authors had investigated correct answer rate of the moving orientation and analyzed brain activities with different experimental parameters, such as line speed, radius of the apertures, and length of a line. The present authors recorded electroencephalograms (EEGs) from a subject and estimated their sources and latencies in the brain using the equivalent current dipole source localization (ECDL) method. We compared localized ECDs for two different line speeds (Type 1: 10msec/pixel and Type 2: 20msec/pixel). At the latency of the appearance of aperture, ECDs were localized along the ventral pathway concern with the recognition of form. After appearance of the line, ECDs were localized along the dorsal pathway concern with the recognition of movement. In addition, after appearance of another aperture, ECDs were localized to the middle frontal gyrus and the inferior frontal gyrus.**

I. Introduction

Many researches on the human brain have proved that the early process of vision is done in the occipital robe, the process of static vision is done along the ventral pathway, and dynamic visual stimulus is processed along the dorsal pathway.

The aperture problem is motion perception through a small window involved ambiguity both in a speed and a direction of the motion. It has been analyzed in various experimental approaches with knowledge about the early motion process in visual pathways of the human brain [1]. Nishina et al. [2] have already insisted that the recognition of visual perception strongly depends on the experimental parameters (radius, distance between circles, display time, etc). Some of the present authors had argued about the dependence of correct answer rate for moving speed of a bar in case of slow display speed [3], [4]. They had also investigated correct answer rate of the moving orientation of the bar (by psychophysical analysis) and had analyzed brain activities (by EEG analysis) with different experimental parameters, such as line speed, radius of apertures and length of a line [5].

In this paper, we recorded EEGs of a subject who had recognized changes of speeds of a bar. We also estimated their sources and latencies using the ECDL method [6]-[8] and compared with a previous study.

II. Experiments

A. Experimental Apparatus

Subject is a male university student aged in 22 and has normal visual acuity. His dominant hand and eye are right ones. The subject put on an electrode cap and watched a 21 inch CRT 30 cm in front of him. His head was fixed on a chin rest on the table. Stimulus had been stored on the disk of PC as a file and was presented in random order. The Positions of the electrodes on the cap were followed to the International 10-20 system and other two electrodes were fixed on the upper and lower eyelids of eye movement monitoring. Their impedances were adjusted to less than 10 kΩ. Reference electrodes were put on both earlobes and the ground electrode was on the base of 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 1 kHz and stored on a hard disk in a PC.

B. Conditions of Stimulus Presentation

We conducted an aperture experiment with four conditions (Fig. 1). We call a bar which moves in the back of the center circle *a base bar*, and a bar which moves in the back of the

added circles *a flanking bar*. Orientations of the bar's movement are four patterns (0, 45, 90 degree, and no line), and bar's speed are two types (Type 1: 10 msec/pixel and Type 2: 20 msec/pixel). Each stimulus is presented at random, and measurements are repeated sixty times on each stimulus; thus the total of the measurements is 480 times.

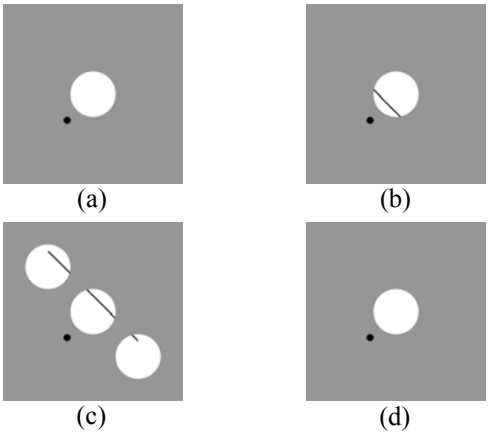

Fig. 1 Four types of aperture experiment; (a): A fixation point and a circle are presented at the center of CRT; (b): A bar is moving from the lower left side to upper right; (c): Two other circles are presented to both sides of center circle, and bar's orientation is perceived; (d): The center circle and the fixation point remain after two circles are disappeared.

The base bar moves from the left lower side (the starting point) to the upper right side. After two circles appeared on the both sides of the center circle, the subject would perceive as if the orientation of the base bar's movement was dragging with the flanking bar, and the base bar's direction changed into the same orientation with the flanking bar. We call this phenomenon "*optical illusion*". Through the experiment, radius, distance between circles, and length of a bar are fixed.

The present authors have recorded EEGs from one subject and estimated sources and their latencies using the equivalent current dipole source localization (ECDL) method, and compared with ECDs for two different line speeds.

III. Experimental Results

We measured EEGs of the Type1 and the Type2; both data was summed and averaged according to line speeds and moving patterns in order to obtain event related potentials (ERPs). The ECDL method was applied to each ERP with a PC-based ECDL software "SynaCenter" (NEC Corporation). An example of ERPs of Type1 is shown in Fig. 2.

Regardless to the orientations, the remarkable change of ERPs was observed around 250 msec in Type 1 and Type 2. The ECDs were localized to the visual area 1 (V1) (Fig. 3), to the visual area 2 (V2) (Fig. 4), to the visual area 4 (V4) (Fig. 5), to the temporal occipital area (TEO) (Fig. 6) and to the temporal area (TE) (Fig. 7) within 400 msec (Table 1 and Table 2); ECDs were localized along the ventral pathway, which concerns with the recognition of form. ECDs localized along the ventral pathway were derived from the appearance of the center circle, because the center circle appears at latency of 0 msec in the both types.

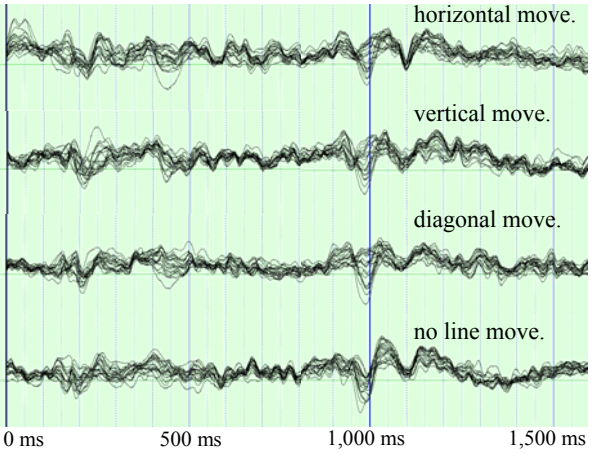

Fig. 2 An example of ERPs of Type1; horizontal (top), vertical (second), diagonal (third) and no line movements (bottom)

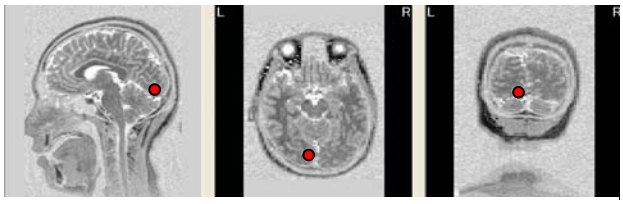

Fig. 3 An example of ECD localized to the left V1

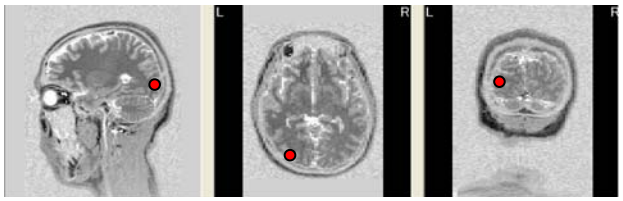

Fig. 4 An example of ECD localized to the left V2

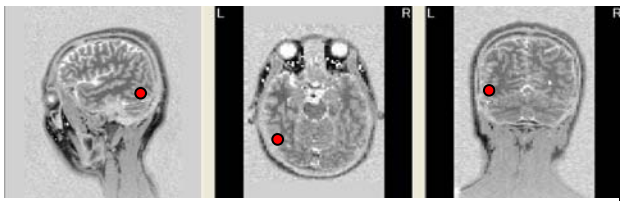

Fig. 5 An example of ECD localized to the left V4

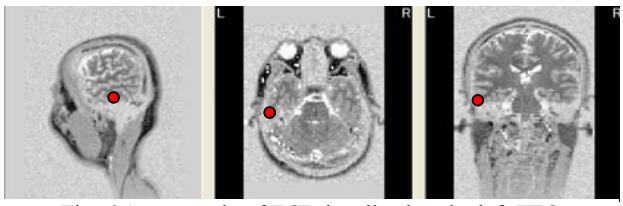

Fig. 6 An example of ECD localized to the left TEO

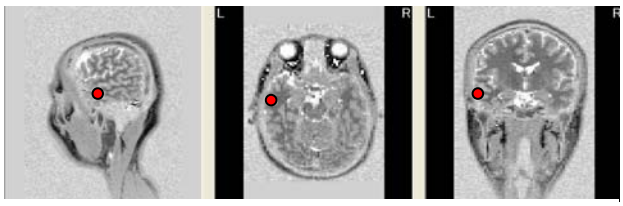

Fig. 7 An example of ECD localized to the left TE

Table 1 Relationship between localized source and its latency in case of Type1 (ventral pathway)

Moving direction	V1	V2	V4	TEO	TE
Horizontal	33	86	97	147	215
Vertical	54	109	165	314	400
Diagonal	52	130	239	281	369

[ms]

Table 2 Relationship between localized source and its latency in case of Type2 (ventral pathway)

Moving direction	V1	V2	V4	TEO	TE
Horizontal	30	75	175	259	364
Vertical	44	103	232	261	319
Diagonal	78	121	152	239	312

[ms]

Except for the moving pattern of no line, the change of ERPs was observed around 450 msec after the appearance of the center circle in Type 1 and around 600 msec in Type 2. ECDs were localized to the V1 (Fig. 8), to the V2 (Fig. 9), to the middle temporal gyrus (MT) (Fig. 10) and to the postcentral gyrus (PstCG) (Fig. 11) after the latency of 200ms in Type1 and after the latency of 400ms in Type2 (Table 3 and Table 4); therefore ECDs were localized along the dorsal pathway. The dorsal pathway relates to the recognition of movements. Because the base bar appears at 120 msec in Type 1 and at 340 msec in Type 2, ECDs localized along the dorsal pathway were derived from the movement of the base bar.

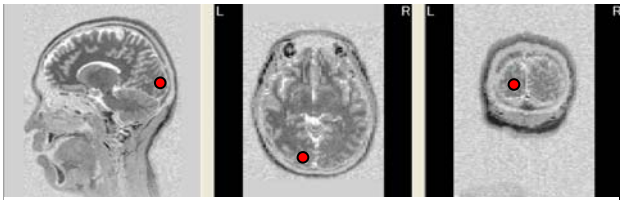

Fig. 8 An example of ECD localized to the left V1

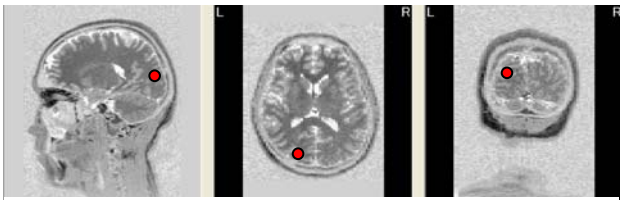

Fig. 9 An example of ECD localized to the left V2

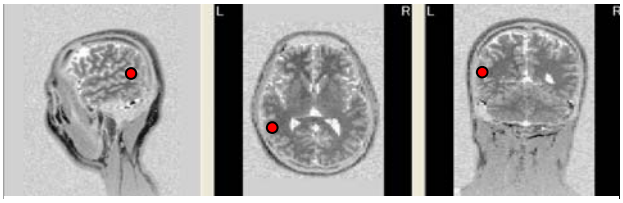

Fig. 10 An example of ECD localized to the left MT

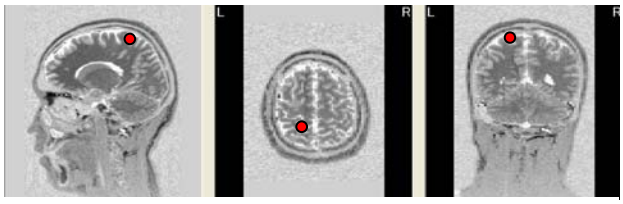

Fig. 11 An example of ECD localized to the left PstCG

Table 3 Relationship between localized source and its latency in case of Type1 (dorsal pathway)

Moving direction	V1	V2	MT	PstCG
Horizontal	232	319	426	619
Vertical	216	267	369	577
Diagonal	225	271	401	511

[ms]

Table 4 Relationship between localized source and its latency in case of Type2 (dorsal pathway)

Moving direction	V1	V2	MT	PstCG
Horizontal	457	498	592	638
Vertical	481	538	587	709
Diagonal	481	518	587	636

[ms]

By comparing the latencies of ERPs and these localized ECDs, we have observed that the latencies of localized ECDs along the ventral pathway correspond to the change of ERPs. Similarly, we have observed that the latencies of localized ECDs along the dorsal pathway correspond to the change of ERPs.

From 900 msec to 1,100 msec in Type 1 and from 1,700 msec to 1,900 msec in Type 2, the large change of amplitude was observed in any orientation. These latencies are just after two circles on the both sides were presented. ECDs were localized to the middle frontal gyrus (MFG) and to the inferior frontal gyrus (IFG) from 1,000 msec to 1,100 msec in Type 1. Similarly, ECDs were localized to the same parts from 1,800 msec to 1,900 msec in Type 2. When two other circles are presented, the subject perceives the orientation of the bar's movement. In addition, the MFG and the IFG relate to the spatial recognition as the working memory. Therefore, ECDs localized to the MFG and to the IFG were derived from the perception of orientation of the bar's movement.

IV. Conclusion

In this paper, we discussed the brain activity area of the perception in aperture problem depending on the speeds of a bar. As a result, no difference was observed on estimated areas regardless to types of the speed of a bar. ECDs were localized along the ventral pathway at the latency of the appearance of the center circle (Fig. 12). After the appearance of the base bar, ECDs were localized along the dorsal pathway (Fig. 13). Moreover, after two circles on both sides were presented, ECDs were localized to the MFG and IFG. These results are similar to the previous study.

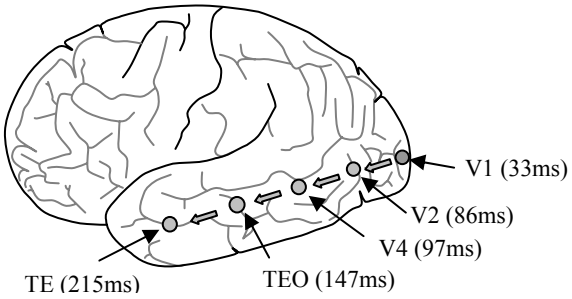

Fig. 12 Ventral pathway in Type 1

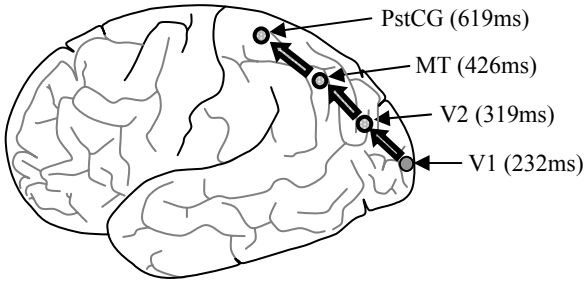

Fig. 13 Dorsal pathway in Type1

Acknowledgments

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