The visual responses components of the three-dimension parallax stimuli

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Abstract

Viewing things in the three-dimensions (3D) is not a simple task for the visual system. To perceive 3D, the visual system has to reconstruct 3D configurations of objects, their structures and locations in space, from their 2D image on the retinas. In this study, we used the EEG to analyze the brain activities during the subjects watched the horizontal size disparity pattern and the vertical size disparity pattern (two similar binocular parallax activities) stimulus, and compared the difference between these conditions. The experiment results indicated that a bigger negative voltage appeared at occipitotemporal sites around 120 ms latencies when using the horizontal size disparity. However, there is no obvious change when using the vertical size disparity. All of the data in this experiment suggest that the brain activities activated by the horizontal size disparity pattern are stronger than those by the vertical size disparity.

Key words:

EEG, ERP, 3D parallax stimuli, P3, N1.

1. Introduction

Three-dimensions (3D) shape processing is a important function of the visual system for object recognition. 3D shape can be recovered from several visual cues, such as motion, texture, shading, or stereoscopic information [1]. There is a growing body of evidence that shape from monocular cues is processed both in the dorsal and ventral visual system of man [2, 3, 4, 5]. And the vision researches which focus on the visual system building up a 3D representation of the visual world using these depth cues has been a major interesting [6, 7, 8]. Achievement of such capabilities mainly rely on the following several functions of the human eye, which involves binocular parallax, motion parallax, the accommodation of eyes, the convergence of images by brain and so on. Among these kinds of depth cues, binocular disparity has been suggested to be critical in many psychophysical studies [9]. Neurons in striate [10] and extrastriate visual areas [11, 12]are sensitive to binocular disparity signals. Neurons that code 3D features of a visual surface by higher-order processing of disparity signals have been found in the parietal [13] and temporal [14, 15] association cortices.

The previous researches concerning brain activities on the visual stimulation focused on the eyes watching 3D objects. Recently, more and more studies concentrate on two separate 2D graphics which are seen by two eyes respectively. The emergent view projected to the retina from the two separate 2D images can reconstruct 3D visual representation of the real world. In general, most of the person can feel the 3D stereo visual effects through a short period of practice, but some person never have the receipt even after repeated practice.

Moreover, visual and auditory research studies have demonstrated that the P3 component could be elicited passively and the highest amplitude around the POz point [16, 17, 18, 19]. The P3 component of ERPs represents endogenous processing of a stimulus, involving stimulus classification speed and the ability to attend to and evaluate a stimulus [20, 21]. P3 latency negatively correlates with cognitive capability in normal subjects, such that shorter latencies are related to faster processing speed that reflects superior cognitive performance [22, 23, 24, 25]. As one unique component of the visual evoked potentials (VEP), visual N1 which originated in the primary visual cortex has the maximum volatility on the middle of the scalp or both side of the behind [26].

The objective of this paper is to give an analysis of EEG and visual ERP, which are based on the principle of binocular parallax, to analyze the brain activities when the subjects are watching the horizontal size disparity patterns and the vertical size disparity patterns (two similar binocular parallax activities) stimulus, and to compare the differences between these conditions. The experiment results indicated that a bigger negative voltage appeared at occipitotemporal sites around 120 ms latencies when using the horizontal size disparity. Nevertheless, there was no obvious change when applying the vertical size disparity. All of the data in this experiment exhibited that the brain activities activated by the horizontal size disparity pattern were stronger than those by the vertical size disparity, thus suggesting that under the normal conditions a human being gets the 3D effect easier under the horizontal size disparity than the vertical size disparity. Then, we compare the responses of POz on the occipital come from the parallax stimuli.

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2. Materials and Methods

Ten right-handed health volunteers (including five females, mean age 22 years, range 19-25 years, no elderly people, no bad habits such as smoking [27]) with normal or corrected-to-normal vision, who have not participated in the similar experiences before, are employed to implement the experiment. In the laboratory, the room is completely closed without any noise. The volunteers put heads on the front of the stereoscope. Every volunteer has three times of visual stimulus with 10 times. During the stimulus appeared, we recorded the single whether the volunteer watched the 3D images or not. In this study, horizontal size disparity and vertical size disparity [28] of effects as shown in Figure 1 are utilized as the stimulus.

The experiments are established on the stereoscope which was invented by Charles Wheatstone. The stereoscope is based on the fact that two images of the same scene, with slight horizontal disparity between them, are presented to the left and right eyes separately. The disparity between the two images will construct a 3D representation of the scene from 2D pictures and it will be interpreted as depth by the cortex. Besides, Julesz introduced the random-dot stereograms (RDS) into the field of stereoscopic vision and it had an important effect on later researches. The RDS is two identical images which are viewed dichoptially, and these two patterns are fused into one image and nothing but one speckled pattern is seen. Julesz demonstrated that the depth could be perceived even in the absence of any recognizable pattern. In our experiment, the stereoscope used is shown as in figure 2. The size of RDS patterns are 12×12 cm. Random-dot image (no disparity) is shown as in figure 1.

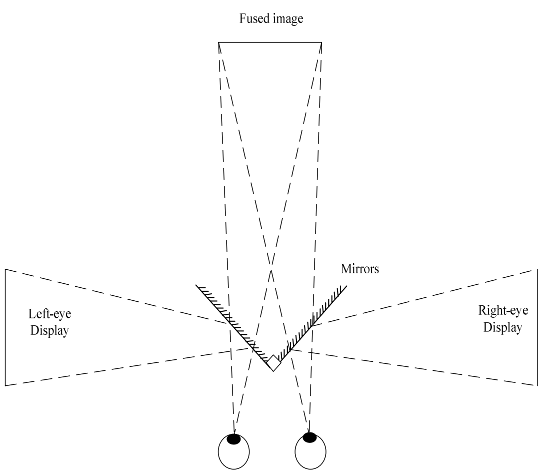

Figure 1. The model of stereoscope.

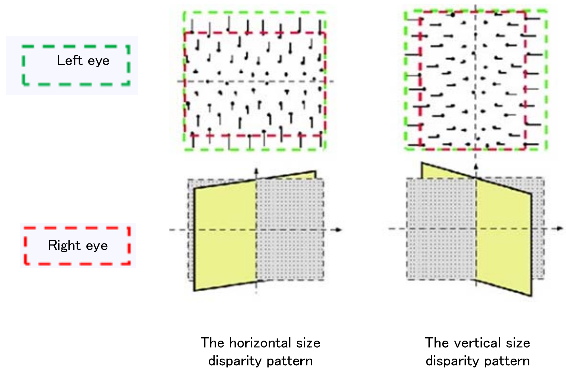

Figure 2. Disparity patterns and the percept surface.

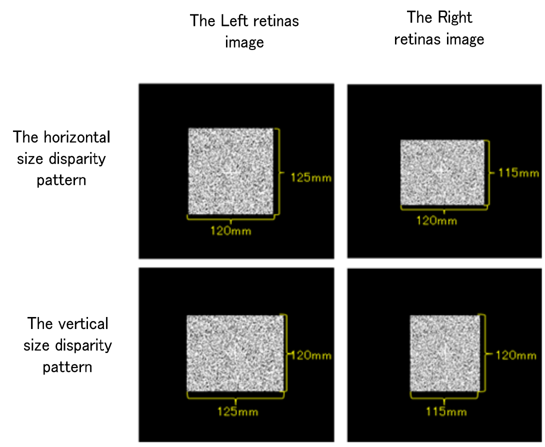

Figure 3. The random-dot images of horizontal size disparity and vertical size disparity for two eyes in the experiments.

In figure 1, the horizontal size disparity pattern denotes that the frontal surface with a horizontal magnification to the left eye is viewed with right-hand edge closer to the observer than the left-hand edge. The vertical size disparity pattern represents opposite effect for the horizontal size disparity. That is to say, the frontal surface with a vertical magnification to the left eye is seen with the left-hand edge closer to the observer than the right-hand edge. The experiment consists of two kinds of stimulus as the horizontal size disparity and the vertical size disparity in a small display. The effects of the parallaxes are shown in figure 3. The stimuli in the experiments are constituted by random pixels which are generated by the computer program.

To complement the single transmission, the Active Two System (ATS) produced by BioSemi Inc. with 64 channels is used to get the signals from the brain activity. Although it is not an easy task to explain an electroencephalogram (EEG or brainwaves), some characteristics of the EEG have been explained quantitatively [29]. The EEG is a kind of oscillated brainwave. Such brainwaves can be characterized using amplitude and frequency. In fact, many researchers have shown that EEG can be classified according to the difference between frequencies and can be compared with consciousness states. Furthermore, it is possible to abstract the effect by duplicating EEG at the same timing because the same kind of results at the same strength of stimuli removes the influence of the spontaneous EEG. Such spontaneous EEG is leveled by duplicating these noises. The event-related potential (ERP) will easily be obtained. All the original data is analyzed by the EEGlab which is the toolbox for processing continuous and ERP, MEG and other electrophysiological data using independent component analysis (ICA), time/frequency analysis, artifice rejection, and several modes of data visualization.

To analyze of the data, the first 300 ms after the presentation of each sensed 3D image is further investigated. The results of EEG will show the changes of the whole brain. For further discussion, the electrodes of the occipitotemporal cortex involving O1, O2, Oz, Pz, POz and CPz [30] will be extracted individually (figure 4).

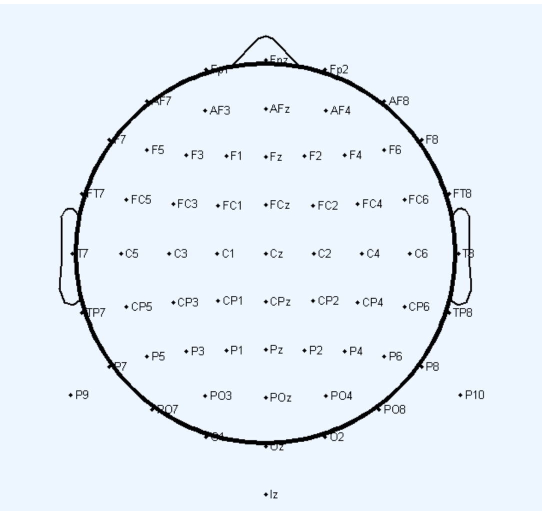

Figure 4. the location of the electrodes

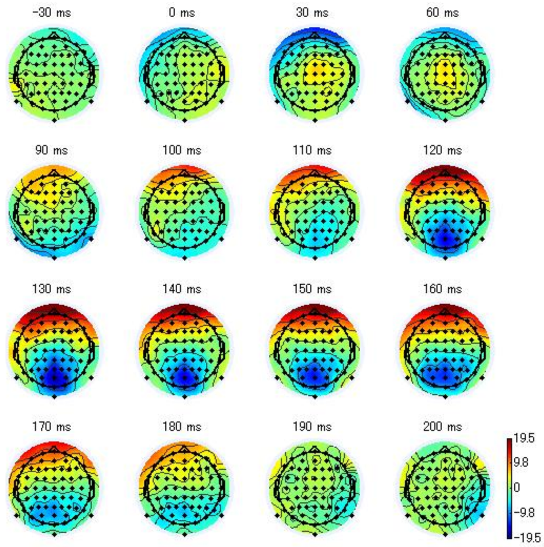

Figure 5. The ERP results of during the horizontal size disparity stimulus appeared 200 ms.

3. Results and Discussion

The ERP power changes during the horizontal size disparity stimulus appeared in every 30 ms is shown in figure 5. In this figure, the color region and gradual change show the intensity of power in ERP spectrum, i.e. the degree of brain activity. Therefore, it can be seen that the power of the occipital region becomes stronger after 110 ms during the stimulus appeared, thus indicating that the visual location has a different change during the 3D stimulus appeared. This figure also shows that the occipitotemporal cortex has activities obviously between 110 ms and 180 ms with the horizontal size disparity. This suggests that the brain is beginning to greet changes at 110 ms after the stimulus happened. The human being's 3D visual responses can be considered that the C1 appeared at 110 ms during the horizontal size disparity exposed. The blue color becomes deeper at 120 ms, but disappeared after 180 ms.

To give more light on this problem, the VEP of occipital region (POz, Pz) are averaged by EEGlab as shown in figure 6(a). It shows that the POz and Pz have negative peaks at 110 ms after the stimulus of the horizontal size disparity presented (N1). At 120 ms, N1 troughs reached the max value (-10μV~ -15μV). After 180 ms, the negative peaks disappeared. These are different from the results for other 3D stimulus (like faces, objects and animals) which are observed in the previous researches.

On the other hand, the stimulus of vertical size disparity evokes the power distribution recorded over the whole scalp (see Figure 7). It can be seen that major

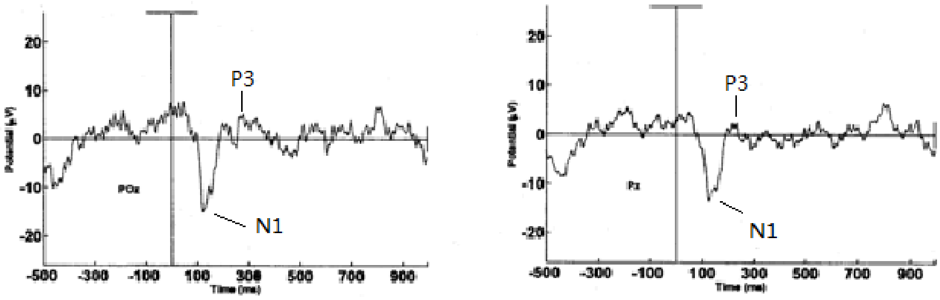

Figure 6 (a) The visual evoked potentials (VEP) of Pz and POz during the horizontal size disparity.

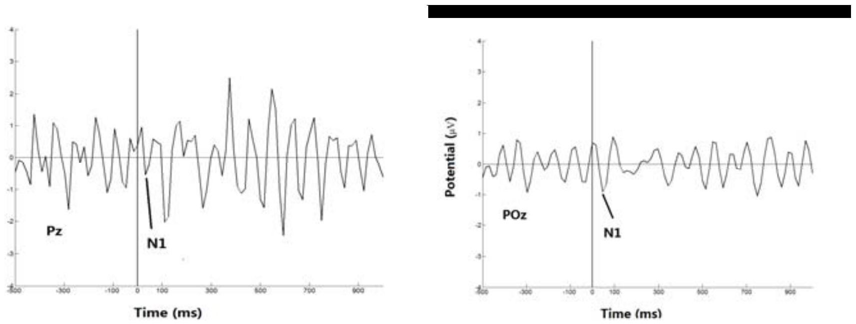

Figure 6 (b) The visual evoked potentials (VEP) of Pz and POz during the vertical size disparity.

differences of the wave forms under the stimulus of horizontal size disparity and vertical size disparity are that there is a remarkable enhancement of negative add deffection from 110 ms to 180 ms at occipitotemporal cortex during horizontal size disparity viewing (comparing Figure 5 & Figure 7). These peculiarities are clearly demonstrated in the energy distribution recorded form 120 ms of horizontal size disparity viewing. The same results that the processes of stereopsis are located in the parieto-occipital cortex can be obtained in the reference [31]. However there is no obvious change in the power distribution which is produced by vertical size disparity in the visual area.

It is well known that vertical size disparities are averaged over larger areas of the visual field but not over the visual field as a whole, the subjects who received the stimulus pattern of vertical size disparity in small area cannot see the impression of a surface slanted. So the stimulus of pattern of vertical size disparity can be produced when not seeing the slanted surface. As the power distribution shown, form 140 ms there is a small negative deflection on the visual area but disappeared at about 200 ms (see Figure 7).

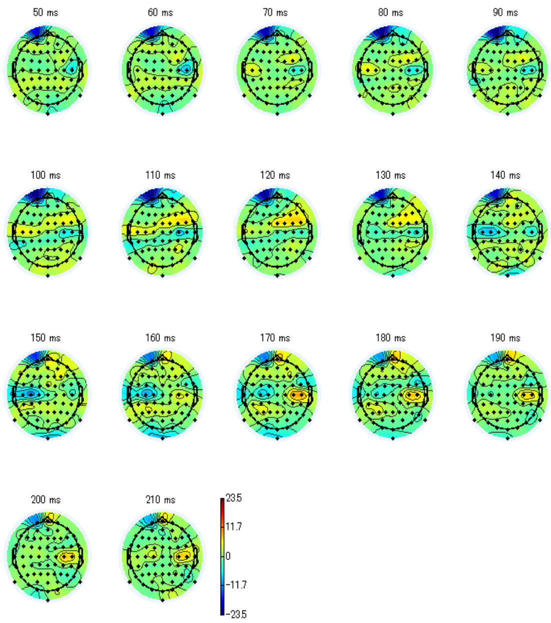

Figure 7. The power distribution of brain during vertical size disparity.

The VEPs of the vertical size disparity is also showed as in Figure 6(b). By comparing the results of two stimulus, two very important results can be remarked: first of all, the response times of the vertical size disparity stimulus are beyond that of the horizontal size disparity, the wave troughs reached the max value on 170 ms (N1); second, the values and the response time of VEP (include P3 and N1)of the vertical size disparity are smaller than that of the horizontal size disparity (the minimum value >-10μV).

In this experiment, the peak with the latency of about 120 ms is found in both situations of the horizontal size disparity and the vertical size disparity. We can also find significative changes in the power distribution from 110 ms to 180 ms. Although the RDS patterns is different, the result is coincident with the prominent negative peak in the studies of Manning and Janssen with a latency in the 200-400 ms [32, 33].

4. Conclusionss

The purpose of this work was to find out the locations and mechanisms of brainwave when the human beings watch the 3D images under the binocular parallax. The results showed that the responds of the horizontal size disparity have different response time and voltage with the vertical size disparity at the visual area (V1) under the similar 3D visual stimulus. Comparing the obtained results, we found that the powers of the primary visual cortex (V1) are different. The responds of Pz and POz have negative peaks (N1, -10μV~15μV) at 120 ms during the stimuli of the horizontal size disparity. However there is no higher negative deflection under the stimuli of the vertical size disparity (N1 appeared at 70 ms). But the statistics results (table 1) suggested that under the normal conditions the human beings inclined to get the 3D effect under the horizontal size disparity than the vertical size disparity. Therefore, the N1 latency cannot be used to judge which is easy to get.

Female

	1	2	3	4	5
H	70	84	77	85	67
V	37	45	52	60	24

Male

	6	7	8	9	10
H	90	86	88	93	82
V	47	41	60	57	57

Table 1, the number for the subject get the 3D effect in 100 times. (H: horizontal size disparity; V: vertical size disparity)

Moreover, the latency of P3 reflects the evaluation and classification time for the stimuli [34, 35]. And P3 maybe have some relation with the end of processing [36, 37]. Here, the P3 responses of the vertical size disparity do not have the fluctuation obviously. But the responses of the horizontal size disparity have the positive peak of P3. So, P3 gives evidence for judging the responses of these two stimuli. These findings suggested that under the normal conditions the human beings inclined to get the 3D effect under the horizontal size disparity than the vertical size disparity.

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