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Deferred Imitation of Object-Related Actions in Human-Reared Juvenile Chimpanzees and Orangutans

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ABSTRACT: *Deferred imitation of object-related actions (e.g., picking up a cloth with a set of tongs) was assessed in 3 enculturated juvenile orangutans (*Pongo pygmaeus*) and 3 enculturated juvenile chimpanzees (*Pan troglodytes*). For each task, animals were given 4 min to explore the objects (baseline), followed by a demonstration of the target behavior, and 10 min later, were re-presented the objects (deferred phase). Each animal displayed deferred imitation on at least one trial, with each species demonstrating deferred imitation on approximately half of all possible trials. The findings were interpreted as reflecting cognitive abilities in juvenile great apes that permit deferred imitation under humanlike rearing conditions. © 2000 John Wiley & Sons, Inc. Dev Psychobiol 36: 218–232, 2000*

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Imitation refers to the matching of one's behavior to that of a model. The primary focus of research on imitation in apes has been on the ability of these animals to imitate actions immediately after a demonstration by an adult human (e.g., Call & Tomasello, 1994; Custance, Whiten, & Bard, 1995; Whiten, Custance, Gómez, Teixidor, & Bard 1996; see Call & Tomasello, 1995 for an exception). Although the objectives of these tests are clear—to determine whether the participants can or cannot imitate object-related or kinesthetic–visual body and facial behaviors—in most cases, they do not effectively assess the issue of whether even primitive, symbolic representation is available to these animals. If a demonstrated behavior is sufficiently complex, symbolic ability may be re-

quired for successful imitation, but immediate imitation, in-and-of-itself, does not require symbolic abilities. Evidence of *deferred imitation*, in contrast, implies that the animal has encoded the modeled action in memory and is capable of retrieving that information at a later time.

This distinction between the cognitive abilities presumed to underlie immediate versus deferred imitation was addressed in early research by Hayes and Hayes (1952). They discussed the propensity of their home-reared chimpanzee, Viki, to imitate actions after some delay, taking these actions as not only examples of imitation, “but of imitation combined with additional higher mental processes” (p. 457). Piaget (1962) considered deferred imitation to be reflective of the symbolic function and noted that it usually appears in human infants between the ages of 18 and 24 months along with other symbolic abilities such as language

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and symbolic play. More recently, several researchers have found that human infants under 1 year of age are capable of imitating novel actions with unfamiliar objects after a delay (e.g., Bauer & Wewerka, 1995; Meltzoff, 1988). There is also evidence that amnesic patients who are able to demonstrate implicit learning (learning without awareness) but not explicit learning (learning with awareness) are unable to perform successfully deferred-imitation tasks (McDonough, Mandler, McKee, & Squire, 1995). This implies that the memory system underlying deferred imitation in infants is similar, if not identical, to the one underlying the explicit (i.e., declarative) memory system in older children and adults (as reflected by autobiographical memory, for example), albeit a nonverbal one (see Meltzoff, 1995; Schneider & Bjorklund, 1998).

Determining whether great apes can display deferred imitation is not an easy matter. In order to qualify as imitation, new behaviors must be learned on the basis of observation alone (Meltzoff & Gopnik, 1989; see Russon, 1996; Nagell, Olguin, & Tomasello, 1993). Outcomes that may appear, on initial inspection, to be the result of imitation can often be attributed to seemingly less sophisticated processes (e.g., social facilitation, responding to the affordances of the objects) rather than imitation (e.g., Boesch, 1991; Nagell et al., 1993; Tomasello, 1994; Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten, 1996).

There is likely not a simple “yes” or “no” answer to the question, “Can great apes imitate?” As an analogy, researchers in human infant cognition have long sought evidence for the earliest age at which infants can demonstrate a particular cognitive ability (e.g., object permanence or deferred imitation). Although researchers have reported earlier and earlier demonstrations of these and related abilities (see, for example, Spelke & Newport, 1998), it has become apparent that infants are very sensitive to the particular testing conditions and task materials that are used to assess a specific ability. Rather than asking “how early” a cognitive ability can be demonstrated, a more proper approach is to specify the conditions under which infants of different ages will display some target behavior (Bjorklund, 2000; Fischer & Bidell, 1991; Meltzoff & Moore, 1998). Similarly, perhaps researchers should approach the question of whether certain cognitive abilities are within the capacity of great apes by asking the question “Under what testing and/or rearing conditions will animals display the ability?”

From this perspective, cognitive abilities are not viewed as something that an animal (ape or human infant) simply “has,” but certain abilities may emerge only within a supportive environment. For most animals, a species-typical environment is sufficient for

species-typical cognitive abilities to develop (Gottlieb, Wahlsten, & Lickliter, 1998). Imitation may be such an ability in humans. Human parents direct their young offsprings’ attention to objects (shared attention), demonstrate behaviors to their children, and provide social support when infants and young children reproduce modeled behavior. Obviously, young children’s brains are “prepared” to take advantage of such environmental input, but the end product (a child who imitates actions he or she observes) is the result of a cognitive system that develops within a supportive environment (Gelman & Williams, 1998).

Apes are not children and do not have the brains to accomplish many of the things that human children do. However, as humans’ closest genetic relatives, they do demonstrate behaviors and cognitive abilities that are more humanlike than any other species (Köhler, 1925; Yerkes & Yerkes, 1929; but see Povinelli, Bering, & Giambrone, in press). Might great apes be more likely to display some of the cognitive characteristics of human children if they were reared in a human-typical environment? The rearing of apes from infancy in an environment similar to that which human children experience has been termed *enculturation*, and this process has recently been viewed as important in developing cognitive abilities such as imitation in the great apes. The term *enculturation* as used by Call and Tomasello (1996) should be applied to apes whose rearing environment includes “something close to daily contact with humans and their artifacts in meaningful interactions” (p. 372). According to this perspective, being raised in the sociocultural environment of modern humans directs our nearest relatives down a cognitive path divergent from that which their wild or mother-reared conspecifics regularly traverse. Specific cognitive abilities (e.g., intentional communication, imitative learning, understanding intentions) might occur in the enculturated ape that in any other ape would not (Call & Tomasello, 1996; Tomasello, 1994).

According to Tomasello and colleagues (1993), the development of imitation is thought to be contingent upon a specific ontogenetic nexus whereby the ability is only realized through the implementation of joint attentional strategies of learning during the human enculturation process. The universal phenomenon of adult human caregivers attending to and attempting to maintain their infants’ attentional states suggests that such adult behavior is a prewired response. One could go further and speculate that this attention to our offsprings’ attention, a behavioral trait ostensibly lacking in wild chimpanzees and orangutans, was influential in allowing the incipient roots of material culture to grow (Premack, 1984; Tomasello, 1996; Tomasello

& Call, 1997). It permitted our ancestors to take advantage of our infants' minds, explicitly teaching them about their environment and maneuvering their attention in synchrony with our own to object-related tasks.

As a cautionary note, however, researchers have not specified the critical environmental inputs associated with immersion in human culture that may facilitate imitation (or other complex cognitive processes) in enculturated great apes (Povinelli, 1996). The "triarchic model" of attention formation involving human–ape–object proposed by Tomasello and colleagues has played a major role in the enculturation hypothesis. It would be premature, though, to identify joint attention as the foundational base upon which a complex cognitive scaffolding is grounded. Scientific data do not yet exist that present a clear picture of the nature of the enculturation process; there have been no controlled, longitudinal studies designed to identify the specific social variables, or the interaction of these variables, leading to the expression of imitative learning in enculturated chimpanzees.

Although there is substantial debate concerning imitation in chimpanzees and whether they explicitly teach and socially reinforce their infants (e.g., Boesch, 1991; Caro & Hauser, 1992; Nagell et al., 1993), these behaviors are undeniably less prevalent in apes than they are in human adult–infant interactions. This is not to say that chimpanzees do not possess some "natural" capacity to imitate actions (otherwise no environment, of human enculturation or not, could result in imitative responses), only that a history of sophisticated social and object-related interactions may be necessary to foster the emergence of imitation (Whiten, 1993).

One study that assessed the hypothesis that human rearing would result in improved imitation abilities in chimpanzees was conducted by Tomasello and colleagues (1993). Tomasello et al. evaluated both immediate and deferred imitation in their study comparing mother-reared chimpanzees ($n = 3$; 2 bonobos [*Pan paniscus*], 1 common chimpanzee [*Pan troglodytes*]; age range: 3 years 7 months–21 years), enculturated chimpanzees ($n = 3$; 2 bonobos, 1 common chimpanzee; age range: 4 years 11 months–10 years 1 month), and 18- and 30-month-old human children ($n = 8$ per group). Unfortunately, the delayed condition comprised only a small portion of the overall study, which focused instead on the differences in immediate imitative performance between groups as a result of their exposure to different rearing environments during development. The expectation was that the enculturated chimpanzees would perform at a level more similar to the children than to the mother-reared conspecifics. This is indeed what they found. In fact,

on the delay trials (which comprised 4 of 16 tasks), the enculturated chimpanzees outperformed every other group, including the human children.

This is an intriguing finding and one that encouraged us to examine further great apes' capacity for deferred imitation on objects. The present study extends Tomasello et al.'s (1993) work and focuses completely on deferred imitation of object-related tasks. Furthermore, whereas 4 of the 6 chimpanzees in the Tomasello et al. (1993) study were bonobos, our sample consisted of 3 orangutans and 3 common chimpanzees (all enculturated). There has been some speculation that bonobos may be particularly adept at humanlike cognitive processing, more so than common chimpanzees (e.g., de Waal & Lanting, 1997; Savage-Rumbaugh et al., 1993). Finding evidence of deferred imitation in the current study in enculturated common chimpanzees would serve to more firmly establish deferred-imitation abilities in this species, distinct from the bonobos used in the Tomasello et al. (1993) experiment. Also, all animals in our study were considered infants or juveniles whereas 2 of the 6 animals in the Tomasello et al. (1993) study were adults.

Tomasello et al. (1993) permitted their apes 4 min to interact with all objects involved in four tasks. Because the animals were presented with at least four different objects during these 4-min baseline periods, it is possible that they did not have enough time to explore and manipulate each object. Thus, it would prove difficult for the experimenters to properly ascertain if the apes would spontaneously display the target behaviors that would later be demonstrated to them. That is, because of the affordances that these objects may have had for the target behaviors, the apes might have "discovered" those behaviors if they had more time to interact with each set of objects without being distracted by the presence of competing objects. In order to more effectively distinguish spontaneous behavior with objects from imitation, we allowed the participants 4 min per task to interact with the objects during baseline conditions.¹ For logistic purposes, we

¹Although our use of a 4-min baseline interval per task is more conservative than that used by Tomasello et al. (1993), we cannot rule out the possibility that the animals might have "discovered" spontaneously the target behavior had the baseline interval been longer. However, we wanted to keep the baseline and deferred interval of comparable length, and an extended deferred interval would have increased the likelihood that a spontaneous behavior displayed during this phase (due to the additional time) would be misclassified as an incidence of imitation. Thus, we believe that the use of 4-min intervals for both the baseline and deferred phases per task provides greater opportunity for a spontaneous target behavior to be displayed at baseline (relative to the procedure used by Tomasello et al., 1993) and minimizes the likelihood that a spontaneous behavior will be erroneously classified as an incidence of deferred imitation.

assessed deferred imitation after only a 10-min delay. Although demonstrating deferred imitation over a longer delay period (e.g., 24 or 48 hr) may be more impressive, the 10-min interval we chose still represents a period of time in which long-term memory processes are required and is similar to the delay used in some studies of deferred imitation in human infants (e.g., Abravanel & Gingold, 1985; Meltzoff, 1985, 1988).

Although several studies have investigated imitation in orangutans (e.g., Call & Tomasello, 1994, 1995; Miles, Mitchell, & Harper, 1996; Russon & Galdikas, 1993, 1995), to our knowledge, this is the first controlled experiment of deferred imitation on object-related tasks in this species. Deferred imitation has been inferred from nonexperimental observations for orangutans. For example, Miles et al. (1996) reported that detailed records were kept of the development of the language-trained orangutan, Chantek, and these showed that on several occasions he displayed spontaneous deferred imitations. Russon and Galdikas (1993) conducted a study of spontaneous imitation in rehabilitant orangutans and found convincing evidence that the species is indeed capable of learning by observation when the model and action are sufficiently motivating, although subsequent research found little evidence for deferred imitation (Russon, 1996). Because the current study included a baseline phase, or "free-play" period, in its design, the presence of deferred imitation can be more reliably assessed than in previous research.

We anticipated that we would observe deferred imitation in our chimpanzees consistent with the findings of Tomasello and colleagues (1993) for group-enculturated chimpanzees and bonobos. Because of the lack of conclusive findings with orangutans (e.g., Miles et al., 1996; Russon, 1996), we were less certain about the deferred-imitative abilities of the juvenile orangutans. However, given the receptivity to human rearing of the orangutans used in the current study, we anticipated that they, too, would display deferred imitative abilities on most tasks. Also, if enculturated chimpanzees and orangutans are capable of deferred imitation, we anticipated that such abilities would increase in both species over the age range tested here (2 to 6 years of age).

METHOD

Subjects

The subjects in the study were 3 orangutans (*Pongo pygmaeus*) and 3 chimpanzees (*Pan troglodytes*)

housed at the Center for Orangutan and Chimpanzee Conservation, a not-for-profit primate sanctuary temporarily located at Parrot Jungle and Gardens in Miami, FL. Five of the apes had been separated from their mothers shortly after birth due to insufficient maternal care; 1 orangutan, Pongo, came to the Center at 3 weeks of age due to a serious medical problem. The enculturated animals used in the study were Grub, a male chimpanzee (5 years 5 months); Kenya, a female chimpanzee (3 years 6 months); Noelle, a female chimpanzee (2 years 1 month); Pongo, a male orangutan, (6 years 5 months); Ruby, a female orangutan, (4 years 7 months); and Christopher, a male orangutan, (4 years 3 months) (all ages at beginning of study).

All of the subjects had been home-reared since early infancy, with both human and conspecific contact. Although separation from their mothers was certainly traumatic, each ape adjusted well to the atypical rearing environment and exhibited the normal amount of sociability associated with infants and juveniles of their respective species. The subjects were in a public area in the park from late morning to early evening, interchangeably housed with their peers in large cages containing a variety of human artifacts (e.g., toys, cardboard boxes, tires, children's pools, cups, bowls, blankets) while one to three human caretakers supervised their activities, frequently interacting with them. The participants' daily lives involved a variety of activities including both human and conspecific interactions. To a large degree, their experiences paralleled those of human children; they were engaged in joint attention strategies of learning each day, were heavily exposed to human artifacts and encouraged to manipulate these objects, traveled extensively throughout the park with human caretakers after the public had left, played in a large field behind the center, and slept in bedlike cages each night.

Testing Environment and Apparatus

The test was conducted in a bare, familiar enclosure with the ape seated on an elevated, rectangular platform (1.5 × .48 m). (The oldest orangutan, Pongo, was tested in a larger enclosure to reduce contact between himself and the experimenter, and also to provide a more suitable reaching space to prevent him from taking the objects during the demonstrations.) The enclosure was out-of-doors, immediately outside the back entrance of the Center. Testing was done on clear days, either in the mornings or early afternoons, between January and March, 1997.

The experimenter/model was a familiar caretaker

Table 1. Descriptions of Tasks and Demonstrated Actions

Task and Objects	Demonstrated Actions on Objects
Simple Tasks	
Drum plastic bowl (26.4 × 20.3 cm); wooden drum stick (26.1 cm length)	Turn the plastic bowl over upon the platform so that its face is down, then pick up the wooden drum stick and use it to strike the bottom of the bowl three times.
Cymbals instrumental cymbals (27.2 cm diameter)	Hold both cymbals by their handles and strike them together three times in close succession, producing a clanging noise.
Hand Drill manual drill (21 cm revolving diameter)	Pick up the drill with one hand, holding it either upright or downright, and turn the crank with the other hand so that it revolves completely (The drill was designed so that when the crank was turned the drill bit holder would rotate).
Complex Tasks	
Form Board perforated wooden form board (24.1 × 17.8 cm), plastic hammer, large plastic nail (5.3 × 1.0 cm)	Pick up the nail, place it in any hole in the wooden board, and then strike its head once with the striking surface of the hammer.
Blocks three large plastic Lego blocks (6.1 × 6.1 cm) (blue, green, and white) with a face drawn on the white block	Stack the Lego blocks upon one another in interchangeable orders by color, so long as the white block is always placed on the top of the stack.
Tongs and Cloth steel tongs (29.7 × 7.1 cm); piece of cloth (17 × 17 cm)	Lift the cloth from a flat surface by using the tongs bimanually, raising it completely from the substrate.
Bungee Cord bungee cord (nonexpanded 11.8 m, expanded 19.1 m); the steel bar of the enclosure (61.1 m)	Attach the hook of the bungee cord onto the steel bar of the cage, then stretch bungee cord so that it expands.

(either the first or third author).² During baseline and deferred trials, the experimenter was seated to the left of the platform in the cage with the ape, approximately .9 m away and facing the ape. This distance allowed the experimenter to present the objects in front of him- or herself and was sufficiently far enough to prevent the ape from reaching for the objects. An uninvolved observer stood outside of the enclosure, about 1.8 m away, and recorded the responses of the participants in situ. Another uninvolved assistant, this time a familiar caretaker, was outside of the enclosure and videotaped all sessions. A second video camera, present for most sessions, was outside of the enclosure and focused on the platform in order to record the ape and

the task at hand. This camera was used only as a backup in cases of malfunction of the handheld camera (which never occurred).

Materials

Seven tasks, five including more than one object, were administered to the apes (see Table 1). The objects were chosen on the basis of both their indestructibility proportionate to the strength of the apes and their manipulative compatibility with the manual dexterity of the apes (Deriagina, 1982). To the best of our knowledge, aside from the cloth, none of the objects had ever been interacted with by the participants prior to their introduction during the course of the experiment, and thus were considered to be fully novel by familiar caretakers. Tasks were chosen that required the articulation of several component objects or, at the very least, several constituent actions on one object. We deemed these qualities important in an

²The first author, an adult male, was a secondary caregiver and had several years experience interacting with the subjects. The third author, an adult female, had been the subjects' primary caregiver since early infancy and had an extensive interactive history with all of the apes. The third author served as model on the majority of trials.

assessment of the imitation of object-related actions by apes.

Although we considered each task to reflect a type of tool use, the tasks differed in their complexity. Three tasks (actions on drum, cymbals, and hand drill) required the animal to perform actions on a single object (hand drill) or to make relatively simple actions between two objects (hitting one object against the next, e.g., cymbals and drum, although the manner in which contact was made was important for these tasks). In contrast, the four remaining tasks (actions on form board, blocks, tongs and cloth, and bungee cord) required more complex coordination of the target materials. (In the case of the bungee cord, although only one object was present, it had to be hooked to the bar of the cage before being pulled.)

Procedure

Because the tests took place in a familiar enclosure, the animals were habituated to the testing environment at the start of the study. Prior to the commencement of the experiment, the apes were informally prepared for experimental conditions by temporarily isolating them from their peers in the testing enclosure and were presented with familiar objects (i.e., a cup, a blanket, etc.). They were then encouraged to immediately imitate actions on these objects after seeing demonstrations of these actions by a familiar caretaker, much as they would be in the actual experimental sessions (i.e., hiding the cup underneath the blanket). These early priming sessions, held several days before the first testing session, did not involve the animals' long-term recall, or deferred imitation; their purpose was to familiarize the animals with the basic requirements of the experimental sessions.

The apes were tested individually in the testing enclosure and were involved in only one session per day, with each session typically lasting about 25 min. Prior to their introduction, the objects associated with each task were hidden from the animal's view so that they would be novel at their introduction in the experiment. The tasks were presented in a predetermined order.³

Each session was divided into three parts. In Part 1, the baseline phase, the animal was given all of the objects involved in one task (e.g., for the first task involving the wooden board, the plastic nail, and the plastic hammer, the animal was given all three objects) for a period of 4 min to determine if the target behavior

(that which would be demonstrated by the experimenter) would be spontaneously displayed by the ape. The experimenter encouraged the participant to interact with each object, without manipulating the objects him- or herself, so that by the end of the baseline the ape had interacted with each object for a significant portion of the 4-min period. If the animal became distracted during the baseline period and had not touched the objects for a period of approximately 1 min, the experimenter said a statement such as "Look what I have," or asked "What is this?" to encourage the animal's attention to the objects. If the animal still did not manipulate the objects, they were handed directly to him or her. At the end of the baseline, the experimenter recovered the objects and again placed them out of view, either under the seat of the experimenter or outside of the enclosure.

Part 2 (demonstration) began 5 min after Part 1 ended. Because we were concerned that the animals would grow tired of the objects if they were required to focus their attention on them continuously during the session, the 5-min interval was established to help sustain interest in the objects. Part 2 involved the experimenter demonstrating the target behavior to the ape six times while the animal was attending to the displayed task (i.e., when animal's gaze was directed toward the model's actions). The experimenter, who remained in the cage with the animal, demonstrated the actions on the objects out of reach of the subject, and the animal was prevented from touching the objects during Part 2. The experimenter verbally described the actions on the objects as they were presented, such as "Take the nail, put it in the hole, and hit it with the hammer." After the demonstrations were complete, the experimenter again hid the objects from view.

For Part 3 of the experimental session (deferred phase), the subject was re-presented the objects and was asked to perform the task demonstrated by the experimenter in Part 2 (i.e., "Do what I did.") The deferred phase began 10 min after the last demonstration. As in the baseline phase, the subject was given 4 min to interact with the objects, and was instructed only to "Do what I did," during this period. The experimenter gave no further direction and made no gestures pertinent to the objects that might have cued the animal to the target behavior. The experimenter also made no comment (praise or encouragement) when the animal displayed the target behavior, minimizing the chance of social cuing. Occasionally, however, as in the baseline phase, the experimenter encouraged the animals to manipulate and interact with the objects if they had not touched the objects for a period of about 1 min. The objects remained in the enclosure with the

³Two of the animals, Grub and Pongo, were administered only six tasks. Each had been exposed to the form-board task during pilot testing, preventing us from using this as a novel task for these animals.

subject for the entire 4-min period, irrespective of the animal's success at imitating the task. No food rewards or social reinforcement were given to the animals for successful imitation.⁴

Coding Procedure

The video records of all sessions were reviewed by two independent scoring groups, one naive to the purpose of the study and the other directly involved in the experimental procedure. Data from the baseline and deferred phases of the sessions were analyzed in 30-s response intervals. We developed three categories of behavior for each task. The first, termed *target* (T), was coded when an animal displayed the behavior demonstrated by the model during Part 2 of the session. (Note that animals could have displayed these behaviors during the baseline phase, before ever witnessing the model.) The second category of behavior was termed *approximation to the target* (AT), and was coded whenever an animal displayed a behavior with the objects that reproduced most, but not all, aspects of the modeled behavior. For example, if the animal struck the cymbals together, but did so "incorrectly" (e.g., struck the handles together rather than the metal instrumental portion), an AT would be scored. The criteria used to classify behaviors as targets or approximation to the targets for each task are provided in the Appendix. If the ape failed to display either the T or an AT behavior during the 4-min interval, a *no imitative behavior* score was recorded. In addition to coding for T and AT behaviors, we also coded whether the animal was in contact with the task material for each 30-s interval. Separate codes were made for contact with each animal's hands, feet, and mouth.

Our differentiation between T and AT behaviors was based on consideration of the motor abilities of the animals and the desired effect of the action. For example, because the manual dexterity of the apes was limited compared to humans, we did not require that a behavior involving substantial dexterity be copied exactly. This was most apparent for the hand-drill and form-board tasks. Also, because these apes were often as dexterous with their feet as with their hands, we counted as "correct" actions executed with their feet as well as their hands.

Each session was scored independently by each of the two observation teams. Initial interrater reliability

⁴If the ape was unsuccessful at either imitating or approximating the previously demonstrated actions on the objects by the end of Part 3, the experimenter would perform the behavior again and attempt to have the ape imitate the action immediately. This was not included in any analyses, but was done to help reduce any feelings of frustration the animal might be experiencing.

was 93% agreement (i.e., classifying the display of a target, approximation to the target, or no imitative behavior for each 4-min session). All discrepancies were resolved by having members of the two teams and a third independent observer review the tapes. In two cases, because camera angles obscured the animals' behaviors, on-line records were examined to resolve discrepancies. Latency of response (initial display in each session of a T or AT behavior) was measured as well.

RESULTS

Contact With the Objects

We initially noted the number of 30-s intervals during which each animal touched the task materials, separately for their hands, feet, and mouth (maximum number of intervals = 8 per body part). We did this because if one species interacted more with the objects than the other, they may be more likely to display the target behavior following demonstration solely on the basis of the time with which they were in contact with the objects. The patterns of contact were similar for the baseline and deferred phases and between the chimpanzees and orangutans. For the 3 chimpanzees, the mean number of intervals (maximum = 8) in which they touched the task materials was 7.7 for their hands, 3.7 for their feet, and 6.1 for their mouths. The corresponding means for the orangutans were 7.6, 2.6, and 6.7 for hands, feet, and mouths, respectively. These data indicate that all animals interacted frequently with the materials, mostly with their hands and mouths, and that any subsequent difference between the species is not likely due to differences in the frequency with which they were in contact with the task materials.

Incidence of Target and Approximation to the Target Behaviors

The incidence of the target (T), approximation to the target (AT), and no imitative behavior (i.e., neither target nor approximation) at the baseline and deferred phases are presented for each animal in Table 2. As can be seen, all but 1 animal (Noelle) displayed at least one AT behavior during the baseline, and each of the 3 orangutans (but none of the chimpanzees) displayed at least one actual T behavior before seeing that behavior demonstrated to them. However, the T behavior was displayed during baseline by no more than 1 animal per task, with no observations of the T behavior for three of the seven tasks. Not surprisingly, T and

Table 2. Incidence of Target (T) Behaviors, Approximation to the Target Behaviors (AT), and No Imitative Behavior (0) for Baseline and Deferred Phases and Latencies (in Seconds) to Display Behaviors (in Parentheses) for Each Animal by Task

Task	Orangutans					
	Pongo		Ruby		Christopher	
	Base	Deferred	Base	Deferred	Base	Deferred
Simple Tasks						
Drum	T (123 s)	0	AT (15 s)	AT (7 s)	AT (10 s)	0
Cymbals	AT (28 s)	AT (85)	T (177 s)	T (142 s)	AT (70 s)	T (15 s)
Hand Drill	0	0	T (169 s)	T (42 s)	0	0
Complex Tasks						
Form Board	Omitted	Omitted	0	T (23 s)	0	0
Blocks	0	0	0	T (240 s)	T (195 s)	AT (50 s)
Tongs & Cloth	0	0	0	AT (95 s)	0	0
Bungee Cord	0	T (235 s)	AT (190 s)	AT (140 s)	0	T (35 s)
%Target	17%	17%	29%	57%	14%	29%
%Approximation	17%	17%	29%	43%	29%	14%
%No Imitation	67%	67%	43%	0%	57%	57%
Mean latency	75.5 s	160 s	137.8 s	98.4 s	91.7 s	33.3 s
Task	Chimpanzees					
	Grub		Kenya		Noelle	
	Base	Deferred	Base	Deferred	Base	Deferred
Simple Tasks						
Drum	AT (15 s)	T (2 s)	0	T (23 s)	0	T (30 s)
Cymbals	AT (131 s)	T (11 s)	AT (10 s)	AT (2 s)	0	AT (5 s)
Hand Drill	AT (8 s)	T (12 s)	0	AT (6 s)	0	0
Complex Tasks						
Form Board	Omitted	Omitted	0	AT (35 s)	0	0
Blocks	0	0	0	0	0	0
Tongs & Cloth	0	T (35 s)	0	T (50 s)	0	0
Bungee Cord	0	T (12 s)	0	T (96 s)	0	0
%Target	0%	83%	0%	43%	0%	14%
%Approximation	50%	0%	14%	43%	0%	14%
%No Imitation	50%	17%	86%	14%	100%	71%
Mean latency	51.3 s	14.4 s	10 s	35.3 s	—	17.5 s

Table 3. Mean Difference Between Incidence of Target (T) or Approximation of Target (AT) Behaviors Between Deferred and Baseline Phases and Corresponding *t*-scores, Separately for Each Animal

	All Trials		Trials with T or AT at Baseline Omitted	
	Mean Deferred		Mean Deferred	
	Minus Baseline	<i>t</i> -score	Minus Baseline	<i>t</i> -score
Orangutans				
Pongo	0.40	<i>t</i> (5) < 1	0.50	<i>t</i> (3) < 1
Ruby	1.0	<i>t</i> (6) = 2.33*	1.67	<i>t</i> (2) = 4.09*
Christopher	0.67	<i>t</i> (6) = 1.23	0.60	<i>t</i> (4) = 1.34
Chimpanzees				
Grub	1.17	<i>t</i> (5) = 3.49**	1.33	<i>t</i> (2) = 1.63
Kenya	1.14	<i>t</i> (6) = 3.10**	1.33	<i>t</i> (4) = 3.64*
Noelle	0.43	<i>t</i> (6) = 1.33	0.43	<i>t</i> (6) = 1.33

Note. Displays of target (T) behavior were assigned scores of 2, approximation to the target (AT) scores of 1, and "no imitative behavior" scores of 0.

**p* < .10.

***p* < .05.

AT behaviors were more frequently observed at baseline for the simple tasks (61% of possible trials) than for the complex tasks (9% of possible trials), suggesting that the simple tasks provided strong affordances for the T behaviors. However, even on these tasks, the T behaviors were not displayed during baseline by more than 1 animal each.

In Table 2, it can be seen that each animal displayed both a T and an AT behavior during the deferred phase for at least two tasks, although there were substantial individual differences. We computed the percentage of trials on which a T or AT behavior was observed during the deferred trials, excluding those trials on which an animal displayed a T behavior at baseline. We included trials on which animals displayed an AT behavior at baseline only if they displayed the more complete T behavior during the deferred phase. That is, we did *not* include trials on which an animal displayed AT behaviors both at the baseline and deferred phases. Using this criterion, the T or AT behaviors were displayed 73% of the time on the deferred trials for the simple tasks (for one of three possible trials for the orangutans, and for seven of eight possible trials for the chimpanzees), and on 50% of possible trials for the complex tasks (for five of nine trials for the orangutans and 5 of 11 trials for the chimpanzees).

The most critical comparisons for our purposes is between behavior at the baseline phase (Part 1) and behavior at the deferred phase (Part 3). In an initial analysis, we examined the percentage of tasks on which each animal displayed the T or AT behaviors during the deferred phase, but only for those tasks on which the animal showed no imitative behaviors at baseline (i.e., omitting all trials on which a T or an AT

behavior was displayed at baseline). As can be seen from Table 2, 3 of the 6 animals (1 orangutan, Ruby, and 2 chimpanzees, Grub and Kenya) displayed the T behavior on at least 50% of these trials during the deferred phase. When combining T and AT behaviors, these 3 animals showed evidence of deferred imitation on 67% or more of the trials (i.e., when no imitative behaviors were coded at baseline). Overall, the T and AT behaviors were observed on 45% of these deferred trials for the orangutans and 53% for the chimpanzees. There were an additional four cases in which an animal displayed an AT behavior at baseline and then displayed the more complete T behavior during the deferred phase (three for Grub, one for Christopher). When these trials were included in the computation, the rate of deferred imitation increased to 50% for the orangutans and 63% for the chimpanzees.

In order to obtain a statistical evaluation of these data, we assigned scores of 2, 1, and 0 each time an animal displayed the target, an approximation to the target, and no imitative behavior, respectively. Then, for each animal, we computed the difference between scores on the deferred phase and scores on the baseline phase, and averaged them over the seven tasks (six tasks for Pongo and Grub). We then conducted *t* tests, based on the deferred-minus-baseline difference scores, separately for each animal using tasks as the random variable and 0 as the expected value.

Mean difference scores for each animal and the corresponding *t* values (including data from all trials) are presented in the two left-hand columns of Table 3. First note that, overall, the mean differences are of a moderate magnitude and comparable for the orangutans (.69) and chimpanzees (.91) (maximum possible

difference = 2.0). Two chimpanzees (Grub and Kenya) and 1 orangutan (Ruby) had mean difference scores of 1.0 or greater, and statistical contrasts for 2 of these animals (Grub and Ruby) were significantly greater than expected by chance, with the difference for the 3rd animal (Ruby) approaching statistical significance, $p < .10$).

We also computed difference scores and t tests omitting those trials on which an animal displayed the T or AT behavior at baseline (see the two right-hand columns of Table 3). Using this criterion, mean difference scores and t values for the 3 animals that showed low levels of imitation (Pongo, Christopher, and Noelle) did not change appreciably. Difference scores increased somewhat for Ruby, Grub, and Kenya using this method, and t values increased for and Kenya and Ruby, but decreased for Grub.

Latencies to Perform Target or Approximation to the Target Behaviors

We computed the latency (to the nearest second) for each animal for each task for the first incident of the T or AT behavior during both the baseline and deferred trials. (Latencies for each behavior are presented in Table 2.) We reasoned that if the animals' demonstration of a T or an AT behavior reflects imitation, they would be more likely to display that behavior earlier (closer to the demonstration phase) rather than later during the 4-min trial. In contrast, display of a T or an AT behavior later during the 4-min deferred phase could reflect accidental "discovery" of the behavior while manipulating the objects.

To get an idea of differences in latencies between species, phases, and behavior type (i.e., T vs. AT), we conducted a series of analyses of variance, using latencies as the random variable. In these analyses, we excluded latencies on deferred trials on which an animal displayed a T or an AT behavior at baseline, except for trials on which animals displayed an AT behavior at baseline and then displayed the more complete T behavior during the deferred phase. Chimpanzees responded significantly faster (30.1 s) than orangutans (108 s), $F(1, 29) = 11.07$, $p < .001$, $MSe = 4247.6$. A phase \times behavior (Baseline vs. Deferred \times T vs. AT) analysis of variance yielded significant main effects of phase, $F(1, 27) = 5.0$, $p < .05$, $MSe = 4600.5$ (baseline: 87.8 s $>$ deferred: 53.3 s) and behavior, $F(1, 27) = 5.91$, $p < .05$ (T: 82.4 s $>$ AT: 47.5 s). Although the Phase \times Behavior interaction was not significant, $F(1, 27) = 2.57$, $p > .10$, the magnitude of the of baseline-deferred difference was greater for the T behaviors (baseline: 166 s;

deferred: 58.5 s) than for the AT behaviors (baseline: 53 s; deferred: 35 s).

For the chimpanzees, 92% of the behaviors occurred within the first 60 s of the trial (and 67% during the first 30 s), with each animal having a median latency of 35 s or less. The pattern was less robust for the orangutans. Yet, half of the observed T and AT behaviors of the orangutans were displayed within the first 60 s, and 33% within the first 30 s of the trial. These data are consistent with the interpretation that the behaviors observed during the deferred trials were the direct result of imitation of the modeled behaviors and not the chance occurrence of these behaviors as a result of mere exposure to the objects. This interpretation is stronger for the chimpanzee than for the orangutan data.

DISCUSSION

The findings of this study indicate clearly that juvenile enculturated (as defined by Call & Tomasello, 1996) orangutans and common chimpanzees are able to display deferred imitation of object-related actions, under controlled conditions, over a 10-min-delay period. Because of the inclusion of a 4-min baseline phase for each set of materials, we are confident that the matching behaviors observed after the modeling of the target behaviors can be attributed to imitation and not to spontaneous displays of the behavior associated with the affordances of the objects. Latencies to display the T or AT behaviors were significantly faster during the deferred than during the baseline phase, particularly for the target behaviors. We believe that displaying the demonstrated behavior early during the deferred phase is a further indication that the behavior can be attributed to imitation rather than a consequence of exploring the properties of the objects (and hence discovering the target behaviors themselves). These findings extend those of Tomasello et al. (1993) in providing evidence of deferred imitation in common chimpanzees (Recall that 2 of the 3 enculturated apes in this Tomasello et al. study were bonobos.) This is the first study, to our knowledge, to illustrate deferred imitation in orangutans under conditions of experimental control.

Deferred imitation has been interpreted as evidence of symbolic (i.e., mental representational) ability (e.g., Bauer, 1997; Meltzoff & Moore, 1997; Piaget, 1962) and explicit memory (i.e., memory with awareness) (e.g., McDonough et al., 1995) in human children. Finding deferred imitation in enculturated great apes seems to indicate that these animals possess some sem-

blance of symbolic abilities and explicit, as opposed to only implicit, memory. We did not have a control group of mother-reared apes, which limits the claims we can make about the effects of rearing environment on the development of symbolic abilities in great apes. However, the lack of unambiguous evidence of imitation in mother-reared apes in other research (see Tomasello & Call, 1997) and the findings of Tomasello et al. (1993), who demonstrated significantly greater imitation for enculturated than for mother-reared bonobos and common chimpanzees, argues strongly that early rearing environment plays a pivotal role in the development of imitation abilities and symbolic representation in these animals.

Our claim is not that the minds of juvenile apes are infinitely pliable and that chimpanzees and orangutans can easily acquire other humanlike abilities simply as a result of being reared as much as possible as human children. Obviously, these animals must have the inherited neural substrate that makes deferred imitation of tool use possible under certain testing conditions and rearing history. Kuo (1967) long ago demonstrated that raising many species of birds and mammals in species-atypical environments can produce species-atypical behavior. What is compelling here is that the species-atypical behavior displayed by the enculturated juvenile great apes is a reflection of symbolic representational abilities. It would be interesting to determine if these animals could also display other behaviors indicative of symbolic functioning in young children, such as theory of mind, or if, perhaps, the abilities illustrated by the apes in this experiment and that of Tomasello et al. (1993) are domain-specific in nature and do not reflect a more general symbolic function, as is presumably the case in human children. False-belief tasks, characteristic of theory of mind, are typically not passed by human children until about 4 years of age (e.g., Wellman, 1990), and recent research has generally indicated no ability of laboratory-reared apes of any age to perform false-belief tasks (e.g., Call & Tomasello, 1999).

We had anticipated that we would find strong evidence of deferred imitation in the common chimpanzees, but were less certain about the orangutans. Previous research with rehabilitant and enculturated orangutans of various ages found conflicting evidence of deferred imitation (Miles et al., 1996; Russon, 1996). Our results indicated comparable levels of deferred imitation for both species of animals on both the simple and complex tasks. The chimpanzees were significantly faster in displaying the T or AT behaviors than the orangutans. This finding is somewhat surprising considering previous research on the manipula-

tiveness of orangutans (e.g., Lethmate, 1982; Parker, 1969). Lethmate noted, for instance, that, "In contrast to chimpanzees, orangutans are inclined to grasp things immediately and without any hesitation" (p. 56). The orangutans in our study interacted as much and as quickly with the materials as the chimpanzees, but simply did not display the T or AT behaviors as soon as the chimpanzees. It is possible that these animals were more intent than the chimpanzees to explore other properties of the objects, resulting in their longer latencies to display the target behaviors. Overall, we have no evidence of differential deferred-imitative abilities between chimpanzees and orangutans. These findings suggest to us that, despite differences in the evolutionary history of these species and in their presumed sociability, each species is receptive to the effects on cognitive development of early human rearing, at least when tested as juveniles.

We had also anticipated that there would be age-related differences in imitative abilities, with the oldest animals being more likely to display imitation than the younger animals. The pattern of results across species was not clear-cut on this issue, and the small sample size precludes any definitive conclusion concerning the effects of age. Tentative support for the developmental hypothesis was found for the chimpanzees. Noelle, 2 years 1 month of age at the start of this study, displayed only one T behavior and one AT behavior (both on simple tasks) during the deferred phase. Yet, given that she never displayed these behaviors during the baseline phase, this still demonstrates deferred imitative abilities in this 2-year-old animal. In contrast, Kenya, age 3 years 6 months, and Grub, age 5 years 5 months, each displayed imitative responses on two thirds or more of the trials, suggesting a substantial improvement in imitative abilities (at least for the tasks used in this experiment) over the juvenile period in chimpanzees. Again, because of the small sample size, this interpretation must be viewed as only tentative.

We did not observe a similar age trend for the orangutans. Based on the most conservative criterion (excluding all trials on which either a T or an AT behavior was displayed at baseline), both the oldest orangutan, Pongo, age 6 years 5 months, and the youngest, Christopher, age 4 years 3 months, made imitative responses on only 25% of the trials. (If an improvement from AT at baseline to T at the deferred phase is considered, Christopher's percentage increases to 40%.) The best performing orangutan was Ruby, age 4 years 7 months (100%), and the only female. Because of our small sample size, it is impossible to determine the reasons for the discrepancy in performance among these 3 animals. Sex is one pos-

sibility (Perhaps female orangutans are better at imitation than male orangutans.) Other explanations for the oldest orangutan's relatively poor imitative behavior are motivational. At 6 years 5 months, Pongo, if he lived in the wild, would be beginning to separate from this mother, and captivity could have accelerated his maturation. This increased independence may have made Pongo less receptive to the requests to imitate (or the desire to copy a human's behavior) than the younger orangutans.

In many experiments designed to test the cognitive abilities of great apes, specific reinforcements are required to elicit complex behaviors (e.g., Whiten et al., 1996). It is worth noting that the enculturated apes in this study displayed deferred imitation in the absence of food or social reinforcements (as was also the case in the study by Tomasello et al., 1993). One possible interpretation for the lack of need for explicit reinforcement found here is that these animals develop an intrinsic motivation to imitate behavior, much as is the case with human infants (Meltzoff & Moore, 1997). Thus, the enculturated great ape, with its history of manipulating human artifacts and developing in an enriched social environment in which imitation is both encouraged and rewarded, is not only able but also motivated to imitate on a more humanlike level than great apes raised in the wild or in laboratory conditions (Nagell et al., 1993; Tomasello, 1994; Tomasello et al., 1993).

The effects of early rearing environments on the elicitation of complex cognitive functioning have been the subject of considerable debate (Boesch, 1991; Povinelli & Eddy, 1996; Premack & Premack, 1983; see Call & Tomasello, 1996 for a review). The results from the present experiment illustrate young apes' ability and willingness to acquire object-related behavior from the observation of a familiar human caretaker. We believe that the data reported here serve to bolster further the contention that the minds of great apes—like the minds of human children—are malleable during development, and that being reared in a human environment can serve to foster the emergence of cognitive abilities not regularly present in the mental repertoire of nonenculturated individuals.

NOTES

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Appendix

DEFINITIONS OF TARGET BEHAVIORS AND APPROXIMATIONS TO THE TARGET BEHAVIORS

Drum

Target (T): The ape strikes the top of the drum at least twice with the drumstick. Note that strike refers to any seemingly deliberate and intentional motion, whether it be merely “tapping” or “beating.” The drum must be placed in the correct position—open part of drum face-down.

Approximation (AT): The ape strikes the drum at least twice with the drumstick, but the drum is not in the correct position—the open part of the drum is face-up, or the ape strikes the drum only once.

Cymbals

Target (T): The ape successfully holds both cymbals by their handles using any means available, then strikes them together. Note, however, that *strike* refers to a deliberate joining of the cymbals, and does not include sliding the cymbals together. Noise is not necessarily invoked from striking the cymbals together.

Approximation (AT): There are several behaviors that would qualify as an approximation to the target, including: (a) The ape holds the cymbals by the metal itself rather than by the handles, then strikes them together—handle to handle; and (b) the ape correctly holds the cymbals by their handles, but instead of striking the two instruments together, slides one against another.

Hand Drill

Target (T): The ape successfully manages to hold drill using either its hands or its feet, either upright or downright, then proceeds to turn the crank so that it revolves completely—360 degrees—at least once.

Approximation (AT): There are several behaviors that would qualify as an approximation to the target, including: (a) The ape successfully manages to hold the drill by the handle, again either upright or downright, and merely touches the crank with its hands or feet—turning it briefly or not at all; and (b) the ape does not hold the drill by the handle, but nonetheless manages to turn the crank so that it revolves completely. This may be accomplished by turning the crank while the drill is lying on a hard substrate in the test area (i.e., floor, cage shelf).

Form Board

Target (T): The ape successfully manages to place the nail in one hole using any means available (i.e., hands, feet, mouth), then proceeds to strike the nail with the head of the hammer at least once. Note, however, that the term strike refers to any contact made between the head of the hammer and the nail in the hole. The ape may use either a sideways striking motion (striking the nail on its side) or strike the nail as demonstrated (striking the head of the nail).

Approximation (AT): There are several behaviors that would qualify as an approximation to the target, including: (a) The ape successfully manages to place the nail in one hole, then strikes the nail with the handle of the hammer (as opposed to the head of the hammer); and (b) the ape successfully manages to place the nail in one hole, turns the entire board over, then uses the hammer to strike the nail from the opposite side of the board.

Blocks

Target (T): The ape successfully stacks the three Lego blocks so that the white block (which has a face painted on it) is on top, using any means available.

Approximation (AT): The ape successfully manages to stack all three blocks, in any order.

Tongs and Cloth

Target (T): The ape successfully manages to pick up the cloth with the tongs, using both hands (or feet) to squeeze. The cloth must be lifted off the substrate at least briefly.

Approximation (AT): There are several behaviors that would qualify as an approximation to the target, including: (a) The ape seemingly attempts to pick up the cloth with the tongs but, for whatever reason, the cloth is not lifted off of the substrate; and (b) the ape uses other means to squeeze the tongs and pick up the cloth (i.e., the ape squeezes the tongs with mouth, or

picks up the cloth using one hand to squeeze the tongs).

Bungee Cord

Target (T): The ape successfully manages to attach the hooked end of the bungee cord to a bar, then proceeds to pull the cord so that the cord stretches. Note that intention is an important function of this task.

Approximation (AT): Without the apes intention, the hooked end of the bungee cord somehow becomes attached to a bar. The ape proceeds to pull the cord so that it stretches. A “no imitative behavior” score was recorded if the ape seemed to pull the cord out of frustration from not being able to detach the hook from the bar.