Visual Illusion and N1 and P1: ERP Evidence

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Abstract

Recently, the brain science has become one of most attractive and important fields in modern science and technology. As the foundation of brain science, visual study of brain attracts researchers more attentions due to its wide applications, including psychology, biology and computer science. In the paper, we construct an experiment that uses the abutting line grating illusion contour stimulus with different number of lines, so that some perceive illusion contours and some do not. Event-related potentials (ERP) involving N1, P1 and power spectra are measured and compared to examine the difference of them when visual illusion stimuli and control stimuli are applied.

Keywords: Visual illusion, event-related potentials, abutting line grating illusion contour, information density, EEG

1. Introduction

Human brains get more than 70% information from their eyes and one of the most important functions of human brain is to process the visual information. A lot researches have been performed on the area. Among them, the research on illusory contours (ICs) is one of the most interesting areas and has been studied for a long time. There are several visual illusion theories, such as the illusions from lateral interaction, the illusory contours, the after-effects and the multi-stable stimuli of active perception. However, most of them focused on the study on the mechanisms of illusion contours. Our purpose is to use illusion contours extensively to study the mechanisms of human brains. There is evidence that cells in early visual cortical areas (V1/V2) in the macaque monkey respond to ICs stimuli and NO ICs stimuli differently. More recently, several brain imaging studies examined responses to ICs and NO ICs in the human brain using fMRI and found that there was a cortical region that responded more strongly to the ICs than to the NO ICs stimuli (Bakin et al., 2000; Stanley & Rubin, 2003). Although such methods as fMRI or CT give the high spatial resolution, they fail to give the temporal resolution. In contrast, despite limited spatial resolution compared with CT or MRI, Electroencephalography (EEG) continues to be a valuable tool for research and diagnosis, especially when millisecond range temporal resolution is required, while this is impossible for CT or MRI.

Electroencephalography (EEG) measures voltage fluctuations resulting from ionic current flows within the neurons of the brain by recording the electrical activity along the scalp (Niedermeyer & da Silva, 2004). Usually, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp. Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory). Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli and the technique has been widely used in cognitive science, cognitive psychology, and psychophysiological research (Luck 2005). When using ERPs as evidences to demonstrate scientific conclusions, several specific types are usually abstracted and utilized. Furthermore, the first negative peak around 150-200 milliseconds (N1) and the first positive peak around 80-120 milliseconds (P1) of ERP are such commonly used potentials within the visual related researches (Liu et al., 2009). In this paper, we use the abutting line grating illusion contour stimulus with different number of lines, so that some illusion contours are perceived and some are not. Event-related potentials (ERP) involving N1, P1 and power spectra are measured and their differences are compared to examine the relationships between visual illusion and the changes of N1, P1 and power spectra, so that the computation carried by human brain.

2. Experiments

2.1 Visual stimuli

The visual stimuli were created using Visual C++ and were presented to binocularly to the volunteers. It is a typical line-inducing illusion contours called the abutting line grating illusion contour. The reason why we selected the abutting line grating illusion contour as our visual stimuli is that we can create illusion contours stimuli or control stimuli by just changing the number of the lines. These experimental visual stimuli were composed of five types with different number of dark lines against white background, as shown in Fig. 1. The stimuli of Fig. 1(a) and (b) did not produce illusion contours, (c) slight and (d) and (e) strong illusion contours for most of people.

1.2 Experiment Setup

The display was put on the front of volunteers with the distance of 50 cm as shown in Fig. 2. In the experiment, two types of stimuli which produce illusion or not, appeared randomly on the display. It started with one second standard stimulus, then 300 milliseconds target stimulus and finally a 1.2 seconds rest as shown in Fig. 3. The experiments were repeated several hundred times. Thus, we can obtain the start time for analyzing very easily.

1.3 Subjects

The right-handed health volunteers (including three females, mean age of 23 years old, range from 21 to 26 years old, no elderly people, no bad habits) with normal or corrected-to-normal vision, who have not participated in the similar experiences before, were asked 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. We inserted many events randomly in every trial data and averaged them. For further discussion, the electrodes of the occipital temporal cortex involving Pz, Poz have been extracted individually. Note that in our experiment, we did not ask the volunteers to tell us if they perceived illusion contours or not because by the pre-experiments, we knew which stimulus would produce illusion and which would not.

3. Results and Discussions

For different stimuli shown in Fig. 1, the power spectra, P1 and N1 were recorded one by one respectively. First of all, the power spectra for the stimuli of Fig. 1(a)-(c), and Fig. 1(d), (e) are shown in Fig. 4(a) and (b), respectively. Each colored trace represents the spectrum of the activity of one data channel. The leftmost scalp map shows the scalp distribution of power at 6Hz, which was concentrated on the frontal midline. The other scalp maps indicated the distribution of power at 8Hz and 22Hz. According to the ERP images, the energy of the brain became higher at V1 area when the people watched picture different with the beginning of the stimuli happened. These were the complete visual response. The ERP power changes during the stimulus appeared in every 20 ms is shown in Fig. 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 became stronger after 20 ms during the stimulus appeared, thus indicating that the visual location had a different change during the visual illusion stimulus appeared. This figure also shows that the occipital temporal cortex had activities obviously between 20 ms and 100 ms with the visual illusion. This suggests that the brain was beginning to produce a large change at 20 ms after the stimulus was applied.

To give more light on this problem, the VEP of occipital region (P7, P3, Pz, P4, P8, PO4, PO3, O1, Oz, O2) were averaged by EEGlab as shown in Fig. 6. If the number of the lines was increased, the tester would be easier to perceive the illusion contours. However, if the number of the lines was sparse, the illusion contours would disappear. From the picture we can see clearly that P1 did appear in 20-40 seconds.

We have examined ERPs to visual stimuli, and undoubtedly recorded N1 components as can also be seen by visually inspecting the waveforms. The visual N1 is a visual evoked potential, and is a type of event-related electrical potential which is produced in the brain and recorded on the scalp. The N1 is so named to reflect the polarity and typical timing of the component. The "N" indicates that the polarity of the component is positive with respect to an average mastoid reference. The "1" originally indicates that it is the first negative component, but it now better indexes the typical peak of this component, which is around 150 to 200 milliseconds post-stimulus.

The N1 deflection may be detected at most recording sites, including the occipital, parietal, central, and frontal electrode sites (Herrmann & Knight, 2001). Although the visual N1 is widely distributed over the entire scalp, it peaks earlier over frontal than posterior regions of the scalp, suggestive of distinct neural and/or cognitive correlates (Koivisto & Revonsuo, 2010). The N1 is elicited by visual stimuli, and is part of the visual evoked potential – a series of voltage deflections observed in response to visual onsets, offsets, and changes. Both the right and left hemispheres generate an N1, but the laterality of the N1 depends on whether a stimulus is presented centrally, laterally, or bilaterally. When a stimulus is presented centrally, the N1 is bilateral. When presented laterally, the N1 is larger, earlier, and contralateral to the visual field of the stimulus. When two visual stimuli are presented, one in each visual field, the N1 is bilateral. In the latter case, the N1's asymmetrical skewedness is modulated by attention (Wascher et al., 2009). Additionally, its amplitude is influenced by selective attention, and thus it has been used to study a variety of attentional processes (Luck et al., 2000).

Similarly, P1 is a typical surface positive component at 80-120ms of ERP and used in various visual related studies (Klimesch 2011; Zheng et al., 2012). In this experiment, we used N1, P1 together with the power spectra to reflect the changes of the activities of the subjects' brain by recording and comparing the P1 and N1 and found the difference of responses between the illusion stimuli and control stimuli for both the P1 and N1. The P1 component is a positive component that typically begins around 70-90ms with a peak around 80-130ms. The amplitude of the wave is around 5~10μV. In the experiment, P1 wave appeared at 20-40ms by Fig.4, appeared in 20-50 ms by Fig.5 and it also appeared in 80-120 ms in Fig.6, respectively. The amplitude of the wave was around under 5μV. We also found that for the illusion contours stimuli, beginning from 70ms to 100ms, the peak was around 90-120ms.

Furthermore, it is very interesting to find that when the stimuli changed from Fig. 1(a) to (e), the illusion became more and more clear, and from the VEP, we can also see the occurrence time of N1 came earlier, and the peak became larger. Because the N1 is a negative component, "larger" amplitudes correspond to being more negative, whereas "smaller" amplitudes correspond to being less negative. It is well known that the amplitude of N1 is affected by certain visual parameters, including stimulus angularity and luminance, both of which are directly related to the size of N1. In the experiment, the effect of stimulation was not very clear, and this may be related to the experimenter's inattention. In experiment, three stimuli occurring time were different from the other experimental groups. That might be due to some noise during the experiment.

4. Conclusions

In the present study, we have constructed a new experimental method that used the artificially-created visual stimuli of illusion contours or non-illusion contours, and measured the difference in EEG signals between the stimuli so that we can understand why illusion contours appeared and how such "wrong" computations were performed in human brain. Based on the experimental results, we can conclude that the occipital region became stronger after 20 ms during the stimulus appeared, thus indicating that the visual location had a different change during the visual illusion stimulus appeared. Furthermore, it is very interesting to point out that when illusion contours could make the occurrence time of N1 came earlier, and the peak became larger

References

Bakin, J. S., K. Nakayama, & C. D. Gilbert, (2000). Visual responses in monkey areas V1 and V2 to three-dimensional surface configurations, *J. Neurosci.*, 20 8188–8198.

Stanley, D. A., & N. Rubin, (2003). fMRI Activation in Response to Illusory Contours and Salient Regions in the Human Lateral Occipital Complex, *Neuron*, 37(2), 323-331.

Niedermeyer, E, & F. L. da Silva, (2004). *Electroencephalography: Basic Principles, Clinical Applications, and Related Fields* (Lippincot Williams & Wilkins).

Luck, S. J. (2005). *An Introduction to the Event-Related Potential Technique* (Cambridge, MIT Press).

Qiu, J, D. T. Wei, H. Li, C. Y. Yu, T. Wang & Q. L. Zhang, (2009). The vase-face illusion seen by the brain: An event-related brain potentials study, *International Journal of Psychophysiology*, 74(1), 69-73.

Herrmann, C. S., & R. T. Knight, (2001). Mechanisms of human attention: event-related potentials and oscillations, *Neuroscience and Biobehavioral Reviews*, 25(6), 465-476.

Koivisto, M., & A. Revonsuo, (2010). Event-related brain potential correlates of visual awareness, *Neuroscience and Biobehavioral Reviews*, 34(6), 922-934.

Wascher, E., S. Hoffman, J. Sanger & M. Grosjean, (2009). Visuo-spatial processing and the N1 component of the ERP, *Psychophysiology*, 46, 1270–1277.

Luck, S. J., G. E. Woodman & E. K. Vogel, (2000). Event-related potential studies of attention, *Trends in Cognitive Sciences*, 4, 432-440.

Klimesch, W. (2011). Evoked alpha and early access to the knowledge system: The P1 inhibition timing hypothesis, *Brain Research*, 1408, 51-71.

Zheng, X., C. J. Mondloch & S. J. Segalowitz, (2012). The timing of individual face recognition in the brain, *Neuropsychologia*, 50(7), 1451-1461.

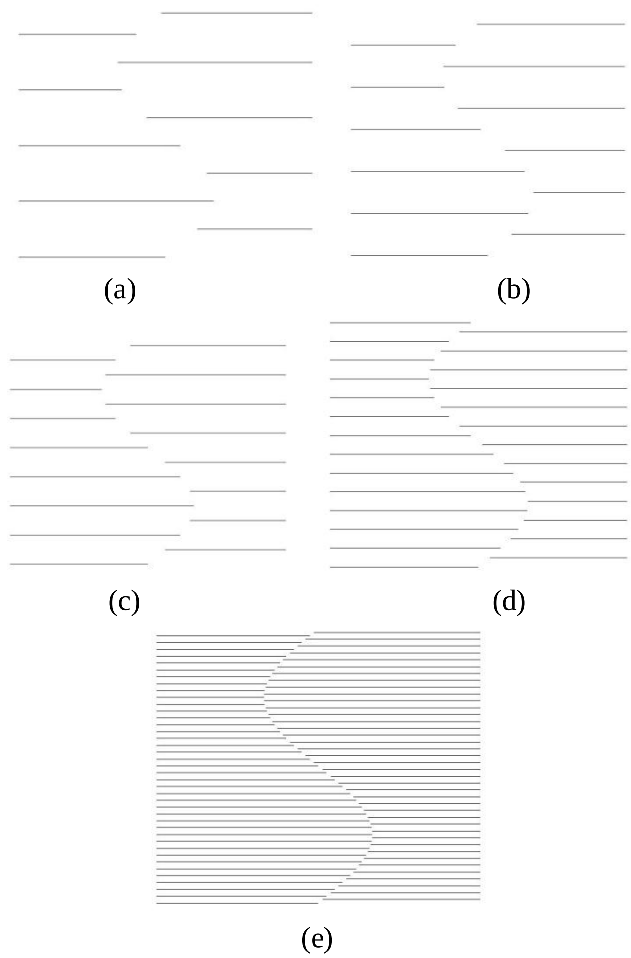


Fig. 1 Visual stimuli presented to the subjects.

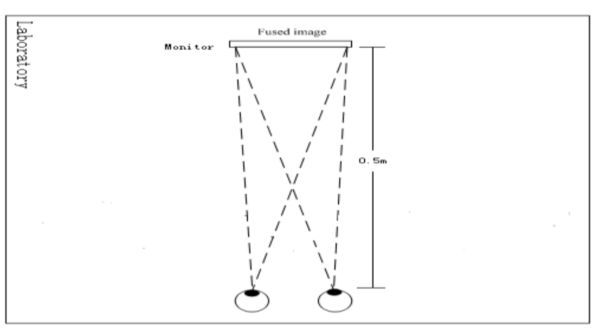


Fig. 2 Model of stereoscope used in the experiment.

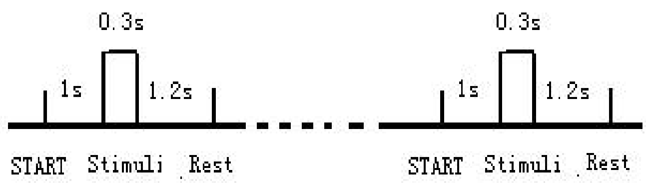
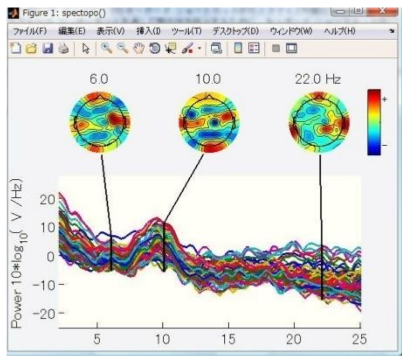
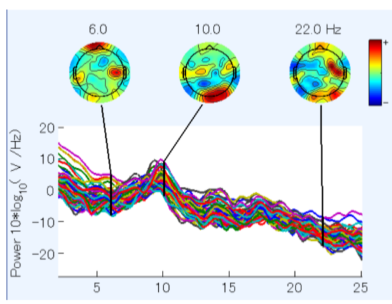


Fig. 3 Experimental flow-chart that illustrates the frequency of activating the stimuli.

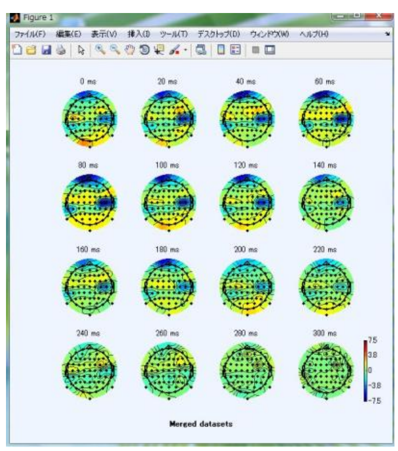


(a)

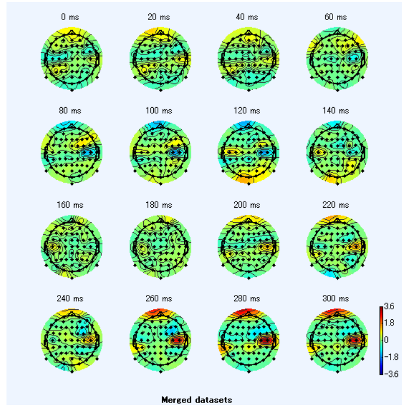


(b)

Fig. 4 The power spectra reflected by the subjects when viewing the stimuli of Fig. 1(a-c) (a) and for (d) and (e) (b).

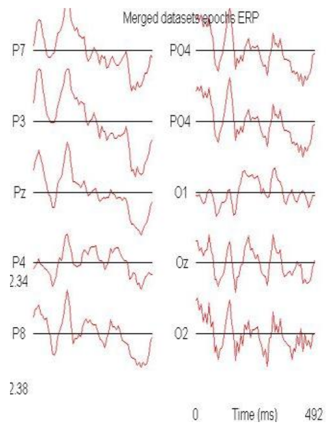


(a)

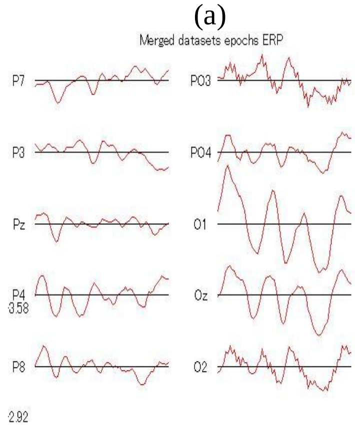


(b)

Fig. 5 The ERP images for stimuli of Fig. 1(a-c) (a) and Fig. 1(d) and (e) (b).



(a)



(b)

Fig. 6 The P1 and N1 of P7, P3, Pz, P4, P8, PO4, PO3, O1,Oz,O2 occur during the visual illusion of different stimuli (a): Fig. 1(a-c) and (b): Fig. 1(d) and (e).