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ORIGINAL ARTICLE

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Cognitive development in object manipulation by infant chimpanzees

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Abstract This study focuses on the development of spontaneous object manipulation in three infant chimpanzees during their first 2 years of life. The three infants were raised by their biological mothers who lived among a group of chimpanzees. A human tester conducted a series of cognitive tests in a triadic situation where mothers collaborated with the researcher during the testing of the infants. Four tasks were presented, taken from normative studies of cognitive development of Japanese infants: inserting objects into corresponding holes in a box, seriating nesting cups, inserting variously shaped objects into corresponding holes in a template, and stacking up wooden blocks. The mothers had already acquired skills to perform these manipulation tasks. The infants were free to observe the mothers' manipulative behavior from immediately after birth. We focused on object–object combinations that were made spontaneously by the infant chimpanzees, without providing food reinforcement for any specific behavior that the infants performed. The three main findings can be summarized as follows. First, there was precocious appearance of object–object combination in infant chimpanzees: the age of onset (8–11 months) was comparable to that in humans (around 10 months old). Second, object–object combinations in chimpanzees remained at a low frequency between 11 and 16 months, then increased dramatically at the age of approximately 1.5 years. At the same time, the accuracy of these object–object combinations also increased. Third, chimpanzee infants showed inserting behavior frequently and from an early age but they did not exhibit stacking behavior during their first 2 years of life, in clear contrast to human data.

Keywords Cognitive development · Infant · Chimpanzee · Object manipulation · Object–object combination

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Introduction

The present study aims to report the development of object manipulation, a precursor of tool use, in infant chimpanzees. Tool use has been reported in many primate species (van Schaik et al. 1999). The great apes, especially chimpanzees, are known to manufacture and use various kinds of tools unique to each community (Goodall 1986; McGrew 1992; Whiten et al. 1999; Yamakoshi 2001). Tool-using behaviors have often been a focus of research in wild chimpanzees, as useful indicators of the chimpanzees' intelligence. Consequently, there is a need to assess the nature and development of cognitive capabilities required for the manufacture and use of tools.

Tool-using behaviors require the skill of object manipulation – an ability that is prominent in primate species. Primates are dexterous "quadramana" who have four hands for manipulation (Matsuzawa 2001). Torigoe (1985) investigated object manipulation in 74 species of primates and distinguished 506 manipulation patterns in their interactions with objects (a nylon rope and a wooden cube). The author discussed the relationship between object manipulation and tool use, suggesting that the ability to use tools does not arise as a function of the diversity of manipulations exhibited per se but the extent to which the animal relates an object with other objects, such as putting object A on object B, hitting object A with object B, and so forth. Therefore, object manipulation, and in particular object–object combination, is likely to be an important prerequisite of tool-using behaviors.

Object–object combinations – relating an object with another object – exhibited by infants can also be used as a scale for cognitive development, as well as for inter-species comparisons since no verbal responses are required. In the case of stone tool use for nut cracking, for example, object manipulation starts out as a simple manipulation, manipulating a single object in a single manner, and then develops into more complex forms, manipulating multiple objects in multiple manners (Matsuzawa 1994; Inoue-Nakamura and Matsuzawa 1997).

Human infants start to relate an object with another object at around 10 months of age (Tanaka and Tanaka

1982). This type of manipulation, orienting an object to another object, has attracted the attention of researchers, resulting in studies of object manipulation focusing primarily on the combination of objects. Torigoe (1985) coined the term "secondary manipulation" to refer to object manipulation in relation to some specific feature of the environment. Takeshita and Walraven (1996) used the term "orienting manipulation" to describe the action in which an individual orients an object towards a substrate, one's own body, or another detached object. Several authors used the term "combinatory manipulation" or "combinatorial manipulation" to define placement of an object in relation to another object (Westergaard 1993; Westergaard and Suomi 1994) and to a substrate (Fragaszy and Adams-Curtis 1991; Takeshita 2001). In the present study, we focused on object–object combination by infant chimpanzees, disregarding the manipulation of an object in relation to a substrate or the subject's own body.

Previous studies reported that infant chimpanzees less than 1 year old did not exhibit object–object combination (Vauclair and Bard 1983; Takeshita et al. 1989), which means that the age of onset of object–object combination was delayed in chimpanzees compared to humans (at around 10 months). There are several studies that report the occurrence of object–object combination in 1- to 2-year-old chimpanzee infants (Potì and Spinozzi 1994; Potì 1996; Inoue-Nakamura and Matsuzawa 1997). Takeshita (2001) noted that three chimpanzee infants, aged from 2 years and 11 months to 4 years and 8 months, constantly exhibited object–object combination. However, there have been no previous studies that have systematically examined the postnatal long-term development of object manipulation in chimpanzees from immediately after birth.

Several well-known developmental scales have been devised to evaluate progressive changes in human infants' cognitive and physical capabilities. The Bayley Scales of Infant Development (Bayley 1969) consist of 244 tasks on mental and psychomotor scales. These can be applied from 2 months to 2.5 years of age. The Ordinal Scales of Psychological Development by Uzgiris and Hunt (1975) consist of seven scales (schemata, means, causality, object, space, gestural, and vocal imitation) based on Piaget's theory of stages of cognitive development, and can be applied from 1 month to 2 years of age. In the present study, we applied four tasks from the Kyoto Scale of Psychological Development (KSPD, Ikuzawa 2000). The KSPD was designed to assess cognitive development in human infants and young children. It consists of 321 tasks in three main areas: postural-motor, cognitive-adaptive, and language-social areas. The KSPD can be applied from 1 month to 14 years of age and has been tested on 1,562 normal human subjects in Japan (ranging from 1 month to 13 years of age) to obtain an average scale of development.

The present study used the four tasks in the cognitive-adaptive area of the KSPD: (1) inserting objects into corresponding holes in a box, (2) seriating nesting cups, (3) inserting variously shaped blocks into corresponding holes in a template (form board), and (4) stacking up wooden blocks. The average age at which human infants pass these four tasks are shown in Table 4.

The present study aimed to establish a naturalistic setting for cognitive testing in infant chimpanzees, paying close attention to social contexts of learning in the wild. The following three points characterize our unique test setting. First, the subjects were not isolated from their mothers. They were reared by their own mothers, and were members of a captive group living in an enriched environment. This was in clear contrast with previous studies, in which the chimpanzee subjects were mostly hand-reared by humans. Second, a human tester conducted cognitive tests – identical to those used with humans – with the mother chimpanzee in a face-to-face situation. The mothers performed the cognitive tasks in front of the tester and their infants, much like the situation in the wild where chimpanzee mothers perform nut cracking with stone tools. Third, the infants watched the mothers' performance. Following requests from the tester, the chimpanzee mothers showed object–object combinations frequently during the task. The infants were allowed to freely engage in the test situation. In this sense, the mother took the role of the model: the observers and the models belonged to the same species. The infants had free access to the objects while their mothers were performing the tasks. However, no specific object manipulation by the infants was ever reinforced by food. In this respect, we were only recording spontaneous object manipulation by infants who were not trained by the human tester to make "correct" responses.

The aim of the present study was thus to investigate the developmental process of object–object combination in mother-reared chimpanzees during the first 2 years after birth. We employed tasks used in normative studies of cognitive development of human infants and recorded spontaneous object manipulation by infants who were exposed to their mothers' successful performance of the tasks.

Methods

Subjects

The subjects of the present study were three chimpanzee mother–infant pairs living in a group of 14 chimpanzees at the Primate Research Institute of Kyoto University, Japan. The three mothers had extensive prior experience participating in various kinds of cognitive tasks (Matsuzawa 2003), including some that involved manipulating various kinds of objects (Myowa-Yamakoshi and Matsuzawa 1999, 2000). The chimpanzees lived in an outdoor compound (approx. 700 m^2) enriched by 15-m-high climbing frames and about 500 planted trees of approximately 60 species (Ochiai and Matsuzawa 1997). Housing and feeding conditions were in accordance with the *Guide for the Care and Use of Laboratory Primates* produced by the Primate Research Institute, Kyoto University (2nd edn, 2002). More detail on the subjects is shown in Table 1.

Table 1 Subjects

Name	Date of birth	Sex	Mother	Father
Ayumu	24 April 2000	Male	Ai	Akira
Cleo	19 June 2000	Female	Chloé	Reo
Pal	9 August 2000	Female	Pan	Akira

Fig. 1 **a** A chimpanzee mother–infant pair and the human tester in a face-to-face situation in the play room. **b** A human mother–infant pair and the human tester in a face-to-face situation in the play room

Testing period

Testing began during the infants' first month of life. On average, we tested each mother–infant pair once a week, over the 2 years that followed the birth of the infants. Each testing session lasted about 40–70 min.

Materials and procedure

The test situation corresponded to what we have termed "cognitive tests based on a triadic relationship," within the framework of a "participation–observation" method. A human tester (T.M.) faced a mother–infant pair in a play room (Fig. 1a). The same human tester conducted each session with all three subject pairs throughout the 24 months of testing. With the assistance of the mother chimpanzees who had built a strong bond to the human tester, the infant subjects could be handled much like human infants. The size of the playroom was 19 m^2 and was separated from an outer area for observation by acryl panels. The behavior of each mother and infant during test sessions was recorded by two digital video cameras (SONY DCR-TRV10) positioned at different angles. Recordings were made from outside of the play room through the transparent panels.

The materials used in our study and the testing procedures are described below.

1. Inserting objects into corresponding holes in a box ("box," Fig. 2a). The subjects were presented with a box (25 cm length× 38 cm width×18 cm height) with a circular hole (1.6 cm diameter), a small rectangular hole (2.5 cm length×3.4 cm width), and a large rectangular hole (8.0 cm length×2.5 cm width), arranged in a row on the upper surface of the box. The tester gave two rods (1.0 cm diameter×10 cm length) and a square block (7.3 cm× 7.3 cm×2.0 cm) to the subjects. The rod could be inserted into any of the holes but the tester requested that the mother insert the rod into the circular hole. The square block only fit into the large rectangular hole, provided that it was oriented correctly. Once inside the box, the objects could be retrieved by the tester through an opening in the side of the box.
2. Seriating nesting cups ("cups," Fig. 2b). We used five plastic cups (4.4 cm, 5.8 cm, 7.2 cm, 8.6 cm, and 10.0 cm in diameter × 4.5 cm in height), which could be combined by nesting. The cups were presented in a seriated structure at first. Then, the tester disassembled the nesting cups in front of the subjects and scattered the five cups randomly on the floor. The mother was requested, verbally and gesturally, to seriate the cups.
3. Inserting shaped blocks into corresponding holes in a template ("template," Fig. 2c). The subjects were presented with a template (16 cm length×36 cm width×1.2 cm thickness) with a circular hole (9 cm diameter), a triangular hole (9 cm along the length of each side), and a square hole (8 cm×8 cm), arranged in a row on the template. The tester then presented a circular block, a triangular block, and a square block to the subjects. Each block fit into only one of the three holes. The tester requested that the mother place all three blocks into the holes with the corresponding shapes in the template.
4. Stacking of wooden blocks ("blocks," Fig. 2d). We used eight red and eight green wooden blocks (2.5 cm×2.5 cm×2.5 cm cubes) and a steel cup with a handle (7 cm diameter, 7 cm height). The tester gave the subjects eight red blocks by placing them on the floor in a random arrangement. These were to be stacked vertically, horizontally, or both. Then, eight green blocks were added to the red blocks, also to be stacked. After the stacking test, the tester gave the cup to the mother. She was encouraged to put the blocks into the cup and thus return them to the tester.

When the mother performed the tasks in the appropriate manner, she was given social praise and a piece of food. Infants were free to observe their mothers' behavior from a close distance. However, no specific object manipulation by the infants was ever reinforced by food. The human tester prohibited manipulation by the mothers when the infants began to manipulate the objects on their own. This enabled us to observe object manipulation by the infants without any interference from the mothers. In addition to the chimpanzee subjects, we tested two human children in exactly the same test situation (Fig. 1b) to confirm that their performance in our test situation corresponded to the normal range on the KSPD scale. The two human children were first tested at the age of 16 and 37 months old, and we continued to test them longitudinally once a month.

Data analysis

In the present study, we used the average number of object–object combination bouts per session per month as an index of the frequency of object–object combination. We differentiated object–object combination bouts from other forms of object manipulation on the basis of three considerations. First, contact had to occur between the manipulated object and another task-related object. We excluded cases in which the manipulated object was related with a substrate or an object not used in the ongoing task. Second, the object had to be held by the subject at the onset of the contact between the objects. Thus, we excluded cases in which the infant released the object before it contacted another object. Third, an object–object combination bout was said to begin when contact between the objects was first made through manipulation by the subject, and ended when the contact or the manipulation itself stopped.

In other words, an object–object combination bout corresponded to a single contact between objects. However, in the task

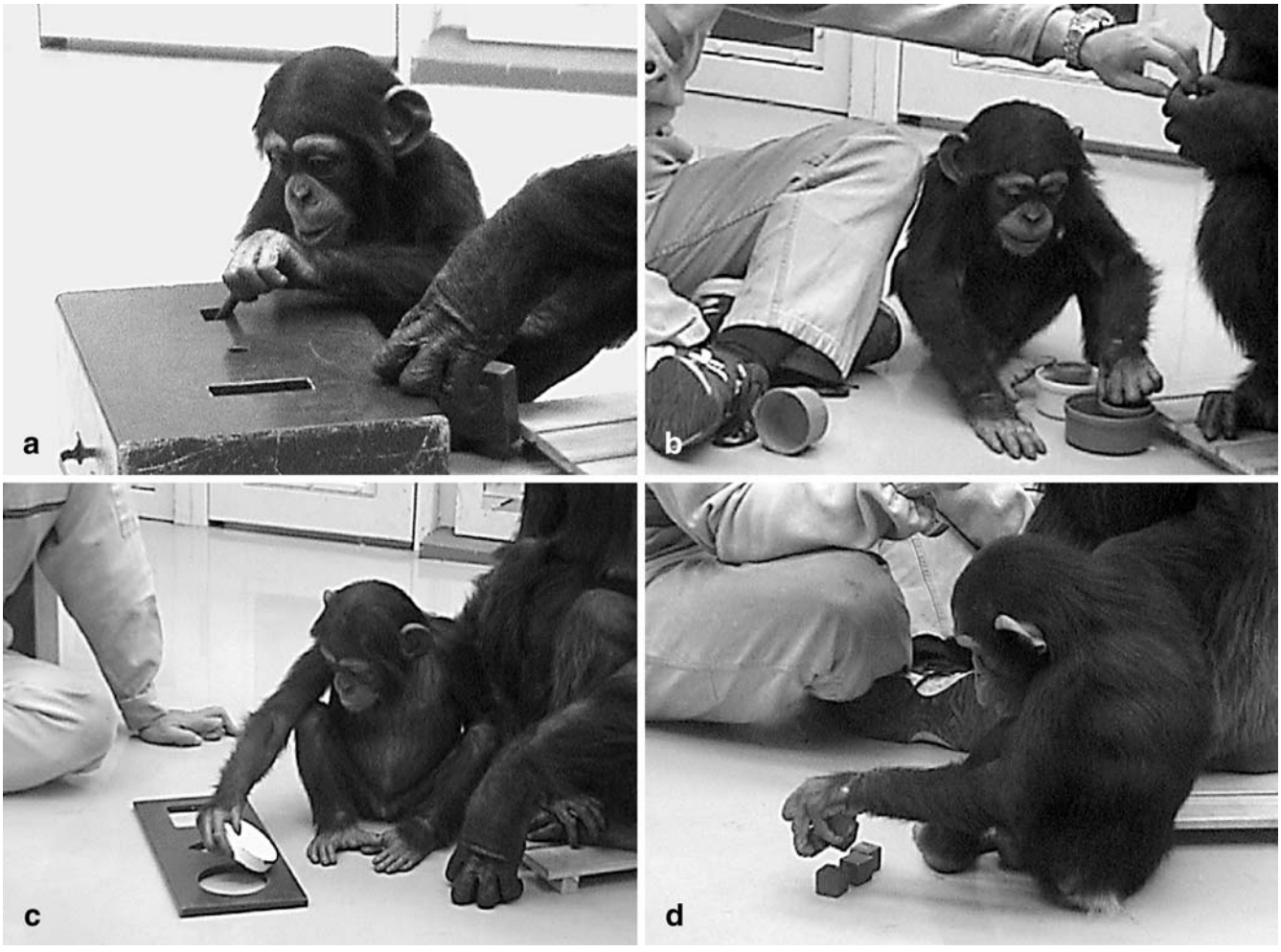

Fig. 2 **a** Inserting a rod into a hole in a box. **b** Seriating nesting cups. **c** Relating a circular block to a template. **d** Relating blocks to other blocks

of inserting objects into a box, the large and continuous surface of the box enabled the subject to relate objects with the box repeatedly in quick succession. We recorded the lengths of 100 intervals between one touch and the next for each subject and used these to estimate "bout critical interval" as 1.0 s using log-survivorship analysis. Thus, we disregarded intervals which were less than 1.0 s and instead considered the successive contacts as a single object–object combination bout. If the infant changed the hole with which to relate the manipulated object, we counted this as a separate bout of object–object combination.

Results

Performance of the mother chimpanzees

The mothers exhibited object–object combination frequently during the tasks and mastered the tests through social praise and food reward. The four tasks used in the present study corresponded to the cognitive performance of human children up to around 28 months old. The mothers passed all the task requirements with the exception of stacking four blocks in a two-dimensional manner, that is, both horizontally and vertically. We noted some other difficulties in mastering the tasks in each subject. One mother, Ai, had difficulties adjusting the direction of the square block and inserting it into the large rectangular hole in the box for the first 9 months, although she succeeded eventually. The other two mothers, Chloé and Pan, had difficulties seriating all five cups into a nesting structure for the first 5 and 6 and 5 months, respectively. To improve their performance, we reduced the number of cups and encouraged the subjects to make nesting structures. The two subjects succeeded in seriating all five cups reliably after 3 further months of training.

Development of object–object combination in infant chimpanzees

Figure 3 shows the average number of object–object combination bouts observed per session as a function of age. All three infants first exhibited object–object combination before they reached 1 year of age (range 8–11 months). The development of object–object combination thereafter was not gradual: the number of object–object combination bouts remained at a low frequency during the period between 11 and 16 months old, followed by a dramatic increase in the number of object–object combination bouts at around 1.5 years of age in all three infants.

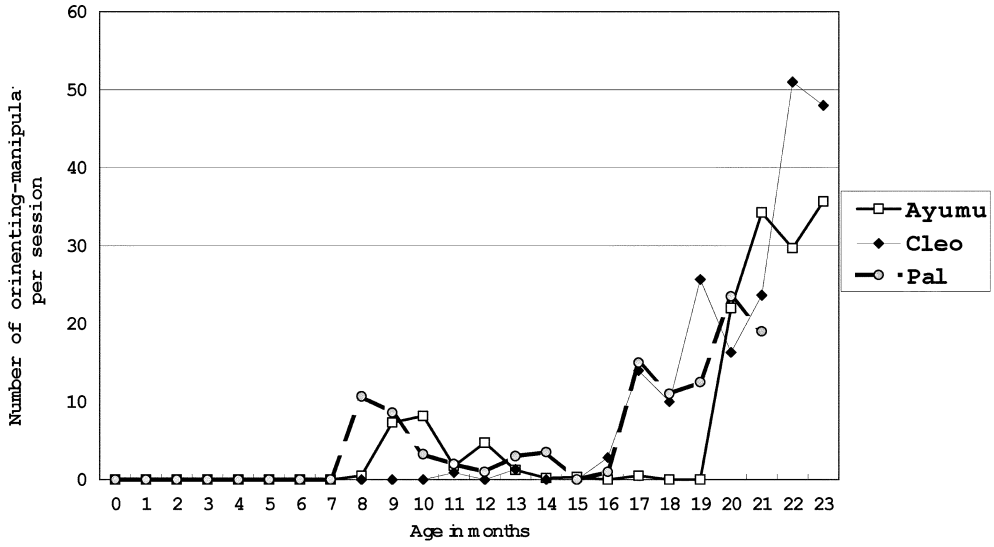

Fig. 3 The average number of object–object combination bouts observed per session as a function of age

Table 2 Two phases of object–object combination

	Phase of object–object combination (Age in months)	
	First phase	Second phase
Ayumu	8–19	20–
Cleo	11–16	17–
Pal	8–16	17–

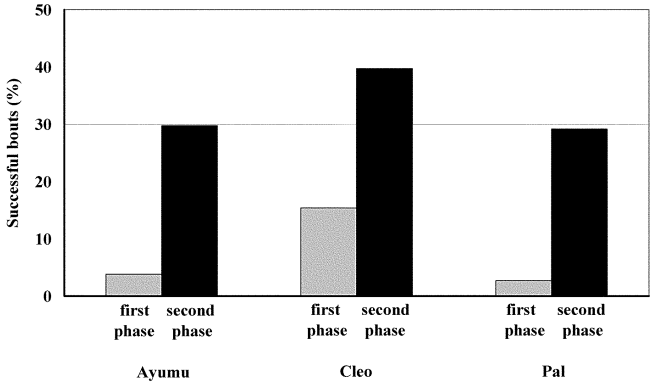

Fig. 4 Successful bouts as a percentage of the total number of object–object combination bouts in the two phases in each subject

We found two different phases of development in object–object combination. The first phase began when the subjects first exhibited object–object combination, and included the next several months during which the subjects almost completely ceased to perform object–object combinations. The second phase began when object–object combinations reappeared and the number of object–object combination bouts in a month became at least five times larger than the average numbers in the previous 3 months. The ranges of the two phases in each subject are shown in Table 2. We recorded a total of 105 object–object combination bouts in phase 1 and 343 in phase 2 for Ayumu, 13 and 383 for Cleo, and 112 and 173 for Pal, respectively.

Change in accuracy of object–object combination

We also compared the accuracy of object–object combination in the two phases. The successful instances in each task were defined as "inserting rod or square block into a hole in the box and releasing it," "putting a cup into a larger nesting cup and releasing it," "inserting a shaped block into the corresponding hole in the template and releasing it," "putting a block into the cup and releasing it." We did not observe a successful instance of the "stacking up of blocks" during the first 2 years of observation analyzed in the present study. (One infant, Pal, stacked up blocks for the first time at 2.5 years of age. The other two infants never spontaneously stacked up blocks throughout their first 3 years of life.) If a shape was placed on the template (form board) by the infant's manipulation, for example, we scored it as an object–object combination but not as a successful occurrence. Accuracy was calculated as the percentage of successful bouts among the total number of object–object combination bouts. Figure 4 shows the percentage of successful bouts in the two phases in each subject. The percentage of successful bouts was significantly higher in the second phase than in the first phase in two infants [chi-square test, $\chi^2(1)=28.50$, $\chi^2(1)=21.34$, $P<0.01$, for Ayumu and Pal, respectively]. In one infant, Cleo, we observed only 13 object–object combination bouts in the first phase and the difference between the two phases was not significant [$\chi^2(1)=2.19$, $P>0.10$].

Differences among the four tasks

Object–object combinations were not uniformly observed in all four tasks employed in our study. Table 3 shows the average number of object–object combination bouts ob-

Table 3 Average number of object–object combination bouts observed in each task per session

Age in months	Ayumu				Cleo				Pal			
	Box	Cups	Template	Blocks	Box	Cups	Template	Blocks	Box	Cups	Template	Blocks
8	0.5	0	0	0	0	0	0	0	10.7	0	0	0
9	7.3	0	0	0	0	0	0	0	8.6	0	0	0
10	8.2	0	0	0	0	0	0	0	3.0	0	0.3	0
11	1.8	0	0	0	0.7	0	0.3	0	2.0	0	0	0
12	2.8	0	2.0	0	0	0	0	0	1.0	0	0	0
13	1.3	0	0	0	0.3	0.7	0	0.3	3.0	0	0	0
14	0.2	0	0	0	0	0	0	0	3.3	0	0.3	0
15	0	0	0.3	0	0	0	0	0	0	0	0	0
16	0	0	0	0	2.5	0	0.3	0	0	0	0	1.0
17	0	0.3	0.3	0	0	13.0	0	1.0	15.0	0	0	0
18	0	0	0	0	3.0	6.0	1.0	0	11.0	0	0	0
19	0	0	0	0	18.0	7.7	0	0	8.0	4.5	0	0
20	20.0	1.0	1.0	0	12.3	3.0	1.0	0	18.5	3.0	2.0	0
21	19.3	10.8	3.8	0.5	16.0	5.0	0.7	2.0	13.3	1.0	2.0	0
22	9.3	8.3	7.0	5.0	30.5	14.0	4.0	2.5	18.0	1.0	0	0
23	16.7	17.7	0.7	0.7	21.0	9.0	8.0	10.0	17.0	1.0	0.5	0
Sum of first phase	21.9	0.3	2.6	0	3.5	0.7	0.6	0.3	31.6	0	0.5	1.0
Percentage[a]	88.6	1.0	10.4	0	68.9	13.2	11.4	6.5	95.5	0	1.5	3.0
Sum of second phase	65.3	37.8	12.4	6.2	100.8	57.7	14.7	15.5	65.8	8.5	4.0	0
Percentage[a]	53.7	31.1	10.2	5.1	53.4	30.6	7.8	8.2	84.0	10.9	5.1	0

[a] Percentage of total number of object–object combination bouts in each phase

served per session in each task as a function of age in months. During the first phase, most of the object–object combinations were observed in the box task. In the second phase, although this pattern remained, object–object combinations increased in other tasks as well. However, the subjects showed object–object combinations frequently in two tasks in particular: box and cups, and less frequently in the two other tasks: template and blocks.

Comparison between humans' and chimpanzees' performance on the same tasks

Having applied tests identical to those originally designed to assess cognitive development in human infants, we compared the performance of the three mother and three infant chimpanzees to human data reported in Ikuzawa (2000). Table 4 shows the comparison of performance in chimpanzees and humans assessed by the four tasks employed in our study. The performance of the chimpanzee mothers was comparable to human data. The chimpanzee infants also succeeded in the three tasks (excluding the blocks task) at an age comparable to the human data. However, a more detailed comparison revealed a marked difference between the two species. Human infants passed the box and the blocks tasks at almost the same age (around 1 year and 1 month on average). The chimpanzee infants began to insert the rod into a hole in the box at around 9 months (two infants) and around 1 year and 6 months (third infant). For the first two subjects, the age of the onset of insertion was even earlier than in human infants. In contrast, none of the three chimpanzee subjects ever stacked up blocks in the block task throughout our 2 years of observation.

Discussion

The present study clearly demonstrated the following three points. First, there was precocious appearance (first appearance not followed by monotonic increase in frequency) of object–object combination in infant chimpanzees at less than 1 year of age (range: 8–11 months). Second, object–object combinations in chimpanzees increased dramatically at around 1.5 years old. At the same time the accuracy of object–object combinations also increased. Third, chimpanzee infants frequently showed inserting behavior but they did not exhibit stacking behavior during their first 2 years of life. The following section discusses these findings in detail.

Precocious appearance of object–object combination

The three infant chimpanzees began to exhibit object–object combination within the first year of life. The age of onset in chimpanzees was thus comparable to that in hu-

Table 4 Comparison of performances in chimpanzees and humans assessed by the four tasks employed. The human data are based on Ikuzawa (2000), showing the age of 50% and 75% of infants to pass each task. The performances of the mother chimpanzees are shown as *Yes* or *No*. The age of first success in each behavior is shown for the infant chimpanzees

Task	Subcategory	Behavior	The age of passing test in humans (months)		Performance of mother chimpanzees			Performance of infant chimpanzees		
			50%	75%	Ai	Chloé	Pan	Ayumu	Cleo	Pal
Box	Box	Inserting rod into circular hole in box	13.4	14.2	Yes	Yes	Yes	9.3	18.0[a]	8.8
		Inserting square block into large rectangular hole in box	18.3	20.4	No-Yes	Yes	Yes	–	22.9	–
Cups	Cups	Seriating three nesting cups	17.3	22.8	Yes	Yes	Yes	13.0	17.8[a]	–
		Seriating five nesting cups	27.4	33.0	Yes	No-Yes	No-Yes	–	–	–
Template	Template	Inserting circular block into circular hole in plate	11.9	13.0	Yes	Yes	Yes	12.2	–	14.2
		Inserting circular block into circular hole after rotation of plate	15.4	17.4	Yes	Yes	Yes	–	–	–
		Inserting three shaped blocks into corresponding holes in plate	17.8	19.7	Yes	Yes	Yes	–	–	–
		Inserting three shaped blocks into corresponding holes after rotation of	19.8	22.9	Yes	Yes	Yes	–	–	–
Blocks	Blocks and cup	Inserting block into cup	9.2	10.8	Yes	Yes	Yes	21.1	17.8	20.1
	Stacking blocks	Relating block to another block	11.7	13.1	Yes	Yes	Yes	22.0	22.3	–
		Stacking blocks into tower of two blocks	13.8	15.1	Yes	Yes	Yes	–	–	–
		Stacking blocks into tower of five blocks	18.2	20.2	Yes	Yes	Yes	–	–	–
		Stacking blocks into tower of eight blocks	25.1	28.6	Yes	Yes	Yes	–	–	–
	Constructing locks	Stacking four blocks in a two-dimensional manner	28.0	33.2	No	No	No	–	–	–

[a] Incomplete successes in infant chimpanzees: rod was inserted into hole other than circular hole for „Box"; the top cup in a nesting of three was inverted for „Cups"

mans. This result contradicts previous studies which reported that chimpanzees less than 1 year old did not exhibit combinatory manipulation (Vauclair and Bard 1983; Takeshita et al. 1989; Potì and Spinozzi 1994). In some respects, the present study presented a unique testing situation. The infant subjects of the previous studies had been hand-reared or isolated from their biological mothers temporarily for the purposes of testing. In contrast, we tested infants who were being reared by their own mothers. The mothers displayed the object–object combinations required in the tasks and the infants were free to observe these manipulations from a close distance, as well as freely access the objects. In this sense, our study provided a setting similar to that under which transmission processes of tool use occur in wild chimpanzees. Matsuzawa et al. (2001) used the term "education by master–apprenticeship" to describe the way knowledge and skills are transmitted in chimpanzees. While the mother does not actively teach the infant, the infant attempts to copy the mother's behavior through a spontaneous motivation for imitation based on an affectionate bond. We found no evidence of active teaching in our three mother–infant pairs during the 2 years of observation. However, the infants were motivated to observe their mothers' behavior and spontaneously began to manipulate objects. Such long-term intensive exposure to the mothers' object–object combinations together with a rich experience of manipulating objects may have led to the early appearance of object–object combination during the first year of life.

Dramatic increase in object–object combination at around 1.5 years of age

After their first appearance, object–object combinations remained at a low frequency for several months. Around 1.5 years old, the number of object–object combination bouts increased dramatically in all three infants, and furthermore, the accuracy of object–object combinations also increased: the infants exhibited a greater number of successful instances. The pattern may indicate non-gradual developmental changes of object–object combination in infant chimpanzees. Similar developmental depression was reported in studies of human infants (King and Seegmiller 1973; Kopp et al. 1974). These authors reported that although there was an overall progression in stage development for sensorimotor behaviors, occasional declines in performance were also present in 12–18 month olds. The results were discussed in relation to Piaget's statement that infants periodically show behaviors that can be classified as transitional or remnants of preceding stages. In the present study, the infant chimpanzees had not yet begun to move actively when they exhibited object–object combination for the first time. Only later did they begin to move around by themselves. It seemed that after the infants' motor ability increased, their behavior shifted to manipulations that required more global motor patterns. Then, in the second phase, object–object combinations reappeared in a more accurately controlled manner. Another point is relevant to the increase of accuracy in object–object combination. In the first phase, the infants oriented an object to another object while still holding on to the first one. The second phase can be characterized by the behavior of "releasing," which we used in our definition of successful instances. The infants oriented an object and released it, then proceed to repeat the action. We will need to examine further the developmental pattern shown in object manipulation by infant chimpanzees in the future. We noted an interesting coincidence between the increase in the frequency of object–object combinations and the infants' first successful attempts at tool use. Just after the dramatic increase in object–object combination at around 1.5 years, all three chimpanzee infants succeeded for the first time (at around the age of 1 year and 9 months) to use tools in a honey-fishing task designed to simulate ant dipping in the wild (Hirata and Celli 2003).

Differences among the four tasks

In the first phase of object–object combination, almost all instances of object–object combinations occurred in the task of inserting objects into a hole in a box. Even after the dramatic increase in the frequency of object–object combinations, the infants showed a greater number of object–object combinations in this task and in the seriating of nesting cups than in the other two tasks. We also compared the performance of human and chimpanzee infants on the same tasks. Human infants start to insert a rod into a circular hole in a box (box task) at around the same age (1 year and 1 month) as they start to stack up blocks into towers of two blocks. In contrast, chimpanzee infants showed inserting manipulation at as early an age as in human infants, but no stacking manipulation occurred during the first 2 years of life. Thus, in the case of human infants, the two types of object–object combinations, inserting and stacking up, develop at almost the same age. However, in the case of chimpanzee infants, the development of inserting precedes that of stacking up. These results suggest the possibility that chimpanzee infants have a strong tendency to insert objects into a hole or hollow. The developmental process of object–object combination may therefore reflect specific aspects of tool use in their natural habitat. Tool use in wild chimpanzees such as termite fishing in Gombe (Goodall 1964) and ant dipping in Mahale (Nishida 1990) requires the action of inserting a stick into a small hole. Researchers from a number of study sites have described tool-using behaviors that require an inserting action (Whiten et al. 1999). On the other hand, among a total of 57 different types of tools reported from 14 sites (Yamakoshi 2001), we did not find a single example that requires an action similar to the stacking up of blocks. Taken together, the present study has demonstrated the developmental process and the unique features of object–object combination in infant chimpanzees in their first 2 years of life.

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