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Research report

Visual search for moving and stationary items in chimpanzees (*Pan troglodytes*) and humans (*Homo sapiens*)

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Abstract

Four visual search experiments were conducted using human and chimpanzee subjects to investigate attentional processing of movement, and perceptual organization based on movement of items. In the first experiment, subjects performed visual searches for a moving target among stationary items, and for a stationary target among moving items. Subjects of both species displayed an advantage in detecting the moving item compared to the stationary one, suggesting the priority of movement in the attentional processing. A second experiment assessed the effect of the coherent movement of items in the search for a stationary target. Facilitative effects of motion coherence were observed only in the performance of human subjects. In the third and fourth experiments, the effect of coherent movement of the reference frame on the search for moving and stationary targets was tested. Related target movements significantly influenced the search performance of both species. The results of the second, third, and fourth experiments suggest that perceptual organization based on coherent movements is partially shared by chimpanzees and humans, and is more highly developed in humans.

Keywords: Chimpanzee; Perceptual organization; Search asymmetry; Coherent movement; Reference frame

1. Introduction

Detecting a moving item is highly important for animals living in dynamically changing visual environments, and this explains why our perceptual mechanisms are so well-developed for that purpose. The visual search paradigm has frequently been used to investigate visual attention mechanisms for processing motion information [8,16,20,31,32]. For example, search asymmetry for motion was found in studies that tested human visual search performance in two display conditions, one of which consisted of a moving dot and stationary dots and the other symmetrically designed with a stationary dot and moving dots [37,54]. Results indicated that detecting a stationary item among moving items is more difficult than detecting a moving item among stationary items. Royden and colleagues explained these findings according to feature integration theory [49], such that "motion" is a basic feature in our visual system and "stasis" is its absence.

When we think about detecting a target in a dynamic visual field, perceptual organization is also an important consideration because an item's motion is often perceived in the global context of the movement of other items. For example, our visual system is sensitive to movement coherence [56]; coherently moving items are more easily grouped [24]. Also, as is apparent in phenomena such as induced or relative motion, an object's motion is often perceived in relationship to the movements of other items.

This perceptual organization of moving items and its relation to visual search performance has been investigated by several researchers [9,23,55]. In studies using human subjects, motion coherence of the search items was varied and effects on search performance tested. These studies found that the effect of coherent motion was to perceptually group the items as an organized surface, probably processed in the "preattentive" stage of human visual perception [48], and that such perceptual grouping influenced the search for a moving target. Results of these studies indicated a strong tendency for perceptual grouping or organizing of moving items in ways that affected later attentional processing of the items.

In the field of comparative cognition, studies on visual perception in non-human animals have been important in under-

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standing how non-human animals perceive their world, and to manifest the evolutionary foundation of human visual processing [2,46]. Several learning experiments have shown similarities between humans and chimpanzees, our closest evolutionary relatives, in visual perception and attentional processing. For example, chimpanzees showed comparable performance to humans in characteristics of early vision, such as visual acuity [30] and color and brightness perception [14]. In a series of visual search experiments, Tomonaga [46] examined features such as orientation, form, texture pattern, and shape-from-shading cues, and demonstrated "pop out" and search asymmetry phenomena in chimpanzees, similar to those in humans. Perception of movement in visual search, however, has been less frequently investigated in non-human animals, although information about detection and attentional processing of moving items would provide highly important ecological and evolutionary validity.

There has also been little investigation into how non-human animals organize their visual perception of objects. Whereas it is natural for humans to perceive the relationship between items in a visual field [24], previous reports suggest that this is not always true for non-primate animals [5,25,52], or even non-human primates, such as chimpanzees [11,13].

The purpose of this study was two-fold. First, we sought to reveal whether chimpanzees showed search asymmetry for moving and stationary targets. The question was whether, like humans, chimpanzees more rapidly detect a moving item than a stationary item. In Experiment 1, we used a visual search task to compare the performance of humans and chimpanzees in detecting a moving target among stationary distractors, and a stationary target among moving distractors. This allowed us to measure the most basic visual processing tendencies of chimpanzees.

Second, we examined the organization of visually perceived discrete moving objects. Previous studies of perceptual organization in chimpanzees used stationary stimuli [12]; we attempted to test the dynamic aspect of perceptual organization in non-human primates. In Experiment 2, a stationary item among moving distractors was presented to the subjects under two search conditions in which the uniformity of the movement of the distractors was varied.

To further investigate perceptual organization, search performance for moving and stationary targets as in Experiment 1 was evaluated in Experiment 3 (3a and 3b), with the addition of a moving reference frame. These two experiments examined the perceptual organization of discrete items in the context of related movement.

2. General methods

2.1. Subjects

Five chimpanzees: Ai (27 years old, female), Akira (28 years old, male), Mari (28 years old, female), Pendesa (27 years old, female), and Ayumu (3.5 years old, male), participated in the experiments. Ai and Akira participated in Experiments 1, 3a, and 2 in that order. Mari, Pendesa, and Ayumu participated in Experiment 3b.

The subjects were experienced in performing various perceptual-cognitive tasks. At the time of the present study, Ai was experienced in matching-to-sample-tasks, such as symbolic and identity matching tasks [1,27,29], and had relatively little experience in visual search tasks [43,44]. Akira had been highly trained in visual search tasks [42,45,47]. However, neither of these subjects had prior experience of the task used in the present study. Mari and Pendesa also had experience in performing discrimination tasks [1,27,41], and had learned the visual search for a moving target task [28] in advance of this study. Ayumu had little experience in computer-controlled tasks, but he had also learned the visual search task that used a moving target among stationary discs [28].

The subjects lived with 10 other chimpanzees in an environmentally enriched outdoor compound and attached indoor residences [33]. They were not deprived of food at any time during the study. Care and use of the chimpanzees adhered to *The Guide for the Care and Use of Laboratory Primates* of the Primate Research Institute, Kyoto University, Japan.

In addition to the chimpanzees, human volunteers participated in the experiments. They were not informed about the purpose of the experiments. All were right-handed and reported normal or corrected-to-normal visual acuity.

2.2. Apparatus

Chimpanzees were tested in an experimental booth (approximately 1.8 m × 1.8 m × 2.0 m) with acrylic panels as walls on all four sides. Stimuli were generated on a Pentium-based computer and displayed on 21-in and 22-in CRT monitors (Totoku CV-213PJ for Ayumu and Mitsubishi TSD-221S for the other subjects) equipped with capacitive and surface acoustic wave touch screens. This monitor system served to present the stimuli, and was also the input device for subject responses with accurate information for touch locations. Monitor resolution was 1024 × 768 pixels with 8-bit color mode. The refresh rate was 75 Hz and the display was synchronized with the vertical retrace of the monitor. The positions of the moving stimuli were updated on every screen retrace to give the impression of smooth motion. Subjects observed the monitor at a viewing distance of about 40 cm without head restraint. The viewing distance was roughly restricted by an acrylic panel, which was attached between the monitor and subjects to prevent the destruction of the monitor by the chimpanzees. Stimulus luminance was measured using a colorimeter (Topcon, BM-7). A universal feeder (Biomedica, BUF-310) delivered small pieces of a food reward (apples or raisins) into a food tray below the monitor.

Human subjects were tested with the identical apparatus in the experimental booth. The only exception was that they were not rewarded with pieces of food. They were required to observe the monitor from a distance of about 40 cm and to respond with a finger touch as did chimpanzees.

3. Experiment 1: asymmetry in visual search for moving and stationary targets

Experiment 1 tested visual search for moving and stationary items. Targets and distractors were designed symmetrically in two search display conditions (Fig. 1). In one condition, subjects searched for a moving target among stationary items, and in the other, they were required to detect a stationary target among moving distractors.

3.1. Methods

3.1.1. Subjects

Two chimpanzees (Ai and Akira), and five undergraduate students (three males and two females) ranging in age from 18 to 22 years (mean = 19.2 years), participated in Experiment 1.

3.1.2. Stimuli

The total screen area subtended 392 mm × 292 mm (52.2° × 40.1° of visual angle at a viewing distance of 40 cm), and the maximum display area (with 12-item display) was 230 mm × 172 mm (32.1° × 24.3°), excluding the lower part of the screen where a warning stimulus, which showed the