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Eccentricity dependency of the perception of biological motion

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The visual system is equipped with a very sensitive mechanism for recognizing others' actions (Johansson, 1976). One possible role of biological motion perception is to select biologically relevant targets for later visual processing. If so, then biological motion should be salient across the visual field. In this study, we compared the detection performances of biological motion at the foveal and peripheral visual fields. The expected lower spatial resolution at the periphery was to be compensated by spatial magnification. Correct and scrambled biological motions were successively presented. They were both embedded in motion noise. Subjects indicated which of the two intervals contained the biological motion. Detection performance (defined resistance against noise) was determined by using a staircase method. Both in the foveal and peripheral visual fields, detection performance saturated as the stimulus size increased. However, the performance at the fovea remained higher than that at the peripheral fields in spite of the spatial scaling. Moreover, the inversion effect (Sumi, 1984) disappeared when the stimulus was viewed at the 12-deg periphery. These results suggest that the resource or mechanism for biological motion perception is confined to the central region visual field.

Keywords: Biological motion, Eccentricity, Visual, Spatial Scaling

Introduction

Since the perception of actions performed by others is key to survival, it is not surprising that the visual system is equipped with a sensitive mechanism for recognizing such actions. In his original study, Johansson (1973) attached small light sources to the main joints of an individual who was walking and presented it in darkness to remove all other visual information. Even though there were only highly impoverished visual information, observers could easily see a person walking. This ability has been called "biological motion perception". Following Johansson's study, numerous others have investigated the perception of biological motion (Thornton, Pinto, & Shiffrar, 1998; Verfaillie, 2000; Giese & Poggio, 2003). However, no study has examined the ability to detect biological motion at the periphery. This is rather surprising because, if the main purpose of biological motion perception is to select biologically relevant targets for later visual processing, biological motion should be salient across the entire visual field. This is because visual stimuli seldom appear on the fovea. The present study aimed to examine eccentricity dependency of biological motion perception.

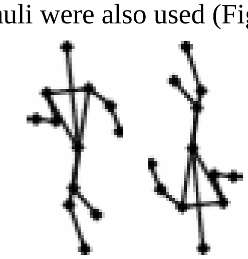
Materials & Methods

Subjects

Six subjects (two female, four male) participated in the study.

Stimuli

Point-light biological motion sequences were created from videotapes of an individual performing five activities (jumping, running, walking, kicking, and throwing a ball) while wearing dark clothing with reflective tape on the12 major joints. The videotapes were digitized at 25 Hz. Biological motion was expressed as a motion of 12 black dots on a white background. The visual stimuli were presented in 7 sizes (0.5, 1, 2, 4, 8, 12, and 16 deg in visual angle). They were also presented at 3 eccentricities (0, 4, and 12 deg). The stimulus size was changed by magnifying all spatial dimensions of the visual stimulus, That is, the dot size was also increased. In addition to the upright biological motion stimuli, inverted biological motion stimuli were also used (Figure 1).



(a) (b)

Figure1. (a) an example of upright biological motion used in the present study (b) inverted biological motion

Procedure

Subjects were instructed to maintain a firm fixation during each trial and initiate a trial by pressing a key on a computer keyboard. A single trial consisted of two 800-ms intervals of stimulus presentation. They were separated by a blank period of 500 ms. One interval was the correct biological motion stimuli (upright or inverted). The other interval contained a scrambled version of the correct stimulus. The scrambled stimulus was made by randomizing the starting positions of the signal dots within the area of the biological motion stimulus. The presentation order was randomized. After viewing the stimulus sequence, subjects reported which stimulus interval contained the correct biological motion by pressing appropriate keys (2-alternative forced-choice).

Detection performance of biological motion was defined as resistance against motion noise (Cutting, Moore & Morrison, 1988; Bertenthal & Pinto, 1994). A staircase method was used to measure noise resistance: Three consecutive correct responses added 4 noise dots. One incorrect response reduced the noise level by 4 dots. When the number of reversals reached 18, the session was finished. The noise resistance (performance) in a session was determined by averaging the noise levels of the last 5 reversals.

Three subjects were tested with all combinations of 2 stimulus types (upright and inverted), 7 stimulus sizes, and 3 eccentricities, resulted in 42 conditions. For the other three subjects, the largest stimulus size (16 deg) and 3 eccentricities were used [6 conditions]. Each subject performed four sessions of staircase for each condition and performances were averaged for each condition.

Result

Results for three subjects who tested in all condition are presented in Figure 2. Performances of the detection of biological motion (defined as noise resistance) are averaged and plotted as a function of stimulus size. As expected, in all stimulus-type conditions, the performance increased as stimulus size increased and as the eccentricity decreased. However, the performance levels saturated at certain stimulus sizes. This was true for all the three eccentricities. Most importantly, the maximum performance level was different for different eccentricities. In other words, the stimulus magnification did not compensate for the reduced performance with peripheral viewing. This discrepancy of saturation levels among different eccentricities was clearer in the upright condition. The performance was higher in the upright condition than in the inverted condition (i.e., inversion effect; Sumi, 1984; Verfaillie, 1993; Pavlova & Sokolov, 2000; 2003; Shipley, 2003; Troje, 2003). However, the inversion effect seemed to diminish at the peripheral visual field.

Figure 3 shows the performance as a function of eccentricity, averaged for the 6 subjects who performed the task with the stimulus size of 16 deg. The performance was higher at smaller eccentricities and for the upright conditions. A two-way ANOVA with repeated measures revealed significant main effects of eccentricity ($F(2,10) = 27.93$, $p < 0.05$) and stimulus type (upright vs. inverted, $F(1,5) = 18.65$, $p < 0.05$). The interaction was also significant ($F(2,10) = 7.0$, $p < 0.05$). Post-hoc Tukey HSD tests indicated that the inversion effect was significant at the 0- and 4-deg eccentricities ($p < 0.05$) but not at the 12-deg eccentricity.

One of the additional subjects performed the task while his eye movements were monitored (Eye-link II tracker, SR Research, Ontario, Canada). The pattern of his results was similar to those of the others, and there was virtually no eye deviation during single trials.

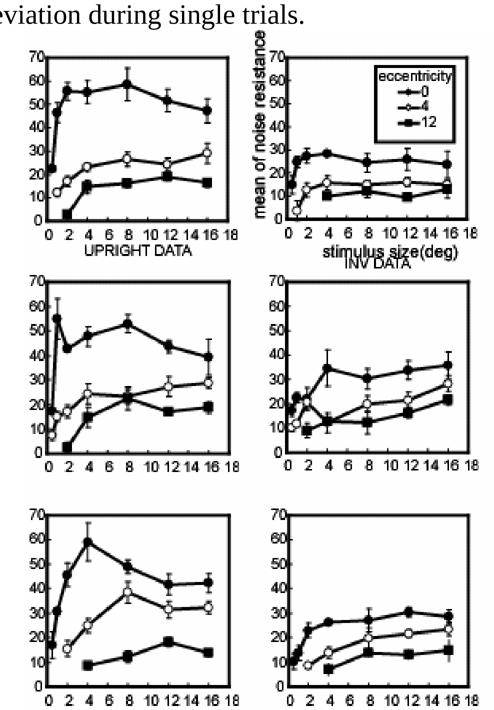


Figure 2. Results for three subjects who tested all condition. Averaged performances of the detection of biological motion (defined as noise resistance) are plotted as a function of stimulus size.

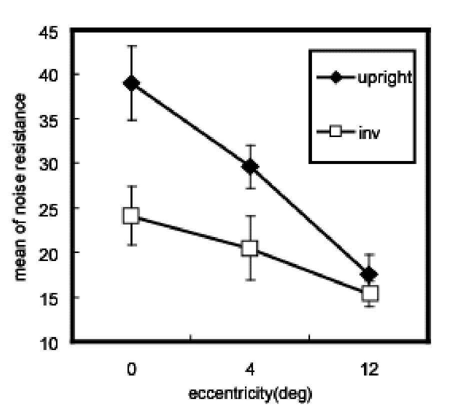


Figure 3. Performance averaged for the 6 subjects which were added three additional subjects who performed the task with the stimulus size of 16 deg are shown. The performance was plotted as a function of eccentricity.

Discussion

The performance for perceiving biological motion at the peripheral visual field was always worse than at the central visual field. This cannot be accounted for by the spatial resolution factor. For, the maximum performance at the fovea remained superior to those at the peripheral fields, irrespective of the spatial scaling. Moreover, the inversion effect of biological motion perception depended on stimulus eccentricity; the advantage of upright biological motion disappeared when the stimulus was viewed at the 12-deg periphery. These results suggest that the resource for biological motion perception is not uniformly distributed across the visual field but, rather, is limited to the central region of the visual field.

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