

Acquisition and transmission of tool making and use for drinking juice in a group of captive chimpanzees (*Pan troglodytes*)¹

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Abstract: The present study examined the acquisition and transmission of tool making and use in a group of chimpanzees. We set up a piece of apparatus that provided orange juice in an outdoor compound for a group of nine chimpanzees. Although they could reach the juice with their hands, eight of the nine subjects used tools. Fifteen kinds of tools in total were used, such as straw, twigs, and some kinds of leaves. The chimpanzees showed high selectivity with regard to tool type. They preferred to use *Thuja occidentalis* as a tool although there were 28 species of tree and several kinds of grass available in the compound. Two females initiated the use of the *Thuja* tool. Since then, five other individuals have begun to use it selectively. Before making the tools by themselves, these five chimpanzees first watched others using the *Thuja* tool for drinking juice, and then used the *Thuja* tool which had been used and left by another chimpanzee.

Key words: chimpanzees, tool use, acquisition, transmission.

Among nonhuman primates, chimpanzees in the wild are well known for behaviors involving the use of tools such as nut cracking (Boesch & Boesch, 1990; Sugiyama & Kohman, 1979), ant dipping (Goodall, 1968; Nishida, 1973, 1987; Sugiyama, 1995a), termite fishing (Goodall, 1968; McGrew & Collins, 1985; McGrew, Tutin, & Baldwin, 1979), pestle pounding (Yamakoshi & Sugiyama, 1995) and so on. Recent studies have revealed that each community has its own traditional way of making and using tools (McGrew, 1992, 1994). Although there are still controversies (e.g., Galef, 1996; Heyes & Galef, 1996; Tomasello, 1996; Visalberghi & Fragaszy, 1990), these skills are considered to be trans-

mitted culturally between communities and across generations (Matsuzawa, 1994; Matsuzawa & Yamakoshi, 1996; Yamakoshi & Matsuzawa, 1993).

Wild chimpanzees drink rain water from the hollow of trees using leaves. This tool-use behavior, called "leaf sponging," has been reported in several habitats of chimpanzees: Gombe (Goodall, 1968, 1986), Mahale (McGrew, 1977; Wrangham, 1992), Budongo (Quiatt & Kiwede, 1994), and Bossou (Sugiyama, 1995b; Tonooka, Inoue, & Matsuzawa, 1994). Few reports, however, have provided quantitative details of the behavior. There might be some difference among the communities about the

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techniques of the tool use and/or the selection of tool materials (Tonooka, 1994).

Tonooka (1995, 1996, 1997) set up an outdoor laboratory for the intensive observation of tool use for drinking water at Bossou, Guinea. A total of 70 episodes were video-recorded. Most of the group members (14 out of 15), excluding individuals under 3 years old, used leaves for drinking water. The chimpanzees' use of leaves was more like paper folding than sponge use, so that this technique can be called "leaf folding." They preferred (75%) to use one species of plant, *Hybophrynium braunianum*.

How have these chimpanzees acquired this tool-using behavior? There are only a few studies on the acquisition and transmission of tool-using behavior in wild chimpanzees. For example, in West Africa, chimpanzees are known to crack hard nuts using stone or wooden tools. At Bossou, chimpanzees crack the oil palm nut (*Elaeis guineensis*), whereas in the Nimba Mountains on the Ivory Coast, 10 km away from Bossou, the chimpanzees crack coula nut (*Coula edulis*). There were no coula trees at Bossou. Matsuzawa and his colleagues attempted a field experiment by giving the coula nut to the Bossou chimpanzees. Most of the chimpanzees showed exploratory stereotyped reactions to the novel nut: looking at it, sniffing it, picking it up, and/or biting it. They did not eat it and never tried to crack the hard shell. One adult female, however, cracked the coula nut immediately, without any exploratory reactions. Through observational learning, two juveniles began to crack the new nut. The interpretation was as follows: The adult chimpanzee grew up in a neighboring community which has the tradition of coula nut cracking, and then moved to Bossou with the knowledge. This proved the first evidence of cultural transmission between communities and across generations (Matsuzawa, 1994; Matsuzawa & Yamakoshi, 1996; Yamakoshi & Matsuzawa, 1993).

Some studies also reported developmental changes in nut-cracking behavior in wild chimpanzees (Boesch, 1991; Inoue & Matsuzawa, 1997; Inoue, Tonooka, & Matsuzawa, 1996). All

these studies in the wild suggest the importance of social interactions between infants and other members of the community, especially their mothers. However, we have not yet observed the entire process of tool emergence, use and transmission in a group of wild chimpanzees.

In captivity, there have been several experimental studies of tool use by chimpanzees (Kitahara-Frisch & Norikoshi, 1982; Limongelli, Visalberghi, & Boysen, 1995; Nagell, Olguin, & Tomasello, 1993; Sumita, Kitahara-Frisch, & Norikoshi, 1985; Tomasello, Davis-Dasilva, & Camak, 1987; Visalberghi, Savage-Rumbaugh, & Fragaszy, 1995). Among them, Kitahara-Frisch and Norikoshi (1982) tried to examine the potential for sponge-making behavior in a chimpanzee. They gave the chimpanzee a container of juice and some branches with leaves. As the sessions progressed, the technique used to obtain juice changed. However, social learning or social transmission of the tool use could not be examined in this context.

In order to simulate the acquisition and transmission processes of leaf-using behavior for drinking water in the wild, we set up an outdoor booth in an outdoor compound where a group of chimpanzees live together. A piece of apparatus for juice delivery was attached to a wall of the booth. We also planted various types of trees and grasses in the compound. Our experiment was designed to address the following questions. How does tool making and use emerge? What kinds of tools are used for drinking? Do the chimpanzees show high selectivity in their use of particular leaves as tools, as evidenced by the Bossou chimpanzees? What kind of processes are involved in the social transmission of tool use from one individual to another?

Method

Subjects

Subjects were two male and seven female adult chimpanzees (*Pan troglodytes*) aged between 12 and 29 years. Six of them had served as subjects in a previous study involving a computer-controlled test at the Primate



Figure 1. Outdoor compound for chimpanzees at Primate Research Institute, Kyoto University.

Research Institute of Kyoto University (Itakura & Matsuzawa, 1993; Kojima, 1990; Matsuzawa, 1985; Tomonaga & Matsuzawa, 1992; Tomonaga, Itakura, & Matsuzawa, 1993). The other three chimpanzees had not participated in laboratory studies.

Housing

Subjects lived in an outdoor compound (770 m²) in the daytime (Figure 1). There were 28 species of tree and several kinds of grass in the compound (Takemoto, Kumazaki, & Matsuzawa, 1996). Various objects, such as pieces of wood, rope, and plastic bowls, lay loose around the compound. The chimpanzees received food (fruit, vegetables, and chow) at least three times a day (7:00, 12:00, and 17:00).

Apparatus

There was an outdoor booth for the experiments. The booth was connected by an underground tunnel to the adjacent building. The

apparatus, an acrylic cylinder 10 cm in diameter, 1 cm thick, and 110 cm high, was fixed to a wall of the booth (Figure 2) and when full provided 60 ml of pure orange juice to the chimpanzees. The apparatus had a hole (10 cm in diameter) 70 cm above ground level for access to the juice. A tube connected the cylinder to a bottle of juice in the outdoor booth, so that the availability and the amount of juice was easily controlled by the experimenters from inside the booth. The experimental session started 3 days after the apparatus was set up, to allow habituation to it.

The chimpanzees had free access to leaves, twigs, branches, straw, and the other material for tool use. Within approximately 3 m of the apparatus, there were 10 species of trees available, including *Ilex crenata*, *Osmanthus fragrans*, *Camellia sasanqua*, *Hydrangea macrophylla* (var. *macrophylla*), *Thuja occidentalis*, and so on. A Sony TRV90 video camera was used to record each experimental session.

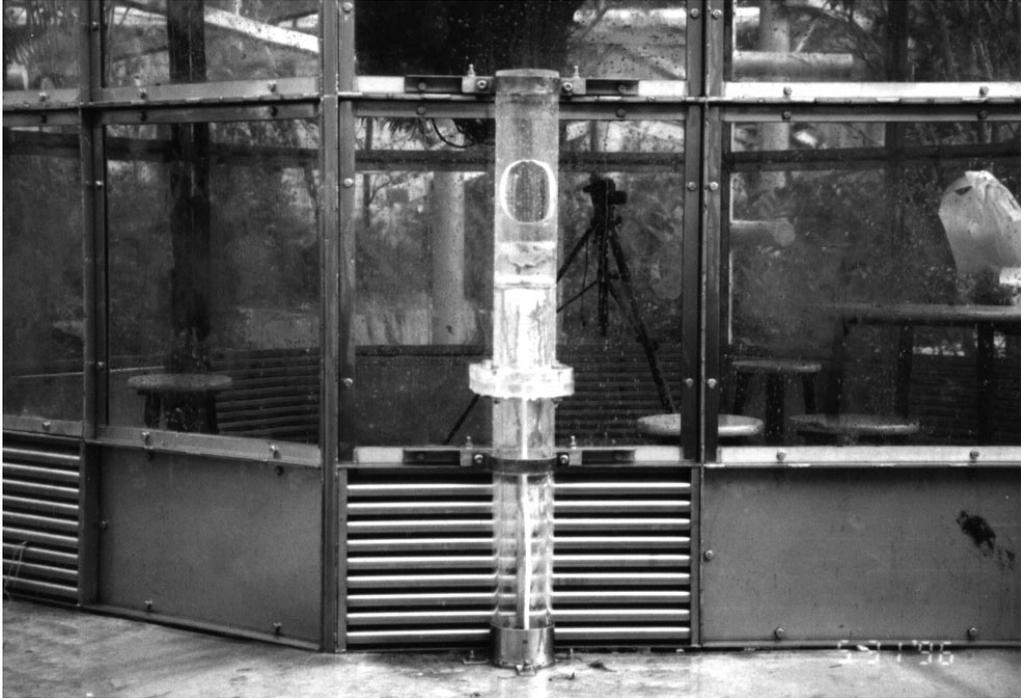


Figure 2. Outdoor booth and the apparatus for juice delivery.

Procedure

The experiment was conducted at noon. One session took 30 min. Three sessions were conducted per week. The present study reports the first 31 sessions. The behavior of individuals within 3 m of the apparatus was video-recorded and behavior beyond was directly observed. Recording started as soon as the experimenters entered to the outdoor booth through the underground tunnel. The experimental session started within approximately 5 min, when we provided orange juice. Once the juice was finished, the experimenter replenished it. However, in cases where one subject drank juice repeatedly or maintained an exclusive presence in front of the apparatus, juice was not supplied again until the subject left. Leaves used as tools by chimpanzees were collected and identified in the evening after the chimpanzees left for their indoor residence.

Data analysis

The behaviors of chimpanzees were classified into two major categories: drinker's behavior – drinking juice with hands or tools, and the behaviors for manufacturing the tools; and observer's behavior – seeing other individuals drinking juice with hands or tools, sitting nearby the drinker or watching the scene at a distance (within 3 m). Tool-using behaviors were further classified into subcategories, as shown in Table 1. Each 30-min session was divided into 30-s intervals, and all the occurrences of each behavioral category was counted using one-zero sampling method (Altmann, 1974).

Results

We will focus on the data concerning the emergence and the social transmission of tool use in the context of drinking juice from the artificial tree hollow. All nine chimpanzees came to the juice supply at least once in the sessions.

Table 1. Total number of subjects drinking juice by hand and with tools as a function of sessions

	Sessions																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Cumulative number of subjects drinking juice	12	11	5	3	3	6	5	2	7	5	4	7	3	5	3	2	3	5	5	6	4	4	3	5	7	4	4	4	3	6	4
Number of subjects drinking by hand	5	3	3	3	2	2	1	0	1	2	1	1	1	2	1	0	1	2	2	1	2	1	1	2	2	1	2	2	1	2	0
Cumulative number of subjects drinking with tools	7	8	2	0	1	4	4	2	6	3	3	6	2	3	2	2	2	3	3	5	2	3	2	3	5	3	2	2	2	4	4
Tools used																															
Twig	1	1			1	1	1					1		1						1						1			1	2	
Pellet	1																														
Calyx of banana	2																														
Grass	1																														
Bark	1									1																					
Straw	1	3	1		1	1		2																							
Paper		3			1			1																							
Withered grass		1																			1										
Setaria			1																		1										
Mass of withered grass					1																										
Cup							1					1																			
Cleyera												2	1	1																	
Ilex																				2	1					3	1				
Juniperus							1	2																							
Thuja									2	3	3	2	1	1	2	2	2	3	1	1	2	3	2	3	2	1	2	2	2	3	2

Variety of drinking tools

Table 1 shows the change in the ways of drinking juice over the sessions. Figure 3 shows the time allocations of each behavioral category for each subject as a function of sessions. The size of each dot indicates the percentage of occurrence of each behavioral category in a session.

In session 1, a male named Akira was the first to occupy the place to drink juice and used his hand. As Figure 3 shows, most of the subjects (seven of the nine) used their hands for drinking in their first attempts to get juice. The remaining two individuals used straw or grass on their first attempts to get juice from the artificial hollow. In addition to the use of hands, various kinds of tools, such as twigs, pellets, calyx of banana, grass, and straw, were also used to access juice in the early sessions. These tools were easily found around the apparatus. The duration of using these tools was much shorter than hand use.

On average, the chimpanzees inserted these tools into the hole only 2.4 times and then abandoned them. Exceptionally, Pan used a mass of withered grass (19.5 min in session 6) and paper (13.5 min in session 9). Overall, chimpanzees used 15 kinds of tools for drinking, even though they could drink juice with their hands in this situation. As sessions went on, however, the variety of tools decreased and converged to one tool, leaves of *Thuja occidentalis*.

Emergence of the use of Thuja occidentalis

As Table 1 and Figure 3 show, the use of *Thuja occidentalis* emerged in session 9 and continued until the end of the experiment. Below we describe the events which occurred before and after the critical session 9.

In session 7, one young female named Pan picked up a branch with leaves of *Juniperus chinensis* (var. *kaizuka*) about 5 m from the booth, carried it to the apparatus and used it for drinking juice (Figure 4). It was the first utilization of leaves of a tree as a drinking tool. Pan had been observed to use the *Juniperus* branch to dig out a piece of pellet buried on the ground in session 6. The *Juniperus* branch used

in session 6 still remained in session 7. In session 7, Pan drank juice with the leaves for 20.5 min. Another female, named Petite, who is Pan's mother (Kumazaki, 1983; Kumazaki, Matsuzawa, & Matsubayashi, 1986), sat 1.5 m away from Pan and watched her drinking juice with a tool (3.5 min in total).

In session 8, Pan again took and used this particular tool (leaves of *Juniperus*) for 22.5 min for drinking juice. The twig with leaves was actually left near the booth in session 7, the day before. Two individuals, Chloe and Pendesa, watched Pan's tool use for 5 and 1.5 min, respectively. After Pan left, Petite came in front of the apparatus, picked up the *Juniperus* tool used by Pan, and began to use it for the last 7 min of the session. After session 8, the experimenters removed this particular branch of *Juniperus*.

In session 9, Pan drank juice with paper and a piece of straw for the first 15 min, then moved to the wall of the compound, about 6 m away from the apparatus, and sat there. Pan left the straw in the hole. Petite then came to the apparatus, picked up the straw from the hole, used it to drink twice. She then dropped it and suddenly moved to the bush of *Thuja occidentalis*, 1.8 m away from the apparatus. She stripped a twig with leaves of *Thuja* from the bush and then, for the first time, inserted the leaves into the apparatus. Petite used *Thuja* as a drinking tool for 6 min and then left. During this period, Popo sat next to Petite and watched her drinking. Pan still stayed near the wall. After Petite left, Popo started to drink juice with her hand. Immediately after Popo started, Pan approached the apparatus. Pan pushed Popo away from the apparatus (by that time Popo drank juice only five times). Pan drank juice with the *Thuja* tool that had been made and used by Petite.

As shown in Figure 4, *Thuja occidentalis* belongs to the same family as *Juniperus* (Gymnospermae, family Cupressaceae), and its leaves are similar to those of *Juniperus*.

Social transmission of the use of Thuja occidentalis

Figure 5 presents the process of acquisition of using and stripping *Thuja* for each individual.



Figure 4. *Thuja occidentalis* (four samples on right) and *Juniperus chinensis* (var. *kaizuka*) (three samples on left), used by chimpanzees for drinking juice.

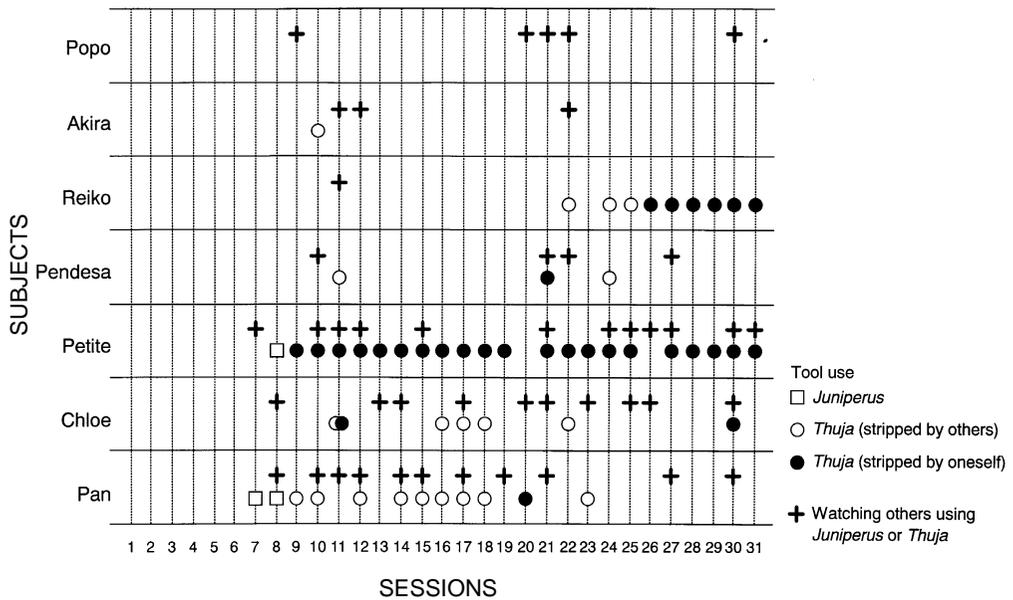


Figure 5. Social transmission of use of the *Thuja* tool. Symbols indicate that the subject used the twig with leaves of *Juniperus* or *Thuja*, or watching others drinking with a *Thuja* tool.

Table 2. Mean number of drinking actions to drink the same amount of juice by hands and *Thuja* for each subject

Drinking type	Subjects	Number of observations	Mean (<i>SD</i>) number of drinking actions ^a
Hand	Akira	1	109.0
	Popo	6	37.8 (15.1)
	Pendesa	10	95.9 (21.6)
	Chloe	8	88.8 (24.0)
	Pan	1	155.0
	<i>Average</i>		97.3 (37.6)
<i>Thuja</i>	Reiko	8	31.0 (16.6)
	Petite	29	39.0 (9.6)
	Chloe	7	40.1 (12.1)
	Pan	12	26.7 (9.8)
	<i>Average</i>		34.2 (5.6)

^a Number of drinking actions was counted until subjects drank 52.5 ml of juice.

In session 10, Pan used *Thuja*, which had been left in front of the apparatus from the beginning of the session. In the middle of this session, Petite replaced Pan. She again went to the bush to strip a twig with leaves of *Thuja* and used it. After Petite left, Akira also came to use the *Thuja* tool for 1.5 min that had been made by Petite. However, this was the only time that Akira used *Thuja*.

In session 11, Chloe also used the *Thuja* tool that had been left by Petite. Then, she went to get another *Thuja* twig with leaves by herself for the first time. Also in session 11, Pendesa used the *Thuja* tool that had been manufactured and used by Petite and then used by Chloe. She first inserted the tool with an incorrect orientation. Rather than inserting the tool from the side with leaves, she inserted the stem side. Pendesa used *Thuja* four times during the present experiment, but she always inserted the stem side. Consequently, she obtained very little juice. Pendesa stripped a *Thuja* twig with leaves by herself for the first time in session 21.

Finally, a female chimpanzee named Reiko started to use a *Thuja* tool that had been left in front of the apparatus in session 22. It was not until session 26 that she stripped a *Thuja* twig by herself. The following point must be noted.

Before showing the tool-making behavior, she also had one opportunity to observe Chloe drinking with a *Thuja* tool (2.5 min) in session 11.

There was only one female, Popo, who never used the leaves as a drinking tool. She consistently used her hands for drinking, even though she had watched the others drinking with the leaves (in total 12.5 min over five sessions).

As Table 1 shows, during the latter half of the sessions, the chimpanzees mostly used either their hands or *Thuja*, and all tool users except Pendesa and Popo virtually stopped hand use. The use of *Thuja* spread among members of the group. The widespread and high selectivity of *Thuja* use may be due to its efficiency for drinking. Table 2 shows the mean number of drinking actions for each subject by hand and with *Thuja*. Drinking action was defined as a bout of repetitive sequence of inserting, dipping, retrieving, and licking. All the episodes of drinking actions were picked up from the video-recording, and the number of repetitive actions was counted until the subject drank up 52.5 ml of juice.

As Table 2 shows, the number of drinking actions were significantly less for drinking by *Thuja* than for drinking by hand (Mann-Whitney's *U* test, $U = 2.0$, $p < 0.05$). This



Figure 6. Pendesa (left) observing Pan drinking with a *Thuja* tool.

efficiency may also explain why Popo did not use tools: the efficiency of drinking by hand in her case (37.8 times in average) was comparable to that of drinking with *Thuja* tools by other subjects (34.2 in average).

Why did the chimpanzees converge in *Thuja* tool use rather than *Juniperus* tool, although the two species are similar? The *Thuja* tree nearest to the outdoor booth was 1.8 m away from the apparatus, while the nearest *Juniperus* was 5 m away. One of the reasons of the convergence of tools toward *Thuja* may be due to a difference in accessibility or availability as a function of spatial arrangement.

Prerequisites of social transmission

Acquisition of *Thuja* as a drinking tool did not occur simultaneously among the members of the group in this experiment. We frequently observed social interactions between tool users and other chimpanzees near the apparatus (Figure 6). Figure 5 shows the patterns of observation by one individual of another using *Thuja*. In the middle of the experiment, Petite

was the only “tool maker,” that means, she herself always went to strip a twig of *Thuja* in the bush. The other chimpanzees (Pan, Chloe, Pendesa, and Reiko) watched Petite using the *Thuja* tool before starting to use it by themselves. In addition to the close observation, all of them had an experience of using a *Thuja* tool that had been made and left by Petite, the inventor of the tool. By session 26, these four individuals had all stripped a twig of *Thuja* by themselves. Among them, however, only Reiko consistently made tools whenever she came to the apparatus just like Petite did. In contrast, the other three stripped a twig of *Thuja* only when there were no tools available near the apparatus.

Table 3 summarizes the relationship among observation, tool use, and tool making. The results clearly show that tool making (breaking off a branch of *Juniperus* or *Thuja* and stripping leaves by themselves) depends on two factors: observation of another chimpanzee drinking with the tool, and the opportunity to use a tool that had been made and left by

Table 3. Relationship between observation, tool use of other's tool, and tool making

Subjects	Observation of using tools	Using <i>Thuja</i>	Making <i>Thuja</i>
Popo	○	X	X
Akira	○	○	X
Reiko	○	○	○
Pendesa	○	○	○
Petite	○	○	○
Chloe	○	○	○
Pan	○	○	○

○: observed.

X: not observed.

someone else. These two conditions are necessary for the acquisition of the tool making by the chimpanzees. However, even when these conditions were met, tool making did not always follow. For example, Akira watched others drinking and actually used the *Thuja* tool made by others, but he did not make a *Thuja* tool by himself. In sum, the two prerequisites, observation and tool use, were necessary but not sufficient for the social transmission of the tool-making skill.

Discussion

The present study set up a situation simulating the emergence and social transmission of tool use and tool making by chimpanzees in the wild. The results provide some parallels to the leaf-folding behavior for drinking water in wild chimpanzees at Bossou. We discuss these below.

First, the chimpanzees used various tools for drinking juice even when they could reach the juice with their hands. They also showed convergence to a specific tool, a stem of *Thuja occidentalis*. Such convergence also arises in the developmental changes of leaf-folding behavior for drinking water in infant chimpanzees at Bossou (Tonooka, 1995, 1996, 1997; Tonooka et al., 1994). The infants were not sensitive to specific leaves and used various kinds of leaves for drinking water, while the adults, in contrast, exclusively used *Hybophrynium braunianum* if it was available.

Second, some of the chimpanzees used the tools incorrectly, putting the stem of the *Thuja* twig rather than the leaves into the hole; this occurred primarily during the early stages of *Thuja* use. Similar kinds of improvement of technique have been observed in the Bossou chimpanzees; infants of approximately 3 years old used a technique similar to leaf sponging: chewing the leaves in their mouth to make a sponge for absorbing water. Then, leaf folding became the dominant technique, as with adults.

Third, it was necessary for the chimpanzees to observe others and try to use tools made and left by others before developing their own tool making. Infant chimpanzees at Bossou always watched their mothers drinking with leaves before they did so on their own. The infants never started making tools or using tools before their mothers started. Furthermore, there were three episodes in which infants interrupted their mothers' drinking and then obtained the leaves that their mothers were currently using (Tonooka, 1996, 1997).

These parallels between the present study and field studies imply that there might be common mechanisms in the acquisition of tool-making and tool-use behavior by the captive chimpanzees in a social context and the developmental changes in the wild.

In conclusion, the present study clarified the processes of acquisition and social transmission of tool making and tool use for drinking juice in captive chimpanzees. The results are summarized as follows.

(1) Eight of the nine chimpanzees in the group used 15 kinds of tools spontaneously, although they could use their hands to access the juice kept in an artificial tree hollow.

(2) Tool making and tool use by the chimpanzees clearly had two stages. One is the creation of the tool. The other is its social transmission. In early stages, various kinds of objects were used as tools. A young female named Pan started to use a twig with leaves of *Juniperus* that had been left on the ground. This was the first step in the emergence of a specific tool use in the group. Another chimpanzee, named Petite, made the second step forward. She used the *Juniperus* tool after Pan left it, then, in the next

session, she selected a similar material, *Thuja occidentalis*, from the bush nearby to make a drinking tool. These two steps resulted in the emergence of *Thuja* as a tool material.

(3) Social transmission of information appeared to be responsible for the other chimpanzees' acquisition of tool-use skills. Four chimpanzees developed tool-making skills through the observation of tool users and the use of the tool by themselves.

In sum, the present study provides an example of how we can examine the processes of acquisition and social transmission of tool making and tool use in captivity to simulate the processes that may occur in the wild.

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