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ORIGINAL ARTICLE

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Finger drawing by infant chimpanzees (*Pan troglodytes*)

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Abstract We introduced a new technique to investigate the development of scribbling in very young infants. We tested three infant chimpanzees to compare the developmental processes of scribbling between humans and chimpanzees. While human infants start to scribble on paper at around the age of 18 months, our 13- to 23-month-old infant chimpanzees had never been observed scribbling prior to this study. We used a notebook computer with a touch-sensitive screen. This apparatus was able to record the location of the subjects' touches on the screen. Each touch generated a fingertip-sized dot at the corresponding on-screen location. During spontaneous interactions with this apparatus, all three infants and two mother chimpanzees left scribbles with their fingers on the screen. The scribbles contained not only simple dots or short lines, but also curves and hook-like lines or loops, most of which were observed in the instrumental drawings of adult chimpanzees. The results suggest that perceptual-motor control for finger drawing develops in infant chimpanzees. Two of the infants performed their first scribble with a marker on paper at the age of 20–23 months. Just prior to this, they showed a rapid increase in combinatory manipulation of objects. These findings suggest that the development of combinatory manipulation of objects as well as that of perceptual-motor control may be necessary for the emergence of instrumental drawing on paper.

Keywords Infant chimpanzee · Scribble · Electronic finger drawing · Combinatory manipulation

Introduction

Human infants start to scribble spontaneously at around the age of 18 months. They usually use various drawing tools (e.g., pens, crayons), which they learn to handle easily. Therefore, the first production of scribbles and learning to use drawing tools seem to happen simultaneously (Cox 1992). There is a considerable amount of research focusing on human children's drawing. Previous studies have investigated the developmental processes of drawing (e.g., Gardner 1980; Cox 1992; Adi-Japha et al. 1998). According to this body of work, human children begin at the scribbling stage of drawing and later acquire the ability to produce representational drawings.

Previous research on drawing in nonhuman primates revealed that captive great apes drew with markers, paintbrushes, or with their fingers without any food reward (Ladygina-Kots 1935; Schiller 1951; Morris 1962; Smith 1973; Boysen et al. 1987). These results suggest that drawing behavior in nonhuman primates may reflect an intrinsic interest in exploratory and manipulative play. However, almost all of the authors agree that the great ape subjects remained at the scribbling stage and would not progress to show representational drawing.

There are only a few systematic studies focusing on the emergence and development of drawing in the great apes. Schiller (1951) was the first to examine the drawings of an adult chimpanzee, named Alpha. Smith (1973) systematically analyzed the drawings produced by young chimpanzees. The chimpanzees in both studies had prior experience drawing or painting. Boysen et al. (1987) examined the drawings of three young chimpanzees aged from 2 years 7 months to 4 years 6 months, who had little experience drawing before the study. All subjects spontaneously participated in drawing tasks without food reward. Morris (1962) described various types of drawings produced by a 1.5-year-old chimpanzee, named Congo, who was being reared by humans in a zoo. Congo had just begun drawing with pencils and paintbrushes at the time when the study began.

Iversen and Matsuzawa (1996, 1997, 2001) trained two adult chimpanzees to draw lines on a touch-sensitive screen using the method of electronic finger drawing. They revealed that the chimpanzees could be taught a simple form of structured drawing guided by a visual model. Through this technique, Iversen and Matsuzawa showed that finger

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Table 1 Background information on each pair of chimpanzees

Infant	Sex	Birth	Age at beginning of study (months)	Name of mother	Age of mother (years)
Ayumu	Male	24 April 2000	23	Ai	26
Cleo	Female	19 June 2000	20	Chloé	21
Pal	Female	9 August 2000	13	Pan	19

drawing on a monitor was an easy task for the chimpanzees. They also demonstrated that one clear advantage of the technique was the automatic recording and storage of drawings by a computer. In addition, they suggested that the touch-screen method was a potentially useful tool for investigating drawing ability in infants too young to handle drawing tools.

In the present study, we attempted to record the development of infant chimpanzees' scribbles. The infants had not drawn with a marker previously, although they had had opportunities to handle markers. We suspected that the infant chimpanzees lacked only the ability to use an instrument, but not the ability to scribble. This may have been the reason why the infants often played with liquids using their fingers as if they were attempting to draw scribbles on the floor. Hence, instead of providing subjects with a marker and paper, we introduced a notebook computer with a touch-sensitive screen to three mother–infant chimpanzee pairs. The computer was programmed to display the trace of the touches that the subjects made on the screen. Based on this new medium, we aimed to analyze the characteristics of finger drawing in infant chimpanzees and to compare them with those in adult chimpanzees and humans.

Methods

Subjects

The subjects were three pairs of mother and infant chimpanzees (*Pan troglodytes*) listed in Table 1. Since their birth, all infants were reared by their mothers. The infants and mothers were members of a community of 14 chimpanzees living in an enriched outdoor compound with attached indoor rooms (Ochiai and Matsuzawa 1998). The infants had been taking part in various types of cognitive tasks starting soon after birth (e.g., Matsuzawa 2002; Okamoto et al. 2002; Hirata and Celli 2003). The mothers had also participated in a variety of experiments for many years prior to our study (e.g., Kawai and Matsuzawa 2000; Matsuzawa 2001; Tanaka 2001; Tomonaga and Matsuzawa 2002).

All of the mother chimpanzees had extensive experience in drawing with markers on paper. During the period in which the present study was conducted, all mother–infant pairs had regular opportunities for drawing, as this constituted one of several tasks in another experiment conducted once a month (Hayashi and Matsuzawa 2003). The infant chimpanzees had been able to observe their mothers draw on paper from the age of 4 months. The infants had also had opportunities to handle markers themselves, but they had never used them for drawing on paper or on the floor.

Fig. 1 Video print showing the finger drawing process. An infant chimpanzee, Pal, touches the screen and moves his finger across the screen, leaving a *loop-shaped trace* behind

Apparatus

Each mother–infant chimpanzee pair was called by name from the outdoor compound into an experimental booth. An experimenter also entered the booth and remained inside with the subjects throughout each session. The experimenter placed a notebook computer equipped with a 10.4-inch touch-sensitive screen (NEC, VA-50H) on the floor near the edge of the booth opposite the infant and the mother. The screen was set at angle of approximately 120° to the keyboard.

The transparent touch-screen enabled automatic recording of the location of every touch on its surface. Each touch generated "electronic ink" at the corresponding location on a white background, and the computer recorded the location of the touch as well as the time the touch occurred, measured from the beginning of the session. The ink appeared as a fingertip-sized colored dot (4-mm-diameter filled circle) on the screen. Continuous movement of the finger over the screen surface produced a visual trace consisting of a series of connected and overlapping colored dots that remained on the screen for the rest of the trial (Fig. 1). The computer scanned for and recorded the touches at approximately 12-ms intervals.

Procedure

Within a single session, both mother and infant chimpanzees were allowed access to the touch screen for 3 min. No more than one session was given per day. The reason for conducting such short sessions at such long intervals was to prevent habituation and the extinction of responses, since no food was given during the session. The experiment was performed approximately 6 days a week and continued for 18 sessions.

A 50-ms buzzer informed the subjects of the beginning of a session, and one dot appeared with an arrow-type mouse pointer at the center of the white screen. The mouse pointer was always present on the screen during the experiment and tracked the location of each subsequent touch, always remaining with the last response recorded. The subjects were allowed to touch the screen in any way they chose for 3 min. After 3 min had passed, touches did not produce any further dots on the screen. Six colors (black, red, blue, green, yellow, and white) were used for electronic ink. The white ink provided the control condition since it was the same as the background color. In this condition, touching did not produce a visible trace on the screen, although the mouse pointer did move to the location where the touch had occurred. Regardless of visual feedback, the computer recorded all touches to the screen. The color of the ink remained the same for any given session, but changed from each session to the next to prevent habituation. Testing was carried out in blocks of six sessions, repeated three times. In each block, black ink was used in the first session and white ink in the sixth session. The order of the other colors was randomized within each block. All sessions were videotaped.

The records of the subjects' responses were divided, assigning each touch to either the mother or the infant based on time-stamped data recorded by the computer and inspection of the videotapes. When the infant sat near the computer, the experimenter prevented the mother from touching the monitor. Therefore, two chimpanzees never touched the screen simultaneously.

Analysis of data

We used "stroke" as the unit in our analyses because we did not expect the subjects to produce any form of representational drawing. A stroke was defined as a series of consecutive dots, where each dot was recorded less than 100 ms after the one immediately preceding it. When an interval of more than 100 ms passed between the recording of one dot and the next, the first dot became the end of the previous stroke and the second dot the beginning of the next stroke.

Quantitative analysis

We counted the number of strokes produced in each session by each subject. The distances between each two consecutive touches were calculated based on their on-screen coordinates, and the total length of each stroke was calculated by summing the distances between neighboring dots. As the diameter of each dot was 4 mm, and as the radii of the dots at both ends of the stroke were included in the total length, strokes were about 4 mm longer on screen than the lengths calculated from the computer data. The calculated lengths were used for quantitative analysis. The total time taken to produce each stroke was calculated in the same way.

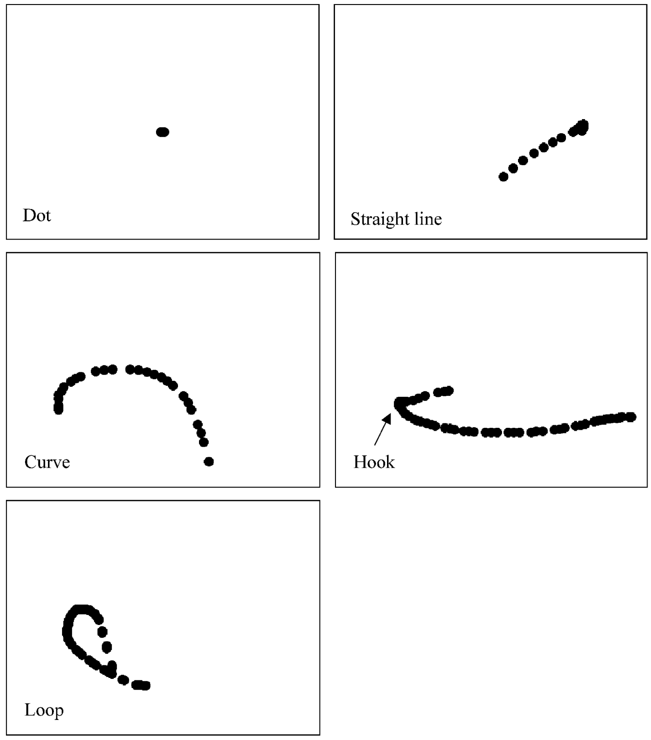


Fig. 2 Examples of different types of strokes

Qualitative analysis

Two testers independently classified each stroke into one of the following six types. A program was used to play back each stroke in real time based on the time-stamps recorded for the touches by the computer. The strokes that thus appeared on the screen were used for qualitative analysis:

1. Dot: The length of the stroke was less than two diameters of a dot (i.e., 8 mm).
2. Straight line: The length of the stroke was more than two diameters, and did not include a turn.
3. Curve: The stroke included one or more turns with an angle of more than 90°. The distance between the bend and the end points had to be more than two diameters of a dot.
4. Hook: The stroke included one or more turns with an angle of less than 90°. The distance between the bend and the end points had to be more than two diameters of a dot.
5. Loop: The stroke returned to cross its own path, and enclosed an untouched area.
6. Miscellaneous: The tester could not classify the stroke, as it was not clear how the subject moved his/her finger to produce the shape.

Figure 2 shows examples of the different types of strokes. Dots or straight lines had to occur in isolation. Curves, hooks, and loops could occur alone or in combination with one another within the same stroke in any order. If the testers classified a stroke as "miscellaneous," they did not include the same stroke in any of the remaining five types.

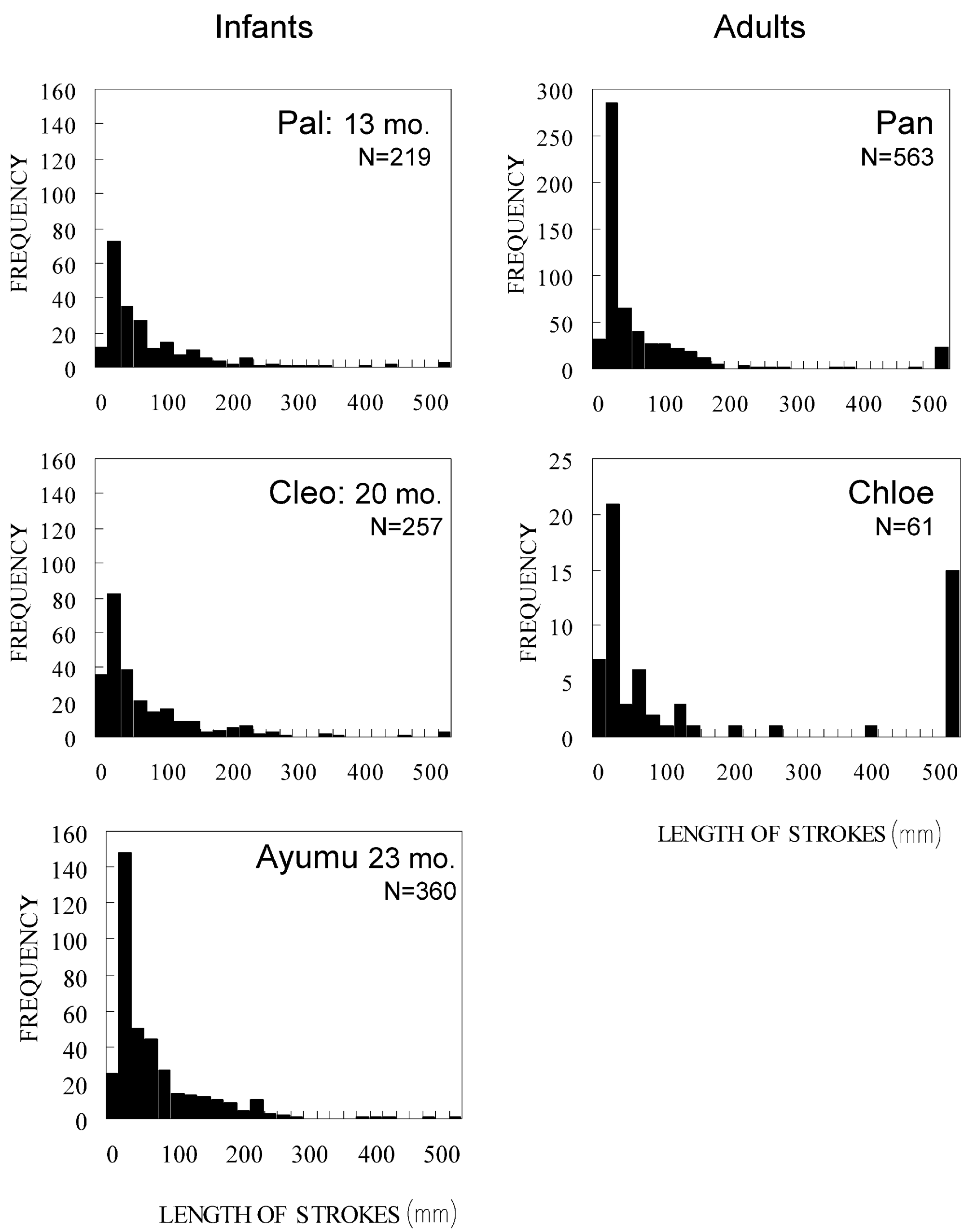
Results

All three infants touched the screen and made scribbles on it with their fingers without any food reward. Two of the three mothers also touched and drew on the screen. The third mother, Ai, did not touch the apparatus during the experiment, while her son, Ayumu, began to do so by himself from the first session onwards. Two infants, Cleo and Pal, avoided the apparatus at the start, but they began to touch the screen after they saw their mother touch and scribble on it. Adult chimpanzees sometimes engaged in very intense scribbling, which continued for most of the duration of a session. All infants engaged in scribbling on the screen for much shorter overall durations than the adults. While a mother was engaged in scribbling, her offspring would very frequently observe her actions and would sometimes touch the screen.

Quantitative analysis

Figure 3 shows histograms of the lengths of strokes for each infant and mother, as well as the total number of strokes produced. The results in both infants and mothers revealed that the peak frequency of stroke length was between 20 and 40 mm. Ninety percent of strokes were shorter than 200 mm in all three infants as well as one of the mothers, Pan. Chloe drew much less frequently than the infants and Pan, but she often drew very long strokes. The percentage

Fig. 3 Histograms of the length of strokes for three infants and two adults. *N* indicates the total number of strokes



of strokes more than 500 mm long was 24.2% in Chloe. The distribution of the frequency of different stroke lengths in Pan was similar to those in the infants, but the percentage of strokes more than 500 mm long was higher in Pan (Pan: 4.26%, Ayumu: 0.27%, Cleo: 1.40%, Pal: 1.38%, respectively). A chi-square test (*df*=1) revealed that Pan drew strokes longer than 500 mm significantly more often than Ayumu (χ^2=12.4, P<0.001), but the difference was not significant in comparison with Cleo (χ^2=3.00, ns) and Pal (χ^2=3.06, ns).

A Mann-Whitney *U*-test of age class (adult, infant) revealed that the mean length of strokes was significantly longer in the adults than that in the infants (mean length, adults: 143 mm, infants: 58.8 mm; Z=3.24, P<0.01). A Mann-Whitney *U*-test of age class also revealed that the mean duration for each stroke was not significantly different between the adults and the infants (mean duration, adults: 1,024 ms, infants: 700 ms; Z=–1.70, ns). However, a Wald-Wolfowitz runs test revealed that the distribution of samples was different between the adults and the infants (Z=5.14, K<0.001).

Figure 4 shows the mean number of strokes for each color of ink in the three infants. Data from the two adults, Pan and Chloé, were omitted as these subjects did not touch the screen in all of the sessions. The graphs clearly revealed that the number of strokes produced by the infants varied with color. When the electronic ink was visible, all infants tended to draw more strokes than when the ink was white (i.e., traces were invisible). A one-way ANOVA of color of ink was conducted and revealed that the main effect of color was significant [F(5, 48)=2.44, P<0.05]. A contrast analysis revealed a significant difference in the number of strokes between white and the other five colors of ink [F(1, 48)=6.83, P<0.02].

With white ink, the subjects could not see dots on the screen. Nevertheless, all infants responded to the screen and a total of 40 strokes were recorded. Even in the case of one of the mothers, Pan, 47 strokes were recorded in the first block with white ink, although she touched only twice in the second block and never touched in the third block. Cleo also ceased to touch in the second and third blocks with white ink. However, in the other two infants, Ayumu and Pal, a total of 16 and 8 strokes were recorded in the second and third blocks with white ink.

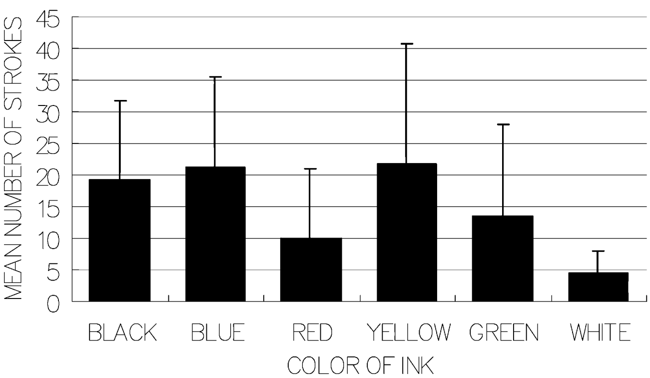


Fig. 4 Mean number of strokes for each color of electronic ink in the three infants. The *error bars* indicate standard deviations

Qualitative analysis

We classified a total of 1,460 strokes. The percentage of agreement between the two testers was 89.3%. If the type of stroke that one tester used to classify the shape did not agree with the type that the other tester recorded, the stroke was classified as a miscellaneous stroke. The percentage of miscellaneous strokes was 12.7%. Figure 5 shows the frequency with which each type of stroke was produced by the infants and their mothers. The results revealed that all infants, even the 13-month-old, produced all types of strokes. Moreover, the proportion of curves, hooks, and loops, which seemed to be more complex than

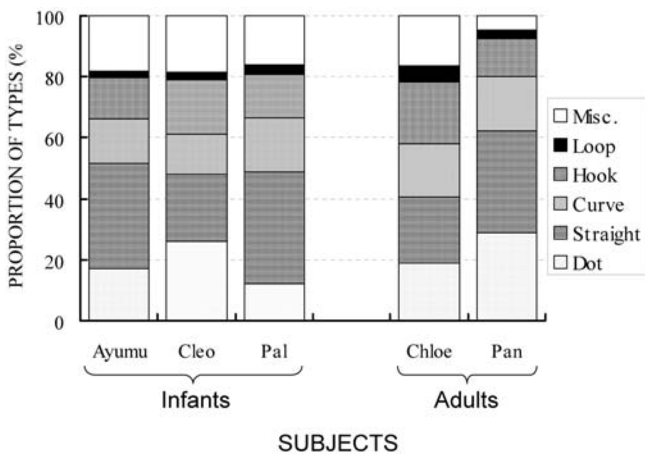


Fig. 5 Proportion of different stroke types in the infant and adult chimpanzees. *Misc.* in the legend indicates "miscellaneous" type. When the type was not matched between two testers, the stroke was classified as a miscellaneous stroke

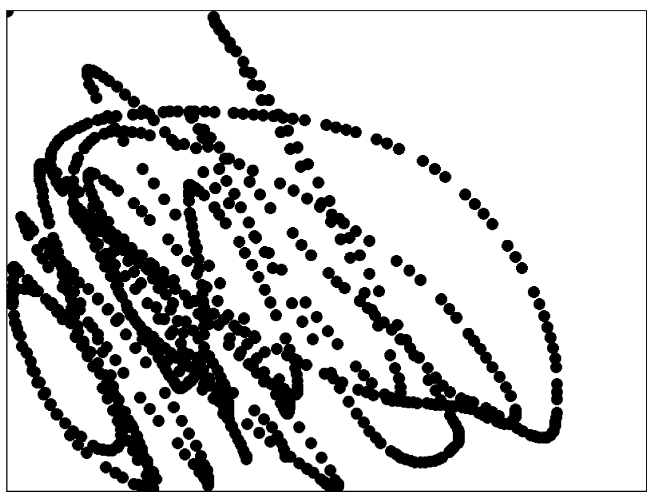


Fig. 6 A very long stroke made by a mother chimpanzee (Pan). A large number of *curves*, *hooks* and *loops* were contained in a single stroke

dots and straight lines, was more than 30% in all the infants (Ayumu: 30.2%, Cleo: 33.5%, Pal: 35.2%). This proportion was almost same among the infants, and not very different from that of the adults (Chloé: 43.2%, Pan: 33.0%).

However, both adult chimpanzees sometimes produced very long strokes that contained a lot of bends and loops. In these cases, they moved their arms and fingers repeatedly up and down, or round and round on the screen (Fig. 6). In contrast, the infant chimpanzees never showed such smooth and continuous movement.

Discussion

We introduced a new technique to investigate scribbling in very young infants and succeeded in recording many spontaneous scribbles in both adult and infant chimpanzees. The findings of the present study can be summarized as follows. The infant chimpanzees were able to produce scribbles on the touch-sensitive screen. Strokes were made more often when the color of the ink was visible than when the trace was invisible. All infant chimpanzees produced all types of strokes observed in the adults. However, only the adults produced the scribbles with smooth and continuous movement.

Based on the results summarized above, we would like to elaborate on the following points: (1) the emergence of scribbling as early as 13 months of age, (2) how visible traces contribute to the emergence of scribbles, (3) the contrast between scribbles made with a marker on paper and computer-assisted finger drawing, and (4) the emergence of scribbling on paper.

Scribbles emerging as early as 13 months of age

The present study was the first to introduce finger-drawing on a touch-sensitive screen to chimpanzee infants. This technique may be a useful tool for investigating the emergence and development of drawing in infants, especially those not yet able to use a drawing tool on paper. In the present study, all the infant chimpanzees began to touch the touch-sensitive screen without any food reward. The infants, even the youngest at 13 months, left a large number of strokes on the touch-sensitive screen. The results suggest that chimpanzee infants in the age-period of 13–23 months possess the ability of perceptual-motor control for the visually guided production of strokes using their fingers. The results also suggest that the infant chimpanzees were already able to make scribbles with their fingers before the emergence of instrumental scribbles on paper.

Visible trace promotes the emergence of scribbles

The infants' responses to the screen were maintained without any food reward. They seemed to possess an intrinsic motivation to draw. The results agree with previous studies about scribbling in great apes (Schiller 1951; Morris 1962; Smith 1973; Boysen et al. 1987). Moreover, the infant chimpanzees produced more scribbles when their actions left visible traces than when no such traces were left. These results suggest that visible traces had some form of reinforcing value for the subjects.

All infant chimpanzees produced all five types of strokes defined in the qualitative analysis applied in this study. However, only the adult chimpanzees made very long strokes by moving their fingers repeatedly up and down, or round and round. Kellogg (1969) collected and classified thousands of scribbles on paper drawn by human children. She defined 20 types of scribbles in the first stage of scribbling. Some of them required moving the fingers repeatedly up and down, or to the left and right on paper. The infant chimpanzees did not produce such scribbles with their fingers, but most of these types of scribbles appeared in the adult chimpanzees' drawing. The present study thus suggests that the infant chimpanzees could control their finger movements to some extent, but they were unable to produce such complex and smooth actions as the adults. This difference between the mothers and the infants may be attributed to different levels of maturity in perceptual-motor coordination.

Scribbles with a marker on paper versus computer-assisted finger drawing

All infant chimpanzees tested in the present study had seen their mothers scribble on paper before. Also prior to the study, the infants sometimes took a marker away from their mothers, or placed their finger on the scribbles that the mothers had made. Such experience might have promoted the emergence of scribbling on the screen. However, the infants had never made any scribbles with a marker on paper before the present study; they would sometimes bite markers, but never put them to paper. These results clearly suggest that chimpanzees' capability for scribbling with a drawing tool on paper will develop later than that for scribbling with the finger on a screen.

Inoue-Nakamura and Matsuzawa (1997) explored developmental processes of wild chimpanzees' tool use, specifically the use of hammer and anvil stones to crack hard-shelled oil-palm nuts. They found that the stone–nut manipulation developed from a single action on a single object at around 1 year of age to multiple actions on multiple objects at around 2 years of age. Although infant chimpanzees at the age of 2–3 years have already acquired the basic actions necessary for nut cracking, they cannot combine the actions in an appropriate sequence to perform actual nut cracking. These findings agree with the results of the present study.

Though the infant chimpanzees showed various patterns of scribbles on the screen and could hold a pencil, they never scribbled with a drawing tool on paper. A possible reason for this may have been a failure to combine the necessary actions in the appropriate sequence. Takeshita (2001) studied the developmental processes of combinatory manipulations in young chimpanzees. A combinatory manipulation was defined as an action in which an object was manipulated with respect to another object, body, or substrate. Three young chimpanzees, aged 2–4-years, served as the subjects, and received a set of four diagnostic tests for combinatory manipulation. The test materials and procedures were exactly the same as those adopted for diagnostic tests of cognitive development in human children. The results showed that the 2- to 4-year-old chimpanzees were already exhibiting a lot of combinatory manipulation. The performance of the 2-year-old chimpanzee was estimated close to that of 1-year-old human children. The performance of the 4-year-old chimpanzees was close to that of 1.5-year-old human children. These results suggest that the developmental processes of combinatory manipulation are similar in both humans and chimpanzees, but that the chimpanzees lag behind humans in the speed of development. The infant chimpanzees tested in the present study did not show scribbling with a pencil probably because they had not yet reached the age at which combinatory manipulations begin to occur in the appropriate sequence.

Toward scribbles on paper

After the present study, the infant chimpanzees eventually went on to use a marker on paper to produce visible scribbles (Hayashi and Matsuzawa, personal communication). Pal was then 21 months of age, and Ayumu was 23 months of age. Combinatory manipulation of objects rapidly increased from the age of 20 months in the chimpanzee infants who participated in the present study (Hayashi and Matsuzawa 2003). At the age of 20–22 months, all the three infants first succeeded in another tool-using task: "honey-dipping" (Hirata and Celli 2003). These results suggest that combinatory manipulation and the related cognitive capacity develops rapidly at the age of 20–23 months in chimpanzees. The coincidence between the increase in combinatory manipulations and the appearance of scribbling with a marker suggest that the development of combinatory manipulation of objects as well as that of perceptual-motor control may be necessary to enable drawing with a drawing tool.

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