The Cognitive Animal

Empirical and Theoretical Perspectives on Animal Cognition

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25 Chimpanzee Ai and Her Son Ayumu: An Episode of Education by Master-Apprenticeship

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I have been studying chimpanzee (*Pan troglodytes*) intelligence both in the laboratory and in the wild (Matsuzawa 2001). Chimpanzees in the wild use and manufacture a wide variety of tools, such as twigs to fish for termites or a pair of stones to crack open hard-shelled nuts. Recent studies comparing different communities of chimpanzees have shown that each community develops its own unique set of cultural traditions.

Chimpanzees in the laboratory can also master various kinds of skills, including, to some extent, linguistic and numerical abilities. One question arising from these studies concerns the social transmission of knowledge and skills across generations. How and when does such learning occur and who passes it to whom? To address these questions, this essay briefly summarizes our attempts at synthesizing two distinct approaches to understanding the nature of chimpanzee intelligence: ethological observation in the wild and psychological experiments in the laboratory. In addition, it also provides an account of one of the most impressive episodes of learning by an infant chimpanzee from a skillful mother.

Wild Chimpanzees at Bossou

The forests of Bossou, Guinea-Conakry in West Africa, are home to a group of about 20 chimpanzees. They are known to use a pair of stones as hammer and anvil to crack open oil palm nuts in order to gain access to the kernel inside the hard shell (figure 25.1). Through long-term observation of the nut cracking, my colleagues and I have identified various interesting aspects of this tool-using behavior (Matsuzawa 1994).

For example, each chimpanzee shows perfect laterality in using hammer stones. The "right-handers" always use the right hand for hammering, while the "left-handers" use their left hand exclusively. Such perfect laterality in tool use has never before been found in nonhuman animals. Humans show strong hand preference on the individual level, and there is also a strong right bias at the population level. The chimpanzees of Bossou show a slight bias toward the right for hammering at the population level, with about 67 percent of group members being right-handers. However, there is perfect correspondence in siblings' hand preference. Members of every sibling pair we have come across prefer to use the same hand for hammering. Hand preference is thought to be related to functional lateral asymmetry of brain function, but, with many unanswered questions, this remains a controversial issue in nonhuman animals.

Young chimpanzees require at least 3.5 years to master nut cracking. Furthermore, there is a critical period for learning between the ages of 3.5 and 5 years. Chimpanzees who fail to learn to crack nuts by the end of this period will not acquire the skill in later life. Learning is aided by a form of education by master-apprenticeship. Young chimpanzees learn the skill by carefully observing the behavior of adults for a long time after birth. This observation tends to be a one-way process. Adult chimpanzees seldom observe the behavior of the younger members of the community.

In addition to nut cracking, Bossou chimpanzees possess a unique repertoire of tool-manufacturing and tool-using skills. These include the use of leaves for drinking water, pestle-pounding of oil palms, fishing for safari ants with a wand, scooping algae floating on a pond with a stick, and so forth.

Chimpanzees in the wild have to learn many things besides tool use. For example, there are about 600 different species of plants in the forests of Bossou; of these, the chimpanzee food repertoire includes about 200 species. Various parts of the plants are eaten: the fruit, leaves, young stem, and the bark. Fruits such as figs are highly prized, but efficient foraging has several pre-

Figure 25.1
Chimpanzees at Bossou cracking oil palm nuts using a hammer stone and an anvil stone. Infant chimpanzees, which usually accompany their mothers everywhere, observe the mothers' behavior. There is no active teaching; however, mothers are very tolerant of the infants' observation.

requisites. Chimpanzees must remember where the fig trees are located in the forest. In addition, they have to know what time of year the fruits are ripe. They must recognize that, for instance, the red, mature fruit is tasty, while the green, unripe one is not. They have to learn how to reach the fruit in a large tree. Fig trees can grow to be enormous, too large for the chimpanzees to directly climb the trunks. Instead, they have to remember routes along the branches of nearby trees to reach their destination.

Observational studies in the natural habitat are a fountain of information about chimpanzee intelligence, as well as their society and ecology. However, the constraints associated with observation in the wild preclude us from seeing many of the details of chimpanzee behavior.

Ai Project

Chimpanzees in captivity apply the intelligence evident in the wild to surviving in the human environment. They must learn various skills to communicate with their human cohabitants. In many cases in captivity, chimpanzees have a very limited range or freedom to move from one place to another, to get food, to meet conspecific friends and then to leave them (referred to as the fission-fusion of parties), and so forth. They are in a sense forced to utilize their intelligence to adapt themselves to the human way of communication and lifestyle. Such is the general and common background to the studies of ape intelligence and "ape language" projects so far.

Wolfgang Koehler pioneered the study of chimpanzees. During the early 1910s, he maintained a group of young chimpanzees in a facility located on an island off the west coast of the African continent. His research methods involved providing test situations for the chimpanzees in which they were required to solve a problem. For example, he suspended a piece of banana high up in the air and laid out a selection of sticks and boxes. Chimpanzees were found to move boxes to the spot right underneath the banana, to stack the boxes, to use a stick to prod the banana while standing on the boxes, and even to join two sticks together to extend their instrument if the fruit was still out of reach. In sum, Koehler demonstrated that chimpanzees have the intelligence to make and to use tools for solving given tasks. Today, we can see many parallels between the observations in Koehler's classic work in captivity and the tool manufacturing and use seen in the wild.

Besides tool use, apes raised in a human environment can, to some extent, learn how to use human signs. Through such long-term rearing and training projects, the Gardners and Premacks, as well as other researchers, have contributed a great deal to our understanding of the nature of chimpanzee intelligence.

Ai is one such ape who has learned a variety of skills in captivity. Ai, pronounced "eye" and meaning "love" in Japanese, is a 24-year-old female chimpanzee. In a project that has been running continuously for more than two decades, she has from the age of 1 year learned to communicate through letters and numerals using a computer-controlled device. For example, she learned to touch letters and numerals on a computer terminal to represent the color, identity, and number of items shown to her (figure 25.2) (Biro and Matsuzawa 1999; Kawai and Matsuzawa 2000; Matsuzawa 1985).

A New Project: Infants Reared by Their Mothers

A common disadvantage of captive research is the lack of "community." Most of the "ape-language" studies have concentrated on a single subject or a simple aggregation of multiple subjects. Chimpanzees in the wild live together in a community, which is itself often divided into small parties. Infants less than 3 years old always accompany their mothers. They cling to the mother and the mother in turn embraces the infant. This is the natural way of life and the natural context for learning in the wild.

Ai gave birth on April 24, 2000. In addition to Ai, two other female chimpanzees, Chloé and Pan, also gave birth soon thereafter. Together with these babies, we now have a group of 14 chimpanzees at the Primate Research Institute in Inuyama. The members' ages range from the newborns to a 36-year-old, encompassing three generations of both sexes. This is the Inuyama community of chimpanzees, which simulates the natural way of life of chimpanzees in the African forest (figure 25.3).

In our outdoor compound, we have planted more than 500 trees from 60 different species and built climbing frames more than 50 feet high. The chimpanzees are free to stay outside all day for as long as they wish. However, of their own free will, they prefer to come to experimental booths to interact with human partners.

My colleagues and I are now concentrating on a new project aimed at examining the processes underlying social transmission of knowledge and skills across generations. The three mothers, Ai,

Figure 25.2
The chimpanzee Ai is selecting numerals in an ascending order.

Chloé, and Pan, have learned a variety of computer skills, in addition to many different kinds of tool use much like those of wild chimpanzees. How can such knowledge and skills be transmitted from one generation to the next? When are they transmitted? And from who to whom?

Such questions are not easy to answer. Suppose that one day in the forest you observe a chimpanzee mother and her infant. You can never be sure whether you will have the opportunity to see them again the next day. It may be a week before you see them again, in some cases a month or more. This is the fundamental constraint of behavioral observation in the wild.

However, in our new project, we can observe and also videorecord the chimpanzees (1) 24 hours a day, (2) from a close distance, and (3) with the assistance of the mothers. Without explicit training, the chimpanzee Ai can discriminate about 30 words of human speech: head, mouth, hand, foot, come, go, wait, climb, and so forth. When I first began cognitive tests of the newborn, I announced "Lay down!" and pointed the floor. Although this was the very first instance in my interactive history with Ai of saying such a thing, she immediately realized what was required and lay down, holding her infant.

With such assistance from the mothers, we have been carrying out experiments to observe the cognitive development of chimpanzees reared by their mothers living in a community (figure 25.4). We have been attempting to simulate the natural mother–infant interaction in the context of sophisticated manipulation skills in the wild. The following is the most impressive event of the

Figure 25.3
Outdoor compound for the chimpanzee community of the Primate Research Institute of Kyoto University in Inuyama. Here 14 chimpanzees from 0 to 36 years old live together as a group in a setting that simulates the community-based life of wild chimpanzees in terms of their social and physical environments.

first 10 months in the life of an infant chimpanzee, Ai's son, Ayumu.

Ayumu's First Attempt on the Computer

The infant chimpanzee Ayumu surprised researchers. He attempted a computer task designed for his mother and selected the color brown immediately after he touched the Japanese kanji character meaning "brown." He correctly performed this complex skill on his first attempt.

Ayumu was 9 and a half months old at the time. Sixteen of his deciduous teeth had already erupted; this means that his physical development roughly corresponded to a little less than that of a 2-year-old human infant. Claudia Sousa, a graduate student, was in charge of carrying out the experiment, while Sanae Okamoto, another graduate student, was videorecording the entire process.

The task that was given to Ai consisted of the following two phases. The first was a discrimination task. The chimpanzee had to perform matching-to-sample of colors and the corresponding visual symbols on a touch-sensitive monitor (figure 25.5). The correct answer was rewarded by a 100-yen coin, equivalent to a dollar. The second phase was a coin-use task. The

Figure 25.4
The chimpanzee Ai and her infant son, Ayumu

chimpanzee had to insert the coin into a vending machine to obtain her favored food when pictures of different food items were presented to her on another touch-sensitive monitor (Sousa and Matsuzawa, 2001).

The details of the first task, which happened to be kanji-to-color matching that day, were as follows: First step: Ai touched a white circle on the monitor to start a trial. Second step: immediately after the touch, the white circle was erased and a kanji character, for example "red," appeared in the center of the bottom row of the screen. A touch to the kanji character resulted in the appearance of two alternatives, for example, red- and blue-colored rectangular patches on the screen. Third step: a coin was delivered if the chimpanzee touched the color corresponding to the kanji character, red in this case.

Ai spontaneously saved the coins. After saving three to four coins, she moved to the vending machine located at a distance of about 2 m, and then used the coins for choosing her favorite food. Ayumu had been watching his mother's behavior every day. For a long time since his birth, it had been a daily routine, Monday to Saturday, six times a week. However, he had never touched the screen before the incident described here.

It was 14:31 in the afternoon of February 16, 2001. Immediately after the mother, Ai, moved to the vending machine, Ayumu approached the computer used for the discrimination task. He stood on his feet, holding on to the edge of the computer terminal with his hands. First he touched the white circle on the screen. Once it had vanished, the sample character appeared. It happened to be "brown" in this trial. After staring at the character for about 3 seconds, he touched it. Then two colored patches appeared in a column in the upper right corner of the touch monitor. The color brown was located above the color pink, farthest from Ayumu. The height from the floor to the color brown was about 70 cm.

Ayumu's height was about 60 cm. He stretched his left arm, but failed to reach the color. In the second attempt, he stretched his body while standing on his feet, but again failed to reach it. Then, in his third attempt, he climbed one step up on the wall, resting his feet on the tray located under the monitor. He stood up on the tray and kept his body upright and finally reached the brown color. The videorecord clearly shows that he was definitely aiming to touch the brown-colored patch in the far position.

Since the answer was correct, a 100-yen coin was automatically delivered. Ayumu picked it up, held it in his hand, and continued to mouth and manipulate it throughout the rest of the session, until the very end.

This was Ayumu's first attempt at touching the monitor and he was successful. It is still unclear whether he recognized the relationship between the kanji character and the color, as so far this is the only time this behavior has been seen. However, it is clear that Ayumu knows the flow of a trial.

The infant had witnessed his mother's behavior every day. It reminds me of education by master-apprenticeship (Matsuzawa, 2001), the relationship that exists between, for example, a Sushi master and his apprentice. Just looking,

Figure 25.5
The chimpanzee Ai is performing a computer task (matching a lexigram, or visual symbol meaning "blue," to the kanji character "blue" rather than "orange" in this trial). Her son Ayumu, 9 and a half months old, is observing his mother's behavior.

carefully watching—it is the way of learning in chimpanzees.

You can access the following web site to see a movie clip of this fascinating episode in the life of an infant chimpanzee: click on "Chimpanzee Ai" at http://www.pri.kyoto-u.ac.jp.

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