Anim Cogn (2005) 8: 151–163
DOI 10.1007/s10071-004-0237-8

ORIGINAL ARTICLE

Josep Call · Malinda Carpenter · Michael Tomasello

Copying results and copying actions in the process of social learning: chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*)

Received: 6 May 2002 / Revised: 11 August 2004 / Accepted: 11 August 2004 / Published online: 15 October 2004

Abstract There is currently much debate about the nature of social learning in chimpanzees. The main question is whether they can copy others' actions, as opposed to reproducing the environmental effects of these actions using their own preexisting behavioral strategies. In the current study, chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*) were shown different demonstrations of how to open a tube—in both cases by a conspecific. In different experimental conditions, demonstrations consisted of (1) action only (the actions necessary to open the tube without actually opening it); (2) end state only (the open tube, without showing any actions); (3) both of these components (in a full demonstration); or (4) neither of these components (in a baseline condition). In the first three conditions subjects saw one of two different ways that the tube could open (break in middle; caps off ends). Subjects' behavior in each condition was assessed for how often they opened the tube, how often they opened it in the same location as the demonstrator, and how often they copied the demonstrator's actions or style of opening the tube. Whereas chimpanzees reproduced mainly the environmental results of the demonstrations (emulation), human children often reproduced the demonstrator's actions (imitation). Because the procedure used was similar in many ways to the procedure that Meltzoff (Dev Psych 31:1, 1995) used to study the understanding of others' unfulfilled intentions, the implications of these findings with regard to chimpanzees' understanding of others' intentions are also discussed.

Keywords Social learning · Imitation · Emulation · Children · Chimpanzee

J. Call (✉) · M. Carpenter · M. Tomasello
Max Planck Institute for Evolutionary Anthropology,
Deutscher Platz 6,
04103 Leipzig, Germany
e-mail: call@eva.mpg.de
Tel.: +49-341-3550418
Fax: +49-341-3550444

J. Call · M. Carpenter · M. Tomasello
Yerkes Regional Primate Research Center, Emory University,
Atlanta, GA 30303, USA

Introduction

For the last decade, there has been a lively debate about the nature of primate, especially chimpanzee, social learning in problem-solving situations. Several investigators have looked but have found no evidence that chimpanzees or orangutans actually copy the actions of conspecifics in problem-solving situations that required them to use a tool to obtain food (Call and Tomasello 1994; Myowa-Yamakoshi and Matsuzawa 1999; Nagell et al. 1993; Tomasello et al. 1987). Ape observers in these studies did benefit from watching others using the tool, but various lines of evidence suggest that what they were learning was something about the relation between the tool and the food as they were being manipulated, not about the demonstrator's actions or behavioral strategies. Subsequent studies provided support for this view, especially that of Call and Tomasello (1995), who did not allow orangutans to observe the movements of the tool and food but only the demonstrator's manipulation of one end of the tool. When result information was blocked in this way, no effect of demonstration could be detected in the orangutans' subsequent use of the tool (their behavior was the same as that of a control group who saw no demonstration at all). Studies of the social learning of capuchin monkeys led Visalberghi and Fragaszy (1990) to some similar conclusions about this species.

Recently, Whiten et al. (1996) reported that chimpanzees did copy some of a human demonstrator's actions in a problem-solving task. The methodological innovation of this study was that the demonstrated problem-solving activity was complex and even contained some irrelevant actions. Of particular importance, in one experimental condition subjects saw the human twisting a bolt and then removing it as he tried to open a box—the twisting action being irrelevant to removal of the bolt (or to the way the box opened). Some chimpanzees showed evidence of reproducing this twisting, which Whiten et al. interpreted as evidence that they were copying actions. Tomasello (1996), however, pointed out that even though twisting or not

twisting led to the same ultimate result—removal of the bolt and opening of the box—it is still possible that the chimpanzees learned from their observations simply that the bolt afforded twisting (a kind of lower-level result). This same interpretation applies to recent findings on monkeys and apes (Myowa-Yamakoshi and Matsuzawa 1999, 2000; Custance et al. 1999; Bugnyar and Huber 1997; Stoinksi et al. 2001; Stoinski and Whiten 2003) because subjects witnessed both information about actions and results. Indeed, Myowa-Yamakoshi and Matsuzawa (2000, p. 16) concluded that "chimpanzees anticipate the forthcoming action of others by perceiving the directionality and physical causality of objects as a more available cue than the details of the body movements of the demonstrator performing the manipulation."

In general, Call and Carpenter (2002, see also Carpenter and Call 2002) point out that demonstrations of object manipulations contain many different sources of information, and therefore that an observer might potentially focus on one or many different components of the behavior. They argue that what is needed methodologically is a set of experimental demonstrations in which it is possible to tease apart at least some of these different components. The current study represents an attempt in this direction using an object manipulation task. Although object manipulation tasks typically exhibit a causal correspondence between actions and results, it should be possible to dissociate them, at least to some extent, when a given result can be achieved by multiple actions. For instance, cracking a nut open can be achieved by biting, stomping, or throwing the nut against a hard surface. Likewise, the nut can be opened by splitting it in the center, puncturing a hole in the top, or simply breaking the husk into many small fragments. Using this idea, we presented chimpanzees and children with an object (a PVC tube) that could be opened with different actions, and which could be opened in two different locations corresponding to two different results. In addition to a baseline condition (with no demonstration), there were three experimental conditions. In the Full Demonstration condition (FD) a conspecific demonstrated for subjects how to open the tube; as in previous studies, this was done in different ways for different subjects (e.g., breaking it open vs taking off its cap). In the Action Only condition (AO) the conspecific tried but failed to effect the desired manipulation, thus demonstrating an appropriate action without demonstrating the desired result (e.g., pulling on the tube's ends to no avail—inspired by Meltzoff 1995, and similar to a condition used in Myowa-Yamakoshi and Matsuzawa 2000). In the End State Only condition (EO) subjects were presented with the tube already opened; in this case they saw a salient affordance of the object but without any behavioral manipulations at all. Thus, each of these conditions emphasized actions and/or results to different degrees depending on the degree to which the various components were present in each condition. If subjects copied actions, they would benefit from the FD and AO conditions whereas if they copied results they would benefit from the FD and EO conditions. We tested chimpanzees in one study, and in a second study we gave the same task in the same experimental conditions to human 2-year-old children to serve as a point of comparison. Because our procedure replicated in important ways the procedure of Meltzoff (1995) and Bellagamba and Tomasello (1999) studies of children's understanding of others' unfulfilled intentions, we also were able to make some inferences about intention understanding in the two species as well.

Experiment 1: chimpanzees

Chimpanzees in each of three information conditions (Full Demonstration, Action Only, End State Only) were shown a demonstration of one of two ways that a tube could open: the caps came off the ends or it broke open in the middle. Two of these three conditions (Full Demonstration, Action Only) were social conditions, in which a demonstrator performed some action on the tube. There was also a baseline condition with no demonstration (see Fig. 1 for a summary diagram of the different types of conditions). The demonstrator was another chimpanzee with previous experience with the tube. The basic questions were (1) whether the subjects would copy results—open the tube, open the tube in the same location as in the demonstration and (2) whether they would copy the particular actions chimpanzee demonstrators demonstrated (e.g., bend, twist, pull, etc.). To investigate whether seeing the reward would enhance chimpanzees' learning of the task, half the tubes in each condition were transparent, with food visible inside, and half the tubes were opaque, with no food inside.

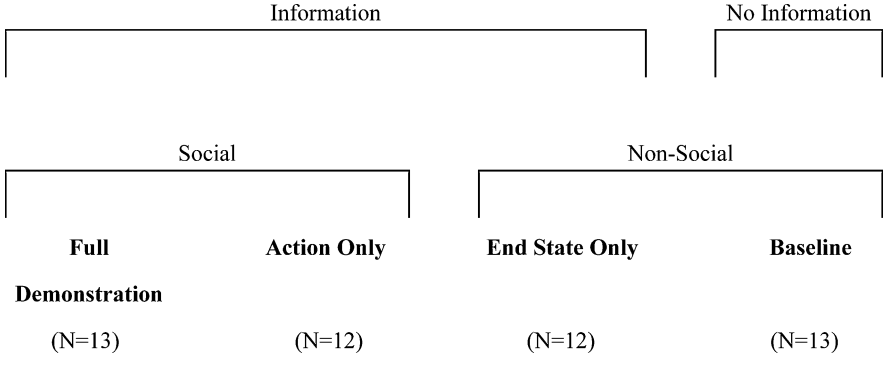

Fig. 1 Number of subjects assigned to each of the four conditions

Subjects

Fifty chimpanzees (*Pan troglodytes*) housed at the Yerkes Regional Primate Research Center participated in this study. There were 34 females and 16 males with a mean age of 11.5 years (range 4–40 years). Subjects were tested individually in their indoor cages. Two adult female chimpanzees (both dominant in their respective groups) acted as the main demonstrators in the social conditions. Seven other chimpanzees also acted as demonstrators for their respective offspring. Subjects were fed according to their normal daily routine (i.e., twice a day on a diet of fruit, vegetables, and monkey chow). Water was available ad libitum, and subjects were not food or water deprived during testing.

Materials

The apparatuses each consisted of sets of two cylindrical tubes (10×4.5 cm, 0.5 cm thickness) and two white PVC caps (3.5 cm in height, 5 cm in diameter). There were two types of tubes: opaque and transparent. The opaque tubes were made of opaque gray PVC and the transparent tubes were made of transparent PVC. The two 10-cm tubes were glued together (with "super glue" at four points) to create a 20-cm-long tube and a cap was fitted onto each end of the 20-cm tube to create a dumbbell-shaped object. Although this recomposed 20-cm tube stayed together as a unit, it still could be opened by either removing the caps from the ends, or by separating the two 10-cm tubes in the center (see Fig. 2).

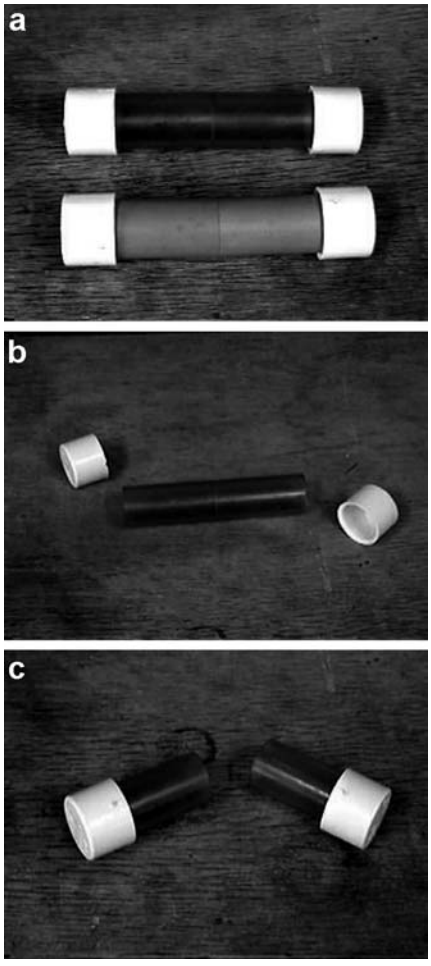

Fig. 2 Intact tubes (**a**) and opened tubes showing the two possible end results (**b**, **c**)

Procedure

Subjects were randomly assigned to one of four conditions with the only constraints being that age and sex were approximately equivalent across groups. There were 13 subjects in the Full Demonstration (7 caps and 6 middle, see below) and baseline conditions and 12 subjects in the Action Only and End State Only conditions. Half of the subjects in each condition received transparent tubes whereas the other half received opaque tubes. Transparent tubes had fruit inside and opaque tubes were empty. In addition, in the three information conditions (i.e., Full Demonstration, Action Only, and End State Only), half of the subjects received information about removing the *caps* while the other half received information about breaking the tube in the *middle*. The conditions consisted of the following steps:

– Full Demonstration. The subject was placed in the same room with a proficient demonstrator who opened two tubes in succession in full view of the subject. The demonstration always took place after the subject had joined the demonstrator. Although the subject was subordinate to the demonstrator, it approached and observed her behavior. If the subject failed to look at the demonstrator, the experimenter provided another tube until the subject had observed two consecutive demonstrations of how to open the tube. The subject thus saw both the actions of the demonstrator and the end state of the tube in this condition.
– Action Only. The subject was placed with a proficient demonstrator who attempted (but failed) to open a tube in full view of the subject. This condition thus corresponds to the intention condition of Meltzoff (1995). In this condition, subjects saw only the actions necessary to open the tube, without ever seeing the end state of the tube open. To prevent demonstrators from opening the tube, we glued the caps and used a 20-cm piece of PVC that had not been cut in two. To simulate the appearance of a cut tube, we traced a groove in the center of the uncut tube. Human observers could not distinguish the cut from the uncut tube and chimpanzee demonstrators seemingly treated it as a cut tube—repeatedly trying to open it. We kept subjects in the same room with the demonstrator until they had witnessed several attempts, at which time the subject was moved to a different cage and given an experimental tube. One shortcoming of using chimpanzee demonstrators in this condition is

Table 1 Definitions for the various actions that subjects applied to the tube

Action	Definition
Shake	Hold the tube with one hand and move quickly up and down or back and forth using quick wrist or arm movements
Bend	Hold onto both caps with each hand and push to break the tube in the center or place foot on the center of the tube, grab onto both caps with each hand and pull up to break the tube in the middle. This also includes cases where subjects used a twisting motion in the center of the tube
Twist	Hold cap with hand while applying twisting motions to it
Pull	Hold cap with hand and pull away from the tube
Drop	Release tube to the ground
Hit substrate	Hold tube with one hand and apply a quick arm or hand motion to strike some other object such as the ground, the fence, or any other objects present
Hit center[a]	Hold the tube with one hand and strike its center part or caps with the palm of the other hand
Bite-lick[a]	Touch the center of the tube with the lips or the teeth
Bite-twist[a]	Hold cap with teeth while applying twisting motions to it
Bite-pull[a]	Hold cap with teeth and pull up away from the tube
Touch substrate	Hold the tube with one hand and contact some part of the enclosure in a directed manner
Roll	Make the tube rotate on the ground in its main axis
Hit palm[a]	Strike the center or caps of the tube with the palm while the tube is resting on the ground
Hit wrist[a]	Strike the center or caps of the tube with an inverted wrist while the tube is resting on the ground
Press on	While the tube is resting on the ground, apply pressure (weight) on its center or caps with feet, hands, or body. This may include such actions as stepping or sitting on the tube

[a] These actions were only observed in chimpanzees

that when they discovered that their usual actions did not work, they attempted other actions. Despite this shortcoming, the target action (i.e., action used to try to open the tube) was still the main action used by the demonstrators.[1]

– End State Only. The experimenter placed two empty, opened tubes inside an empty cage and then allowed the subject to enter that cage and find the tubes. The subject thus saw only the end state of the tube, without seeing any of the actions necessary to open it. This would be analogous to finding some cracked nutshells in the forest. All subjects looked at the tubes inside the cage and in most cases chimpanzees picked them up and carried out simple manipulations on them such as mouthing them.
– Baseline. The subject was simply handed one tube without any kind of prior exposure to the tubes.

We trained the demonstrators to perform the appropriate actions by offering a baited tube that could only be opened using one method. For instance, to shape the middle condition, we glued the caps to the tube so that the only method to open the tube was breaking it in the middle. We repeated this process until the subject had opened the tube four times. Then, we offered a tube that could be opened in both ways (middle or caps) for four additional trials. If a subject opened the tube using the shaped method in all four trials it was judged fit to serve as a demonstrator.

After the exposure to the demonstration in the information conditions, subjects were moved to an adjacent cage and were allowed to manipulate a test tube for 180 s. If subjects opened the tube within the 180-s period, they were given a second tube. Otherwise testing was terminated. All sessions were videotaped.

Data analysis

Across experimental conditions we analyzed four different measures: percentage of subjects who opened the tube, mean latency to open the tube, percentage of subjects matching the tube's result, and percentage of subjects matching the demonstrator's actions. Opening the tube consisted of either breaking the tube in the middle or removing at least one of the caps within the 180-s period. Latency consisted of the time it took the subject to open the tube after it was placed in the cage within its reach. Since latency to open the tube is directly influenced by whether subjects were successful at opening the tube, we restricted the latency analyses to those subjects that opened the tube. In this way, latency is not directly dependent on the percentage of success. Matching the tube's result consisted of reproducing the end state of the tube in each of the three information conditions. For instance, if the subject witnessed the demonstrator removing the cap, a match was scored if the subject removed the cap (regardless of the action used to do so) whereas a mismatch was scored if the subject broke the tube in the center.

Finally, matching the demonstrator's actions consisted of reproducing the demonstrator's action regardless of the body part used to execute the action (see Table 1 for the actions that we considered). Matching the actions that

[1] Note that this condition may have also offered some indirect information about results in the form of information about which actions do not produce the desired results.

they witnessed can only be studied in the social conditions because they are the only conditions in which subjects witnessed a demonstration. However, the significance of the percentage of matches remains unclear unless it is compared to a baseline. A high or a low percentage of matches is meaningful only if it significantly differs from the baseline. To assess whether the matches in the social conditions occurred more than expected by chance, we used the subjects' behavior in the non-social conditions in which subjects had seen no demonstration. These two conditions allowed us to estimate the probability that subjects would use some actions also used by the demonstrator after they had encountered an opened tube (End State Only condition) or without any prior information (baseline condition).

However, estimating this probability is not straightforward. One possibility is to pool all the demonstrators' responses and compare them to the subjects' responses. This practice, however, compromises any inferential statistical tests. Another possibility is to randomly pair the subjects' and the demonstrators' actions. The problem with this option is that there are multiple ways in which the subjects' and the demonstrators' actions can be paired. We solved the problem of multiple possible pairings by pairing the subject's actions with 100 permutations of the demonstrator's actions (we used the actions of the two main demonstrators) in the Full Demonstration condition and calculating the percentage of agreement between the subject's actions and each of the 100 permutations. The distribution of the percentage of agreement, and in particular, the median value of the distribution, was used to establish the chance probability of matching the demonstrator's actions in each of the non-social conditions. This is the value that appears in Fig. 5 for the End State Only and baseline conditions. Note that this does not reflect the percent of matches between the subject's and the demonstrator's actions. It simply reflects the expected probability of matching the actions of a model if the subject did not have an opportunity to observe the model. When matching the demonstrator's actions in the Full Demonstration condition with the subjects' actions in the End State Only condition, we kept the results consistent. In other words, we paired the actions used by the demonstrator to remove the cap in the Full Demonstration condition with the actions of those subjects who found tubes with the caps off in the End State Only condition.

A second observer scored 20% of the subjects to assess the inter-observer reliability of the subjects' actions. Inter-observer reliability was excellent (Cohen's κ=0.78). All statistical tests were two tailed.

Results

Tube opening

Figure 3 presents the percentage of correct responses as a function of experimental condition in trial 1. There were no

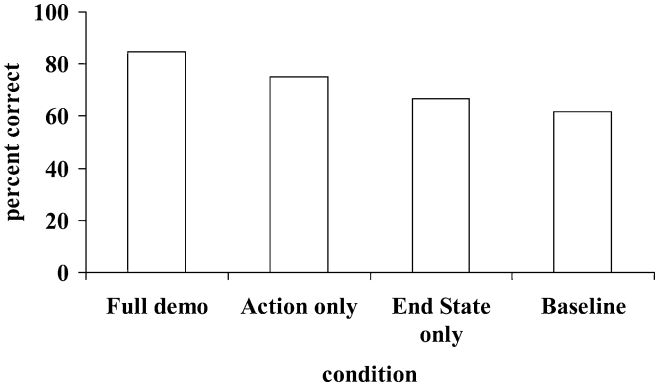

Fig. 3 Percentage of subjects who opened the tube across conditions

significant differences across conditions (χ^2=1.96, *df*=3, *n*=50, *P*=0.58). Similarly, there were no significant differences between the information conditions (combined) and the baseline condition (Fisher test: *P*=0.47). The type of tube used (i.e., opaque or transparent) did not have any overall (Fisher test: *P*=0.35) or specific effect within any of the experimental conditions (Fisher tests: *P*>0.54 in all cases). Likewise, in the second trial there were no significant differences across conditions (χ^2=2.22, *df*=3, *n*=35, *P*=0.53) or between the information conditions and the baseline condition (Fisher test: *P*=0.30). However, subjects were more likely to open transparent compared to opaque tubes in this second trial (Fisher test: *P*=0.003).

Latency

Focusing on the successful chimpanzees, we analyzed their latency to open the tube across conditions. A mixed 4×2×2 analysis of variance (ANOVA; Condition: Full Demonstration, Action Only, End State Only, baseline; Type of tube: transparent, opaque; Order: trial 1, trial 2) on the latency to open to the tube indicated only a significant effect of Order, $F(1,24)$=5.42, *P*=0.029, and no effect of Type of tube, $F(1,24)$=0.16, *P*=0.69, Condition, $F(1,24)$=0.23, *P*=0.88, Order × Type of tube, $F(1,24)$=3.30, *P*=0.082, or Order × Condition, $F(3,24)$=0.87, *P*=0.47. Thus, subjects opened the tube in the first trial with equal speed regardless of the type of tube and experimental condition but took less time to open the tube in the second trial (*M*=16.7, SE=4.0) compared to the first one (*M*=42.5, SE=8.0). Restricting the analysis to the first trial only also confirmed no significant effects of Type of tube, $F(1,42)$=0.19, *P*=0.66, Condition, $F(3,42)$=0.86, *P*=0.47, or Type of tube × Condition, $F(3,42)$=0.28, *P*=0.84.

Matching results

Figure 4 presents the percentage of subjects who matched the tube result (or the demonstrator's attempted result in the Action Only condition) in each of the experimental

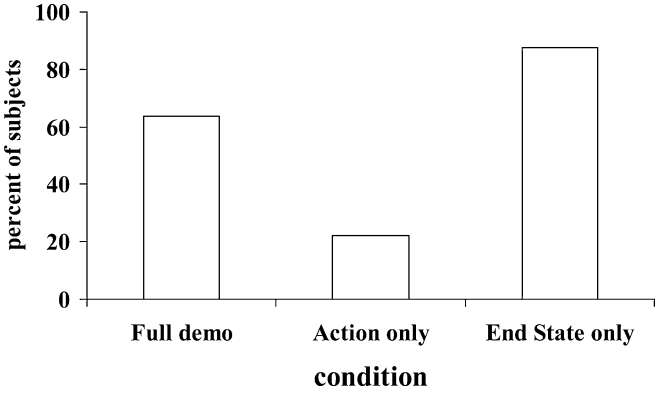

Fig. 4 Percentage of subjects that copied the tube result across conditions

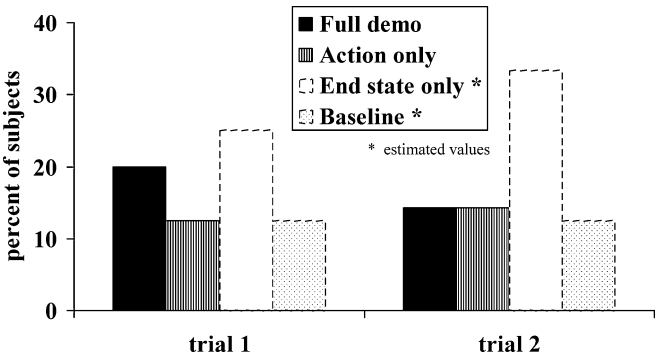

Fig. 5 Percentage of subjects that opened the tube matching the demonstrator's actions in the Full Demonstration and the Action Only conditions. Also shown is the estimated probability of matching the demonstrator's actions in the End State Only and baseline conditions, which represent the chance probability of matching the demonstrator's actions without having seen the demonstrator

conditions. Since the type of tube did not have any effect, data are shown after collapsing the transparent and opaque tube conditions. There were significant differences across conditions (χ^2=7.68, *df*=2, *N*=37, *P*=0.021). Significantly more subjects matched the tube result in the End State condition than in the Action Only condition (Fisher test: *P*=0.015). In fact, subjects in these two conditions produced the opposite results. There were no significant differences between the Action Only condition and the Full Demonstration condition (Fisher test: *P*=0.092) or between the End State Only condition and the Full Demonstration condition (Fisher test: *P*=0.34). Thus, chimpanzees matched the demonstration's result more often in the condition in which only the end state was shown.

Matching actions

We conducted two separate analyses, each with different criteria for scoring a match between the demonstrator and the observer. The first analysis (the most restrictive) considered a match only if the subject successfully used the same action as the demonstrator to open the tube. Consequently, this analysis only included successful subjects. The second analysis considered a match if the subject used the same action that the demonstrator had used to open the tube, regardless of whether that action was successful.

Figure 5 presents the results of the first analysis: the percentage of successful subjects that matched the demonstrator's successful (or failed in the Action Only condition) actions in each condition for trial 1 and trial 2. There were no significant differences between conditions with and without a demonstration in trial 1 (Fisher test: *P*=1) or trial 2 (Fisher test: *P*=0.66). Note that only two out of ten (20%) chimpanzees in the Full Demonstration and one out of eight (12.5%) in the Action Only condition matched the demonstrator's actions. Moreover, note that subjects in the End State Only condition obtained comparable scores, even though they had not witnessed a demonstrator in that condition. This means that subjects that witnessed the demonstrator's actions produced the same actions as those that were not exposed to the demonstrators' actions, just its results.

Our second analysis considered subjects' behavioral attempts, not just their successful actions (thus including all subjects), because it was possible that subjects tried to reproduce the demonstrator's actions but failed to produce the successful results. Table 2 presents the number of subjects that copied the successful (or failed) actions of the demonstrator regardless of whether the subject's actions produced the result of opening the tube (i.e., this analysis includes subjects' attempts). Recall that the values in the End State Only and baseline conditions represent estimated values. We used a lenient criterion and credited subjects with matching the demonstrator's actions if among all their actions there was one that matched the successful action of the demonstrator. There were significant differences between the information conditions (combined) and the baseline condition (Fisher test: *P*=0.05). In particular, 48.0% of the subjects in the information conditions matched the demonstrator's successful action whereas only 15.4% of the subjects in the baseline condition did so. However, there were no significant differences across the information conditions (χ^2=2.79, *df*=2, *n*=31, *P*=0.25). Thus, there was no evidence that observing the actions of a demonstrator had an effect on the subjects' actions because those that observed a demonstrator were no different from those that did not observe one. A similar pattern was observed in the second trial.

Discussion

Chimpanzees opened the tube equally as often in each of the four experimental conditions. The majority opened the tube even in the baseline condition, in which they saw no demonstration at all. Chimpanzees that opened the tube took the same time to do so across conditions. Comparing those conditions in which chimpanzees witnessed only the result (End State Only) or only the action (Action

Table 2 The number of chimpanzee subjects that copied the successful (or failed) actions of the demonstrator (including attempts) in the first trial. *Bold and normal numbers* represent chimpanzees that matched or did not match, respectively, the actions of the demonstrator. Excluded from the analysis are those subjects that did not do anything to the tube. Also excluded are two cases (one in the Full Demonstration and another in the Action Only condition) in which the demonstrator's actions could not be determined with precision. *2 nm* Two or more of the non-demonstrated actions (bend, twist, pull, or hit); *other* an action not listed here. If a subject observed the demonstrator bend, and, for example, the subject both bent and twisted the tube, only bend was counted; if the subject observed the demonstrator twist, and the subject twisted and did some other action, only twist was counted

	Bend	Twist	Pull	Hit	2 nm	Other
FD						
Bend				1	1	
Twist		**1**	1		2	1
Pull			**2**	1		
Hit				**1**		
AO						
Bend	**2**				2	
Twist			1		2	
Pull			**1**			
Hit				**1**		
EO[a]						
Bend	**2**				1	
Twist		**3**			1	
Pull			**2**			
Hit	1					
0[a]						
Bend	**1**		1			2
Twist			3			1
Pull				1		2
Hit			1	**1**		

[a]In these conditions, subjects did not see a demonstrator's actions.

FD: Full Demonstration; AO: Action Only, EO: End State Only, BA: Baseline

Only) revealed that subjects were more likely to copy the result upon seeing the result than upon seeing the action. In contrast, subjects did not copy actions more often after witnessing actions than after witnessing results (or after witnessing both actions and results; Full Demonstration).

Our interpretation of these results is that chimpanzees are more likely to copy results than actions. However, this does not mean that chimpanzees were totally insensitive to the actions that they witnessed. First, after observing unsuccessful actions in the Action Only condition, they tended to open the tube with the part that the demonstrator had not tried. That is, if they witnessed the demonstrator trying unsuccessfully to remove the caps, they tended to break the tube in the center and vice versa. This means that the actions informed them about what did not work—the tube did not afford opening in that particular place. Second, presenting actions and results in the Full Demonstration condition reduced to some extent the likelihood that they would copy the observed result. Note that there was no significant difference between the Full Demonstration and the Action Only conditions in the percentage of subjects that copied the observed result, but there was a difference between the Action Only and the Ends Only conditions. Third, overall, subjects matched more actions when they observed a demonstration than in the baseline condition. However, subjects also produced the same actions as the demonstrators even if they did not have a chance to observe them, as in the End State Only condition. One possible interpretation of these results is that in the social conditions subjects matched the demonstrator's actions while in the End State Only condition subjects were guided by the affordances of the object. However, another interpretation that does not postulate two different processes depending on the condition is that the matches between subjects' and demonstrators' actions in those conditions in which the actions were available represent not genuine matches but the expected probability of using the same actions as the demonstrator once the subject knows that the tube can be opened. Moreover, even if one were to accept their matching in the social conditions as genuine, note that there was still no difference across conditions when matches concerned specifically the actions that produced a successful outcome. In other words, in the vast majority of cases in which subjects succeeded in opening the tube, they used different actions from those used by the demonstrators.

Thus, we found some evidence that chimpanzees copied results. While we found suggestive evidence that they might *use* others' actions, there was little if any evidence that they *copy* them. In other words, observing the actions of the demonstrator appears to have contributed to the solution of the task, but that does not mean that given the same task they would use the same actions to solve the problem. One potential caveat of the current study is that the task may have been too easy for the chimpanzees. The high baseline performance in the current study may have obscured the effects of the experimental conditions on the percentage of subjects that opened the tube, as the results with regard to latency to open the apparatus seem to suggest. Yet this task was still valid to test the percentage of subjects that matched the demonstrator's results and actions.

Experiment 2: children

In experiment 2, we tested 2-year-old children on the same task, using the same apparatus and experimental conditions. Based on the results of similar studies by Meltzoff (1995) and Bellagamba and Tomasello (1999), and other studies of children's social learning (e.g., Nagell et al. 1993), we expected that more children would open the tubes in the social conditions, in which they saw the demonstrator's actions (i.e., the Full Demonstration and Action Only conditions), than in the non-social conditions (i.e., the End State Only and baseline conditions). An important extension of the current study is our focus on reproducing results versus actions. Along with the addition of two methods of opening the tube (the result), we also added a "style" component

(see Hobson and Lee 1999) to the demonstrator's action that was unnecessary to open the tube: the demonstrator either removed the cap with an obvious twisting motion or broke the middle by pushing her thumbs up against it. We expected that, unlike chimpanzees, children would copy the demonstrator's method of opening the tubes very closely—not just the location in which the tube opened but also the particular actions she used to achieve that result. Finally, we were also interested in whether children would learn more effectively if they saw a toy in the tube before and during the demonstration (transparent condition) than if they did not see a toy (opaque condition).

Method

Subjects

Forty-eight 2.5-year-old human children (*Homo sapiens*) participated in this study. There were 28 girls and 20 boys (mean age 30.2 months, range 28–32 months). Children were recruited from daycare centers in Leipzig, Germany and were tested individually in a quiet room of their daycare center.

Materials

Tubes and caps matching those in experiment 1 in all important respects but size were used. Children's tubes were smaller (21×2.5 cm, 0.1 cm thickness) and lighter. Their opaque tubes were made by covering the transparent ones with opaque tape. Instead of food, children's transparent tubes each had a different-colored toy car inside.

Procedure

The same experimental conditions (Full Demonstration, Action Only, End State Only, baseline), methods of opening (cap, middle), and type of tube (transparent, opaque) as in experiment 1 were used with 12 children assigned to each condition. An adult human served as demonstrator. In most respects, the procedure for children was identical to that for chimpanzees in experiment 1; only the differences are presented here.

Children's sessions began with a brief warm-up period with other toys. Once children appeared to be comfortable with the experimenter (E) and situation, E began the test.

- Full Demonstration. E faced the child, attracted the child's attention if necessary, and opened two tubes.
- Action Only. E attempted five times to open a (glued) tube. Unlike chimpanzee demonstrators, E attempted to open the tube in the same way (either pushing up on the middle of the tube or twisting one of the caps) on every attempt. The full action was shown (it just was not successful), and there were no other actions like, for example, the hand slipping off the toy (Meltzoff 1995). E showed natural facial expressions (frustration) and vocalizations (effortful grunts) during her demonstration.
- End State Only. After the warm-up period, E walked with the child over to two empty, opened tubes that were lying on the floor several meters away. The child was not prevented from touching these tubes but was not encouraged to do so either.
- Baseline. After the warm-up period, the child was simply handed one test tube without any kind of prior exposure to the tubes.

Following the demonstration, the child was given a tube and told, "Here, look at this." In the Full Demonstration and End State Only conditions, the tubes from the demonstration were left in view of the child. The child's response period lasted 60 s. If the child opened the tube within the 60-s period, the child was given a second tube. Otherwise testing was terminated. We videotaped all trials.

E used a distinctive style that was unnecessary to open the tube in all demonstrations. For cap demonstrations, E always twisted the caps with large wrist motions while pulling (or attempting to pull) them off and for middle demonstrations, she always bent the center of the tube up with her thumbs while breaking (or attempting to break) the tubes. These styles were unnecessary to open the tubes because the caps could be pulled or shaken off and the middle could be broken by hitting the tube against something, for example.

Data analysis

Data analysis was conducted in the same way as in experiment 1, except that we did not need to use the permutation analysis because the demonstrator always used the same actions. A second observer coded 20% of the sessions to assess inter-observer reliability on children's behavior toward the tube. Inter-observer reliability for action used was excellent (Cohen's κ=0.77). We used two-tailed tests.

Results

Tube opening

Figure 6 presents the percentage of correct responses as a function of experimental condition. There were significant differences across conditions (χ^2=9.75, df=3, n=48, P=0.021). Children in social conditions obtained a higher percentage of correct responses than in non-social conditions (Fisher test: P=0.005). Overall, children were more likely to open the transparent than the opaque tube (Fisher test: P=0.03). However, an analysis within each condition revealed that this effect was only statistically

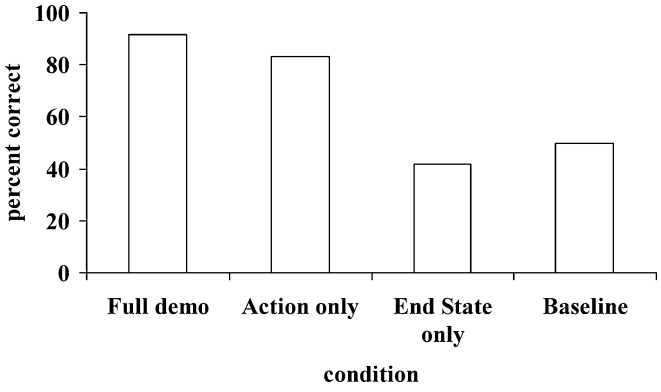

Fig. 6 Percentage of subjects who opened the tube across conditions

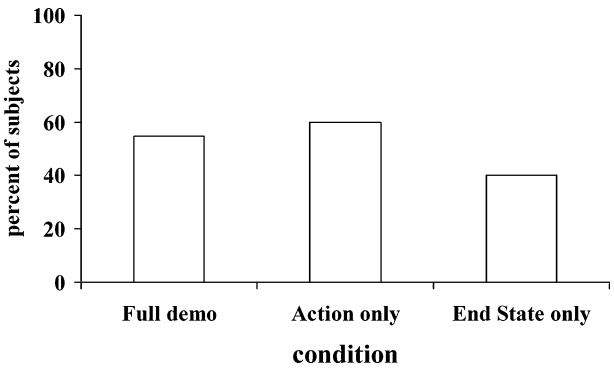

Fig. 7 Percentage of subjects who copied the tube result across conditions

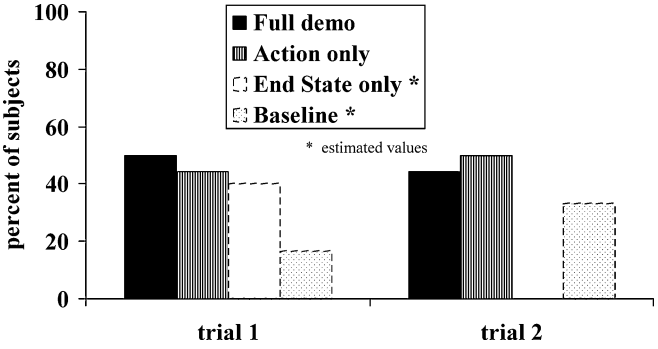

Fig. 8 Percentage of subjects who opened the tube matching the demonstrator's actions in the Full Demonstration and the Action Only conditions. Also shown is the estimated probability of matching the demonstrator's actions in the End State Only and baseline conditions, which represent the chance probability of matching the demonstrator's actions without having seen the demonstrator

significant in the End State Only condition (Fisher test: P=0.015). Except for one child, all subjects who opened the tube in the first trial also opened the tube in the second trial.

Latency

Focusing on the successful children, we analyzed their latencies to open the tube across conditions. A mixed 4×2×2 ANOVA (Condition: Full Demonstration, Action Only, End State Only, baseline; Type of tube: transparent, opaque; Order: trial 1, trial 2) on the latency to open to the tube indicated only a significant effect of Order, $F(1,25)$=8.55, P=0.007. There was no effect of the Type of tube, $F(1,25)$=1.73, P=0.20, Condition, $F(3,25)$=1.04, P=0.39, Order × Type of tube, $F(1,25)$=1.21, P=0.21, or Order × Condition, $F(3,25)$=1.70, P=0.19. Thus, subjects opened the tube in the first trial with equal speed regardless of the type of tube and experimental condition but took less time to open the tube in the second trial (M=4.7, SE=0.8) compared to the first trial (M=12.1, SE=2.8). Restricting the analysis to the first trial only also confirmed no significant effects of Condition, $F(3,25)$=1.41, P=0.26, Type of tube, $F(1,25)$=2.46, P=0.13, or Type of tube × Condition, $F(2,25)$=0.62, P=0.55.

Matching results

Figure 7 presents the percentage of children who matched the tube result (or the demonstrator's attempted result in the Action Only condition) in each of the information conditions. There were no significant differences across conditions (χ^2=0.54, df=2, n=26, P=0.76). An analysis within each of the two type-of-tube conditions (i.e., transparent, opaque) produced similar results.

Matching actions

Figure 8 presents the percentage of successful subjects who matched the demonstrator's successful (or failed) actions (bend vs twist) in each condition for trial 1 and trial 2. There were no significant differences between social and non-social conditions in trial 1 (Fisher test: P=0.47) or trial 2 (Fisher test: P=0.25).

These results, however, may be influenced by children's reluctance to break the tube (only 1 child broke the tube in the middle). Therefore, we also investigated children's attempts. Table 3 presents the number of children who copied the demonstrator's successful (or failed) actions regardless of whether children's actions produced the result of opening the tube (i.e., including attempts). As with chimpanzees, we credited children with matching the demonstrator's actions if among their actions there was one that matched that of the demonstrator. Although children matched the demonstrator's actions in the first trial more often in the social (14 out of 22 children: 64%) compared to the non-social conditions (8 out of 24 children: 33%), this difference was not statistically significant (Fisher test: P=0.075). However, if this analysis is restricted to the two actions used by the demonstrator (i.e., bend and twist), thus excluding other actions (see Table 3), children significantly matched the demonstrator's actions more often in the social compared to the non-social conditions (Fisher test: P=0.035, Table 3). Furthermore, focusing exclusively on the two social conditions and the two actions used by

Table 3 The number of children who copied the actions of the demonstrator (including attempts) in the first trial. *Bold and normal numbers* represent children who matched or did not match, respectively, the actions of the demonstrator. One child is missing in the Full Demonstration and Action Only conditions (twist) because detailed coding was not possible due to the camera position

	Bend	Twist	Other
FD			
Bend	**3**	1	2
Twist	0	**4**	1
AO			
Bend	**2**	0	4
Twist	0	**5**	0
EO[a]			
Bend	**0**	2	4
Twist	0	**3**	3
BA[a]			
Bend	**0**	3	3
Twist	1	**5**	0

[a]In these conditions, subjects did not see a demonstrator's actions.

FD: Full Demonstration; AO: Action Only, EO: End State Only, BA: Baseline

demonstrators (i.e., bending and twisting), children significantly reproduced those actions that they had seen (Fisher test: P=0.002, Table 3). In the social conditions, 5 of the 6 children who witnessed the demonstrator bending the tube reproduced this action, whereas none of the 9 children who witnessed twisting bent the tube. Conversely, all 9 children who witnessed the demonstrator twisting the tube reproduced this action, whereas only 1 of the 6 children who witnessed bending twisted the tube. Overall, 14 out of 15 children (93%) copied the action used by the demonstrator. A similar pattern was observed in the second trial.

Discussion

Children opened the tube significantly more often (but not more quickly) in the social conditions, in which E's actions were demonstrated (i.e., the Full Demonstration and Action Only conditions), than they did in the other two conditions in which no actions were demonstrated (the End State Only and baseline conditions). We found no difference between the two social conditions: seeing only E's actions, without seeing the end state of the open tube, was just as effective in prompting children to open the tube themselves as seeing the full demonstration.

Children reproduced E's result equally often in each of the information conditions. Their performance was rather low—children only succeeded in matching the result of the demonstration about 50% of the time. This was probably because children were reluctant to break the tube. Only one child succeeded in breaking the tube, although many children—only among those who saw E break the tube—made tentative attempts to do so before taking off the cap. When children's attempts were considered along with their successes, much higher rates were found. Of the children who saw the twist cap demonstration in the social conditions, 100% opened or attempted to open the tube by opening the cap, and of the children who saw the break middle demonstration, 83% opened or attempted to open the tube by breaking the middle.

Although these results suggest that children were indeed trying to reproduce the result, further results concerning reproduction of E's specific actions suggest that this was probably brought about by children's tendency to copy E's actions. Children reproduced the actions they saw E perform, and even her specific style of opening the tube (especially twisting the cap), even though this action was unnecessary to open the tube. When attempts were included, 93% of children matched the *specific* action they saw (twist or bend) as opposed to other actions that may have produced the same result (cap off or broken tube). Moreover, children matched the demonstrator's actions more often in the social than the non-social conditions. In the non-social conditions, children mostly used novel actions (i.e., actions not previously used by the demonstrators in other conditions). This contrast between social and non-social conditions in the types of actions used suggests that social learning was responsible for the results of the social conditions and individual learning was responsible for the results of the non-social conditions.

Future studies with children should focus on their reproduction of others' actions more closely and attempt to further tease apart the social and action factors. This could be done, for example, by including a "ghost control" in which children see the tubes magically opening in some specific way but without a human actor.

General discussion

Children but not chimpanzees were more successful at opening the tube when they saw the demonstrator's actions (either successful or not). However, both species used the information derived from the demonstrator's actions and/or the results on the tube but they differed in how they used this information. Chimpanzees varied the results they produced (but not their actions) depending on what they observed. Upon witnessing a given result they reproduced it whereas upon witnessing an action that produced no result, they produced the opposite result to that attempted by the demonstrator. In contrast, witnessing or not witnessing the actions of the demonstrator had no effect on the actions used by chimpanzees to successfully open the tube. In other words, chimpanzees opened the tube using different actions from those used by the demonstrators; and the actions used did not differ across information conditions.

Conversely, children adjusted their actions but not the results that they produced depending on what they observed. They copied the actions that they witnessed even if these produced no physical changes in the tube. In contrast, at least at the level of success, children were not influenced

by the tube results that they witnessed—they did not use the end state of the tube to figure out how to open the tube. Thus, the current results support the idea that chimpanzees in social learning situations focus primarily on reproducing results (which is consistent with emulation) whereas children focus primarily on reproducing actions (which is consistent with imitation).

An objection that could be leveled against our overall conclusions is that we interpreted children's copying the demonstrator's style (i.e., twisting or pulling the tube cap) as evidence of copying actions. Yet one could argue that children were focused on the changes that occurred to the tube (i.e., cap spinning) rather than on the actions that produced those changes (i.e., hand twisting), as discussed above. However, there are two arguments against this conclusion. First, children also copied the demonstrator's actions in the absence of any changes in the state of the tube (Action Only condition). In fact, this condition did not differ from the condition in which children witnessed both the demonstrator's actions and results (Full Demonstration). Moreover, just observing the end result (End State Only) produced very different results compared to the social conditions. Second, our results are consistent with previous studies that have shown that children focus on the actions rather than the results (Nagell et al. 1993; Bellagamba and Tomasello 1999; Horner and Whiten 2004). Thus, our current results with children are likely to reflect the same inclination for copying actions over results as has been documented in previous studies. In contrast, there is no comparable evidence with apes that can throw some light on the precise source of information that they use. Currently, chimpanzee data including those from the artificial fruit task (e.g., Whiten et al. 1996) could reflect copying results (e.g., bolt motions), instead of actions (Tomasello 1996).

This study replicated in many ways Meltzoff (1995) study and other studies focusing on the understanding of others' unfulfilled intentions in children (Bellagamba and Tomasello 1999; Johnson et al. 2001). In those studies, infants witnessed an adult who demonstrated her intention to perform some target action but who never succeeded in performing that action. Fifteen-month-old to 18-month-old infants in those studies produced the target action equally as often when they saw this intention demonstration as they did when they saw a full demonstration of the completed target action. In contrast, children in the current study and the Bellagamba and Tomasello (1999) study failed to use the information provided by the End State condition, in which the final result was presented without the actions that produced it. It thus appears as though 15-month-old to 2.5-year-old children do not preferentially use information about results to solve problems—instead, they use information about others' actions.

However, it is important to note that although children tend to copy actions at high rates, they do not do so blindly. The intention condition in Meltzoff (1995) and other studies (e.g., Carpenter et al. 1998) shows that children copy the actions that adults intend to do, not exactly those that they actually do (so children in Meltzoff's study pulled two parts of a dumbbell apart instead of copying the adult's hands slipping off the sides in the intention condition). Similarly, in the Action Only condition of the current study, children who saw the unfulfilled demonstration opened the tube as often as those children who saw the full demonstration. Since they did not do this in the baseline and End State Only conditions, this means that children in the Action Only condition learned that the tube could be opened, and then they opened it themselves in a different way from the demonstrator. This learning was about more than just a physical property of the tube (its openability); instead it probably related to the goal of the demonstrator, that is, the demonstrator was trying to open the tube. Otherwise children would have performed at high levels in the End State Only condition in which the tube's openability was clearly evident. Thus, children's behavior in the Action Only condition is an example of goal emulation, and it shows that children are capable of both copying actions and copying goals.

For chimpanzees the results are not as clear-cut. In a similar study conducted by Myowa-Yamakoshi and Matsuzawa (2000; experiment 1), five chimpanzees watched a human demonstrator first trying but failing to open a container, and then opening the container. Chimpanzees opened the container equally as often following failures as following successes, mirroring the Meltzoff (1995) finding with infants. However, after the many trials in which chimpanzees had already opened the container in a prior baseline condition were excluded, results in this chimpanzee study are based on only two instances of opening in each condition. While this was numerically more than was found in an extended baseline control condition with different objects, it is not a very strong result. Note that Myowa-Yamakoshi and Matsuzawa (2000) also investigated whether chimpanzees used the same method of opening the container as the demonstrator. They found that chimpanzees generally used their hand when the demonstrator used his hand, and used an irrelevant tool when the demonstrator used the tool. However, they did not copy the particular actions (pushing, pulling, or twisting) that the demonstrator used. In a second experiment in which the demonstrator first succeeded and then failed to open the container, chimpanzees again copied the hand versus tool use, but only when the demonstrator succeeded. Then they continued to use this strategy after the demonstrator's failed attempt.

In the current study, again, baseline performance was very high, limiting what we can conclude about the finding of no differences between the Full Demonstration and Action Only (intention) conditions. However, although chimpanzees matched the demonstration's result in those conditions in which that result was available (Full Demonstration and End State conditions), when the successful result was not shown (Action Only condition), they tended to produce the *opposite* result to the one that the demonstrator attempted (and failed) to do. This finding may indicate that chimpanzees realized what the demonstrator was trying to do, and that she was not succeeding, and then they decided

to try a different method of opening the tube themselves. If that were the case, this would also constitute an example of goal emulation.

However, there is at least one other equally plausible interpretation for these results. Chimpanzees may have learned from the demonstrator's mistakes—instead of emulating the demonstrator's goals, they may have realized that the tube did not open in the location the demonstrator was focusing her behavior on so they tried a different location instead. Nevertheless, this would still indicate that chimpanzees were capable of shifting from using results to using information about the parts of the tube (or its locations) that the demonstrator was focusing her behavior on. Little is known about the types of information that observers extract from a demonstrator's unsuccessful actions or mistakes (see Myowa-Yamakoshi and Matsuzawa 2000; Templeton 1998; Want and Harris 2001) and future studies should focus on this aspect of social learning and the extent to which non-human primates benefit from mistakes rather than successes.

Whereas copying others' actions is clearly important for young children, as they grow older, they become more able to focus on results and may emulate more often (Horowitz 2003). An intriguing possibility is thus that the primacy of results over actions in chimpanzees is due to the age of the subjects tested in the current and previous studies. Most subjects in these studies were adult or subadult apes. It would be interesting to investigate whether infant or juvenile chimpanzees are more predisposed to copy the demonstrator's actions than adult or subadult chimpanzees. In fact, one study that found some positive results used young chimpanzees as subjects (Whiten et al. 1996). Another factor that complicates the interpretation of the current findings (and the findings of other similar studies; Myowa-Yamakoshi and Matsuzawa 2000) is task difficulty. Chimpanzees in the current study opened the tube equally often in all conditions. The high level of performance in the baseline condition is especially troublesome and future studies should use tasks in which subjects do not score as high in the baseline condition. Another issue related to task difficulty is how much causal knowledge they have about the task. Horner and Whiten (2004) have found that chimpanzees are more prone to emulate (as opposed to imitate) when the causal relations between the problem elements are visible as opposed to hidden. Finally, there is the issue of how much demonstration subjects are allowed before they have access to the tube. Perhaps a single demonstration as in the current study is not enough to elicit in chimpanzees the kind of social learning that we observed in human children. The effect of continued observation of a proficient demonstrator on the subject's responses is an issue that deserves future research attention.

In conclusion, this study showed that children copied actions (and goals) from a demonstrator whereas chimpanzees mostly copied results. These results add to a growing body of evidence that suggests that apes and children differ in the social learning mechanisms that they use in problem-solving situations (see Call and Carpenter 2003, for a review). Future studies should investigate the conditions that promote the use of the various sources of information (i.e., results, actions, and goals) from a comparative perspective.

Acknowledgements This investigation was supported in part by a grant RR-00165 from the National Center for Research Resources to the Yerkes Regional Primate Research Center. The Yerkes Center is fully accredited by the American Association of Laboratory Animal Care. We thank three anonymous referees for helpful comments on an earlier version of this manuscript.

References

Bellagamba F, Tomasello M (1999) Re-enacting intended acts: comparing 12- and 18-month-olds. Infant Behav Dev 22:277–282

Bugnyar T, Huber L (1997) Push or pull: an experimental study on imitation in marmosets. Anim Behav 54:817–831

Call J, Carpenter M (2002) Three sources of information in social learning. In: Dautenhahn K, Nehaniv C (eds) Imitation in animals and artifacts. MIT Press, Cambridge, Mass., pp 211–228

Call J, Carpenter M (2003) On imitation in apes and children. Infanc Aprendiz 26:325–349

Call J, Tomasello M (1994) The social learning of tool use by orangutans (*Pongo pygmaeus*). Hum Evol 9:297–313

Call J, Tomasello M (1995) The use of social information in the problem-solving of orangutans (*Pongo pygmaeus*) and human children (*Homo sapiens*). J Comp Psychol 109:308–320

Carpenter M, Call J (2002) The chemistry of social learning. Dev Sci 5:23–25

Carpenter M, Akhtar N, Tomasello M (1998) Fourteen through 18-month-old infants differentially imitate intentional and accidental actions. Infant Behav Dev 21:315–330

Custance D, Whiten A, Fredman T (1999) Social learning of an artificial fruit task in capuchin monkeys (*Cebus apella*). J Comp Psychol 113:13–23

Hobson RP, Lee A (1999) Imitation and identification in autism. J Child Psychol Psychiatry 40:649–659

Horner V, Whiten A (2004) Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). Anim Cogn (in press)

Horowitz AC (2003) Do humans ape? Or do apes human? Imitation and intention in humans (*Homo sapiens*) and other animals. J Comp Psychol 117:325–336

Johnson SC, Booth A, O'Hearn K (2001) Inferring the goals of a nonhuman agent. Cogn Dev 16:637–656

Meltzoff AN (1995) Understanding the intentions of others: re-enactment of intended acts by 18-month-old children. Dev Psychol 31:1–16

Myowa-Yamakoshi M, Matsuzawa T (1999) Factors influencing imitation of manipulatory actions in chimpanzees (*Pan troglodytes*). J Comp Psychol 113:128–136

Myowa-Yamakoshi M, Matsuzawa T (2000) Imitation of intentional manipulatory actions in chimpanzees (*Pan troglodytes*). J Comp Psychol 114:381–391

Nagell K, Olguin R, Tomasello M (1993) Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). J Comp Psychol 107:174–186

Stoinksi TS, Wrate JL, Ure N, Whiten A (2001) Imitative learning by captive western lowland gorillas (*Gorilla gorilla gorilla*) in a simulated food-processing task. J Comp Psychol 115: 272–281

Stoinski TS, Whiten A (2003) Social learning by orangutans (*Pongo abelii* and *Pongo pygmaeus*) in a simulated food-processing task. J Comp Psychol 117:272–282

Templeton JJ (1998) Learning from others' mistakes: a paradox revisited. Anim Behav 55:79–85

Tomasello M (1996) Do apes ape? In: Heyes CM, Galef BG Jr (eds) Social learning in animals: the roots of culture. Academic Press, New York, pp 319–346

Tomasello M, Davis-Dasilva M, Camak L, Bard K (1987) Observational learning of tool-use by young chimpanzees. Hum Evol 2:175–183

Visalberghi E, Fragaszy DM (1990) Do monkeys ape? In: Parker ST, Gibson KR (eds) "Language" and intelligence in monkeys and apes. Cambridge University Press, Cambridge, pp 247–273

Want SC, Harris PL (2001) Learning from other people's mistakes: causal understanding in learning to use a tool. Child Dev 72:431–443

Whiten A, Custance DM, Gómez JC, Teixidor P, Bard KA (1996) Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). J Comp Psychol 110:3–14