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ORIGINAL ARTICLE

Recognition of pictorial representations by chimpanzees (*Pan troglodytes*)

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Abstract In this study, I investigated chimpanzees' ability to recognize pictorial representations. Four adults and three juvenile chimpanzees were trained to choose images of photographs of flowers among 12 items belonging to four categories on a touch-sensitive monitor. As a generalization test, the following five types of images were presented: (1) novel photographs, (2) colored sketches (more realistic), (3) a colored clip art (cartoon-like images), (4) black-and-white line drawings, and (5) Kanji characters (as the control images). One adult and all three juvenile chimpanzees were able to choose any style of the nonphotographic images of flowers significantly above the chance level, whereas none could choose the correct Kanji characters corresponding to a flower significantly above the chance level. The other three adult chimpanzees' performance level did not exceed the chance level in terms of choosing nonphotographic images although they showed good transfer skills to novel photographs. The results revealed that not all chimpanzees could recognize pictures used by humans without training. The results also suggest "critical period" in acquisition of skill in recognizing pictures in chimpanzees. Only one adult chimpanzee, who had acquired skill in recognizing visual symbols, also recognized pictures aside from the juvenile chimpanzees. Her learning history might have aided her in acquiring this skill. The results of this study suggest a relationship between pictorial competence and symbolic one.

Keywords Chimpanzee · Categorization · Pictorial representation · Picture · Critical period

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Introduction

Pictures (e.g., sketches or cartoons) are forms of abstraction from their corresponding objects. There are various types of pictures. Some pictures are very realistic, whereas some are not. There are also differences in drawing styles between cultures. Human children usually start to draw spontaneously at approximately 18 months. Previous studies of drawing in children showed the involvement of developmental processes in the acquisition (Gardner 1980; Cox 1992). On the contrary, it is controversial about the developmental processes of ability to recognize pictures. Some studies suggest that the ability to recognize pictures would not depend on previous experience or cultures (Hochberg and Brooks 1962; Kennedy and Ross 1975). However, DeLoache et al. (1998) suggest that infants begin to acquire a concept of "picture" by 19 months of age through experience. Human children have usually seen many pictures in books before they start to draw. Parents often explain to their children what these pictures represent. Children can thus learn how to recognize pictures in such opportunities. Therefore, it is not surprising that human children can recognize pictures before they can draw representational pictures by themselves.

It is difficult for human children to investigate developmental processes of recognizing pictures because they have many opportunities to learn in social and physical environments. In animals, it is possible to investigate their abilities to recognize pictures because we can control their opportunities to learn. In animal cognition studies, many researchers investigate the abilities of abstraction. In particular, concept formation studies showed that nonhuman animals were able to form various types of concepts that are composed of many exemplars (e.g., Herrnstein and Loveland 1964; Sands et al. 1982; Bhatt et al. 1988). Recent studies have shown that even infants of Japanese macaques and chimpanzees were able

to distinguish certain categories from others (Murai et al. 2004, 2005). Successful categorization requires that nonhuman animals should be able to abstract some shared elements among various exemplars belonging to one category. Previous studies suggest that subject animals can abstract these shared elements from two-dimensional stimulus slides, and that they can use such elements to distinguish novel slides.

Nonhuman animals are also able to match three-dimensional objects to their corresponding two-dimensional stimuli (Watanabe 1997). Pigeons are also able to discriminate the painting styles of various European artists (Watanabe et al. 1995; Watanabe 2001a). However, some studies suggested that pigeons do not recognize cartoons as representations of humans (Cerella 1980; Watanabe 2001b). It may not be sufficient to abstract physical features from visual stimuli to recognize pictures. Recent studies suggest that pigeons are able to perceive both global and local aspects of pictures (Kirkpatrick-Steger et al. 1996; Matsukawa et al. 2004). It is still controversial whether nonhuman animals perceive and recognize pictures in the same manner as humans do.

Previous studies on drawing in nonhuman primates revealed that captive great apes spontaneously made paint (Morris 1962; Smith 1973; Boysen et al. 1987). Even a 13-month-old chimpanzee can spontaneously draw using fingers on a touch-sensitive screen (Tanaka et al. 2003). These results suggest that drawing behavior in nonhuman primates may reflect an intrinsic interest in exploratory and manipulative play. However, most of the authors agree that great apes will continue to remain at the scribbling stage and will not progress to the acquisition of representational drawing skills.

In this study, I investigated the ability of chimpanzees to recognize pictures. This study used four adult and three juvenile chimpanzees and investigated whether they could recognize pictures. I used four types of pictures (i.e., from detailed realistic to cartoon-like pictures) to estimate the effects of styles of pictures. I also examined the effect of training using Kanji (Chinese) characters as symbols, which denote only an arbitrary relationship for the subjects.

Experiment 1

In experiment 1, four adults and three juvenile chimpanzees were trained to select photographs of flowers from images belonging to four categories. After training, the subjects' ability to choose novel photographs of flowers was tested.

Methods

Subjects

The subjects were four adults and three juvenile chimpanzees (*Pan troglodytes*). Table 1 shows the profile of each subject. They were previously tested regarding their cognitive abilities in various experiments (e.g., Kawai and Matsuzawa 2000; Tanaka 2001; Matsuzawa 2003; Tomonaga et al. 2004; Matsuzawa et al. 2006). In particular, Ai, an adult chimpanzee was intensively trained using visual symbolic system or Arabic numerals (Matsuzawa 2003). Chloe, another adult chimpanzee mainly participated in perception studies (Fagot and Tomonaga 2001; Tomonaga 2002). Pan was intensively trained particularly in auditory-visual cross-modal matching (e.g., Kojima et al. 2003). Mari participated in less number of studies than the other adult chimpanzees. In addition to their care in scientific studies, the adult chimpanzees were also cared for by human caregivers using a variety of materials during their young age. Juvenile chimpanzees also participated in various cognitive studies from perception to social intelligence domain (Matsuzawa et al. 2006). Each juvenile chimpanzee has been taken care of by his/her own mother from birth. Thus, each juvenile chimpanzee always participated in this study with his/her mother. While the juvenile chimpanzees were tested, their mothers were doing

Table 1 Subjects and their profiles

Name	Age at test	Sex	Note
Ai	23 years	Female	Mother of Ayumu. Experiments were held before giving birth. The subject in Tanaka (2001).
Mari	23 years	Female	The subject in Tanaka (2001).
Chloe	24 years	Female	Mother of Cleo. She was tested in the same period as Cleo did.
Pan	16 years	Female	Mother of Pal. Experiments were held before giving birth. The subject in Tanaka (2001).
Ayumu	4 years 10 months to 5 years 3 months	Male	A son of Ai.
Cleo	4 years 8 months to 5 years 1 month	Female	A daughter of Chloe.
Pal	4 years 6 months to 11 months	Female	A daughter of Pan.

other tasks. The subjects were members of a community of 14 chimpanzees living in an enriched outdoor compound with attached indoor rooms. They were not deprived of food throughout the entire 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 (2002).

Apparatus

The subjects were trained and tested in an experimental booth (1.8 m in width, 1.8 m in depth, and 2.0 m in height). A 21-inch CRT monitor with a touch screen (Totoku, CV213PJ), or a 15-inch LCD monitor with a touch screen (Pro-Tect, PD-105TP15) was installed on one wall of the booth. A universal feeder (Biomedica, BUF-310) delivered small pieces of food reward (pieces of apples, or raisins) into a food tray. Personal computers controlled the equipment.

Stimuli

The stimuli used were digitized color images made from photographs of natural or artificial objects. Each image was presented on a 7 cm × 7 cm square on a 21-inch CRT monitor, and on a 5.6 cm × 5.6 cm square on a 15-inch LCD monitor. Each of the objects belonged to one of four categories: flower, tree, grass, and "others." The "others" category included ground surfaces, walls, rocks, or water. The objects are normally found in the subjects' environment, or are normally seen daily. During training, each category was composed of 12 different exemplars, resulting in a total of 48 pictures. The stimuli used in the training were the same as those used by Tanaka (2001), in which the chimpanzees were able to discriminate the four categories from one another. Three adult chimpanzees, namely, Ai, Mari, and Pan, participated in the study of Tanaka (2001). In addition, 480 novel digitized color photographs were used for the generalization test. Each photographed item was different from all the other items. These 480 items belonged to four categories as mentioned earlier. Each category contained 120 exemplars.

Procedure

Experiment 1 consisted of two phases, a training phase and a test phase.

Training phase: A trial was started by presenting a solid gray square (4 cm) in the lower half of the monitor display as a starting stimulus. After the subject touched the stimulus, the stimulus disappeared and 12 images showing 12 different items were presented on the monitor display (in 4 columns and 3 rows) (see Fig. 1). Each set of 12 images consisted of three photographs each of flowers, trees, grasses, and the items from the others category. When the subject touched the image of a flower, there was a sound of a chime and a food reward was delivered, followed by an immediate blackout of the monitor display. Touching the images of the other items was followed by an immediate blackout of the monitor display. After a 1 s blackout, the stimuli were presented again except for those that the subject previously touched. The trial continued until the subject had chosen three items. The subjects were given three food rewards if they selected all the photographs showing flowers from among the 12 images presented. The subjects were thoroughly familiar with this procedure having participated in a previous study involving the choice of more than one item among several on the monitor display (Tanaka 2003). One session consisted of 56 trials. All possible combinations of three flowers chosen from a total of eight kinds of flowers for training were combined with nine items from the other three categories and presented once in a session. The training phase continued until the subject chose the flowers with more than 90% accuracy in each choice opportunity of a trial in five successive sessions. However, Mari did not achieve this learning criterion. In her case, the training phase ended when the overall percentage of her correct choices within a session was more than 90% in 10 successive sessions.

Test phase: The general procedure was the same as that in the training phase. A session of the test phase consisted of eight test trials in addition to 56 trials of the training phase (baseline trials). In the test trials, 12 novel photographs were presented. The 12 photographs consisted of three images each from the flowers, trees, grasses, and the items from the other categories. The test trials were intermixed randomly among the 56 baseline trials. In the test phase, each novel image was presented three times over 15 sessions. In the first five sessions (i.e., the first presentation of each of the novel stimuli), the subject received a food reward irrespective of the chosen category. In the following 10 sessions (i.e., the second and third presentations for each novel stimulus), the subject received a food reward only after choosing the images of flowers, as in the baseline trials.

Data analysis: The number of correct stimuli in the second or third choices was dependent on the subject's choices in previous opportunities in a trial. Therefore, chance level was based on the total number of correct choices in a 5-session block. The chance level score was calculated as follows: If the subject touched the stimuli randomly, each category should have been chosen the same number of times. That is, the subject would choose 30 flowers among 120 opportunities (i.e., 5 sessions × 8 trials × 3 opportunities).[1]

[1] Calculation of chance level in test trials. There are 220 ways in which the subject chose three items among the 12 different presented items (i.e., ${}_{12}C_3 = 220$). Among the combination of the chosen items, there is one combination wherein all three items are flowers. In this case, the

Fig. 1 Video-captured image showing experimental procedure. The subject touched an image of a flower among 12 presented images

Results and discussion

Training phase

All juveniles and the three adult chimpanzees (Ai, Chloe, and Pan) started choosing flowers with almost perfect accuracy very soon after the start of the training. In contrast, Mari's percentage of correct choices of flowers was near the chance level (total: 25%) at the beginning, and she required several sessions compared with the other subjects for her to achieve the revised learning criterion. All the subjects, however, eventually learned to choose the flowers accurately, although there was considerable difference among the ease of choosing with which the subjects achieved the learning criterion (see Fig. 2).

Test phase

In the baseline trials throughout the test phase, all the subjects maintained their high levels of performance (Ai: 98.6%, Mari: 93.2%, Chloe: 97.7%, Pan: 96.7%, Ayumu: 97.9%; Cleo: 97.6%, Pal: 97.3%). In the test trials, the subjects also chose the novel images of flowers significantly more than the chance level on the first presentation in both adult and juvenile chimpanzees (see Table 2 and Fig. 3) even though they received a food reward after their choices of nonflower items. Repeated presentations and differential feedback led to an increase in the number of correct choices by Ai and Pan. Chloe and three juvenile chimpanzees showed very good performance at the first presentation and maintained their high level of performance at the second and third presentations. For Mari, the number of correct choices (Fig. 3) was slightly low, but her choice rates of the images of flowers were significantly above the chance level (second presentation, $\chi^2 = 9.74$, $p = 0.002$; third presentation, $\chi^2 = 6.81$, $p = 0.009$).

ANOVA using the variables age class (adult and juvenile) and presentation times (three) performed on the number of correct choices revealed neither the main effect of

Table 2 Numbers and percentage of the correct choices, χ^2 and p-values at the first presentation in each subject

Subject	Number	%	χ^2, df = 1	P
Adult				
Ai	72	60.0	30.1	$p < 0.001$
Mari	57	47.5	13.1	$p < 0.001$
Chloe	85	70.8	50.5	$p < 0.001$
Pan	66	55.0	22.5	$p < 0.001$
Juvenile				
Ayumu	84	70.0	48.7	$p < 0.001$
Cleo	84	70.0	48.7	$p < 0.001$
Pal	86	71.7	52.3	$p < 0.001$

subject chose three correct images in total (1×3). There are 27 ways in which the subject chose two flowers and one item from the other three categories (i.e., ${}_3C_2 \times {}_9C_1$). In these cases, the subject chose 54 correct images in total (27×2). There are 108 ways in which the subject chose one flower and two from the other categories (i.e., ${}_3C_1 \times {}_9C_2$). In these cases, the subject chose 108 correct images in total (108×1). If the subject randomly chooses three items among the presented items in 220 trials, the subject will choose a total of 165 correct images. In the same way, the number of images chosen from the other three categories will be calculated as follows: tree: 165, grass: 165, and others: 165. Thus, the calculated chance level was 25%.

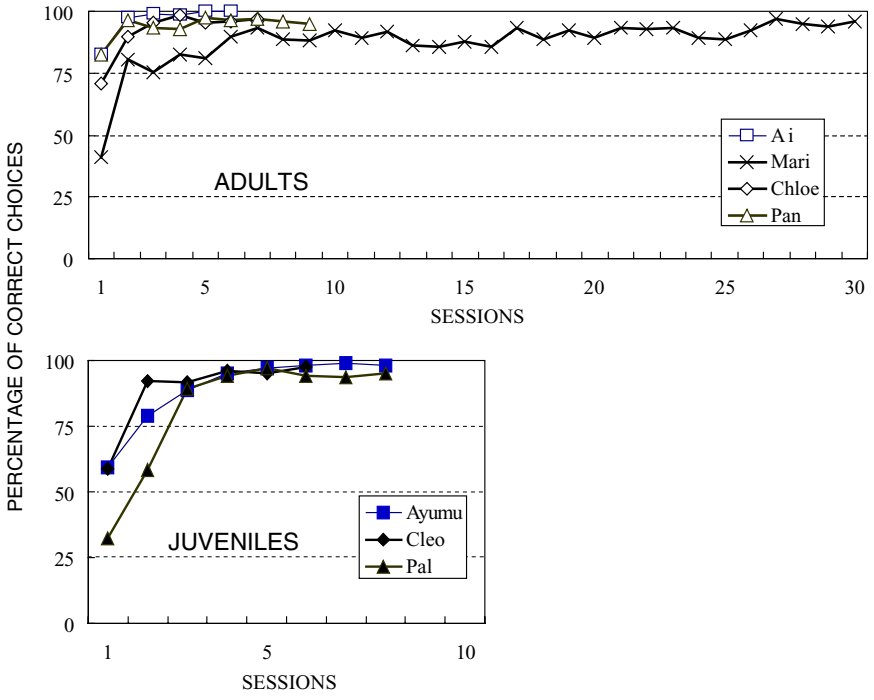

Fig. 2 Percentage of correct choices per session for each subject in training phase of experiment 1. The chance level is 25% because within each set of 12 images presented to the subjects, only three were flowers

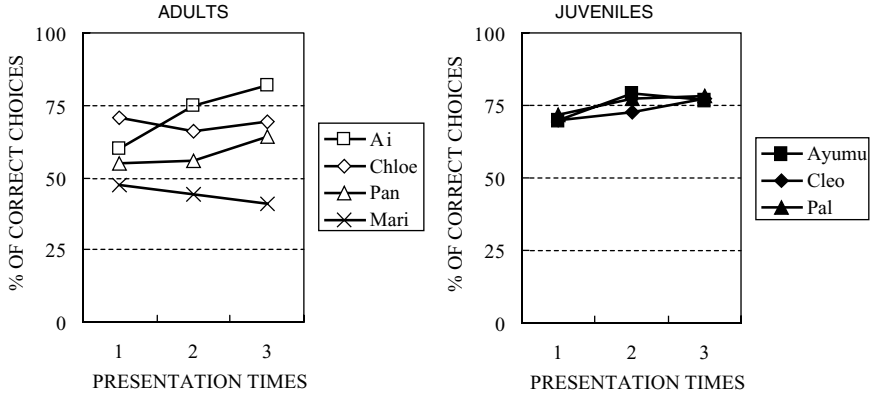

Fig. 3 Percentage of correct choices in baseline and test trials in each 5-session block of test phase of experiment 1

Age class ($F_{1,\ 5} = 3.51$, $p = 0.12$), nor presentation times ($F_{2,\ 10} = 2.42$, $p = 0.14$), and no interaction ($F_{2,\ 10} = 0.245$, $p = 0.79$).

The results suggest that the chimpanzees learned to choose all three images of flowers correctly from among the 12 images on the monitor display and that they could transfer this skill to the novel photographs. Some features of the images of flowers were shared with those of trees and grasses (e.g., green leaves), and images of the others category sometimes contained a red, yellow, or white patch similarly contained in the images of flowers. The subjects sometimes chose such images, but all the subjects chose the images of flowers much more than the chance level.

In some adult subjects (Ai, Mari, and Pan), the number of correct choices decreased in the later sessions of the first presentation (i.e., session 4 or 5). This may be due to a food reward being given regardless of the category of their choices. However, after changing the feedback procedure, Ai and Pan regained to their high levels of performance as observed in the early sessions of the test phase. In the following experiments, the subjects received a food reward only after making the correct choice of flowers.

Experiment 2

In experiment 2, two types of pictures were used to examine the transfer of skills in the chimpanzees. One type included more realistic sketches, which are used in illustrated reference books on plants and flowers. The second type contained clip art from computer software, but these pictures were not realistic but cartoon-like. It is assumed that humans can recognize both types of pictures as corresponding to real-life objects.

Methods

Subjects and apparatus

The subjects and apparatus were the same as those in experiment 1.

Stimuli

The stimuli in the baseline trials were the same as those in experiment 1. In the test trials, 480 images of colored sketches were used. These were taken from illustrated reference books on plants and flowers for children. One hundred twenty of these images were of flowers, whereas the other images were of trees, leaves, branches, grasses, or ground surfaces. Another 480 images of color clip art were also used. These were not realistic, but were cartoon-like pictures taken from computer software. One hundred twenty of these images were those illustrating flowers, whereas the remaining images were of various types of trees, leaves, grasses, and some daily objects, which the subjects had not seen.

Procedure

The general procedure was the same as that in the test phase in experiment 1. One session was composed of 56 baseline trials and 8 test trials. All the subjects were tested whether they could recognize sketches of flowers. The subjects were given three blocks of five sessions, in which each sketch image was presented once within a 5-session block. After 15 sessions with sketch image presentations, the subjects were given another three blocks of five sessions, in which clip art images were used in the test trials. Each clip art image was presented once within a 5-session block.

Results

Throughout experiment 2, the performance in the baseline trials was stable and high (more than 90% correct) in all the subjects. The percentage of correct choices in the test trials for each subject is shown in Fig. 4. The four adult subjects differed in their performance. Ai was able to choose images of flowers in both types of pictures (colored sketch and clip art) during the first presentation. The percentage of correct choices was much higher than the chance level (chi-square test, df = 1, sketch: $\chi^2 = 27.4$, clipart: $\chi^2 = 45.3$, p's < 0.001). The number of correct choices in both types of pictures increased with repeated presentations of the images (second presentation, sketch: $\chi^2 = 38.8$, clip art: $\chi^2 = 72.8$; third presentation, sketch: $\chi^2 = 42.0$, clip art: $\chi^2 = 79.8$, p's < 0.001). Chloe was able to choose the sketch images of flowers very well (first presentation: $\chi^2 = 18.1$, $p < 0.001$). Her performance level with the clip art images was also higher than the chance level (first presentation: $\chi^2 = 5.53$, $p = 0.019$), but was not good as that with the sketch images. In contrast, Mari's percentage of correct choice of the clip art images of flowers was significantly higher than the chance level for the first presentation ($\chi^2 = 6.15$, $p = 0.013$), but the number of correct choices did not increase in the second and third presentations (second: $\chi^2 = 4.93$, $p = 0.026$; third: $\chi^2 = 8.97$, $p = 0.003$). Pan did not choose significantly above the chance level with either sketch or clip art images (sketch, first presentation: $\chi^2 = 0.86$, second presentation: $\chi^2 = 0.19$, third presentation: $\chi^2 = 0.75$, p's > 0.3; clip art, first presentation: $\chi^2 = 0.34$, second presentation $\chi^2 = 1.65$, third presentation: 0.53, p's > 0.19). Her performance did not improve after repeated image presentations.

Three juvenile chimpanzees showed very good performance with both types of pictures. In the first presentation of nonphotographic images, Pal chose the images of flowers as many as her choice of the chance level (sketch: $\chi^2 = 2.42$, $p = 0.12$), but her performance improved markedly in the second and third presentations (second presentation: $\chi^2 = 42.0$, third presentation: $\chi^2 = 72.8$, p's < 0.001). Ayumu and Cleo's percentage of choosing the images of the sketch flowers were significantly higher than the chance level for the first presentation (Ayumu: $\chi^2 = 5.53$, $p = 0.019$, Cleo: $\chi^2 = 27.4$, $p < 0.001$). After repeated image presentations, Cleo maintained a high level of performance (second presentation: $\chi^2 = 34.3$, third presentation: $\chi^2 = 32.9$, p's < 0.001), and Ayumu's number of correct choices increased (second presentation: $\chi^2 = 22.5$, third presentation: $\chi^2 = 42.0$, p's < 0.001). All juvenile chimpanzees were able to choose the clip art images of flowers for the first presentation (Ayumu: $\chi^2 = 30.1$, Cleo: $\chi^2 = 35.8$, Pal: $\chi^2 = 62.0$, p's < 0.001) and maintained a high level of performance.

ANOVA using the variables image types (sketch and clip art), age class (adult and juvenile), and presentation times (three) revealed that the main effects of age ($F_{1,10} = 5.47$, $p = 0.041$) and presentation times ($F_{2,\ 20} = 13.4$, $p < 0.001$) were significant and that the interaction between age and presentation times was significant ($F_{2,\ 20} = 4.60$, $p = 0.023$). Sheffe's test revealed that the number of correct choices of images in the first presentation was significantly lower than those after repeated image presentations [first vs. second presentations, $p = 0.014$; first vs. third presentations, $p < 0.001$].

Discussion

The results revealed a clear difference between adult and juvenile chimpanzees in their performance with either type of nonphotographic images. The results suggest that juvenile chimpanzees could recognize both realistic (i.e., sketch) and nonrealistic (i.e., clip art) images with only a few times of

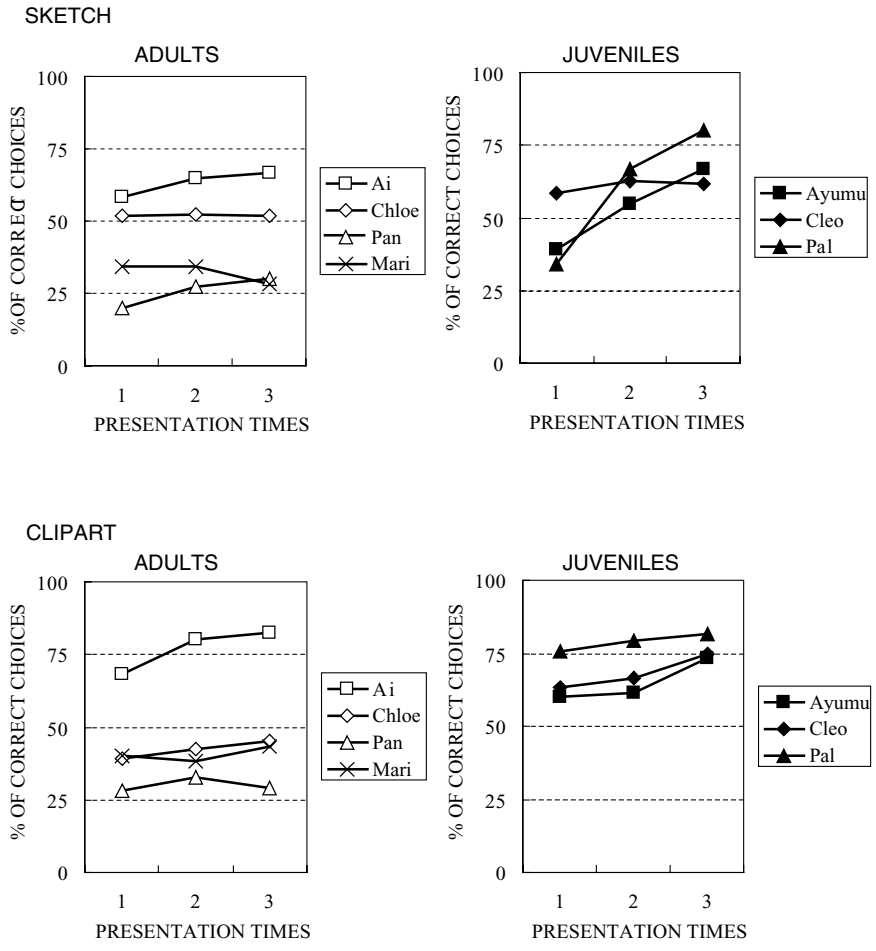

Fig. 4 Percentage of correct choices in test trials in each 5-session block of experiment 2

image presentation. Ai was the only adult chimpanzee that showed high performance with either types of image similar to the juvenile chimpanzees. The results suggest that not all chimpanzees could show the same response to photographic and nonphotographic images even after repeated image presentations.

It is likely that the flowers in the sketch images resembled real flowers more closely, at least for humans, than those in the clip art images, because the sketch images were taken from illustrated reference books. However, only Chloe showed better performance of making the right choice with sketch images than with clip art images. Most subjects showed no difference in their performance of making the right choice between the sketch images and the clip art images, or slightly better performance with the clip art than the sketch images. The results suggest that the subjects did not merely transfer recognition skill to the new stimuli on the basis of perceptual similarity to photographic images used in the training. The chimpanzees might not perceive resemblance between the flowers in the pictures and real flowers.

In particular, Mari could not accurately choose the correct images among the colored sketches above the chance level. She might have possibly made her choices on the basis of the perceptual features of the flower images (i.e., bright color, round shape), which were rare in the other, nonflower images. Such features might have aided the other chimpanzees' choices.

Experiment 3

In experiment 3, the subjects were tested for their ability to recognize line drawings of flowers that had no color cue. In addition, the subjects were trained to choose specific visual symbols corresponding to flowers. In experiment 3, I examined whether the subjects could recognize line drawings from the start of the test phase, and how this recognition compared with the recognition of arbitrary symbols.

Methods

Subjects and apparatus

The subjects and apparatus were the same as those in experiments 1 and 2. One chimpanzee, Ai, was trained to

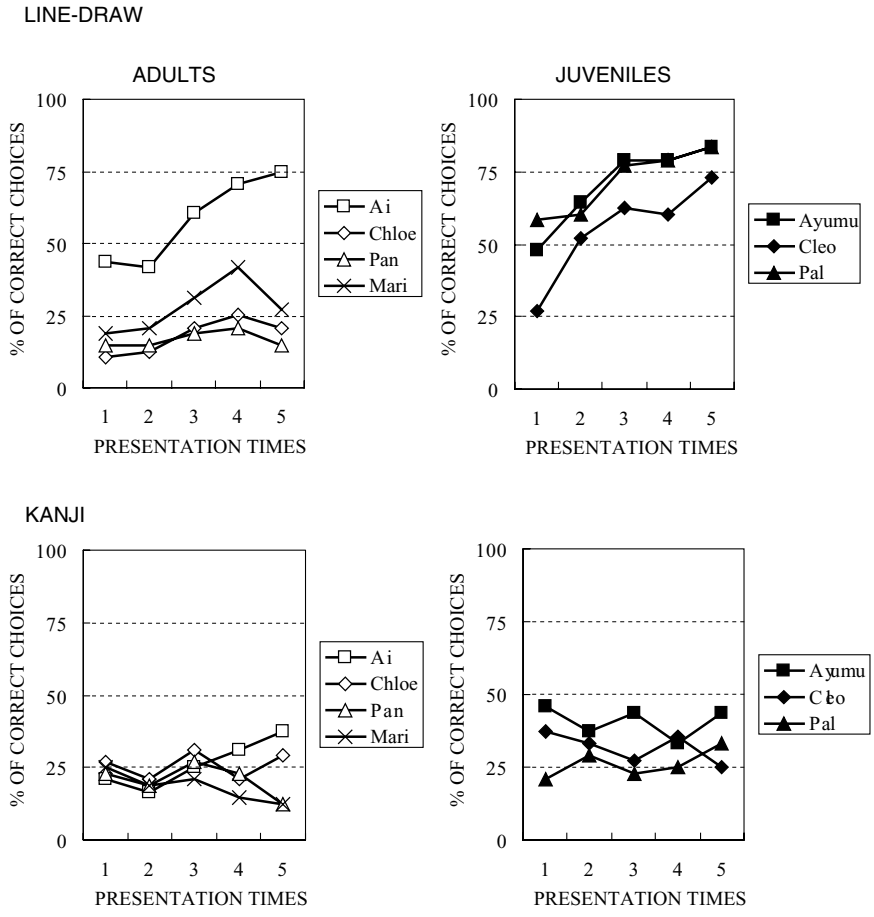

Fig. 5 Percentage of correct choices in test trials in each 2-session block of experiment 3

match symbols to the corresponding objects or concepts (Matsuzawa 2003), but had never seen the symbols used in experiment 3.

Stimuli

The stimuli in the baseline trials were the same as those in experiment 1. In the test trials, 48 images of black-and-white line drawings were used. These images were taken from a variety of books with illustrations. These included 12 images of flowers whereas the remaining images were images of trees, leaves, branches, grasses, or parts of daily objects that the subjects had not seen. Four Kanji (Chinese) characters were used, whose meanings corresponded to the concepts of flower, tree, grass, and others. Each character was presented in 12 different computer fonts.

Procedure

The general procedure was the same as that in experiment 2. One session was composed of 56 baseline trials and 8 test trials. The subjects were given five blocks of two sessions, in which each line drawing image was presented once within a 2-session block. After 10 sessions with line drawing image presentations, the subjects were given another five blocks of two sessions, in which Kanji character images were used in the test trials. Each Kanji character image was presented once within a 2-session block.

Results

Throughout experiment 3, the performance of the subjects in the baseline trials was stable and high (more than 95% correct choices) in all the subjects. The percentage of correct choices in the test trials for each subject is shown in Fig. 5.

The four adult subjects differed in their performance levels. Ai chose the line drawing images of flowers with good accuracy above the chance level, although the numbers of correct choices did not exceed the chance level significantly in the first and second image presentations (chi-square test, df = 1, first presentation: $\chi^2 = 3.74$, $p = 0.053$, second presentation: $\chi^2 = 3.00$, $p = 0.083$). In subsequent sessions, the number of correct choices of the line drawing images increased and Ai's performance level increased significantly above the chance level from the third presentation onwards (third presentation: $\chi^2 = 12.3$, fourth presentation: $\chi^2 = 20.2$, fifth presentation: $\chi^2 = 24.0$, p's < 0.001).

The number of correct choices of the line drawing images did not exceed the chance level significantly for Mari (for the following image presentations: first: $\chi^2 = 0.55$, $p = 0.45$, second: $\chi^2 = 0.24$, $p = 0.63$, third: $\chi^2 = 0.46$, $p = 0.50$, fourth: $\chi^2 = 3.00$, $p = 0.083$, and fifth: $\chi^2 = 0.05$, $p = 0.82$), Chloe (for the following image presentations: first: $\chi^2 = 3.50$, $p = 0.06$, second: $\chi^2 = 2.46$, $p = 0.12$, third: $\chi^2 = 0.24$, $p = 0.63$, fourth: $\chi^2 = 0$, $p = 1.00$, and fifth: $\chi^2 = 0.24$, $p = 0.63$) and Pan (for the following image presentations: first: $\chi^2 = 1.64$, $p = 0.20$, second: $\chi^2 = 1.64$, $p = 0.20$, third: $\chi^2 = 0.55$, $p = 0.46$, fourth: $\chi^2 = 0.24$, $p = 0.63$, and fifth: $\chi^2 = 1.64$, $p = 0.20$).

Three juvenile chimpanzees showed good performance with the line drawing images. Ayumu and Pal chose the line drawing images of flowers with good accuracy above the chance level from the first presentation onward (Ayumu: for the following image presentations: first: $\chi^2 = 5.44$, $p = 0.020$, second: $\chi^2 = 15.2$, $p < 0.001$, third: $\chi^2 = 28.2$, $p < 0.001$, fourth: $\chi^2 = 28.2$, $p < 0.001$, and fifth: $\chi^2 = 32.9$, $p < 0.001$; Pal: first: $\chi^2 = 11.0$, second: $\chi^2 = 12.3$, third: $\chi^2 = 26.1$, fourth: $\chi^2 = 28.2$, and fifth: $\chi^2 = 32.9$, p's < 0.001). For the other juvenile chimpanzee, Cleo's performance level increased significantly above the chance level from the second presentation onward (for the following image presentations: first: $\chi^2 = 0.05$, $p = 0.82$, second: $\chi^2 = 7.43$, $p = 0.006$, third: $\chi^2 = 13.7$, $p < 0.001$, fourth: $\chi^2 = 12.3$, $p < 0.001$, and fifth: $\chi^2 = 22.1$, $p < 0.001$).

In contrast, none of the subjects chose the correct Kanji characters at a significant level more than the chance level throughout experiment 3, except for Ayumu's first image presentation ($\chi^2 = 4.55$, $p = 0.033$). The performance of all the subjects did not improve. Even in the case of Ayumu, the number of correct choices of Kanji characters decreased (for the following image presentations: second: $\chi^2 = 1.75$, $p = 0.19$, third: $\chi^2 = 3.74$, $p = 0.05$, fourth: $\chi^2 = 0.81$, $p = 0.37$, and fifth: $\chi^2 = 3.74$, $p = 0.053$).

ANOVA using the variables image types (line drawing and Kanji), age class (adult and juvenile), and presentation times (five) revealed that main effects of image type ($F_{1,10} = 12.3$, $p = 0.006$), age class ($F_{1,10} = 9.54$, $p = 0.011$), and presentation times ($F_{4,\ 40} = 10.6$, $p < 0.001$) were significant and that the interaction between the image type and the presentation times was significant ($F_{4,\ 40} = 11.3$, $p < 0.001$).

Discussion

The results revealed a clear difference between the adult and juvenile chimpanzees in their performance with line drawing images (i.e., pictures), but not with Kanji characters (i.e., symbols). The results suggest that juvenile chimpanzees were able to recognize line drawing images with few presentation times. The subjects did not use any color cues to distinguish the categories. Nevertheless, two of the juvenile chimpanzees were able to choose the correct images of flowers from the first presentation. The other juvenile chimpanzee was also able to choose the correct images from the second presentation.

In contrast, Ai was the only adult chimpanzee that showed as high performance level similar to the juvenile chimpanzees (at least from the third presentation onward). The other three adult chimpanzees could not recognize the line drawing images as flowers, or could not distinguish the line drawings of flowers from those of the other images. These results suggest that it is not easy for chimpanzees to recognize line drawing images, and that line drawings are not assumed as equivalent to photographs for all chimpanzees.

In experiment 3, none of the chimpanzees acquired the skill of choosing the correct Kanji character images. One chimpanzee, Ayumu, exceeded the chance level for the first presentation, but his number of correct choices decreased in the following presentations. Ai's performance started to improve, but eventually failed to learn the task by the end of the experiment. The other chimpanzees did not show any improvement in all the testing sessions.

Kanji characters are symbols whose association with flowers was arbitrary for the chimpanzees. The results in the three chimpanzees, namely Mari, Chloe, and Pan, suggest that the line drawing images for these subjects were not different from the Kanji characters in that such images did not contain sufficient information to identify them as the correct choice. In the three juvenile chimpanzees and one adult chimpanzee, Ai, the line drawing images became more meaningful than the Kanji characters. At least for them, the black-and-white line drawing images were equivalent to colored pictures.

General discussion

In the present study, I examined whether the adult and juvenile chimpanzees could choose various types of nonphotographic images of flowers as accurately as their photographic equivalents. The subjects were trained to select images of photographs of flowers from among a set of images of photographs depicting other real-life objects, and they were then tested to recognize such images using sketches, clip art, and line drawings images. The subjects were also tested to select the correct Kanji character to estimate the effect of learning during the experiment. The results differed considerably between juvenile and adult chimpanzees. Juvenile chimpanzees could correctly select the images of flowers in any type of novel picture set and novel photographs. However, they did not acquire the skill of choosing the correct Kanji character. The three adult chimpanzees, namely Mari, Chloe, and Pan, could correctly select novel photographs of flowers, but they

could not choose the corresponding correct clip art, or line drawings of flowers.

The results revealed that not all chimpanzees could recognize nonphotographic images as representations of natural objects, or even photographs without specific training. Whether the images were realistic or not, or colored or not, they did not convey as much information to the chimpanzees regarding the depicted objects in the photographs. The results suggest that the ability of chimpanzees to recognize pictures is not genetically programmed, but should be acquired as a skill after birth. This is related to the findings that chimpanzees did not draw any representational images (e.g., Morris 1962; Boysen et al. 1987; Tanaka et al. 2003). It may not be reasonable to expect chimpanzees to recognize representational images because they do not draw representational images themselves.

An exceptional adult chimpanzee, Ai, showed the same performance level as those of the juvenile chimpanzees. Among the adult chimpanzees, only Ai has acquired the skill of a visual symbolic system (Matsuzawa 2003). Ai was previously tested with line drawings of portraits of familiar humans, chimpanzees, and an orangutan (Itakura 1994). At that time, Ai was 12 years old. She was also able to match line drawings to the letters of the alphabet that corresponded to an individual's name. Her learning history might promote her skill of recognizing visual stimuli.

The three juvenile chimpanzees that participated in this study have never acquired the skill of the visual symbolic system that Ai did. All of them, however, acquired the skill of recognizing pictures easily. However, the three adult chimpanzees other than Ai have also participated in various cognitive studies for a long time (e.g., Tanaka 2001; Tomonaga 2002; Matsuzawa 2003). The results suggest a critical period of acquisition of pictorial representation in chimpanzees. The studies of tool use in wild chimpanzees suggest a critical period for their acquisition of the tool use skill (Matsuzawa 1994; Inoue-Nakamura and Matsuzawa 1997). Longitudinal observation revealed that almost all young chimpanzees acquired oil palm nut cracking skills using a pair of stones in four stages, whereas at least two adult chimpanzees never used stone to crack oil palm nuts. However, all of their offspring had no difficulty in cracking nuts with stones. Similarly, the adult chimpanzees, namely Chloe and Pan, could not recognize the pictures, whereas their daughters, Cleo and Pal, showed no difficulty in recognizing pictures. It may be necessary for chimpanzees to learn some types of association within several years in their early age.

Callaghan (1999, 2000) suggested that the production and understanding of graphic symbols (i.e., pictures) can be supported by verbal symbolic abilities. In a study by Callaghan (2000), 2.5-year-old children failed to match any pictures to their referents, whereas 3-year-old children performed very well. When verbal labels were available, these 2.5-year-old children performed better than when these labels were unavailable. These findings are supported by the results in this study. Among the adult chimpanzees, only Ai acquired matching association skills between language-like symbols and their referents and consistently maintained her skill level. Moreover, only Ai could correctly choose the flower images in any styles of pictures presented to her in this study. Although the other adult chimpanzees could correctly choose photographs of flowers, they could not transfer this skill to nonphotographic images of flowers. It was not clear whether Ai used a "verbal" label, but her previously acquired skill might have aided her performance.

Through this study, it is concluded that chimpanzees could not recognize nonphotographic pictures without learning. In addition, it may be necessary for chimpanzees to learn during "critical period" in childhood. The results of this study suggest a relationship between pictorial competence and symbolic one.

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