manual organization in cases where a supporting hand (frame) holds an object that is manipulated by the preferred hand, which, metaphorically, provides content elements (MacNeilage 1987). This important evolutionary development accompanied the evolution of hand-internal control in higher primates. As I pointed out earlier, the hierarchically organized acts that Greenfield considered under the manual heading are not necessarily closely linked to specific manual movements as such. Consequently, the postulation of a frame/content mode of manual organization, cited here to argue for evolutionary similarities between manual and vocal systems, has no direct implications for the cognitive bases of the manual tasks considered by Greenfield. It seems here that the task should be to explore the cognitive *but not the motor* relations between the tasks Greenfield considers and grammar. Surely, in both evolutionary and developmental terms, such cognitive concepts as subordination or coordination or temporal sequence have common implications for actions either in grammar or in operations on objects in the external world. This commonality will not be found in motor homology, however, as is revealed by the fact that grammatical morphemes are signaled differently in manual sign language (typically by movements superimposed on a concurrent sign for an open class morpheme) and in vocal language (typically by temporally discrete movement complexes). Action, in motor terms, was probably a very important factor in the evolution of cognition, but cognition is not necessarily closely constrained by action today.

Frame/content modes of organization are not confined to manual and vocal systems operating alone. Other frame/content modes are the coordination of both hands with the mouth (as in squirrels) and the coordination of one hand with the mouth, which became possible with the evolution of the prehensile hand in early primates (MacNeilage 1991). These modes of interaction between the hand and the mouth highlight a further problem with Greenfield's position. Her evolutionary view is one of the development of homologous manual and vocal organizational states from a hitherto undifferentiated substrate. Thus, she interprets Rizzolatti's finding of neurons in lateral frontal cortex that discharge only when the hand touches the mouth as evidence of a lack of differentiation in nonhuman primate cortex. I believe she underestimates these animals. It is more likely that these neurons help to mediate the very elegant frame/content operations of hand-mouth interaction in feeding that have probably been important throughout primate evolution.

The view that organizational similarities between manual and vocal systems are to some degree a matter of convergent evolution of frame/content modes of organization does not necessarily imply that there is no homologous substrate for the two domains. Elsewhere, my colleagues and I have argued that there is a fundamental homology linking the two domains in the form of a left hemisphere postural control specialization, from which both manual (right hand) and communicative specializations may have evolved (MacNeilage 1991; MacNeilage et al. 1987; 1988).

Nesting cups and metatools in chimpanzees

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Greenfield's target article was very stimulating. Having studied the cognitive behavior of chimpanzees in captivity and in the wild, I would like to present two related findings about chimpanzees for further discussion from the viewpoint of a primatologist or a cognitive psychology. One is "the subassembly strategy to nest the seriated cups by captive chimpanzees" and the other is a metatool use in wild chimpanzee nut-cracking behavior using stone hammer and anvil.

I made systematic observations on nine chimpanzees from ages 2 to 26 playing with seriated nesting cups (Matsuzawa 1986a, Table 1). The procedures are the same as those of Greenfield et al. (1972). Seven chimpanzees aged 4 and younger failed to make the seriated structure of five cups and always used the "pot" strategy of putting cups into a "pot" cup. It was also interesting that the chimps were not satisfied with the nonseriated structure and spontaneously put back the cups, trying again and again to make the structure follow the pot strategy. Two adult chimpanzees who had intensive experience in language-like skills, however, behaved just as human children of more than three years old do.

A chimpanzee named Sarah made a five-cup seriated structure in the first trial. She was given five cups, $A < B < C < D < E$ from small to large. Her performance was as follows: In the first step, she put B into C. In the second, she put D into E. Third, she put the subassembly of BC into DE. Finally, she put A into BCDE. Sarah used the most advanced "subassembly" strategy

Table 1 (Matsuzawa). *Summary data for the manipulation of seriated cups by chimpanzees.*

Name	Sex	Age	Test place	Number of cups given	Trials	Seriated?	Strategy
Pan	f	2	Japan	3	24	Yes/no	Pot
Reo	m	4	Japan	3	24	Yes/no	Pot
Popo	f	4	Japan	3	24	Yes/no	Pot
Whiskey	m	4	U.S.A.	5	10	No	Pot
Opal	f	4	U.S.A.	5	10	No	Pot
Liza	f	4	U.S.A.	5	10	No	Pot
Frieda	f	4	U.S.A.	5	10	No	Pot
Ai	f	13	Japan	5	10	Yes	Subassembly
				6	5	Yes	Subassembly
				9	1	Yes	Subassembly
				10	1	Yes	Subassembly
Sarah	f	26	U.S.A.	5	4	Yes/no	Subassembly
				6	1	Yes	Subassembly

Ai and Sarah are language-trained chimpanzees. Whiskey and Opal have some experience with plastic-sign language. Popo, Reo, and Pan have intensive experience on match-to-sample.
Source: Modified from Matsuzawa 1986.

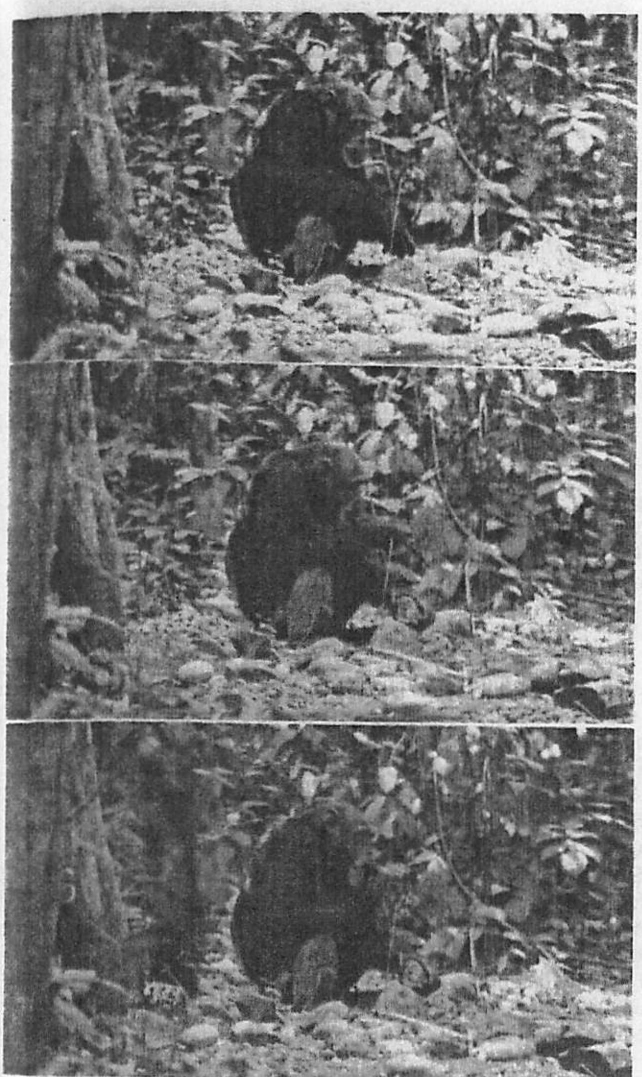

Figure 1 (Matsuzawa). A wild chimpanzee of Bossou, Guinea, is cracking an oil-palm nut using a pair of stones as hammer and anvil in the "outdoor laboratory." This adult female chimpanzee is named "Jire." She is using her left hand to hold the hammer and her right hand to manipulate the nuts. The coordinated behavior of both hands is necessary in cracking nuts with the stone-tool. The chimpanzees showed perfect handedness at the individual level but no left/right bias at the population level. [See MacNeilage et al. "Primate Handedness Reconsidered" *BBS* 10(2) 1987.]

and made the seriated structure in the minimum necessary steps. She succeeded in making the seriated structure in two of the four test trials and used the subassembly strategy in all cases.

Another chimpanzee (named Ai) behaved just like Sarah. Ai never failed to make the seriated structure of five cups from the beginning. Without any training, in the first trial she succeeded in making a 10-cup seriated structure by nesting the cups following the strategy hypothesized to be the most advanced, the "subassembly" strategy. Eventually, Ai would put one subassembly into another and the resultant large subassembly into the other subassembly in the course of making 9- or 10-cup seriated structures.

It must be noted that Ai had intensive experience of visual symbols called "lexigrams" and "graphemes" used for a language-like system (Matsuzawa 1985a; 1985b; 1989; 1990a). She could combine "words (lexigrams)" into a "phrase" like "red/pencils/five" in her favorite word order (Matsuzawa 1985a) and construct a "word" from the elements called graphemes (Matsuzawa 1989). Her cognitive skill in memorizing a complex geometrical figure presented for a brief duration and in reproducing the copy from its elemental figures is comparable to that of human adults (Fujita & Matsuzawa 1990). In these tasks, Ai showed the ability of constructing a whole image from scratch. Sarah had shown a similar ability in "putting a face together" (Premack 1975). In conclusion, the chimpanzees can construct copies of existing or imaginary figures by means such as assembling pieces of existing materials.

One can raise the question of whether Ai and Sarah are especially gifted chimpanzees. Did the intensive training induce something different from what happens with the ordinary chimpanzee? My answer is "no." They are not superchimpanzees. I think all chimpanzees are super. I have been in Africa three times to study the cognitive behavior in wild chimpanzees since 1986. I recently observed an interesting metatool use in a wild chimpanzee.

The chimpanzees at Bossou, Guinea, use a pair of natural stones as hammer and anvil to open oil-palm nut seeds (Figure 1). I constructed an "outdoor laboratory" in the chimp ranging area to analyze the nut-cracking behavior experimentally (Sakura & Matsuzawa 1991). Each of about 50 stones was marked and the stone use was observed and recorded. Nuts were also gathered and provided by the experimenter. On January 16, 1991, an old female named Kai appeared with the other seven members in the laboratory and began cracking nuts. Kai took a pair of stones for a hammer and anvil and spontaneously took the third stone to keep the surface of the anvil flat. Kai left the three-level tool there, a hammer on an anvil on an anvil-as-anvil. Such use of a tool for another tool must be described as "metatool" use.

The experimental analysis of stone tool use in wild chimpanzees revealed that they mastered the skill at the age of about four; the skill of a seven-year-old, however, was far from the refined level of adult chimpanzees. I did the same experiment with human children from 2 to 11 years old at Bossou and found that the children under three could not use a pair of stones for nut-cracking. They could manipulate stones but failed to find the three-term relationships: nut-hammer-anvil. Young chimpanzees and humans had a tendency to miss a part: striking a nut with a hammer without an anvil; striking a nut on an anvil by hand rather than by hammer; putting nuts again and again on an anvil, and so on. I observed an 11-year-old boy put a stone under an anvil to keep the surface flat as just as Kai the chimpanzee did.

What I would like to point out is the depth of cognitive hierarchical structure shown in the skills of chimpanzees in captivity and in the wild. The cognitive ability of chimpanzees is still underestimated. The genetic difference between *Pan troglodytes* and *Homo sapiens* is estimated to be 1.7 in a comparison of DNA sequences (Koop et al. 1986). I directly compared the cognitive development of chimpanzees with that of human children in a series of diagnostic tests of stacking blocks (Matsuzawa 1987), sorting objects into plates (Matsuzawa 1990b), manipulating seriated cups (Matsuzawa 1986a), and so on.

In my opinion, the developmental course of the two species is the same. On many occasions, chimpanzees showed the rudimentary form of the most advanced stage of cognitive development in each diagnostic test. The critical difference between the two species might be the depth of the hierarchical self-embedded structures in cognitive functions. So far as is known, no "language" trained chimpanzees have mastered such metalanguage as "noun" and "adjective." Although the chimpanzees in the wild have a long list of tool use – such as sticks for termite-fishing, leaf sponges for drinking water, and stone tools for nut cracking – there are few examples of metatool use and no reports of the meta-metatool use, such as a tool for a tool for a tool. Greenfield's approach to the analysis of the depth of cognitive hierarchical structures is stimulating and exciting.