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Journal

International Journal of Comparative Psychology, 8(2)

ISSN

0889-3675

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Publication Date

1995

DOI

10.46867/C4QP4F

International Journal of Comparative Psychology, Vol. 8, No. 2, 1995

ACQUISITION AND COMPREHENSION OF A TOOL-USING BEHAVIOR BY YOUNG CHIMPANZEES (*PAN TROGLODYTES*): EFFECTS OF AGE AND MODELING

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ABSTRACT: The acquisition of a tool-using ability was investigated in six young chimpanzees (*Pan troglodytes*, 2 to 4 years old). Age-matched pairs were presented with a horizontal transparent tube with a food item inserted in the center, and a wooden tool. Insertion of the tool into the tube was required in order to obtain the food item. One of each pair was exposed to a model performing the task successfully, whereas the age-matched peer was not. Following acquisition, subjects were tested with more complex versions of the task to evaluate their comprehension. Age affected acquisition; older individuals learned to solve the task in fewer number of trials than younger chimpanzees. The presence of a model influenced acquisition only in the 3-and-4 year-old groups and not in the 2-year-old group. Moreover, older individuals made fewer errors when faced with tools requiring modification, and the performance of older individuals on these complex tasks improved with limited practice. These results are related to recent findings on cognitive development in chimpanzees indicating that self-recognition emerges between 24 and 30 months and that 4 year-old chimpanzees can imitate novel arbitrary actions. Comparisons with human cognitive developmental data and findings on the same task with older apes point to the link between the emergence of imitation, self recognition, and comprehension of the cause-effect relation present in this task. Competence in all these domains is somewhat delayed in chimpanzees compared to humans.

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Field observers have often suggested that young chimpanzees acquire specific feeding skills, including those involving the use of tools, through social learning, perhaps including imitative copying (e.g., Boesch, 1991; Goodall, 1986). Imitation (sensu Visalberghi & Fragaszy, 1990), or imitative copying (sensu Galef, 1988; Russon, in press; and Parker, in press) is the relatively faithful reproduction of a novel behavior as a result of observation of another performing the behavior. In a tool-using context, imitative copying should lead the observer to learn the manner in which to use a tool more efficiently than it could learn to do so on its own. However, how social influences affect the acquisition of new behaviors by novice individuals is a matter of conjecture or debate (e.g., Bard, 1992; Tomasello, 1990). Our own studies cast doubt on the notion that monkeys acquire novel behaviors from observing others (Fragaszy & Visalberghi, 1989; Visalberghi & Fragaszy, 1990) but suggest that after providing chimpanzees with appropriate tutorials, chimpanzees do acquire novel behaviors from observing others (e.g., Custance, Whiten, & Bard, 1994; 1995; Custance & Bard, 1994). By tutorial, these authors mean providing a variety of learning aids, such as scaffolding and demonstration, excluding shaping. Without a background knowledge that others are worth watching, there may be only minimal benefit to young chimpanzees (*Pan troglodytes*) accrued from observation of an experienced model (Custance & Bard, 1994; Whiten, Custance, Gomez, Texidor & Bard, in press; Tomasello, Davis-Dasilva, Camak, & Bard, 1987).

Imitative capacities have been documented in studies with chimpanzees who have been shown arbitrary gestural actions by human models (Custance et al., 1994; 1995). These studies suggest that there may be two constraints in imitative learning: a developmental change in the ability of chimpanzees to benefit from the demonstration of a new skill; and the importance of a social relationship between model and imitator (e.g., Russon & Galdikas, 1994). The first constraint is also evident in the imitative performance of human infants. Studies with human children have indicated that observing a model affords a benefit to a child learning a new skill only if the task is nearly within the child's ability at the time the modeling occurs (e.g., Wood, Bruner, & Ross, 1976). If chimpanzees do face this constraint, social influences on learning new skills would be limited among chimpanzees during the very early years of life.

Alternatively and not exclusively, young chimpanzees may be able to copy gestural or arbitrary actions, but still be unable to benefit from watching a model perform a novel action involving the production of relations between two objects in an instrumental task. Visalberghi, for example, has argued that one of the reasons that capuchins are unable to copy the behavior of a model using a tool is that they do not understand the relation between the movement or properties of the tool and the solution of the task (e.g., Visalberghi, 1993). This limitation is particularly noticeable because some individual monkeys can solve tool tasks quickly after experience with them. In addition, after practice capuchins can solve even difficult tasks quickly but they continue to exhibit errors. These continuing errors indicate that capuchins do not plan ahead of action and/or do not have a mental image of what size and shape tool produces the relations which solve the task. Thus, the conclusion is made that capuchins do not reach the sixth Piagetian stage of "invention of new means through mental combination" (Natale & Antinucci, 1989; Schino, Spinozzi, & Berlinguer, 1990; Visalberghi & Trinca, 1989). Human infants in their first year are capable of solving instrumental problems primarily through associative processes linking action with outcome (e.g., Bates, Carlson-Luden, & Bretherton, 1980); the ability to solve instrumental problems (Connolly & Dalgleish, 1989) or to plan behavior through conceptual processes (e.g., relational concepts, or representation of absent stimuli or events) is increasingly apparent in the second year of life and beyond (e.g., Piaget, 1952; 1954). Chimpanzees use both associative and conceptual processes in solving various problems in captivity (Chevalier-Skolnikoff, 1977; Köhler, 1927; Mathieu & Bergeron, 1981), and certainly the diversity and flexibility of their tool-using behavior in natural settings suggest the presence of conceptual solutions (e.g., Boesch & Boesch, 1990; van-Lawick Goodall, 1968; Sakura & Matsuzawa, 1991; Sugiyama & Koman, 1979). However, it remains unclear whether they can benefit from watching a model solve a tool task.

In this study, we address the relation between learning context (with or without a model) and age in the initial performance of a tool-using behavior in young chimpanzees. We ask three questions: 1) Does age contribute to ease of acquisition of this behavior? 2) Can young chimpanzees benefit from observation of a competent and successful model in the acquisition of this behavior? If so, is an age effect evident in the ability to benefit? and 3) is ease of acquisition associated with comprehension of the important aspects of the task as indexed by performance on the complex tool task?

METHOD

Design

A two-part experiment was performed. The first phase, *acquisition*, addressed the influence of a social model on the learning of a tool-using skill. In the first part, six subjects were presented with a task which could be solved by inserting a tool into a clear tube to push out a food treat. The subjects were randomly assigned in age-matched pairs to one of two conditions, differentiated by the degree of social scaffolding provided by the experimenter. One member of each pair was presented the task with no aid by the experimenter beyond expression of interest in the food item (No-model group). The other member was shown, by the experimenter, how to solve the task (Model group). Following criterion performance on the task (3 consecutive successful trials over two sessions), subjects advanced to the second part of the experiment.

The second part of the experiment, *comprehension*, addressed the subjects' understanding of the tool task. The aim of this phase was to probe the subjects' understanding of the properties of the tool and the task (see Visalberghi & Trinca, 1989). All subjects were treated equally in this phase: no modeling was provided. In this part, three variations of the tool were provided which required the subject to combine or modify the tool to achieve solution of the task. Each subject completed two blocks of twenty trials (a grand total of 40 trials). Within each block there were five trials for each of the three tool variations and for the original tool.

Subjects

Six chimpanzees (*Pan troglodytes*) in three age-matched pairs were tested. Pair 1, Donald and Jarred, were 2 years of age at the start of testing. Pair 2, Katrina and Scott, were three years. Pair 3, Tank and Keith, were 3.6 years and 4 years, respectively. The first member of each pair (Donald, Katrina, and Tank) was assigned to the No-model group, and the other to the Model group.

These subjects were raised in the nursery at the Yerkes Regional Primate Research Center due to inadequate maternal care at birth or injury (see Bard, 1995; 1994-a for more information with regard to maternal competence in chimpanzees). They were all reared in peer groups of five or six individuals from as early as 3 months of age. All subjects had spent considerable time (minimum of one Atlanta spring/summer/fall season) in outdoor play yards where trees, branches and leaves fall, exposing each to potential tools. All subjects received exposure to the wooden dowels used for this experiment, however, only during the course of testing. Additional details about the subjects' rearing conditions and the details of normative performance on standardized tests of neonatal neurobehavioral integrity and cognitive/ manipulative skills can be found elsewhere (Bard, 1993; Bard & Gardner, in press; Bard, Platzman, Lester, & Suomi, 1992; Bard, Gardner, & Platzman 1991).

Apparatus

A tube of transparent Lexan (3.8 cm diameter) was mounted horizontally on a metal frame and attached to the interior wire mesh wall of a group play room. A tube 33cm long was used for all except the first 50 trials (during acquisition) of the first two subjects (Donald and Jarred). These initial trials used a tube 48cm long which proved too long for 2-year-old chimpanzees. The tube was positioned approximately 36 cm above the ground, and 5 cm in front of the mesh fencing. It was thus at about shoulder height for our subjects if they were seated in front of it. Food items were fresh grapes or (rarely) small candy-coated chocolates.

Wooden dowels (2.5 cm diameter) were provided as tools. The length of the dowels matched the length of the tube (48 and 33 cm). A single straight dowel was provided as the tool during acquisition. The complex conditions involved the following tools: a) *bundle*: a variety of dowels of different lengths and diameters held together with masking tape. The diameter of the bundle was approximately twice the diameter of the single straight dowel and exceeded the diameter of the opening to the tube; b) *H-tool*: a dowel which was the correct length and diameter but which was blocked at each end with a small perpendicular tool (pencils with masking tape, approximately 12 cm in length), and c) *Short-tool*: two half-length dowels.

Procedure

The procedures were standardized on two pilot subjects, whose data are not included in the following results. Each subject was tested in the setting most conducive to optimal performance for that subject (i.e., some subjects had a peer present for comfort). A favorite adult human provided each subject with a comfortable situation in which to work. These human companions were very familiar and had maintained a social relationship with the subjects over the course of between 6 months and 3 1/2 years.

Phase I: Acquisition

No model Group: The apparatus was baited with a single grape before the subject arrived at the testing site. A tool was placed on the floor below the tube, perpendicular to the longitudinal axis of the tube. Each 4-minute trial began when the subject's attention was directed to the grape by the experimenter giving food barks (vocalizations denoting the presence of preferred foods: Goodall, 1986), looking at the food, and pointing to the food. If no solution occurred within the first 25 trials, the experimenter began a graduated series of interventions to facilitate performance. The first intervention consisted of providing a shorter tube and tool (this intervention was used only with Donald and Jarred). The second intervention involved placing additional food items into the tube at the beginning of each trial while the subject watched. The third intervention involved placing the tool partially into the tube, with several centimeters remaining between the tool and the food. The final intervention was providing a modeled solution prior to each trial. The schedule at which these interventions occurred, and the number of trials per test day, varied across subjects in accord with the experimenter's judgment about the subject's progress and interest in the task.

Model Group: In a 30-sec period at the beginning of each 4-min trial, while the subject was attending, the experimenter inserted the tool into the tube, purposefully hitting the interior of the tube with the tool as it entered, and slowly pushed the food item out the far end of the tube. Food barks were given by the experimenter while solving the task. The food item was then shared between the experimenter and the subject. The tube was re-baited in view of the subject, and the tool was placed beneath the tube, as in the no-model group.

For both groups, a trial ended when solution occurred or after 4 min; whichever occurred first. The acquisition phase ended when solution was achieved in three consecutive trials over two sessions. Testing in this phase was completed in 2 months or less for all subjects.

Phase II: Comprehension

All subjects who succeeded in solving the task to criterion in Phase I advanced to Phase II (complex tool conditions) on their next test session. Phase II was divided into two blocks of 20 trials. In each block, four different tools (the original, and the three variations described above) were provided for five trials each. Within each block, the first trial used the plain dowel, and in subsequent trials in the same block the order of presenting the four tools was determined by the experimenter in accord with the subject's progress and interest. No interventions occurred on these trials. Trials lasted 4 min, or until solution occurred, whichever came first. Testing in this phase began within 5 days of reaching criterion on the acquisition task, and was completed in 2 weeks or less.

Analysis

Phase I: Each 4-min trial was divided into 24 10-sec sampling periods. The 10-second sampling periods were scored for four mutually exclusive and exhaustive classes of behavior: 1) no attempts to solve, which included no attention to tool or tube, and exploratory behaviors toward either the tool or the tube; 2) attempts to solve without the use of the tool, which included attempts to solve by reaching directly for the food, and attempts to solve with non-tool objects; 3) attempts to solve with the use of the tool in which the tool was aimed at the side of the tube, at the food, or at the end of the tube, but was not inserted; and 4) correct attempts to solve and success.

Phase II: Each 4-minute trial was divided into 48 5-second sampling periods. The size of the sampling period corresponded to the smallest time period that one error could occur, in other words, 5 seconds. Each sampling period was scored for a) success, b) correct attempts, and c) type of errors. Errors were scored with a coding system developed by Visalberghi and Trinca (1989) for use with another species (capuchins) but with the same task and tools. In brief, the errors were defined conceptually as Type I, use of objects that are not combined properly, such as ineffective insertion of a short tool in Short condition; Type II, using objects that are insufficiently modified, such as use of the bundle that was too large, or insertion of the H-tool without removal of the blocking piece on the inserted end; and Type III, using objects of grossly insufficient length, shape, or rigidity, such as insertion of short pieces from the H-tool, or insertion of grass or leaves. An additional error type, Type Z, was noted if a correct tool was chosen but then discarded prior to solution. The frequency of errors by Type (and percent of samples in which errors occurred) was calculated per 10-trial block.

Reliability: Many sessions were coded live and all trials in both phases were videotaped for later coding and reliability assessment.

One coder scored all trials of phase I (acquisition) either live or from videotape. Reliability assessments were conducted by an additional coder on 27 trials (percent agreement was 88 and Cohen's Kappa was .80). A second coder scored all trials of phase II (comprehension). Reliability assessments were conducted by a third coder on all 40 trials of one subject. Reliability of comprehension coding consisted of three parts: (1) type of error (percent agreement was 86; Cohen's Kappa was .74); (2) success analysis (percent agreement was 75; Cohen's Kappa was .63); and (3) modification analysis (percent agreement was 94, Cohen's Kappa was .83). These reliability estimates are considered good to excellent (Bakeman & Gottman, 1986).

RESULTS

Phase I: Acquisition

Five of the six subjects learned to solve the tool task, i.e., they achieved criterion for acquisition in Phase I (see Table 1). The sixth, Jarred, in the model condition, had not learned to solve the task after 163 trials, and testing with this subject was discontinued. A clear effect of age is evident in trials to criterion. The youngest subject required 163 trials; the oldest two subjects required 25 trials and 1 trial respectively.

All subjects were interested in the task. Most subjects initially attempted to solve the task without the tool, i.e., they touched the side of the tube near the food with their hands, trying to reach the food directly. Following failures at direct reaching, subjects attempted to reach the food by inserting their fingers or tongues into the end of the tube, another type of behavior coded as an attempt to solve without the tool. Solution occurred soon after the subject attempted to touch the food with the tool, except for the youngest subject Donald (see Table 2). This subject attempted to touch the food with the tool as early as the 5th trial, and repeatedly thereafter, but did not succeed until much later, after intervention. He was also one of the first subjects tested, and was initially presented with the longer tube. Some of his difficulty with the task appeared to derive from the biomechanical problems posed by a long tool. When the shorter tube and tool were substituted after Trial 77, he rarely attempted to contact the tube with the tool until an intervention was initiated at trial 131. This intervention consisted of having the tool inserted half way into

Table 1. Performance during Phase I for each chimpanzee. Interventions: 1, shorter tool and tube; 2, additional food items; 3, tool partially in the tube; 4, model solution before each trial (intervention 4 is considered an intervention only in the no-model condition).

Condition	Subject	Age (Yrs; Mos)	Trials to solution	Intervention type and trial
No Model	Donald	2;0	163	1(77), 3(131)
	Katrina	2;10	79	1(19), 3(46), 4(67)
	Tank	3;7	25	no intervention
Model	Jarred	2;1	dropped after 163	1(77), 3(131)
	Scott	2;11	27	1(27)
	Keith	4;0	<1	no intervention

Table 2. Summary of behaviors in first and last 25 trials in Phase I (acquisition). * solved in first 25 trials; + never did solve.

Cond.	Subject	First 25 Trials			Last 25 Trials		
		Total # Intervals	Attempts to solve (%)		Total # Intervals	Attempts to solve (%)	
			No Tool	With Tool		No Tool	With Tool
No Model	Donald	486	14	11.5	509	16	9.8
	Katrina	600	26	0	549	26	5.1
	Tank	579	20	0.3	*		
Model	Jarred				+		
	Scott	589	25	5	*		
	Keith	2	50	50	*		

the tube. He subsequently solved the task 2 trials later, and intermittently for the next 30 trials, passing criterion at trial 163.

All the subjects except Keith explored and manipulated the tool prior to attempting to use it to reach the food, and all except Tank showed behaviors combining the tool with the tube just preceding solution. Following their initial solution, only the youngest subject did not proceed directly through 3 successive solutions.

The presence of a model was associated with a substantially reduced number of trials to solution in the two older age groups. The two-year-old who observed the model, however, was unable to solve the task. The 3-year-old, Scott, with a human model, solved the task in approximately one-third the amount of time that Katrina, with no model, took to learn to solve the task (see Table 1). In fact, Katrina received intervention up through modeling by a competent human; Katrina achieved solution after 12 trials of modeling. Among the 4-year-olds, Tank (without a model) solved the task in 25 trials but Keith, with a model, solved in the first trial. The plan was for a human to model for Keith. However, because Katrina was present as his social companion, and she was already proficient at solving the task, we let her model the first trial. Since Keith solved the task after this first model trial, there was no human model provided for him.

Phase II: Comprehension

All subjects solved most tasks but there was some variability in number of successful trials (see Table 3). Again, there appeared to be a difference among subjects attributable to age. The youngest solver (Donald) succeeded at the H-tool and short tools on a few trials but had no success with the bundle. The older subjects were much more successful. The 3-year-olds, Katrina and Scott, solved most trials of all three complex tools. They had more trouble with the H-tool than the other complex tools (both solved 3 out of 5 trials in the first block and 4 out of 5 in the second). The 4 year-olds, Tank and Keith, exhibited the most disparity. Keith solved all trials of all complex conditions in both blocks. Tank, however, solved only 2 out of 5 trials of the bundle in the first block, and never solved the H-tool problem in either block of trials.

Type I errors, inserting one short-tool on each side of the tube, were observed to occur at least once in each subject in the short-tool trials. Occasionally, the younger subjects removed the initially correctly placed single short-tool (Type z error) but neither of the 4-year-olds exhibited this error with the short-tool. Common errors

Table 3. Number of trials solved and number of errors made by chimpanzees in each block of 5 trials in Phase II (Comprehension). N; Number of trials solved; E; Errors made in each block.;* indicates less than 5 trials per block.

		Regular Tool				Short tool			
Condition	Subjects	First Block		Second Block		First Block		Second Block	
		N	E	N	E	N	E	N	E
No Model	Donald	5	0	5	0	3	3	2	2
	Katrina	5	0	5	0	4	4	5	5
	Tank	5	0	5	0	5	3	5	1
Model	Scott	5	0	2*	0	5	2	5	5
	Keith	5	0	5	0	5	0	5	1

		Bundle				H - tool			
Condition	Subjects	First Block		Second Block		First Block		Second Block	
		N	E	N	E	N	E	N	E
No Model	Donald	0		0		1	3	1*	3
	Katrina	3	1	5	1	3	5	4	0
	Tank	2	8	5	5	0		0	
Model	Scott	5	4	2*	3	3	4	4	8
	Keith	5	3	5	0	4*	3	5	6

with the bundle included attempting solution prior to detaching a tool of an appropriate diameter (Type II error), and attempting solution by using grass, pieces of masking tape, or water (Type III error). With the H-tool, both Type II errors (trying to solve without first detaching the block) and Type III errors (trying to solve with pieces that were too small, or with inappropriate objects, such as grass or water) were

Table 4. Comparison of first and second block of trials in Phase II (Comprehension). C denotes change from first to second block; - decrease, + increase, = no change.

Conditions		Total # Errors	Trials with errors (%)			Trials solved (%)			Trials solved with errors/trials solved		
			Trials 1-5	Trials 6-10	C	Trials 1-5	Trials 6-10	C	Trials 1-5	Trials 6-10	C
By Subject	Donald	27	40	33	-	27	20	-	50	33	-
	Katrina	57	47	40	-	67	100	+	40	40	=
	Tank	88	80	67	-	47	67	+	71	60	-
	Scott	57	67	83	+	87	92	+	38	18	-
	Keith	22	40	33	-	93	100	+	43	33	-
By Condition	No Model	145	63	53	-	57	83	+	53	48	-
	Model	79	53	55	+	90	96	+	41	27	-
By Age	3-year olds	114	57	59	+	77	96	+	39	31	-
	4-year olds	110	60	50	-	70	83	+	52	44	-

exhibited by all the subjects. Katrina, the 3-year-old without a model, did not make any errors in the second block of trials with the H-tool.

The percentage of trials with errors is shown in Table 4. Note that Donald, the youngest subject, had relatively few errors, but there were many trials in which he did not attempt solution. He correctly solved only 44 percent of the trials overall, none of the bundle, and only one in each block of the H-tool. In contrast, the older individuals solved the task on 67% to 100% of trials and made attempts to solve with each type of tool.

Exposure to a model during acquisition appeared to affect the subject's performance in the complex conditions (Table 4). More total errors were found in the subjects who did not have a model compared to those who did receive a model (145 compared with 79 errors). Moreover, the percent of correctly solved trials was higher for the model sujects (96% vs 76%). In contrast to acquisition, in the complex conditions, it did not appear that age contributed to either fewer errors (114 vs 110 errors) or a higher percentage of correctly solved trials (88% versus 84% correct).

Performance improved for almost all subjects in the second block of trials compared to the first block (Table 4). This was true if performance was considered as an increased percentage of trials solved (4 out of 5 subjects solved a greater percentage of Block 2 compared with Block 1 trials), a decreased percentage of trials with errors (4 out of 5 subjects), or a decrease in the percentage of solved trials with errors (4 out of 5). Again, by this analysis, the subjects who had models performed better than the subjects who did not have a model. The older subjects did not, however, perform better than the younger subjects in the complex tool conditions.

DISCUSSION

The answer to the first question we posed was a clear "yes". Age contributed to acquisition and competence in the tool-using task presented to young chimpanzees. The 2-year-old chimpanzees had the most difficulty learning to solve the tool task, whereas the 4-year-old chimpanzees had the least difficulty learning. The answer to the second question was a qualified yes. Observation of a competent and successful model facilitated acquisition, but only for the older subjects. Finally, the answer to the last question was also yes; the ease of acquisition was associated with comprehension. We discuss these findings below in terms of the linkages among spontaneous acquisition, effectiveness of a model, and other indicators of cognitive abilities.

Link between acquisition and effectiveness of a model

Three- and four-year-olds learned to use the tool more quickly than two-year-olds, and also showed benefit from exposure to a model. It appears that the model was only effective, however, when operating in the "zone of proximal development" (Vygotsky, 1978), as illustrated with the failure to learn by the 2-year-old Jarred. This is similar to the picture with human children; 13 months is the lower limit of age to solve this task spontaneously (Troise, 1991). Children between 13 and 14 months exposed to a model were no more likely to solve this task than like-aged children not exposed to a model (Visalberghi & Limongelli, in press). Thus, the facilitatory effect of a model, for human and some nonhuman primates, can operate only after a certain developmental threshold has been reached. Finally, this study suggests that a 4 year-old chimpanzee may have imitated the solution of the task demonstrated by a conspecific model.

In general, the effect of the model increased in potency with the age of the subject. For chimpanzees two years and younger, and for children 14 months and younger, exposure to a model did not improve the subject's performance with the same objects. Older human and chimpanzee subjects were able to extract more information from the model's behavior such that specific actions might be copied or further direct exploration of the task might be promoted.

Link between effectiveness of a model and social cognition

Recent thinking about the process of social learning in human children suggests that observation of models and participation in the activities of others serves a fundamental role in the development of many features of species- and culture-normal activities (Rogoff, 1990). In humans, this process has at its base the human tendency to attend to other individuals, often called social referencing (Rogoff, 1990; Stern, 1985). Social referencing in humans emerges within the first year of life, and is evident in the normal interchange between infants and others from about 6 months of age onward (Feinman, Roberts, Hsieh, Sawyer & Swanson, 1992), well before infants are able to copy tool-using actions, for example. Other data from Bard's laboratory (Bard, 1991; Bard, in press; Bard, Platzman, Suomi, & Lester, 1994; Bard et al., 1992) have shown that nursery-reared chimpanzees attend to a human caretaker's face and show social referencing by one year of age (e.g., Russell, Bard, & Adamson, 1995). Gomez (1990) has reported similar capabilities in a hand-reared gorilla interacting with humans.

Tomasello, Kruger, & Ratner (1993) argue that chimpanzee subjects in successful studies of imitation and cultural learning have been reared and tested in predominantly human environments and that studies with individuals living in conspecific groups have not produced evidence of imitation. We agree that the human social environment has a potentially powerful influence in the shaping of chimpanzee behavior (e.g., Bard, 1994-b, Bard et al., 1995) but we would highlight two additional points. The first point deals with the assumption that imitation occurs only in the human environment and, thus, does not occur in the natural habitat (Russon, Bard, & Parker, in press). The existence of neonatal imitation, both in humans (Meltzoff & Moore, 1977; Kuguimutzakis, 1985) and in chimpanzees (Bard, in press), however, suggests that there is a congenital capacity for imitation in both species. Second, the human social environment is potentially as important a shaper of behavior in humans as in nonhuman primates. Therefore, the argument that imitation emerges as a result of being reared within a human environment could hold true for human infants as well as for chimpanzee infants. What remains to be addressed is the question of process: do chimpanzees imitate via processes that are similar to those of humans?

Young chimpanzees might also profit from scaffolding of activities similar to that present in a typical human rearing environment. Available data indicate that adult aid for youngsters' activities is more often serendipitous than intentional in chimpanzees, although a few examples of active "teaching" have been reported (Boesch 1991, see also Bard, 1993; for a review see Caro & Hauser, 1992).

In humans, social attention and attraction to others on the part of the infant is paralleled by activities of others that structure the young individual's learning experiences. The social basis for such learning, and the recognition on the part of the infant that others are capable of more than itself, is evident in the infant's behavior of asking for help. This is a characteristic of young children during tasks which are just beyond their capability, such as 14-month-old human infants given the tube task (Troise, 1991; Visalberghi & Limongelli, in press). It is interesting to note that neither Donald, Katrina, nor Tank, the no-model subjects, made any requests for help from the experimenter. All enjoyed interactions with the experimenters during the task. One subject from the model condition, Scott, did solicit help from the experimenter. After the model demonstrated solution and the tools were laid under the tube, Scott picked up the tool, handed it to the demonstrator and looked expectantly at the tube. Whether soliciting help is an individual characteristic or a product of age and test condition is unanswerable from our data set. All the children tested by Visalberghi & Troise (1993) asked for help prior to learning to solve the task.

Link between acquisition, effectiveness of a model, and cognitive abilities

Our findings can also speak to a proposed link between the ability to recognize oneself in a mirror (MSR) and the ability to imitate a model's actions (Lin, Bard, & Anderson, 1992; Parker, 1991; Whiten & Ham, 1992). The two youngest subjects in the present study, Jarred and Donald, were both tested for ability to recognize themselves in a mirror when they were 2.1 years of age, at the same period of time as the tool task (Lin et al., 1992). The two subjects performed at an equivalent general level (uncertain self-recognition). In the present study, Jarred was not able to solve the task following 163 trials in which a model solved the task while he watched. Donald, in contrast, eventually solved the task without the aid of a model. Additionally, Tank exhibited probable self-recognition at 3 years, 7 months and Keith definitely showed evidence of self-recognition at 2 years, 4 months. Additional evidence suggests MSR develops between 28 and 30 months in chimpanzees (Bard, Roosevelt, & Love, 1995), or as early as 14 months under conditions of extensive mirror experience (Inoue, 1994).

These findings do not support the notion that ability to recognize one's self in the mirror is necessary to succeed at a tool-using task, nor that it is sufficient to predict benefit from observing a model in acquiring a novel tool-using behavior. A more definite test of the lack of a link of MSR with tool use (or imitation of tool use) would be success in the tool task (or benefit from the model in a tool task) combined with the absence of MSR such as is evident in monkeys (Anderson & Marchal, 1994; Anderson & Roeder, 1989). We believe that the ability to benefit from a model may link better with indicators of cognitive capacity other than self-recognition.

The tool task used in this study is designed to differentiate competent performance mediated by associative processes from performances mediated by conceptual processes (Visalberghi &

Trinca, 1989). If subjects can solve all the complex conditions without error then recognition of the causal relations present in the task is indicated. Both human and chimpanzees infants tested to date exhibit incomplete comprehension. Children given the complex tasks displayed errors, just as did the chimpanzees. Sometimes the errors persisted for several months following initial acquisition (Troise, 1991). In fact, only children at 26 months, solved the complex conditions without errors. Apparently the complex conditions do require more from the subject than direct generalization of the behavior which led to success previously. Nevertheless, the decline in inappropriate behaviors and the occasional immediate success with a novel complex condition in both taxa suggest that a conceptual basis for behavior emerges readily in children and apes of appropriate developmental status.

Comparison with other species

A study using the same tool task has been performed with bonobos, chimpanzees, and orangutans (Visalberghi, Fragaszy, & Savage-Rumbaugh, 1995). The subjects ranged in age from three years to over 20. Acquisition by the older apes was almost immediate and quicker than for the young subjects in the present study. Both development and previous experience are likely important contributors to the differences in the rapidity of acquisition. The two youngest subjects, which overlapped in age with the subjects in this study, solved the task about as quickly as the subjects of the current study. The very youngest bonobo subject (3 years of age) did not solve the task in 13 5-minute trials of which the last 5 were interspersed with 10 demonstrations of solution by a conspecific. The other young chimpanzee subject (3 years and 6 months) solved on his 7th 5-minute trial with no exposure to a model, and followed a course of acquisition similar to that observed in the subjects in this study. These results provide corroborating support for our hypothesis that age constrains both acquisition and the effectiveness of a model.

Some capuchins learned to solve the tool task within 2 hours, whereas others have never learned (Visalberghi, 1993). In contrast to humans and apes, modeling solution of the tube task had only nonspecific effects on behavior toward the tool task in both adult and juvenile capuchins (Visalberghi 1993; for an overview of social influences on tool use in monkeys see Fragaszy & Visalberghi, 1990 and Visalberghi & Fragaszy, 1990).

Conclusions

The field setting provides important information on the development of tool use in chimpanzees. In nature, young chimpanzees learn to use tools at tool sites in the presence of their mothers and after watching them for extended periods. During the long tool-using sessions, infant chimpanzees explore, chew, and play with discarded tools, and exploit the food obtained by their mothers (and other individuals). In this social milieu, they gradually acquire their skills in using tools (Boesch, 1991; Boesch & Boesch, 1990; Goodall, 1986; Matsuzawa & Yamakoshi, in press; McGrew, 1992). A field site is surely not the ideal place in which to study experimentally the possible influences of exposure to model on learning. However, it provides insight on the variety of factors which are involved in the acquisition of skills in a social setting. The present experiment used nursery-reared chimpanzees for which the social milieu was peers and humans. In this case exposure to models was controlled. Our results highlight the positive role that watching somebody performing a tool using behavior can have on its acquisition. This study also demonstrates that, as is the case for human children, there is no advantage to chimpanzees of observing a model when the task is too far beyond their capabilities, i.e., the observers are too young. Although all the chimpanzees older than 2 years learned the tool task, they all showed errors in modification of a complex tool prior to its use. Young chimpanzees, like young children, evidently have an incomplete understanding of the properties of a successful tool. Further confirmation of the generality of our findings awaits future research.

ACKNOWLEDGEMENTS

This investigation was supported in part by NIH Grant RR-00165 from the National Center for Research Resources to the Yerkes Regional Primate Research Center, by NIH Grants RR-03591 to R. B. Swenson, RR-06158 to K. A. Bard, by a Research Scientist Development Award to D. Fragaszy from the National Institute of Mental Health, and by a Bilateral Italy- USA Travel Grant to E. Visalberghi from the Consiglio Nazionale delle Ricerche. We thank the following people for their assistance in this project: Carolyn L. Fort, Karen Coleman, Josh Schneider, Dick Wagner, Ben Smith, Mike Ringer, Dara Johnston, Sheryl Williams, Sue Curry, Katherine Tate

Nagell, and Kathryn Gardner. We extend special acknowledgements to Mike Tomasello who provided enthusiastic support during the year of data collection and to the anonymous reviewers, and Anne Russon for constructive critiques of the manuscript.

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