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NATURALISTIC APPROACHES TO ORANGUTAN INTELLIGENCE AND THE QUESTION OF ENCULTURATION

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ABSTRACT: Field studies have been, and continue to be, important contributors to the understanding of great ape cognition—especially with regard to questions of cognitive ecology or the key cognitive challenges in the evolution of primate intelligence. They are also critical to resolving a current debate, whether human enculturation boosts great apes' cognition, because only studies of problem-solving in feral contexts can resolve the question of whether abilities are higher in enculturated than non-enculturated great apes. To this debate, this paper offers findings from observational field studies on free-ranging rehabilitant orangutans' cognitive capabilities, as revealed in their food processing and arboreal positioning, and on the possible social transmission of that expertise. These findings are combined with published findings on wild and enculturated great apes as a basis for assessing the effects of human enculturation on great ape cognition. This assessment joins several others in showing that free-ranging great apes independently achieve cognition of the same order of complexity as enculturated great apes, in concluding that claims for the effects of human enculturation are likely inflated, and in suggesting that the basis for the effectiveness of human enculturation is that great apes normally "enculturate" themselves.

INTRODUCTION

Field studies have been important contributors to understanding great ape cognition. My own research, as one example, aims to assess great apes' highest cognitive achievements by studying their solutions to their most intellectually challenging problems. The approach is to isolate these problems on the basis of evolutionary reconstructions which propose selection pressures that could have favored cognitive enhancement in great apes. Modern versions of these pressures likely differ from ancestral ones but may remain near-maximal challenges for living great apes and elicit peak cognitive performances. Whatever

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these pressures are, they concern social or ecological conditions that characterize natural rather than captive environments, that create real problems for great apes, and that engage their problem-solving efforts. This question and this perspective strongly favor studies of spontaneous, species-relevant behavior as it occurs in natural contexts.

It is also important to assess cognition under natural conditions because otherwise, great apes' achievements remain liable to dismissive interpretation as captive artifacts. The current incarnation of this interpretation is human "enculturation", which some claim to bestow higher level abilities on great apes than they attain independently, or create new abilities that otherwise would not exist (Tomasello, Savage-Rumbaugh, & Kruger, 1993; Call & Tomasello, 1996; Tomasello & Call, 1997). Enculturation was originally an anthropological term for immersing an agent in a system of meaningful human relations that includes language, behavior, beliefs, and material culture (Miles, Mitchell, & Harper, 1996). In primate cognition, it refers to rearing nonhuman primates in human settings with the intent of transmitting cultural models and symbolic communication, so that they become active agents within a meaningful system of relations which they come to embody in their own actions and understanding (Miles, 1978; Miles, 1999), or rearing them in human homes where they are treated as agents whose behaviors are intentional (Call & Tomasello, 1996; Tomasello et al., 1993). Enculturation differs from cross-rearing, cross-fostering, or socialization in going beyond simply teaching a static set of rules or skills (Miles, 1978).

My studies of forest-living orangutans in Borneo may shed some light on questions of the impact of human enculturation. These studies concern the cognition governing orangutans' solutions to two foraging problems, obtaining difficult foods and arboreal foraging, because current evolutionary reconstructions suggest they pose the greatest intellectual challenges to great apes (e.g., Byrne, 1997; Parker & Gibson, 1977; Povinelli & Cant, 1995; Russon, 1998). This paper compares my findings on orangutans' cognitive achievements with similar findings on wild and enculturated great apes, and assesses the potential for cultural transmission in these orangutans' achievements.

Findings on orangutans represent data collected from 1995 to 1997 on ex-captives reintroduced to a protected forest, Sungai Wain, by the Wanariset Orangutan Reintroduction Project (ORP) (Figure 1). A total of 82 orangutans were reintroduced into this forest from 1992 to 1996, in six groups and at five different sites (K1-K5 on Figure 1). At their release they varied in age from older infants to adults, with most in the young juvenile to young adolescent range. I observed 18 orangutans who ranged near two release/provisioning sites, K3 and K5; all were

between 4-15 yrs of age and 0-6 yrs' experience in Sungai Wain. I observed two of them over three years, five over two years, and eleven in one year. Nine of them were members of a large group reintroduced to the forest in 1996; all were monitored for their first two months post release and four were followed a year later. Sungai Wain Forest lies just outside the city of Balikpapan, East Kalimantan, Indonesia. Officially, it comprises 9,783 ha of lowland mixed dipterocarp forest with extensive swamp areas but encroachment, drought, and fire have reduced it to about 3,500 ha (Russon & Susilo, 1999). Data collection was structured as event sampling (target events were bouts of obtaining a key food item) within a framework of full-day focal individual follows. Observations totalled +/- 400 hrs in each year.

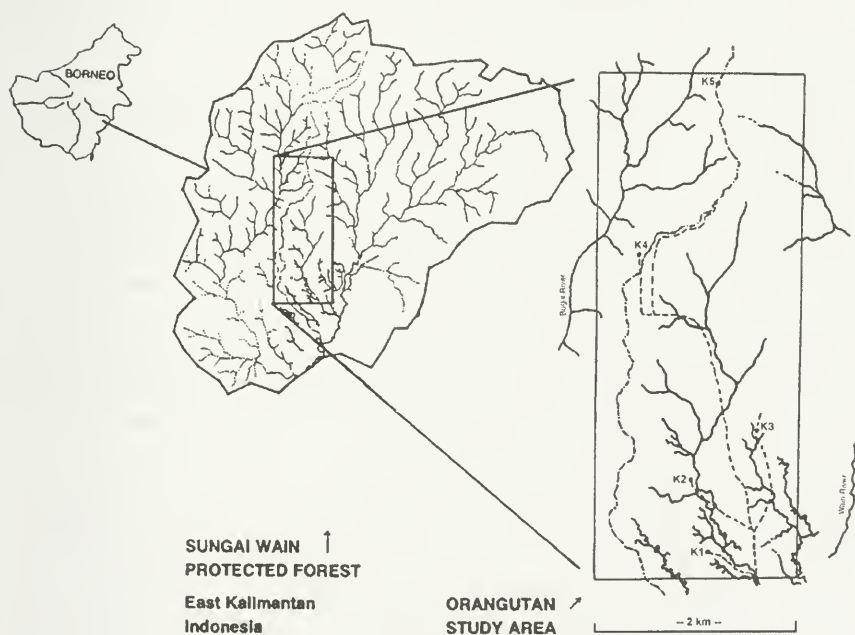


Figure 1. Sungai Wain Forest, E. Kalimantan, Indonesia.

Measuring Cognition

Assessments of the cognition governing great apes' performances are open to interpretation and considerable dispute. This results, in part, from complexities in the body of available data. Empirical studies have adopted a variety of cognitive models, measures, and tasks, and this variation is substantial between free-ranging and captive conditions. In addition, much of the relevant data on free-ranging great apes was collected for other purposes and was neither described nor analyzed with cognition in mind. Despite the difficulties this creates for an integrated interpretation of great ape cognition, and for comparing enculturated with free-ranging great apes, two major reviews of great ape cognition have recently appeared (Parker & McKinney, 1999; Tomasello & Call, 1997). I have relied primarily on these reviews for comparative discussions because they offer up-to-date, integrative overviews. Tomasello and Call lean to skeptical interpretations and Parker and McKinney to generous ones, so the two positions can be taken as bracketing the range of interpretations currently considered plausible.

Both reviews faced the difficulty of finding theoretical models that afford integrating a highly diverse body of information. As a basis for understanding their interpretations I have sketched their positions on physical world cognition, which refers to the suite of abilities used to handle problems in the physical as opposed to the social world (e.g., space, logic, cause-effect, quantity). These are the cognitive abilities most relevant to foraging and arboreal problems. Both favor models of cognition as products of evolution and ontogeny, where environmental pressures and experience are important contributors to the cognitive capabilities realized, and both rely heavily on Piagetian-based models and measures of cognitive complexity.

Tomasello and Call focus on sensorimotor or first-order cognition modeled as an ordered series of stages spanning human cognitive achievements from birth to 18-24 months of age. Primarily, these achievements involve the construction of cognitions or "schemata" for ordering simple sensory and motor phenomena (Piaget, 1952; Piaget, 1954; Piaget, 1962). First-order cognition spans the range of cognitive processes traditionally considered applicable to nonhuman species, such as reflex-driven action and schemata for simple motor actions, objects, forces, or object sets. It culminates, in stage 6, with the achievement of rudimentary symbols. In physical cognition, early symbols commonly represent object-object relationships like "in" or "on" and show primitive understanding of abstract relational categories.

Parker and McKinney (1999) also consider first-order cognition but extend their consideration to capabilities that emerge in human development beyond the sensori-motor period. The move beyond first-order cognition is seen as the product of cognitive hierarchization or metarepresentation, i.e. building new cognitions by re-representing existing ones. The first form of hierarchical cognition that emerges is often termed second-order cognition; like first-order cognition, second-order cognition spans several levels of complexity (e.g., Langer, 1996; Whiten & Byrne, 1991). Case (1985) offers one of the few methods for indexing rudimentary hierarchical cognition, based on his model of second-order cognition as "interrelational", that is, second-order cognition processes phenomena in terms of the simple physical relationships (object-object relationships) involved and the cognitive structures that coordinate several physical relationships with one another (interrelational structures). The number of object-object relationships that can be handled in a coordinated fashion, within one overarching interrelational structure, can be used as an index of the level of second-order cognition being used—the more relationships coordinated within one structure, the higher the level (Case, 1985; Parker & McKinney, 1999; Russon & Galdikas, 1993).

Cognition in food processing

Food processing refers to preparing food items for consumption. It is considered to pose challenging intellectual problems for great apes because some of their essential foods are "technically" difficult, i.e., embedded and/or otherwise defended from predation (e.g., Byrne, 1997; Parker & Gibson, 1977). Among the more difficult foods in Sungai Wain are two permanent foods, colonial nest-building termites and the meristem (heart or cabbage) of several palm species. The most difficult of the termites consumed are embedded, within their nests; some of the nests are cement-hard, invisibly buried underground, and tangled within a maze of tree roots. The palm's heart is also embedded, either within a crown or beneath a tough sheath; it may also be protected by additional physical defenses, such as fences of sharp spines or razor-edged leaves and petioles, or by chemical defenses, such as bitter flavors or otherwise noxious chemicals (Jones, 1995). Palm heart also represents a set of naturally graded problems rather than a single problem because palms range in size from slender immature rosettes on the forest floor to massive crowned trees 10-15 m tall.

Any one such food may then present several difficulties, so processing these food commonly requires elaborate processing strategies involving the coordinated use of several different kinds of

food manipulation. The strategy for removing bark has several variants, for instance, including biting off small bits repeatedly to make a long trench along the underside of a branch or scoring the bark by biting it repeatedly along a length then tearing off the whole loosened strip in one pull. Analyses of the orangutans' complex strategies for obtaining heart material from *Borassodendron borneensis* palms indicated hierarchical cognition (Russon, 1998).

This finding on food processing in orangutans complements findings on wild great apes. Hierarchical cognition has been detected in the food processing techniques of mountain gorillas (e.g., Byrne & Byrne, 1991) and chimpanzees (e.g., Matsuzawa, 1991, 1994; Yamakoshi & Sugiyama, 1995). In chimpanzees, some of these hierarchically governed food processing techniques are tool-assisted. Using Case's model of second-order cognition, several tool-based techniques used by chimpanzees involve coordinating two object-object relationships (one interrelational structure), e.g., probing for ants/termites (probe-nest, probe-ants/termites) and cracking nuts with hammer-and-anvil tool sets (hammer-nut, nut-anvil). This level is typically achieved by 27-40 months in human children (Case, 1985).

One of the most complex food processing techniques known in wild great apes involves a tool set with a "metatool", i.e. a tool that is used to make another tool. Matsuzawa observed three chimpanzees at Bossou who cracked nuts with hammer-anvil tool sets adding a third rock as a wedge to level their anvil rock, i.e., to modify or improve their anvil tool. Assessing Bossou chimpanzees' metatool use for its cognitive complexity is important: In addition to being one of the most complex forms of spontaneous food processing in great apes, both reviews consider this case and metatool use is one of few phenomena that can be compared directly across enculturated and free-living apes. Parker and McKinney's interpretation concurs with two others (Matsuzawa, 1996; Russon & Galdikas, 1993) that this metatool use coordinates three object-object relationships in one interrelational structure (wedge-anvil, anvil-nut, hammer-nut). This level of complexity is not typically achieved by human children before 40-60 months of age (Case, 1985). Tomasello and Call review this metatool use but offer no analysis beyond their overall assessment that, at best, some great ape tool use may show stage 6 first-order cognition. They offer this assessment with caution, however, on the grounds that the nature of background experience (with its implied trial-and-error learning) is not precisely known.

The tasks presented to enculturated great apes that most resemble food processing in their cognitive demands are using tools and manipulating objects, which invoke causal abilities mainly (means-end

or cause-effect reasoning, especially in force-based manipulation) and logical abilities sometimes (if alternative techniques or tactics are used). Several captive great apes, some of whom were enculturated, have mastered metatool use. Two captive chimpanzees learned to use a rock to break open a bone for food inside, then used a fragment of the bone to pierce a skin covering a desirable drink (Kitahara-Frisch, Norikoshi, & Hara, 1987), and an enculturated language-trained bonobo (Kanzi) and a captive orangutan learned to make flake tools from humans, then used them to cut ropes for access to food (Toth, Schick, Savage-Rumbaugh, Sevcik, & Rumbaugh, 1993; Wright, 1972). Parker and McKinney credit human enculturated great apes with achieving second-order cognition in their solutions to such tasks. Tomasello and Call hesitate to credit their metatool use fully because all cases reported were heavily scaffolded by humans; their assessment of enculturated great apes' tool use and causal abilities remains stage 6 first-order cognition at best.

Based on difficult food problems, wild and other free-ranging great apes attain cognitive levels similar to those attained by enculturated great apes: second-order cognition. Free-ranging chimpanzees independently master metatool use, the most cognitively sophisticated product, while enculturated great apes have mastered it only with extensive human scaffolding. This contradicts the effects claimed for human enculturation because it is free-ranging great apes, not human enculturated ones, that demonstrate, independently, the highest level cognition.

Cognition in arboreal life

Arboreal life, in the form of arboreal travel, has been considered to pose critical cognitive challenges for great apes (Bard, 1993; Chevalier-Skolnikoff, Galdikas, & Skolnikoff, 1982; Povinelli & Cant, 1995). Among the challenges identified are long-distance navigation through dense tropical rain forest, establishing travel routes through the discontinuous forest canopy, and moving their exceptionally large and heavy bodies through a canopy that does not readily support such weight. Food more than travel, however, is considered the main reason that primates are in the trees and the major influence on their locomotor habits (Fleagle, 1984). Arboreality adds several complications to the problem of obtaining difficult foods, notably arboreal positioning for *accessing* food and arboreal positioning for *manipulating* food, and each can be cognitively challenging (Cant, 1987; Povinelli & Cant, 1995; Russon, 1998).

Analyses of juvenile rehabilitant orangutans' arboreal locomotion during their approach to arboreal food sources indicated hierarchical cognition (Russon, 1998). One juvenile rehabilitant male made a proto-tool, a handle for his vehicle tree. Vehicle trees, themselves proto-tools, are slender pole trees that orangutans sway deliberately to cross the gap between their current position and their next target tree (Bard, 1993). This juvenile male made his handle by cracking a branch of his vehicle tree until it dangled loosely; holding the handle, he could reach farther than he could by holding his unmodified vehicle tree and successfully transferred into his target food tree (Russon, 1998). This handle comes close to a metatool because, like Matsuzawa's wedge, it modified a tool--the vehicle tree proto-tool. Limited observations in 1998-99 suggest that adolescents and adults, perhaps because they are heavier-bodied than juveniles, may construct more elaborate proto-tools to position themselves for obtaining arboreal food items. One adolescent male positioned himself on two slender pole trees near an arboreal food item, then climbed the two trees like a rungless ladder to access the food. Spatially, this involves coordinating at least two object-object spatial relationships, disregarding the self: pole trees--food, pole tree--pole tree. One adult female also used two pole trees to access a food item and in addition modified them to make a seat on which to sit while processing the food. She chose two slender pole trees, spaced ± 1.5 m apart and within reach of a rattan food, then climbed into them. She pulled the two trees across one another to form an "X" then sat in the side of the X closest to the rattan, her weight on its lower leg and one arm holding the adjacent upper leg for balance. To position herself arboreally for obtaining the rattan, she coordinated at least three object-object relationships: pole tree--pole tree (initial, spatial), pole-tree--pole-tree (modified, causal), pole-trees--rattan (spatial).

Some earlier studies of the cognition governing free-ranging orangutans' arboreal navigation and locomotion have detected upper-level first-order cognition (Bard, 1993; Chevalier-Skolnikoff et al., 1982). These studies did not assess cognition beyond the first-order level, however, and Bard's study focused on cognitively immature youngsters, but both hint at cognition that is more complex. Both describe use of vehicle tree "proto-tools". To the extent that the "self" figures into calculations as an object of a particular size and weight to be manoeuvred through the canopy (Povinelli & Cant, 1995), vehicle tree use suggests coordinating two object-object relationships (self-vehicle tree, vehicle-tree--target tree). Povinelli and Cant's own descriptions of orangutans' clambering mode of arboreal locomotion suggest hierarchical cognition. These findings likewise point to great

apes' attaining hierarchical cognition in their arboreal positioning; that is, at least second-order cognition.

Tasks for captive great apes that most resemble the complex arboreal problems of feral life are spatial and causal tasks. Spatial tasks are relevant because arboreal positioning and travel entail identifying relationships between forest structures (and the self) that afford travel trajectories and/or provide bodily support. Causal tasks are relevant because orangutans deliberately apply force to deform vegetation during arboreal travel or positioning. Using force to change the physical world is a classic application of causal reasoning (Chevalier-Skolnikoff et al., 1982). Tomasello and Call review studies on great apes' spatial cognition based on complex maze or obstacle/ detour tasks, but this research is patchy and does not single out enculturated apes. The findings they consider include several chimpanzees tested on both types of tasks but only single members of the other great ape species, tested on one of the tasks. Tomasello and Call find no evidence for spatial cognition beyond sensorimotor stage 6 in any captive great apes. Parker and McKinney include additional studies on spatial cognition which show stage 6 first-order cognition in great apes as young as 4 years old (e.g., Poti', 1996) and second-order cognition in older great apes, to levels seen in 3-year-old human children. Great apes' highest levels of spatial cognition have been shown in drawing tasks; one top performer was Chantek, a human-enculturated orangutan (Miles et al., 1996) but the second was a zoo chimpanzee unlikely to qualify as human enculturated (Morris, 1962). Parker and McKinney conclude that great apes achieve second-order cognition spontaneously in solving spatial problems and that enculturated great apes may reach slightly higher levels but these remain within the second-order range. Their conclusion is based on evidence from a range of spatial tasks, including block assembly, drawing, symbol reading, and knot tying.

Here too, the cognitive achievements of free-ranging great apes are on a par with human-enculturated great apes and may even exceed them, if Tomasello and Call's interpretation is accepted.

Centralized Cognitive Mechanisms

An alternative to assessing cognition in terms of abilities is to consider centralized generative mechanisms. Three centralized mechanisms are considered to underlie human cognitive achievements--combinatorial mechanisms, hierarchization, and integration (e.g., Langer, 1996). Hierarchization has been discussed. Combinatorial mechanisms create combinations of multiple mental items, to allow handling them simultaneously. They often operate in conjunction with

hierarchization in humans, as “hierarchical mental construction”, so that higher-level cognitions comprise several lower-level cognitions coordinated into a new higher-level one (e.g., Gibson, 1993). Integration affords interconnections or interplay between different types of cognition, i.e. relatively independent sets of special-purpose cognitive structures like causal or logical abilities, to allow applying several to a single problem. Many problems are solved best, or only, by several abilities used interactively rather than one ability used alone. Integration is considered the most sophisticated of the three processes because it can operate only within cognitive systems that are already hierarchical (Langer, 1996). Hierarchization and combinatorial mechanisms are relatively well studied in nonhuman primates, the former because of its apparent role in great ape cognition and the latter because it is considered common. Integration has received less attention, partly because studies have focused on problem-specific cognitive abilities and partly because integration has been considered beyond nonhuman primates’ capacity (e.g., Langer, 1996).

Rehabilitant orangutans’ handling of arboreally-located difficult foods suggests cognitive integration, which may therefore have considerable significance for models of great ape cognition. Arboreal location increases difficulties in obtaining difficult foods because it adds a second complex task that must be handled simultaneously. Increases in difficulty go beyond adding more tasks, moreover, because food processing and arboreal positioning entail different cognitive abilities (food-causal; positioning-spatial) and the two tasks can interact (e.g., orangutans shift their arboreal position to accommodate food processing activities). Orangutans are also not physically equipped to handle the two tasks independently: they have in total five manipulators but each task often requires three. Orangutans’ arboreal feeding postures enlist three manipulators over 60% of the time (Cant, 1987; Reynolds, 1991; Kaplan & Rogers, 1994). Some of their food processing operations also involve three manipulators; two hands may be used to tear apart a tough protective matrix, for instance, while a third hand or the mouth pulls the desired inner item out (Russon, pers. obs.). When a difficult food operation coincides with a difficult feeding posture, the two tasks can simultaneously require three manipulators (Russon, 1998).

Orangutans cope successfully with arboreally-located difficult foods and they do so by interconnecting their solutions to the two problems. Examples of tactics include sharing a manipulator between the two tasks (using a manipulator to contribute to positioning and food processing simultaneously) and briefly transferring a manipulator from one task to the other (e.g., a hand may drop its positioning role to assist

with food processing, then return to its positioning role a few seconds later). Both tasks can require second-order cognition, so the combined problem itself could in some instances entail integrated use of second-order causal and second-order spatial cognition. In proto-tool-assisted arboreal positioning, these orangutans also showed integrated use of two types of cognition--spatial abilities to identify an appropriate initial spatial layout and to envisage an improved one, and causal abilities to modify the support or vehicle trees. Interconnected solutions point to cognitive integration--that is, orangutans can and do apply multiple abilities interactively.

Wild great apes also offer evidence cognitive integration, in the form of applying multiple cognitive abilities to one problem. Examples include chimpanzees substituting tools, because identifying equivalent tools involves applying logical abilities to a causal problem (Sakura & Matsuzawa, 1991), and orangutans using spatial abilities to establish initial and equivalent spatial layouts for obtaining food with tools (Fox et al., 1999).

In captive great apes, interactions between cognitive abilities that have been detected include: language abilities enhancing logical abilities (language-trained chimpanzees performed at higher levels on analogy problems than non-language trained chimpanzees--Premack, 1984), logical and causal abilities combining to expand the basis for classification and the range of means-end behavior (e.g. classifying items by their causal function or identifying equivalent items that can function as the same tool--Langer, 1996; Russon, 1996a), and imitation contributing to causal understanding (e.g., imitation contributing to the acquisition of tool use--Meinel, 1995; Toth et al., 1993). Some of the performances suggesting cognitive integration were by human-enculturated great apes, but others were not.

Both free-ranging and enculturated great apes offer evidence of cognitive integration. If anything, the expression of cognitive integration may be more robust in free-ranging great apes because it is needed to handle problems that are encountered on a daily basis. Its expression by enculturated great apes is liable to dismissal as scaffolded, whereas it is not in free-ranging great apes. If anything, the ensemble of findings suggests that free-ranging great apes express these most complex generative processes more strongly than enculturated great apes.

Contributions of social transmission

Enculturation entails, at minimum, social transmission of some facets of these cognitive capabilities. In the rehabilitant orangutans,

several lines of evidence point to social transmission as an important contributor to their foraging expertise.

Bandang hearts. The heart (meristem) of *Borassodendron borneensis* palms (locally, *bandang*) is a preferred food among Sungai Wain orangutans as well as a key permanent one. The palm's heart is embedded within its stem near its growing tip. In *bandang* seedlings, it is in the center of a small, slender-leafed rosette on the forest floor. In mature *bandang*, it is atop a sturdy trunk rising 10-15 m tall, embedded within a massive fibrous crown, and surrounded by 50-100 sturdy, sharp-edged leaf stalks. These orangutans' technique for obtaining *bandang* hearts is to pull the newest leaf out of its socket then bite the heart matter from the base of the pulled leaf. Tactically, the set of manipulations applied varies with the size of the palm.

Nine of the 18 orangutans I followed were naive to *bandang* heart when I first observed them. Only 3/9 acquired techniques for obtaining *bandang* hearts within my three years' observations—Paul, Enggong, and Bento, juvenile males 5-6 yrs old who had ranged near site K3 for 0.5, 1.5, and 2 yrs respectively. In my first month I followed each for three days (85 hrs total) and observed none eat *bandang* heart although all often ate a simple *bandang* food, the leaf blade. Sariyem, a juvenile female +/- 5 yrs old, twice visited the K3 area for 3-4 days in the following 1.5 months and while there she obtained and ate several *bandang* hearts. The males all scrounged *bandang* heart from her and one once pulled a new leaf from a small *bandang* but then ate its tip. Between Sariyem's visits, none of the males was observed eating *bandang* heart (55 hrs/8 days observation) but six months later, all three regularly obtained *bandang* hearts independently. This suggests that their expertise with *bandang* hearts started with input from Sariyem. They could have acquired the expertise independently but this seems unlikely because they had not done so despite ample opportunity (.5 to 2 years' living in areas where this food was abundant) and all three males acquired the expertise over the same short period despite large differences in forest experience.

Six other orangutans appeared naive to the technique for *bandang* hearts at their release in Sungai Wain at site K5. Four of the six were followed one year later and two of those four were followed a year beyond that, all still apparently naive. The six naive orangutans were from a group of 22 that I followed over the first two months after their release in 05/96. During those observations (110 hrs/18 days), 3/22 orangutans independently obtained *bandang* heart but all three left the area rapidly (one within two days and second within a month; the third stayed three months but she was a very young juvenile with only rudimentary expertise). Naive orangutans' failure to acquire *bandang*

expertise coincides with their lack of social learning opportunities.

Rattan hearts. Orangutans obtained rattan hearts using a technique similar to that for *bandang* hearts; the tasks are similar since rattans are climbing palms (Jones, 1995). Rattan hearts are simple to obtain from immature plants at the sucker stage. Rattan suckers are much like *bandang* seedlings, small rosettes on the forest floor with new leaves like slender shoots of grass that can be extracted in one easy pull. Nonetheless, some newly released orangutans did not obtain rattan shoots or recognize them as food. One, Jaja, did not acquire this expertise even though other orangutans pulled and ate shoots before her eyes. Our observations and background information from the reintroduction project suggest that the likely reason was that Jaja was highly human-oriented and did not interact with orangutans. A young woman student whom Jaja liked finally taught Jaja how to obtain rattan shoots by demonstration. In front of Jaja, she pulled out a rattan shoot, pulled it apart a little at the bottom, then ate its tender base. Jaja watched then took a rattan leaf and pulled it apart, but ate the tip instead of the base. The student demonstrated the correct technique again and gave Jaja the shoot. Jaja ate it immediately, pulled one on her own, then spent the rest of the day going from rattan to rattan, pulling then eating their shoots.

Bandang Pith. From *bandang*, these orangutans also often ate pith from the leaf petiole. Processing entails tearing the petiole open lengthwise, pulling strips of fibrous pith (parenchyma) away from the sheath, and chewing the strips for their juice.

In the first month after their release at K5, none of three small females (Kiki, Ida, Siti, +/- 5 yrs old) was observed eating *bandang* pith although they were monitored by researchers and project technicians daily. Technicians observed and recorded Kiki's independent discovery of this food and her inventing a technique for obtaining it. Ida and Siti, who commonly traveled and foraged with her, immediately began scrounging Kiki's *bandang* pith. Within two weeks Siti was obtaining this pith independently.

Petiole choice for *bandang* pith suggested social influence. In 1995 and 1996, all three males ranging near K3 ate *bandang* pith from mature leaves but never from the newest or second newest leaf. In 1997, only two females ranging near K5 ate *bandang* pith, Judi and Siti, who had become regular traveling companions since their release in 1996. Both ate pith from the second newest leaf but never either mature or newest leaves. Competition played no role in selection. No others near K5 ate this pith, *bandang* palms are plentiful, and each palm has 50-100 mature leaves to one second newest leaf.

Social influences were also likely in Judi and Siti's techniques for

obtaining *bandang* pith. These two often selected palms with a liana or branch running horizontally or diagonally through the crown. To expose pith, they regularly made their first bite into the petiole sheath near the leaf base. This often cracked the petiole and it often flopped over the liana/branch. The liana/branch then served as a hanger for the petiole, probably helping secure it in place as they tore it apart. I did not detect this pattern until late in my data collection so I lack reliable figures on its frequency of occurrence. It occurred on at least five occasions, however, which suggests that the layout and place of biting were deliberate parts of their processing technique. No other orangutans were observed using this tactic. Orangutans near K3, in contrast, normally made their first bite about a third of the distance down from the leaf base and never used a hanger.

Dauu Biru Pith. Orangutans ate pith of another palm common in Sungai Wain, *Licuala sp.* (locally, *dauu biru*) but only, to our knowledge, after 1997-98 drought and fires (Fredriksson, 1995; Peters, 1995; Russon, unpub. data). In 06/97, directly after the drought and fires, I followed Tuti, an adolescent female released at K2 in 1993. Within half a day, she ate pith from several *dauu biru* palms, tearing open 5-6 petioles from each palm. After Tuti had finished a palm, its crown was badly shredded and broken. Neither project staff nor researchers had reported seeing *dauu biru* palms in this state of destruction in the four years prior to the drought and fires. Staff and researchers followed and observed the rehabilitants regularly and this damage was very striking, so observers would not have missed this damage if it had been common. I concluded that this was a new food and a new technique that Tuti acquired after the drought and fires. Within a month I followed Charlie, a subadult male released at K1 in 1992. Within a day he ate *dauu biru* pith and left the palm in a similar state of destruction. Charlie and Tuti were known to travel together, intermittently, for several days at a time. It is likely that they were pushed to find new foods because of scarcities occasioned by fires and drought; either one of them discovered this food and the technique independently then transmitted the expertise to the other while travelling together, or they developed the expertise jointly.

Bark. Aming, an adolescent male with four years' experience in Sungai Wain, was translocated to K3 in 1996. On his first day there, he ate bark from a tree that bore no signs of previous bark removal even though it was located within 20-30 m of K3, at the intersection of two main trails that the residents had used daily for at least 1.5 years. Enggong approached and watched the work intently over Aming's shoulder. Enggong neither scrounged Aming's bark nor began eating bark independently elsewhere in the same tree--either of which would

have been the normal if he had been familiar with this food. As soon as Aming left, Enggong took the position Aming had just vacated and tried to remove bark from the place that Aming had been working. Enggong used the same basic technique as Aming, biting then tearing bark off, but he succeeded in freeing only tiny chips of bark per bite whereas Aming could free long lengths. These observations suggest that this particular bark food was unknown to Enggong before observing Aming, and that Enggong learned its identity and something of its processing technique by observing Aming.

Avenues and mechanisms of social learning. These incidents illustrate at least three types of social experience in these orangutans that could contribute to social transmission of food-related expertise: scrounging, scavenging, and coaction. Social learning mechanisms that could operate during coaction (a learner's intimate participation in an expert's activity--Visalberghi & Fragaszy, 1989) include stimulus and response priming, social reinforcement, shaping, and imitative (observational) learning. Those afforded by scavenging and scrounging include local or stimulus enhancement induced by the producer's behavior or its aftereffects and imitative learning. All these mechanisms are within great apes' cognitive reach. That social transmission supports orangutans' acquisition of complex expertise is then entirely plausible.

IMPLICATIONS

These findings have implications for the problems and models appropriate for assessing great apes' cognitive capacities, the cognitive achievements of free-ranging versus enculturated great apes, and the impact of human enculturation on great ape cognition.

Orangutans' difficult foods often pose multiple problems, in the form of a diverse host of anti-predator defenses. When these foods are arboreally located, as they often are, the problems multiply in number, diversity, and interactive complexity. This contrasts with the unidimensional (single ability) problems aimed at sensorimotor level cognition that have commonly been posed to captive great apes (Russon & Bard, 1996). The implication is that forest problems tap more complex cognitive processes.

A prerequisite for assessing great apes' cognitive achievements is resolving discrepancies between the interpretations offered by Parker and McKinney versus Tomasello and Call. They agree that relational understanding is a key feature of great ape cognition, in the sense of understanding how external entities or third parties relate to one another

when the actor is not directly involved. Their major difference concerns whether relational understanding represents the ceiling or the threshold of great apes' highest cognitive capacities. Tomasello and Call offer a ceiling-like interpretation, because they offer a flattened view of relational cognition as representing a narrow range of understanding--understanding relational categories. While first-order cognition culminates in the understanding of abstract relational categories, beyond its scope is the interrelational understanding required to manage interplay among multiple relational categories. Interrelational understanding underpins a significant range of capabilities, perhaps the whole of the pre-operational or second-order stage that characterizes human cognition between about 2 and 6 years of age (Case, 1985). This suggests problems with Tomasello and Call's preferred models, which span only first-order cognition systematically. First-order models lack the conceptual and methodological tools to index some of great apes' complex techniques, including metatool use, because these techniques require coordinating interplay among multiple relational categories. When models of second-order, interrelational cognition are used to analyze great apes' techniques, as they are by Parker and McKinney and by others (e.g., Byrne & Byrne, 1991; Byrne, 1995; Langer, 1996; Russon, 1998; Russon et al., 1998), evidence of interrelational cognition is clear up to levels found in human 3-year-olds.

In this light, free-living orangutans as well as gorillas and chimpanzees show cognitive levels on a par with enculturated great apes. In addition, their solutions to feral problems tend to be "orchestral" in the sense that they involve using multiple cognitive abilities (e.g., Parker & McKinney, 1999). It is in orchestral problem-solving that great apes offer evidence of cognitive integration, in the form of interconnected use of social, logical, causal, and spatial abilities. In free-ranging great apes this sort of cognitive interplay occurs frequently; in enculturated great apes, it has rarely been detected. Enculturated apes' achievements are also human scaffolded while free-living great apes' are not. The appropriate conclusion is that free-ranging great apes achieve equally if not more advanced capabilities than enculturated great apes in physical world cognition.

These findings also reflect on models of great ape cognition. They indicate that great ape cognition is better construed as a system of interconnected abilities designed for handling multifaceted problems than as an aggregate of independent, module-like abilities for handling unidimensional ones. Most studies of great apes have adopted traditional models that portray nonhuman cognition as an aggregate of isolated ability structures (e.g., Cheney & Seyfarth, 1990; Davey, 1989; Hirschfield & Gelman, 1994). Few have advocated interconnectedness

between semi-independent abilities (e.g., Mitchell, 1994; Parker, 1996; Rumbaugh & Pate, 1984a, b; Whiten, 1996; Whiten & Byrne, 1991; and Tomasello & Call, 1997, promote this for all primates). Findings on reintroduced orangutans support interconnectedness as the more appropriate model. Findings also suggest that studies designed around module-like abilities likely underestimate great apes' full intellectual power.

These findings do not imply that enculturation, in the sense of the cultural transmission of expertise, plays no important role in great apes' cognitive capabilities. Sungai Wain orangutans appear to make substantial use of social transmission in acquiring foraging expertise, as do wild chimpanzees, gorillas, and orangutans (e.g., Boesch, 1993; Byrne & Byrne, 1993; Fox et al., 1999). Free-ranging great apes show sophisticated social learning mechanisms that could support cultural transmission, such as imitative learning (e.g., Russon & Galdikas, 1995; Russon, 1999) and demonstration teaching (Boesch, 1991, 1993). It is now widely accepted that expertise is culturally transmitted in chimpanzees (e.g., McGrew, 1992; Whiten et al., 1999; Wrangham, McGrew, de Waal, & Heltne, 1994) and orangutans are suggesting similar patterns (Fox et al., 1999).

While this makes it likely that human enculturation has an important effect on great ape cognition, findings suggest three caveats. (1) It is likely that human enculturation can enhance great apes' cognitive capabilities because cultural forces are normal facets of great ape cognitive development in the wild—as Parker and McKinney put it, wild great apes “enculturate” themselves. (2) Human enculturation probably bends great apes' cognition in atypical directions because great ape cognitive development is dependent on experience, as it is in humans. A great ape's cognitive capabilities should take on the shape of his or her individual rearing conditions and living problems, as is evident in human-enculturated great apes' developing abilities that are not apparent in feral conspecifics, like mathematics or language. By the same token, however, enculturated great apes show impoverished cognitive capabilities when faced with forest problems like processing foods or navigating. Among ex-captive orangutans newly reintroduced to forest life, human-enculturated ones stand out painfully for their poor cognitive capabilities. Even after having experienced forest foods, climbing apparatus, and orangutans during rehabilitation, once in the forest they have difficulty recognizing even common forest foods, ignore cues to forest living from other orangutans, and are inept at figuring out how to obtain foods, travel arboreally, and navigate through the forest (Russon, 1996b). What human enculturation seems to offer, then, is refinement of problem-specific abilities that are

important in human contexts. (3) The impact of human enculturation has likely been exaggerated. Parker and McKinney offer what may be the best analysis of the forces involved, based on work by Fischer et al. (1993). Fischer and co-workers have shown that an individual's cognitive competence with a given type of problem constitutes a range of levels, not a fixed level, and that unsupportive contexts elicit low levels in the range while socially supportive contexts elicit high levels (Fischer et al., 1993). The exceptional performances of human-enculturated great apes have occurred in socially supportive conditions, so they could represent the highest levels of these apes' current competence range which were expressed because of especially supportive conditions.

Naturalistic field studies have been important recent contributors to the understanding of great ape cognition and they will remain essential when addressing questions concerning cognitive ecology, cognitive evolution, and the like. It is such studies that have convinced scholars that great apes have cultures (e.g., Boesch, 1996; McGrew, 1992; Whiten et al., 1999; Wrangham et al., 1994) and it is only such studies that can provide the evidence needed to resolve the issue of the impact of human enculturation on great ape cognition. It appears that reports of the impact of human enculturation have been greatly exaggerated.

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