Japanese Psychological Research
1996, Volume 38, No. 3, 126–135
Special Issue: Cognition and behavior of nonhuman primates

Visually guided drawing in the chimpanzee (*Pan troglodytes*)[1]

IVER H. IVERSEN
Department of Psychology, University of North Florida, Jacksonville, Florida 32224, USA

TETSURO MATSUZAWA
Section of Language and Intelligence, Department of Behavioral and Brain Sciences, Primate Research Institute, Kyoto University, Inuyama 484, Japan

Abstract: Two captive, female chimpanzees (*Pan troglodytes*) were taught to draw straight lines with a method of electronic finger painting. Subjects faced a touch-sensitive monitor. Because a touch instantaneously generated electronic ink in the form of a graphic symbol at the touched location, movement of the finger over the monitor surface produced a visible trace. Drawing was taught in several steps, beginning with pressing separate small circles one at a time. As the circles were moved closer and overlapped, the subjects began to connect them without lifting the finger. After smooth drawing was established, two small dots, 12 cm apart, appeared on the monitor in different orientations. Each subject drew a line connecting the dots by placing a finger on one dot and moving the finger, without lifting, to the next dot. Thereby the dot orientations guided the drawing. The subjects were not drawing by tracking a moving object but were truly free drawing. The fully automated training and recording methods generated highly accurate drawing behavior that could be measured quantitatively. Our results provide clear evidence that with training the chimpanzee is capable of structured drawing guided by visual commands.

Key words: chimpanzee, drawing, electronic finger painting, successive approximation, behavior shaping.

Captive apes are known to draw with markers or paint brushes. However, the drawings are mere scribbles, with only occasional evidence of visually guided drawing (Boysen, Berntson, & Prentice, 1987; Morris, 1962; Schiller, 1951; Smith, 1973). No previous study has demonstrated that an ape can be taught to draw reliably in a controlled manner. Here we briefly describe some highlights of an automated training method of electronic finger painting that established accurate visual guidance of free drawing in two adult female chimpanzees. Our approach is based on principles of behavior shaping by successive approximation (e.g., Eckerman, Hienz, Stern, & Kowlowitz, 1980; Gleeson, 1991) and methods of moment-to-moment behavior analysis (Iversen, 1991). Because it is new, the training method is outlined in general here and in more detail under Method.

[1] The present study was supported by grants from the Ministry of Education, Science, and Culture, Japan (Nos. 04551002, 04651017, 05044006, 06260222, and 07102010) to Matsuzawa and a Visiting Research Scholarship to Iversen. We thank the following people for their assistance: M. Tanaka, S. Nagumo, M. Tomonaga, K. Fujita, and S. Kojima. We also thank the two research partners, Ai and Pendesa.

Subjects faced a touch-sensitive monitor that displayed visual stimuli. Figure 1A illustrates the steps of training. Each step consisted of several sessions, and each session consisted of several trials. On each trial, the monitor presented a stimulus pattern. First, several non-overlapping circles were presented in a linear pattern, and the subject had to press the circles from top to bottom or from right to left (steps 1 and 2). Each training step had four types of trials, based on the orientation of the stimulus pattern, as indicated for step 2 in Figure 1A. The rationale of the early training is illustrated in Figure 1B. At first the subject presses an open circle, and it turns into a blue disk to provide visual feedback and leave a trace on the monitor in the form of electronic ink. The subject then lifts the finger and presses the next circle, and so on. Reinforcement is delivered when all circles have been touched. With circles gradually overlapping more and more (step 3), we predicted that the lifting movement would diminish and eventually disappear, resulting in generation of a continuous, sweeping movement. Once a sweep was generated, the stimuli were modified in several steps to two small dots (step 10). During the first nine steps, drawing generated ink only in a confined target area, defined by the location of the stimuli. In step 10, ink was generated at any location the subject touched; the task was now very much like drawing on paper with a marker. From step 6 on, a trial-termination response was added to the task; after having completed the drawing, the subject had to press a white patch in the lower right-hand corner of the monitor to provide reinforcement.

The goal of training was to establish visual guidance of drawing behavior, as illustrated in Figure 1C. Each trial starts by the display of two dots in one of four orientations (A–D). The subject aims at one dot and sweeps over the monitor surface in one continuous touch to the other dot, thereby leaving a trace that connects the dots; the subject then lifts the finger, and ends the trial by pressing the patch in the right-hand corner.

Method

Subjects

We studied two captive, adult, female chimpanzees (Ai, aged 16 years, and Pendesa, aged 15 years) who had had prior laboratory experience (e.g., Kojima & Kiritani, 1989; Matsuzawa, 1985a, 1985b, 1990; Tomonaga & Matsuzawa, 1992). Ai had considerable experience with free drawing on paper with markers or other material. She had also used a touch-screen monitor, when she learned to construct complex visual patterns from their elemental components in a task called constructive matching-to-sample (Fujita & Matsuzawa, 1990). In contrast, Pendesa had no such experience and was naive experimentally compared with Ai regarding drawing and the use of a touch-screen monitor.

Both subjects spontaneously and exclusively used the right hand for drawing in the present study. In simple reaching for food, Ai was ambidextrous and Pendesa showed a right-hand preference (Tonooka & Matsuzawa, 1995). Subjects were not food deprived and received 100–200 daily training trials. The chimpanzees were kept in a group of seven chimpanzees who live in an outdoor enclosure with an attached indoor residence. They were cared for according to *Guide for the care and use of laboratory primates* of the Primate Research Institute, Kyoto University.

Apparatus

From the outdoor enclosure, subjects entered an experimental booth (150 cm × 180 cm × 200 cm) equipped with a Mitsubishi FHC Vex color-display 21 inch touch-screen monitor on one wall. Bits of fruit or candy were delivered automatically as reinforcement into a small cup on the left-hand wall. A NEC (Model PC-9801F2) personal computer was used for programming using the QuickBasic language.

Procedure

Subjects faced the touch-screen monitor, which displayed visual stimuli. The location of a touch on the monitor was recorded automatically. The stimulus presented on the monitor was an

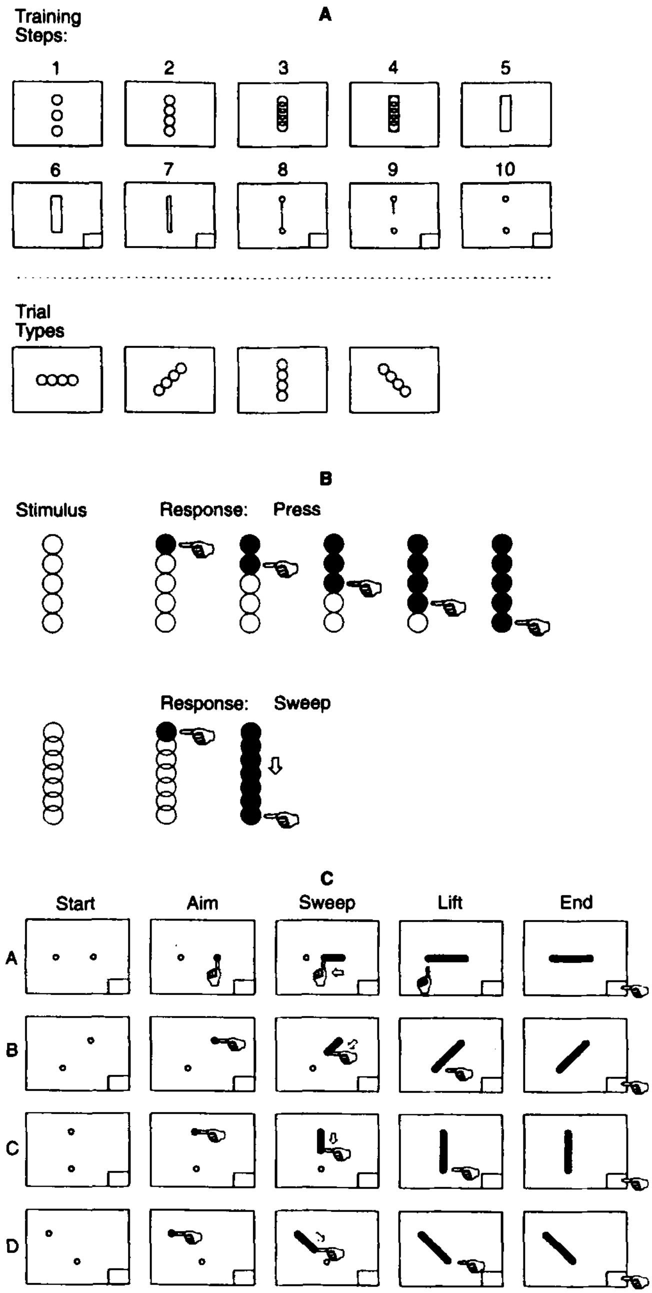

Figure 1. Schematic diagrams showing the logic of the experiment. (A) shows the 10 steps of training. Each frame exemplifies what was displayed on the monitor. The stimulus pattern on each trial was one of four orientations or types, as shown for training step 2. For illustrative purposes, the stimulus patterns are enlarged relative to the monitor size. (B) shows the two ways of responding to the screen: first, the subject pressed a circle, lifted the finger, pressed the next circle, and so on; later, the subject moved the finger over the circles in one continuous, sweeping movement without lifting the finger. (C) The goal behavior of drawing in response to the two-dot pattern for each trial type (A–D) in step 10.

alignment of white unfilled circles in training steps 1–4 (Figure 1A), a white unfilled rectangle in steps 5–7, or two white filled dots in steps 8–10. Four types of each stimulus were displayed, as shown for step 2 in Figure 1A. The four stimulus types occurred equally often and in mixed order within each session. In steps 1–4, four to eight circles (diameter 50 pixels) were presented (stimulus dimensions are given in pixels; for the monitor used 100 pixels equalled 6 cm). The subject had to press the circles from top to bottom on vertical or diagonal displays or from right to left on the horizontal display. Touching a circle in its proper order instantaneously produced electronic ink on the monitor at the touched location in the form of a blue disk of the same size as the circle; if a circle was pressed out of order, it was not covered by a blue disk. The circle center-to-center distance was gradually reduced in steps 1–4, from 100 pixels (circles apart) to 50 pixels (circles touched) and further to 32 pixels (circles overlapped by 18 pixels). In steps 5–7, circles were removed and replaced with a rectangle that was gradually reduced in width (from 40 to 10 pixels); rectangle length varied from 90 to 120 pixels. As the subject moved the finger over the rectangle, blue disks (diameter 40 pixels) appeared, as in earlier training steps, and covered the rectangle. In steps 8–10, two filled white dots (diameter 10 pixels) appeared at a fixed distance of 200 pixels apart, and blue disks were reduced to 32 pixels in diameter (fingertip size). In step 8, a line connected the dots, and in step 9 the line was gradually faded away.

In steps 1–9, the blue response-feedback disks could appear only at the correct target location. Touching a target location out of order or touching outside the target area did not produce visual feedback. In step 10, drawing was allowed on any location on the screen; thus, blue disks appeared anywhere the subject touched, and the restriction in direction of drawing was lifted.

From step 6 on, a white patch appeared in the lower right-hand corner of the monitor at trial onset. To deliver the reinforcer after the drawing was completed, the subject had to press this patch. The rationale of this trial-termination response is to ensure that cessation of drawing is controlled by the stimuli on the monitor and not by reinforcer delivery. In steps 1–8, reinforcement occurred on each trial. In step 9, reinforcement was withheld if the subject moved the finger beyond the second dot by more than 50 pixels.

Final performance

On each trial in step 10, reinforcement was delivered if the drawn trace satisfied all of three criteria. Each drawn trace consists of a series of x, y pairs of actual screen contact points that are generated as thé subject moves the finger over the monitor surface. The criteria for reinforcement were based on an on-line analysis of these contact points. (1) The trace length from first touch to last lift had to be 200 ± 40 pixels. (2) The angle of an imaginary straight line connecting first touch and last lift had to be within $\pm$ 15° of the angle of an invisible straight line connecting the two stimulus dots. (3) The linear quality (or variability) of each drawn trace was calculated as the average absolute distance between each touchpoint and the imaginary line that connected first and last touch point; this value is zero when a perfectly straight trace is drawn; the reinforcement criterion regarding linear quality was 10 pixels or less for the data presented here. When the subject pressed the trial-termination patch, the computer determined instantaneously whether a drawn trace satisfied all three criteria for reinforcement. For a reinforced trial, a chime sounded for 0.5 s and a bit of food or candy was delivered to the subject. The screen then went blank, and an inter-trial interval of 2 s ensued. If a reinforcer was not presented, the screen went blank and the inter-trial interval started.

Steps 1 to 10 had, respectively, 9, 4, 9, 2, 2, 4, 4, 6, 31, and 35 sessions for Ai, and 7, 4, 6, 3, 7, 3, 4, 4, 27, and 35 for Pendesa. Some of the training steps had additional changes that will be covered together with additional results in a more comprehensive publication (Iversen & Matsuzawa, in preparation).

Results

To illustrate the development of the sweeping motion, Figure 2 shows for Pendesa all successive trials of the 45° display for sessions 11–16, training steps 2 and 3. The number of circles was gradually increased and the distance between circles was reduced, as indicated for each session. The time to complete each drawing from first touch to last lift is given as a vertical line above the trial data.

Up to session 13, Pendesa pressed all circles individually; that is, she pressed a circle and then lifted the finger to press the next circle, and so on. A press followed by lifting the finger is indicated by a small disk inside each circle (on the monitor the disk covered the circle). In session 13 (step 3), Pendesa began to connect successive circles without lifting the finger, as indicated by a diagonal bar from one circle to the next. In session 14, several trials with a full sweep emerged. On such trials, the time to complete the drawing was reduced considerably, as the vertical lines above each trial show. By session 16, Pendesa rapidly swept the finger over the stimulus display on each trial without lifting.

For the remaining trial types, vertical sweeps (90° display) began in session 15, and horizontal (0° display) and the remaining diagonal (135° display) sweeps began in session 16. For Ai, the first sweep occurred for the 45° diagonal in session 19, followed by vertical and horizontal in session 20 and the remaining diagonal in session 21. For both subjects, the trial completion time shortened considerably once sweeping occurred. Before sweeps had developed, the completion time was generally 0.5–1.5 s. Once sweeps had developed, the completion time was generally 0.15–0.5 s. By step 8, full sweeps occurred on 90–100% of all trials for both subjects; trials without a full sweep consisted of two or more short sweeping motions, not of individual presses. Thus, for both subjects, the behavior changed from repeated pressing and lifting to continuous sweeping within a few sessions once the subject made contact with the embedded contingency of finishing the trial faster by moving the finger over the monitor surface as opposed to repeated pressing and lifting.

The directional requirement for drawing was lifted in step 10, and drawing could now occur in any direction and on any location touched. Remarkably, both subjects continued to draw in the previously trained directions within the target area defined by the two-dot pattern. Thus, the previous training (steps 1–9) of directional drawing in a confined area transferred to the new task of connecting two points by free drawing (step 10). Figure 3 shows an example of what the monitor looked like at trial onset (top) and the electronic ink generated by the subject as she connected the two dots in a sweeping motion (bottom).

To analyze the precision of drawing generated by the training method, data were sampled for both reinforced and non-reinforced trials for five sessions in step 10 (72 trials for each trial type for each subject). The four boxes in the upper part of Figure 4 present printouts of individual trials showing how the screen looked when drawing was completed (the two white dots that appear at trial onset were covered by ink but are shown here to indicate the precision of drawing; S indicates start location of drawing). Frequency distributions of the angle of the drawn trace to horizontal are shown for each subject for each dot orientation, as indicated in the individual trials. The clear separation of the distributions reveals how effectively the two-dot patterns guided the angular component of drawing. For Ai, all trials fell within the ±15° reinforcement criterion. For Pendesa, all but one trial fell within this criterion. For each dot pattern, the mean angle of the drawn trace deviated by not more than 3° from the angle formed by an invisible ideal line between the two dots. The mean (*SD*) angles for the 0°, 45°, 90°, and 135° patterns were for Pendesa –2° (4°), 44° (3°), 87° (3°), and 133° (3°); for Ai the values were –2° (5°), 42° (4°), 89° (3°), and 132° (5°).

Figure 5 presents frequency distributions of trace length for each dot orientation. The distributions appropriately peaked at a value near the distance between the two dots (200

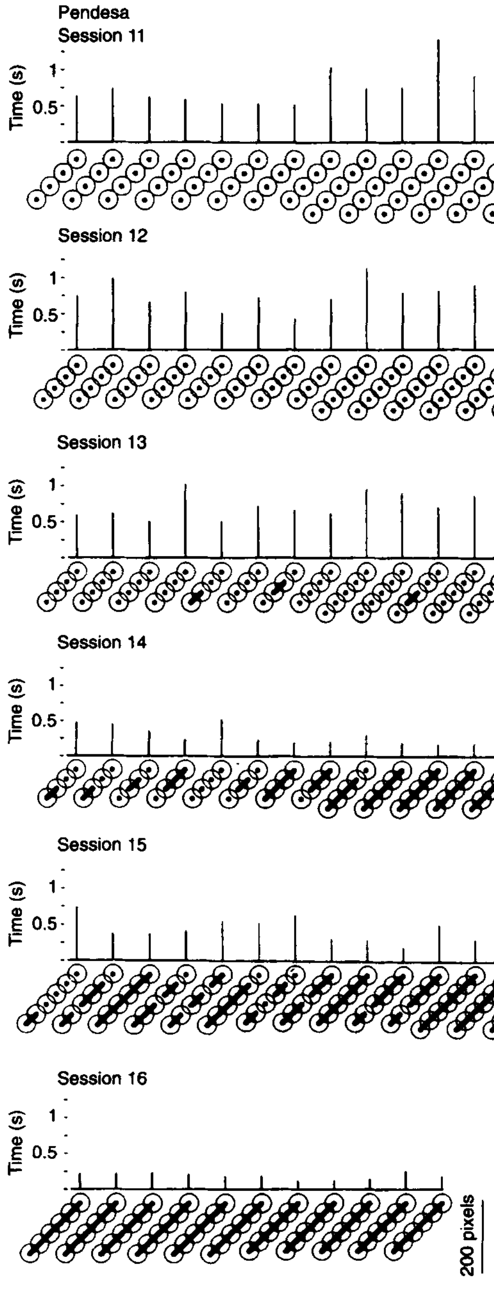

Figure 2. Illustration of the development of a sweeping drawing motion for Pendesa for one trial type: the 45° diagonal. All trials of this type are shown for six successive sessions, covering training steps 2 (session 11 only) and 3. A small disk inside a circle represents a single press followed by a lift at the same location (when pressed, the circle was actually covered by a blue disk). A bar connecting two or more successive circles represents a continuous movement from one circle to the next without lifting; thus, a bar going through all circles indicates a continuous sweeping motion without lifting. Each trial also shows in a vertical line the time to complete the drawing from first screen touch to last finger lift from the screen.

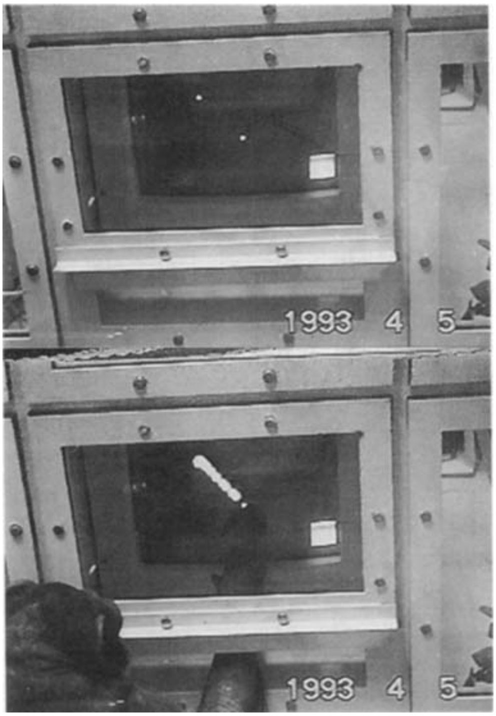

Figure 3. Video prints of the drawing behavior. Top: the monitor display at trial onset. Bottom: the chimpanzee, Pendesa, connected the two dots in a sweeping motion. The finger movement generated instantaneous electronic ink in the form of blue disks on the monitor at the touched location.

pixels). For Pendesa, on 3.4% of all trials (10/288) the length of the drawn trace was outside the reinforcement criterion of ±40 pixels. For Ai, the length of the drawn trace fell outside this criterion on 15.3% (44/288) of the trials. The mean (*SD*) lengths for the 0°, 45°, 90°, and 135° patterns were for Pendesa 203 (21), 203 (18), 202 (14), and 191 (14) pixels. For Ai the values were 231 (27), 201 (23), 209 (18), and 216 (26) pixels.

Additional data of interest are the linear quality, percent reinforced trials, and sweep duration, which are presented in summary form only. The mean (*SD*) linear quality for the 0°, 45°, 90°, and 135° patterns were for Pendesa 6 (6), 5 (4), 4 (3), and 5 (3) pixels; for Ai the values were 10 (7), 6 (3), 8 (4), and 11 (6) pixels. For the data analyzed in Figures 4 and 5, the percent reinforced trials for the 0°, 45°, 90°, and 135° patterns were 86%, 92%, 97%, and 93% for Pendesa; for Ai the values were 50%, 94%, 90%, and 61%. For both subjects, unreinforced trials primarily resulted from a trace drawn at an appropriate angle but with a length falling outside the reinforcement criterion of 200 ± 40 pixels. Occasional unreinforced trials were drawings with an appropriate angle and length but a curvature that yielded a linear quality that exceeded the criterion of 10 pixels or less. The mean (*SD*) sweep duration (time from first touch to last lift) for the 0°, 45°, 90°, and 135° patterns were: 0.79 (0.26), 0.73 (0.29), 0.68 (0.39), and 0.65 (0.23) s for Pendesa; for Ai the values were 0.33 (0.10), 0.44 (0.07), 0.51 (0.08), and 0.53 (0.18) s.

Of the total 288 (4 × 72) sampled trials for each subject, six were excluded from analysis for Pendesa and eight for Ai because extreme curvature of drawing prevented a meaningful linear analysis. Figure 6 shows instances of individual trials excluded from the analysis. For the three examples shown, the measures of linear quality were, from left to right: 18, 14, and 27 pixels. Notice how the path is corrected as the subject aims at the lower dot. These data reveal the dynamic nature of the drawing behavior; it was not a fixed motor movement that could not be altered once initiated.

Discussion

The training described here established visual guidance of drawing behavior in the chimpanzee with a method of electronic finger painting. The smooth, sweeping motion of the finger over the monitor developed rapidly. The drawing became so reliable that one could predict from trial to trial what the subject would draw given the two-dot pattern shown at trial onset. The automated and precise control of drawing makes the method useful

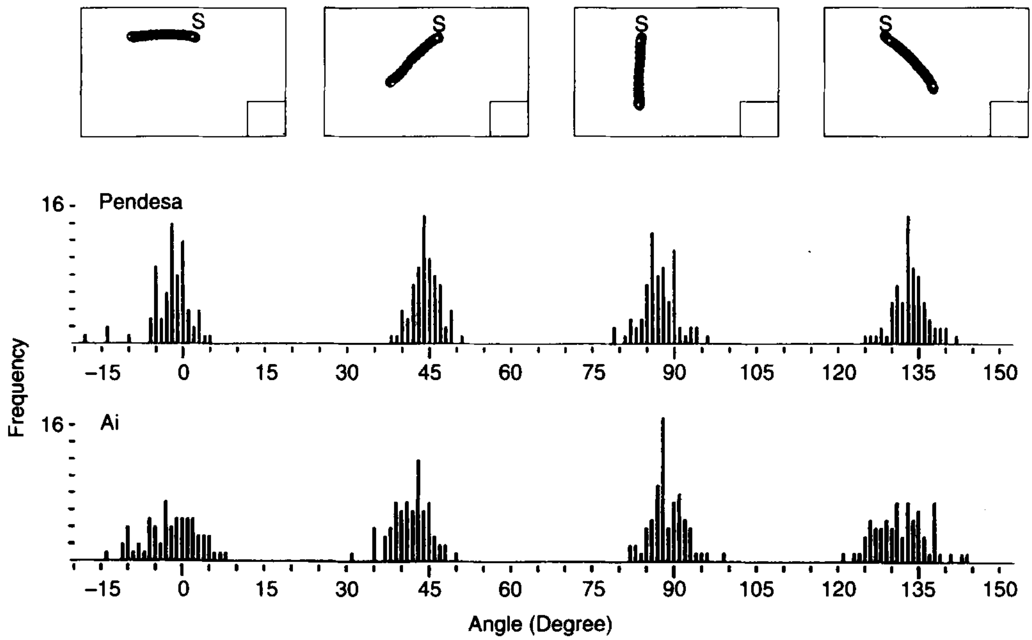

Figure 4. Quantitative analysis of the angular component of drawing in step 10. Examples of individual traces presented at the top show what the screen looked like after the subject had moved the finger from one dot to the other without lifting (S indicates start position of drawing). The white dots that appeared at trial onset were actually covered by the drawing but are shown here to indicate the precision of drawing (the dot distance was 200 pixels). Frequency distributions of the angle of the drawn trace to horizontal are shown for each trial type, as indicated by the upper display of individual trials. The angular criterion for reinforcement of ±15° is indicated for each distribution. Data cover both reinforced and non-reinforced trials and are sampled from five sessions, after 30 training sessions, in step 10. For Pendesa six and for Ai eight non-reinforced trials were excluded from analysis because of extreme curvature (see text).

for studies of fine perceptual-motor coordination in chimpanzees.

Our results establish a first step in training of primate written communication. The training method provides a foundation for future studies designed to examine whether visually guided drawing can be advanced further by combining lines into symbols to establish some form of written communication between man and ape. We believe that the automated training methods also may be of value to establish basic elements of drawing and writing in human subjects who may lack such skills (e.g., Mori & Masters, 1980).

References

Boysen, S. T., Berntson, G. G., & Prentice, J. (1987). Simian scribbles: A reappraisal of drawing in the chimpanzee (*Pan troglodytes*). *Journal of Comparative Psychology*, **101**, 82–89.

Eckerman, D. A., Hienz, R. D., Stern, S., & Kowlowitz, V. (1980). Shaping the location of a pigeon's peck: Effect of rate and size of shaping steps. *Journal of the Experimental Analysis of Behavior*, **33**, 299–310.

Fujita, K., & Matsuzawa, T. (1990). Delayed figure reconstruction in a chimpanzee (*Pan troglodytes*) and humans (*Homo sapiens*). *Journal of Comparative Psychology*, **104**, 345–351.

Gleeson, S. (1991). Response acquisition. In I. H. Iversen & K. A. Lattal (Eds.), *Techniques in the*

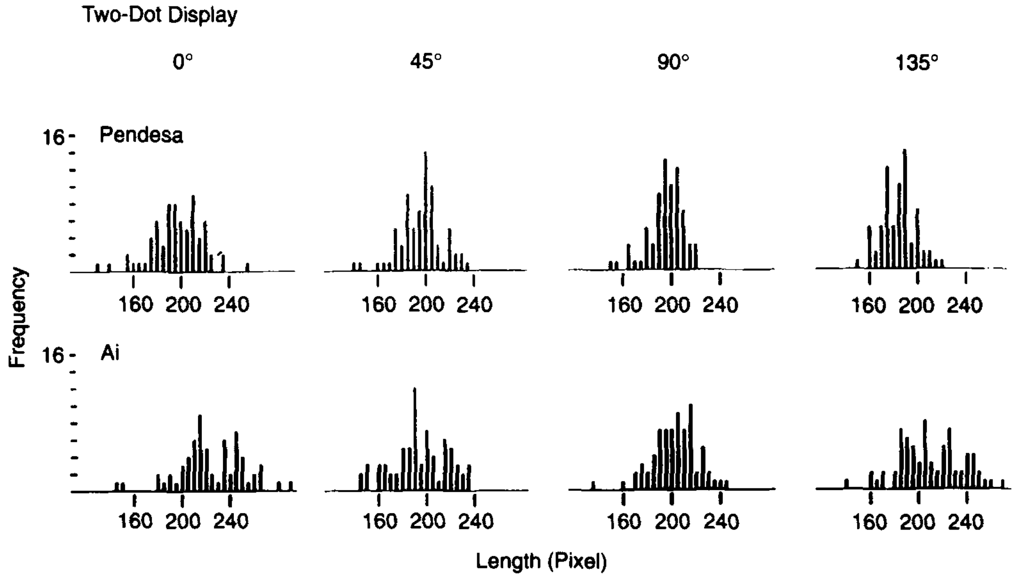

Figure 5. Quantitative analysis of the length component of drawing in step 10. Frequency distributions of the length of the drawn trace to horizontal are shown for each trial type, as indicated at the top. The length criterion for reinforcement of 200 ± 40 pixels is indicated for each distribution. Data cover both reinforced and non-reinforced trials and are sampled from five sessions, after 30 training sessions, in step 10. For Pendesa six and for Ai eight non-reinforced trials were excluded from analysis because of extreme curvature (see text).

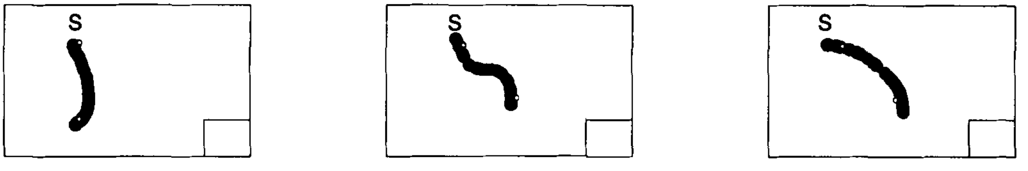

Figure 6. Examples of individual trials excluded from the quantitative analysis presented in Figures 4 and 5. Data are from Ai. The white dots were actually covered by the drawing but are shown here to indicate the precision of drawing (the dot distance was 200 pixels). S indicates start position of drawing.

behavioral and neural sciences: experimental analysis of behavior, Part 1 (pp. 63–86). Amsterdam: Elsevier.

Iversen, I. H. (1991). Methods of analyzing behavior patterns. In I. H. Iversen & K. A. Lattal (Eds.), *Techniques in the behavioral and neural sciences: experimental analysis of behavior, Part 2* (pp. 193–241). Amsterdam: Elsevier.

Kojima, S., & Kiritani, S. (1989). Vocal–auditory functions in the chimpanzee: Vowel perception. *International Journal of Primatology*, **10**, 199–213.

Matsuzawa, T. (1985a). Use of numbers by a chimpanzee. *Nature*, **315**, 57–59.

Matsuzawa, T. (1985b). Color naming and classification in a chimpanzee (*Pan troglodytes*). *Journal of Human Evolution*, **14**, 283–291.

Matsuzawa, T. (1990). Form perception and visual acuity in a chimpanzee. *Folia Primatologia*, **55**, 24–32.

Mori, A. A., & Masters, L. F. (1980). *Teaching the severely mentally retarded*. London: Aspen.

Morris, D. (1962). *The biology of art*. London: Methuen.

Schiller, P. (1951). Figural preferences in the drawings of a chimpanzee. *Journal of Comparative and Physiological Psychology*, **44**, 101–111.

Smith, D. A. (1973). Systematic study of chimpanzee drawing. *Journal of Comparative and Physiological Psychology*, **82**, 406–414.

Tomonaga, M., & Matsuzawa, T. (1992). Perception of complex geometric figures in chimpanzees (*Pan troglodytes*) and humans (*Homo sapiens*): Analysis of visual similarity on the basis of choice reaction time. *Journal of Comparative Psychology*, **106**, 43–52.

Tonooka, R., & Matsuzawa, T. (1995). Hand preferences of captive chimpanzees (*Pan troglodytes*) in simple reaching for food. *International Journal of Primatology*, **16**, 17–35.

(Received Nov. 9, 1995; accepted March 16, 1996)