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Localization of the Brain Activity during Stereopsis for Random-dot Stereo-grams by Use of Spatiotemporal Dipole Source Localization Method

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Abstract

Binocular disparity is one of the most important cues for depth perception of human. Previously, some of the present authors have measured electroencephalogram (EEG) from subjects who were watching random dot stereograms (RDSs) with three types of binocular disparities : no or small or large disparity, and estimated brain areas where the visual information is processed, by use of equivalent current dipole source localization (ECDL) method. The results showed that : 1) the postcentral gyrus (PstCG) is involved in visual processing of stereopsis ; and 2) all-channels of averaged EEGs for all subjects had converged and the convergence time for the large RDS disparity is longer than that for the small one [1].

Application of the ECDL method to averaged data for small and large disparities showed that visual processing route before the PstCG consists of two pathways : one is from V1 to V4 and then to the TE field ; and the other is from V1 to the MT field and then to the PstCG. This result did not depend on the types of disparity. After the PstCG, ECDs were localized to the superior colliculus (SC) and the frontal visual field(FEF),both of which are involved in ocular movements. At interval between the FEF localization and the EEG convergence, ECDs were localized to the inferior frontal gyrus (IFG) and the middle frontal gyrus (MFG). For RDSs with large disparity, the IFG and MFG ECDs were estimated earlier than those for small disparity, while for large disparity the convergence time and the time when ECDs were localized to the IFG just before the convergence time were later than those for small disparity.

I. INTRODUCTION

The laterality of the human brain is a known fact [2][3]. Human early visual process for shape recognition passes through the visual area 1 (V1), the visual area 2 (V2), the visual area 4 (V4) and the temporal field (TE) ; these route is called the ventral visual pathway. On the other hand, human early visual process for spatial recognition passes through the V1, the middle temporal field (MT) and the postcentral gyrus (PstCG) ; called the dorsal visual pathway. And then, the logical thought is mainly performed in the left hemisphere and the intuitive process is performed mainly in the right hemi-

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sphere. Precisely, the left hemisphere is dominant for speech and language functions. It is also dominant for motor planning skills. The right hemisphere, on the other hand, is dominant for spatial abilities and for some aspects of music. There is also some evidence that it is more involved in various aspects of emotional behavior than the left hemisphere.

The present study deals with the human early visual process and the laterality of recognition of spatiotemporal perception. We measured electroencephalograms (EEGs) from subjects observing three−dimensional visual stimuli, and estimated human brain activities by use of the equivalent current dipole source localization (ECDL) method.

II. EXPERIMENT

Subjects are university students from 21 to 22 year−old and have normal visual acuity. Four subjects are male and two subjects are female. A dominant hand of nine subjects is the left one, and another subject is the right. The subjects put on an electrode cap (ECI, Electrocap International) and watched the 21 inch 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.

Electroencephalograms (EEGs) were recorded on the digital EEG measuring system (NEC Corporation, Synafit EE2500) ; the amplitude was 5μV/V, the frequency band was between 0.15 and 100Hz. Analog outputs were sampled at a rate of 1kHz and stored on a hard disk in a PC.

The system consists of a personal computer, a vertical synchronizer (Solidlay) and field−sequential liquid crystal glasses. This enables to control the simultaneous signals by infrared. With the system, a random dot stereogram (RDS) to the left eye and the other RDS to the right eye are displayed independently. Presenting Presented RDS is formatted foreground RDS and background RDS. Each foreground RDS is shifted horizontally ; we call horizontal difference of foreground RDS as disparity $\varDelta$ (Fig.1). The disparity generates foreground RDS to three−dimensional image (Fig.2).

A distance between foreground RDS and background RDS, which a subject observes is given by :

$$d = \frac{\varDelta d_b}{\varDelta + d_e} \qquad \ldots (1)$$

where de is a distance of a subject's pupil and db is a distance between a subject and the CRT.

In the present study, RDSs were presented in the center of CRT during 3000ms, then followed a masking period during 2000ms. Subjects were asked to push a key. (Fig.3).

III. EXPERIMENTAL RESULT

We have measured EEGs to the three disparities RDS experiments ; each EEGs data were summed

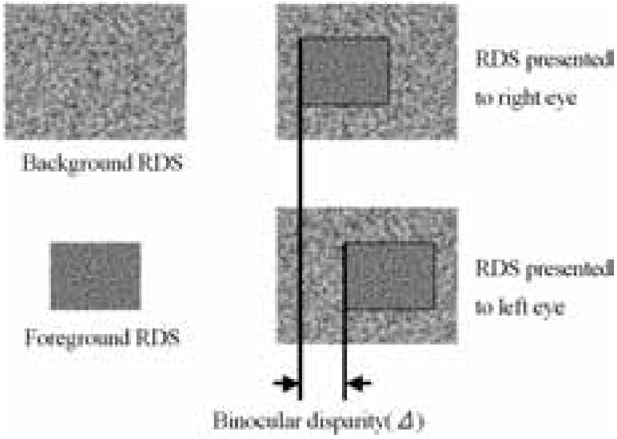

Fig. 1 Relationship between RDSs and binocular disparity (Δ)

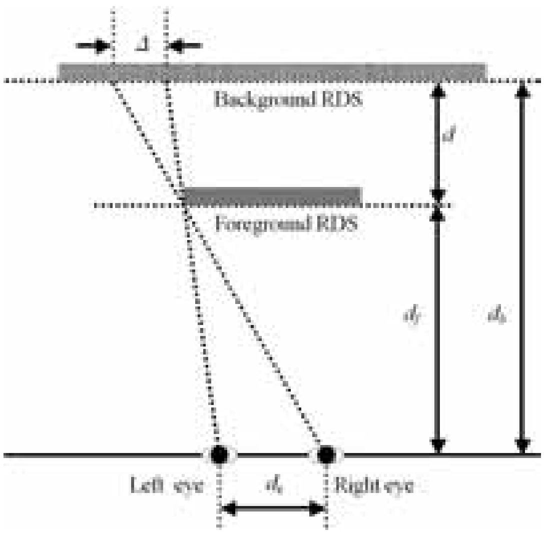

Fig. 2 Relationship between binocular disparity (Δ) and perceived depth

Fig. 3 The flow of the present experiment (repeated a total of 240times)

and averaged according to the disparities and the subjects, respectively, in order to get event related potentials (ERPs). Then the ECDL method was applied to each ERPs by each subject. Because of the number of the recording electrodes was 19, three ECDs at most were estimated by a PC-based ECDL analysis software "SynaCenter" [4] (NEC Corporation). The goodness of fit (GOF) of ECDL was

Fig. 4 Example of ECD localized to the V1 at 39ms (Subject KN) : ⊿ = 10 pixels

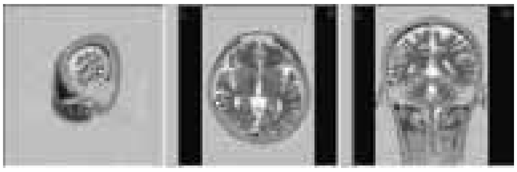

Fig. 5 Example of ECD localized to the left MT at 186ms (Subject KN) : ⊿ = 10 pixels

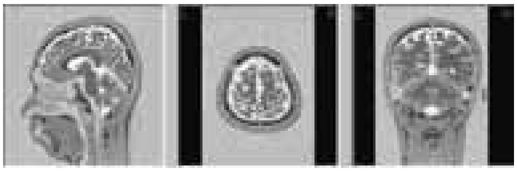

Fig. 6 Example of ECD localized to the PstCG at 382ms (Subject KN) : Δ = 10 pixels

Table 1 Relationship between localized source and its latency (before the PstCG)

[ms]

disparity	subject	V1	V4	MT	TE	PstCG
10 pixels	KN	39	102	186	310	384
	MH	33	103	179	319	388
	ED	49	105	182	332	379
	KA	42	112	170	353	379
30 pixels	KN	31	97	194	312	403
	MH	22	116	190	336	385
	ED	49	80	194	322	403
	KA	46	132	186	355	388

over 99.8%.

In the case of small disparity, ECDs were localized to the visual area 1 (V1) (Fig.4), the visual area 4 (V4), the middle temporal field (MT) (Fig.5). the temporal field (TE) and the postcentral gyrus (PstCG) (Fig.6).

In the case of large disparity, ECDs were localized to same position (Table1). And latencies localized to the same position in case of small disparity were almost the same.

After the PstCG, EEGs were converged around the latency of 700ms. In the case of small disparity, ECDs were localized to the frontal eye field (FEF) (Fig.7), the superior colliculus (SC) (Fig.8), the

Fig. 7 Example of ECD localized to the left FEF at 586ms (Subject KN) : Δ = 10 pixels

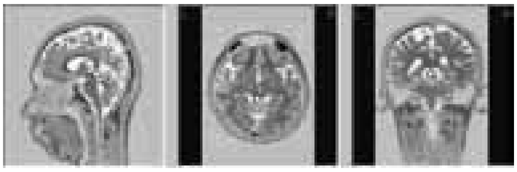

Fig. 8 Example of ECD localized to the SC at 594ms (Subject KN) : Δ = 10 pixels

Fig. 9 Example of ECD localized to the left IFG at 648ms (Subject KN) : Δ = 10pixels

Fig. 10 Example of ECD localized to the left IFG at 684ms (Subject KN) : Δ = 10pixels

Fig. 11 Examples of ECDs localized to left MFG and IFG (Subject KN) : Δ = 10pixels

left inferior frontal gyrus (IFG) (Fig.9) and the left middle frontal gyrus (MFG) (Fig.10). And before EEG's conversion, ECDs were localized to the left IFG, the left MFG (Fig.11) and the right MFG. These tendencies are almost the same regardless to disparity and subject.

IV. DISCUSSION

Before latency of 400ms, ECDs were localized to the V1, MT and PstCG ; along the dorsal visual pathway, and localized to the V4and TE ; along the ventral visual pathway. In this study, presented stimuli ware constructed shape and spatial factors. Then brain activities estimated the dorsal and ven-

Table 2 Relationship between localized source and its latency (after the PstCG)

[ms]

disparity	subject	FEF	SC	IFG (1)	MFG	IFG (2)	EEGs' conv.
10 pixels	KN	586	594	648	677	684	687
	MH	596	614	671	676	707	711
	ED	589	633	644	678	697	716
	KA	574	600	646	671	673	685
30 pixels	KN	556	560	613	643	720	721
	MH	569	570	591	626	716	734
	ED	545	552	596	663	719	731
	KA	552	567	605	650	697	707

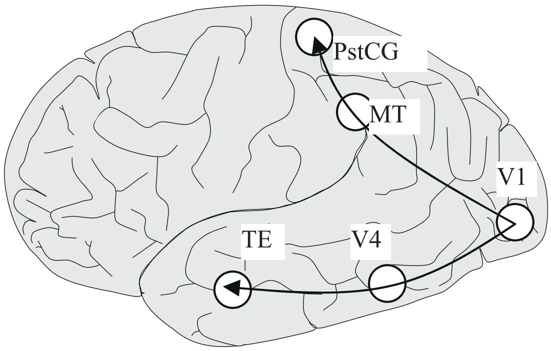

Fig. 12 Estimated dorsal visual pathway and ventral visual pathway (before latency of 400ms)

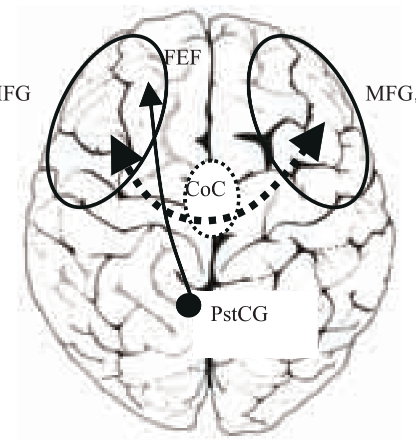

Fig. 13 Spatiotemporal transition of estimated ECDs (after latency of 400ms)

tral visual pathways simultaneously (Fig.12).

In comparison between case of small disparity and large disparity, localized ECDs were almost the

Table 3 Result of t–test for disparity parallax (after the PstCG)

Source	*t* value	Significance Level	Parallax (pixel)
FEF	−4.51	*	30
SC	−5.03	**	30
IFG	−6.40	**	30
MFG	−3.82	*	30
IFG	2.48	*	10
EEGs' conversion	2.33	*	10

**：１%，*：５%

same positions and latencies. Therefore, the spatial recognition is not activated in the early visual processing in human brain.

After latency of 400ms, ECDs were localized to the MFG and IFG in both hemispheres. These areas are called the working memory for spatial recognition. And left MFG is an area for the logical processing. Therefore, the depth judgment is divided a part of spatial recognition and a part of depth recognition.

In comparison between small disparity and large disparity, ECDs were localized to almost the same area, but their latencies had some difference. In the case of the small disparity, the latency localized to the FEF was later than that of large disparity, but the latency of EEGs' conversion were earlier than that of large disparity for each subject from the result of t–test (Table3).

In comparison with the result of this EEG study and results of fMRI study [5][6][7], estimated areas after the PstCG are almost the same. Moreover, the result of our study is localized to the visual areas. We suppose that the difference is caused by difference of measuring apparatus. The time resolution of fMRI is more than five seconds, although that of EEG we used is less than one millisecond. This means that measurement and analysis by use of EEG for detecting the activity in the brain is more useful.

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