VISUAL SEARCH BY CHIMPANZEES (*Pan*): ASSESSMENT OF CONTROLLING RELATIONS

MASAKI TOMONAGA

PRIMATE RESEARCH INSTITUTE, KYOTO UNIVERSITY

Three experimentally sophisticated chimpanzees (*Pan*), Akira, Chloe, and Ai, were trained on visual search performance using a modified multiple-alternative matching-to-sample task in which a sample stimulus was followed by the search display containing one target identical to the sample and several uniform distractors (i.e., negative comparison stimuli were identical to each other). After they acquired this task, they were tested for transfer of visual search performance to trials in which the sample was not followed by the uniform search display (odd-item search). Akira showed positive transfer of visual search performance to odd-item search even when the display size (the number of stimulus items in the search display) was small, whereas Chloe and Ai showed a transfer only when the display size was large. Chloe and Ai used some nonrelational cues such as perceptual isolation of the target among uniform distractors (so-called pop-out). In addition to the odd-item search test, various types of probe trials were presented to clarify the controlling relations in multiple-alternative matching to sample. Akira showed a decrement of accuracy as a function of the display size when the search display was nonuniform (i.e., each "distractor" stimulus was not the same), whereas Chloe and Ai showed perfect performance. Furthermore, when the sample was identical to the uniform distractors in the search display, Chloe and Ai never selected an odd-item target, but Akira selected it when the display size was large. These results indicated that Akira's behavior was controlled mainly by relational cues of target-distractor oddity, whereas an identity relation between the sample and the target strongly controlled the performances of Chloe and Ai.

Key words: visual search, stimulus control, matching to sample, odd-item search, relational learning, perceptual cues, screen touch, chimpanzees

Recently, visual search performance in animals has been of interest to researchers of complex stimulus control (D. S. Blough, 1986, 1989; P. M. Blough, 1984, 1989; Blough & Blough, 1990; Cook, 1992a, 1992b; Tomonaga, 1993a, 1993b, 1993d). Visual search procedures can be classified into three types. The first type is called *specific-item search* (D. S. Blough, 1979, 1989), in which discrimination of the target (S+) is taught to the subjects in advance through differential reinforcement training (D. S. Blough, 1979). Specific-item search is procedurally the same as simultaneous discrimination. This procedure can use nonuniform search displays (one target and several distractors that differ from each other) such as those used in the study of conjunction search (Cook, 1992a, 1992b; Treis-

man & Gelade, 1980; Treisman & Sato, 1990; Wolfe, Cave, & Franzel, 1989). Furthermore, if the subject is trained with multiple targets, the specific-item search can manipulate the "memory set" size (D. S. Blough, 1979; P. M. Blough, 1984). There are, however, some methodological limitations of the specific-item search procedure. It requires relatively long-lasting differential reinforcement training to establish simultaneous discrimination. Furthermore, whenever the target is changed, it is necessary to retrain the subjects.

The second type of procedure is the odd-item search (D. S. Blough, 1986, 1989), in which the target is defined as an odd item in the search display. Odd-item search is an extension of oddity discrimination (Carter & Werner, 1978; McCulloch & Nissen, 1937; Moon & Harlow, 1955; Nissen & McCulloch, 1937a, 1937b; Zentall, Hogan, & Edwards, 1980; Zentall, Hogan, Edwards, & Hearst, 1980). If the subject acquires generalized oddity discrimination (Moon & Harlow, 1955), target and distractor items can be changed from trial to trial. In odd-item search, a target is easily defined by manipulating the number of items in the search display; when the search display contains one A and 10 Bs, A is the

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target; conversely, B is the target if the display contains one B and 10 As. Hence, odd-item search can be useful for studying search asymmetry (Allan & Blough, 1989; Treisman & Gormican, 1988; Treisman & Souther, 1985; Tomonaga, 1993b). Conversely, because the target is defined as the odd item in the search display in odd-item search, nonuniform search displays cannot be used in this procedure (Cook, 1992a, 1992b; Matsuzawa, 1985; Treisman & Sato, 1990; Wolfe et al., 1989). For example, if the search display contains one A, one B, and 10 Cs, the target cannot be defined as the odd item in the search display.

The third type of visual search procedure is called *multiple-alternative matching to sample* (MTS). Tomonaga (1992, 1993a, 1993b, 1993d) developed a modified version of the MTS procedure for the study of visual search performance in a chimpanzee, in which a sample stimulus is followed by the search display containing one target (identical to the sample) and several distractors. Because the target is defined as an item identical to the preceding sample in multiple-alternative MTS, the sample plays an instructional role in human search experiments or serves as a "prime," as in the study of P. M. Blough (1989, 1991). As for the odd-item search task, it is also necessary for the subject to acquire generalized identity matching (Carter & Werner, 1978; Oden, Thompson, & Premack, 1988) in the multiple-alternative MTS if one wants to change the target from trial to trial. The multiple-alternative MTS can use a nonuniform search display (Matsuzawa, 1985; Tomonaga, 1993d) and change the target-distractor combination from trial to trial (Tomonaga, 1993a, 1993b, 1993d).

These distinctions among the three types of visual search tasks are not functional but merely procedural. It is quite possible that the controlling relations of individual behavior during these tasks may be potentially the same irrespective of their procedural differences. For example, when the uniform search display (one target and several uniform distractors) is presented in multiple-alternative MTS, the subjects can utilize two different relational cues. One is the physical identity between sample and target (identity rule), and the other is oddity between target and the distractors in the search display (oddity rule). The former rule involves successive discrimination, and the lat-

ter involves simultaneous discrimination. Furthermore, subjects' behavior can also be controlled by perceptual cues contained in the search display. In pigeons, their behavior during the odd-item search task is controlled by the perceptual contrast (or so-called pop-out) between the target (figure) and uniform distractors (ground) rather than by oddity rule (D. S. Blough, 1989; Zentall, Hogan, & Edwards, 1980; Zentall, Hogan, Edwards, & Hearst, 1980). A visual search procedure is quite useful for studying complex stimulus control processes such as attention (Allan & Blough, 1989; P. M. Blough, 1989, 1991; Tomonaga, 1993a, 1993b), memory (P. M. Blough, 1984), and foraging (Bond, 1983; Bond & Riley, 1991; Reid & Shettleworth, 1992) in animals and to compare such stimulus control among species, including humans. However, before going forward to study complex or "cognitive" behavior by using these visual search tasks, assessment of controlling relations in these tasks is necessary (see also Mackay, 1991).

In the present experiment, 3 experimentally sophisticated chimpanzees were trained on a multiple-alternative MTS task. Before the onset of the present experiment, they had a long training history on identity matching, but had no experience with odd-item search or oddity discrimination (see Table 1). As a result of the long training on identity matching, they showed generalized identity matching (Tomonaga, 1991, 1993c; Tomonaga & Matsuzawa, 1992; see also Matsuzawa, 1989a, 1989b, 1990). This fact may lead us to assume that their behavior can be characterized by an identity rule during multiple-alternative MTS.

The major aim of this paper was to assess the controlling relations in multiple-alternative MTS by these 3 chimpanzees. For that purpose, I conducted two series of tests. The first series clarified the role of the sample stimulus and assessed control by sample-target identity by testing the subjects for transfer from the multiple-alternative MTS to odd-item search. The second series also assessed the controlling relations in multiple-alternative MTS by using various types of test trials.

METHOD

Subjects

Three adult chimpanzees (*Pan*), Akira (male, 15 years old), Chloe (female, 11 years

Table 1
Experimental history of each subject.

Name	Age (Jan. 1992)	Sex	Initiation of the present experiments	Initiation of the first experiment in our institute	Training history involving conditional discrimination
Akira	15	male	June 1991	1976	generalized identity matching, arbitrary matching, test for symmetry, language training, numerical discrimination, individual recognition, category learning
Chloe	11	female	June 1991	1985	generalized identity matching, arbitrary matching, test for symmetry, stimulus class formation, MAMTS, form perception, mental rotation, serial learning, same/different discrimination, categorical sorting of objects
Ai	15	female	November 1991	1976	generalized identity matching, arbitrary matching, language training, color perception, form perception, form reconstruction, delayed form reconstruction, symbolic form reconstruction, numerical labeling, individual recognition, sex discrimination, use of "pronouns," description of action, MTS with real objects, categorization task, test for stimulus equivalence, face perception, transitive inference, serial learning with Arabic numerals

old), and Ai (female, 15 years old), served as subjects in the present experiments. Table 1 summarizes their previous experimental history. They had been trained on various types of conditional discrimination tasks such as MTS, although there were some differences in training duration, content, and levels of achievement among them. In particular, they had been extensively trained on identity matching with various visual stimuli, which had resulted in the formation of generalized identity matching (Tomonaga, 1991, 1993b; Tomonaga & Matsuzawa, 1992). All subjects had no experience with oddity discrimination and odd-item search. Chloe had been the subject in previous experiments using multiple-alternative MTS procedures (Tomonaga, 1993a, 1993d).

The subjects lived in an outdoor corral (624 m²) with 4 other adult chimpanzees. They maintained their free-feeding weights with no special deprivation throughout the present experiments. The experimental session was scheduled before daily feeding. They were housed, cared for, and used in accordance with the *Guide for the Care and Use of Laboratory*

Primates of the Primate Research Institute, Kyoto University (1986).

Apparatus

Experimental sessions were conducted in an experimental compartment for chimpanzees (2.7 m by 2.1 m by 1.5 m) situated adjacent to the enclosure. A 14-in. color CRT monitor (NEC Model N5923) with an optical touch panel (Carol Touch International Model UL-94V-0) was installed on one wall about 40 cm above the floor. A touch to the screen of the monitor was defined as a response. Two steel pipes (30 cm by 1.2 cm) protected the monitor and divided the screen into three horizontal rows. Each row was divided into six areas for stimulus presentation. The upper two rows were used for the presentation of the search display (12 areas), and the bottom row was used for the presentation of the sample stimulus (see Figure 1). The chimpanzee sat about 30 cm from the monitor. A universal feeder (Davis Scientific Instruments Model UF-100) delivered a food reinforcer (peanuts, chocolates, etc.) to the food tray installed to the lower left of the monitor. All equipment was con-

Fig. 1. Schematic diagrams of various types of trials in the present experiment. A: multiple-alternative MTS trial; B: sample/nonuniform distractors trial; C: odd-item search trial; D: no sample/nonuniform distractors trial; E: neutral sample/uniform distractors trial; F: negative sample/uniform distractors trial. Type A was used for baseline trials. Type C appeared in the first test series, and Types B, D, E, and F appeared in the second test series.

trolled by a personal computer (NEC Model PC-98XA).

Stimuli

Complex geometric forms made from two of nine elements (Kyoto University Lexigrams, 2.5 cm by 2.5 cm; Asano, Kojima, Matsuzawa, Kubota, & Murofushi, 1982; Matsuzawa, 1985; Tomonaga & Matsuzawa, 1992) were employed in the present experiments (see Figures 2 and 3). These stimuli were white on a black background. Each subject had been trained on identity matching with some stimuli from the Kyoto University Lexigrams (Asano et al., 1982; Tomonaga & Matsuzawa, 1992).

Procedure

Multiple-alternative MTS. In the present experiment, Tomonaga's (1993d) multiple-alternative MTS procedure was used with slight modifications. Figure 1A illustrates a typical trial of the multiple-alternative MTS in the present experiment. After the 3-s intertrial interval (ITI), a warning signal (white cross, 1 cm by 1 cm) was presented on the center of

the bottom row accompanied by a 1-s beep sound. When the subject responded to this warning signal, the signal disappeared and the sample stimulus was presented on the same location for 0.5 s, after which a white bar (30 cm by 4 cm) was presented on the bottom row (intended to mask any afterimage of the sample); simultaneously, the search display was presented. The search display contained one target identical to the preceding sample and several uniform distractors that were different from the sample but identical to each other. These items were presented on some of the 12 areas of the upper two rows and changed locations randomly from trial to trial, with the restriction that the target never appeared in the same location in successive trials. When the subject responded to the target, the search display was turned off, a 1-s chime was presented, and a reinforcer was given to the subject. When the subject responded to one of the distractors, the search display again was turned off, but a 0.5-s buzzer was presented and 2-s timeout was added to the usual ITI. When the subject made an error, the same target-dis-

Fig. 2. Target-distractor pairs employed in the baseline training and testing in the first test series. T: target, D: distractor.

tractor combination was presented with a different spatial arrangement until the subject made the correct response.

Acquisition training of multiple-alternative MTS. Each subject was initially trained on a standard two-alternative MTS with the same procedure described above. Each session consisted of 84 trials in which two of 36 two-element lexigrams were randomly presented as target and distractor. The search display contained only one target and one distractor. This training was continued for 13 sessions for Akira, 11 for Chloe, and 1 for Ai.

In the next phase, 12 target-distractor pairs were prepared by combining 12 lexigrams as shown in Figure 2. Each subject was trained on three-alternative MTS with these target-distractor pairs. Each session consisted of 84 trials, so that each target-distractor pair was repeated seven times in a session. On each trial, the search display had one target and two uni-

form distractors. This training was given for eight sessions to Akira and Chloe and for two sessions to Ai.

Next, training with variable display size (i.e., the number of stimulus items in the search display was varied) was introduced. In this training, the display size varied among 1 (target only), 2, 4, 6, 8, 10, and 12 items. Each session had 84 trials, in which each target-distractor pair appeared once for each display size. Each subject was given six sessions of this training.

First test series: Transfer from multiple-alternative MTS to odd-item search. Test sessions for transfer to odd-item search started after training with the variable display size. Each test session consisted of 72 multiple-alternative MTS baseline trials, in which the display size varied among 1 (12 trials), 2, 4, 6, 8, 10, and 12 items (10 trials for each display size), and 12 odd-item search probe trials in which the

Fig. 3. Sets of target and distractors employed in the second test series. On trials with uniform search display, D1 was used as the distractor. When the display was nonuniform, distractors were picked from D1 through D7. D2 was also used as the sample in neut/UD probe trials.

display size varied among 2, 4, 6, 8, 10, and 12 items (two trials for each display size) and the target-distractor pairs were the same as in baseline trials. Odd-item search probe trials were randomly interspersed among the baseline trials. Each subject was given six test sessions, yielding 12 trials (one for each target-distractor pair) for each display size. Figure 1C shows a schematic diagram of odd-item search probe trials. On these trials, the warning signal remained on for 0.5 s after the initial response to it, resulting in the simultaneous presentation of the white masking bar and the search display. While differential reinforcement was in effect on baseline trials, responding to an item in the display had no conse-

quences on probe trials other than termination of the display and initiation of the next ITI. Ai was given six-session odd-item search tests twice. Before the onset of the second test, she was given two sessions of variable display-size training on multiple-alternative MTS with a change of temporal variables; the duration of the sample was reduced from 0.5 s to 0.1 s, and the interval between the offset of the sample and the onset of the search display (sample-display interval) was lengthened from 0 s to 1 s. In the second test, these values were reset to a 0.5-s sample duration and a 0-s sample-display interval. *Second test series: Assessment of controlling relations in multiple-alternative MTS.* The sec-

ond test series further assessed controlling relations in multiple-alternative MTS using various types of probe trials. After the first series, each subject was immediately shifted to the second series. Figure 3 shows the eight stimulus sets employed in this series. Each set had one target and seven different distractors. On multiple-alternative MTS baseline trials, the distractors were all Stimulus D1 (Figure 3). Stimuli D2 through D7 were used for probe trials in which nonuniform distractors appeared (see below for details). In this series, each session consisted of 96 baseline multiple-alternative MTS trials and 20 probe trials. On probe trials, no differential consequences were given (as in the previous test phase) while differential reinforcement was in effect on baseline trials. The display size on baseline trials varied among one (target only), two, three, four, six, and eight items. Eight target-distractor pairs appeared twice for each display size. On probe trials, the display size varied among two, three, four, six, and eight items. Four types of probe trials appeared once for each display size (see below). Each subject was given 16 test sessions, so that each type of probe trial appeared 16 times for each display size during testing.

In the second test series, four types of probe trials appeared. On the first—sample/nonuniform distractors (SMP/NUD; Figure 1B)—the sample stimulus was followed by the search display containing one target identical to the sample and several nonuniform distractors. For example, with Display Size 4, the search display contained one target and distractors D1, D2, and D3. On the second type of probe trial—no sample/nonuniform distractors (ϕ /NUD; Figure 1D)—no sample was presented; only the nonuniform search display was shown. The target was arbitrarily defined by the experimenter because it could not be defined by the sample.

On the third type—neutral sample/uniform distractors (neut/UD; Figure 1E)—the sample stimulus was followed by a search display that contained one target and several uniform distractors. However, the sample was different from the target and distractors and was called a neutral sample. The neutral sample was drawn from D2 in Figure 3. If the subjects' behavior was controlled by oddity or perceptual pop-out during multiple-alternative MTS, then they would select an odd item in the search display on this type of trial. A response to an

odd item in the search display was defined as a correct response. For trials with Display Size 2, the correct stimulus (target) was arbitrarily defined by the experimenter. On the fourth type of probe trial—negative sample/uniform distractors (neg/UD; Figure 1F)—the sample stimulus was identical to the distractors in the subsequent uniform search display and was called a negative sample. This probe assessed the difference in degree of control by identity, oddity, and perceptual pop-out. If identity were dominant over oddity or perceptual pop-out, the subjects should select one of the distractors that was identical to the negative sample. On the other hand, if oddity or perceptual pop-out were dominant, the subjects should select the odd item. An odd item in the search display was defined as the correct item. With Display Size 2, the target was defined as the item different from the sample.

RESULTS

Acquisition Training

In two-alternative MTS training, Akira showed 90.4% correct in the first session and 90.5% on average for the last two sessions. Chloe showed 94.0% correct in the first session and maintained 96.4% on average for the last two sessions. Ai was 100% correct in all sessions. The mean accuracy during three-alternative MTS training was 90.8% for Akira, 97.9% for Chloe, and 98.8% for Ai. For the last two sessions of variable display-size training, Akira showed 93.8% correct, Chloe 97.9%, and Ai 99.3% (note that trials with Display Size 1 were omitted from these calculations).

First Test Series

Figure 4 shows the results from odd-item search test sessions for each subject in the first test series. Each data point for odd-item search probes is calculated on the basis of 12 trials. This figure also shows chance level calculated on the basis of display size ($1/\text{display size} \times 100$) and the significant above-chance level at the 5% level based on a binomial test that used a chance level dependent on the display size and the number of probe trials (12) for each data point.

On the baseline trials in multiple-alternative MTS, all subjects showed more than 90% correct for all display sizes, except on trials with Display Size 2 for Akira; these had a slightly lower accuracy (85%). Akira and Chloe

Fig. 4. Mean percentage correct on baseline and odd-item search probe trials for each subject in the first test series. Horizontal axis indicates the display size. Filled circles indicate the baseline multiple-alternative MTS trials, and open circles indicate the odd-item search probe trials. The solid line curve shows chance level dependent on display size, and the dotted line shows the statistically significant level (binomial test, $\alpha = .05$). An asterisk was added if the accuracy was statistically significant versus a conservative chance level (50%).

showed statistically significant above-chance performances on odd-item search probe trials for all display sizes, except for Display Size 2 in which the target could not be defined by an odd item in the search display. Although Ai showed significant above-chance performance on odd-item search probe trials with Display Sizes 6 and 8, her overall accuracy was near chance irrespective of the display size in her first test. During the second variable display-size multiple-alternative MTS training with a shorter sample duration and a longer sample-display interval, Ai showed 70.8% correct for trials with Display Size 2, 95.8% for Size 4, 91.7% for Sizes 6 and 8, 95.8% for Size 10, and 87.5% for Size 12. In the second odd-item search test, Ai showed highly accurate performance on odd-item search probe trials with larger display sizes (from 8 to 12), and showed statistically significant above-chance performance on small-display odd-item search probe trials (Display Sizes 4 and 6).

Second Test Series

Figure 5 presents the results from probe test sessions for each subject in the second test se-

ries. The upper panel shows the mean accuracy on SMP/NUD and ϕ /NUD trials, and the lower panel shows accuracy on neut/UD and neg/UD trials. Each panel also shows mean accuracy on multiple-alternative MTS baseline trials. As in Figure 4, the size-dependent chance level and significant level at 5% (binomial tests) calculated from the size-dependent chance level are also shown.

All subjects showed highly accurate performances (more than 90% correct) on multiple-alternative MTS baseline trials for all display sizes. On SMP/NUD trials, there was a difference in accuracy between Akira and the other 2 subjects. Akira showed an accuracy decrement as a function of display size, although choice accuracy remained significantly above chance, whereas Chloe and Ai showed highly accurate performance. Results of the ϕ /NUD trials showed a near-chance performance and decreased along with size-dependent chance level for all subjects.

Individual differences were also evident in the neut/UD and neg/UD trials. Akira showed almost 80% correct on neut/UD trials, whereas the performances of Chloe and Ai on these

Fig. 5. Mean percentage correct on baseline and probe trials for each subject in the second test series. Each panel includes the results of baseline multiple-alternative MTS trials, size-dependent chance level (solid line curve) and significant level at 5% on the basis of size-dependent chance level (dotted line) and conservative (50% correct) chance level (asterisk). Upper panel: SMP/NUD and ϕ /NUD trials; lower panel: neut/UD and neg/UD trials.

trials varied between 40 and 60% correct. On neg/UD trials, all subjects selected an item identical to the negative sample with Display Size 2 (one target and one distractor). Chloe and Ai consistently selected a distractor even when the large display was presented. In contrast, Akira showed a gradual increase in accuracy along with the display size; he selected an odd item as reliably as on neut/UD trials with Display Size 8.

DISCUSSION

The results of the first test series suggest that transfer from multiple-alternative MTS to odd-item search occurred in chimpanzees. Improvement of odd-item search probe performance for Ai from the first to the second odd-item search test gives some information about this transfer. By shortening the sample duration and inserting a sample-display interval, the second multiple-alternative MTS training weakened the control by the sample (or the sample-positive comparison relation) over her visual search behavior and resulted in strengthening of control by some other cues existing in the search display (i.e., Ai's performance was controlled by oddity or perceptual pop-out of the target). In other words,

manipulation of experimental variables that alter (or diminish) the saliency of one cue type (e.g., sample-positive comparison relation) is likely to alter control by that cue type in choice among comparisons. If the subject were trained on multiple-alternative MTS with nonuniform distractors, control by the target-distractor relation might diminish and control by the sample-positive comparison relation would increase. This possibility should be examined in the future.

Another possibility concerning the effects of the second training series is that Ai simply came not to "attend to" the sample. This possibility might be supported by the fact that she showed lower accuracy on multiple-alternative MTS trials with Display Size 2 during the second training series. However, this second possibility cannot explain the results of the second test, because the second test was conducted under the same conditions as the first test, and Ai showed 100% correct on baseline multiple-alternative MTS trials with Display Size 2 during this test.

Although I tentatively concluded that the chimpanzees did show positive transfer from multiple-alternative MTS to odd-item search, one critical problem is involved in interpreting the present results. Do the present results from

odd-item search probe trials really confirm control by oddity? D. S. Blough (1989) conducted a transfer test of odd-item search performance from trained to new stimuli with pigeons. In his experiment, he set the chance level at 50% (rather than the size-dependent chance level applied in my experiment), because he assumed that two sources of bias affected probe performance. One was the target-distractor similarity, and the other was the preference for the specific stimuli. These factors may be difficult to control precisely. The pigeons in Blough's experiment showed accurate performances on transfer test trials with a new target and new distractors only with the maximum display size (24); they showed less than 50% correct on trials with Display Sizes 3 and 8. From these results, Blough drew the conclusion that the pigeons' odd-item search performance was controlled by a perceptual isolation (or pop-out) of the target from the distractors or by familiarity with the target-distractor combination rather than by oddity, because if oddity controlled behavior, "performance should be degraded by large displays, because . . . [the oddity rule] implies serial processing at least until the different target has been found" (D. S. Blough, 1989, p. 21). Zentall, Hogan, Edwards, and Hearst (1980) also examined the effect of the number of stimulus items (display size) on oddity discrimination and obtained a decrease of accuracy as the number of incorrect stimuli (distractors) decreased. They also concluded that the pigeons' behavior was mainly controlled by perceptual figure-ground relations. Such a deterioration (or no improvement) of performance (decrease in accuracy and increase in response time) with a decrease in display size has also frequently been reported in human visual search experiments and treated as evidence for the influence of perceptual cues (Pashler, 1987; Teichner & Krebs, 1974).

If Blough's "conservative" chance level was applied to the first test series of my experiment (see asterisks in Figures 4 and 5), the present results could be reinterpreted. In Figure 4, asterisks were added near the data points if they were significantly above the conservative 50% correct level (i.e., to be significantly above 50%, the percentage correct had to exceed 83.3%). Akira showed significantly above-chance performance even on trials with the minimum display size, whereas Chloe and Ai

(in the second test) showed evidence for transfer to odd-item search only on trials with a relatively large display size. Nissen and McCulloch (1937a, 1937b; McCulloch & Nissen, 1937) also found that chimpanzees showed rapid acquisition on oddity tasks with large display size, although they did not with small display sizes (e.g., 3). This reanalysis of the present results confirmed that control by oddity was in part involved in Akira's odd-item search performance, but not for Chloe and Ai. Their performances depended not on oddity but on the perceptual isolation (pop-out) of the target from the distractors, as was the case for Blough's pigeons. This conclusion, that their behavior was controlled by perceptual pop-out on odd-item search probe trials, is itself very interesting, because generalized MTS is considered to require the subjects' behavior to come under control of sample-comparison identity relations. The results from Chloe and Ai suggest that control by perceptual cues emerged during the multiple-alternative MTS training.

The results of the second test series also indicate a difference in stimulus control in multiple-alternative MTS between Akira and the other 2 subjects. For Akira, performance on neut/UD and neg/UD trials improved as a function of the display size. These results clearly illustrate the change of stimulus control from the sample-target relation to other cues in the search display, such as oddity or perceptual isolation of the target, when the display size became larger. He showed accurate performance on odd-item search probe trials with smaller display sizes in the first test series. These results taken together suggest that when the sample-target relation was not available, target-distractor oddity (which is a relational cue) was the discriminative cue for Akira.

In contrast, Chloe and Ai always selected a distractor on neg/UD trials, whereas their performances were almost perfect on SMP/NUD trials. These results clearly indicate that their performances were strongly controlled by an identity relation between the sample and the target. Furthermore, when identity was not present on neut/UD trials, these subjects showed almost chance (conservative, 50%) performances, although they were significantly above size-dependent chance when the display size was large; this might indicate that their performances depended in part on perceptual isolation of the target on the large-display tri-

als. This aspect of the results may be consistent with the results of the first test series.

In sum, the present tests revealed that in multiple-alternative MTS, control by identity was relatively stronger for Chloe and Ai than for Akira. Furthermore, if the sample was absent or the sample-target relation was inappropriate, Akira's behavior was controlled mainly by another relational cue (i.e., oddity, whereas perceptual isolation of the target controlled the behavior of Chloe and Ai).

Where did the individual difference come from? The subjects had different experiences on conditional discrimination tasks (Table 1). For example, Ai had a much longer training history on identity matching than the other subjects. Chloe, although having experienced a shorter training duration than the others, showed stronger transfer of identity matching than Akira in the previous experiments (Asano et al., 1982; Tomonaga, 1993c; Tomonaga & Matsuzawa, 1992). This difference in degree of establishment of generalized identity matching may have caused a difference in degree of stimulus control in the present experiment. This view is also supported by the fact that Akira's performance on SMP/NUD trials in the second series became worse as the display size became larger, suggesting less control of his behavior by the sample-target relation than for the other chimpanzees.

The present results may be somewhat weak to support a general conclusion concerning the chimpanzees' general ability on generalized identity matching or oddity discrimination. However, the fact that chimpanzees show great individual variability or flexibility (e.g., Asano et al., 1982; Tomonaga, 1993b; Tomonaga, Matsuzawa, Fujita, & Yamamoto, 1991) should make us recognize the need for a survey of each individual's past stimulus-control history and assessment of controlling relations of present behavior. Visual search is a revealing procedure for the comparative study of complex types of stimulus control such as cognition and perception. This task can assess such abilities in humans and animals under the same procedure (Allan & Blough, 1989; Dursteler & von der Heydt, 1992; Tomonaga, 1993b, 1993d). The present study offers some useful information about visual search at the procedural level and about conducting comparative perception/cognition studies using humans and animals.

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