1995

Comprehension of Cause-Effect Relations in a Tool-Using Task by Chimpanzees (Pan troglodytes)

Luca Limongelli
Sapienza University of Rome

Sarah T. Boysen
The Ohio State University, emmanharper@aol.com

Elisabetta Visalberghi
Consiglio Nazionale delle Ricerche

Recommended Citation
Limongelli, L., Boysen, S. T., & Visalberghi, E. (1995). Comprehension of cause-effect relations in a tool-using task by chimpanzees (Pan troglodytes). Journal of Comparative Psychology, 109(1), 18.

Comprehension of Cause-Effect Relations in a Tool-Using Task by Chimpanzees (*Pan troglodytes*)

Luca Limongelli[1], Sarah T. Boysen[2], and Elisabetta Visalberghi[3]

[1] *Sapienza University of Rome*
[2] *Ohio State University*
[3] *Consiglio Nazionale delle Ricerche*

ABSTRACT

Five chimpanzees (Pan troglodytes) were tested to assess their understanding of causality in a tool task. The task consisted of a transparent tube with a trap-hole drilled in its middle. A reward was randomly placed on either side of the hole. Depending on which side the chimpanzee inserted the stick into, the candy was either pushed out of the tube or into the trap. In Experiment 1, the success rate of 2 chimpanzees rose highly above chance, but that of the other subjects did not. Results show that the 2 successful chimpanzees selected the correct side for insertion beforehand. Experiment 2 ruled out the possibility that their success was due to a distance-based associative rule, and the results favor an alternative hypothesis that relates success to an understanding of the causal relation between the tool-using action and its outcome.

According to Cheney and Seyfarth (1990), cognition is the ability to relate different unconnected pieces of information in new ways and apply the resulting knowledge in an adaptive manner. Similarly, knowledge concerning the behavior of objects allows one to act on them effectively and to predict their behavior (Spelke, Breinlinger, Macomber, & Jacobson, 1992). Tool use is a goal directed behavior that allows an organism to overcome a wide variety of problems: Tool use connects means to goals, causes to effects, in ways that respond to the requirements of the task.

The capacity to use tools has been considered one of the major achievements of the human species both at the ontogenetic and phylogenetic levels. The acquisition of means-ends relations and tool use is an important acquisition in child development (Piaget, 1952, 1954), and they are among the few measures of cognitive development that correlate with language acquisition (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). During the 2nd year of life, children begin to solve tool-using problems by trial and error. Children are also gradually able to analyze the problems they face and to comprehend the cause-effect relations between action and outcome. Thus, children acquire the capacity to anticipate the outcome of their actions, mentally represent such outcomes, and plan their behavior accordingly.

Several primate species, such as chimpanzees *(Pan troglodytes),* orangutans (*Pongo pygmaeus*), and capuchin monkeys *(Cebus apella),* show repertoires of tool-using behaviors that appear similar in terms of variety and complexity (Beck, 1980; McGrew, 1992; Tuttle, 1986: Visalberghi. 1990; Visalberghi & Trinca, 1989). However, according to Reynolds (1982),

> tools are as much mental as material, and their description is not a photograph of the material object itself but an empirically verifiable characterization of the mental knowledge and behavioral programs which allow the object to be produced and used. (p. 377)

At this level of investigation, it may be possible to characterize and contrast the key features of tool use in different species that exhibit behaviors similar in appearance.

For example, when a primate uses a stick to displace a reward and thereby render it accessible, does it foresee where the reward is going to go in space? Can it learn to anticipate or represent where its action is going to displace the reward? Does success in tasks that require the displacement of an object by means of another object imply an appreciation of causality? Can success be achieved otherwise?

It is difficult to extract from field observations information about the extent to which an animal appreciates, anticipates, or represents the outcome of its own behavior. Often, as is the case for termite fishing (McGrew, Tutin, & Baldwin, 1979), neither the human observer nor the chimpanzee itself can precisely assess the requirements of the task and the best strategy for success. For example, by observing an animal's use of a tool for termite fishing, it is not possible to assess how deep the termites are in the mound and, accordingly, how long the tool must be to retrieve them. In this case, the human observer can evaluate performance but not competence; success provides a measure of how well the animal handles the task but not the cognitive strategies it uses.

Field studies may frustrate an experimental approach; however, observations in the wild do provide ideas for experiments in the laboratory. An experimental approach may offer an opportunity to present subjects with tasks in controlled situations (e.g., Kummer, Dasser, & Hoyningen-Huene, 1990). For example, paleoanthropologists have found new insights on flaking behavior by providing a bonobo *(Pan paniscus)* with suitable stones for flaking; they demonstrated that the animal was capable of flaking and of appreciating the relation between the sharpness of flakes and their efficiency in cutting (Toth, Schick, Savage-Rumbaugh, Sevcik, & Rumbaugh, 1993). Similarly, Visalberghi and Limongelli (1994) designed an experiment to test whether tool-using capuchin monkeys were able to represent the consequences of their action before the execution of the action itself. For this purpose, Visalberghi and Limongelli (1994) presented capuchins with a transparent horizontal tube that had a trapping hole in the middle (trap tube). A food reward was randomly placed on either side of the hole. Depending on the side in which the stick was inserted, the reward was either pushed out of the tube or fell through the hole into the trap and became inaccessible. Both the capuchin and the human observer could monitor the position of the reward and the effect of the tool on the movement of the reward. Therefore, the nature of the trap-tube task and its visibility were such as to provide systematic information about the subjects' strategies to solve it.

In the trap-tube task, a subject can be 50% successful simply by systematically inserting the stick into the same side of the tube or by inserting it in one of the two sides in every trial by chance. In contrast, rates of success higher than chance can be obtained by avoiding the trap. In the latter case, the subjects could either choose right away the correct side for insertion. or they could first insert the stick and, by watching the tube-reward-stick configuration or monitoring their own attempts, decide their next approach. The former behavior implies an a priori representation of an action that fulfills the requirements of the task (representational strategy), whereas the latter implies an appreciation of the outcome of the ongoing action (anticipatory strategy). (Note that in the anticipatory strategy, representational elements also play a role.) Therefore, this distinction aims mainly at characterizing performances in which the entire strategy is correctly planned in advance from performances in which the strategy is not correctly planned and the subject changes the side of insertion.

Furthermore, in the trap-tube task, it is possible to investigate the processes that lead the subject to above-chance solution, that is, whether the subject develops a rule of action (associative process) or understands that some key features of the task, such as the trap, affect the outcome of the pushing action (comprehension of causality process). We note that the latter process is a multifaceted ability that a species may possess to different extents in relation to different physical principles or in different domains. In this experimental study, we considered causal comprehension to be the subject's knowledge about the causal relation between its pushing action with the stick and the consequent movement of the reward into the trap or out of the tube.

In a previous study with the trap-tube paradigm (Visalberghi & Limongelli, 1994), it was found that only 1 capuchin subject (out of 4) was successful above chance. This successful performance was anticipatory and was based on an associative process. On the basis of these results, Visalberghi and Limongelli argued that the capuchins tested did not understand the causal consequences of their actions nor did they appear to learn to do so on the basis of repeated experiences. These findings are in contrast to Chevalier-Skolnikoff's (1989) claim that capuchin monkeys understand the causal relation between tool-use behavior and outcome.

The literature on the use of tools in chimpanzees shows that tool-using behavior appears spontaneously in a variety of contexts, is flexible, and often (as is the case for children) requires years of practice to be fully mastered (e.g., nut-cracking behavior, Boesch, 1991, 1993; Boesch & Boesch, 1983; termite fishing, McGrew et al., 1979; see also Nishida & Hiraiwa, 1982). In addition, there are solid data that show that when nuts are not yet in view, chimpanzees look for, select, and carry hammers of different weights and material (wood vs. stone) according to the type of nuts (i.e., their hardness) they intend to crack open (Boesch & Boesch. 1990). Furthermore, when at the tool site, chimpanzees seem to use the tool efficiently and with foresight: They choose the most appropriate tool available to them, they position the nut on the anvil so that their hits become more effective, and as Matsuzawa (1991) recently reported, they sometimes make use of a wedge stone to keep the anvil stone flat and stable. Therefore, field observations strongly support the hypothesis that chimpanzees represent in advance the requirement of the problem they are going to deal with and the relation between their actions and the outcome (McGrew, 1992).

The capacity to attribute mental states to others involves the comprehension of the causal relation between seeing and knowing. Recent experimental studies have shown that chimpanzees are capable of perspective taking, mental attribution, and empathy (Povinelli, Nelson, & Boysen, 1990, 1992). These findings suggest that chimpanzees may possess the requisite representational abilities to effectively solve the trap-tube task.

In this experimental study we examined the behavioral strategies (representational or anticipatory) used by chimpanzees to perform a goal-directed activity in the context of a tool-using task (Experiment 1) and the cognitive processes (association or comprehension of causality) that may underlie such strategies (Experiment 2).

In Experiment 1, we used the same experimental design previously adopted for capuchins by Visalberghi and Limongelli (1994). On the basis of the literature on tool use in chimpanzees and the recent experimental findings that chimpanzees may be able to appreciate the causal relation between seeing and knowing (Povinelli, Nelson, & Boysen, 1990, 1992), we anticipated that chimpanzees would be capable of understanding the causal relations involved in this tool task.

Experiment 1

Method

Subjects

Five common chimpanzees *(Pan troglodytes)* served as subjects (3 males. Darrell, 13 years old. Kermit, 12 ½ years old, and Bobbv 5 ½ years old, and 2 females, Sarah, 34 years. old, and Sheba, 11 ½ years old). Kermit and Darrell were peer-raised in a laboratory nursery until ages 3 and 3 ½ respectively, and Sheba was human cross-fostered from 4 months until she was 2 ½ years. Sarah was wild born and has been the subject of over 2 decades of studies on linguistic and other cognitive abilities (e.g., Premack. 1976). Bobby came from the entertainment business and arrived at the lab at age 19 months old; he had training on a variety of matching-to-sample studies and other cognitive abilities.

All animals had been immersed in interactional training with their teachers and caregivers in a variety of cognitive tasks (see for example, Povinelli et al.. 1990: Boysen. 1992, 1993: Boysen, Berntson, Shreyer, & Quigley, 1993). However, the chimpanzees had not had formal testing of their tool-use abilities. In the past the subjects had received as an environmental enrichment device a bucket-and-stick apparatus to accommodate dipping behaviors, and they also showed a variety of spontaneous tool-using behaviors with play objects and other materials available in their enclosure (e.g. straw and sticks).

Apparatus

Plain rube. In the baseline condition the apparatus was a horizontal transparent polycarbonate (Lexan) tube 46 cm long and with an internal diameter of 3.7 cm.

Trap-tube apparatus. The trap-tube apparatus was similar to the plain tube, with the exception that it had a cylindrical trap (4 cm deep) secured below a 3.6-cm hole in the center of the tube.

All the chimpanzees adopted two alternative strategies of solution: One consisted of pushing with the stick with enough force that the reward jumped over the hole (a successful *skip* strategy) and the second, of hitting the trap or the tube from above so that the rewards caught in the trap bounced out of the trap, back into the tube. By using these strategies the subjects could ignore the presence of the trap, and they were not compelled to choose the side for insertion on the basis of the position of the reward. Therefore, the apparatus was slightly modified to maintain the required experimental constraints (see Figure 1).

In the new version of the apparatus, the tube remained visible but could not be hit directly (the Lexan transparent sides of an A-frame protected it), and the trap consisted of a wider hole that could not be skipped. The trap tube was a 50-em-long tube with a hole 11 cm long and 4 cm wide in its middle part. This tube was secured in a transparent Lexan A-frame with the tube readily visible. No trap was used, however, because the A-frame sides prevented the chimpanzees from retrieving the candy rewards that fell to the ground through the hole. Because the A-frame apparatus has the same cognitive requirements of the trap tube, we refer to either tube as a *trap tube.*

The A-frame apparatus was introduced at Block 5 for Sarah, at Block 3 for Darrell, at Block 4 for Kermit and Sheba, and at Block 7 for Bobby.

The tube was mounted on an inverted V-shaped metal frame that held the tube 46 cm above the ground. The A-frame apparatus was also fixed to this metal frame. The entire apparatus was then fixed to the floor of an outdoor cage (3.10 m wide × 2.36 m high × 5.32 m long). The distance of the apparatus from the walls was at least 1.1 m. and the subject was thus free to move around it. The tool provided to push the reward out of the tube was a wooden dowel (46 cm long and 3.2 cm in diameter).

Figure 1. The A-frame trap-tube apparatus. Bobby opens his mouth while pushing the reward with the stick. In this case the reward (placed on the right hand side of the trap) is going to fall ino the trap because the stick has been inserted in the wrong side of the tube.

Procedure

The subjects were tested individually. Baiting was not seen by a subject. A trial began when a chimpanzee approached the apparatus (about 1 m) and attended to the tube. Before entering Experiment 1, the subjects (who were all naive with the tube task) were presented with 10 trials of the plain tube task, which they spontaneously solved. The youngest subject, Bobby, required one instance of modeling by an experimenter before he could reach solution for the first time. In the following trials, Bobbv did not perform differently from the other subjects. Therefore, when Experiment 1 began, all subjects were equally experienced and proficient in the simple version of the task.

The reward was placed on the right or left side of the trapping hole inside the tube (from the experimenter's point of view). The reward could be obtained (solution) only by inserting a stick into the side opposite to where the reward was located and pushing it out of the other opening. Conversely, if the subject inserted the stick into the opening of the tube that was closer to the reward and pushed the stick, the candy fell into the trapping hole (failure). Trials in which solution was reached by using alternative strategies (e.g. skip strategy or hitting strategy) were discarded and repeated at the end of each block. The subjects were exposed to the task in 14 blocks of 10 trials, and each subject underwent a maximum of 3 blocks per day.

Behavioral Variables

The experiment was videotaped, and the following behavioral variables were scored from the tapes by Luca Limongelli: (a) the number of successes and failures (i.e., number of rewards obtained or pushed into the hole) per block; (b) the time to solution measured from when the subject first approached to within 1 m of the apparatus to when solution or failure was achieved (if a subject left the apparatus without completing the trial, because it was distracted by noises or by social interactions in the other cages, the stopwatch was stopped and reset); and (c) the side and the number of insertions performed, including those that did not lead to success or failure.

Insertion was defined as the act of inserting the stick into the opening of the tube to a depth of at least 2 cm. As shown in Figure 2. a subject could then push the stick all the way through (single-insertion trial), or it could retrieve the stick out of the tube and perform another insertion (in the same side or in the other; multiple-insertion trial).

The performance of each chimpanzee was first analyzed to establish whether it was at chance or above chance. Performances above chance were further analyzed to assess whether the subjects were representing the requirements of the problem before acting on it (representational strategy) or whether they first inserted the stick and then, by watching the tube-trap-reward-stick configuration and monitoring their own attempts, decided what to do next (anticipatory strategy). For this purpose the trials were scored to assess whether single insertions accounted for solution more than expected by chance. The representational strategy was hypothesized when in a significant number of trials, success was achieved after the subjects inserted the stick only once; otherwise, the representational strategy was rejected, and an anticipatory strategy was hypothesized.

Finally, other behaviors relevant for distinguishing representational and anticipatory strategies were scored from the tapes.

Data Analysis

The binomial test was adopted to assess the statistical significance of the results, the null hypothesis being 50% success. The data were analyzed in terms of the number of successes per block, performance in the first half of the experiment (Blocks 1-7) versus the second half of the experiment (Blocks 8-14), and the number of right versus left insertions. Wilcoxon's test was used to compare times to solution.

Results

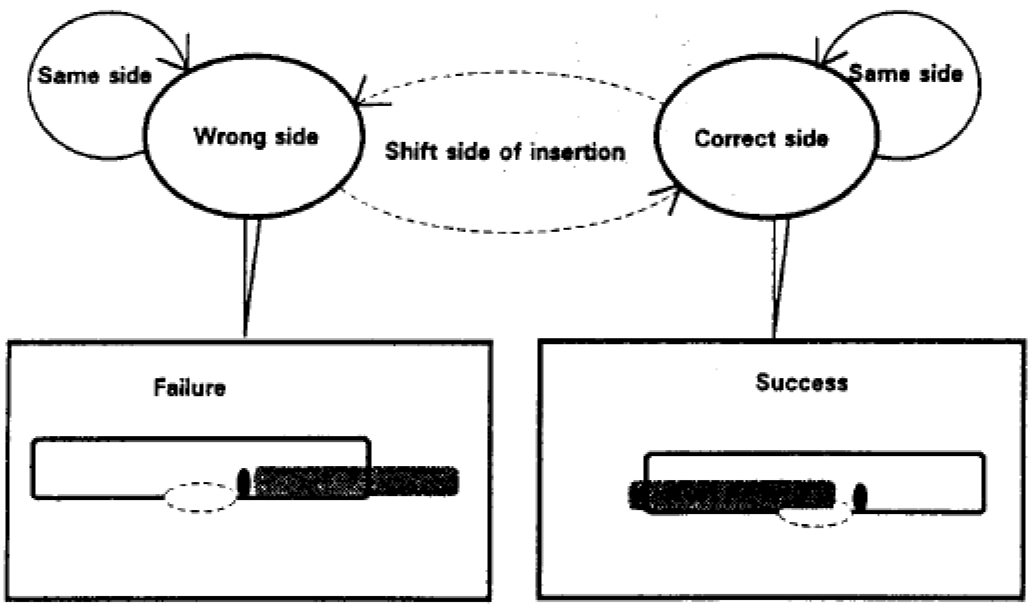
In the first trials all subjects behaved toward the trap tube as if it were a plain tube and reacted to the loss of the reward. The chimpanzees attempted to recover the candies that had fallen into the trap and tried to break the tube open with their hands or hit it with the stick. Furthermore, after they lost the reward, they kept inserting and moving the stick back and forth inside the tube. Such behaviors decreased and eventually disappeared within the first few blocks.

Only Darrell and Sheba solved the trap-tube task significantly above chance. Darrell's rate of success was 69% (binomial test, $N = 140$, $p < .001$), and Sheba achieved 72% (binomial test, $N = 140$, $p < .001$; see Table 1 and Figure 3). In particular, we note that although in Blocks 1-7, their performance was at chance, their success in Blocks 8-14 increased dramatically, reaching 90% for Darrell and 99% for Sheba.

To explore whether Sheba and Darrell used a representational strategy or an anticipatory strategy, we analyzed their performance in Blocks 8-14, that is, once they were solving the task above chance. By comparing the number of successful single-insertion trials with the number of successful multiple-insertion trials, it is possible to assess which solution strategy was used. Under these criteria Sheba was able to represent beforehand the outcome in 64 of 69 (93%) successful trials. Darrell solved the task by representing beforehand the outcome in 52 of 63 (83%) successful trials.

Kermit's rate of success remained at chance throughout the experiment. Bobby's performance was significantly below chance level throughout the experiment, and Sarah's performance was below chance level for the first half of the experiment (Blocks 1-7) and remained at chance level thereafter (see Figure 3 and Table 1). Performance below chance may reflect a direct bias toward the candy and an associated stick insertion in the nearest end of the tube.

Figure 2. The possible sequences of insertions of the stick into the trap tube. In both examples a reward is placed on the right side of the trap. The choice made by the subject when inserting the stick for the first time is described in the oval. The first insertion may be correct or incorrect; if the subject pushes the stick all way through, the correct insertion leads to success, whereas the wrong insertion leads to failure. Arrows indicate retrieval of the stick, and a new insertion in the same side of the tube. Dashed lines indicate retrieval of the stick and a shift in the side of insertion.



A chimpanzee that performs multiple insertions and switches side of insertion has more opportunities of experimenting with the relation between its actions and outcomes. For example, in the second insertion the subject may persist in its choice or change it. In other words, depending on whether the previously chosen side was correct or not, the subject can positively or negatively change the outcome of the trial by shifting side. Obviously, if there is no side shift, the outcome of the trial is not changed. Following this line of reasoning, we analyzed multiple-insertion trials in both successful and nonsuccessful subjects.

Overall, multiple insertions were infrequent. Both Kermit and Sarah performed multiple insertions in 1% of the trials, Sheba in 4% of the trials, Bobby in 7% of the trials, and Darrell in 19% of the trials. The performances of Bobby (an unsuccessful subject) and Darrell (a successful subject) on multiple insertion trials were further investigated to assess whether multiple insertions represented a strategy for correcting erroneous insertions. Data show that Bobby in 5 trials (across all blocks) shifted from the wrong side of the tube to the correct side and that in 2 trials he shifted from the correct side to the wrong side. Darrell instead never ended up in a failure by shifting side; in all the 11 trials in which he shifted side, he corrected a wrong insertion.

Mean times to solution were 11.7 s for Sarah, 10.7 s for Darrell, 9.9 s for Kermit, 8.1 s for Sheba, and 42.0 s for Bobby. Bobby's mean time to solution was significantly higher than those of each of the other subjects (Wilcoxon test, for all comparisons, *ps* < .01). Bobby's higher latencies to solution were mostly because his trials were continuously interspersed with playful behaviors that involved the apparatus, the tools, and other objects available in the cage. For each subject the comparison of the mean times to solution in Blocks 1-7 with that in Blocks 8-14 did not evidence a change.

Table 1. Chimpanzees' Performance (Percentages of Correct Solutions) in Experiment 1

	Blocks			
Subject	**1-14**	**1-7**	**8-14**	**Right-hand insertions**
Sheba	71.4**	44.3	98.6**	67.1**
Darrell	69.3**	48.6	90.0**	30.7**
Kermit	55.0	57.1	52.8	60.7
Sarah	42.8	35.7*	50.0	24.3**
Bobby	32.1**	37.1*	27.1**	48.6

Note. Data are from 140 total trials. For data below 40%, a significance value indicates a significant prevalence of failures. All significance values are based on binomial tests.

* $p < .05$. ** $p < .001$.

Qualitative Descriptions

Sarah. In Blocks 1-7, Sarah tended to choose the side of insertion closest to the reward, and thus her success rate was below chance. In Blocks 8-14, she nearly always inserted the stick into the left side of the tube (64 times out of 70; binomial test, $p < .001$), and overall, her way of approaching the apparatus and her movements for inserting the stick became more stereotyped.

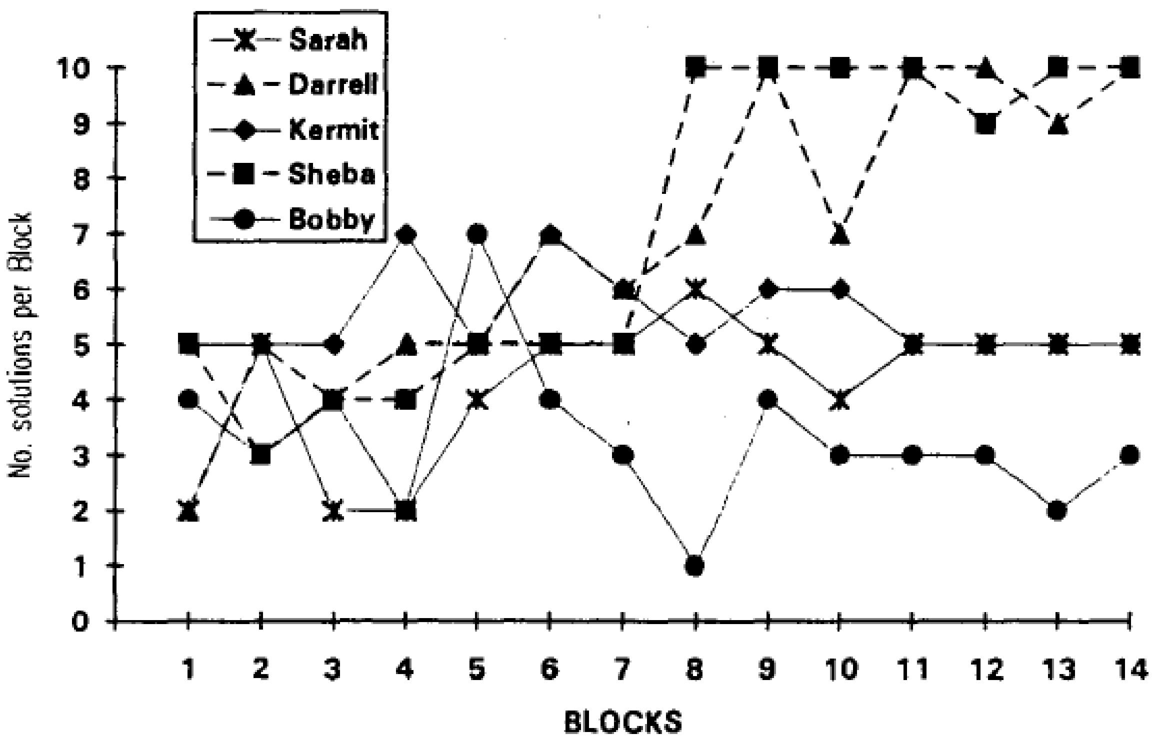
From Block 5 on, a new behavior appeared. Sarah, after inserting the stick into the tube and before pushing it, positioned her hand at the other end of the tube, as if anticipating the arrival of the reward. This behavior was noted in 32 trials, only 16 of which were solutions. This finding suggests that Sarah was not correctly anticipating the actual consequence (failure or success) of her insertion of the stick inside the tube.

Kermit. Across blocks Kermit showed different side preferences. The right-hand opening was chosen in 93% of the trials in Blocks 1-3, in 13% of the trials in Blocks 4-9, and in 98% of the trials in Blocks 10-14.

Kermit kept using the skip strategy even when the apparatus was modified by widening the trap hole so that the reward could not skip over the hole anymore. He performed the skip strategy either while inserting the stick in the wrong side (51 trials) or while inserting it in the correct side of the tube (53 trials). Therefore, Kermit adopted the skip strategy, whether or not the trap was in the way. The fact that Kermit attempted to prevent failure even in those trials in which his behavior would have been correct suggests that he was not able to anticipate the outcome of his ongoing action with the tool.

Bobby. Bobby showed a preference for inserting into the left side of the tube only in Blocks 1-7 (45 left insertions out of 70 trials; binomial test, $p < .05$), and as the experiment progressed, he adopted the wrong strategy of inserting the stick into the opening of the tube closer to the reward, no matter if it was the left or right side (51 failures out of 70 trials in Blocks 8-14; binomial test, $p < .001$).

Figure 3. Results of Experiment 1. Ten trials were given per block.



In 52 trials Bobby kept his mouth open at one opening of the tube while pushing the reward with the stick from the other side (see Figure 1). In 27 trials the stick was inserted in the correct side of the tube, but in 25 trials it was inserted in the wrong side. These findings suggest that Bobby was not able to anticipate failure or success.

Darrell. In the first half of the Experiment, Darrell preferred to insert the stick in the left side of the tube (63 left insertions out of 70 trials; binomial test, $p < .001$). In Blocks· 8-14, he attained 90% correct performance and no longer exhibited a side bias.

On one occasion, during Sarah's Blocks 11 and 12, Darrell was in an adjacent cage and could readily see the apparatus and Sarah working at the tube. In fact, during most of her trials, Darrell sat near the wire mesh partition close to Sarah and the apparatus. (On that same day, Darrell had solved the trap-tube task in 20 out of 20 trials.) In Block 11, Sarah persisted in inserting the stick from the left side of the tube only and failed in Trials 1, 2, 4, 6, and 9. During Trials 4, 6, and 9, Darrell uttered a low bark, which is a low-level alarm call in chimpanzees. It was not possible to assess whether this behavior was intentional or not. On Sarah’s Trial 5 of Block 12, in which she again failed, Darrell spit some water at her, which had not been previously observed. However, Darrell's behaviors did not seem to affect Sarah in any way.

Sheba. In the first half of the experiment, Sheba had a strong preference for inserting the stick into the right-hand side of the tube (60 right insertions out of 70 trials; binomial test. $p < .001$), which she abandoned abruptly in Block 8. From that point on she became highly successful.

During Trial 9 of Block 5, Sheba performed an unexpected type of tool behavior: She used long, rigid pieces of straw to dislodge rewards that had fallen to the ground under the A-frame. In fact, there was a narrow space between the floor and the panel of the frame, which allowed her to insert the straw and rake out the candy. During Trial 10, soon after she made this discovery, she used a straw to rake in the reward from inside the tube. That trial was discarded, and straw rigid enough for raking was removed from the cage.

Experiment 2

In the study by Visalberghi and Limongelli (1994), the only successful capuchin monkey solved the trap-tube task by adopting a distance-based associative rule. The capuchin inserted the stick in the side of the tube that was farther from the reward and did not comprehend how the tool action affected the displacement of the reward inside the tube. In Experiment 2, we investigated whether Sheba and Darrell had developed a distance-based associative rule to solve the trap-tube task.

Method

Subjects

The subjects in Experiment 2 were those chimpanzees who solved the task in Experiment 1, Sheba and Darrell.

Apparatus

In addition to the framed trap tube used in Experiment 1 (hereinafter, *Trap Tube* A), a second tube was used *(Trap Tube B:* 50 cm in length and 3. 7 cm in inner diameter) but with a trap opening (7 cm long and 4 cm wide) at 7 cm from the middle part of the tube (see Figure 4). That is, the hole (trap) in Trap Tube B was closer to one end of the tube. The reward was placed beside the trap (and therefore displaced from the center of the tube). If the chimpanzees used the position of the reward as a landmark to decide which side of insertion was correct, the use of the same rule with the new modified apparatus would lead to failure. In short, the design of Trap Tube B was such that a different success rate from that of Trap Tube A was predicted if a distance-based rule was adopted.

Design

In Experiment 2, trials with Trap Tube A were alternated with trials with Trap Tube B. Trap Tube B reversed the distance-based rule that could be used for solving the task.

Procedure

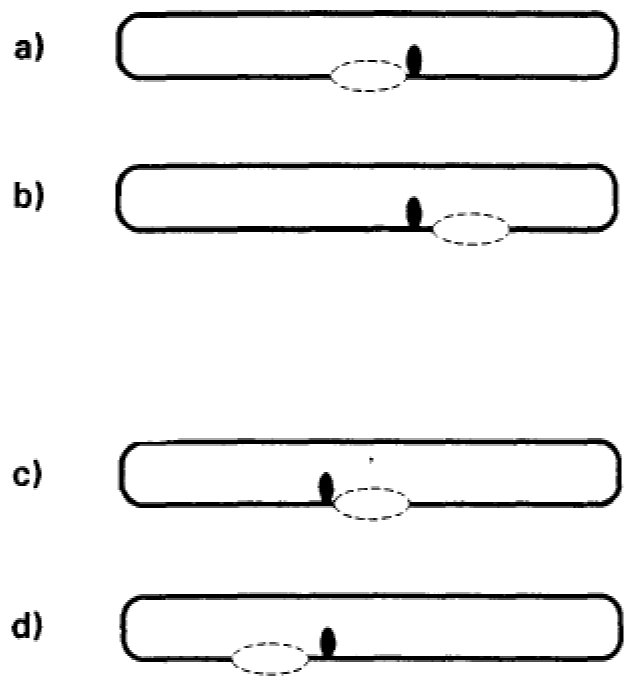
Experiment *2* consisted of 3 blocks of 20 trials each. Trap Tubes A and B were alternated every 5 trials. For the two apparatuses, the sequences of the side of the tube in which the reward was placed were matched and consisted of 5 left- and 5 right-hand positions for each tube. For example, in the first block the sequence was (*R* stands for right, and *L* stands for left) RLRRL with Trap Tube A, followed by RLRRL with Trap Tube B, then LLRLR with Trap Tube A. and followed by LLRLR with Trap Tube B.

This procedure allowed direct comparison of the performance of the subjects with the two types of tubes.

Results

Both Sheba and Darrell solved both conditions highly above chance. In the Trap Tube A condition, both animals scored 30 solutions out of 30 trials ($p < .001$, binomial test). In the Trap Tube B condition, out of a total of 30 trials, there were 29 solutions for Sheba (she failed only in the first trial of this condition, in Trial 1 of Block 1) and 27 solutions for Darrell (he failed in Trials 2 and 9 in Block 1 and in Trial 6 in Block 2). Both subjects were successful above chance in the Trap Tube B condition ($p < .001$, binomial test; see Figure 5).

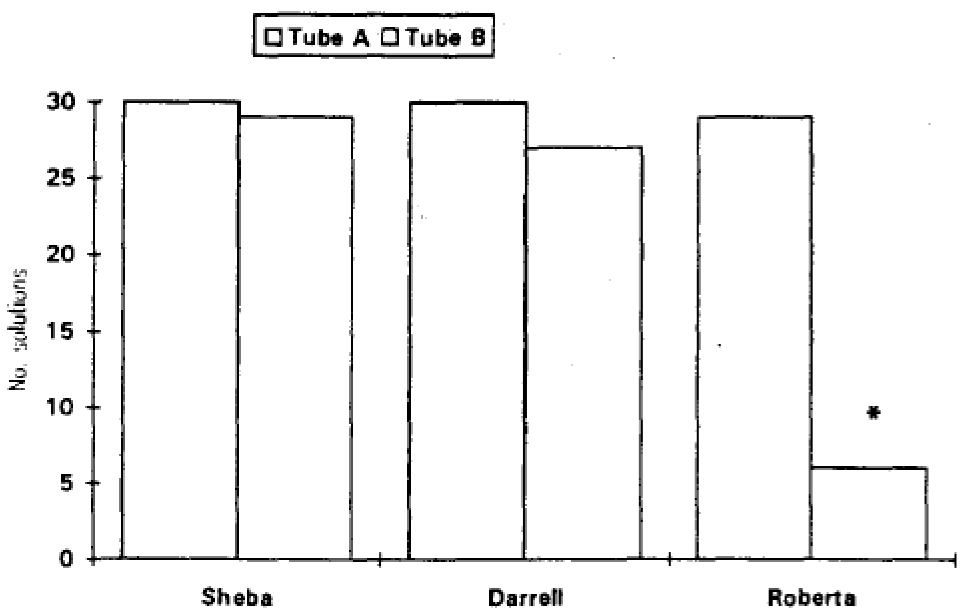
Figure 4. The two apparatuses used in Experiment 2, according to the possible locations of the reward at the beginning of each trial. With the reward on the right side, the trap in Trap Tube A (a) is located in the middle of the tube, but in Trap Tube 8 (b), the trap is displaced from the middle part of the tube, although the reward is in the same position in the tube as in Panel a. With the reward on the left side, the trap in Trap Tube A (c) is located in the middle of the tube, but in Trap Tube 8 (d), the trap is displaced from the middle part of the tube, although the reward is in the same position in the tube as in (3).



As a post hoc comparison, we replicated Experiment 2 of this study with 1 capuchin subject. This monkey (Roberta) was the only subject of 4 tested who was successful above chance in a previous experiment with the trap-tube task (Visalberghi & Limongelli, 1994). Roberta was highly successful with Trap Tube A (29 solutions out of 30 trials; binomial test, $p < .001$). In contrast, when the capuchin was tested with Trap Tube 8, her performance was significantly below chance level (success in 6 out of 30 trials; binomial test, $p < .001$). This subject showed a highly significant statistical difference in performance with the two apparatuses, $\chi^2(1, N = 60) = 36.27$, $p < .001$ (see Figure 5).

As for Experiment 1, to assess whether the chimpanzees adopted a representational or an anticipatory strategy, a comparison between the number of solutions achieved by multiple insertions and single insertions of the stick was performed. When tested with Trap Tube A, Sheba always performed single insertions; when tested with Trap Tube B, she performed 27 single insertions and 2 multiple insertions. When tested with Trap Tube A, Darrell performed 28 single insertions and 2 multiple insertions; when tested with Trap Tube B, he performed 13 single insertions and 14 multiple insertions. These findings suggest that Sheba was able (as in Experiment 1) to choose beforehand the correct side for insertion in both conditions (representational strategy), whereas Darrell was able to do so only with Trap Tube A. When tested with Trap Tube 8, Darrell switched to an anticipatory strategy.

Figure 5. Successful trials with Trap Tube A and with Trap Tube 8 by 2 chimpanzees (Sheba and Darrell) and 1 capuchin monkey (Roberta) in Experiment 2. Each subject was given 30 trials with each apparatus. * *p* < .001 (chi-square test).



Discussion

In Experiment 1, repeated exposure to the trap-tube task allowed 2 (of 5) chimpanzees to solve the task highly above chance. The analysis of their performance allowed us to establish that they represented beforehand the consequence of their actions and mentally organized a strategy for solution. However, when a different apparatus was presented (Trap Tube B in Experiment 2), one of the two subjects did not use the representational strategy anymore.

The results of Experiment 2 rule out the possibility that solution in Experiment 1 was achieved by means of a distance-based rule and argue in favor of the subjects' taking into account other features of the task. This indicates that the success of Sheba and Darrell may have been based on a causal understanding of the relation between action and outcome, because their performance took into account the position of the trap, which is a crucial feature of the trap-tube task.

The performances of the unsuccessful chimpanzees (Sarah, Kermit, and Bobby) are also worth discussing because they provide insights into their strategies. Their performance suggests that a chimpanzee that uses a stick to push a reward out of a tube does not necessarily take into account the causal relations between its action with the tool and the consequent movement of the reward. In fact, some behaviors that we describe earlier indicate that these chimpanzees did not necessarily respond differently to a pending success or failure. The findings suggest that these subjects did not represent effectively nor anticipate the consequences of their action. Furthermore, the comparison of Bobby's multiple-insertion trials with Darrell's suggests that Bobby was not able to take advantage of these opportunities.

Sarah and Bobby (but not Kermit), though unsuccessful, did not choose the side of insertion by chance. These chimpanzees developed systematic strategies and changed them during the experiment. In contrast, with the exception of the only successful subject, the other capuchins did not develop any systematic strategy across blocks, and thus their success rate never deviated from chance (Visalberghi & Limongelli, 1994). We believe that the production of strategies is an important step for the discovery of a rule of action that may lead to success or for the discovery of the relation between action and desired outcome.

Overall, the findings that 3 of 5 chimpanzees were not successful and that it took 70-80 trials for Sheba and Darrell to solve the task above chance suggest that the task was more difficult than we had expected. The difficulty of the trap-tube task is also suggested by the preliminary results of an ongoing study in which 22 children (ages, 27-66 months) were presented with 20 trap-tube trials. Ten out of the 11 younger subjects (below 36 months) performed at chance level. In contrast, 9 out of the 11 older ones succeeded by representing the requirements of the task: the number of trials to criterion (six correct responses in a row) ranged from *2* to 11 trials (Limongelli & Visalberghi, 1994). In contrast to adult humans and older children, our chimpanzees and capuchins did not seem to have an immediate and complete comprehension of where the action was going to displace the reward.

The trap-tube task allows a finer examination, within and across species, of strategies and processes of solution. In capuchin monkeys the presence of the task, at best, led 1 subject (out of 4) to develop an anticipatory strategy based on the distance of the reward from the openings. Instead, 2 chimpanzees (out of 5) developed a representational strategy that took into account the presence of the trap.

Despite the fact that some major species differences were found, we believe that further experiments are needed to evaluate which causal relations are mastered by chimpanzees using tools, and which physical constraints are taken into account. Furthermore, it is also important to assess the extent to which associative learning played a role in the kind of analysis of the task achieved by our successful chimpanzees.

Studies by Povinelli, Nelson, and Boysen (1990, 1992) have suggested that chimpanzees are capable of mental attribution, perspective taking, and empathy, which all require causal understanding. For example, chimpanzees were able to attribute knowledge to an experimenter who witnessed the hiding of food and not to one who did not. In contrast, monkeys did not seem to be able to pass the same kind of tests (Povinelli, Parks, & Novak, 1991, 1992; for a discussion, see Heyes, 1993). Our findings, which suggest that chimpanzees may be able to understand the causal relationships between their action and the outcome, match the evidence for such a capacity in the social domain.

Recently, the theoretical debate on language, deception, and other abilities related to social intelligence in nonhumans has suggested that similar performances may develop from rather different cognitive capacities and that extreme caution is necessary when describing, labeling. and interpreting them. Several authors have urged the necessity of controlled experimentation (e.g., Heyes, 1993; Kummer et al., 1990). The similarities of forms and variety in the use of tools in some nonhuman primate species warrant further investigation. The extent to which the forms of tool-using activities in nonhumans emerge from similar strategies and processes and therefore represent similar comprehension of the key features of a task must be more fully explored. *Tool use* will remain a useful label only if researchers become aware of what a tool is in the mind of its user.

References

Bates. E .. Benigni, L., Bretherton. 1., Camaioni. L., & Volterra, V. (1979). *The emergence of symbols: Cognition and communication in infancy.* New York: Academic Press.

Beck. B. B. (1980). *Animal tool behavior.* New York: Garland Press.

Boesch. C. (1991). Teaching among wild chimpanzees. *Animal Behaviour, 41,* 530-532.

Boesch. C. (1993). Aspects of tool-use transmission in wild chimpanzees. In K. R. Gibson & T. Ingold (Eds.), *Tools, language, and intelligence* (pp. 171-183). Cambridge. United Kingdom: Cambridge University Press.

Boesch, C.. & Boesch. H. (1983). Optimization of nut-cracking with natural hammers by wild chimpanzees. *Behaviour. 83,* 265-285.

Boesch, C., & Boesch, H. (1990). Tool use and tool making in wild chimpanzees. *Folia Primatologica. 54,* 86-99.

Boysen, S. T. (1992). Pongid pedagogy: The contribution of human-chimpanzee interaction to the study of ape cognition. In H. Davis & D. Balfour (Eds.), *The inevitable bond* (pp. 205-217). Cambridge, United Kingdom: Cambridge University Press.

Boysen, S. T. (1993). Counting in chimpanzees: Non-human principles and emergent properties of number. In S. T. Boysen & E. J. Capaldi (Eds.), *The development of numerical competence* (pp. 39-59). Hillsdale, NJ: Erlbaum.

Boysen, S. T., Berntson, G. G., Shreyer, T. A., & Quigley, K. S. (1993). Processing of ordinality and transitivity by chimpanzees *(Pan troglodytes). Journal of Comparative Psychology, 107,* 208-215.

Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world: Inside the mind of another species.* Chicago: University of Chicago Press.

Chevalier-Skolnikoff, S. (1989). Spontaneous tool use and sensorimotor intelligence in *Cebus* compared with other monkeys and apes. *Brain Behavioral Sciences, 12,* 561-627.

Heyes, C. M. (1993). Anecdotes, training, trapping and triangulating: Do animals attribute mental states? *Animal Behaviour, 46,* 177-188.

Kummer, H., Dasser, V., & Hoyningen-Huene, P. (1990). Exploring primate social cognition: Some critical remarks. *Behaviour, 112.* 84-98.

Limongelli, L., & Visalberghi, E. (1994). [Children and apes compared in a tool-using task: How can we "trap" the difference?) Unpublished raw data, Istituto di Psicologia, Consiglio Nazionale delle Ricerche, Rome, Italy.

Matsuzawa, T. (1991). Nesting cups and meta-tools in chimpanzees. *Behavioral and Brain Sciences, 4,* 570-571.

McGrew, W. C. (1992). *Chimpanzee material culture.* Cambridge, United Kingdom: Cambridge University Press.

McGrew, W. C., Tutin. C. E. G., & Baldwin, P. J. (1979). Chimpanzees, tools, and termites: Cross cultural comparisons of Senegal. Tanzania, and Rio Muni. *Man (New series), 14,* 185-214.

Nishida. T., & Hiraiwa, M. (1982). Natural history of a tool-using behavior by wild chimpanzees in feeding upon wood-boring ants. *Journal of Human Evolution. 11,* 73-99.

Piaget. J. (1952). *The origins of intelligence in childhood* (Margaret Cook, Trans.). New York: International Universities Press.

Piaget, J. (1954). *The construction of reality in the child* (Margaret Cook. Trans.). New York: Basic Books.

Povinelli, D. J., Nelson, K. E .. & Boysen, S. T. (1990). Inferences about guessing and knowing by chimpanzees *(Pan troglodytes). Journal of Comparative Psychology, 104,* 203-210.

Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1992). Comprehension of role reversal in chimpanzees: Evidence of empathy? *Animal Behaviour, 43,* 633-640.

Povinelli, D. J., Parks, K. A., & Novak, M.A. (1991). Do rhesus monkeys *(Macaca mulatta)* attribute knowledge and ignorance to others? *Journal of Comparative Psychology, 105,* 318-325.

Povinelli, D. J., Parks, K. A., & Novak, M. A. (1992). Role reversal by rhesus monkeys, but no evidence of empathy. *Animal Behaviour, 44,* 269-281.

Premack, D. (1976). *Intelligence in ape and man.* Hillsdale, NJ: Erlbaum.

Reynolds, P. C. (1982). The primate constructional system: The theory and description of instrumental tool use in humans and chimpanzees. In M. Von Cranach & R. Hasse (Eds.), *The analysis of action* (pp. 343-385). Cambridge, United Kingdom: Cambridge University Press.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review, 99,* 605-632.

Toth, N., Schick, K. E., Savage-Rumbaugh, E. S., Sevcik, R. A., & Rumbaugh, D. (1993). *Pan* the tool-maker: Investigation into the stone tool-making and tool-using capabilities of a bonobo *(Pan paniscus). Journal of Archeological Sciences, 20,* 81-91.

Tuttle, R. H. (1986). *Apes of the world.* Park Ridge, NJ: Noyes Publications.

Visalberghi. E. (1990). Tool use in *Cebus. Folia Primatologica. 54.* 146-154.

Visalberghi, E., & Limongelli, L. (1994). Lack of comprehension of cause-effect relations in tool-using capuchin monkeys *(Cebus apella). Journal of Comparative Psychology. 108,* 15-22.

Visalberghi, E., & Trinca, L. (1989). Tool use in capuchin monkeys: Distinguishing between performing and understanding. *Primates, 30.* 511-521.