Chapter 9
A Measure of Localization of Brain Activity for the Motion Aperture Problem Using Electroencephalograms

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ABSTRACT
When viewed through a limited-sized aperture, bars appear to move in a direction normal to their orientation. This motion aperture problem is an important rubric for analyzing the early stages of visual processing particularly with respect to the perceptual completion of motion sampled across two or more apertures. In the present study, a circular aperture was displayed in the center of the visual field. While the baseline bar moved within the aperture, two additional circular apertures appeared; within each aperture, a “flanker bar” appeared to move. For upwards movement of the flanker lines, subjects perceived the flanker bar to be connected to the base bar, and all three parts to move upward. The authors investigated the motion perception of the moving bars by changing the line speeds, radii of the apertures, and distances between the circular apertures and then analyzed spatio-temporal brain activities by electroencephalograms (EEGs). Latencies in the brain were estimated by using equivalent current dipole source (ECD) localization for one subject. Soon after the flankers appear, ECDs, assumed to be generated by the recognition of the aperture’s form, were localized along the ventral pathway. After the bars moved, the ECDs were localized along the dorsal pathway, presumably in response to motion of the bars. In addition, for the perception of grouped motion and not normal motion, ECDs were localized to the middle frontal gyrus and the inferior frontal gyrus.

DOI: 10.4018/978-1-4666-2539-6.ch009
INTRODUCTION

The brain perceives information from the outside world and translates this information into intelligence and knowledge (Wilson, R.A. 1999, Palmer, S.E. 1999, Eysenck, M. 2006). If we want to construct a computational model of brain function, there are two kinds of approaches: a bottom-up layered model which identifies the higher brain function from the neuronal network level by analysis of synaptic transmission of the neuronal network and a top-down layered model which identifies the lower layer of brain function by perceptual experiments. In addition, both approaches include a center layer model. We call these models Biologically Inspired Models (BIMs). The authors have proposed BIMs that use soft computing approaches (Kudoh, S.N. 2006, Hayashi, I. 2007a, Kudoh, S.N. 2007). The aperture problem (Ben-av, M.B. 1995, Okada, M. 2003, Pack, C.C. 2001, Chey, J. 1997) is a psychological paradigm to analyze the binding mechanism of spatial recognition in an early stage of the visual pathway. The authors are interested in a hierarchical model related to the early vision system of the brain, particularly, the ventral and dorsal pathways. To discuss this model, we need to analyze the data of psychological experiments such as those derived from the aperture problem.

In the aperture problem, a circular aperture is displayed in the center of the visual field, and, in its baseline condition, a bar initially appears to move from the lower-left to the upper-right inside the aperture. We call this the normal motion direction. While the baseline bar is moving, two additional circular apertures appear; within each aperture, a “flanker bar” moves in one of three orientations: horizontally, vertically, or in the same direction as the ends of the baseline bar. The ends of the flanker bars are visible in the two apertures and thus the motion of the base bar depends on the motion of the flanker bars. Subjects may perceive the base bar to be connected to the flanker bars with all three parts moving together as one line, changing the perceived movement of the base bar to match the orientation of the flanker bars. Even though parts of the line are actually obscured by the foreground, humans “fill in” the gaps of the line based on the outline information of the line in all three apertures. This perception phenomenon is called “a modal supplement.” We can treat the aperture perception as an example for the construction of a hierarchical model that describes the ability of the modal supplement.

Okada and Nishina et al. (Okada, M. 2003) have already claimed that perception strongly depends on the radii of the circular aperture, the distance between circles, and the display time of the flanker bars. In this paper, we investigate motion perception of the moving bars by changing the line speed, the radii of the circular apertures, and the distances between circles while recording activities by electroencephalograms (EEGs) (Hayashi, I. 2002a, Hayashi, I. 2004a) and then analyze spatio-temporal brain activities (Moritaka, A. 2008, Hayashi, I. 2007b). In particular, we should note that the motion perception drops at display times greater than 550 ms. Therefore, we should discuss the change of the motion perception accuracy as a function of display time, and we will specifically analyze the experimental data for the delay time using trend analysis.

Latencies in the brain are estimated using equivalent current dipole source (ECD) localization for one subject (Moritaka, A. 2008, Hayashi, I. 2007b). Soon after the base bar and flankers appear, the localization of ECDs, e.g., the visual evoked potential (VEP) and event related potential (ERP) which are assumed to be generated by recognition of the aperture’s form and the bar motions, respectively, are estimated. In addition, for the perception of grouped motion, the ECDs are localized to the frontal gyrus. Finally, from the results provided by the two kinds of experiments, we discuss all experimental results of the aperture perception.
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