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Brain Dynamics and Interactions for Object Detection and Basic-level Categorization

김지현, 권혁찬, 이용호

Jihyun Kim, Hyukchan Kwon and Yong Ho Lee

The Center for Brain and Cognitive Science Research

Division of Convergence Technology

Korea Research Institute of Standards and Science.

ABSTRACT

Rapid object recognition is one of the main stream research themes focusing to reveal how human recognizes object and interacts with environment in natural world. This field of study is of consequence in that it is highly important in evolutionary perspective to quickly see the external objects and judge their characteristics to plan future reactions. In this study, we investigated how human detect natural scene objects and categorize them in a limited time frame. We applied Magnetoencepahlogram (MEG) while participants were performing detection (e.g. object vs. texture) or basic-level categorization (e.g. cars vs. dogs) tasks to track the dynamic interaction in human brain for rapid object recognition process. The results revealed that detection and categorization involves different temporal and functional connections that correlated for the successful recognition process as a whole. These results imply that dynamics in the brain are important for our interaction with environment. The implication from this study can be further extended to investigate the effect of subconscious emotional factors on the dynamics of brain interactions during the rapid recognition process.

Keyword: Object Recognition, MEG, Visual Perception

1. Introduction

In every environment, we recognize objects surrounding us to make proper reaction at real time. We would fail to survive if we cannot rapidly and accurately process the object information. In line with the importance of object recognition, studies have shown that human recognition process is not only invariant and selective (Tarr & Vuong, 2002), but also very rapid (Thorpe, Fize, & Marlot, 1996). Many studies revealed that only 30 to 60 ms of exposure duration is enough for recognition using event-related potential recordings (Bacon-Mace, Mace, Fabre-Thorpe, & Thorpe, 2005), fMRI (Grill-Spector, Kushnir, Hendler, & Malach, 2000), and single-cell recordings (Rolls, Tovee, & Panzeri, 1999). Yet, we do not often realized that how complicated, in fact, object recognition process is. Only to simplify, we should separate a specific figure from the background (object detection) and classify the figure into a specific category objects (categorization). In order to understand how visual system accomplishes these processes rapidly and accurately, here we performed a preliminary study investigating object detection and basic-level categorization and accompanying brain activation using MEG.

2. Methods & Results

Three participants, including one author, recorded MEG while they performed separate sessions of object detection and basic-level categorization tasks. We presented object images consisting of six categories: bird, car, dog, flower, house, and plane. In detection tasks participants were asked to discriminate any object images from textures containing pixel-wise scrambles of the original object images. In categorization tasks, participants reported whether they saw object images of a certain category (e.g. bird) or object images not pertaining to the category (e.g. car, dog, flower, house, and plane).

Brain magnetic field responses to the stimuli were recorded in sampling-rate of 500 Hz using 152-channel KRISS MEG system in a magnetically shielded room (Figure 1). Acquisition for each trial lasted for 1 s, including 200 ms of pre-trigger recording the mean of which determined the base-line of activity. All data were base-line-corrected and filtered by 1 to 40 Hz band-pass filter and averaged.

Figure 2 illustrates root-mean-square (RMS) of averaged magnetic-field responses for all channels from stimulus onset for 500 ms. Event-related magnetic-field appeared starting from 100 ms until 400 ms in similar patterns across participants. In a limited time window, we could observe the visible differences of brain activation between when participants saw object images

Figure 1. KRISS 152 channel MEG system.

and when saw texture images. Note that solid-black (detection target), dashed-black (categorization target), and dashed-gray (categorization distractor) lines in the figure all depict activity for object images, while solid-gray (detection distractor) line represents activity for texture images. First of all, for all the participants, texture images yielded bigger peak of magnetic-field responses at the early durations (100~200 ms). These results were probably because signals from the texture images were stronger than in the object images, because scrambling of the images made sharp edges and high contrast in the images. Activities specific to object images appeared from 300 to 400 ms, peaked around 350 ms for all the participants. These results indicate that while early brain activation might reflect low-level information of the images (in 100~200 ms), information as high as object-level probably reflected in later durations (300~400 ms).

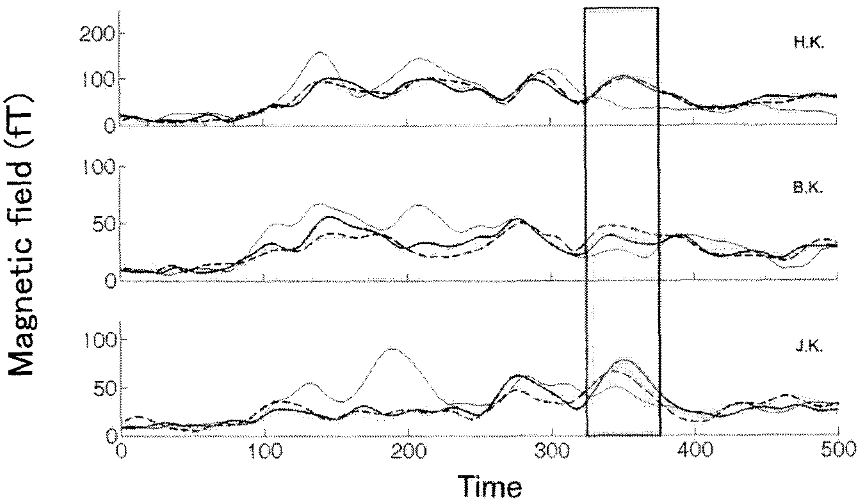

Figure 2. Root-mean square plot of averaged magnetic field responses during object detection (solid) and categorization (dashed) tasks (black lines: target, gray lines: distractor).

3. Discussion

The results of this study showed that object recognition involved distinct information processing stages in the visual system along the time. We observed the movement of the source of the magnetic field which started from left visual cortex and proceeded to the right hemisphere. These results were consistent with the report that activation (MEG recording) during object recognition in the left visual field occurred prior to that in the right visual field (Bar et al., 2006). However, the time frame of object-related magnetic field responses in our study (100~400 ms, object-specific peak at 350 ms) was delayed as compared to the previous study (100~300 ms, object-specific peak at 215 ms). As well as delay time to display the images on the screen, since various factors such as complexity of the information or attentional demand engage in the temporality of phase in event-related magnetic fields, we will need further studies to the factors specifically affecting the phase or amplitude of activation during object detection and categorization.

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