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Learning From Others' Mistakes? Limits on Understanding a Trap-Tube Task by Young Chimpanzees (*Pan troglodytes*) and Children (*Homo sapiens*)

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A trap-tube task was used to determine whether chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*) who observed a model's errors and successes could master the task in fewer trials than those who saw only successes. Two- to 7-year-old chimpanzees and 3- to 4-year-old children did not benefit from observing errors and found the task difficult. Two of the 6 chimpanzees developed a successful anticipatory strategy but showed no evidence of representing the core causal relations involved in trapping. Three- to 4-year-old children showed a similar limitation and tended to copy the actions of the demonstrator, irrespective of their causal relevance. Five- to 6-year-old children were able to master the task but did not appear to be influenced by social learning or benefit from observing errors.

Keywords: chimpanzees, children, causal, trap tube

Wild chimpanzee behavior often involves tool use, such as using plant stems to fish for social insects or using stones to crack open hard shelled nuts (Boesch & Boesch-Acherman, 2000; Brewer & McGrew, 1990; Goodall, 1986; Sugiyama, 1985; Sugiyama, 1997; Sugiyama & Koman, 1979; Suzuki, Kuroda, & Nishihara, 1995). Experimental studies focusing on how such skills can be learned by observation have identified a suite of different social learning mechanisms at chimpanzees' disposal, from stimulus enhancement to more complex forms of learning such as emulation and imitation (Whiten, Horner, Litchfield, & Marshall-Pescini, 2004). Research in this area has now progressed to determine when social learning is used (Tonooka, Tomonaga, & Matsuzawa, 1997) and to determine the conditions under which different learning mechanisms are used. Two recent studies indicated that chimpanzee social learning is influenced by the causal relationships involved in a task. Horner and Whiten (2005) found that chimpanzees could selectively exclude irrelevant actions from an observed sequence when the relationship between the tool and part of the apparatus was visible. Similarly, Call, Carpenter, and Tomasello (2005) found that chimpanzees who observed a conspecific fail to open a food container by using one of two alternative methods were more likely to try the nondemonstrated method when they were given the container themselves. Thus, it appears that chimpanzees can determine the causal relevance of certain actions by observing the behavior of others.

Researchers in child development have also become interested in how children learn to use tools by observation and have made explicit links with work in comparative psychology (Want & Harris, 2001). By the age of 3 years, children are able to solve tasks that involve basic causal principles such as contact (Bates, Carlson-Lunden, & Bretherton, 1980), force (von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998), and gravity (Hood, 1995), as well as tasks that require the combination of these principles to correctly predict the outcome of causal events (Bullock, Gelman, & Baillargeon, 1982). Studies that have presented chimpanzees with similar tasks have concluded that chimpanzees may rely more heavily than children on forming associative rules that link causes to effects (Köhler, 1927; Visalberghi & Tomasello, 1998; Povinelli, 2000; Povinelli & Dunphy-Lelii, 2001).

Despite considerable interest in the age at which children learn particular causal relationships, few studies have investigated how children acquire and use this knowledge in the context of social learning. Several studies that have claimed children learn causal relationships by observation have relied on showing that children can transfer knowledge learned in one task to a second task (Bauer, 1992; Bauer & Kleinknecht, 2002; Brown, 1990; Chen, Sanches, & Campbell, 1997). However, in these studies children were given the opportunity to interact with the first set of apparatus before being tested with the second. Accordingly, individual learning, rather than social learning, may have influenced children's appreciation of the causal relationships tested in the transfer condition.

Want and Harris (2001) instead used a trap-tube paradigm—developed by primatologists Visalberghi and Limongelli (1994), who built on previous tube paradigms used by Yerkes (1943) and Ladygina-Kots (cited in Ladygina-Kots & Dembovskii, 1969, and Lethmate, 1977, 1979)—to try to test more directly whether children could learn causal relationships by observation alone. Specifically, they were interested in whether children would learn

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better if they observed an adult perform errors as well as successes in a tool-use task. A similar task is used in the present study.

To solve the trap-tube task, the participant must use a tool to push a desirable reward from a clear plastic tube. However, the task is complicated by the presence of a trap located in the floor of the tube leading into a small enclosed compartment. Because the tool fits snugly into the tube, the only way to retrieve the reward without pushing it into the trap is to insert the tool into the correct end of the tube (see Figure 1). The reward can be placed on either side of the trapping hole so that the correct end of tool insertion is dependent on the position of the reward relative to the trap. If the position of the reward is counterbalanced across a series of trials, an individual will perform at chance if they either insert the tool randomly into each end or consistently insert the tool into the same end of the tube. Performing significantly above chance levels can be achieved only by avoiding the trap.

To investigate whether children benefit from observing errors, Want and Harris (2001) studied participants who observed one of three different demonstrations: a correct demonstration (C-only) in which the tool was used to successfully retrieve the reward; an incorrect + correct demonstration (I + C) in which the tool was used to first trap the reward and then used to retrieve the reward; and a control demonstration (control) in which the tool was moved above the apparatus but not inserted into the tube. In this design, greater success by participants who observed the C-only demonstration compared with the control demonstration indicated that success was not simply the result of enhancement. Greater success by the I + C group compared with the C-only group indicated that observers benefited from seeing errors.

Want and Harris (2001) found that 3-year-old children who witnessed an adult demonstrator first fail and then succeed in solving the trap-tube task were better able to solve the task in the following 10 trials than those who observed only the correct response. We have used the same basic paradigm to investigate whether chimpanzees benefit from observing errors, and we have included further child groups to permit direct comparison.

Trap-tube tasks have been used to investigate causal understanding in capuchin monkeys (Visalberghi & Limongelli, 1994), apes (Limongelli, Boysen, & Visalberghi, 1995; Reaux & Povinelli, 2000) and birds (Tebbich & Bshary, 2004). These studies provided little evidence that the participants understood the causal relationships involved in the task. Instead, they suggested that successful individuals learned to avoid the trap by forming associative rules of action such as "always insert the tool into the end of the tube furthest from the reward." These rules became evident when the trap was inverted such that it could no longer trap the reward, and participants continued to use rules unnecessarily. More recently, Mulcahy and Call (2006) allowed ape participants to use the tool to rake the reward toward them rather than push it away, as required by the original trap-tube paradigm. With this new methodology, 1 chimpanzee and 2 orangutans learned to avoid the trap. Moreover, their success did not seem to be based on the same set of rules used by apes in previous trap-tube studies because successful participants did not continue to avoid the trap unnecessarily when it was inverted. However, when successful individuals were presented with the original trap-tube paradigm, in which the tool must be used to push the reward through the tube, they failed to avoid the trap. Hence, despite their successful performance with the modified apparatus, they did not seem to fully understand the causal relationships involved in the task because they were unable to generalize the conditions of solution to pushing rather than pulling the tool.

In the present study, unlike previous trap-tube studies, we were not concerned with how the chimpanzees learned to avoid the trap (either by forming rules or understanding causal relationships), only with how many trials it took participants to achieve significant levels of success. In fact, on the basis of the results of previous studies, we predicted that the chimpanzees would solve the task by using associative rules. However, we predicted that chimpanzees who observed a demonstrator perform errors and successes would learn rules faster and hence solve the task in fewer trials than individuals who observed only successes, because chimpanzees can learn by observation to avoid behaviors with undesirable outcomes (Call et al., 2005; Horner & Whiten, 2005). The trap-tube task provides an instructive paradigm to test this hypothesis because when tested individually, chimpanzees can learn rules that allow them to avoid the trap after approximately 60–80 trials (Limongelli et al., 1995; Reaux & Povinelli, 2000). It is therefore a task that is difficult although within the ability of chimpanzees, and hence it is an ideal paradigm with which to test the potential influence of social learning.

We made one possibly significant change to the procedure of Want and Harris (2001), who used a tube with a trap located at one end. Previously, the correct side of tool insertion was alternated by rotating the tube through 180° between each trial, thus making it possible to succeed in successive trials by learning a simple alternating rule. Instead, we used a tube with the trap located in the center and varied the correct side of tool insertion for each trial by placing the reward on either the left side or the right side of the trap in a randomized order. As the results below show, this appeared to

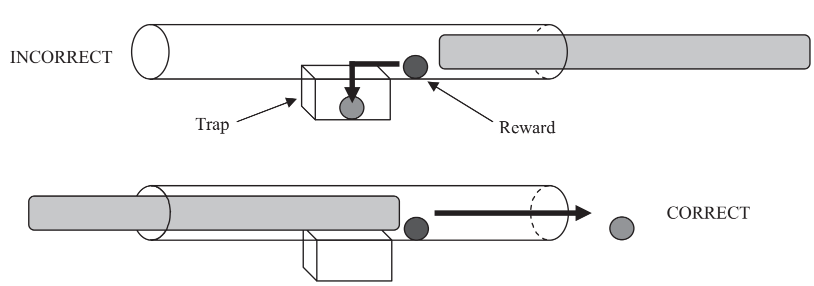

Figure 1. Trap-tube apparatus. Top: Insertion of the tool into the side nearest the reward results in the reward being pushed into the trap. Bottom: Insertion of the tool into the side farthest from the reward results in the food being pushed away from the trap and retrieved.

make the task more demanding even for young children. Accordingly, we have extended the study to include children between 3 and 6 years to permit instructive comparisons.

Experiment 1: Chimpanzees

Method

Participants. Nine chimpanzees (*Pan troglodytes*) from Ngamba Island Chimpanzee Sanctuary, Uganda, participated in the study, ranging in age from 2 to 7 years. For a full description of the study site and the background of the participants, see Horner and Whiten (2005). Fifteen chimpanzees initially took part, but 6 did not complete the study because they became extremely frustrated in their lack of success during the first block of trials and declined to participate further. A similar response to frustration in a study with young chimpanzees was reported by Reaux and Povinelli (2000). The 9 individuals whose data are reported were 3 females (Ikuru, Yoyo, and Pasa, ages 7, 4, and 3 years, respectively), and 6 males (Kalema, Asega, Baluku, Kisembo, Indi, and Okech, ages 6, 4, 4, 4, 3, and 2 years, respectively).

Apparatus. The trap tube was a horizontally mounted transparent polycarbonate tube (60 cm in length, 4 cm internal diameter) with a rectangular trap (6 cm × 6 cm × 12 cm) in the center (see Figure 1). The trap had a small lockable door located on the side to allow the experimenter (but not the chimpanzee) to remove trapped rewards. The tube was mounted 15 cm above the ground on a wooden board bolted to the floor of the research room (see Horner & Whiten, 2005, for details of the testing environment). This allowed participants to move freely around the apparatus and insert the tool into either side of the tube. The tool was constructed from a wooden broom handle, 60-cm long and 3-cm in diameter. Both the trap tube and tool were placed outside the chimpanzees' living area for 24 hr prior to the start of the experiment to reduce the potential for neophobic responses. The 3 youngest individuals, Okech, Pasa, and Indi, had difficulty in accurately manipulating the tool so were given a lighter hollow aluminum tool with a slightly smaller diameter (2 cm) that they could more easily control.

Procedure. The participants were divided into three groups, each with 3 chimpanzees of approximately equal age (the group allocation of each chimpanzee can be seen in Table 1). The chimpanzees in each group observed the experimenter perform one of the following demonstrations: a C-only demonstration, which consisted of a single tool insertion into the correct side of the tube such that the reward was retrieved; an I + C demonstration, in which the tool was first inserted into the incorrect side of the tube to trap the reward, and then the apparatus was rebaited and the tool reinserted into the correct side of the tube to result in success; or a stimulus enhancement control (control), in which the tool was moved across the top of the apparatus but not inserted into the tube. During half the stimulus enhancement control demonstrations, the tool was moved in the direction of a correct solution, during the other half the tool was moved in the direction of an incorrect then correct solution.

The experimenter ate the majority of the rewards she retrieved, but on a few occasions the participant monopolized the end of the apparatus and was able to scrounge the reward. Under natural foraging conditions, it is not unusual for young chimpanzees to scrounge food from older conspecifics (Boesch, 1993), therefore scrounging was minimized but not completely prevented.

The C-only and I + C groups initially received two blocks of 12 trials with a demonstration before each trial. However, the chimpanzees lost interest in these numerous demonstrations, leaving the apparatus to play, and so the number of trials and demonstrations per block was reduced. Participants received eight further blocks of 10 trials with only four demonstrations spread over the block. This new methodology greatly improved participant motivation such that chimpanzees observed all demonstrations and attempted 92.3% of trials (see *Results*). The number of trials in which the food was on the left or right of the trap was counterbalanced within each block and presented in a randomized order such that the reward was never placed on the same side for more than 2 consecutive trials. Each block of trials had a different pattern of reward location (see Figure 2 for an example). Chimpanzees received one block of trials per day, presented as far as possible on 10 consecutive days. The control group received eight blocks of 10 trials with four "demonstrations" (tool not inserted), interspersed within each block, presented as far as possible on 8

Table 1
Percentage of Correct Responses by Chimpanzee Participants

Chimpanzee	Percentage correct: Overall	Blocks 1–5	Blocks 6–10	% left insertions
C-only				
Yoyo	58	50	**67***	91**
Pasa	17**	21**	12**	44
Baluku	32	38	0	41
I + C				
Asega	55	43	**86****	33**
Kalema	18**	17**	18**	52
Okech	23**	19**	31	55
Control				
Kisembo	—	—	—	—
Indi	—	—	—	—
Ikuru	4**	0**	10*	61

Note. Scores for Kisembo and Indi were not recorded because of participant frustration. Bold numbers indicate scores for participants performing above chance. For results less than 50% correct, significance indicates a performance significantly below chance. % left insertions is a measure of side bias.
$^{*}p < .05$. $^{**}p < .001$.

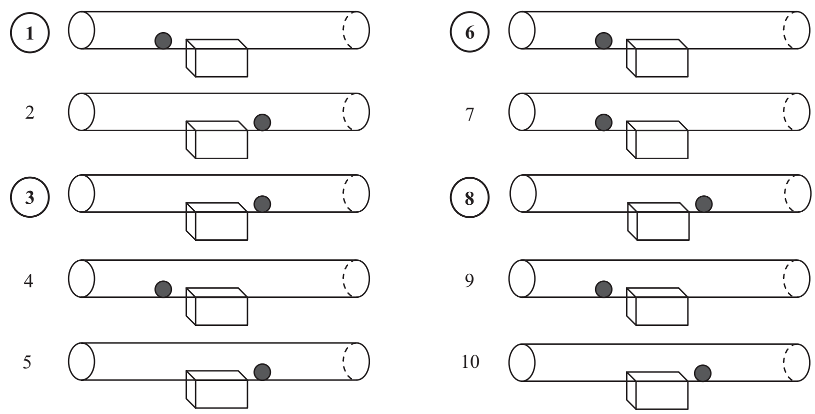

Figure 2. Schematic representation of the reward location during a block of 10 trials—each block had a different pattern. Circles indicate trials that were preceded by a demonstration.

consecutive days. Control participants did not receive the initial two blocks of 12 trials because we had discovered that young chimpanzees rapidly lost interest with this procedure. We therefore used only the improved "10 trial–four demonstrations" format, which elicited increased interest in the task.

Before the very first demonstration, the chimpanzees were given a 2-min familiarization period to explore the apparatus. Participants then observed a demonstration (C-only, I + C, or control; see Figure 3a). During demonstrations, the experimenter first pointed to the reward inside the tube and gave food grunts before using the tool to either retrieve or trap the reward. The chimpanzee was distracted by a second experimenter while the apparatus was rebaited for the chimpanzee trial.

Following an incorrect demonstration, in which the food was trapped in the case of the I + C group (or the tool was moved in the incorrect direction in the case of the control group), the experimenter said "uhh ooh!" to express disappointment. Similarly, following a successful demonstration, for both C-only and I + C groups (or when the tool was moved in the correct direction for the control group), the experimenter said "yay!" Such vocalizations, with their characteristic intonations, are common in studies with human children (Bellagamba & Tomasello, 1999; Carpenter, Akhtar, & Tomasello, 1998; Want & Harris, 2001) and were included here because the Ngamba chimpanzees were familiar with humans making similar vocalizations in conditions of disappointment and pleasure. We realize that these are highly culture-specific expressions that may not have influenced the chimpanzees, but they were included to parallel the potential enhancement of demonstrated actions available in child studies.

Before each trial the tool was placed on the floor near the center of the apparatus, perpendicular to the tube. A trial lasted for 4 min or until the reward was retrieved or trapped, whichever occurred first. All demonstrations and trials were recorded on a camcorder by the second experimenter.

Video coding and data analysis. Behavioral data were coded for the total number of tool insertions, the side of tool insertion on each trial, and the number of correct solutions. These data were analyzed with nonparametric statistics (Mann–Whitney *U* test for unmatched samples). Evidence of cumulative learning effects were examined with a Spearman's Rank Correlation test. All statistics are two-tailed. Occurrences of instructive qualitative data were also noted and are discussed below. A second experimenter, naive to the hypothesis of the study and the identities of the chimpanzees, recoded one block of 10 trials for each chimpanzee, chosen at random to represent 30% of the data set. The codes of the first and second experimenter were then compared with the Kappa coefficient of agreement to calculate the level of interobserver reliability.

Results

One of the chimpanzees from the C-only group, Baluku, requires special consideration because he developed an alternative strategy that did not use the tool to retrieve the reward. Baluku's left hand was injured, and hence his manipulation of the tool was awkward. After 24 trials, he developed a strategy of vigorously shaking the apparatus, which resulted in the reward being shaken away from the trap and retrieved on approximately 50% of trials. Baluku's behavior might be considered a form of tool use because he manipulated an external object (the tube) to gain access to a reward. However, the statistical analysis only includes data for trials in which he attempted to use the wooden tool because the focus of the study was participants' appreciation of critical relationships between the wooden tool, the tube, and the trap.

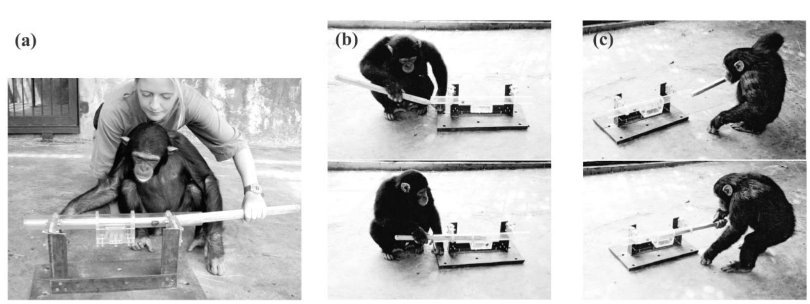

Figure 3. (a) A chimpanzee participant from the I + C group observes the experimenter trap the reward, (b) the participant traps the reward, and (c) the participant succeeds.

All data were coded from the videotapes. Interobserver reliability was extremely high (Kappa coefficient of agreement = 1.0, n = 90).

Stimulus enhancement control group. Chimpanzees from the control group attempted the task (inserted the tool into the tube irrespective of whether the correct side was chosen) on fewer trials than the C-only and I + C groups, who both attempted the task on a median of 92% of trials, compared with a median of 0% by the control participants. The eldest, Ikuru (age 7), attempted the task on 10 trials but succeeded only once. The remaining control participants, Indi and Kisembo, were initially highly motivated to retrieve the reward and spent the majority of their 4-min trial periods trying to squeeze their hands into the end of the tube, biting the tube, or hitting it with the tool. They did not attempt to insert the tool. These activities and interest in the apparatus decreased dramatically during the second half of the experiment.

C-only and I + C groups. Two chimpanzees, Yoyo from the C-only group and Asega from the I + C group, eventually achieved significant levels of success, but only in the latter half of the study after they had extensive experience with the task (see Table 1). The remaining 4 participants did not perform above chance levels. Indeed, 3 performed at levels significantly lower than chance because they repeatedly inserted the tool into the end of the tube closest to the reward (see Table 1). Unsuccessful chimpanzees also attempted to insert objects that were either too short to reach the reward (small sticks and pieces of chewed paper) or too wide to fit the opening of the tube (plastic bottles). These behaviors were spread particularly throughout the first 5 blocks. The 2 successful chimpanzees, Yoyo and Asega, were members of different groups, and hence it is not surprising that there was no significant difference in the performance of the C-only and I + C groups (median success C-only = 32%, median success I + C = 23%; $z = -0.22$, $N_1 = 3$, $N_2 = 3$, $p = .827$). Therefore, there is no evidence that the chimpanzees benefited from observing errors as well as successes.

Successful chimpanzees. Yoyo (C-only) and Asega (I + C) both learned to perform at levels exceeding chance during the second half of the study, in Block 8 after at least 80 trials. Studies using the trap-tube paradigm to investigate individual problem solving indicate that chimpanzees can achieve significant levels of success after approximately 60 to 80 trials (Limongelli et al., 1995; Reaux & Povinelli, 2000). There is therefore little evidence that the performance of Yoyo and Asega was influenced by social learning. However, a more detailed examination of their behavior is instructive.

Yoyo and Asega were the only 2 participants to show a significant side bias. Yoyo preferred to insert the tool into the left side of the tube and Asega in the right. Both individuals were only able to perform above chance, given their respective biases, because they learned to correct their initial side choice by withdrawing the tool if the reward moved close to the trap and reinserting it into the opposite side (see Figure 3b and 3c). This strategy was learned over the course of the experiment because there was a significantly positive relationship between increasing block number and success (Spearman's ρ: Yoyo = 0.825, $p = .003$; Asega = 0.830, $p = .003$; see Table 1 and Figure 4).

The ability to correct mistakes, which at first appears to suggest some insight into the crucial properties of the trapping process, was, however, interspersed with errors. Having corrected a mistake on one trial, it remained possible that they would not correct a mistake on a subsequent trial and so would repeatedly trap the reward. In addition, during each trial neither chimpanzee used single fluid movements to retrieve or trap the reward. Both used several small pushes of the tool on almost every trial. A single push was defined as contacting the reward with the tool causing it to move a short distance along the tube, then pausing before moving the reward again. Yoyo used a mean of 5.6 pushes per trial, and Asega used a mean of 5.8 pushes per trial. There was no significant difference between the number of pushes used for successful trials compared with failed trials, indicating that the chimpanzees did not differentiate between actions that would result in failure or success (Yoyo: median pushes on failed trials = 2, median on successful trials = 3, N-ties = 29, $z = -1.27$, $p = .204$; Asega: median pushes on failed trials = 3, median on successful trials = 2, N-ties = 21, $z = -1.51$, $p = .130$). Even when the correct side of tool insertion had been chosen and the reward was moving away from the trap, they continued to use small tool pushes. Yoyo and Asega were both seen to hold their hands under the reward as it moved through the tube in an apparent attempt to catch it, should it fall (see Figure 5).

These results suggest that chimpanzees did not benefit from observing errors and found the task conceptually difficult. The performance of the successful chimpanzees was not qualitatively different from studies of individual problem solving (Limongelli et al., 1995; Reaux & Povinelli, 2000), despite repeated demonstrations of the correct solution and additional cues (pointing to the reward and vocalizations by the experimenter) that could have been used to form useful associations about the conditions of success. There is therefore no evidence that their behavior was influenced by social learning.

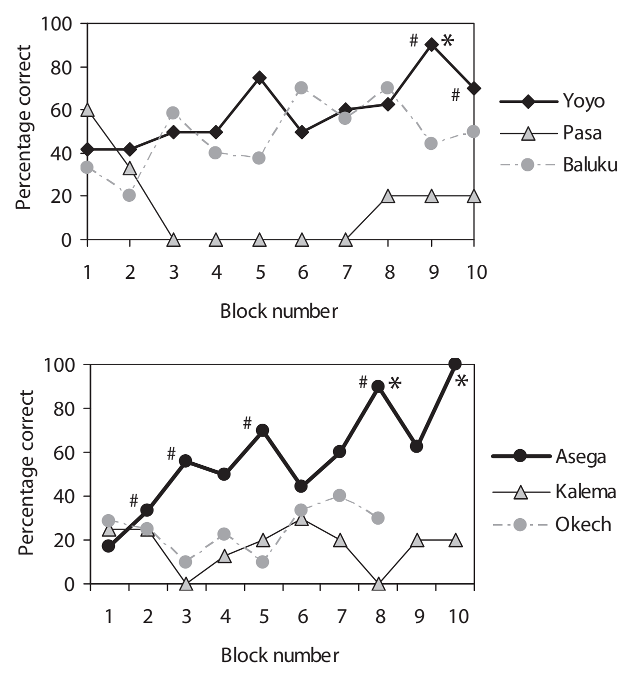

Figure 4. The percentage of correct responses made by chimpanzees: (top) C-only and (bottom) I + C. *Blocks in which the participant performed significantly above chance ($p < .05$). #Blocks in which the participant corrected a mistake. Okech declined to complete the final two blocks of the study.

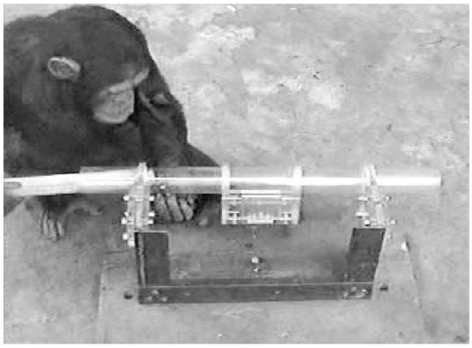

Figure 5. Asega moves his hand under the reward as he pushes it along the tube in an apparent attempt to catch it should it fall through the plastic.

Experiment 2: Children Age 3 to 4 Years

Method

Participants. The participants were 12 children (*Homo sapiens*) age 3 years (M = 3 years 5 months, range = 3 years 0 months–3 years 11 months) and 18 children age 4 years (M = 4 years 3 months, range = 4 years 0 months–4 years 6 months) of both sexes (16 male; 14 female). The children were recruited from a nursery school in St Andrews, United Kingdom.

Apparatus. Relatively trivial modifications were made to the apparatus to make it more suitable for children. Instead of the robust support necessary for chimpanzees, the tube was mounted on legs so it could stand on a table 10 cm from the surface. Children were given a plastic tool constructed from PVC piping, 3.5 cm in diameter and 60 cm in length. In place of food rewards, children had the opportunity to retrieve 10 brightly colored toy dinosaur eggs to avoid potential food allergies.

Procedure. The children were divided into three groups, each of which observed the same demonstrations as the chimpanzees. Whereas Want and Harris (2001) offered just one demonstration followed by 10 trials, we presented children with one block of 10 trials with four demonstrations spread through the block (see Figure 2). This procedure was intended to make testing comparable with the first block of trials for chimpanzees in the control group and with the first block of trials for the C-only and I + C groups once the methodology had been revised to increase interest in the task. A pilot investigation revealed that children were more reluctant than the chimpanzees to interact with the apparatus during the 2-min familiarization period. Thus, the experimenter drew the children's attention to specific features of the apparatus (notably the holes in each end) that appeared to have been discovered by the chimpanzees' physical exploration, so that children had comparable information about the structure of the tube before the first trial.

Children were tested individually in a separate room within the nursery. The apparatus was placed on a small table and the child was asked to sit on a chair in front of the apparatus for the initial explanation and the first demonstration. During demonstrations, the experimenter used the same vocalizations following successful and unsuccessful trials as with the chimpanzees. After the first trial, the majority of children chose to stand up and were allowed to move freely around the apparatus, as was the case for chimpanzee participants. It was felt that the best comparative data would be collected under testing conditions that were as similar as possible. Each session was recorded with a video camera mounted on a tripod behind the apparatus. The video tapes were later coded to determine the side of tool insertion and whether that child had successfully retrieved the reward. A second experimenter, naive to the hypotheses of the study and the identities of the children recoded the video from 1 child from each group, selected at random (representing 25% of the data set) to determine the level of interobserver reliability. At the end of the 10-trial session, every child was given a toy dinosaur, irrespective of their performance.

Results

Interobserver reliability was extremely high (Kappa coefficient of agreement = 1.0, n = 30).

Stimulus enhancement control group. Like the chimpanzees, 3- to 4-year-old children from the control group did not perform as well as children from the C-only and I + C groups (median control = 0, median C-only = 50, median I + C = 55; $\chi^2(2, N = 30) = 7.487$, $p = .024$; see Table 2). These results were not affected by the age of the children (control: median for age 3 years = 68.75, median for age 4 years = 40.00; $z = -1.55$, $N_1 = 4$, $N_2 = 6$, $p = .121$; C-only: median for age 3 years = 50.00, median for age 4 years = 48.33; $N_1 = 4$, $N_2 = 6$, $p = .515$; I + C: median for age 3 years = 55.00, median for age 4 years = 47.22; $N_1 = 4$, $N_2 = 6$, $p = .747$). There was no evidence of a learning effect across trials (Spearman's ρ: control participants = 0.39, $p = .253$; C-only = 0.44, $p = .199$; I + C = 0.451, $p = .191$).

Although the control group performed relatively poorly, their behavior was qualitatively different from that of the control chimpanzees. Four control children reproduced the irrelevant actions that they had observed, moving the tool over the top of the apparatus, in some cases even reproducing the irrelevant vocalizations.

C-only and I + C groups. There was no significant difference between the number of successful responses performed by children in the C-only or the I + C group (median C-only = 50, median I + C = 55; $z = -0.27$, $N_1 = 10$, $N_2 = 10$, $p = .798$), and neither group retrieved the reward significantly more often than would be expected by chance (C-only vs. chance, $z = -0.51$, N-ties = 7, $p = .611$; I + C vs. chance, $z = -1.55$, N-ties = 8, $p = .121$). Hence, 3- and 4-year-old children, like the chimpanzees, did not significantly benefit from observing errors.

Four children showed evidence of a consistent bias (100%) to the left side of the tube (binomial test = 10/10, $p = .002$, for each child; see Table 2), which was the correct side of tool insertion during the first demonstration. This suggests that these children were copying the side used by the experimenter on her first successful trial and continued to do so for subsequent trials, rather than taking account of the causal properties of the task. The unexpected low success of these children, who did not seem to benefit from observing errors, led us to explore how an older sample of children would perform.

Experiment 3: Children Age 5 to 6 Years

Method

Participants. The participants were 9 children between ages 5 and 6 (M = 5 years 6 months, range = 5 years 0 months–6 years 3 months) of both sexes (4 males and 5 females). Children were recruited from a primary school in St Andrews, United Kingdom.

Apparatus and procedure. The apparatus and procedure were identical to Experiment 2. A second experimenter, naive to the hypothesis of the study and the identities of the children, recoded a block of 10 trials for 1 child in each group, selected at random, representing 30% of the data set.

Results

Interobserver reliability was extremely high (Kappa coefficient of agreement = 1.0, n = 30).

Table 2
Percentage of Successful Trials Among Children

	Control		C-only		I + C	
Age/gender	% correct	% left	% correct	% left	% correct	% left
3M	62.5	37.5	100*	50	40	40
3M	—	—	50	50	50	100*
3F	—	—	50	100*	60	90
3F	75	50	50	100*	70	20
4M	30	80	80	50	44.44	44.44
4M	—	—	30	100*	90*	60
4M	—	—	80	50	40	70
4F	50	100*	30	60	50	80
4F	—	—	66.67	30	66.67	44.44
4F	—	—	10*	40	70	40
Median	0	50	50	50	55	52.22

Note. Dashes indicate that children did not insert the tool. For results less than 50% chance, significance indicates a performance significantly below chance. M = male, F = female.
* $p < .05$.

All groups compared. Members of this age group acted in a very different way in comparison with the younger children. Whereas the younger children performed at only chance levels, the older children's success rate was at or close to 100%. Consistent with this near-ceiling achievement, there was no significant difference, nor even a trend, toward differences in percentage success across the three groups (median success = 90% for all groups; N-ties = 9, $\chi^2(2, N = 9) = 0.327$, $p = .849$). These children solved the task significantly more often than would be expected by chance ($z = -2.67$, N-ties = 9, $p = .007$). There was also no evidence of a side bias (median left control = 50, median C-only = 50; $z = -0.69$, $N_1 = 3$, $N_2 = 3$, $p = .487$; median I + C = 40; $z = -0.94$, $N_1 = 3$, $N_2 = 3$, $p = .346$). Therefore, by the age of 5–6 years, children "suddenly" showed good mastery of the trap-tube task, irrespective of their group allocation and thus, the demonstration that they observed.

General Discussion

Chimpanzees

Chimpanzees from the full demonstration groups (C-only and I + C) attempted the task, irrespective of whether the correct side had been chosen, more frequently than those who observed the stimulus enhancement control demonstrations. This difference in performance cannot be explained by differential enhancement, insofar as all groups observed the demonstrator move the tool the same distance in the same direction. The key difference between groups was that chimpanzees from the control group did not observe the tool make contact with the reward and bring about a desirable result. The control chimpanzees were motivated to solve the task, as indicated by their attempts to retrieve the reward by hitting the apparatus and squeezing their hands into the ends of the tube. Previous studies indicated that chimpanzees can solve the trap-tube task via individual learning (Limongelli et al., 1995; Reaux & Povinelli, 2000), and the participants in the present study have used tools in previous social and individual learning contexts (Horner & Whiten, 2005). In addition, it has been suggested that the tendency to use tools is an intrinsic predisposition in chimpanzees, a view supported by the prevalence of probing behavior in numerous wild populations (Whiten et al., 1999; 2001) and in all captive populations for which suitable conditions apply (McGrew, 1992). Why then did the chimpanzees in the control group not use the tool? We think the most likely explanation is that they tended to ignore the tool because they did not view it as relevant to solving the task, as indicated by the failure of the demonstrator to use it to achieve a salient result. This interpretation fits with the findings of Call et al. (2005), who reported that chimpanzees who observed a demonstrator fail a task by using one of two alternative techniques were more likely to avoid the demonstrated method when they were given a chance to solve the task themselves. It is also consistent with our previous study in which the same chimpanzees excluded observed actions that were not directly related to solving a tool-use task (Horner & Whiten, 2005). Thus, the poor performance of the control group, and in particular their lack of tool use, may reflect their sensitivity to the causal relevance of observed actions, extending to neglecting actions that are shown not to be relevant.

Within the groups who observed full demonstrations (C-only and I + C), only 1 chimpanzee from each group learned to avoid the trap, and there was no significant difference in performance at the group level. This result indicates that chimpanzees did not benefit from observing errors in addition to successes. The remaining 4 unsuccessful chimpanzees, Pasa and Baluku (C-only) and Kalema and Okech (I + C), continuously failed to avoid the trap (see Table 1), despite repeated demonstrations of the correct solution in addition to cues from the experimenter (pointing to the reward and making vocalizations) that could have been used to form useful associative rules about the conditions of success. During both demonstrations and trials, they were outwardly distressed by the loss of the reward but despite witnessing the conditions of failure, seemed unable to use this information to modify their own behavior in later attempts. Possible reasons for their poor performance are discussed in more detail below.

The 2 chimpanzees who did learn to avoid the trap—Yoyo (C-only) and Asega (I + C)—both had a side bias, and because the correct side of tool insertion was counterbalanced across trials, they performed at chance during the first half of the study. During the second half of the study, they were able to perform significantly better than chance because they learned to withdraw the tool when the reward moved close to the trap and to reinsert it into the other side. Their respective side biases may actually have aided their performance by adding a level of constancy to their behavior because only the position of the reward altered between trials. This may have made it easier to recognize the conditions of success and form appropriate rules. Their ability to correct mistakes appears at first to rely on some causal understanding of the task. However, their insightful behavior was interspersed with errors, a mixture recognized in Köhler's (1927) classic work. Having corrected a mistake on one trial, it was possible that they would trap the reward on a subsequent trial. In addition, during each trial both chimpanzees used several small tool pushes to move the reward along the tube, with no significant difference in the number of pushes used for successful or failed trials. This behavior indicates that the chimpanzees regarded the whole tube as a "danger zone" and did not appreciate that if the reward was moving away from the trap it was "safe." A similar behavior was reported in woodpecker finches when presented with a trap-tube task (Tebbich & Bshary, 2004). Yoyo and Asega were also seen to move their hand underneath the reward as it moved through the tube, in what appeared to be an attempt to catch it should it fall through the solid plastic.

Visalberghi and Limongelli (1994) and Limongelli et al. (1995) distinguished between *representational* task solution and *anticipatory* task solution. A representational strategy predicts that an individual has a mental representation of the requirements of the task, enabling him or her to solve novel reward–trap configurations by deciding on the correct response in advance. In contrast, an anticipatory strategy predicts that an individual constantly monitors the outcome of his or her actions and uses this information to determine the next maneuver. Yoyo and Asega's multiple push strategy, coupled with their strong tendency to move their hand under the reward, indicates that they were constantly monitoring the outcome of each action before performing the next movement, and hence, their behavior conforms most closely to an anticipatory rule-based strategy.

Overall, the behavior of chimpanzees in the C-only and I + C groups does not seem to have been influenced by the alternative demonstrations they observed. Their data fit most closely with studies that have used the trap tube as an individual learning paradigm. These studies reported that only a subset of chimpanzees learned to avoid the trap (Limongelli et al., 1995; Reaux & Povinelli, 2000) and typically did so by using anticipatory rules about the relation between the tool, the trap, and the reward (Povinelli, 2000; but see Limongelli et al., 1995, who report a representational strategy).

Visalberghi and Tomasello (1998) and Povinelli (2000) have argued that the trap-tube task may be conceptually difficult for chimpanzees because it involves multiple causal relationships: the relationships between the tool and the tube, the tool and the reward, the reward and the tube, and the reward and the trap. It may therefore take chimpanzees many trials to uncover a rule that encompasses each of these relationships. In the present study, 100 trials do not seem to have been sufficient to uncover the crucial rules. In fact, we suspect that rule formation may actually have been hindered by presenting the task as a social learning paradigm, in which the multiple causal relationships were presented simultaneously in the demonstrations, possibly overtaxing information processing capacities. Although Bard, Fragaszy, and Visalberghi (1995) found that chimpanzees could benefit from observing a demonstrator solve a tube task, the tube did not contain a trap, and therefore only one causal relationship was involved in solution: contact between the tool and the reward.

Why is the trap-tube task so difficult? One reason may be that the apparatus is transparent, and therefore it may appear that the reward is floating in midair because it is not perceptually in contact with a solid surface. This may account for the behavior of Yoyo and Asega, who held their hands under the reward as it moved through the tube. In addition, successful retrieval of the reward required that the participant insert the tool into the end of the tube farthest from the reward and, because chimpanzees typically sat in front of the tube opening, they had to push the reward away from their body toward the opposite end. Previous studies have found that chimpanzees have difficulty inhibiting the desire to choose solutions that look perceptually desirable, even if they have experience to the contrary (Boysen & Berntson, 1995; Boysen, Berntson, & Mukobi, 2001). In a recent trap-tube study, Mulcahy and Call (2006) found that a chimpanzee and 2 orangutans performed better when they were allowed to use the tool to rake the reward toward their bodies, rather than push the reward away. It seems that it is hard for chimpanzees to inhibit the desire to take the shortest route to the reward, and therefore the unsuccessful chimpanzees in the present study may have been trying to rake the reward toward themselves. Nevertheless, they had over 100 trials in which to investigate an alternative technique and failed to do so, indicating a lack of understanding of the conditions of failure and therefore the causal relationships involved in the task. It therefore seems possible that although some chimpanzees can learn rules that allow them to solve the trap-tube task in some cases, providing demonstrations actually confused, rather than benefited, the chimpanzees because their ability to learn associations that can be used to form rules was overloaded by presenting multiple causal relationships at once. The conceptual difficulty of the trap-tube task may have overshadowed any evidence that chimpanzees could benefit from observing errors; therefore, it remains possible that positive results might be obtained with a simpler paradigm, as suggested by the results of Call et al. (2005), who used a task that control chimpanzees could solve.

At first, our results appear to contradict our previous findings (Horner & Whiten, 2005), in which the same participants learned to solve a task more efficiently when the irrelevance of certain actions (errors) were made visible. However, in that study, the demonstrations were always the same, and the crucial causal relationship was the single one of contact. The task therefore did not present the complexity of the trap tube.

Young Children Compared With the Chimpanzees

Children from the control group solved the task significantly less frequently than children who observed the full demonstrations (C-only and I + C). However, children of this age group, like the chimpanzees, seemed to benefit from seeing the tool make contact with the reward but did not benefit from observing errors. Nevertheless, their mistakes revealed a different set of misconceptions. Children from the control group rarely inserted the tool into the apparatus, but instead of trying in vain to insert their hands into the tube (as the chimpanzee control participants had done), they tended to reproduce the irrelevant actions of the demonstrator. Several of the children recreated the irrelevant movements of the tool across the top of the tube, in some cases repeating the demonstrator's irrelevant vocalizations. Similarly, children from the C-only and I + C groups showed a bias toward inserting the tool into the same side of the tube as the demonstrator had done on the first successful trial. These observations indicate interesting species differences. It seems that when chimpanzees have an incomplete understanding of an observed behavior, they tend to ignore much of the demonstration and try to achieve success by using their own alternative strategy. In contrast, when human children have an incomplete understanding, they tend to copy a large proportion of the actions that they see, irrespective of their causal relevance. This finding fits with a number of studies that have found children to imitate in situations in which chimpanzees, although capable of imitation, rely more heavily on emulation (Horner & Whiten, 2005; Nagell, Olgin, & Tomasello, 1993; Whiten, Custance, Gomez, Teixidor, & Bard, 1996).

Previous studies have shown that young children (Limongelli, 1995; cited in Visalberghi & Tomasello, 1998), and adults (Silva, Page, & Silva, 2005) are able to solve the trap-tube task when it is presented as an individual problem solving paradigm. The developmental literature also has indicated that children of this age can solve tasks with the same causal relationships as the trap tube: contact, force, and gravity (Bullock et al., 1982; Hood, 1995; In-Kyeong & Spelke, 1999; Krist, Fieberg, & Wilkening, 1993; Shultz, Pardo, & Altmann, 1982; Spelke, Phillips, & Woodward, 1995; von Hofsten et al., 1998). However, knowledge of each relationship is often tested individually. Although Bullock et al. (1982) showed that 3-year-old children were able to combine these relationships to correctly predict the outcome of an observed sequence of events, the children were required to determine the only possible outcome and did not have to choose between alternative solutions. Therefore, for similar reasons as the chimpanzees in Experiment 1, the multiple causal relationships that were presented in the trap-tube demonstrations may have been conceptually difficult for 3- to 4-year-old children.

These results contrast with the conclusions of Want and Harris (2001), who reported that 3-year-old children benefited from observing errors in a similar, yet not identical, task. However, as discussed earlier, the methodology used by Want and Harris may have made the task significantly easier than the present design, increasing the potential for children to solve the task by learning to alter the side of tool insertion on every trial. When tested in a similar way to the chimpanzees in our study, 3- to 4-year-old children similarly failed to benefit from observing errors.

5- to 6-Year-Old Children

Children age 5 to 6 years from all three groups retrieved the reward more often than the younger children and the chimpanzees. The successful performance of the control group indicates that 5 to 6 year olds could solve the trap-tube task without the need for a successful demonstration, so it is therefore not surprising that they did not benefit from observing errors. The results suggest that although younger children may have knowledge about the causal relationships involved in the trap-tube task, they may not be able to apply this knowledge until they are older. Similarly, in the wild it takes chimpanzees many years to learn tool-use tasks such as nut cracking that involve multiple causal relationships. Longitudinal studies have shown that youngsters learn to nut crack in stages, first combining nuts and anvils, then hammers and anvils, only later combining all three relationships to successfully crack nuts (Inoue-Nakamura & Matsuzawa, 1997). This observation supports the hypothesis that chimpanzees, like children, learn single causal relationships first and then with experience, learn to combine these relationships to solve more complex tasks.

The contrast in behavior of children from different age groups highlights the importance of age as a variable in social learning. At the age of 3 to 4 years, children appeared to be overwhelmed by the multiple causal relationships presented in the trap-tube task, with some children showing a significant side bias for the end of the tube used by the experimenter in her first successful trial and thus relying on imitation rather than an understanding of the causal relationships involved. However, by the age of 5 to 6 years, children showed no evidence of a side bias and thus did not seem to imitate the actions of the demonstrator in this respect. It appears that as the children's individual understanding of the causal relationships increased, their reliance on imitation decreased. In the context of the present study, it seems that a critical level of understanding was reached by children between the ages of 5 and 6 years, when individual learning negated a reliance on social learning.

As indicated by the development of nut cracking, a similar developmental progression may be true of chimpanzees. Previous studies that have used tube tasks have reported that the youngest chimpanzees often have the most difficulty (Limongelli et al., 1995; Visalberghi, Fragaszy, & Savage-Rumbaugh, 1995). Visalberghi et al. (1995) reported that their youngest ape was unsuccessful with a tube task at age 3 years but solved the task when retested at age 5 years. It is therefore possible that observing others' mistakes may benefit older chimpanzees.

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