

Rational Tool Use and Tool Choice in Human Infants and Great Apes

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G. Gergely, H. Bekkering, and I. Király (2002) showed that 14-month-old infants imitate rationally, copying an adult's unusual action more often when it was freely chosen than when it was forced by some constraint. This suggests that infants understand others' intentions as rational choices of action plans. It is important to test whether apes also understand others' intentions in this way. In each of the current 3 studies, a comparison group of 14-month-olds used a tool more often when a demonstrator freely chose to use it than when she had to use it, but apes generally used the tool equally often in both conditions (orangutans were an exception). Only some apes thus show an understanding of others' intentions as rational choices of action plans.

Human infants understand the basics of others' intentional action from a very early age. By 6 months, they understand others' actions as object directed (Woodward, 1998). By 9 months, they understand that others' actions are governed by internal goals and that others persist in pursuing their goals when they are not achieved, for example, in the case of failed attempts or accidents (Behne, Carpenter, Call, & Tomasello, 2005). Beginning around 12 months, infants use this understanding when imitatively learning from others, copying others' actions selectively according to the others' goals (e.g., Carpenter, Akhtar, & Tomasello, 1998; Carpenter, Call, & Tomasello, 2005; Meltzoff, 1995). Infants thus have a relatively complex understanding of others' goals by around their first birthdays.

But 1-year-old infants' understanding of intentional action extends beyond determining the goals of others. In addition, infants understand that intentions comprised both a goal (*what* a person is doing) and a means chosen to achieve that goal (*how* she is doing it), along with the rational dimensions of this choice (*why* she has chosen to do it in that particular way). That is, infants know that others choose particular means in particular situations for *reasons*. Gergely, Bekkering, and Király (2002) showed that one such reason that 1-year-olds understand is constraints on the other person. In their study, 14-month-olds watched an adult switching on a lamp with her head. For half of the infants, the adult had to use this

unusual means because her hands were occupied by holding a blanket around her shoulders. The other half of the infants saw the adult use the same unusual means to switch on the lamp even though she could have just as easily (or more easily) used a much more usual means: her hands (they were free). When later given the chance to act on the lamp themselves, infants reproduced the adult's unusual action more often when she had freely chosen to use that action than when she had been forced to use it because of her circumstances. Gergely et al. (2002) explain their results in terms of infants' understanding of efficient action rather than in terms of making inferences about others' rational, intentional choices. But we think that much is hidden in the term "efficient" (or "rational" as they use it). An action is rational or efficient only with respect to a particular goal in a particular circumstance. For example, twisting a screw into a wall is rational for the goal of hanging a picture but not for the goal of obtaining food. We therefore believe that the appropriate analysis of rational action includes an understanding of goals and intentions. Relatedly, it is important that infants in this same age range understand such things as failed attempts and accidents in other experimental paradigms (e.g., Behne et al., 2005). This also supports the claim that instead of just seeing others' surface behavior, infants go deeper and interpret others' behavior in terms of their internal goals that may or may not match external reality.

Perhaps surprisingly, given previous research showing little understanding of others' mental states in apes (see Tomasello & Call, 1997, for a review), there is now evidence that great apes, too, understand some aspects of intentional action. Like

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infants, they understand that others pursue their goals past failed attempts and accidents (Call, Hare, Carpenter, & Tomasello, 2004; Call & Tomasello, 1998). Some chimpanzees—especially those with much experience with humans—can even use this understanding in social learning situations, preferentially copying actions marked as intentional over actions marked as accidental and completing others' failed attempts (Tomasello & Carpenter, 2005; see also Call, Carpenter, & Tomasello, 2005; Myowa-Yamaguchi & Matsuzawa, 2000, for other studies of this with less clear results).

However, little work has been done on apes' understanding of others' intentions. There are several reasons why this aspect of intentional action might be more difficult than goals for apes to understand. First, one can often infer others' goals on the basis of observable behavior (e.g., directedness toward an object, repeated attempts, and signs of surprise or disappointment at unintended results). However, plans for action, and especially the rational consideration and choice of means, are not observable at all. Second, in general, apes may be less likely than humans to seek out the reasons why things happen. For example, in a nonsocial task, Povinelli and Dunphy-Lelii (2001, Experiment 2) found that whereas young children usually sought explanations for unexpected physical events (blocks falling down), chimpanzees never did this. Finally, in general apes copy others' actions in social learning situations far less often than do human children (see Call & Carpenter, 2003, for a review). This is consistent with the idea that apes do not understand the choices or reasons behind others' actions: If one does not understand that others have chosen their actions for a reason, then there is little incentive to copy those actions. Still, at least some apes, chimpanzees, can determine the *physical* efficiency of actions and use this information in social learning tasks (Horner & Whiten, 2005) so it is possible that they may understand a more mental version of this, rationality, as well.

Just one study has tested apes' understanding of others' intentions. Buttelmann, Carpenter, Call, and Tomasello (2007) used Gergely et al.'s (2002) task to test for rational imitation in a small group of chimpanzees who had had much contact with humans—and so who might be expected to engage in more imitative behavior than chimpanzees who had not been reared in such an “enculturated” environment (see, e.g., Tomasello, Savage-Rumbaugh, & Kruger, 1993). Buttelmann et al. found that, indeed, these chimpanzees imitated rationally: Like human 14-month-olds, they reproduced the adult's unusual action more often when he had freely chosen to use that action

than when he had been forced to use it because of his circumstances.

The question thus arises whether all apes, not just enculturated apes, have this more complex understanding of intentional action. In the current studies, we thus tested the understanding of others' intentions as rational choices of action plans in all four species of great apes (chimpanzees, bonobos, gorillas, and orangutans), using nonenculturated apes as participants. Because these apes are generally not so good at imitating others' body movements—and so they would not be expected to do well on Gergely et al.'s (2002) head touch task—we designed a new set of tasks. These tasks (three different pairs of tasks, six tasks in total) had the same logic as that of Gergely et al. but only required participants to decide whether to use a tool or not (Studies 1 and 2) or to make a choice between two different tools (Study 3) based on the choice a human demonstrator made. The same logic applied to all the tasks used: Participants first observed the experimenter using a tool, either as a free choice (in which case they should make the same choice) or as one forced by the circumstances (in which case they could safely ignore the demonstration because those circumstances did not apply to them). Particularly in Study 3, these tasks included behaviors that are part of apes' natural repertoire (i.e., pulling a reward toward themselves) and did not depend on imitation of others' specific body movements. Because the tasks we designed were different in this and other procedural respects to Gergely et al.'s (2002) task, we also tested 14-month-old human infants for comparison and validation—which also served to test if infants could show their understanding of others' rationality in a variety of tasks.

Study 1: Rational Tool Use: String and Spoon

This study tested whether apes and human infants were more likely to use a tool after seeing a demonstrator freely choose to use that tool than after seeing the demonstrator have to use the tool because of some constraint. Thus, in one condition, the demonstrator had to use a tool to obtain a reward because direct access to the reward (with the hand) was blocked by a barrier. In the other condition, the demonstrator could have easily used her hand to directly access the reward (there was no barrier) but she chose instead to use the tool. Participants in both conditions thus observed the demonstrator use the tool instead of her hand but for different reasons. In both conditions during the response phase there were no barriers present for participants—direct access with the hand

was possible. We measured how often participants used the tool to obtain the reward.

Method

Participants. Twenty-eight 14-month-old human infants from German middle-class families (mean age = 13.95, range = 13.69–14.23, 14 females, 14 males) and thirty-three 3- to 31-year-old great apes (16 chimpanzees, 5 bonobos, 5 gorillas, and 7 orangutans; 15 juveniles, 18 adults; 22 females, 11 males) participated in this study. Infants were recruited from a list of parents who had volunteered to participate in child development studies. All infants tested were Caucasian. Eight additional infants were tested but had to be dropped because of not cooperating or fussiness (crying, persistent inattentiveness; 7) or experimenter error (1). Apes were housed in social groups (separated by species) in a zoo equipped with research facilities. The participants were accustomed to being separated in adjacent enclosures from their group members for testing. They were not food deprived and water was available throughout testing. They were free to stop participating at any time. None of the apes tested could be considered enculturated except for 1 young chimpanzee, who had been raised in a human home for 14 months and who then continued to spend his days interacting with caretakers in human activities in a nursery for 25 months. Some of the other apes had been nursery raised for varying amounts of time but, with two exceptions, their interactions with humans centered on caretaking activities. The two exceptions were 2 young chimpanzees who participated in somewhat richer interactions with humans for a period of 38 months. (The results from these 3 young chimpanzees with extensive human contact have also been reported by Tomasello & Carpenter, 2005.) However, by the time of testing all the apes were housed with their conspecific social group and so no longer had intensive human contact other than for routine caretaking and testing.

Materials. Apes completed the experiment first, and infants' materials and procedure were then matched to theirs as closely as possible. Apes were tested in a familiar mesh enclosure; E and E2 were outside the enclosure. Cut into the mesh was a rectangular hole, to the frame of which a $77 \times 62 \times 60.5$ cm transparent plexiglass box was attached such that it protruded outside of the enclosure (Figure 1a). The apes' side of the box could be opened and closed (and locked) with a sliding plexiglass panel, as could the left side of the box (to allow access into the box for the experimenters). A large (40.5×40.5 cm) transparent plexiglass barrier was used for the demonstration in

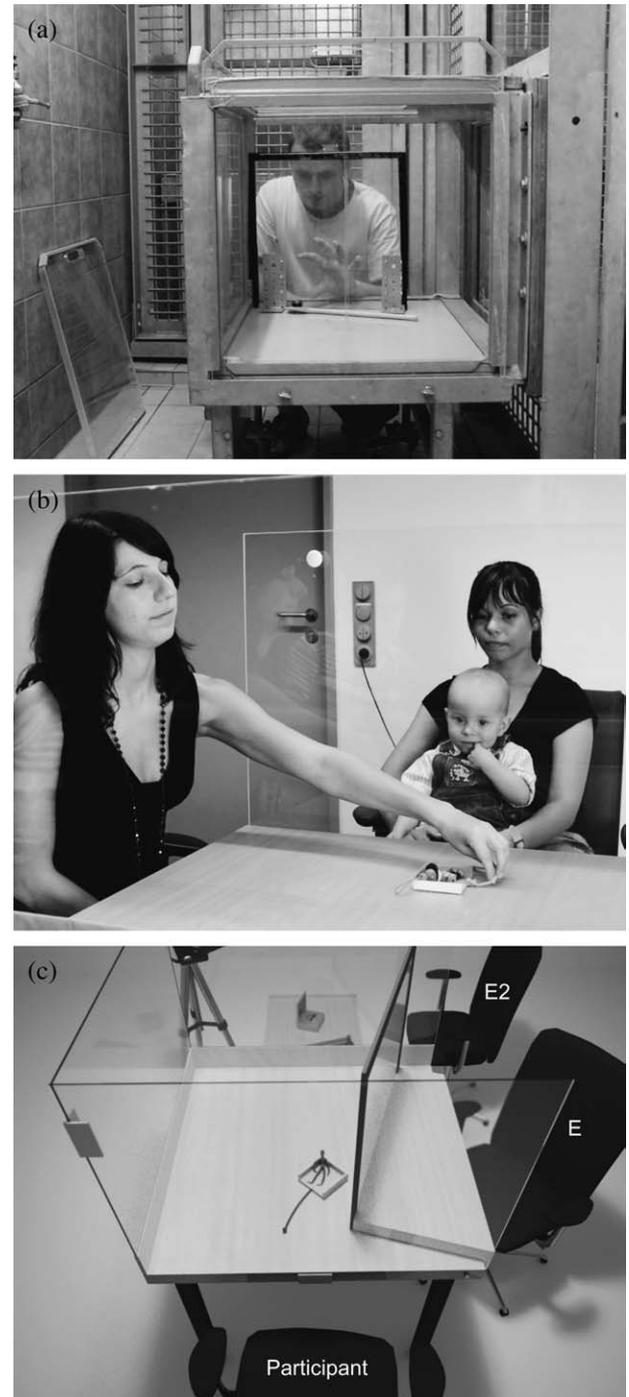


Figure 1. The setup in Study 1: (a) a simulation of the demonstration in the blocked condition of the spoon task for an ape (apes watched the demonstration from E's left side), (b) E performing a demonstration in the not blocked condition of the string task for an infant, (c) the setup in the blocked condition of the string task for an infant.

the blocked condition (Figure 1a). A grape was used in each trial as a reward. Two different types of tools were used for comparisons across conditions. One was a 35-cm-long wooden spoon (with a small hole in

the platform to stick the grape in; Figure 1a); the other was a 35-cm-long string of wood wool, normally used as bedding material, which was tied to the grape. In both cases, apes could either pick up the grape directly with their hands or else use the tool (the spoon handle or string) to pull it in.

Infants were tested in a similar situation, with similar materials. Infants (on their mother's lap) and E sat on movable office chairs facing an 80 × 80 cm table; E2 sat to the side. Attached to three sides of the table were three plexiglass panels (each 54 cm high), one in front of the infants, one on the left side of the infants, and one on the side opposite the infants (Figure 1b). The panel on the infants' side could be moved away sideways by E2 to give infants full access to the table. E's side of the table was accessible throughout the whole testing session. A large (60 × 43.5 cm) transparent plexiglass barrier was used for the demonstration in the blocked condition. Because pilot infants often put the wooden spoon in their mouth, it was replaced by a spoon-like wooden tool (an 8 × 7.5 cm platform with a 14.5 cm long and 0.8 cm thick handle). The other tool was a small cardboard platform (8 × 7.5 cm) with a yellow wool string (14.5 cm long) attached to it. The rewards for infants were small toys. Again, infants could either pick up the reward directly with their hands or else use the tool (the "spoon" handle or string) to pull it in. To maintain infants' interest across trials while at the same time controlling for individual preferences, a different set of three similar toys (e.g., three different-colored beaded necklaces, three different-colored rubber ducks) was used for each response period.

Design. There were two experimental conditions—a blocked condition and a not blocked condition (for explanations, see the following discussion). Participants received two sessions, each in a different condition, on different days. The delay between the two sessions was 1–5 days for apes and 14–21 days for infants. Each session included two demonstrations in the same condition, each followed by a response period consisting of three trials, for a total of 12 trials, 6 in each condition. Tools were randomly assigned to conditions such that half of the participants were presented with the spoon tool in the blocked condition and the string tool in the not blocked condition and vice versa. The order of conditions and tools was counterbalanced, as were the toys used for the infants in each trial of the response periods.

Procedure. Before the apes' first test session, they were presented with a reaching session to ensure that all participants were comfortable reaching into the plexiglass box. In this session, E2 placed a series of grapes in a location that was further away from where

the grape would be placed during the tests, that is, 47 cm or more from the hole in the apes' side of the panel. No tools or barriers were present during this session. All participants met the criterion of reaching for the grapes before entering the test stage.

The following procedure was then the same for infants and apes: First, participants were given a warm-up period of approximately 15 min, during which the experimenters played with the infants and talked to their parents or fed and talked to the apes. The participants then entered the testing room and took their place in front of the apparatus. At the beginning of each session, participants were allowed to reach for a reward placed at the same location as the reward would be placed later in response periods (47 cm away for apes and 21 cm away for infants); no tools or barriers were present yet. This reaching trial was administered to ensure that all participants could easily reach the rewards with their hands in the following response periods and that they were not dependent on the use of a tool. After that, the participants were shown that E could also easily reach into her side of the plexiglass box and obtain three consecutive rewards out of it with her hand, even at this further position (about 64–74 cm opposite E), too, as the usual way of getting things out of it. E reached the rewards with her left hand and then handed the grapes to the apes through the mesh or turned to the infant and played for a short time with the toy before putting it away in a box on the floor.

Then, E2 prepared for the first demonstration. Through the opening in E's side of the apparatus, E2 placed the tool and the reward as follows: First, he put the tool on the table with its platform (the future location of the reward) on the same marked spot from which the participants already had taken a reward in the reaching trial. The handle or string end of the tool was also placed on a marked spot such that it was closer to the participant than the platform (and therefore the reward). From E's perspective, however, the platform of the tool was closer than the handle/string (Figure 1c); this was done to emphasize to participants that E clearly intended to use the handle/string. E2 then placed the reward on the platform of the tool (and placed the barrier in front of E's opening, if applicable) and then moved away. E (who was at the other side of the room in the apes' tests or was bending down, distracted with other tasks during all this in the infants' tests) then approached, called participants by name and waited until they attended, and performed the demonstration, as follows.

Blocked condition (E had to use the tool—the reward was not accessible): E first tried unsuccessfully to

reach the reward directly with her hand three times: With an effortful facial expression, she first tried to reach through the large transparent barrier that blocked most of the opening at her side of the apparatus, then tried to reach around the side of the barrier, and then over the top of the barrier. She then hesitated for a moment, examined the situation visually, and then pulled the reward slowly (with three short pulls) around the barrier into reach, using the tool with the same hand she had tried to reach with before.

Not blocked condition (E freely chose to use the tool—the reward was accessible): No barrier was present. E examined the situation visually, reached in, and directly used the tool to bring the reward in slowly (with three short pulls) in exactly the same way as in the blocked condition.

Note that in both conditions, E pulled in the reward using the tool and did so in exactly the same manner. The difference between conditions was whether she *had* to do so to access the reward or whether she *freely chose* to do so despite being able to access the reward easily without the tool. After each demonstration, E gave the grape to the ape or allowed the infant to touch the toy for about 3 s and then turned away and bent down to put the toy away in a box behind her.

For apes, E then moved to the corner of the room. E2 returned and removed the barrier if applicable, rebaited the tool with the grape, and reset the plexiglass box so that E's side was closed and the ape's side was open. Then a sequence of three response trials was given, after each of which E2 rebaited the tool. Once the ape had retrieved the grape (in whatever manner), the response trial was over. Thus, unlike in Gergely et al.'s (2002) study, participants in the current study had no chance to use different ways of retrieving the reward within individual trials but were only able to switch their strategy across trials.

For infants, after the demonstration, E2 returned and removed the barrier if applicable. E turned back to the table as E2 moved the plexiglass panel on the infant's side away to allow full access for the infant. E2 rebaited the tool with the same toy as was used in the demonstration and turned away for the rest of the trial. After E2 had placed the toy for the infants, E told them "Now, you!" Then, in most cases, the same sequence of trials followed as for the apes. However, in contrast to apes, who never hesitated to act on the tool or the reward, some infants were shy and did not immediately react after E's invitation. In such cases, E repeated her invitation a maximum of two more times, each at 20-s intervals. Infants' trials were stopped after a total

of 60 s (three invitations). If they did not show any interest in the toy during this time and/or did not touch any of the materials, the previous demonstration was repeated but using a different type of toy. Trials ended as soon as infants had lifted the reward.

For each of the two tasks (string and spoon), E performed one demonstration followed immediately by 3 participant response trials, then a second demonstration followed immediately by a further three response trials. There were thus a total of two demonstrations and six response trials for each participant for each task. For both tasks, no barrier was present during the participants' response periods in either condition. During demonstrations, E2 always ensured that participants (both infants and apes) paid attention to the experimenter's actions; demonstrations were repeated in the case of inattentiveness. Infants' mothers were instructed not to touch any of the materials and to remain quiet throughout the testing session. Testing was videotaped.

Coding, reliability, and analysis. Coding was done by the first author using videotapes such that condition could not be determined. For each trial, we coded whether participants directly took the reward with their hand without using the tool, and two types of behavior with the tool: (a) use of the tool to bring the reward closer to themselves (i.e., copied the demonstrator) and (b) any other behavior with the tool besides use before taking the reward (this included play with the tool and random—but intentional—movements of the tool). We also coded whether participants took both the tool and the reward at the same time. Coding was stopped as soon as the participants obtained the reward. To assess interobserver reliability, a second coder scored 25% of the trials, also blind to condition. Reliability was excellent: Cohen's kappas were .91 for the infants and 1.0 for the apes.

For infants, we analyzed the percentage of trials in which infants used the tool to obtain the reward with a mixed-model analysis of variance (ANOVA) with condition (blocked vs. not blocked) as within-subjects factor and order of tool and order of condition as between-subjects factors. For apes, this mixed-model ANOVA included condition as within-subjects factor, species, order of tool, and order of condition as between-subjects factors, and age as a covariate. Because infants (but not apes) often played with the tools, for infants an additional ANOVA with the same factors was run on a combination of the measures "tool use" and "any other behavior with the tool" to analyze the percentage of trials in which infants manipulated the tool before taking the reward (regardless of the function of that manipulation). Finally, because the procedure of this study differed

from that of Gergely et al. (2002) in the number of trials following demonstrations, we also investigated participants' response behavior immediately following the demonstrations (as was done in their study) by analyzing the percentage of participants who used the tool in the first and the fourth trials separately, using McNemar tests. Exact p values are reported for all analyses. Because there already is evidence that infants imitate rationally (e.g., Gergely et al., 2002; Schwier, van Maanen, Carpenter, & Tomasello, 2006), whereas there are no previous studies of this ability in nonenculturated great apes, we used one-tailed p values for infants and two-tailed p values for apes.

Results

Infants. As expected, infants were more likely to use the tool in the not blocked condition in which E had freely chosen to use the tool than in the blocked condition in which he had been forced to use the tool, $F(1, 24) = 4.90, p = .019$ (Figure 2). The same result was found when combining the measures "tool use" and "any other behavior with the tool" to analyze the percentage of trials in which the infants manipulated the tool before taking the reward (not blocked, 30.6%; blocked, 13.8%), $F(1, 24) = 5.86, p = .012$. No other factors or interactions were significant, $ps > .71$. Significantly more infants used the tool in the not blocked than the blocked condition in the fourth trial (not blocked, 21.4%; blocked, 0.0%; McNemar test, $p = .016$) but not in the first trial (not blocked, 28.6%; blocked, 35.7%; McNemar test, $p = .39$).

Apes. Unlike infants, apes used the tool equally often in both conditions, $F(1, 16) = .009, p = .93$ (Figure 2). However, there was a significant interaction between the apes' likelihood of using the tool and the order of condition, $F(1, 16) = 6.83, p = .019$. Specifically, those apes tested in the blocked condition first used the tool significantly more often in the not blocked (47.2%) than in the blocked condition (33.3%), $t(17) = 2.24, p = .039$. The other group of apes did not differ significantly in their performance (not blocked: 23.3%, blocked: 41.1%), $t(14) = 1.68, p = .17$.

There was no effect of order of tools, $F(1, 16) = .25, p = .63$, but tool use decreased with the increasing age of the subjects, $F(1, 16) = 7.95, p = .012$, independent of condition. Further, there was a significant effect of species, $F(3, 16) = 4.07, p = .025$, due to the fact that orangutans used the tool more often than any other species (orangutans: 64.3%, nonorangutans: 29.2%) but no Species \times Condition interaction. There were no significant differences between conditions in the number of apes who used the tool when the first (not blocked, 27.3%; blocked 30.3%) and fourth (not blocked, 36.4%; blocked, 42.4%) trials were analyzed separately (McNemar tests, $ps \geq .75$).

Discussion

With the infants, we replicated Gergely et al.'s (2002) findings using a different task: Fourteen-month-olds used a tool more often when the adult had freely chosen to use that tool than when the adult had been forced to use the tool because of some

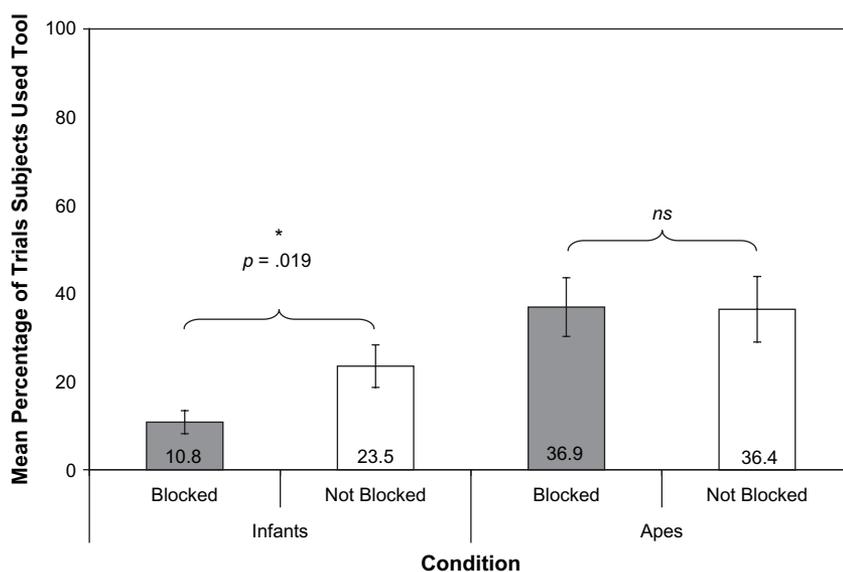


Figure 2. Mean percentage of tool use (with standard error of the mean) in each condition of Study 1 (collapsed across tasks, within subjects) for infants and apes.

constraint. Interestingly, infants did not show this effect in their first trial; they only showed it after the second demonstration (and this replicates the finding of Schwier et al., 2006, that 12-month-olds showed the effect on yet another version of this task only after they had watched a second demonstration). Perhaps it is not until after they see the adult use the unusual action multiple times (in Gergely et al.'s study, the adult used it three times) that infants know that she really chose it in the sense of having committed herself to it.

The results for apes were not as clear. Apes who participated in the blocked condition first showed the same pattern as infants, but apes who participated in the not blocked condition first showed no such pattern. This lack of a clear result was not due to a general inability or unwillingness to use the tool: Apes actually used the tool more often than infants in both conditions. To try to get a clearer answer about whether apes understand others' intentions as rational choices of action plans, we conducted a further study with similar procedures but different materials. If apes have this understanding, then they should show it in new contexts. We made two main changes: We used a different type of tool and, in the blocked condition, a different kind of constraint.

Study 2: Rational Tool Use: Seesaw and Elevator

In this study, we created a new set of tools: a "seesaw" that brought the reward closer to the participant when the seesaw was pushed downward and an "elevator" that brought the reward closer to the participant when it was pulled up. In addition, we modified the constraints used in the blocked condition: In this study, the barriers were attached to the apparatuses directly so that they blocked direct access to the reward in a more obvious and causally transparent way than the barrier used in Study 1. Finally, to minimize the likelihood of carryover effects, we made the tools more different from each other, both visually and in terms of the actions the tool user had to perform. We used the same design as in the previous study.

Method

Participants. Twenty-four different 14-month-old human infants (mean age = 14.0, range = 13.85–14.20, 11 females, 13 males) and 32 of the apes tested in Study 1 participated in this study. The remaining ape, a juvenile female chimpanzee, was afraid of the new apparatuses and would not participate. Apes were tested on average 8 days (range = 1–29 days) after the

completion of Study 1. Fourteen additional infants were tested but had to be dropped because of not cooperating or fussiness (11), experimenter error (1), or difficulty operating the apparatus (2).

Materials. Both tasks involved a small wooden box. The seesaw box (15 × 15 × 13 cm for infants and 22 × 15 × 14 cm for apes) was open on the top and front side and a seesaw (20 × 12 cm for infants and 18.5 × 25 cm for apes) was mounted in the box such that its end protruded out of the box (7 cm for infants and 11 cm for apes). During the tests, rewards were placed on the far, lower end of the seesaw such that they slid out of the box when the protruding near end was pushed down (Figures 3a and 3b). In the blocked condition, a barrier (15 × 15 × 4 cm for infants and 22 × 15 × 4 cm for apes) was mounted on top of the box such that no direct access to the reward was possible (Figure 3a). The elevator box (15 × 15 × 13 cm for infants and 22 × 16 × 14 cm for apes) was open only on the top. A platform with a handle rested inside. The handle could be used to lift the platform from the bottom of the box up to its top position to retrieve the reward on the platform. The handle extended out of the box (10 cm for infants and 8 cm for apes; Figures 3c and 3d). In the blocked condition, a barrier (17.5 × 7 cm for infants and 30 × 7 cm for apes) was mounted on top of the box such that no direct access to the reward was possible (Figure 3c).

For apes, the boxes were placed in the large plexiglass testing box used in Study 1. For infants, the boxes were attached to a table like the one used in Study 1 but without any plexiglass walls. The two experimenters and the infant (on the mother's lap) sat at the table, with E next to the infant and E2 on the infant's other side. Again, rewards were grapes for apes and small toys for infants.

Design. All participants were tested within subjects on both boxes, one in each condition (see the following). Infants were tested on both tasks in a single visit, but apes experienced a delay of 1–20 days between the sessions because of testing-time limitations. The assignment of boxes to conditions, the order of conditions, and the toys used for the infants in individual trials were counterbalanced.

As in Study 1, each task consisted of an initial demonstration followed by a response period consisting of three trials. This sequence was then repeated for a total of two demonstrations and six trials per participant per task.

Procedure. As in Study 1, each session started with a warm-up play period, followed by a reaching trial for participants and then a series of three reaching demonstrations by E. The only difference from the previous study was that for the reaching trial and

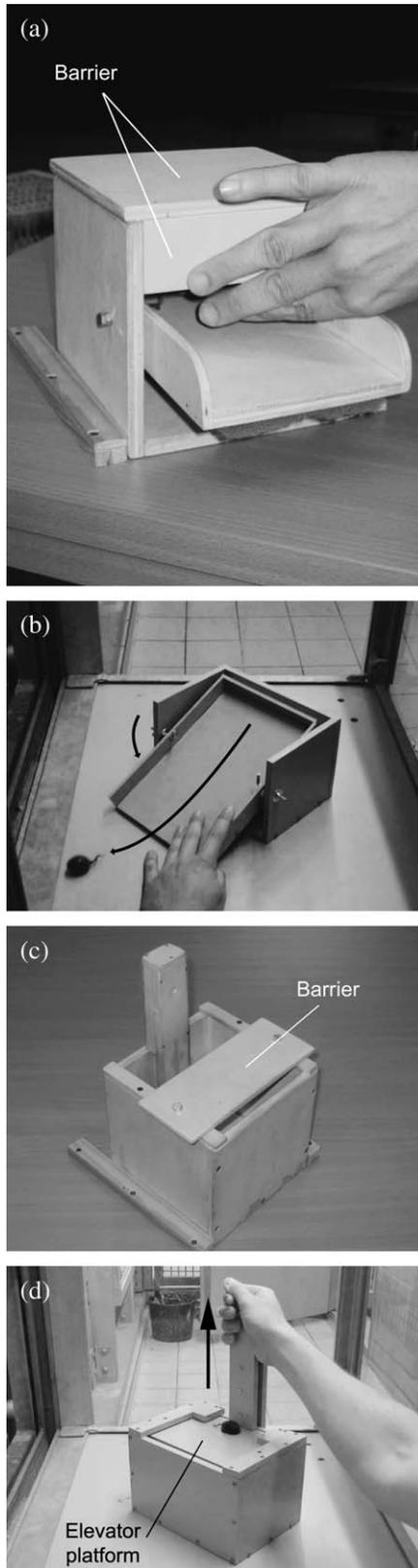


Figure 3. The boxes used in Study 2: Seesaw task: (a) E demonstrating the blocked access to the toy for an infant in the blocked condition and (b) E demonstrating use of the seesaw for an ape in the not blocked condition. Elevator task: (c) direct access to the toy inside the box is blocked in the blocked condition (infants' apparatus) and (d) the elevator pulled up to its final position in the not blocked condition (apes' apparatus). Both infants and apes watched the demonstration from the left side.

demonstration the reward was visibly placed inside a bucket (infants: 14 cm high, diameter 12.5 cm; apes: 18 cm high, diameter 20 cm). This way we ensured that participants (a) were able to take a reward out of a container similar to the test boxes and (b) had observed E taking something out of a container with her hand as a normal action.

After E's reaching demonstration, the bucket was removed and E2 placed the test box in the plexiglass box or mounted it on the table. The two conditions are described below for each task separately. As in Study 1, in each task in both conditions E used a tool to obtain the reward. The only difference was that in the blocked condition she *had* to use the tool in order to access the reward, and in the not blocked condition she *freely chose* to use the tool despite being able to access the reward easily without the tool. The procedure followed that of Study 1.

Seesaw task. E approached, called participants by name and waited until they attended, and performed the demonstration, as follows:

Blocked condition (E *had* to use the tool—the reward was not accessible): First, E watched as E2 placed a reward in the test box. Then, while E was bending down to look for something underneath the table, E2 covered the box with a barrier such that direct access to the reward was not possible. When E again attended to the box she looked surprised and then tried repeatedly to reach for the reward unsuccessfully: With an effortful facial expression she reached from three different angles (she first tried to reach from above, then tried to reach from below the front of the barrier, and then through the top back end of the barrier). She then stopped, briefly inspected the situation visually, and pressed on the protruding end of the seesaw so that the reward came into reach.

Not blocked condition (E *freely chose* to use the tool—the reward was accessible): E2 placed a reward inside the box as in the blocked condition, but while E was bending down, E2 did not cover the box with a barrier. When E again attended to the box she briefly inspected the situation visually

and then directly used the seesaw, even though she could have taken the reward easily without any use of the tool.

All of E's actions in both conditions were performed with her left hand.

Elevator task. The procedure of the blocked and the not blocked conditions followed that of the seesaw task; the main difference was that E needed two hands to operate the apparatus (she had to pull the elevator up with her right hand and then take the reward with her left hand).

For both tasks, no barrier was present during participants' response periods in either condition. Trials ended as soon as participants obtained the reward. Infants' mothers were instructed not to touch the tools and to remain quiet throughout the testing. Testing was videotaped.

Coding, reliability, and analysis. The coding procedure was identical to that used in Experiment 1. To assess interobserver reliability, an independent coder (blind to condition) scored 20% of the trials. Reliability was excellent in all cases (Cohen's kappas: infants: seesaw task, .90; elevator task, 1.0; apes: seesaw task: 1.0, elevator task: 1.0).

We analyzed participants' performance only in the seesaw task because only 2 human infants and 3 great apes (1 chimpanzee, 2 orangutans) used the tool in the elevator task at all. Because the data of both the infants and the apes were not normally distributed, we used nonparametric tests. Exact p values are reported for all analyses.

Results

Infants. As expected, infants used the tool significantly more often in the not blocked condition than in the blocked condition, Mann-Whitney $U = 42$, N (blocked) = 12, N (not blocked) = 12, $p = .028$ (Figure 4). Although they showed the same pattern of results in the first and the fourth trials separately, these differences were not statistically significant (first trial: not blocked: 25.0%, blocked: 16.7%; fourth trial: not blocked: 33.3%, blocked: 8.3%; Fisher's tests, both $ps \geq .16$).

Apes. Although for apes, the mean percentage of trials in which they used the tool in the not blocked condition is twice as large as that in the blocked condition (Figure 4), this difference was not significant, Mann-Whitney $U = 106$, N (blocked) = 14, N (not blocked) = 18, $p = .38$. There were also no significant differences when the first and the fourth trials were analyzed separately (first trial: not blocked: 33.3%, blocked: 21.4%; fourth trial: not blocked: 16.7%, blocked: 7.1%; Fisher's tests, both $ps \geq .61$).

We found no effect of age on performance (Spearman's $r_s = -.08$, $p = .67$, $N = 32$), but we found significant differences in the species' performance, Kruskal-Wallis $H(3, N = 32) = 9.53$, $p = .016$, such that orangutans used the tool more often than any other species (orangutans: 35.7%; nonorangutans: 10.0%). When we analyzed the effect of condition for each species separately, orangutans used the tool significantly more often in the not blocked (54.2%) than in the blocked (11.1%) condition; Mann-Whitney

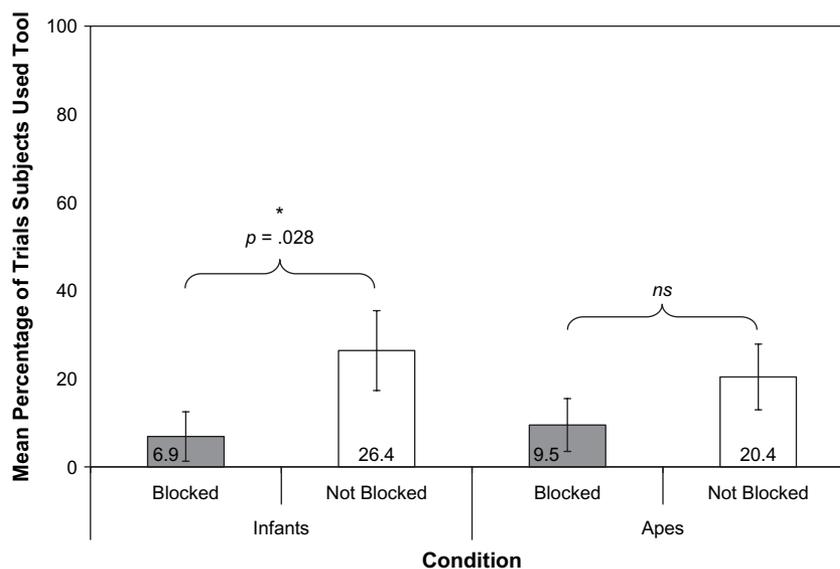


Figure 4. Mean percentage of tool use (with standard error of the mean) in each condition of the seesaw task in Study 2 (between subjects) for infants and apes.

$U = 0$, N (blocked) = 3, N (not blocked) = 4, $p = .029$. No significant effects were found for chimpanzees, bonobos, or gorillas (Mann–Whitney U tests: $p \geq .73$ in all cases).

Discussion

Unfortunately, only 2 infants and 3 apes ever used the tool in the elevator task. Although this task was designed to be relatively simple, two hands were needed to retrieve the reward at the lifted position (one hand to operate the elevator and another hand to take out the reward); this may have made the elevator more difficult to manipulate than the seesaw and so less likely to be used. However, because participants were randomly assigned and order of task and condition were counterbalanced, this meant that we could analyze the seesaw task on its own.

For infants, again, we replicated the results of Gergely et al. (2002, Study 1): Infants were more likely to use the demonstrated means (the seesaw) to access the reward after they had observed a demonstrator freely choosing to use it than after they had observed the demonstrator being forced to use it due to some constraint. Again, infants did somewhat better in the fourth trial (the one immediately following the second demonstration), but this time this difference did not reach significance for either this or the first trial separately.

And again the results for apes were unclear: Whereas apes as a group used the tool about twice as often in the not blocked condition as in the blocked condition, this difference did not reach statistical significance. Only the orangutans used the tool significantly more often when the demonstrator had freely chosen to use it than when she had been forced to use it. No other species showed this effect, even though as a group they used the tool approximately equally as often as infants overall so this could not have been the reason for their difficulty with this study. Because after dropping the elevator task, we ended up having to use a between-subjects design in this study, it is possible that despite random assignment to conditions individual differences in such things as motivation to use tools or motivation to use the same tools others do might have influenced the results. A within-subjects design (like that used in Study 1) would be a stronger experimental test because there individuals would have to switch their behavioral patterns across the different conditions. We thus tried one more version of the task, within subjects, and this time with a slightly different type of measure.

Study 3: Rational Tool Choice: Blue Table and Yellow Table

Although infants' results were clear, in both of the previous two studies evidence of any understanding of intentions as rational action plans in apes was at best extremely weak. One possible reason for this is the type of task used. Both sets of tasks in those studies required participants to decide whether or not to use a tool (differentially across conditions). In a final study, we tried a different type of task, one in which a tool was always necessary to obtain the reward. Two tools were available and participants had to choose which one of them to use. The tools were identical in terms of their functionality (i.e., both could be used equally successfully to obtain the reward), but one tool (a rope) was more familiar to participants as the kind of object that can be used to pull things toward oneself. The other (a wooden block) was more unusual, at least in the context of tool use. Again, the tasks had the same logic as that of Gergely et al. (2002). In both conditions, participants observed a human demonstrator obtain a reward by pulling the unusual tool toward himself. In one condition, first he attempted to use the usual tool but access to it was blocked. In the other condition, the demonstrator freely chose to use the unusual tool even though the other more usual option was easily available. Participants could then choose either the unusual tool or the usual tool to perform the task.

Method

Participants. Twenty-eight different 14-month-old human infants (mean age = 13.95, range = 13.76–14.30, 12 females, 16 males) and 28 of the previously tested great apes (17 chimpanzees, 4 bonobos, 2 gorillas, 5 orangutans; 10 juveniles, 18 adults; 19 females, 9 males) participated in this study. Apes were tested on average 35 weeks after the completion of Study 2. We attempted to test 5 additional apes (3 gorillas, 1 bonobo, 1 chimpanzee), but they did not complete the study because they were either unmotivated to perform the task or reluctant to operate the apparatus. Twenty-one additional infants were tested but had to be dropped because of fussiness (10), parental errors (6), experimenter errors (3), or not attending the second session (2). The high number of infants who became fussy likely was a result of their frustration at not being able to get the reward immediately and at being placed in front of a plexiglass window during the response periods.

Materials. Two tables (infants: 80 × 80 cm, apes: 100 × 50 cm), each with a movable top platform (infants:

34 × 15 cm, apes: 80 × 50 cm) and a different set of tools (see below) served as the two apparatuses in this study; Figure 5. Each table stood behind (from the participants' perspective) a plexiglass window, which had three holes in it close to the level of the table (for infants: left and right, 4 cm diameter; middle, 8 cm diameter; for apes: 5 cm diameter for all three holes). The two tables were identical in size and functionality but, to reduce carryover effects, each one had a different color (blue or yellow) and a different set of two tools paired with it: a rope as *usual tool* (different colors across tasks) and a wooden block attached to a thin string as *unusual tool* (different shapes of blocks—cylindrical or rectangular with holes—across tasks); see Figure 5 for one exemplar. Note that most of the apes in this study had already had repeated experience with different tasks in which they needed to pull in rewards using ropes (e.g., Jensen, Hare, Call, & Tomasello, 2006; Melis, Hare, & Tomasello, 2006)—and no experience to our knowledge pulling things in with wooden blocks—so it is very likely that they, like infants, saw the rope as the more usual tool for pulling.

Each of the tools could be used to pull in the movable platform with the reward on top with the exact same degree of functionality. Only the end of the rope and the wooden block protruded loosely through the left and right holes of the plexiglass window on the participants' side (the string attached to the wooden block was behind the plexiglass window at the beginning of the trial). By pulling either the rope or the block, the movable platform moved closer and so brought the reward into reach, so that it could be taken through the middle hole. Because of the different average hand size of the infants and apes, the tools for each group differed in length (infants: 15 cm long, apes: 25 cm long). Infants sat on their mother's lap on a movable office chair in front of the plexiglass window. Apes were tested in the same testing room as in the previous studies; no plexiglass box was needed because the tables could be attached directly to a plexiglass window in the mesh. Rewards were small toys for the infants and grapes for the apes.

Design. The design was the same as in the previous studies except that participants were always presented with the blue table in their first session and the yellow table in their second session. A delay was imposed between the sessions (14–22 days for infants and 2.5–4.2 months for apes) in order to reduce any carryover effects. The order of condition, the side of the unusual tool, and the toys used in individual trials were counterbalanced.

Procedure. After a warm-up period of approximately 15 min outside of the testing room (infants)

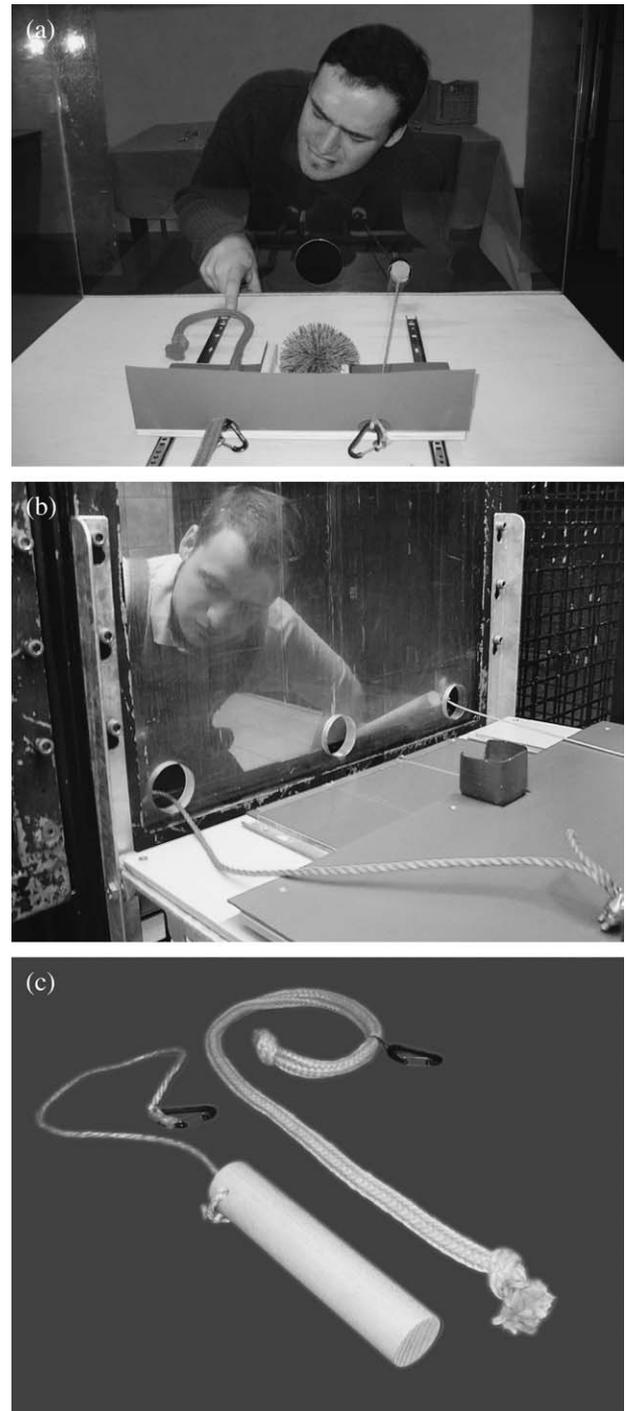


Figure 5. The setup in Study 3: (a) E trying unsuccessfully to reach the usual tool in the blocked condition in a demonstration for an infant, (b) E visually inspecting the usual tool before "rejecting" it in the not blocked condition as demonstrated for an ape, and (c) the set of tools used in the blue table task for the infants: The unusual tool (a wooden block) and the usual tool (a rope). Infants always watched the demonstration from E's right side; apes watched either from the left or the right side (depending on the construction of their enclosure).

or inside the testing room (apes), participants observed the first demonstration. E called participants by name and waited until they attended and then brought in the reward using the *unusual* tool. What differed between conditions were the constraints present and how E behaved toward the *usual* tool before this demonstration:

Blocked condition (E *had* to use the unusual tool—the usual tool was not accessible): While E was talking to the participant, E2 put the unusual tool within E's reach (by sticking it through the hole in the plexiglass window) but placed the usual tool on the table behind the plexiglass window out of E's reach (Figure 5a). E2 then called E's name and showed him a reward. E2 placed the reward in a small, open container in the middle of the movable platform. E called the participant's attention and then tried unsuccessfully (with an effortful facial expression) to reach the usual tool through the hole in the plexiglass for 8 s (three attempts), then looked at the unusual tool and pulled it to bring in the reward (three slow, short pulls).

Not blocked condition (E *freely chose* to use the unusual tool—the usual tool was accessible): While E was talking to the participant, E2 put both tools within E's reach (by sticking them through the holes in the plexiglass window; Figure 5b). As in the other condition, E2 called E's name, showed him a reward, and placed the reward in the container on the movable platform. E then called the participant's attention, inspected the usual tool visually without touching it for 8 s (three looks to different sides of it), then "rejected" it nonverbally with a mildly dismissive facial expression, and, exactly as in the other condition, then looked at the unusual tool and pulled it to bring in the reward (three slow, short pulls).

For response periods in both conditions, participants were always given equal access to both tools. E2 called participants by name, showed them a reward, and placed the reward in the container on the movable platform. She then encouraged participants by saying "Now you!" The rest of the procedure differed slightly for infants and apes.

For infants, after this encouragement, the participant's mother moved closer, to the center of the plexiglass window, to give her infant equal access to both tools. After each trial, the mother moved backward away from the tools (approximately 0.5 m) so that E2 could reset everything for the following trial or the second demonstration. If infants did not pull in the

reward within 20 s, E2 called their name, and held the reward up above the platform for 5 s, talking about it excitedly. This was repeated if the infant still did not pull on either tool in the following 20-s interval. If the infant did not bring in the reward within 1 min, E2 replaced that toy with a new toy and repeated the response trial.

For apes, following E2's encouragement, keepers released the ape into the testing enclosure. Only rarely was encouragement needed for apes to pull in the reward, perhaps because these apes were well accustomed to plexiglass windows from other studies. On the rare occasion that an ape did not pull either of the tools, E2 put a second piece of food on the movable platform after 90 s and a third one after a total time of 150 s, to motivate apes to pull. No repetition of any trial was necessary for apes.

After three trials, the participants were shown a second demonstration, followed by three more response trials. If E2 ever had to correct the position of one of the tools she always touched both tools. Infants' mothers were instructed not to touch the tools and to remain quiet throughout the testing. Testing was videotaped.

Coding, reliability, and analysis. The coding procedure was similar to that used in the previous studies except that we coded whether participants pulled the usual tool, the unusual tool, or both tools at the same time to bring the reward into reach. Furthermore, we also coded whether participants intentionally (looking at the platform at some point while moving it) or accidentally (not paying attention to the platform) moved the tools. Only intentional pulls were used for analyses.

To assess interobserver reliability, an independent coder (blind to condition) scored 25% of the trials. Reliability was excellent in all cases (Cohen's *kappas*: infants: blue table: tools: 1.0, intentional pulls: .84; yellow table: tools: 1.0, intentional pulls: 1.0; apes: blue table: tools: .86, intentional pulls: 1.0; yellow table: tools: 1.0, intentional pulls: 1.0).

The infants' performance was analyzed using a mixed-model ANOVA with condition (blocked vs. not blocked) as within-subjects factor and order of condition as between-subjects factor. The apes' mixed-model ANOVA included condition as within-subjects factor, species and order of condition as between-subjects factors, and age as a covariate. Again, we also analyzed the first and the fourth trials separately. Finally, given that the tasks were presented in the same order for all participants, we also analyzed the blue and the yellow table tasks separately between subjects (nonparametric statistics were used for the apes' blue table task because the

data were not normally distributed in that task). Exact p values are reported for all analyses.

Results

Infants. As expected, infants chose the unusual tool significantly more often in the not blocked condition than in the blocked condition, $F(1, 26) = 8.75, p = .004$ (Figure 6). There was no effect of order of condition, $F(1, 26) = .80, p = .44$. Infants showed this pattern of results in both the first and fourth trials separately (McNemar tests: first trial: not blocked: 89.3%, blocked: 60.7%, $p = .019$; fourth trial: not blocked: 85.7%, blocked: 50.0%, $p = .003$).

Moreover, this result held for each task individually as well. In the blue table task, the infants chose the unusual tool in 82.1% of the trials in the not blocked condition compared to 58.3% of the trials in the blocked condition, $t(26) = 2.10, p = .023$. Similarly, in the second, yellow table task, infants chose the unusual tool in 82.9% of the trials in the not blocked condition compared to 61.9% of the trials in the blocked condition, $t(26) = 1.82, p = .039$.

Apes. Unlike infants, apes chose the unusual tool equally often in both conditions, $F(1, 20) = 2.68, p = .117$ (Figure 6). There were no effects of species, order of condition, or age, all $ps \geq .28$, and no significant interactions, all $ps \geq .088$. Furthermore, there was no difference between the conditions in either the first trial (not blocked: 53.6%, blocked: 46.4%) or the fourth trial (not blocked: 39.3%, blocked: 32.1%), McNemar tests, ($ps \geq .69$).

The apes showed similar results in each of the individual tasks as well: they used the unusual tool equally often in both conditions in the blue table task, (not blocked: 37.5%, blocked: 29.2%, Mann–Whitney $U = 85, N$ (blocked) = 12, N (not blocked) = 16, $p = .61$), as well as in the yellow table task, not blocked: 43.1%, blocked: 44.8%, $t(26) = 0.11, p = .91$.

Discussion

We replicated the infants' results yet again, with a new type of task involving a different type of measure. Infants chose the same, unusual tool the demonstrator chose more often when they saw the demonstrator freely choose to use it than when they saw him choose it only because there was no other option available. In this study, they did this from their very first trial.

For apes, in this study, results were clear: There was no difference in apes' choice of tool between the two conditions. By necessity apes used a tool in all trials, and even used the unusual tool in about 40% of trials, but unlike infants, they did not do this differentially as a function of why the demonstrator chose that tool himself.

Overall Results for Apes

Analyses

Because apes participated in all three studies, we were able to analyze their performance—both as

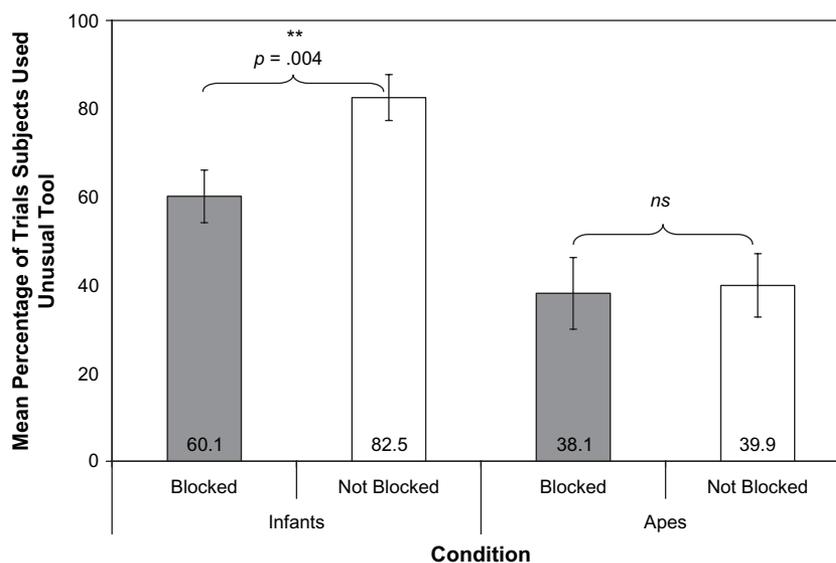


Figure 6. Mean percentage of tool use (with standard error of the mean) in each condition of Study 3 (collapsed across tasks, within subjects) for infants and apes.

a group and as individuals—across all three studies combined. For the overall group analysis, we ran a mixed-model ANOVA on the percentage of trials in which apes used/chose the unusual tool across tasks, with condition (blocked vs. not blocked) as within-subjects factor, species as between-subjects factor, and age as a covariate. We then analyzed the species separately using paired samples *t* tests. For the analysis of individual patterns, for each participant, we ran a Fisher's test comparing the number of trials in which the participant used/chose the unusual tool in each condition.

Results and Discussion

For apes as a group, across all three studies combined apes used/chose the unusual tool equally often in both conditions (not blocked: 39.3%, blocked: 41.3%), $F(1, 29) = .11, p = .74$. There was also no interaction between age and condition, $F(1, 29) = .02, p = .88$. However, there was a marginally significant interaction between condition and species, $F(3, 29) = 2.41, p = .088$. A closer inspection of the data revealed that orangutans used/chose the unusual tool significantly more often in the not blocked (60.3%) than in the blocked (39.7%) condition, $t(6) = 4.02, p = .007$. For all the other species, there were no significant differences, $p_s \geq .22$ (Figure 7).

On the individual level, across all three studies combined, all the orangutans (7 of 7) used/chose the unusual tool at least somewhat more often in the not blocked than in the blocked condition. Only about half of chimpanzees (9 of 17) and bonobos (3 of 5) did

this and no gorillas did. Two apes showed a significant difference between conditions individually. One female orangutan used/chose the unusual tool significantly more often in the not blocked condition than in the blocked condition, $p = .009$. However, 1 female bonobo significantly showed the opposite pattern, $p = .001$.

In summary, when the results of all three studies were analyzed together, we found that only orangutans showed strong evidence of rational tool use and tool choice, both as a group and, to some extent, as individuals. There is thus some evidence that one species of ape, orangutans, understands others' intentions as rational choices of action plans, despite having no human enculturation.

General Discussion

With infants, we replicated the findings of Gergely et al. (2002) in each of three different tasks. Fourteen-month-old infants in all of these studies used the same unusual action a demonstrator used more often when the demonstrator freely chose to use this action (not blocked condition) than when she was forced to use it because of some constraint (blocked condition). Apparently, they used the unusual action in the not blocked condition because they assumed that there must have been some reason why the demonstrator chose this action over other possible, more usual ones, and by performing it themselves they might figure out what this reason was. In the blocked condition, on the other hand, infants apparently assumed that the

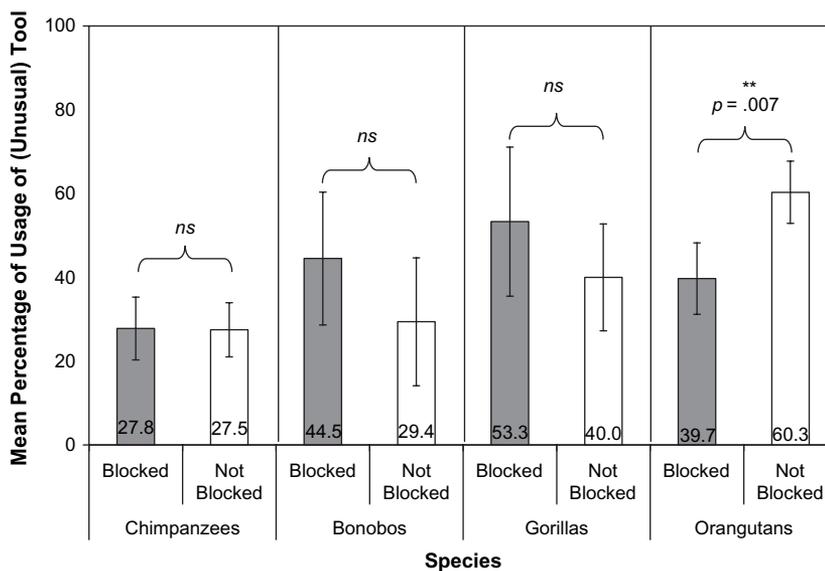


Figure 7. Mean percentage of use/choice of the unusual tool (with standard error of the mean) in each condition for each species across all three studies combined.

demonstrator only used the unusual action because she was forced to do so by her circumstances, and that, because they were not constrained in the same way, they were free to use a more usual action. Fourteen-month-olds thus apparently understand others' intentions in terms of rational choices of action plans to achieve goals. They do this flexibly across a wide variety of different tasks (see also Schwier et al., 2006, for yet another version with 12-month-olds). In addition, the current studies show for the first time that they can even do this on a within-subjects basis, responding differently when presented with different versions of the same task in different conditions.

Orangutans in the current studies behaved like the infants in some analyses, particularly in the second study, thus suggesting that they, too, understand others' intentions in terms of rational choices of action plans to achieve goals, as do enculturated chimpanzees in Buttelmann et al.'s (2007) study. However, the other apes we tested showed no evidence of this understanding. Although apes used the tools equally as often as infants overall, chimpanzees, bonobos, and gorillas did not use the tool that the demonstrator had used differentially depending on the reasons underlying the demonstrator's choice of that tool.

As always, negative results are difficult to interpret. For example, there were several methodological differences between infants' and apes' procedures that might have put apes at a disadvantage compared to infants. Two such differences included (a) the use of the same apes but different infants in each study and (b) the length of the delay between conditions. However, already on the first day of the first study, when neither apes nor infants had ever been tested on these tasks before and there had been no delay, infants (in their fourth trial) showed the correct pattern of responding but apes did not, so it is unlikely that either of these factors influenced the results. Another important methodological difference was that infants were tested using a conspecific demonstrator, whereas apes were tested using a nonconspecific demonstrator. This meant that apes had to read *human* intentions to succeed at this task, and this might have been more difficult for them than reading conspecifics' intentions. However, currently, the strongest evidence we have that apes understand different psychological states of others comes from studies using human experimenters as demonstrators. In these studies—some of which included as participants some of the same individuals as in the current studies—apes have been shown to understand humans' perception and knowledge (Hare, Call, Agnetta, & Tomasello, 2000; Hare, Call, & Tomasello, 2001), desires (Buttelmann, Call, & Tomasello, in

press), and, most importantly for current purposes, goals (Call & Tomasello, 1998; Call et al., 2004; Call et al., 2005; Tomasello & Carpenter, 2005). The only observable information apes could have used to succeed in many of these tasks was exactly the same kind of information we presented them with here: human facial expressions, looking patterns, and actions such as reaching (see also Hare & Tomasello, 2004; Warneken & Tomasello, 2006, who showed that these chimpanzees understand human reaching just as well as conspecific reaching). Although future research using conspecific demonstrators would be helpful, we thus are confident that these facial expressions and/or actions are comprehensible to apes and that they could have used them in the current studies—as indeed the orangutans did.

If methodological differences do not explain why most of the apes did not differentiate between conditions, then perhaps other, more general differences between apes and infants not involving intention understanding played a role. For example, perhaps a difference between apes' and infants' understanding of physical causality explains why apes did not use the unusual tool more often in the not blocked than the blocked condition. That is, if apes possessed a deeper understanding of physical causality than infants, then they might have been less likely than infants to believe that there might be some advantage to using the unusual tool and so would be less likely to use that tool themselves because that was not necessary for them. However, in Study 1, at least, apes actually used the tools more often than infants (in both conditions). In addition, again, orangutans showed the same pattern of results as infants in the current studies but they are no worse (or better) than the other ape species tested in other tasks involving understanding of physical causality (e.g., Girndt, Meir, & Call, 2008; Martin-Ordas, Call, & Colmenares, in press), suggesting that this cannot be the full explanation.

Perhaps, then, general differences in more social factors between apes and infants can explain the negative findings with most of the apes. For example, although we reduced the imitative demands of the test situation as much as possible, to succeed, in the not blocked condition, participants had to use the tool the demonstrator used. It is unclear whether the choice of the same tool the demonstrator chose constitutes imitation—it does not involve copying specific body movements, for example, and we did not test whether participants might have been using other social learning mechanisms. But if our tasks do require some imitation, then differences between apes and infants in the motivation to copy others could have influenced the results. That is, we and others have proposed that

whereas human children often imitate for social reasons—to communicate to others that they are like them (see Užgiris, 1981)—apes' social learning has a more instrumental function (Carpenter & Call, in press; Nielsen, in press). Thus, it is possible that apes fully understood the demonstrator's rational choice of the unusual tool but were simply not motivated to copy this choice. Instead, they might just have concentrated on the goal of the action and then chose whatever means they themselves preferred to achieve that goal (emulation; Tomasello, 1990). However, although this might be a plausible explanation for the difference in results between enculturated and nonenculturated chimpanzees (on different tasks)—enculturated chimpanzees may be more motivated to copy others—again there is no reason to believe that nonenculturated orangutans are more socially motivated than other nonenculturated apes: They are no better (or worse) than other apes on social learning tasks (e.g., Call & Tomasello, 1994; Nagell, Olguin, & Tomasello, 1993; Tennie, Call, & Tomasello, 2006).

So why do orangutans and enculturated chimpanzees, but not nonenculturated chimpanzees, bonobos, and gorillas, succeed on these tasks? One possibility is that all apes understand others' intentions—like they understand others' goals (see Buttellmann, Call, & Tomasello, 2008; Call & Tomasello, 1998; Call et al., 2004)—but that only some of them are able to show this understanding in the current experiments, for example, due to special attentional and/or motivational qualities. Enculturation, for instance, might make apes more sensitive to human pedagogical cues manifesting new and relevant information (see Gergely & Csibra, 2006). Or it might provide apes with the combination of a heightened interest in the reasons why humans do things and an increased social motivation to do things the way others do (see Carpenter, 2006), which then allows them to succeed on these tasks. At this point, we can only speculate about why nonenculturated orangutans, who are evolutionarily more distantly related to humans than other apes, show evidence of rational tool use and tool choice, whereas other nonenculturated apes do not. One possible explanation involves the type of attention orangutans might have paid to the demonstration. Although we made sure that all apes (like infants) watched each demonstration, it is possible that orangutans focused on the relevant parts more closely than the other apes did. They might have done this for several reasons, for example, because in general they may be more interested in tool use than other apes (we found that they used the tools more often than the other species overall) or because they might have been slightly less food motivated than the

other apes and so could focus more easily on other aspects of the demonstration (we noticed that occasionally orangutans played with the tools before taking the food, whereas other apes did not do this). Future studies using different methods—especially completely nonimitative methods—are needed to determine the extent of other apes' understanding of intentional action.

One might challenge our interpretation of the current results by arguing that there is another crucial difference between the procedure of the current studies and that of Gergely et al. (2002): In all three of the current studies, in the blocked condition, participants were shown a failed attempt to use the usual method of obtaining the reward (hand or usual tool), whereas in Gergely et al.'s study, participants saw only the use of the unusual action in both conditions. It could thus be argued that the differential responses that successful participants showed were based simply on an understanding of failed attempts (goals) instead of an understanding of rational choice of action plans (intentions). More specifically, it is possible that infants and orangutans used the unusual tool less often in the blocked condition *only* because they were trying to reenact the demonstrator's failed attempt to use the usual tool/hand. There are at least two arguments against this idea, however.

First, for infants, three other previous studies have used a similar procedure in which a failed attempt is demonstrated before a successful action in the equivalent to our blocked condition (Király & Gergely, 2002; Nielsen, 2006; Schwiier et al., 2006). However, very different patterns of results are found across these studies. In Király and Gergely's (2002) and Nielsen's (2006) studies, 12- and 14-month-olds used the tool the demonstrator successfully used more often in the blocked condition than in the not blocked condition. In contrast, in Schwiier et al.'s (2006) and the current three studies, 12- and 14-month-olds showed the opposite pattern of results: They reenacted the failed, usual action more often in the blocked than in the not blocked condition. Interestingly, there is a crucial methodological difference between the two types of studies, which nicely explains this pattern of results. In Király and Gergely's and Nielsen's studies, the constraints for the infants and the demonstrator were identical, so infants could assume that the first action would not work for them either. However, in Schwiier et al.'s and the current studies, the constraints for the infants and the demonstrator were unequal—only the demonstrator was constrained—so infants could assume that they did not need to perform the unusual action but instead could use the usual action, the one

the demonstrator had originally wanted to use (note that the current studies are closer to the original study of Gergely et al., 2002, in that respect). Taken together, this pattern of results suggests that infants do not simply reenact a demonstrator's failed attempt when given a choice; if they did this they would have reenacted this action in all of these studies. Instead, they support the current interpretation by showing that infants take into account the constraints on the demonstrator—the reasons why she acted the way she did—as well as the constraints on themselves and then choose an action themselves rationally.

The second argument against a failed attempt interpretation of the current results concerns the apes. As far as we know, there are no previous studies of orangutans' understanding of others' failed attempts (the closest is Call & Tomasello's, 1998, study of their understanding of accidents) and therefore no studies that present orangutans with both a failed and a successful action, as in the infant studies discussed above. Thus, the failed attempt explanation of orangutans' results is still viable. However, there are several studies of chimpanzees that argue against a failed attempt explanation in the current studies. That is, there is some evidence that chimpanzees recognize failed attempts and respond accordingly in social learning situations (Call et al., 2005; Tomasello & Carpenter, 2005) but chimpanzees were not successful on the current tasks. This suggests, again, that successful participants—both apes and infants—were going beyond failed attempt understanding and using an understanding of others' intentions as rational choices of action plans in these tasks.

An understanding of others' intentions, along with an understanding of others' goals, allows individuals to interpret others' actions in powerful new ways. For example, it can help an individual predict what a competitor might do next—something apes are already quite good at (see, e.g., Hare & Tomasello, 2004). But this understanding is especially helpful in more cooperative activities, such as cultural learning and collaboration—things apes are not so good at (see Tomasello, Carpenter, Call, Behne, & Moll, 2005, for a review). If I know that you have chosen to do something in a particular manner, and if I even have some idea of why you might have chosen to do it in that particular way, then I can better decide what I should copy from you or how best I can help or coordinate with you (e.g., Bratman, 1992; Sebanz, Bekkering, & Knoblich, 2006; Tomasello et al., 2005).

Some apes apparently have this understanding of others' intentions, but they do not copy or collaborate with others to anywhere near the same extent as humans. Thus, although an understanding of others'

intentions is necessary for human-style cultural learning and collaboration, it clearly is not sufficient. Also needed are the skills and the motivation for *sharing* intentions and other psychological states with others (Tomasello & Carpenter, 2007; Tomasello et al., 2005). This is what turns more individualistic skills of social learning and group action into their collectively based, uniquely human counterparts of cultural learning and collaboration.

References

- Behne, T., Carpenter, M., Call, J., & Tomasello, M. (2005). Unwilling versus unable: Infants' understanding of intentional action. *Developmental Psychology, 41*, 328–337.
- Bratman, M. E. (1992). Planning and the stability of intention. *Minds and Machines, 2*(1), 1–16.
- Buttelmann, D., Call, J., & Tomasello, M. (2008). Behavioral cues that great apes use to forage for hidden food. *Animal Cognition, 11*, 117–128.
- Buttelmann, Call, & Tomasello, M. (in press). Do great apes use emotional expressions to infer desires? *Developmental Science*.
- Buttelmann, D., Carpenter, M., Call, J., & Tomasello, M. (2007). Enculturated chimpanzees imitate rationally. *Developmental Science, 10*, F31–F38.
- Call, J., & Carpenter, M. (2003). On imitation in apes and children. *Infancia y Aprendizaje, 26*, 325–349.
- Call, J., Carpenter, M., & Tomasello, M. (2005). Copying results and copying actions in the process of social learning: Chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Animal Cognition, 8*, 151–163.
- Call, J., Hare, B., Carpenter, M., & Tomasello, M. (2004). "Unwilling" versus "unable": Chimpanzees' understanding of human intentions. *Developmental Science, 7*, 488–498.
- Call, J., & Tomasello, M. (1994). Production and comprehension of referential pointing by orangutans (*Pongo pygmaeus*). *Journal of Comparative Psychology, 108*, 307–317.
- Call, J., & Tomasello, M. (1998). Distinguishing intentional from accidental actions in orangutans (*Pongo pygmaeus*), chimpanzees (*Pan troglodytes*), and human children (*Homo sapiens*). *Journal of Comparative Psychology, 112*, 192–206.
- Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in imitation. In S. J. Rogers & J. Williams (Eds.), *Imitation and the development of the social mind: Lessons from typical development and autism* (pp. 48–70). New York: Guilford.
- Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- to 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior and Development, 21*, 315–330.
- Carpenter, M., & Call, J. (in press). Comparing the imitative skills of children and nonhuman apes. *Primateologie*.

- Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science*, *8*, F13–F20.
- Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature*, *415*, 755.
- Gergely, G., & Csibra, G. (2006). Sylvia's recipe: The role of imitation and pedagogy in the transmission of human culture. In N. J. Enfield & S. C. Levinson (Eds.), *Roots of human sociality: Culture, cognition, and human interaction* (pp. 229–255). Oxford, UK: Berg.
- Girndt, A., Meir, T., & Call, J. (2008). Task constraints mask great apes' causal knowledge in the trap-table task. *Journal of Experimental Psychology: Animal Behavior Processes*, *34*, 54–62.
- Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. *Animal Behaviour*, *59*, 771–786.
- Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know? *Animal Behaviour*, *61*, 139–151.
- Hare, B., & Tomasello, M. (2004). Chimpanzees are more skillful in competitive than in cooperative cognitive tasks. *Animal Behaviour*, *68*, 571–581.
- Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition*, *8*, 164–181.
- Jensen, K., Hare, B., Call, J., & Tomasello, M. (2006). What's in it for me? Self-regard precludes altruism and spite in chimpanzees. *Proceedings of the Royal Society of London, Series B—Biological Sciences*, *273*, 1013–1021.
- Király, I., & Gergely, G. (2002, April). *Imitation of goal-directed acts in infants is a selective interpretive process*. Poster presented at the meeting of the International Society of Infant Studies, Toronto, Canada.
- Martin-Ordas, G., Call, J., & Colmenares, F. (in press). Tubes, tables, and traps: Great apes solve two functionally equivalent trap tasks but show no evidence of transfer across tasks. *Animal Cognition*.
- Melis, A. P., Hare, B., & Tomasello, M. (2006). Engineering cooperation in chimpanzees: Tolerance constraints on cooperation. *Animal Behaviour*, *72*, 275–286.
- Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 1–16.
- Myowa-Yamakoshi, M., & Matsuzawa, T. (2000). Imitation of intentional manipulatory actions in chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, *114*, 381–391.
- Nagell, K., Olguin, K., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees and human children. *Journal of Comparative Psychology*, *107*, 174–186.
- Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology*, *42*, 555–565.
- Nielsen, M. (in press). The imitative behaviour of children and chimpanzees: A window on the transmission of cultural traditions. *Primatologie*.
- Povinelli, D. J., & Dunphy-Lelii, S. (2001). Do chimpanzees seek explanations? Preliminary comparative investigations. *Canadian Journal of Experimental Psychology*, *5*, 93–101.
- Schwier, C., van Maanen, C., Carpenter, M., & Tomasello, M. (2006). Rational imitation in 12-month-old infants. *Infancy*, *10*, 303–311.
- Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences*, *10*, 70–76.
- Tennie, C., Call, J., & Tomasello, M. (2006). Push or pull: Emulation versus imitation in great apes and human children. *Ethology*, *112*, 1159–1169.
- Tomasello, M. (1990). Cultural transmission in the tool use and communicatory signaling of chimpanzees. In S. T. Parker & R. K. Gibson (Eds.), *“Language” and intelligence in monkeys and apes. Comparative and developmental perspectives* (pp. 274–311). New York: Cambridge University Press.
- Tomasello, M., & Call, J. (1997). *Primate cognition*. New York: Oxford University Press.
- Tomasello, M., & Carpenter, M. (2005). The emergence of social cognition in three young chimpanzees. *Monographs of the Society for Research in Child Development*, *70*(1, Serial No. 279).
- Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*, 121–125.
- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*, 675–691.
- Tomasello, M., Savage-Rumbaugh, S., & Kruger, A. (1993). Imitative learning of actions on objects by children, chimpanzees and enculturated chimpanzees. *Child Development*, *64*, 1688–1705.
- Užgiris, I. C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development*, *4*, 1–12.
- Warneken, F., & Tomasello, M. (2006). Altruistic helping in human infants and young chimpanzees. *Science*, *311*, 1301–1303.
- Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, *69*, 1–34.