Vision Research 50 (2010) 577–584

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

# Object-based attention in chimpanzees (*Pan troglodytes*)

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ARTICLE INFO

*Article history:*
Received 28 May 2009
Received in revised form 1 December 2009

*Keywords:*
Object-based attention
Spatial attention
Attentional shifting task
Amodal completion
Perceptual organization
Chimpanzees

## ABSTRACT

We conducted three experiments to investigate how object-based components contribute to the attentional processes of chimpanzees and to examine how such processes operate with regard to perceptually structured objects. In Experiment 1, chimpanzees responded to a spatial cueing task that required them to touch a target appearing at either end of two parallel rectangles. We compared the time involved in shifting attention (cost of attentional shift) when the locations of targets were cued and non cued. Results showed that the cost of the attentional shift within one rectangle was smaller than that beyond the object's boundary, demonstrating object-based attention in chimpanzees. The results of Experiment 2, conducted with different stimulus configurations, replicated the results of Experiment 1, supporting that object-based attention operates in chimpanzees. In Experiment 3, the cost of attentional shift within a cued but partly occluded rectangle was shorter than that within a rectangle that was cued but divided in the middle. The results suggest that the attention of chimpanzees is activated not only by an explicit object but also by fragmented patches represented as an object at a higher-order perceptual level. Chimpanzees' object-based attention may be similar to that of humans.

## 1. Introduction

Regulating unimportant sensory input and focusing on processing important information is essential for fast and efficient visual recognition. For example, devoting too many cognitive resources to information processing about trees or pedestrians might result in failure to detect a red light. Visual attention represents one mechanism for filtering out unimportant objects and events in order to primarily process important information.

Visual attention has been conventionally explained by metaphors about spotlights (Posner, 1980) or zoom lenses (Eriksen & Yeh, 1985), in which the degree of activation is determined solely by the eccentricity from the focal center, termed "space-based attention." Specifically, any area in the visual field is considered as more highly activated when it is nearer to the attended location. On the other hand, the object is also a determinant of the degree of attentional activation; humans perform a double task more efficiently when it involves reporting both color and shape related to a single object versus when those qualities are individually related to two objects (Duncan, 1984). It is clear that space-based and object-based attention are not mutually exclusive. Egly, Driver, and Rafal (1994) demonstrated that both spatial- and object-based aspects of attention affect performance. In their experiment, participants were instructed to press a key when a target appeared in one end of one of two rectangles arranged in parallel. A brief presentation of a cue preceded the presentation of the target, which appeared in the same or another end of the rectangles. In 75% of the trials, the cue appeared at the same site as the target, working as a predictor of the target location; hence, the reaction time (RT) decreased. This phenomenon can be explained by spotlight-like space-based attention; the attention for the cued site was triggered, and the target appearing at the activated site could be detected rapidly. In half of the remaining trials (i.e., 12.5% of trials), the target was presented at the other end of the same rectangle in which the cue appeared, whereas the target appeared at the nearer end of the other rectangle in the other half of these trials. The distance from the cued site to the target site in both types of trials was the same. Interestingly, the RT was slightly but reliably shorter in the former than in the latter trials, suggesting the inadequacy of a space-based account of attention because spotlight-like attention should have activated both sites equally. Object-based attention may have activated the cued object as a whole.

Consideration of the results presented by Egly et al. (1994) necessitates reserving conclusions about the robustness or generalizability of the "within-object benefit" observed in their experiment because they used only rectangular frames as objects. Moore, Yantis, and Vaughan (1998) replicated the study conducted by Egly et al. (1994) using a similar spatial cuing task and demonstrated that a within-object benefit was observed even when the

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doi:10.1016/j.visres.2010.01.003

object was subjectively constructed with illusory contours or when it was partially occluded by another object. Robertson and Kim (1999) found that the smaller cost for attentional shift (i.e., faster response) involving a visual illusion that causes an object to be seen as short suggests that object-based attention operates even on represented objects. Moreover, the attention in question appeared to extend over a perceptually organized group rather than merely in response to circumscribed sensory input. Thus, the nature of object-based attention renders it suitable for investigating how visual patches are organized into a meaningful object on the basis of whether the benefit in attentional shifting occurs. We will return to this issue in the Section 5.

Because the world contains many objects, animals are required to extract meaningful objects from their environments. Therefore, many animal species might share an object-based attentional process, and the nature of this process might vary according to the environment of each species. Although comparisons among species are essential for exploring issues of the adaptive significance and phylogenetical origins (i.e., ultimate causes) of human object-based attention, minimal evidence of object-based attention in nonhuman animals has been collected, except with regard to pigeons and monkeys. Lazareva, Vecera, Levin, and Wasserman (2005; see also Lazareva, Levin, Vecera, & Wasserman, 2006; Lazareva, Vecera, & Wasserman, 2006) trained pigeons to discriminate between displays in which two dots were presented on either of two differently colored areas (objects) and in which each object contained one dot. The pigeons could successfully complete this training, suggesting that they could arrive at certain judgments according to the characteristics of two-dimensional objects. In further research (Lazareva, Castro, Vecera, Wasserman, 2006), pigeons were required to discriminate between a target square included in the object area and one presented in the surrounding area. The pigeons exhibited faster RTs when the target appeared in the object area than in the surrounding area. These results suggested that the attention of the pigeons was captured by the object.

Roelfsema, Lamme, and Spekreijse (1998) required macaques to fixate on a point (dot) and, after a brief delay, presented two disks. One disk was connected to the fixation point with a curved line, whereas another line extending from the other disk was not connected to the fixation point. Monkeys were rewarded for moving their focus of attention onto the former disk. The results showed that the neurons whose receptive field contained the line connected to the fixation point were activated more than were the neurons whose receptive field contained the other line, indicating that the monkeys visually attended to the entire line they were tracking.

In the present study, we examined the extent to which the attentional processes of chimpanzees involve object-based attention from the comparative–cognitive perspective. We used a methodology very similar to that used for human participants (Egly et al., 1994) and employed a spatial cuing task. Chimpanzees are the species closest to humans, and their performance in spatial cuing tasks has been shown to be similar to that of humans (Tomonaga, 1997, 2007). Thus, the present study will contribute to understanding the phylogenetic origins of human attentional processes.

## 2. Experiment 1

In Experiment 1, two chimpanzees participated in the task used by Egly et al. (1994), as modified for chimpanzees.

The object-based enhancement of spatial cues demonstrated by Egly et al. (1994) has been countered by arguments in favor of object-based inhibition of return (IOR) (Jordan & Tipper, 1998, 1999; Tipper, Weaver, Jerreat, & Burak, 1994). IOR is the phenomenon in which visual attention does not return to the location on which attention had been focused previously when the stimulus onset asynchrony (SOA) between a cue and a target extends beyond 300 ms (e. g., Klein (2000), Posner and Cohen (1984), for a review). Jordan and Tipper (1998) used the same procedure as that used by Egly et al. in which a cue appeared in one end of two rectangles and a target appeared in the same or in another place after a delay following the offset of the cue. Jordan and Tipper, however, added a longer SOA and found that the response to a target appearing in the cued object was longer than was that to the target appearing in the other object with the long SOA. Thus, we used two SOA conditions, 200 ms and 600 ms, in the present experiment. If chimpanzees' visual attention processes involved object-based IOR, we would expect that the response times (RTs) for both the target at the cued site and that within the cued object would be longer in the 600-ms SOA condition.

### 2.1. Methods

#### 2.1.1. Participants

Two adult female chimpanzees (*Pan troglodytes*), Chloe and Pendesa (see Fig. 1, bottom panel), participated in this study. Both had an extensive training history in various kinds of computer-controlled perceptual–cognitive tasks (Imura, Tomonaga, & Yagi, 2008; Inoue & Matsuzawa, 2007; Matsuno & Tomonaga, 2006; Matsuzawa, 2006; Tanaka, 2003, 2007; Tomonaga, 1997, 2007, 2008) and lived in a social group of 14 individuals in an environmentally enriched outdoor compound of the Primate Research Institute, Kyoto University, Japan (770 $m^2$; Matsuzawa, 2003, 2006). The experimental room could be reached by an overhead tunnel. This study involved no special food or water deprivation. Care and use of the chimpanzees adhered to the 2002 version of the Guide for Care and Use of Laboratory Primates of the Primate Research Institute. The research protocol was approved by the Animal Welfare and Animal Care Committee of the Institute.

#### 2.1.2. Apparatus

Experiments were conducted inside an experimental booth for chimpanzees (1.8 × 2.15 × 1.75 m). A 21-in. color CRT monitor (NEC PC-KH2021) with a capacitive touchscreen device (Microtouch SM-T2) was installed 15 cm from the floor on one side of the experimental booth. A touch to the monitor's surface by a participant's finger was defined as a response. The screen was protected from deterioration by a transparent plexiglass panel and fitted with an armhole (10 × 47 cm), which allowed hand contact with the CRT. The resolution of the monitor was 640 × 400 pixels. A food tray was installed below the CRT. A universal feeder (Biomedica BUF-310) delivered food items (small pieces of apple or raisins) to this tray. The equipment was connected to a personal computer (NEC PC-9821 Xn) that controlled the stimulus display, touch detection on the CRT, reward delivery, and data collection.

#### 2.1.3. Stimuli

The display of the present experiment consisted of objects, a cue, and a target (Fig. 1, top panels). The object was a solid black rectangle (9.9 cm long × 1.7 cm wide). We arranged two rectangles parallel to each other in either a vertical or a horizontal direction. The distance between these objects (center to center) was 9.9 cm. The cue was a yellow square frame (1.1 cm × 1.1 cm, 1 mm in thickness) and the target was a solid red circle (0.7 cm in diameter).

#### 2.1.4. Procedure

Each trial started with the presentation of a blue square (start key; 3.3 cm × 3.3 cm) and the two solid black rectangles (Fig. 1, bottom panel). The start key was located at the bottom center (below the rectangles) of the display so that the stimulus display was