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Research report

Active processing of biological motion perception: an ERP study

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Abstract

The purpose of this study was to measure event-related potentials (ERPs) to clarify how attention affects neural activity during the visual perception of biological motion (BM). Thirteen healthy subjects observed BM or scrambled motion (SM). For SM, each point had the same velocity vector as in BM, but the initial starting positions were randomized. Each BM and SM was overlaid with ten noise dots and four rectangles. For the rectangles, one was or was not rotated 90° relative to the others. Subjects were required to undertake two kinds of visual tasks. For the attention-to-motion condition, subjects directed their attention to the type of motion. For the attention-to-rectangle condition, subjects directed their attention to the rotational angle of the overlaid rectangles. As in our earlier study, the ERP response to the perception of BM had two negative components at ~200 ms (N200) and ~330 ms (N330) in both attentional conditions. Our analysis focused on the amplitude of the second negative component, which was sensitive to BM. There was a significant interaction between attention and the type of motion regarding the amplitude of N330. Specifically, the amplitude of N330 in response to BM was greater in the attention-to-motion condition than in the attention-to-rectangle condition, and was greater than the amplitude of the response to SM in the attention-to-motion condition. These results suggest that in this experimental design, processing of BM is modulated by attention.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Biological motion; Event-related potentials; Visual stimuli; Visual processing; Attention; Motion perception

1. Introduction

The human visual system can reconstruct complex visual images based on astonishingly little information. For example, we can vividly perceive the movement of a human figure from just a dozen moving points of light, and this phenomenon is well known as an example of biological motion (BM) perception [29]. In addition, based only on moving points of light, individuals can discriminate various kinds of information, such as gender [5,12,32,35], personal identity [14], action categorization [16], and emotion [6,9,17,55].

Recent neuroimaging studies have revealed the locations of the neural substrates that subserve perception of BM. In macaques, the superior temporal polysensory area plays an important role in the perception of BM [42,43], whereas in humans, the superior temporal sulcus (STS) appears to be involved in BM perception [7,8,20–23,28,45,47,53]. In addition to the STS, a portion of the lingual gyrus [50], as well as the amygdala [8], fusiform face area [22], and frontal region [49], is activated during the perception of BM. The dynamics of neural activation during BM perception have also been investigated. A recent MEG study revealed the time course of brain activation for BM perception [44]. Pavlova et al. found that oscillatory gamma brain activity was only observed over the parietal and right temporal lobes within 200 ms for BM perception. In a previous study, we measured

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event-related potentials (ERPs) and found perception of both BM and scrambled motion (SM; in which each point had the same velocity vector as in BM, but the initial starting positions were randomized so that the subjects could not perceive a walking person) elicited negative ERP responses over the bilateral occipitotemporal region at ~200 and ~240 ms (designated N200 and N240, respectively) [24]. Moreover, the amplitude of the second negative peak was significantly greater in response to BM than in response to SM. We assumed that the first negative component reflected general (nonspecific) motion processing, whereas the second negative component reflected the processing of BM [24]. Recently, another group [30] also reported two negative peaks during the perception of three kinds of visual stimuli (BM, inverted BM and SM). For the first negative component (N170), the amplitude of the BM condition was greater than that of the inverted BM and SM conditions, and the authors speculated that the first negative component reflected the pop-out effect of a moving dot pattern representing the highly familiar form of a human figure. For the second negative component (N300), the amplitudes of the BM and inverted BM conditions were larger than that of the SM condition, and the authors interpreted that the second negative component may be associated with the specific analysis of motion patterns providing biologically relevant information.

These neuroimaging studies have revealed the responsible area and time course of BM processing, and the STS appears to be the primary center for processing BM. However, the functional properties of the neural responses to BM have not been investigated. Several early psychophysical studies suggested that BM perception is a bottom-up or low-level process, since BM can be perceived spontaneously (i.e., automatically) [29,36]. For example, Johannson noted that a mathematically lawful spatiotemporal relationship determined the perceptual responses, and suggested that the perception of BM was a spontaneous, automatic phenomenon [29]. Other studies have also found aspects of low-level processing during the perception of BM (e.g., [36]) and several computational models have been based on these findings [25,58]. These observations suggest that the attentional effect for BM perception is very low. On the other hand, recent psychophysical studies have suggested that BM processing involves a top-down [10,16] or attentional [11,51,52] process.

In this study, we focused on how attention affects the processing of BM. We measured ERPs, as in our previous study [24], and used the second negative component of the ERP response (which is likely to be associated with BM perception) as an index of neural activation. We hypothesized that if the process of BM perception does not involve attention, the amplitude of the second negative component would remain unaffected by attention, whereas if BM perception does involve attention, the second component would be affected by attention. We conducted the following experiments based on this hypothesis.

2. Materials and methods

2.1. Subjects

We studied 13 subjects (range/mean age: 18–30/23.7 ± 3.9 years; 9 males, 4 females). All subjects were right-handed and had normal or corrected-to-normal vision. All subjects provided informed consent for a protocol that was approved by the Ethics Committee of the University of Tokyo. Each subject participated in four trial blocks.

2.2. Visual stimuli

Our stimuli were modified from the dual-task paradigm used by Thornton et al. [52] (Fig. 1). Each stimulus comprised 11 moving points of light that were masked by 10 randomly moving (noisy) points and 4 rectangles, that is, the stimuli had 3 features: motion type; noise velocity; and a rectangle configuration. The motion type was either BM or SM (Fig. 1a). For BM, points were attached to 11 joints of a walking person; this produced an animation that made the walking motion immediately obvious to the subject. For SM, each point had the same velocity vector as for BM, but the initial starting positions were randomized so that the subjects could not perceive a walking person. The rectangle configuration was either changing (RC) or unchanging (RNC) (Fig. 1b). For RC, one of four rectangles was rotated 90° after 272 ms. For RNC, the positions of the rectangles were fixed throughout the trial. For both the RC and RNC conditions, four rectangles were displayed spatially randomly within 3 × 3°area. To regulate the difficulty of distinguishing between BM and SM, the noise velocity was either fast (FN) or slow (SN) (Fig. 1c). For FN, the velocity of the noisy points was approximately equal to that of the target points (4.3° per second). For SN, the velocity of the noisy points was 1/10 the velocity for FN. We assumed that SN would interfere with motion detection to a lesser degree than FN because the velocity of SN noisy points differed from that of the target points.

Animations were generated using Cutting's algorithm [13] to calculate the coordinates of each point for a walking speed of 2.0 gait-cycles per second. Animations were displayed on a 17-in. monitor using E-Prime (Psychological Software Tools, Pittsburgh, PA) on a personal computer. Each subject was seated 115 cm from the display in a dimly lit room. All the points were white against a black background (5.8 cd/m^2). Each point subtended an angle of 9.0 arcmin. The rectangles were 0.40 × 0.15°. The entire visual stimulus was approximately 3 × 3°. Each animation comprised 15 frames,