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Short communications

An event-related potentials study of biological motion perception in human infants

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Abstract

To clarify the dynamical processing aspect of biological motion (BM) perception from a developmental point of view, we measured event-related potentials (ERPs) in 8-month-old infants during the perception of BM or a scrambled motion (SM; randomization of BM's spatial structure). We found that activation of the right hemisphere in 8-month-old infants was similar to that of adults, suggesting that the neural substrates for processing BM perception begin to mature at around 8 months of age.

Theme: Neural basis of behavior
Topic: Cognition

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

Humans can perceive the behavior of other humans using an astonishingly limited amount of information. For example, we can perceive vividly the movement of a human figure from just a dozen moving points of light: this phenomenon is well known as an example of biological motion (BM) perception [14]. Interestingly, humans can also reliably discriminate light-point figures of males from females [15] and familiar individuals from strangers [9].

At what stage of brain development does the BM processing mechanism mature? Whether the processing of BM is innate or acquired is controversial; one view is that BM perception is an innate capacity of the visual system, rather than one acquired through experience (e.g., Ref. [14]). In an early examination of BM perception in infants, Fox and Mcdaniel [10] revealed that the sensitivity to BM patterns is manifested between 4 and 6 months of age. In other studies, 9- [2], even 3-month-old infants [3] reliably discriminated BM from scrambled motion (SM; each point had the same velocity vector as for BM, but the initial starting positions were randomized). These behavioral studies suggested that 3- to 9-month-old infants might recognize the difference between BM and SM.

Recent neuroimaging studies of healthy adults have revealed the superior temporal sulcus (STS) to be a candidate for BM perception (e.g., Refs. [5,11]); in addition, temporal dynamics were clarified by measuring event-related potentials (ERPs) [12].

However, how neural activity in response to BM changes with development has not been investigated. In the present study, based on the results of psychological and neuroimaging studies and a previous study of ours, we measured ERPs in 8-month-old infants to elucidate changes in neural activation in response to BM. We also measured ERPs in adults under the same experimental conditions as for the infants, both to confirm the results of our earlier study [12] and to evaluate the validity of the experimental conditions that were used in the present one.

First, seven 8-month-old infants (four males and three females aged between 235 and 302 days; mean=257 days) were tested. An additional 16 infants were excluded from the analyses, because their data failed to reach the minimum

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criteria due to fussiness (15 infants) or failure to record a videotape of the behavior (1 infant). Informed consent was obtained from the parents of the infants prior to experimentation. The experiment was approved by the Ethics Committee of the Graduate School of Arts and Sciences at the University of Tokyo.

Each infant sat on its parent's lap 70 cm from a 17-in. computer monitor within an acoustically and electrically shielded, dimly lit room. A video camera was mounted below the monitor to record the infant's face and gaze direction. Infants viewed two different light-point animations (BM, SM; Fig. 1A and B). The infants included in the final sample typically completed 20–72 trials. The electrical brain activity of each infant was recorded using a Geodesic Sensor Net consisting of 62 silver–silver chloride electrodes [17] that were distributed evenly across the scalp. All recordings were referenced initially to the vertex and later to the average potential over the scalp. The electrical potential was amplified with a 0.1- to 100-Hz bandpass, digitized at a sampling rate of 250 Hz, and stored on a computer for offline analysis. Subsequently, a 30-Hz low-pass filter was reapplied to the recorded electroencephalogram (EEG) data. A video recording of each infant's behavior was analyzed and trials in which an infant did not fixate on the screen while the stimulus was presented were excluded. We analyzed infants who performed at least 10 trials per condition (mean available number of trials: 26.1±9.2 for BM and 23.1±9.1 for SM).

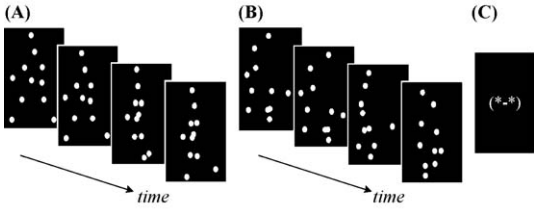

Fig. 1. Infants' experimental conditions and procedures: (A) Example segments of the presented stimuli for biological motion (BM). The light-points were attached to 11 joints of an animation of a walking person that was obvious to normal healthy adults. (B) Example segments of the presented stimuli for scrambled motion (SM) stimuli. Each point had the same velocity vector as in the BM stimuli, but the initial starting positions were randomized so that the adults could not perceive a walking person. To generate animations, we used Cutting's algorithm [8] to calculate the coordinates of each point for a walking speed of 2.0 steps/s. The animations were displayed using E-Prime (Psychological Software Tools, Pittsburgh, PA) on a personal computer. All the points were white against a black background (5.8 cd/m^2). Each light point subtended an angle of 14.7 arcmin and the entire light-point figure was approximately 4.9×4.9°. Each animation comprised 15 frames displayed over 510 ms. The interframe interval was approximately 34 ms and the light-point sequences produced a smooth animated motion. In each trial, the target stimulus was presented in a random order and was followed by the presentation of a face-like figure (panel C; 0.65×0.65°) for 500 ms. After 10 BM or SM stimuli had been presented, an attractive animation was presented for 3000 ms to focus the infant's attention on the center of the monitor. When an infant looked away from the monitor, an attractive sound was played for a short time. We generated 29 frames for each condition and used 15 continuous frames per trial. The initial frame was shifted by seven frames between different conditions to prevent the infant from judging each condition based on the starting position of the point. Each condition had five different initial starting positions. Adults' experimental conditions and procedures: The presented stimuli were approximately 3×3° and each light-point was 9.0 arcmin. The stimuli were presented 50 times for each (BM, SM) condition in a random order during one block. Totally, participants performed 4 blocks with 1-min interblock intervals, and were presented 200 times for each condition. Participants were instructed to fixate on the center of the screen to avoid the inclusion of confounding motor artifacts.

To reject artifacts, we applied the following condition: trials in which the signal variation exceeded 200 μV on the EEG or electrooculograms (EOG) were excluded from the trial average [6,7]. Averaged ERPs were calculated after being time locked to the onset of the stimulus presentation and by correcting the baseline to the average amplitude of the 100-ms interval that preceded the stimulus onset.

To avoid a loss of statistical power [16] and to improve the signal-to-noise ratio, we collapsed 26 electrodes into two sites around the electrodes that were used to record from the bilateral occipitotemporal regions. Fig. 2A shows the grand mean of the waveforms recorded in each group. To clarify the activation in the target epoch, we averaged the amplitudes within the 200- to 300-ms latency range (Fig. 2B). The latency range was based on adult ERPs from our earlier study in which two negative peaks were observed within 200 to 300 ms of the stimulus onset [12]. The averaged ERPs were analyzed by a two-way analysis of variance (ANOVA) (laterality vs. stimulus type) which revealed that only the laterality×stimulus type interaction was significant [$F(1,6)=7.1$, $p<0.05$]. We then analyzed the main effect of the interaction, which revealed that: (1) during perception of BM, the averaged amplitude in the right hemisphere was greater than that in the left hemisphere [$F(1,12)=7.1$, $p<0.05$], and (2) the amplitude of the response to BM was significantly greater than that to SM in the right hemisphere [$F(1,12)=6.7$, $p<0.05$].

Next, to replicate our earlier study [12] and to evaluate the validity of the experimental conditions that were applied to the infants in the present one, we measured ERPs in adults under the same experimental conditions as used for the infants. Fourteen paid, healthy adult participants took part (mean age: 22.1±3.9 years; 12 males and 2 females). All participants were right handed and had normal or corrected-to-normal vision. All participants provided informed consent before participating in the experiment. The analysis condition was different from that in the infants': the criteria for artifact rejection were stricter than for the infants, so trials in which the signal variation exceeded 50 μV in the EEG or EOG were excluded from the average.

As in the analysis of the data from infants, 26 electrodes were collapsed into two sites around the electrodes that were used to record from the bilateral occipitotemporal region. Fig. 2C shows the grand mean waveforms that were recorded in the bilateral occipitotemporal areas of adults. There were two negative peaks at ~200 and ~280 ms, which is almost consistent with our earlier study [12]. As with the