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Cognitive behaviour in Asian elephants: use and modification of branches for fly switching

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Asian elephants, *Elephus maximus*, have the greatest volume of cerebral cortex available for cognitive processing of all extant terrestrial animal species. A manifestation of cognitive behaviour is tool use and tool manufacture. Fly switching with branches is a type of tool use previously shown in captive Asian elephants to be effective in repelling flies and to vary in frequency with the intensity of flies. In the first part of the present study we report on observations of one juvenile and 33 adult wild elephants comprising 26.7 h of cumulative observations in Nagarhole National Park, Karnataka, India. Eight of these elephants were observed using branches presumably to repel flies. In the second part of the study, conducted also in Nagarhole Park, we presented to 13 captive elephants, maintained under a naturalistic system, branches that were too long or bushy to be effectively used as switches. The long branches were presented in two trials to each elephant and they were given 5 min to either attempt switching with the long branch, or modify the branch and switch with the altered branch. Eight of these elephants modified the branch on at least one trial to a smaller branch and switched with the altered branch. There were different styles of modification of the branches, the most common of which was holding the main stem with the front foot and pulling off a side branch or distal end with the trunk. We propose that fly switching with branches is a common form of tool use in wild Asian elephants when fly intensity is high. Our documentation of the manufacture of a tool by elephants, together with the fact that these animals have a volume of cerebral cortex available for cognitive processing that exceeds that of any primate species, would appear to place this animal in the category of great apes in terms of cognitive abilities for tool use and tool manufacture.

There is considerable interest in understanding the expressions of cognitive behaviour among many mammalian species, such as great apes, that are long lived and have large, complex and highly encephalized (corticalized) brains. Among primates the use of tools and tool manufacture are increasingly studied as manifestations of cognitive behaviour (van Schaik et al. 1999). With forelimb prehensile dexterity, primates are not only able to hold, orient and manipulate a tool, but sometimes modify the tool, allowing the animal to more effectively attain a goal.

Elephants, particularly Asian elephants, *Elephus maximus*, comprise another taxonomic group of animals that are long lived (maximum life span potential of 70 years) and have by far the largest brain of all terrestrial animals (e.g. 5000, 1400, 440 g for the Asian elephant, human and chimpanzee, *Pan troglodytes*, respectively; Jerison 1973; Cutler 1979). The volume of the cerebral cortex is largely determined by brain size (Hofman 1982a; Jerison

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1985). The volume of cortex available for complex multimodal or higher-order brain functions, apart from cortex needed for body-size related sensimotor functions, has been modelled by Hofman (1982a). While the Asian elephant brain is less encephalized than humans in terms of the ratio of cortex for higher-order brain functions ('extra cortex') to cortex for body-related functions, it has more than twice the amount of extra cortical tissue than the human brain (approximately 1600 versus 700 cm^3) and more than 10 times that of the chimpanzee brain (Hofman 1982a). Even the estimated number of 'extra' cortical neuronal modules of the elephant brain far exceeds that of the human and chimpanzee brains (Hofman 1982b). The commonly used encephalization quotient, EQ (Jerison 1973), is 2.3 for Asian elephants (Cutler 1979) compared to 2.5 for chimpanzees and 7.5 for humans (Jerison 1973). Interestingly, the EQ of African elephants, *Loxodonta africana*, with a much larger body and only slightly larger brain, is only 1.3.

Elephants are special in another sense in that they have a prehensile trunk capable of some of the same manipulative movements performed by primates with their fingers and thumb. The sensorineural specializations of the trunk are extensive (Rasmussen & Munger 1996), allowing delicate manipulations with the 'finger' of the trunk (Asian elephants) for picking up objects as small as a straw or an American dime from a concrete floor (Shoshani 1997). Some investigators have drawn a parallel in the fine-grained motor neural control of the elephant trunk with that of primate digits (Onodera & Hicks 1999).

These intriguing similarities of elephants with tool-using primates led us to further pursue the study of fly switching as a form of tool use in wild elephants and also to systematically study the possibility of tool manufacture, expressed by Asian elephants, modifying branches so they could then be used for switches. Among the more frequently reported examples of tool use seen in both captive and wild Asian and African elephants are throwing sticks, logs and stones at other animals or human observers and using sticks to scratch parts of the body (Kuhme 1962, 1963; Douglas-Hamilton & Douglas-Hamilton 1975; Chevalier-Skolnikoff & Liska 1993; Kurt & Hartl 1995; Wickler & Seibt 1997). A third type of tool use, that of using branches for fly switching, is referred to in two nineteenth century historical accounts. The adventurer Harris, in a narration about encounters with wild African elephants, describes seeing elephants emerging into an open glade and 'bearing in their trunks the branches of trees with which they indolently protected themselves from flies' (Harris 1838, page 169). A note in an 1871 field newsletter (Zoophilus 1871) describes an encounter in India by the author with a wild bull elephant in which the elephant was 'observed whisking off flies with a leafy branch'. Even the great storyteller Rudyard Kipling alludes to elephants fly switching in the chapter 'The Elephant's Child' in his 1902 *Just So Stories*. The elephant's child, having acquired a new trunk (courtesy of the crocodile), starts home and Kipling notes that, 'when flies bit him he broke off the branch of a tree and used it as a fly-whisk' (Kipling 1902).

A systematic study conducted on the use of branches as tools to repel biting flies by 15 captive Asian elephants in Nepal revealed that the rate of switching corresponded to the intensity of flies on and around the elephants (Hart & Hart 1994). When no branch was available for switching, the median fly count on the elephants was about double that recorded when elephants were able to engage in fly switching. The observations were consistent with Darwin's mention, under the topic of the 'Intelligence of Beasts' in *The Descent of Man*, that 'tamed Indian elephants were well known to break off branches of trees and use them to drive away flies' (Darwin 1871). Darwin referred to claims of other authorities (no citations) that sometimes captive elephants modified branches by removing side stems or shortening the branch. In another historical account referring to tool modification, Peal (1879) reported that a captive elephant upon which he was riding stripped down a branch before breaking it off and using it as a switch.

To observe and systematically document the frequency and nature of the use of branches as fly switches in free-ranging wild Asian elephants, we chose as a study site the protected natural ecosystem that is part of the Nagarhole-Nilgiris-Eastern Ghats region containing the largest population of elephants in southern India (Sukumar 1989). To study the modification of branches requiring experimental trials, we chose captive elephants living in jungle camps at the same study area where observations of wild elephants were conducted. The captive environment of these elephants would be classified as extensive by Kurt & Hartl (1995) or naturalistic by others. The elephants had access to forests at night and part of the day, found their own food and met with wild and domesticated conspecifics in the forest; there was active reproduction in the captive elephants with females bred by wild bulls. The behavioural characteristics of elephants in such environments are more like that of wild elephants (Kurt & Hartl 1995).

The use of branches as fly switches by elephants satisfies the generally accepted definition of animal tool use, in that the animal is using an unattached environmental object to alter the form, position or condition of another object or organism, when the user holds or carries the tool during its use and is responsible for a proper and effective orientation of the tool (Beck 1980). Preliminary observations indicated that encounters with wild elephants using branches for fly switching in wooded environments would be too disrupted by vegetation to expect to see modification of the branches.

OBSERVATIONS ON WILD ELEPHANTS

Several instances of fly switching by wild elephants with branches of trees or shrubs had been observed opportunistically by one of us (C.R.S.) while travelling through the study site. Thus, for the present study, observations were made with the intention of acquiring data about the relative frequency of fly switching during a time of moderate or mild fly intensity, recording the number of switching bouts typically performed, indications of the presence of flies and types of vegetation used in switching.

Table 1. Record of observational sightings of wild elephants

Sighting	Subject(s) observed fly switching*	Duration (min)	Group composition	Time of day
1	♂ A, ♂ B	165	2♂	Morning
2	♂ C	118	1♂	Morning
3	♂ D	6	1♂	Late afternoon
4	♂ E	75	4♀, 1 juvenile ♂, plus young	Late afternoon
5	♀ F	40	5♀	Late afternoon
6	♀ G, ♀ H	38	11♀ plus young	Early afternoon
7	—	30	6♀ plus young	Early afternoon
8	—	5	3♀ plus young	Early afternoon

*See Table 2.

Table 2. Wild elephants observed engaging in bouts of fly switching and indications of fly presence

Subject	Bouts	Plants*	Indications of flies (yes, Y; no, N)	
			Ear flapping, tail switching	Flies on or near elephant
A. Adult male	2	Fi	Y	Y
B. Adult male	4	Fi, Eu, Bu	Y	Y
C. Adult male	1	Gr	Y	Y
D. Adult male	1	Bg	Y	N
E. Juvenile male	1	Gr	Y	Y
F. Adult female	2	Eu	N	N
G. Adult female	1	Gr	N	Y
H. Adult female	1	Le	N	Y

*Plants: Fi: *Ficus infectoria*; Eu: *Eupatorium odoratum*; Bu: *Butea monosperma*; Gr: grass, unidentified species; Bg: Bamboo grass; Le: Leafy plant, unidentified.

Methods

The study was conducted in Nagarhole National Park, Karnataka, in southwestern India where wild elephants freely range through three contiguous national parks (Nagarhole, Bandipur, Mudumali). The approximate area of elephant habitat in Nagarhole is 1500 km^2 and the population of elephants is estimated between 600 and 800 (Sukumar 1989). During most of the year when water supplies are well distributed, elephants are dispersed and difficult to see because the bush-like habitat is fully leafed out and elephants can only be seen a short distance from the access roads. During the dry season, February–May, local water holes dry up and elephants tend to gather in Nagarhole Park, where the receding Kabbini River backwaters produce green grassy vegetation and a reliable supply of water. Elephants are seen relatively easily during the dry season but there are few flies at this time. In hundreds of hours of observing elephants during this season, we have not seen any fly switching in free-ranging wild elephants. With the monsoons, beginning in late May and early June, flies can become prevalent but elephants gradually become more dispersed and the vegetation becomes more dense. This study was conducted during August, 1999, when the fly intensity was decreasing from its peak, but when elephants could still be readily observed.

The observations occurred from a vehicle carrying three to four investigators on access roads in the main park regions. While driving on the dirt access roads investigators looked for one or more elephants in the vicinity of bushes or trees that could serve for fly switches; when elephants were seen they were usually foraging. Two investigators watched the elephants with binoculars, another investigator recorded observations and one took photographs or videotaped fly-switching behaviour if the animals were close enough for such photography. The animals were observed for the presence of flies or for signs of flies in the vicinity, as indicated by rapid movement of the ears, tail and trunk. Our observations were made in the morning (0700–1100 hours), early afternoon (1200–1430 hours) and evening (1600–1900 hours). Bouts of fly switching were designated as the elephant holding a branch with its trunk and switching the leafy end of the branch against some part of the body, generally the belly, shoulder or neck. When switching occurred, we noted the type of vegetation used and, when possible, the botanical name of the bush or tree. Observations of fly switching were confirmed by two observers. Our intention was to observe elephants under circumstances where fly switching was possible or likely for at least 20 h of cumulative direct observations.

Most observations were made of the elephants as they foraged on the margin of the wooded area just beyond a

Figure 1. Fly switching with a *Ficus* branch by a wild bull elephant who was foraging on a *Ficus* tree (a, b). The branches were eaten after they were used for a bout of fly switching.

30–40 m view lane on either side of the road (maintained free of brush for the purposes of game viewing). Park visitor numbers were controlled by a policy where visitors could only be taken into the jungle in one of five Park vehicles.

Results

During the 5 days of this study, eight sightings for data collection were made where one or more elephants could be observed for at least 3 min. The number of elephants observed at the sightings ranged from one to 11. A total of 8 h was spent at these sightings. The mean time spent per sighting was 1 h (range 5–165 min). Observations included sightings on four adult males (estimated age 20–40 years), of which two were foraging together for most of the sighting. The other sightings were of female groups including young and juvenile males, comprising 3–11 elephants per group. Taking into account the number of elephants present at each sighting, the study included a total of 26.7 h of cumulative observations. The ambient temperatures of observations ranged from 23–31 °C for morning, 27–29 °C for early afternoon and 21–26 °C for late afternoon.

In observations on one juvenile male and 33 adult male and female elephants, fly switching was observed in four adult males, one juvenile male and three adult females in six of eight sightings. Table 1 presents information on the eight sightings, listing elephants that were observed switching, the duration of observations, group composition and time of day. Indications of the presence of flies observed around the elephants were recorded in seven of eight switching elephants (Table 2). One to four bouts of switching was observed for each subject seen engaging in the behaviour. Typically the branch was swung in a pendulous motion, hitting the body at the end of a somewhat circular swing, two to three times in succession (range 1–6). Although switching on alternate sides was common within a bout, elephants also sometimes repetitiously switched to a single side or the belly. Following a bout of switching the elephant would (1) hold the branch for a few minutes and then use it for a second bout, (2) eat the branch, or (3) drop it. Of the branches we observed being used for switching, the leaves or the bark were edible. The length of the branches generally used was estimated to be 0.75–2 m.

The most clearly visible example of fly switching was seen in two adult male elephants, one estimated to be approximately 40 years of age and the other 25–30 years of age and which seemed to be travelling and foraging together. The first male was foraging upon the bark of a *Butea* tree (*Butea monosperma*; flame of the forest), which he apparently had pushed over an hour or two before we came upon him. The brush immediately surrounding

Table 3. Branch modification and switching behaviour of captive elephants (N=13)

Behaviour	Number
Long branch presentation	
Modified long branch and switched with altered part at least once	8
No modification of long branch; switched with long branch	2
Short branch presentation	
No switching with long branch but switching with short branch	2
No switching with either long or short branch	1

Long branch: bushy branch of *Butea* species 2.5–4 m considered too awkward for efficient switching; short branch: 0.5–1.5 m *Butea* species. Elephants that did not pick up the long branch within 5 min were presented with a short branch. This procedure was followed on each of two trials.

him was heavy and apparently quite dense with flies, as indicated by almost continuous flapping of his ears and switching with the tail. Next to the downed *Butea* tree was a *Ficus* tree (*F. infectoria*) upon which he was also foraging. With a 2-m branch from the *Ficus*, the elephant delivered a switch with the leafy end of the branch against the belly and subsequently put the branch into his mouth, stripped off and ate the leaves before dropping the stem. He then picked up the bare stem 2–3 min later and switched the right shoulder and left neck, before eating the stem. He then took a new branch, also of approximately 2 m, and delivered a bout of switches to the right shoulder, belly and left shoulder with the bushy end (Fig. 1a, b). He then stripped off the leaves of this branch in his mouth, ate the leaves and part of the stem, and dropped the branch. This male was then joined by the second adult male, who took over the foraging site around the felled *Butea* tree. This elephant switched his belly with a branch of the *Ficus* and then proceeded to remove bark from the *Butea* tree, whereupon he delivered a bout of switches to the left side with a 1-m length of the bark before eating the bark. The first elephant was observed for a total of 165 min, the second for 123 min, with most of the observation time on the two elephants overlapping.

Other elephants observed to be fly switching used not only *Ficus* branches, but also branches of *Eupatorium odoratum* (introduced non-native species), grasses, bamboo grass and an unidentified leafy plant (Table 2). The switching movements were the same as those of the male elephants described above.

BRANCH MODIFICATION BY CAPTIVE ELEPHANTS

We conducted this study in Nagarhole National Park at two communities or camps in which captive elephants are maintained. The elephants of one site, referred to as the riding camp, were females that were used to take tourists to view wildlife in the surrounding forest. The elephants of the other site, referred to as the logging camp, were occasionally used for work and were mostly males. The elephants at both locations grazed freely in the adjacent forest at night and part of the day; they were retrieved and stabled when needed for work. At the stables they were fed a rice-molasses supplement but were not generally provisioned with branches or other plant material. Further aspects of the care and the daily schedule used with the elephants have been described previously in more detail (Hart & Sundar 2000).

As mentioned, the environment of the captive elephants would be considered as naturalistic or extensive according to the classification by Kurt & Hartl (1995), who maintain that the behaviour of extensively managed elephants is more similar to that of wild elephants than intensively managed elephants such as those in circuses or zoos. No stereotypic behaviours, such as weaving, swaying or head nodding, which are common in intensively managed elephants, were seen in the captive elephants of this study.

The goal of this aspect of the study was to arrange for the presentation of branches to the elephants such as to provide an opportunity for them to modify the branches for use as switches for repelling flies. Thus, an overly long and bushy branch that could not easily be used for switching was presented. Of particular interest was the specific technique used to alter the size and shape of the branch. For example, a side branch might be pulled off the main stem and used as a switch or, alternatively, the main stem might be broken in half and the distal end used as a switch.

Methods

The subjects were five adult females at the riding camp and six adult males and two adult females at the logging camp. Two females at the riding elephant camp had young, one a female of 9 months old and another a male of 18 months of age. Since elephants at both camps were allowed to forage in surrounding woodland areas, all animals were accustomed to obtaining branches from edible trees for food and were familiar with trees with unpalatable leaves, such as *Butea*. On two occasions, at least 1 day apart, we presented each elephant with a branch of *Butea* 2.5–4.0 m long. In preliminary observations, this length of branch was found to be too long for convenient switching. As mentioned, the leaves of *Butea* are not generally eaten by elephants, although they will eat bark stripped from the plant; *Butea* is found abundantly throughout the Park. Branches from edible trees or shrubs are used by elephants for switching, sometimes just before eating the plant, so removal of parts of a branch from an edible species might be attributed to foraging on the branch, not modification of a branch for switching. Thus, all branch presentations were with *Butea* branches. In preliminary observations we found that captive elephants never ate the leaves nor the bark or stems of *Butea* branches presented to them.

We allowed the elephant under observation 5 min to interact with the branch. If the elephant did not pick up the branch and modify it, or attempt to switch with the

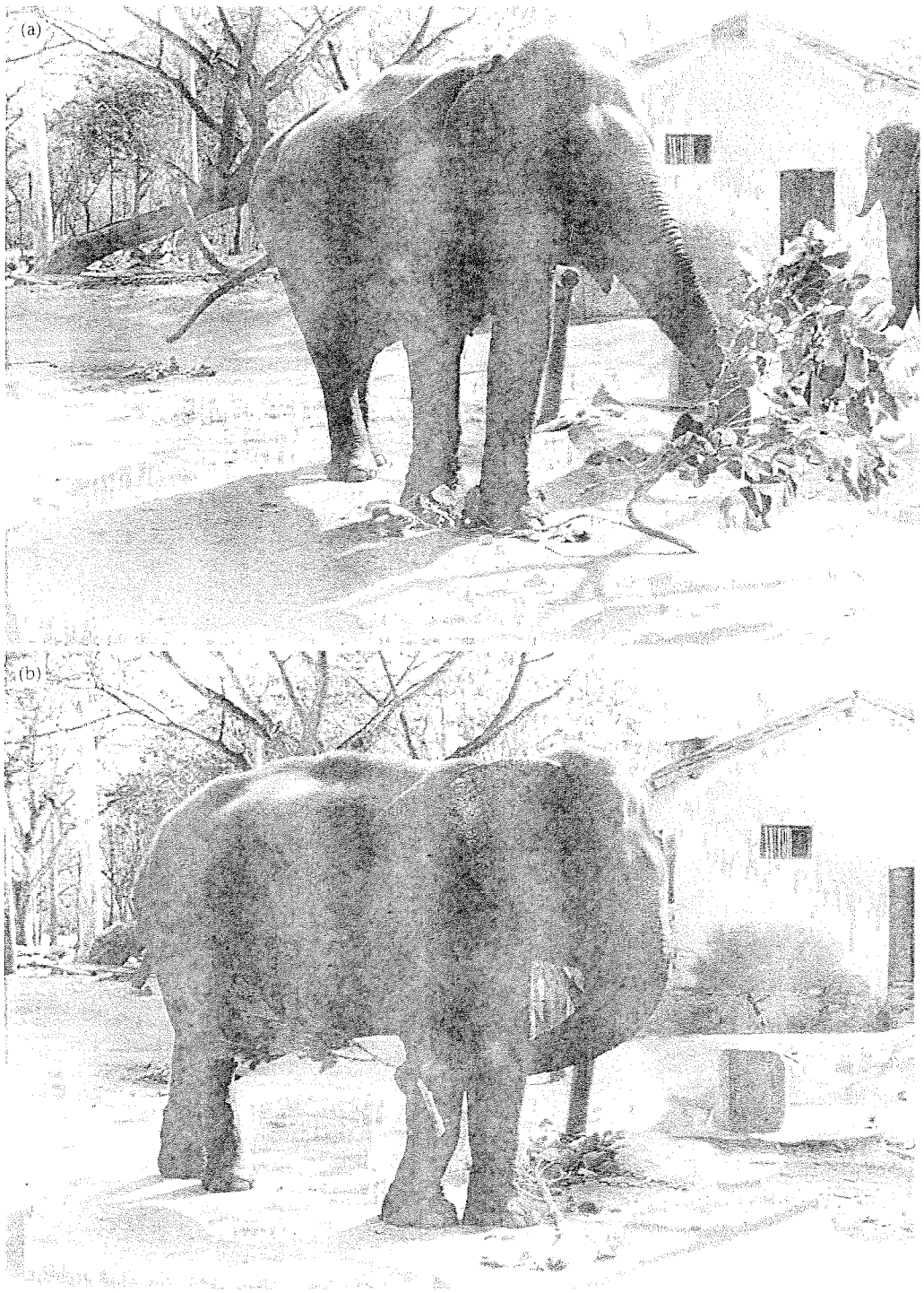

Figure 2. A captive female elephant removing a side branch from a long *Butea* branch (a), and switching with this modified branch (b).

branch, we presented a short 0.5–1.5 m branch of *Butea*, deemed easily used for switching, to the elephant. The behaviours recorded with regard to the long branch presentation were: (1) attempts to switch with the unaltered long branch; (2) modification of the long branch by removal of side branches or shortening the main stem; (3) switching with the shortened branch or part removed. If modification was performed, we recorded the behaviour involved in modification. We made no attempt to record indications of fly intensity during these tests.

Although branches were not systematically presented to the young elephants, they were usually near their

mothers and had access to branches presented to their mothers. When they manipulated or attempted to switch with a branch we recorded the behaviour.

Results

As presented in Table 3, eight of the 13 elephants modified the branch on at least one presentation. With one exception this modification occurred prior to making any attempt at switching with the long branch. After modifying the branch, the elephants always switched immediately afterwards with the modified part. Of the elephants not modifying, two attempted to switch with the large branch, although to the investigators the switching seemed awkward and ineffective. Two elephants that did not switch with the large branch on either trial did switch with the short branch. One elephant did not switch with any branch that was presented, including a small branch.

The style of branch modification seen in the elephants that did modify was of two general approaches. One general approach involved removing a side branch. This was done in either of two ways: (1) by holding the main stem on the ground with a front foot and pulling the side stem off with the trunk (Fig. 2a, b); (2) by coiling the trunk around the side stem and twisting and swishing it against the weight of the main branch. On some occasions if the latter method did not result in a side stem being broken off, the elephant then stepped on the main branch and pulled off the side stem.

The second general approach of branch modification involved shortening the main stem by breaking it into two parts and switching with the distal part. As with removal of side branches, this could be done in either of two ways: (1) the front foot was used to hold the main branch and the distal part broken off with the trunk; (2) the main stem of the large branch might be broken by coiling the trunk around the distal part of the branch and twisting and turning it against the weight of the main branch. A behaviour that was seen but was not part of an official trial in the experiment was a type of modification in which the elephant held the main stem in the mouth and broke off the distal end with the trunk. The frequency with which we recorded each method of branch modification over the course of two trials per elephant is presented in Table 4. One elephant used a different style on each of the two trials.

With regard to the two baby elephants, the 18-month-old male removed a side branch and switched with the modified smaller branch (Fig. 3). The 9-month-old female seemed to lack the coordination to switch effectively, but movements appeared to be attempts to imitate the fly-switching behaviour of the older elephants.

Table 4. Styles of modification of long branches (N=8)*

Modification style	Number of elephants using the style
Remove side branch from long branch	
Use front foot to hold branch, pull off side branch with trunk	3
Side branch removed by twisting and turning with trunk	2
Shorten main stem of long branch	
Use front foot to hold branch, break off distal end with trunk	3
Distal end removed through twisting and turning with trunk	1

*One elephant used more than one style of modification.

DISCUSSION

In addition to the two types of manipulative tool use previously observed in both wild and captive Asian elephants, namely scratching parts of the body with a stick (Kurt 1992; Chevalier-Skolnikoff & Liska 1993; Hart & Hart 1994) and throwing objects at other animals or people (Kurt 1992; Chevalier-Skolnikoff & Liska 1993; Wickler & Seibt 1997), we can now add fly switching with branches (Hart & Hart 1994; the present study). An indication of the frequency of the other types of manipulative tool use is the mention by Kurt & Hartl (1995) that in 500 h of observations on wild bull elephants, throwing branches at other animals (jackals and leopards) was observed only three times. Thus, contrary to the assertion by Kurt & Hartl that fly switching is rare in wild free-ranging elephants, we maintain that when flies are present and branches are available, fly switching may be the most common type of manipulative tool use in Asian elephants.

All of the wild elephants observed to be fly switching were foraging and fly switching at the same time; indications of flies were recorded in switching bouts of seven of the eight elephants. Because both switching and foraging require use of the prehensile trunk, switching competes with foraging. Switching behaviour that uses the same branches that are eaten is more efficient than using separate branches for switching. Not surprisingly, all of the observations of fly switching by free-ranging wild elephants involved branches that the animal was also foraging upon.

Although observations of free-ranging elephants were usually made at too great a distance to notice any branch modification, when fly-switch use was visible, no modification was observed. This is to be expected because elephants that are foraging on fallen or upright trees or bushes would generally remove branches that could be manipulated into the mouth and these branches would be the size useful for switching. Also, one would not expect to see elephants that are foraging to save branches for switching as reported for captive elephants (Hart & Hart 1994).

The observations on eight captive elephants that modified the long branch revealed four methods by which the animals could end up with a branch of appropriate size, the most common of which was to pull off a side branch or distal portion with the trunk while holding the main stem with the front foot. Given the background of relatively frequent fly switching by wild elephants during the fly season (the present study), and the correlation of

Figure 3. The 18-month-old male removed a side branch (a) and switched with the short branch (b).

fly switching with fly intensity, plus documentation of the effectiveness of fly switching in repelling flies (Hart & Hart 1994), we consider this branch modification for the envisioned goal of effective switching. This conclusion is strengthened by the fact that the modified branches were, in all cases, immediately used for switching. Furthermore, the goal of repelling flies can also occur with objects other than branches, and we have previously reported that elephants will use strips of bark or burlap bags for fly switching (Hart & Hart 1994). Thus, we conclude that in correspondence to their large cerebral cortical capacity, Asian elephants comprise a taxonomic group, in addition to great apes, in which tool manufacture occurs at least in captive animals maintained under naturalistic conditions.

The involvement of manual dexterity in the use of tools in primates has led van Schaik et al. (1999) to introduce the concept of bimanual asymmetric coordination in the use of the two hands to perform different, but complementary, actions on a detached object. In elephants the use of the trunk to remove a side branch, while holding the main stem with the front foot, is logically analogous to the bimanual asymmetric coordination seen in primates in tool use for extraction of food.

Some additional comparisons of tool use in Asian elephants with that of primates may be useful. The types of tool use that have also been observed in primates have been recently catalogued (van Schaik et al. 1999; Whiten et al. 1999). Only chimpanzees and orang-utans, *Pongo pygmaeus*, are known to manufacture and use tools regularly on a population-wide basis (van Schaik et al. 1999). The modification of branches for fly switching potentially places Asian elephant tool use behaviour at the same level as that of these great apes. What is missing for a more convincing claim that Asian elephants are comparable to great apes in the manufacture of tools are observations of tool modification by elephants in the wild. However, as noted (van Schaik et al. 1999), even in great apes, most situations requiring tool use in the wild are uncommon and intermittent in time.

One other area of overlap in the use and modification of tools in great apes and elephants is the role of social learning seen in the young with extensive developmental dependency on adults. Such a lifestyle makes possible the imitation or emulation by the young towards the acquisition of tool use. We have reported here the imitation of fly switching by two young elephants 9 and 18 months of age. The 18-month-old removed a side branch and was coordinated in switching the body compared with uncoordinated responses of the 9-month-old. We suggest that further studies of tool modification in both wild and captive elephants, along with studies of developmental aspects of tool use, will shed additional light on the interesting comparisons between great apes and Asian elephant cognitive behaviour.

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