Research report

Action-based distractor effects on the manual response times of chimpanzees during discrimination tasks

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Abstract

Two chimpanzees performed visual search and simple discrimination tasks in which manual pointing to the target stimulus was required. To clarify the action-based interference effects of the distractors, response time data were analyzed on the basis of the relationship among the positions of the target, distractors, and hand. In both tasks, clear action-based interference effects were observed. Firstly, distractors along the path of the manual response to the target caused greater interference (the response-path effect). Secondly, when distractors were located ipsilateral to the responding hand, response times were longer (the ipsilateral effect). These results are consistent with previous studies on selective reaching in humans, and they suggest that manual responses in chimpanzees are controlled by action-centered attention as is the case for humans. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

In most of the behavioral tasks for nonhuman primates in which manual responses, such as pointing and reaching, are required, the subjects often show positional biases in accuracy and response speed [14,16]. For example, Tomonaga [16] found that a chimpanzee showed faster manual response times when the target stimulus was presented on the ipsilateral side of the hand used and longer response times when the target was presented further from the starting position of the manual response. Usually, these biases are not discussed intensively but are considered merely as factors to be counterbalanced. These biases, however, may have some implications for cognitive processing in animals, including humans. One of the most important insights was made by Tipper et al. [12], who tested human subjects in a selective reaching task in which the time subjects took to move their hand from a starting position to a target object was measured. They found that limb movements toward target objects are affected by the presence and location of distractor objects. Tipper et al. [12] showed that manual responses were affected when the distractor was on the same side as the hand trajectory to the target. These findings suggested that biases in manual response times are not simply due to target location, as is usually suggested, but to the relationships between the target, distractor, and hand positions. They concluded that attention accesses action-centered internal representations during such manual response tasks and their findings have been replicated by other researchers using various kinds of manual tasks [1,7,9]. Furthermore, Tipper and his colleagues also found similar effects in macaque monkeys [10]. So, are chimpanzee’s manual response times during discrimination tasks also affected by spatial relationships among the target, distractor, and hand, and not simply by target locations? In this paper I reanalyzed chimpanzee response time data from previous visual search experiments on search asymmetries [13] and additionally trained one chimpanzee on a simple discrimination task. Both

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tasks required subjects to ‘touch’ the target stimulus on a touch-sensitive CRT display.

2. Methods

2.1. Subjects

Two adult chimpanzees (Pan troglodytes), Chloe (female) and Akira (male), participated in the previous visual search experiment [13]. One of these chimpanzees, Akira, also participated in the additional simple discrimination experiment. They lived in an outdoor compound with five other chimpanzees and had previously been the subjects of various kinds of visual discrimination tasks in which a manual response to the stimulus was required. The care and use of these chimpanzees adhered strictly to the 1986 version of the ‘Guide for Care and Use of Laboratory Primates’ of the Primate Research Institute, Kyoto University. During the experiments, deprivation of food and water did not occur. Both chimpanzees always used their right hand for manual responses.

2.2. Apparatus

Experiments were conducted in an experimental compartment (2.7 m×1.5 m×2.1 m) adjacent to the outdoor compound. A 14-in CRT display (NEC N5923) with an optical touch screen (Carroll Touch International UL-94V-0) was installed on one wall about 40 cm above the floor. Two steel pipes (30 cm×1.2 cm) protected the CRT screen and divided it into three horizontal rows. The subject sat about 30 cm away from the screen. A universal feeder (Davis Scientific Instruments UF-100) delivered a food reward (pieces of apple, raisins, peanuts, etc.) to the food tray installed on the lower left side of the monitor. A personal computer (NEC PC-98XA) controlled all experimental events.

2.3. Procedure

2.3.1. Visual search task

Fig. 1a is a schematic representation of a visual search trial [13,15]. After a 3-s intertrial interval (ITI), a white cross (1 cm×1 cm) was presented as the warning signal in the bottom center region of the CRT screen. When the subject touched the warning signal, the search display was presented in the top and middle rows of the screen. The search display contained a target and several uniform distractors. These stimuli were 2.5 cm-by-2.5 cm white geometric forms (Fig. 1a), which are used for various perceptual and cognitive experiments in our laboratory [3,5,6,13,15,17]. The subject was required to detect an odd-item target and touch it (odd-item search). When the subject touched the target, a food reward was given and a 1-s chime was sounded. Touching one of the distractors

![Fig. 1. Schematic diagrams of (a) visual search and (b) simple discrimination trials. Shaded arrows indicate the direction of hand movements.](image-url)
resulted in a 0.5-s buzzer sound. Response time was defined as that from the onset of the search display to the subject’s touch of the stimulus.

Each session consisted of 112 trials. Of these, 56 were odd-item search trials. The sample stimulus was followed by a search display in the other 56 trials (multiple-alternative matching-to-sample). These matching trials are not discussed in this report. Display sizes (i.e., the number of stimulus items) varied between 1 (only the target), 4, 7, and 12 items from trial to trial. The subjects were given four 10-session blocks.

The subjects exhibited more errors in the odd-item search trials when the display size was 4 (8.1% for display size 4 and 2.4% for the other sizes) and these trials had been omitted for further response-time analyses in a previous paper on search asymmetries [13]. In the present report, however, I have reanalyzed the response-time data with a display size of 4.

2.3.2. Simple discrimination task

As shown in Fig. 1b, after the 3-s ITI, a warning signal and 3×2 blank squares (2.5 cm×2.5 cm) appeared on the CRT screen. The warning signal was presented randomly at the top or bottom row of the screen from trial to trial. When the subject touched the warning signal, a target (β) and a distractor (*), both colored white, were presented in two of the six squares. The target and distractor stimuli were randomly and equally presented at each location. The consequences of the subject’s correct or incorrect responses were the same as those described above in the visual search experiments. Each session consisted of 144 trials. The warning signal appeared in the top row for half of the trials, and in the bottom row for the rest of trials. In 24 of these trials, only the target stimulus was presented. The subject was given 20 sessions.

3. Results

3.1. Visual search task

Mean response times averaged across subjects were 0.675 s for target-only trials and 1.238 s for correct trials with a display size of 4.

Tipper et al. [12] found two sources of distractor effects in their selective reaching task. First, when the distractor was located along the path of the manual response to the target, response times were longer compared to other conditions (response-path effect). Second, when the distractors were located in the hemispace ipsilateral to the responding hand, response times were also longer (ipsilateral effect). In the present experiment, each trial had a different spatial configuration from every other trial. I allocated these various configurations into several categories for the analyses of the two types of distractor effects.

![Fig. 2](image-url)
3.1.1. Response-path effect

Visual search trials were initially categorized into two categories on the basis of the vertical location of the target (top and bottom rows). Each category was then further divided into four subcategories on the basis of the number of distractors in the bottom row (0, 1, 2, and 3), irrespective of the horizontal location of the target (Fig. 2a). Configurations in which the target appeared alone in one of the rows or where all items appeared in the same row (i.e. the number of distractors in the bottom row was 0 or 3) were omitted from subsequent analyses because these extreme configurations occurred less frequently than the other configurations and might constitute rather different sources of response time bias from those being investigated here. The total number of correct visual-search trials used for data analysis was 653 (82.7% of total correct trials). Target-only trials were also divided into two categories on the basis of the vertical location of the target, irrespective of horizontal location. To distinguish between the simple effect of target location ([14,16] cf. Ref. [2]) and action-based distractor effects, mean response times for each condition were subtracted from the mean response times for target-only trials (i.e. display size 1). Hereafter, these values are called the ‘distractor effect’.

Both subjects exhibited stronger distractor effects when the number of the distractors in the bottom row was 2 than was 1, that is, at the midpoint of the response path to the target (Fig. 2a). A three-way [Target location (top or bottom) × Session blocks (three blocks) × Number of distractors (1 or 2)] analysis of variance (ANOVA) with subjects (N = 2) as repeated measures showed that the main effect of the number of distractors in the bottom row only was significant [F(1,1) = 506.25, P < 0.05].

3.1.2. Ipsilateral effect

To clarify the ipsilateral effect, visual search trials were again subdivided into two categories on the basis of the vertical location of the target and then each category was divided into four subcategories on the basis of the number of the distractors to the right of the target, that is, ipsilateral to the responding right hand, irrespective of the horizontal location of the target and the vertical locations of the distractors (Fig. 2b). For the same reason as in the analysis of response-path effect, extreme configurations, such as those in which all distractors appeared to the left or right of the target (i.e. the number of ipsilateral distractors was 0 or 3) were omitted from subsequent analyses. The total number of correct visual-search trials used for data analysis was 532 (67.3% of total correct trials). Target-only trials were again divided into two categories on the basis of the vertical location of the target, irrespective of horizontal location.

Fig. 2b clearly shows that the distractor effect was stronger when the number of distractors on the right side of the target was 2 rather than 1. A three-way [Target location (top or bottom) × Session blocks (three blocks) × Number of distractors (1 or 2)] ANOVA with two subjects as repeated measures statistically consolidated these results. The main effect of the number of distractors [F(1,1) = 489.85; P < 0.05] and interaction between target location and the number of distractors were significant [F(1,1) = 274.09; P < 0.05].

3.2. Simple discrimination task

The subject gave a highly accurate performance during the 20 sessions of testing. Mean percent error averaged across 20 sessions was 2.9% for trials with the warning signal in the top row, and 1.8% for trials with the warning signal in the bottom row. Mean response times were 0.605 s for target-only trials and 0.742 s for discrimination trials.

3.2.1. Response-path effect

As in the visual search task, response times for correct trials were initially averaged on the basis of the location of the distractor, target, and warning signal. Various target–distractor configurations were initially divided into two categories on the basis of the relationship between the target and warning signal (far from or close to the warning signal) for each warning signal location. For the response-path effect, only trials in which the target was located vertically ‘far’ from the warning signal were used for data analysis (1200 trials in total, 50% of the all discrimination trials). These trials were further divided into two types: trials in which the target and distractor appeared in the same row, and those in which the distractor was located vertically closer to the warning signal than to the target (Fig. 3a). As in the visual search experiment, the distractor effect was assessed by the difference between the mean discrimination response times for each type of trial and the corresponding target-only trials.

The subject showed a greater distractor effect when the target was located further from and the distractor closer to the warning signal than when the target and distractor were both far from the warning signal (Fig. 3a). A two-way ANOVA [Location of warning signal (top, bottom) × Location of the distractor (far, near)] with sessions as repeated measures revealed that this main effect of distractor location was significant [F(1,19) = 6.21, P < 0.05].

3.2.2. Ipsilateral effect

Only trials in which the target and distractor appeared in the same row were used for the analysis of the ipsilateral effect (960 trials in total, 40% of all discrimination trials). These trials were further subdivided into two categories on the basis of the relationship between target and distractor locations (target to the left or right of the distractor). As shown in Fig. 3b, when the distractor was located to the right of the target, the distractor effect was stronger than when it was located on the left side, irrespective of the
vertical location of the target stimulus. A two-way ANOVA [Location of warning signal (top, bottom) × Relative location of the distractor (left, right)] confirmed this main effect of distractor location \[F(1,19) = 9.50, P < 0.01\].

4. Discussion

The present paper analyzed the source of biases in the manual response times of chimpanzees during discrimination tasks in which they were required to touch the target with their finger. The present results clearly show that the location biases in response times were not simply due to the positions of the target, but to the location of distractor relative to the hand and target. When the distractor was located along the path of manual response, the subjects showed longer response times than when the distractor was at other locations. Analysis of the visual search data further clarified that this effect was stronger when the number of distractors in the path of the manual response increased. Data from the simple discrimination task showed that this response-path effect was not due to the absolute location of the distractor on the CRT screen. The distractor effect changed consistently as the relationship changed between the positions of the hand (i.e., location of warning signal), target, and distractors. As for humans, chimpanzees also showed a clear ipsilateral effect of distractors. Both chimpanzees consistently used their right hand during the present experiments and the distractor effect was greater when the distractor was on the right side of the target rather than the left in the simple discrimination task. It also increased as a function of the number of distractors to the right of the target in the visual search experiment. These effects have also been observed in humans \[7,12\]. Tipper et al. \[12\] found that the ipsilateral effect occurred even when the subject changed from using their right to their left hand. In the present experiments, I did not manipulate which hand the chimpanzees used. To prove that the present distractor effect was really ipsilateral, and not due
to the absolute relationship between the target and distractor, we should manipulate hand use as in the experiments of Tipper and colleagues.

In summary then, chimpanzee manual response times were affected in part by the distractor positions as is the case in humans. These results suggest that action-based inhibition also controlled the chimpanzees’ manual movement to a considerable degree. Tipper and colleagues further reported that action-based inhibition caused a differential effect on negative priming ([12] cf. Ref. [11]) and on the inhibition of return ([4] cf. Ref. [8]). In the present experiments, only action-based distractor effects were investigated but it seems highly likely that action-based inhibition would affect negative priming and inhibition of return in chimpanzees. Further investigation is necessary to determine how action-centered attention affects the performance of chimpanzees.

Pratt and Abrams [9] reported that the action-based interference occurred in the intervals between stimulus onset and movement onset (reaction time) and between movement onset and the end of the movement (movement time) (see also Ref. [7]). Furthermore, they found that the interference in movement time was only seen in the corrective component (time from the peak velocity to the end of movement) but not in the ballistic component (time from movement onset to peak velocity). In addition, Howard et al. [4] found differential effects in the action-based inhibition of return for each component of human manual movements. Unfortunately, I did not record each path of the subject’s hand movement, so it is unclear as to which components were more affected by the presence of distractors in the present experiments. Future research should focus on these aspects.

The action-based inhibition model seems more ecologically valid than those of other more traditional models of attention in humans [12], because traditional models are derived from the findings of relatively ‘unnatural’ experimental settings, in which typically brief two-dimensional stimuli are presented and arbitrary responses are required. Discrimination tasks that require reaching or pointing responses resemble more closely the natural behavior of organisms. Further research with nonhuman animals on action-centered attention with these kinds of experimental settings will contribute to the understanding of attentional processes from the perspective of comparative cognition.

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