Chapter 8

Use of Leaves for Drinking Water

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8.1 Introduction

Chimpanzees (*Pan troglodytes*) are proficient tool-users, making and using a variety of tools in subsistence and nonsubsistence activities (McGrew 1992; Whiten et al. 1999). Each chimpanzee community has its own tool-use repertoire (McGrew 1992; Whiten et al. 1999, 2001). The chimpanzee community of Bossou is no exception, with a quite large repertoire of 24 different tool-use behaviors (see Chap. 6). Among these, two behaviors concern the use of leaves for drinking water.

Wild chimpanzees are known to use leaves for drinking rainwater from tree holes (Boesch and Boesch 1990; Ghiglieri 1984; Goodall 1964, 1968, 1986; McGrew 1977, 1992; Nishida 1990a; Quiatt and Kiwede 1994; Sugiyama 1989a, 1993, 1995a; Tonooka et al. 1994; Wrangham 1992). Although this behavioral pattern has been observed at many sites, the precise technique used varies considerably across populations. Usually the drinking behavior with leaf tools is described worldwide as the use of leaf sponges (Goodall 1968; McGrew 1977, 1992; Tonooka 2001; Tonooka et al. 1994), a technique first described for Gombe chimpanzees. However, this is not the only technique used by wild chimpanzees. Wild chimpanzees are also known to use leaf spoons (Goodall 1968; McGrew 1977; Sugiyama 1995a) and a leaf-folding technique (Tonooka et al. 1994) for drinking water. We call the behavior leaf sponges when the leaves are crumpled in the mouth (Goodall 1968; McGrew 1977, 1992), leaf spoons when the leaves are used to scoop out the water, without crumpling them up (Goodall 1968; McGrew 1977; Sugiyama 1995a), and leaf-folding when the leaves are folded inside the mouth before use (Sousa et al. 2009), “at about 3-cm intervals” (Tonooka 2001: 326). The finished

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tool is then dipped into a tree hole, retrieved, and put inside the mouth such that the water it carries can be drunk. The sequence is then repeated, using the same tool.

Although at Bossou all these three techniques are reported (Sugiyama 1995a; Tonooka 2001; Tonooka et al. 1994), the most frequent one is the leaf-folding technique for drinking water (Tonooka 2001), which is also exclusively observed among Bossou chimpanzees (see Chap. 6). To perform this tool-use behavior the chimpanzees also show high selectivity for the leaves, preferring the leaves of *Hypophrynium braunianum* as tools (Tonooka 2001).

Tool-use behaviors are assumed to be transmitted culturally between communities and across generations (Matsuzawa and Yamakoshi 1996), that is, they are learned from others who are more proficient than the novice (McGrew 2004). Nevertheless, few studies have explored the acquisition process underlying tool-use behaviors in chimpanzees. Those studies that exist have explored nut-cracking (Biro et al. 2003, 2006; Inoue-Nakamura and Matsuzawa 1997; Matsuzawa 1994, 1999), termite fishing (Lonsdorf 2005, 2006; Lonsdorf et al. 2004), ant-dipping (Humle 2006; Humle et al. 2009), and the use of leaves for drinking water (Biro et al. 2006; Sousa et al. 2009; Tonooka 2001).

Such studies may be scarce because it is difficult to conduct systematic direct observations on chimpanzees performing tool-use activities in the wild. Not all tool-use behaviors occur frequently enough to allow researchers to accumulate sufficient data for such in-depth analysis, and many may be seasonal or difficult to observe because of the nature of the chimpanzees' habitat. For these reasons, an "outdoor laboratory" (Matsuzawa 1994; see also Chaps. 16–18, 21) has been established in the home range of the chimpanzee community at Bossou, Guinea, increasing opportunities of individual group members to perform the behaviors, as well as the researchers' chances of observing them. As a result, we now have extensive annual records on various tool-using behaviors from every member of the Bossou community, including the use of leaves for drinking water.

In this chapter, I bring together the available information on the use of leaves for drinking water by the Bossou chimpanzees. I focus on the learning process underlying the acquisition of the skill, examining some developmental aspects involved.

8.2 Methods

8.2.1 Subjects and Study Site

Behavioral observations involved members of the chimpanzee community of Bossou (7°39' N, 8°30' W), situated in Guinea, West Africa, about 6 km northwest of the foot of the Nimba Mountains on the border with Côte d'Ivoire and Liberia (see Chaps. 27–29).

This community has been studied since 1976 (Sugiyama 1981a, 1984; Sugiyama and Koman 1979a, b; see Chap. 1 for further details) and was habituated to the presence of human observers without food provisioning. Since then the size of the

community has remained relatively stable, varying between 16 and 23 individuals (see Chap. 3). The core area of the community's range encompasses 5–6 km², composed of primary and secondary forest that is surrounded on all sides by dry savannah which the chimpanzees rarely traverse (see Chap. 2).

Individual age ranged from 14 months to 53 years (estimated) old (Table 8.2), divided into four age classes (Goodall 1986; Sugiyama 1994a): adults (11 years old or more), adolescents (between 10 and 8 years old), juveniles (between 7 and 5 years old), and infants (4 years old or less). All individuals were recognized individually.

8.2.2 Data Collection

Observations were carried out in a small clearing in the forest – the “outdoor laboratory” (Matsuzawa 1994; see also Chaps. 16–18, 21) – located on the summit of a hill known as Gban, south of the village of Bossou. A hole with two openings (front and side) was made in the trunk of a tree (*Ricinodendron heudelotii*) (Fig. 8.1) and was refilled to the brim after each visit by chimpanzees to provide fresh water and to monitor the quantity of water consumed by the chimpanzees. The experimenters provided no leaves, so that chimpanzees had to use the vegetation available in the surrounding environment, as in a fully natural condition.

Over the years we recorded the use of leaves in every member of the community along with the identity of the hand used to hold the tool while performing the behav-

Fig. 8.1 The *Ricinodendron heudelotii* tree used in the present study, which contained a water-filled tree hole. A close-up of the two openings of the tree hole are shown: *F*, front opening; *S*, side opening

ior. Data were collected in the dry season, December to February, over a total of 20–30 h of observation each year. Leaf use for drinking water has been studied since 1994, although the data presented here correspond to four field seasons: January 2000, January 2003, January 2005, and January 2006. All chimpanzee visits to the outdoor laboratory were captured on videotape, using a Sony DCR-TRV20 or Sony DCR-TRV9 digital camera. Leaf tools were collected over one study period (January 2003), and systematic measurements (weight, size, and quantity of water carried) were obtained, along with information about tool-user identity, whenever possible.

Subsequent video analysis was conducted to collect further detailed information on the behavior. Only independent bouts were recorded, rather than every manual action. A new bout was said to have commenced if the subject changed hands or if the subject moved from one opening in the tree to the other to drink water.

8.3 Results: Technique Development

8.3.1 *Stages of Learning and Use of Abandoned Tools*

The use of leaves for drinking water involves two distinct phases, the manufacture of the leaf tool and its use. The use of the leaf tool is the first to emerge, at the age of 1.5 years (Sousa et al. 2009). The leaf tools used at this age are not the infants' own; rather, they use the ones discarded by older individuals after use (Table 8.1). Only at the age of 3.5 years do they start to use the leaf tools that they themselves manufacture, and they also continue to use those discarded by fellow group members for several more years (see Table 8.1).

The leftovers, either tools discarded by other individuals or remains that dropped during the manufacturing process, are picked up off the ground, or occasionally taken from the mother's hand, sucked on, and then placed into the water before being retrieved for drinking (tool reuse). Until the age of about 3.5 years, the infants exclusively use these leftovers. The percentage of total episodes of use of leftovers by

Table 8.1 Ability to use leaf tools (made and discarded by other individuals, or made by self) by chimpanzees in different age classes

Age class		Use	Use discarded tool	Make and use own tool
Adult	11–	Yes	No	Yes
Adolescent	8–10	Yes	No	Yes
Juvenile	5–7	Yes	Yes	Yes
Infant	3–4	Yes	Yes	Yes
	2–3	Yes	Yes	No
	1–2	Yes	Yes	No
	0–1	No	No	No

Fig. 8.2 Percentage of episodes in which the drinking tool was already used by other individuals or made from the beginning

infants is 86.7% (Fig. 8.2), consequent to two episodes of making and using a new tool by an infant already 3.5 years old. During this period, until reaching 3.5 years of age, infants also sometimes manufacture a small tool, but they never use it, dropping it immediately after making it, and picking then a leftover to use instead.

8.3.2 *Development and Tool Efficiency*

The leaf tools collected during January 2003 showed a significant correlation between tool weight and the quantity of water they could carry (Pearson's correlation; $n=31$, $r=0.83$, $P<0.001$), with larger tools holding more water (Fig. 8.3). These data also showed lower efficiency of tool-use in younger individuals when compared with the performance of adults. In the former, we find, for example, that leaf tools manufactured by juveniles carry a smaller volume of water per dip than those of adults (Biro et al. 2006).

8.3.3 *Handedness, Adjusting, and Development*

Our long-term records of leaf use for drinking water did not show strict individual-level laterality for the dipping action (Table 8.2, see Sousa et al. 2009 for more details). Of the 24 chimpanzees, 2 infants were never observed drinking water during the study period. Of the remaining 22 individuals, only 3 adults showed consistency in the use of a hand, although these results are based on very small sample sizes (five, two, and six episodes, respectively). The infant indicating the use of only one hand (Veve) only

Fig. 8.3 Average quantity of water (ml) carried by each tool as function of tool weight. Data were collected in 2002. Error bars are standard errors of the mean

had one episode. The remaining 18 individuals were observed to use both the left and the right hand for the dipping action, although 5 of them showed a clear preference for one hand (Fig. 8.4).

A more detailed analysis of the results also showed that juveniles were the ones most likely to change hands during or between dipping bouts, followed by adolescents. Although adults also changed hands to dip, they did so much less frequently (Fig. 8.5). Regarding the use of the two openings of the tree hole (front or side), juveniles were also the ones who alternated most frequently between the holes (Fig. 8.5).

In only 11 (16.18% of all cases of hand change by juveniles) of the 26 episodes in which the juveniles changed holes was this followed by a change of hands. In adolescents, this happened in 5 of 12 episodes of hole changes (15.63% of all cases of hand change by adolescents) and in 1 of 2 episodes for adults (3.33% of all cases of hand change by adults). The only two episodes of hand change in infants occurred also after a hole change, although they were also observed changing holes twice without changing hands.

Figure 8.6 shows the distribution of hand use as a function of which opening of the tree hole individuals were using. Adults exhibit a tendency to use the right hand when dipping at the front opening of the tree hole and to use the left hand when dipping at the side opening. Adolescents and juveniles do not seem to show a preference for using either hand when dipping at the front opening but show a slight preference for the left hand when dipping at the side opening. For infants, data are not sufficient to draw conclusions.

8.3.4 Observing and Learning

Table 8.3 shows the total frequency of observational episodes by chimpanzees during the process of making and/or using drinking tools by other individuals

Table 8.2 Composition of the wild chimpanzee community at Bossou in each field season of the present study: record of handedness in dipping action during the use of leaves for drinking water

Name	Sex	Birth	Age (years:months)	Jan 2000		Jan 2003		Jan 2005		Jan 2006	
				Age class	Hand.	Age class	Hand.	Age class	Hand.	Age class	Hand.
Fana	♀	~1956	44	1	Ar	1	X	1	i	1	X
Fanle	♀	1997, Oct	3:3	4	A	3	A	3	r	2	Ar
Foaf	♂	1980, late	19	1	A	1	i	1	i	1	r
Fokaiye ^a	♂	2001, Jul	-	-	-	4	x	-	-	-	-
Fotaiu ^a	♀	1991, mid	9	2	Ar	1	r	-	-	-	-
Jeje	♂	1997, Dec	3:1	4	x	3	1	3	1	2	Al
Jimato ^b	♂	2002, Oct	-	-	-	4	x	-	-	-	-
Jire	♀	~1958	42	1	A	1	r	1	A	1	1
Joya	♀	2004, Sep	-	-	-	-	-	4	x	4	A
Juru ^c	♀	1993, Nov	6:2	3	r	-	-	-	-	-	-
Kai ^b	♀	~1950	50	1	i	1	X	-	-	-	-
Nina ^b	♀	~1954	47	1	i	1	r	-	-	-	-
Nto ^c	♀	1993, early	7	3	A	-	-	-	-	-	-
Pama	♀	~1967	33	1	X	1	A	1	i	1	A
Peley	♂	1998, Apr	2:9	4	x	3	A	3	A	3	A
Pili ^c	♀	1987, early	13	1	A	-	-	-	-	-	-
Pokuru ^c	♂	1996, Aug	3:5	4	A	-	-	-	-	-	-
Poni ^b	♂	1993, Feb	7:11	3	A	2	A	-	-	-	-
Tua	♂	~1957	46	1	A	1	A	1	i	1	X
Velu	♀	~1959	41	1	X	1	A	1	X	1	i
Veve ^b	♀	2001, May	-	-	-	4	i	-	-	-	-
Vuavua ^a	♀	1991, mid	9	2	A	1	A	-	-	-	-
Yo	♀	~1961	39	1	A	1	i	1	i	1	A
Yolo	♂	1991, mid	9	2	r	1	r	1	A	1	A

(continued)

Table 8.2 (continued)

Age: Age in January 2000

Age class: 1 = adult (11 years and above), 2 = adolescent (8–10 years), 3 = juvenile (4–7 years), 4 = infant (less than 4 years); age presented in years and months (years:months)

^aIndividual disappeared in 2004^bIndividual confirmed dead^cIndividual disappeared by 2001

Hand. (Handedness): L, always uses left hand; R, always uses right hand; A, ambidextrous; l, left biased ($P < 0.05$, statistically significant departures from equal use of both hands, two-tailed binomial test); r, right biased ($P < 0.05$, statistically significant departures from equal use of both hands, two-tailed binomial test); Al, ambidextrous with left-hand bias ($0.05 < P < 0.2$, statistically significant departures from equal use of both hands, two-tailed binomial test); Ar, ambidextrous with right-hand bias ($0.05 < P < 0.2$, statistically significant departures from equal use of both hands, two-tailed binomial test); X, no tool-use observed during period of observation (although individual had previously performed the behavior); x, no tool-use observed during period of observation or at any time previously; i, inconclusive because of the small number of observations

Fig. 8.4 Hand preference during the use of leaves for drinking water. The hand used for the dipping action was recorded for each bout. *All caps*, adults; *lowercase*, non-adults. Statistically significant departures from equal use of both hands: * $P < 0.05$, ** $P < 0.01$, two-tailed binomial test (adapted from Sousa et al. 2009)

Fig. 8.5 Average number of times individuals in different age classes changed hands and changed hole openings during the use of leaves for drinking water at the outdoor laboratory (adapted from Sousa et al. 2009)

Fig. 8.6 Frequency of using the left and right hand at the two openings of the water hole by individuals in the four age classes (adapted from Sousa et al. 2009)

Table 8.3 Frequency of episodes of observations by chimpanzees

Observer	Performer/model				Total
	Infants	Juveniles	Adolescents	Adults	
Infants	0	3	7	26	36
Juveniles	1	1	5	11	18
Subadults	0	0	0	11	11
Adults	0	0	0	2	2
Total	1	4	12	50

Fig. 8.7 A chimpanzee observing another chimpanzee drinking water with a tool made of leaves

(Fig. 8.7), collected during January 2000. Infants and juveniles were responsible for 54% and 27%, respectively, of observational episodes. The majority of the individuals observed performing the behavior were adults (75%). In only one episode was an individual observed to watch a younger individual: a juvenile observing an infant.

8.4 Discussion

This chapter provides an overview of the results obtained through the long-term study of a tool-using behavior by the chimpanzees of Bossou. Based on Matsuzawa's (1996) scheme (see also Chap. 21), a way of classifying tool-use according to its complexity, the use of leaves for drinking water is considered "level 1" tool-use. This classification corroborates the fact that young start leaf drinking at the age of 1.5 years, a younger age than a "level 2" tool-use, as less complex behavioral patterns are likely to appear earlier in development.

However, the question arises if we should consider leaf drinking alone, without the process of manufacturing the tool. The use of leaves for drinking water involves two distinct phases, the manufacture of the leaf tool and its use. If we take into account the manufacturing process, which must precede the drinking action, then this full behavior is only performed starting at the age of 3.5 years, when individuals begin to make and use their own tools. At 3.5 years of age, a "level 2" tool-use appears in development, that is, nut-cracking; this would suggest that the combination of tool-making and tool-using phases, which together facilitate the use of leaves for drinking water, considerably increases the cognitive demands of the task.

Although infants start to use leaves for drinking water at the age of 1.5 years, they do not make their own tools but use those made, used, and discarded by other individuals. Sometimes the infants also manufacture a small tool, but they never use it before the age of 3.5 years old, dropping it immediately after making it, and then picking up a leftover one to use.

From 3.5 years of age, they start to use their own tools for drinking water, but are still using the tools discarded by older individuals. The juveniles already know how to make and use the tool, but are still improving their technique, because they still use tools left by other individuals. Juveniles and adolescents also frequently shift hands when dipping for water with a leaf tool. In addition, juveniles often change from one opening of the tree hole to the other, and change hands more frequently after moving to the other opening.

The switching of hands, as well as changing openings of the tree hole during the performance of leaf-dipping actions, also represent important steps toward the learning of the behavior and suggest a trial-and-error process in acquisition by young individuals, the same way that the switching of tools during nut-cracking may represent young chimpanzees' attempts to learn about the properties and efficiency of different tools (Biro et al. 2006).

An analysis of the leaf tools also provides information on the development of the technique. Leaf tools manufactured by juveniles are smaller and thus carry a smaller volume of water per dip than those of adults (Biro et al. 2006), which also may explain why juveniles still use the discarded drinking tools of older individuals.

The use of leaves for drinking water is frequently performed in a social context, providing the youngster with plenty of opportunities to closely observe skilled tool-users, whether the mother or other adult members of the community, performing the behavior. Such observations may be an important part of the learning process.

Chimpanzees tend to observe conspecifics of the same age group or older, but not younger than themselves, the adults being the most popular targets for observation by individuals across all three age classes. Infants and juveniles are the ones observing older individuals more frequently, while adults are the ones observing less. The pattern of conspecific observation is similar to the one registered for nut-cracking by Bossou chimpanzees (Biro et al. 2006).

During the use of leaves for drinking water, chimpanzees exhibit a nonlateralized pattern, in contrast to nut-cracking activity (Biro et al. 2003), but much like ant-fishing (Marchant and McGrew 2007) (see also Chap. 6 for more details on hand use for other tool-use behaviors at Bossou). Marchant and McGrew (2007) showed a positive correlation between the frequency of hand changes and the incidence of major hand support, as ant-fishing is an arboreal activity. Although in our study leaf drinking is not completely arboreal, it is also not completely terrestrial, as the individual might be standing on the ground or hanging from lianas surrounding the tree containing water. Even if adult individuals do not change their hands frequently while dipping for water, as happens in ant-fishing (Marchant and McGrew 2007), their ambilaterality in hand use might be explained by the necessity for adopting different postural positions, depending on the locations of the hole to drink water, and hence using both hands in different situations. Our data on laterality during leaf drinking might thus suggest some adaptation in terms of handedness to postural position, as there was a tendency for individuals to prefer one hand over the other when dipping at one of the two openings of the tree hole.

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