Child Development, May/June 2006, Volume 77, Number 3, Pages 640 – 663

Cooperative Activities in Young Children and Chimpanzees

Felix Warneken, Frances Chen, and Michael Tomasello
Max Planck Institute for Evolutionary Anthropology

Human children 18 – 24 months of age and 3 young chimpanzees interacted in 4 cooperative activities with a human adult partner. The human children successfully participated in cooperative problem-solving activities and social games, whereas the chimpanzees were uninterested in the social games. As an experimental manipulation, in each task the adult partner stopped participating at a specific point during the activity. All children produced at least one communicative attempt to reengage him, perhaps suggesting that they were trying to reinstate a shared goal. No chimpanzee ever made any communicative attempt to reengage the partner. These results are interpreted as evidence for a uniquely human form of cooperative activity involving shared intentionality that emerges in the second year of life.

From soon after birth, human infants interact with other persons dyadically in coordinated, turn-taking sequences (Trevarthen, 1979). From about 6 to 9 months of age, infants' social interactions become more complex, as they often incorporate outside objects and so become triadic (Tomasello, 1995). Some of these triadic interactions are relatively extended and maintain a turn-taking structure, for example, rolling a ball back and forth or taking turns beating a drum (Gustafson, Green, & West, 1979; Ratner & Bruner, 1978). Most of these early triadic interactions—sometimes called cooperative games—seem to rely on adult scaffolding in fairly ritualized situations, because the introduction of novel toys or a peer partner disrupts them almost totally until 18 months of age (Hay, 1979; Ross, 1982).

In a series of longitudinal studies, Eckerman and colleagues have investigated the emergence of young children's skills in cooperative games of a less ritualized nature (Eckerman, Davis, & Didow, 1989; Eckerman & Didow, 1989, 1996; Eckerman & Stein, 1990). In interactions with both adults and peers in games such as taking turns throwing a ball down a chute, young children seem to become much more skillful at around 20 – 24 months of age, spontaneously generating coordinated acts in nonritualized contexts, even with peers. The main strategy by which they do this is termed the "imitative pattern," as one partner follows the lead of the other by doing what they do in a turn-taking sequence. Eckerman (1993) marks this age late in the second year as the point at which young children go beyond participation in structured, ritualized interactions, and become able to create new forms of coordinated action. In our study, we thus tested children at 18 and 24 months to assess whether this age shift toward more coordinated activities is also apparent in problem-solving tasks.

Ross and Lollis (1987) introduced an interesting experimental manipulation into these games. Focusing on children 9 – 18 months of age interacting with adults, they had the adult partner simply stop participating at a predetermined moment. This manipulation was designed to provoke children into responding in ways that might reveal more about how they understood these cooperative games and the two roles in them. The main finding was that in response to this unwanted interruption, children from about 13 months of age tended to vocalize more often and sometimes took the adult's turn for her. With increasing age, children made reference to both the object and the partner's role by giving the toy to the adult or taking her turn. Ross and Lollis interpreted these behaviors as evidence that the children understood the cooperative nature of the interaction and the reciprocal nature of the roles involved. But this conclusion seems premature for at least two reasons. First, the interactions were mostly familiar,

Many thanks to the children and their parents for their cooperation. We thank Elena Rossi and Kristin Liebal for help with testing the children and Susanne Mauritz, Hanna Petschauer, and the keepers at the Leipzig Zoo for help with testing the chimpanzees. Thanks also to Anja Gampe and Petra Jahn for assistance in coding and to Daniel Stahl for statistical advice. We are grateful to three anonymous reviewers for their comments. These studies were conducted at the Max Planck Institute for Evolutionary Anthropology and the Wolfgang Köhler Primate Research Center in Leipzig, Germany.

Correspondence concerning this article should be addressed to Felix Warneken, Department of Developmental and Comparative Psychology, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, D-04103 Leipzig, Germany. Electronic mail may be sent to warneken@eva.mpg.de.

 0009-3920/2006/7703-00010

possibly ritualized, interactions, and children's vocalizations might simply be expressing frustration at the derailing of the familiar game. Indeed, coding of the vocalizations in this study did not take account of communicative function, that is, it did not attempt to identify the child's goal in vocalizing—what she wanted the adult to do. Second, while taking the adult's turn in the interaction might indicate the infant's full understanding of the cooperative structure of the interaction and its roles, it might also indicate more simply infants' tendency to imitate others, or even attempts to play the game alone. Again, the coding in the study did not attempt to identify the child's goal or intention, and so we cannot distinguish among these possibilities.

There is another tradition in the study of children's cooperative activities that approaches it from a different angle. The study of children's cooperative problem solving has generally focused on older children, either school age or late preschool (see Johnson & Johnson, 1989; Rogoff, 1998, for reviews). Cooperative problem-solving tasks are by definition novel for children, and they have a clear goal that can only be achieved through coordinated action (nothing useful or interesting can be accomplished individually). The coordinated action also needs to take place basically simultaneously and the roles are typically different; therefore, the "imitative pattern" used by younger children is not readily available as a strategy. As one example, Ashley and Tomasello (1998) presented children with a clear tube with a toy inside; to get the toy one child had to pull a string to bring it in front of a door at the same time that the other child worked a lever to open the door. Children were over 3 years old before they could coordinate skillfully and communicate effectively with one another in this difficult task.

The only study that has shown successful cooperative problem solving by younger children is that of Brownell and Carriger (1990, 1991). In their tasks one child had to manipulate a spring-loaded handle to make toys accessible, and the other child simply had to grab them. This task proved impossible for 12-month-olds and very difficult for 18-month-olds (who were only successful accidentally, never reliably). Only children 24 months of age and older were able to coordinate successfully and repeatedly in this task. By designing mechanically less demanding tasks, we wanted to assess whether skillful cooperation can be found also at an earlier age.

In this study, we wanted to combine various features from the two research traditions—cooperative games and cooperative problem solving—to determine how young children coordinate their actions in cooperative activities and what they understand about the social roles involved. Following the theoretical proposals of Tomasello, Carpenter, Call, Behne, and Moll (2005), we were especially interested in cooperative interactions that demonstrate some form of *shared* intentionality, as interactions of this type may be uniquely human. In interactions involving shared intentionality, participants do not just react to one another's actions, but they have intentions toward the other's intentions; they must understand the intentions of the other and incorporate them into their own intention (Bratman, 1992; Gilbert, 1989; Searle, 1990, 1995; Tuomela, 1995). More precisely, in these interactions the interactants have a joint goal (e.g., they each have the goal to get the toy and the goal that the other have that same goal), and they develop joint intentions (plans) for achieving that joint goal. Because having a joint goal implies a commitment to the joint goal, if one partner reneges, the other is often upset with her and attempts to persuade her communicatively to recommit to the goal. We may summarize this by saying that cooperative activities involving shared intentionality involve both a joint goal and interdependent roles (joint intentions) toward that goal.

Therefore, in the current study we presented 18- and 24-month-old children with four tasks requiring cooperation. The partner was an adult because we wanted to utilize the "programmed partner" method in which the adult stops playing his role at key moments. Beyond Ross and Lollis (1987), who originally used this method, we wanted to code the child's reactions to the interruption in terms of her goals—what she wanted the adult to do and what she was trying to communicate to the adult. Thus, we utilize this method to assess shared intentionality: If subjects had formed a shared goal with the other and the partner is not doing his part of the joint activity, they should attempt to reengage him. In this way, we sought to determine if the children had indeed formed with the adult a joint goal (as evidenced by communicative attempts to get him reengaged with the task) and if she understood the different roles involved (components in a joint intention). We designed the tasks to be as simple as possible in terms of cognitive demands. Two of the four tasks were problem-solving tasks with a concrete goal of extracting an object, and in two of them the goal was simply to play a social game together. Both required two participants to each play their role at the same time. Within each of these pairs one task had parallel (highly similar) roles, whereas the other had complementary (very different, but interdependent) roles. The variety of tasks and roles was aimed at providing a more comprehensive and reliable picture of cooperative skills.

In addition, we were interested in the phylogenetic roots of human cooperative behaviors. We adopted a comparative approach to investigate how chimpanzees (our closest primate relatives) would engage in cooperative activities and to identify species-specific behavioral patterns that could address whether the formation of joint intentions and goals is a uniquely human ability. We therefore presented these same four tasks to three young chimpanzees, including the programmed partner manipulation, minimizing changes so that the scenarios faced by the subjects in the two studies were as comparable as possible.

Previous research on chimpanzee cooperation has shown mixed results. Although chimpanzees in the wild engage in some forms of cooperative activity (e.g., cooperative hunting; Boesch & Boesch, 1989), in laboratory experiments their skills seem to be extremely limited. Even in very simple tasks with two parallel roles—such as two chimpanzees each pulling on their own rope to bring a heavy box of food within reach—there is very little coordination beyond each partner timing its activity to coincide with that of the other (Chalmeau, 1994; Chalmeau & Gallo, 1996; Crawford, 1937, 1941; Melis, Hare, & Tomasello, in press; Povinelli & O'Neill, 2000). Furthermore, in none of these scenarios is it clear whether coordination is achieved through the creation and maintenance of joint goals or through well-timed individual efforts. Neither naturalistic observations nor laboratory experiments have specifically addressed the question of whether chimpanzees can engage in cooperative activities involving shared intentionality.

Regarding other primate species, one laboratory experiment has suggested that tamarin monkeys have a capacity for reciprocal altruism (Hauser, Chen, Chen, & Chuang, 2003). However, as the two actors in this experiment were not engaged in an activity requiring simultaneous cooperation, the extent of these individuals' abilities to form shared goals and actively regulate each other's actions remains unclear. Second, Mendres and de Waal (2000) showed that capuchin monkeys successfully cooperated in a pulling task similar to the one used with chimpanzees (e.g., Crawford, 1937, 1941). Although they were sensitive to the presence of a potential pulling partner, there again was no experimental manipulation to assess whether subjects had formed a shared goal and regulated each other's actions.

Our chimpanzees, being human reared in an environment that included close interactions with several human caretakers and numerous enrichment objects, provided a unique opportunity to address the issue of shared intentionality. Our chimpanzees were perhaps maximally prepared for success, as they interacted with a human partner with whom they were highly familiar and with whom they were capable of communicating if, during the interruption, they desired her to reengage.

Study 1: Human Children

In this study, we aimed to assess 18- and 24-month-old children's skills in coordinating their actions with those of an adult partner in cooperative activities, including their attempts to regulate the partner's actions during interruptions. We hypothesized that we would find (1) age differences in children's level of coordination, with the 24-month-old children adjusting their actions better to the partner than the younger age group, and (2) age differences in behaviors during interruption periods, with the older children regulating the activity during interruption periods more than their younger counterparts.

Method

Participants

Participants were 32 children of two age groups: sixteen 18-month-olds ($M = 17.9$ months; range = 17.5–18.5 months; 10 girls and 6 boys) and sixteen 24-month-olds ($M = 24.0$ months; range = 23.5–24.4 months; 10 girls and 6 boys). Nine additional children had to be excluded from the study: 4 because they did not detach from their parent during warm-up, 4 because they failed to come to the second testing session, and 1 because of problems with the videotaping.

Children were recruited from a database of parents who volunteered to participate in psychological studies. All children were seen in a child laboratory, which they visited with a parent for two testing sessions of approximately 20–25 min each. Children received a toy at the end of the second session. They were all native German speakers and came from heterogeneous socioeconomic backgrounds. In each age group, approximately one half of the children had siblings.

Materials and Design

Four tasks were developed for this study (see Figure 1): Two problem-solving tasks and two social games with either complementary or parallel roles.

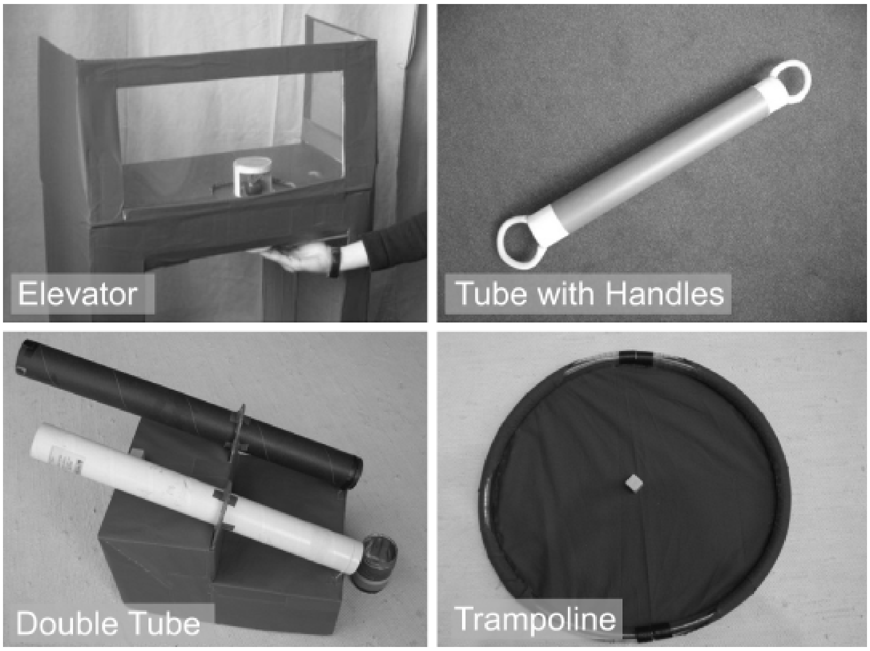

Figure 1. Study 1. Apparatus used for problem-solving tasks (top row) and social games (bottom row) with complementary (left column) and parallel (right column) roles.

In order to perform the tasks successfully, two persons had to operate the apparatus by synchronously performing either one of two different actions (*complementary*) or two similar actions (*parallel*). In problem-solving tasks, familiar toys of approximately 3×3 cm served as target objects (e.g., miniature animals, bells, toy blocks) that were used in a random order. They were all attractive to children as determined through pilot testing.

Problem solving with complementary roles: Elevator task. The goal of this task was to retrieve an object that is inside a vertically movable cylinder. Before one person could access the object through the opening of the cylinder from one side of the apparatus (*role A*), the other person had to position herself on the other side and push the cylinder up from underneath and hold it in place (*role B*). It was impossible for a single person to perform both actions simultaneously, as transparent screens prevented reaching to the opening while pushing the cylinder up.

Problem solving with parallel roles: Tube-with-handles task. The goal of this task was to retrieve a toy that is enclosed in a tube. The tube, which was 110 cm long and 10 cm in diameter with one handle on either side, could only be opened by two persons simultaneously pulling at both ends. The length of the tube made it impossible for children to grasp both handles at the same time.

Social game with complementary roles: Double-tube task. Two 75-cm-long tubes were mounted on a box in parallel, and on a 20° incline. The game was played by one person sending a wooden block down one of the tubes from the upper side (*role A*) and the other person catching it at the other end with a tin can that made a rattling sound (*role B*).

Social game with parallel roles: Trampoline task. Two 3-cm-thick C-shaped hoses were connected with flexible joints to form a ring of 67 cm in diameter, which was covered with cloth. Two persons could make a wooden block jump on the trampoline by holding the rim on opposite sides. Owing to the joints that were integrated in the ring, the trampoline collapsed when being held on only one side.

Children were tested twice during 1 week, with the sessions on average spaced 3 days apart. In each testing session, all four tasks with four trials each were administered. Task order within sessions was counterbalanced by means of a Latin-square design. In tasks with complementary roles, children performed one role on the first and the other role on the second session, in counterbalanced order between subjects.

Procedure

After a warm-up phase with the two experimenters, children were brought to the experimental room accompanied by a parent. Parents were seated in the corner of the testing room and remained passive during sessions. If the child approached the parent, they were asked to draw the child's attention back to the experimenter but not direct the child or give any hints of what she was supposed to do. A male experimenter served as play partner (E1) and a female experimenter (E2) helped during demonstrations, timed trials and interruptions periods, and operated camera 1 when E1 was interacting with the child. The experimental room of 4.5×4 m was carpeted, with camera 1 in one corner of the room providing a front view of the child and camera 2 allowing a bird's-eye view from the ceiling.

The general procedure was the same for all four tasks: In trial 1, after a short familiarization, the two experimenters demonstrated the task once, for example, by showing how one could make the cube bounce on the trampoline. After the demonstration, the child was given the chance to perform the task with the partner. As will be reported in the Results section, one demonstration was sufficient for the majority of children: If they performed the tasks successfully at all, they did so after one demonstration. However, we wanted to give the children who were not immediately successful another chance to succeed by repeating the demonstration up to two times and providing more cues. By this, we attempted to measure how much guidance would be necessary for the children who did not understand the task immediately.

Thus, after the first demonstration was given, E1 acted on the apparatus, inviting the child's participation nonverbally by alternating gaze between the child and the apparatus. In case of success (like retrieving the object in problem-solving tasks), trial 2 was administered. If the child was not successful, the demonstration was repeated and followed by nonverbal and verbal cues of E1. If the child still failed, a final demonstration was given in which E2 placed the child next to her and described what she was doing. From trial 2 onward, no more demonstrations were provided. To avoid frustration, tasks were terminated after 1 min of unsuccessful attempts. Trials 3 and 4 were identical, both being characterized by an *interruption period*: Once the child engaged in the task, E1 interrupted his actions for 15 s (timed by E2). During interruptions, he looked at the child, but did not respond to any attempts of the child to influence his actions. After the interruption, he resumed performing his role.

Detailed descriptions of this procedure as it was adapted for each of the tasks are given in the following paragraphs.

Problem solving with complementary roles: Elevator task. *Familiarization*: E1 guided the child to both sides of the apparatus and showed her the transparent screens by knocking against them. When the child was in position B (pushing side), E1 put a ball on the platform on side A (retrieval side) in order to check whether the child understood that she has to walk around the apparatus to access it. All children were successful in this pretest.

Demonstration: The cylinder was baited with two objects. It was made sure that the children were watching as one experimenter pushed the cylinder up three times and the other experimenter took one of the objects out, leaving the other object inside for trial 1. As in all tasks, E2 went in the corner of the room to operate the camera and remained passive during test phases, only returning if additional demonstrations were necessary.

Trial 1: In trials with role A for the child, E1 pushed the cylinder up, alternating gaze between the child and the object while making a grasping gesture toward the opening. In trials with role B, E1 positioned himself on the retrieval side and made a grasping gesture toward the opening. It was counted as success if the children took the object out of the opening in role A or pushed the cylinder up to make the object accessible to E1 in role B, respectively. In case of success, trial 2 was administered. If the child was not successful for 30 s, the demonstration was repeated by E1 and E2. After the second demonstration, E1 invited the child's participation not only through gaze alternation but also through verbal cues by naming the object for up to 30 s. In case of success, trial 2 was administered. If the child continued to fail for another 30 s, the demonstration was repeated one last time. During the third demonstration, E2 placed the child right next to her and encouraged the child to take the object out with her (role A) or push the cylinder up with her (role B). After the demonstration, the first experimenter performed the same behavior as before. In case of success, trial 2 was administered. If the child did not succeed after 30 s, the task ended.

Between trials, E1 distracted the child while E2 surreptitiously baited the cylinder with another object. The cylinder was quickly pushed up to display the new object to the child.

Trial 2: E1 invited the child's participation through gaze alternation and vocalizations. Once the object was retrieved, trial 3 followed. The task ended if the child was not successful after 60 s.

Trials 3 and 4: These trials were characterized by an *interruption period*. Once the child engaged in the task, the experimenter interrupted his actions for

15 s. E2, who was using a stopwatch, indicated to E1 when the 15 s were over. In role A, he let the cylinder drop when the child was reaching for the object; in role B, he reached for the object when the child pushed the cylinder up but then withdrew his hand. After the interruption period was over, E1 resumed his role or acted like at the beginning of the trial if the child had disengaged during the interruption. The same was done in trial 4.

Problem solving with parallel roles: Tube-with-handles task. *Familiarization*: The two parts of the tube were shown and the child was asked to grab each of the handles.

Demonstration: E1 showed an object to the child and then put it into the tube. The two experimenters pushed the tube together and put it on the floor. Then each one demonstratively grabbed one of the handles with both hands and slowly pulled it open.

Trial 1: E1 held one handle, inviting the child's participation by alternating gaze between the child and the other handle. If the child was successful (taking the handle and pulling the tube open with the partner), the next trial was administered. If the child was not successful within 30 s, the demonstration was repeated. After the second demonstration, E1 invited the child's participation not only through gaze alternation but also through verbal cues by naming the object for up to 30 s. If the child still did not pull the tube apart within 30 s, the demonstration was repeated one last time. During the third demonstration, E2 positioned the child next to her and encouraged her to hold the handle. After the demonstration, E1 invited the child's participation as before. After 30 s of unsuccessful attempts, the task ended.

Between trials, another object was shown to the child and put inside the tube which was pushed together by the experimenters.

Trial 2: E1 held one handle and invited the child's participation through gaze alternation and vocalizations. Once the object was retrieved, trial 3 followed. The task ended if the child was not successful after 60 s.

Trials 3 and 4: As before, E1 held one handle and invited the child's participation. When the child grabbed one handle, E1 dropped the tube and placed his hands on the floor for an interruption period of 15 s (timed by E2). After the interruption period was over, E1 resumed his role or acted like at the beginning of the trial if the child had disengaged during the interruption. The same was done in trial 4.

Social games with complementary roles: Double-tube task. *Familiarization*: The child was encouraged to hold the can and look through both tubes.

Demonstration: One experimenter held the tin can under one of the tubes and the other experimenter let the wooden block slide down the same tube. The experimenter threw the block down one tube three times and then switched to the other tube for another three throws.

Trial 1: In role A, E1 placed the block between the two tubes on the upper side of the apparatus, held the can under one of the tubes, and alternated gaze between the child and the tube. If the child put the block down one of the tubes, E1 returned it to the child. In role B, E1 offered the can to the child and put it between the tubes on the lower side of the apparatus. He held the block above the upper end of one tube and alternated gaze between the child and the lower end of the tube.

After three throws, E1 changed to the other tube for another three attempts. The criterion for success was that the child would choose the same tube as the partner in at least four of six times. In case of success, trial 2 followed. If that was not the case or the child showed no interest for 30 s, the demonstration was repeated. After the second demonstration, E1 invited the child's participation verbally by saying either "The block" (role A) or "Can" (role B). If the children still did not play the game successfully, a third demonstration was given. E2 positioned the child next to her and encouraged her to hold either the block (role A) or the can (role B) during the demonstration. The task ended when the child was not successful after the third demonstration.

Trial 2: E1 selected one of the tubes for three attempts.

Trials 3 and 4: E1 switched to the other tube for two throws. After these two throws, he interrupted the game for 15 s (timed by E2) by either withdrawing the can from the lower end of the tube and holding it in front of his chest (*child in role A*) or holding the block but not throwing it down the tube (*child in role B*). After the interruption, he resumed the game for two attempts. After the interruption period was over, E1 resumed his role for two attempts or acted like at the beginning of the trial if the child had disengaged during the interruption. The same was done in trial 4.

Social games with parallel roles: Trampoline task. *Familiarization:*. The child was encouraged to hold the rim of the trampoline.

Demonstration: The experimenters held the rim of the trampoline and let the wooden block bounce on the trampoline for 10 s.

Trial 1: E1 held one side of the rim and started shaking the trampoline. He alternated gaze between the child and the other end of the rim. The criterion for success was that the child would play the game for at least 5 s in the next 30 s. If that was not the case, the experimenters repeated the demonstration. After the second demonstration, E1 alternated gaze and verbalized his intent to play. If the children still did not join the game for 30 s, a third demonstration was given. During this demonstration, E2 placed the child right next to her and encouraged the child to hold the rim together with her. If the children did not successfully play the game after the last demonstration, the task ended.

Trial 2: E1 played the game for another 5 s.

Trials 3 and 4: After 2 s of joint play, E1 dropped the trampoline and put his hands on the floor for 15 s (timed by E2). After the interruption period, he resumed playing or acted like at the beginning of the trial if the child had disengaged from the task. The same was done in trial 4 (each lasting up to 5 s of joint play).

Coding and Reliability

All sessions were videotaped and coded from tape by the first author. Each trial received one score of a rating scale designed to assess the child's skill to coordinate her actions with the partner (see Table 1 for a description of the coding schema). In trials with interruption (trials 3 and 4), this rating was based upon the behavior before and after the interruption period of 15 s (which was analyzed separately, see below). A random sample of 25% of the sessions was independently coded by the second author to assess interrater reliability. Cohen's κ was calculated for categorical ratings and Cohen's weighted κ for ratings with ordinal scales (Fleiss & Cohen, 1973). This resulted in κs ranging from .88 to 1 (elevator: $\kappa = .88$; tube with handles: $\kappa = .98$; double tube: $\kappa = 1$; tram-

Table 1
Study 1. Coding Schema for Level of Coordination

Category	Definition
Task: Elevator	
No success[a]	Child does not attempt or fails to retrieve the object from the apparatus (role A); child does not push the cylinder up and holds it in place (role B).
Uncoordinated	Success after more than 5 s of inappropriate actions such as standing on wrong side, letting cylinder drop more than once, individual play or individual attempts.
Coordinated	Success, but some inappropriate actions or waiting, but not for more than 5 s.
Very coordinated	Success after immediate understanding of their role. Child positions herself in correct location and performs the correct action without making any mistakes.
Task: Tube with handles	
No success[a]	Tube is not being opened.
Uncoordinated	Success after more than 5 s of inappropriate actions such as standing on wrong side, letting tube drop more than once, individual play or individual attempts.
Coordinated	Success, but some inappropriate actions, but not for more than 5 s; releasing handle not more than once.
Very coordinated	Success after immediate understanding of their role. Child positions herself in correct location and performs the correct action without any mistakes.
Task: Double tube	
No success[a]	Child does not throw the block through one of the tubes (role A); child does not hold the can under one of the tubes (role B).
Hit	Child chooses the same tube as the partner when throwing the block (role A) or holding the can under the tube (role B).
Miss	Child chooses the other tube than the partner.
Task: Trampoline	
No success[a]	Child does not hold and lift trampoline.
Low engagement	Joint play but lots of stopping and not too excited. Child needs a lot of persuasion.
Medium engagement	Some stopping or not too excited.
High engagement	Continuous play and rather excited (placing block on trampoline; initiating play; active shaking).

Note. [a]In unsuccessful attempts, children showed one or more of the following behaviors:
Off-task: The child did not approach the apparatus or did not reapproach after the interruption.
On apparatus, play: The child engages with the apparatus, but without an attempt to retrieve the object in the problem-solving tasks or play which is unrelated to the partner's action like banging on the apparatus.
Bystander: The child positions herself next to the apparatus and observes the partner's actions, but does not engage in the task.
Individual attempt: The child tries to retrieve the object individually or play the game on her own.

poline: κ = 1), which is indicative of excellent interrater agreement (Bakeman & Gottman, 1997; Fleiss, 1981).

For interruption periods, we scored children's overall behavior toward the adult, their looks to the adult, and any communicative actions. First, we assessed the *overall behavior* during the 15-s interruption period. If the subject exhibited multiple behaviors in any given interruption period, we categorized the period based on the actions exhibited for the majority of time. With this coding we mainly wanted to determine whether children would rather try to perform the action individually or make some attempt to reengage the partner (κ = .71; see Table 2 for a description of the rating). Secondly, we assessed whether children looked at the partner's face at least once during the interruption (*looks*, κ = .76). Thirdly, we scrutinized more closely for *communicative acts* by performing a second-by-second coding using a computer-based observation software (INTERACT). Interobserver agreement on onset and offset times (±1 s) was established based upon 25% randomly selected tapes that were independently coded by a student research assistant who was unaware of the hypotheses of the study. We were interested in communicative acts by which children addressed the partner and made reference to the apparatus, reflecting cases in which children attempted to regulate the partner's actions. We coded three types of communicative acts: (1) *Referential gestures* (κ = .88) such as pointing at the apparatus with the index finger or the whole hand. (2) *Placing or touching* (κ = .86), in which the child either moves the apparatus toward E1 (e.g., the child would hold on one handle and push the tube toward the partner) or pushes the partner in the direction of the apparatus. (3) *Verbalizations* with reference to the partner or the task (κ = .82), such as "Open," "Look," "Please," "Man, lift it," "Take it out," "The can."

Results

Preliminary Analyses

Neither were the performance in any of the four tasks nor the behaviors during interruption periods influenced by the factors gender or whether the children had older siblings. Task order also had no effect. With one exception, there were no significant differences in the level of coordination in any of the tasks when comparing the first with the second session, the first with the second trial, or trials with versus without interruption. Only in the trampoline task, children showed a lower level of engagement when playing the game in trials with interruption than without interruption (Wilcoxon signed rank test, $Z = -2.89$, $p < .005$), but the reported results about the effect of age still hold if the two types of trials are analyzed separately. Subsequent analyses were thus performed on data collapsed over these factors. For nonparametric tests, exact p-values were computed. Tests on ordinal scales were corrected for ties. Reported differences are significant at $p < .05$ (two-tailed) for all tests.

Success. Table 3 displays the number of children who solved at least the first trial successfully, separately by age and task (and roles A and B for tasks with complementary roles). On this level of analysis, no significant age differences were found for the number of subjects being successful in each task (and role). It can be concluded that children of both ages participated in a variety of tasks successfully.

Number of demonstrations. Do children need several demonstrations before being successful in the task? Table 4 displays the percentage of successful children who needed a single versus repeated demonstrations before passing a trial for the first time. Overall, the majority of children either passed the task after a single demonstration or never during the

Table 2
Study 1. Coding Schema for Overall Behavior During Interruption Periods

Category	Definition
Disengagement	Child leaves apparatus or plays on apparatus without pursuing the goal of the task by banging on the apparatus, climbing on it, etc.
Individual attempt	Child attempts to retrieve the object individually in problem-solving tasks or attempts to continue the game alone in play tasks (e.g., in the elevator task, the child would come over to the side of the experimenter and push the cylinder up herself while reaching for the object; in the tube-with-handles task, the child tries to hold both handles or peel it open on one side).
Waiting	Child remains on correct side of the apparatus and is ready to perform her role.
Reengagement	Child is ready to perform her role and in addition tries to reengage E1, for example, by pushing the cylinder of the elevator up, pointing at the object, and vocalizing while looking at the partner.

Note. The 15-s interruption period served as the unit of analysis. For each interruption period, one of the scores was given.

Table 3
Number (and Percentage) of Children With At Least One Successful Trial Per Task (and Complementary Roles) as a Function of Age

		Age in months		Fisher's exact test ($N = 32$)
Task	Role	18	24	p
Elevator	A	16 (100)	16 (100)	—
	B	12 (75)	15 (94)	.33
Tube with handles		9 (56)	12 (75)	.46
Double tube	A	8 (50)	14 (88)	.054
	B	3 (19)	8 (50)	.14
Trampoline		13 (81)	11 (69)	.69

Note. The right column displays test statistics for age comparisons.

session. In other words, only a few children failed initially and profited from a second and third demonstration. Moreover, practically no age differences were found for the number of demonstrations before success (t tests nonsignificant, $p\text{s} > .22$, partial $\eta^2\text{s} < .16$), with the only exception of double-tube role A, in which 18-month-olds needed more demonstrations: 18 months, $M = 1.88$, $SD = 0.84$; 24 months, $M = 1.07$, $SD = 0.27$; $t(20) = 2.98$, $p < .005$, partial $\eta^2 = .36$. Taken together, these analyses showed that if children passed the task at all, they usually did after only one demonstration.

Main Analyses

Analyses were directed at two major hypotheses: (1) age differences in children's level of coordination, with the 24-month-old children adjusting their actions better to the partner than the younger age group, and (2) age differences in behaviors during interruption periods, particularly a greater proportion of trials with reengagement attempts among the 24-month-olds. We first report the results for age differences in children's ability to coordinate their actions with the partner in the four tasks. We then present a series of analyses examining children's behavior and communication during interruption periods.

Table 4
Percentage of Children Who Needed One Versus Repeated Demonstrations Before Success as a Function of Age and Task

		Age in months			
Task	Role	18		24	
Number of demonstrations		1	>1	1	>1
Elevator	A	75	25	88	12
	B	67	33	93	7
Tube with handles		100	0	75	25
Double tube	A	38	62	93	7
	B	67	33	87	13
Trampoline		77	23	82	18

Coordination

For each child, a score was calculated per task to function as the dependent variable: In the three tasks with an ordinal rating scale to measure their level of coordination (elevator role A and B, tube with handles, trampoline), an individual median performance across all administered trials of the task (and role) was computed. For trial 1 with up to three demonstrations (thus up to three ratings), we chose the performance after the *last* demonstration that was administered to each child as the level of coordination for that trial (i.e., their performance after demonstration 2 or 3, respectively). The alternative assessment of using not only the performance after the last demonstration but also the median of all attempts as the value of trial 1 leads to similar results. In the double-tube task, an individual mean hit rate was calculated separately for roles A and B, representing the mean rate of throws in which the child chose the same tube as the partner. Results for the 18- and 24-month-olds in any of the tasks are shown in Figure 2.

In *Elevator* role A (retrieving the object), both age groups were at ceiling. In role B of pushing the cylinder up and holding it in place, 24-month-olds displayed a significantly higher level of coordination than the 18-month-olds, who were successful but less coordinated, U ($n_{18\text{mo}} = n_{24\text{mo}} = 16$) $= 70.50$, $p < .05$.

In the *Tube-with-handles task*, the level of coordination was significantly higher in 24-month-olds than in 18-month-olds, who were not reliably successful in the task, U ($n_{18\text{mo}} = n_{24\text{mo}} = 16$) $= 76.50$, $p < .05$.

To assess children's coordination of their actions with the partner in the *Double-tube task*, two types of analyses were conducted: First, we tested the performance of each age group against chance. One-sample t tests with a test value of .5 revealed that 18-month-olds performed at chance level in role A, $t(14) = 0.72$, $p = .48$, whereas 24-month-olds chose the target tube significantly more often than expected by chance, $t(15) = 11.15$, $p < .001$. In role B, 18-month-olds always chose the correct tube and 24-month-olds scored significantly above chance with

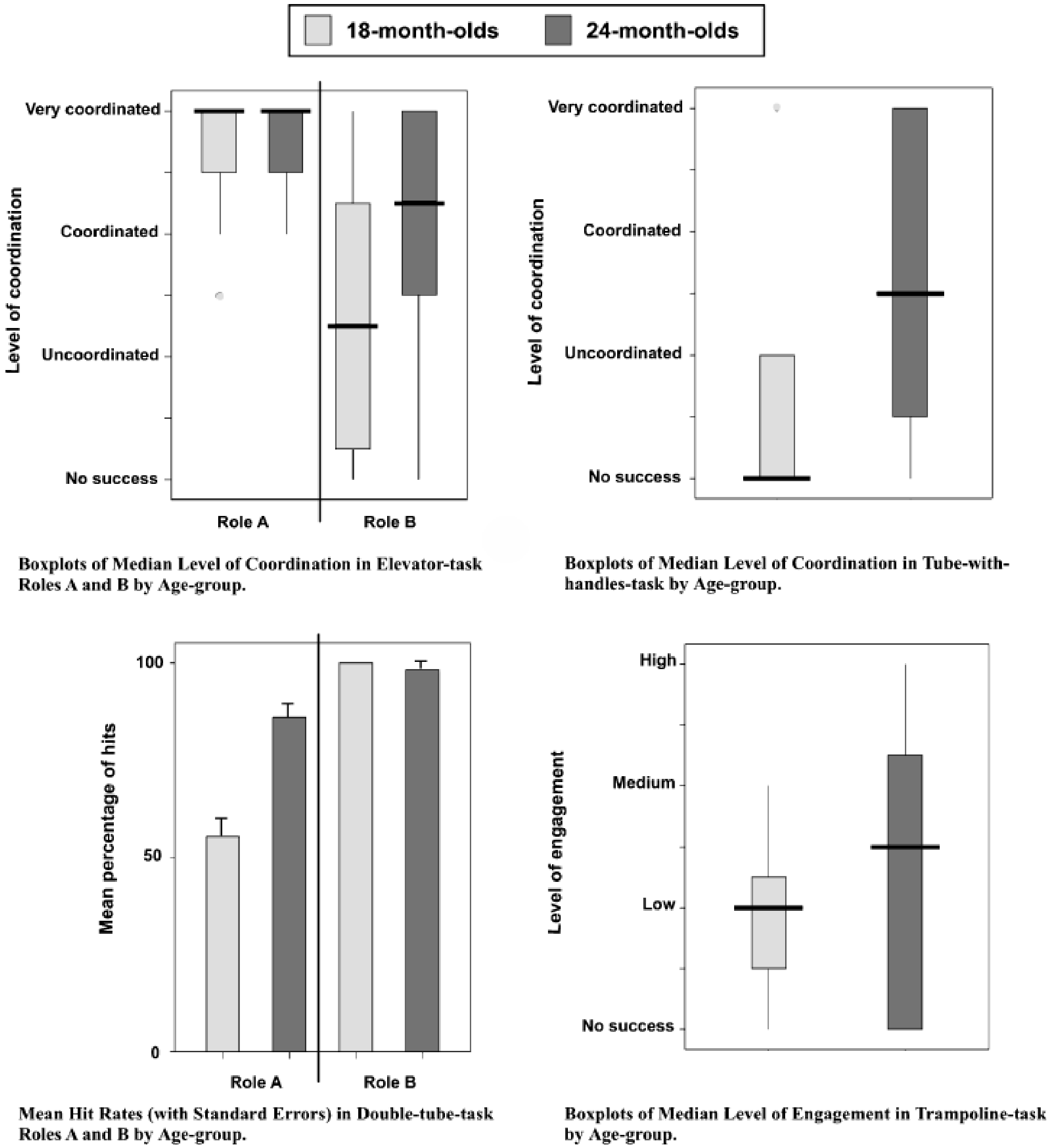

Figure 2. Study 1. Level of coordination as a function of task and age group.

almost perfect performance, $t(10) = 41.29$, $p < .001$. Second, we compared the performances of the two age groups with an independent samples *t* test. In role A, 24-month-olds showed significantly more target behavior than 18-month-olds, $t(29) = -3.92$, $p < .001$, partial $\eta^2 = .35$. In role B, children of both ages were almost at ceiling and therefore no age difference was found. Thus, the children who played role B of holding the can virtually never failed, and 24-month-olds but not 18-month-olds chose the target tube at a greater-than-chance level in role A of throwing the block.

In a next step, we investigated whether 18-month-olds' chance performance in role A was due to randomly changing tubes or perseveration errors. It is possible that children performed role A at chance level because they changed tubes independently of the partner's activity or because they continued to use one of the tubes although the partner had changed to the other side. All 24-month-old children switched the tubes at least once while 5 of 14 18-month-olds who played role A selected one tube and kept on using the same tube during all trials. This age difference was significant, Fisher's exact test

($N = 30$), $p < .05$. We can conclude that 18-month-olds produced more perseveration errors than 24-month-olds.

In order to find out why several children did not pass the first trial of role B, we also scored their *interest* ($\kappa = 1$) in performing this role: This category revealed that 10 of the 21 children who did not pass the first trial showed no interest in the game and 11 wanted to play the other role of throwing the block. Therefore, the reason for failing the first trial was primarily due to a preference of playing role A over role B, not a lack of coordination.

In the *Trampoline task*, the two age groups did not significantly differ in their median performance, U ($n_{18\text{mo}} = n_{24\text{mo}} = 16$) = 106.0, $p = .42$. The score of low to medium level of engagement means that children followed the partner's overture and participated, but remained rather passive in playing the game. At both ages, phases of playing and stopping were more frequent than continuous play.

Taken together, we found reliable age differences in the level of coordination: In three of four tasks, children at 24 months coordinated their actions with that of the partner more skillfully than the 18-month-olds.

Interruption Periods

Preliminary analyses. The analysis was based upon 249 interruptions (133 and 116 at trials 3 and 4, respectively). Because trials 3 and 4, which included an interruption period, could only be administered to children who successfully participated in trials 1 and 2 of each task, the absolute number of interruption periods per child differed depending on the individual performance. As all children participated long enough to have at least two interruption periods, all subjects could be included in subsequent analyses: Individuals were observed in, on average, 7.8 interruptions (range 2 to 14 of 16 possible interruptions; $SD = 3.67$). A 2 × 4 (Age × Task) mixed design multivariate analysis of variance with age as between- and task as within-subject factor revealed that there was neither a main effect of age, $F(1, 30) = 1.88$, $p = .18$, partial $\eta^2 = .06$, nor an Age × Task interaction, $F(3, 90) = 0.59$, $p = .62$, partial $\eta^2 = .02$, but a significant main effect of task, $F(3, 90) = 24.23$, $p < .001$, partial $\eta^2 = .45$. Post hoc comparisons showed that this effect was due to the elevator task ($M = 3.44$, $SD = 0.91$), which had more interruption periods than each of the three tasks which ranged from $M = 1.13$ to 2 (ps $< .001$ for all three comparisons). Thus, as the elevator task was the most motivating one for children of both ages (and, as will be shown later, also for the chimpanzees), it is also represented more in the following analyses. To include all children in the statistical comparison, we collapsed interruption periods across tasks that were equally represented in both age groups and used mean proportions as dependent measures.

Overall behavior. To adjust for the difference in interruption trials per individual, mean proportions of behaviors were calculated for each child (the number of behaviors divided by the number of interruption trials), representing the mean proportion of trials that were characterized by one of the four behaviors. Table 5 depicts this measure as a function of age. A 2 × 4 (Age × Behavior) mixed design analysis of variance yielded no main effects or interactions (ps $> .40$; partial η^2s $< .10$). Thus, the four types of behaviors were distributed evenly and did not vary by age.

Of particular interest was the category *reengagement attempts* because it represents cases in which children actively regulated the joint activity. We hypothesized that reengagement attempts should increase with age. These behaviors occurred in both age groups (in $M = 22$, $SD = 27$ and $M = 38$, $SD = 24$ percent at 18 and 24 months, respectively) with only a tendency of increase by age, $t(30) = -1.76$, $p < .09$, partial $\eta^2 = .09$. On an individual level, 23 of the 32 children had at least one interruption period in which their actions were predominantly aimed at reengaging the partner (9 and 14 children among the 18- and 24-month-olds, respectively; Fisher's exact test, $p = .11$). Thus, already 18-month-olds frequently produced reengagement attempts and did so approximately as often as 24-month-olds.

Looks. In most interruption periods, children looked at the partner's face: On average, 18-month-olds did so in 83 ($SD = 19$) and 24-month-olds in 89

Table 5
Study 1. Overall Behavior During Interruption Periods

	Age in months			
	18		24	
Category	*M*	*SD*	*M*	*SD*
Disengagement	23	21	17	18
Individual attempt	29	22	22	20
Waiting	26	24	22	20
Reengagement	22	27	38	24
Total	100		100	

Note. Mean percentages and standard deviations as a function of age.

($SD = 14$) percent of the interruptions periods, with no effect of age.

Communicative acts. On the basis of the second-by-second coding of the interruption periods we calculated for each subject the mean frequency of each of the three types of communicative acts across all of her interruption trials (see Table 6, left column). Multivariate analyses on the frequency of communicative acts showed no significant main effect of age, Pillai's trace = .12, $F(3, 28) = 1.26$, $p = .31$, partial $\eta^2 = .12$. Thus, the frequency of communicative acts was similar in both age groups, although it should be mentioned that verbalizations tended to be more frequent among the 24-month-olds, univariate analyses of variance, $F(1, 30) = 3.73$, $p = .06$, partial $\eta^2 = .11$.

In a next step, we analyzed communicative acts on the level of the interruption period: In what percentage of interruptions do children produce communicative acts? A trial with a communicative act of some kind would indicate that the children attempt to regulate the partner. Once again, we used mean proportions as dependent variable (see Table 6, right column). A multivariate analysis of variance on the three types of communicative acts yielded an overall effect of age, Pillai's trace = .30, $F(3, 28) = 4.05$, $p < .05$, partial $\eta^2 = .30$. Univariate tests on the level of single categories revealed that trials with verbalizations occurred proportionally more often in the older than in the younger age group, $F(1, 30) = 9.93$, $p < .005$, partial $\eta^2 = .25$.

Taken together, these analyses show that interruption periods with some kind of communicative act were equally likely in both age groups: On average, children communicated with the partner in more than half of the interruption periods ($M = 60$, $SD = 24$ and $M = 64$, $SD = 19$ percent at 18 and 24 months, respectively). However, the type of communication changed with age: The 24-month-olds verbalized more than twice as often as the 18-month-olds.

On an individual level, all children used communicative acts during one or several of the interruption periods. Fifteen children displayed the behavior *placing/touching* (7 and 8 at 18 and 24 months, respectively); 24 children *verbalized* to the adult (9 and 15 at 18 and 24 months, respectively) and each individual produced a *gesture* toward the adult. The analysis of communicative acts therefore revealed that all children attempted at least once to direct the partner's attention toward the apparatus when he refrained from cooperating.

Table 6
Study 1. Mean Frequency of Communicative Acts and Mean Percentage of Trials With a Communicative Act as a Function of Age

	Age in months							
	Mean frequency of communicative acts				Mean percentage of trials with a communicative act			
	18		24		18		24	
Category	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Gesture	.81	0.49	0.79	.50	50	24	48	23
Placing/touching	.03	0.06	0.04	.05	9	12	13	16
Verbalization	.61	1.05	1.23	.72	21	27	50	24

Discussion

The first experiment had three major findings: First, children at 18 and 24 months of age were able to cooperate with an adult partner in a variety of tasks that require the joint activity of two people. Second, the ability to coordinate with the partner significantly improved between children at 18 and 24 months of age. The third and most interesting finding was obtained during periods in which the programmed partner interrupted his activity: When he refrained from cooperating, children of both age groups actively communicated to the adult in an obvious attempt to request his reengagement.

Children at 24 months of age were proficient cooperators. They were successful in all four types of task over a number of trials. They were skillful in spatial and temporal coordination of their actions with the partner in tasks with parallel and complementary roles. These results are in accordance with the findings by Brownell and Carriger (1990, 1991). They also support the findings of Eckerman and colleagues, who found a major shift in coordinated activities just before children turn 2, although we found that their skills are not restricted to activities that can be initiated and sustained by imitating each other (Eckerman, 1993; Eckerman & Peterman, 2001). At 24 months of age, children are adept cooperators not only in activities with parallel but also with complementary roles.

Half a year earlier, children do not yet possess the same skills in performing coordinated activities (displaying less skillful coordination than the older children in three of four tasks), although they already show the potential to cooperate successfully. In our study, 18-month-olds succeeded in several of the tasks over repeated trials. In comparison with other studies, children displayed successful cooperation in problem-solving tasks at an earlier age than had previously been shown (Ashley & Tomasello, 1998; Brownell & Carriger, 1990, 1991). In the study by Brownell and Carriger, 18-month-old peers solved the tasks, if at all, only accidentally, without coordinating their actions appropriately. It remains a question for future research as to what extent these findings are due to our tasks, which may have been less demanding mechanically, or the pairing of children with a more competent partner. It is likely that children at this age would be less coordinated in their efforts when cooperating with a same-aged peer than with a skillful adult as in the current study. Interacting with an adult is probably easier for the children because his behavior is more predictable than that of peers and they might be more likely to keep on task because his actions are most of the time directed at the goal. Nevertheless, the standardized behavior of the programmed partner still differs from adult's scaffolding typically observed in natural interactions in that the experimenter is never telling the child what to do during the task and only minimally accommodates his behavior to that of the child. In addition, the adult's active participation is removed during interruption periods, permitting insight into the children's understanding of the partner's role in the task.

Thus, children in the second year of life engage in novel cooperative activities, encompassing both problem-solving tasks and social games. What appears to develop between 18 and 24 months is the ability to coordinate one's actions with that of the partner spatially and temporally, that is, to execute a joint intention toward a joint goal.

The most interesting findings emerged from the interruption periods: At both ages, children often attempted to reengage the partner when he was not cooperating instead of trying to solve the task individually or abandon the task. For example, when the partner did not do his part of pushing the cylinder up in the elevator task, they pointed repeatedly at the opening of the elevator while looking at him. In the tube-with-handles task, after he dropped his handle, children frequently offered him his handle by pushing the tube toward him while holding on to their own side. Especially 24-month-olds used verbalizations in addition to the nonverbal means, by addressing him (''Man!'') or drawing his attention to the goal (''Ball!'') or his role (''Lift it''). All children communicated at least once to the adult in an attempt to request his cooperation. Children at both ages did so in approximately half of the interruptions. The frequency with which even 18-month-olds performed reengagement attempts by far exceeds what was observed at this age in the peer cooperation study by Brownell and Carriger (1990, 1991). In their assessment of spontaneously occurring disruptions of the joint activity in peer dyads, children almost never responded with a gesture or command before 30 months of age. The same is true for looking at the partner: In Brownell and Carriger's study, it was infrequent among 24-month-olds, but was observed in half of the events among 30-month-olds. In our study, children looked at the partner in almost all interruptions.

The crucial difference between the 18- and 24-months olds was found in the *type* of communication: The older children would more often use verbalizations toward the adult partner than their younger counterparts. This result supplements the findings by Eckerman and colleagues, who detected a major increase of verbalizations from 16 to 24 months of age, regulating the play actions both of peers (Eckerman & Didow, 1996) and of adult partners (Eckerman & Didow, 1989).

The current results also extend studies by Ross and Lollis (1987), who found that children from about 13 months of age communicate to an adult play partner who is not taking her turn in simple play like alternating in beating a drum and probably routinized games like peek-a-boo. By the age of 18 months, children show this capability also in the context of novel tasks, maybe reflecting their growing flexibility in social coordination extending beyond routinized behaviors.

Taken together, children in the second year of life actively regulate actions in various joint activities, using increasingly more specific means of communication (verbalizations) between 18 and 24 months of life.

Our interpretation is that the children in our study were attempting to reengage the adult toward their joint goal. One could claim that when the child is paired with a more skillful adult partner, she might allow the adult to fully regulate the activity while the child executes her action without regard for the partner. Having the adult partner interrupt his activity should help to decide whether this is the case or not:

> [T]he child who has simply learned the appropriate individual behaviors to get the job done, without regard for the partner's role in the job, should simply try another nonsocial, problem-related behavior if the partner violates the appropriate solution sequence. For this child, the peer is not truly a collaborator in the enterprise. (Brownell & Carriger, 1991, p. 377).

In our study, this happened infrequently. Children did not blindly continue to perform their role but rather waited for the partner to resume his activity or even actively attempted to reengage him: They used communicative means such as pointing to the opening of the elevator, moving the trampoline toward him, or pointing to the handle that he should grasp. These communicative acts refer to the role of the partner—rather than just being expressions of frustration at the loss of social contingency. This can be taken as evidence that the children comprehended their own and the partner's actions as interconnected parts of a joint activity toward a joint goal (joint intentions).

Children's responses to interruptions also provide information about their *motivation* to cooperate. If they were only interested in retrieving the objects in problem-solving tasks, children should at least initially try to solve the task individually. This was not the case. Our results indicate that they understood the tasks as involving two roles and were motivated to cooperate with the other and repair breakdowns when they occurred.

One could object that children did not really engage in cooperative activities with a joint goal, but rather imitated the adult's object-directed actions like pushing up the elevator or throwing the cube down the tube. The argument would be that in tasks with parallel roles children just do what the partner is doing, and in tasks with complementary roles they reproduce what the second experimenter was doing during demonstrations. We do not think that this was what they were doing. This is for two reasons: First, imitation of the action as a solitary activity does not warrant coordination with the actions of the partner and, secondly, it does not explain children's responses during interruptions. For instance, if children were just imitating the behavior of pushing the elevator up as an individual object-directed activity, they should do so irrespective of what the partner is doing. However, at least the 24-month-olds consistently pushed it up and waited for the partner to take the object out, indicating that their actions were not self-absorbed imitation, but were related to the actions of the partner. This is even more evident in the double-tube task: Children might have been imitating the behavior of throwing the block down the tube, but that does not explain why the 24-month-olds threw it down the *correct* one. The level of coordination displayed by 24-month-olds speaks against the interpretation that their performance is due to imitation only. An even stronger case against this alternative imitation-interpretation can be made from children's behaviors during interruptions: Interruptions by the partner should not influence the child's actions if they were imitative acts. Why would they wait for the partner or communicate with him during interruptions if their behavior was simply imitation? Even 18-month-olds frequently behaved in ways that are contrary to this interpretation. Therefore, imitation alone does not explain the behavior of either age group.

There was one unexpected finding that might be especially relevant to understand children's motivation to cooperate. Analyses of children's behavior after successful attempts in problem-solving tasks revealed that they frequently attempted to put the object back inside the elevator or the tube with handles after they had retrieved it. Almost all children attempted to do this at least once: 30 of the 32 children did so, 15 in either the elevator- or the tube-with-handles task and 15 in both of them. This can be taken as evidence that children were not solely interested in taking possession of the toy (with cooperation being the necessary action because there was no other way of getting the desired object). Cooperation did not seem to be solely a means to an end. In a sense, they turned problem solving into a playful cooperative activity. In our opinion, their attempts to return the object are indicative of their interest in continuing a cooperative activity, which to them is rewarding in itself.

Study 2: Chimpanzees

Crawford (1937, 1941) had pairs of chimpanzees pull a heavy box containing food within their reach by simultaneously pulling on ropes. None of the dyads cooperated spontaneously. After extensive training they were able to solve the task, but they still failed to transfer their skill to a modified version in which the ropes had to be pulled vertically instead of horizontally (see also Melis et al., in press; Povinelli & O'Neill, 2000). Chalmeau (1994; Chalmeau & Gallo, 1996) trained individuals to retrieve food from an apparatus by pulling two handles simultaneously. In test trials, the handles were further apart from each other, such that one individual could not reach both at the same time and had to cooperate with another individual to obtain the reward. Two out of six chimpanzees were successful in cooperation trials. One male learned to wait until the other was at the other handle and sometimes even solicited her participation by taking her arm and guiding her to the apparatus (the chimpanzees in Melis et al., in press; Povinelli & O'Neill, 2000, never solicited).

Comparing the behavior of chimpanzees and humans on similar cooperative tasks may be particularly fruitful; as chimpanzees are our closest primate relative, such a comparison could provide unique insights about species-specific aspects of human cooperation. We thus modeled Study 2 closely upon Study 1, allowing us to address issues including chimpanzees' understanding of their partner's role in a cooperative task and chimpanzees' capacity to form joint intentions and goals. Unlike previous experiments, the design of this study allowed us to assess the actions of individual chimpanzees in relation to systematically controlled behaviors of a programmed partner on tasks requiring simultaneous cooperation. Previous experiments have also never attempted to engage chimpanzees in triadic social games without an external goal. The chimpanzees' partner was a highly familiar caretaker who often fed them and helped them obtain food; this reduced the effects of tolerance and competitiveness that may have been factors in previous studies involving chimpanzee dyads. We adapted the apparatus and procedures for the chimpanzees where appropriate, but minimized the modifications so that the experiments would be as comparable as possible.

Concordant with the proposal by Tomasello et al. (2005) that shared intentionality might be unique to human interaction, we expected the chimpanzees to respond differently to the interruptions by the experimenter than the children, evidenced by actions directed at pursuing their own individual goal rather than reengaging the partner toward a shared goal.

Methods

Participants

Participants were two female chimpanzees (Annet and Alexandra) and one male (Alex) juvenile chimpanzee housed together at the Leipzig Zoo. All three were raised by humans and had previously participated in various cognitive and social experiments with humans. At the time of the test, the females were both 51 months old; the male was 33 months old. Their partner in the cooperation tasks was a highly familiar caretaker, with whom they interacted on a daily basis in various kinds of activities.

Materials and Design

We again used the four tasks from Study 1 (two problem-solving tasks and two social games with either complementary or parallel roles). Most modifications to Study 1, such as changes in materials or dimensions, were minor and were designed to make the apparatus more suitable for the chimpanzees. In the problem-solving tasks, food was used as a reward rather than toys, after piloting revealed that toys did not serve as an effective motivator. When the experimenter was in the role of retrieving the food, she always offered the food to the subject after a successful trial (this matched the Study 1 procedure in which the experimenter offered the retrieved toys to the child). Although food is a competitive resource for chimpanzees in the wild, our human-raised chimpanzees had a unique relationship with this experimenter and were accustomed to being fed by her. The experimenter had never competed with the subjects for food; in fact, the subjects would occasionally offer her difficult-to-open containers and wait for her to retrieve the food for them. Thus, the subjects were familiar with her as a potential means for obtaining food, rather than as a competitor.

The only major task modification was to the elevator task. We found that a lifting motion was more intuitive to the chimpanzees than pushing, and created a "trapdoor" task that replaced the pushing component of the original elevator task with a lifting motion (see Figure 3). The trapdoor apparatus (*problem solving with complementary roles*) consisted of a $60 \times 40 \times 40$ cm box with a large (80×73 cm) Plexiglas screen on one end and a vertical sliding door bisecting the box. The goal of this task was to retrieve a piece of food by reaching through a hole in the large screen (role A). Because the food was behind the sliding door, the other subject had to position herself behind the screen, pull the sliding door up, and hold it in place (role B). It was impossible for a single individual to perform both roles simultaneously: the large screen prevented reaching the sliding door while also reaching through the hole. The

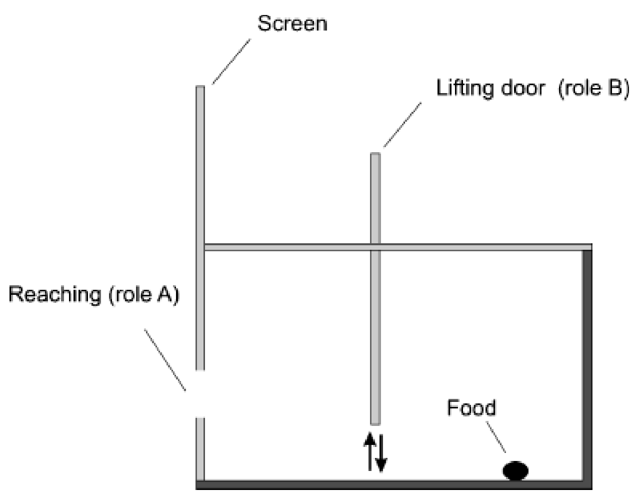

Figure 3. Study 2. Schematic drawing of the trapdoor apparatus (lateral view).

small modifications made to the other apparatus are described in Appendix A.

All three subjects were tested on the four tasks in the same order. On Day 1 and Day 2, subjects were tested on the double-tube task, followed by the tube-with-handles task. On Day 3 and Day 4, subjects were tested on the trapdoor task, followed by the trampoline task. In tasks with complementary roles, subjects performed role A on the first day and role B on the second day. Annet and Alexandra were tested on 4 consecutive days; Alex was tested on 2 consecutive days, and 2 more consecutive days 17 days later.

Procedure

The experimental room included two large wire mesh cages connected by a hydraulic door: a holding cage ($2.5 \times 1.8 \times 2.4$ m) and a testing cage ($3.8 \times 2.4 \times 2.4$ m). The subject watched all demonstrations by the experimenters (E1 and E2) from the holding cage. E2 then left the testing cage, and the subject was allowed into the testing cage to perform the tasks with E1.

The general procedure for the four tasks was almost identical to that of Study 1. We did not include a familiarization period for the chimpanzees, because chimpanzees exploring a novel apparatus sometimes idiosyncratically fixate on an aspect of the apparatus, after which it becomes difficult to draw their attention to other aspects of the apparatus. Thus, the first time the subjects were allowed to interact with the apparatus was after they saw a demonstration. Also, during demonstrations, the subject always watched from the holding cage (which differed from demonstration 3 of Study 1, in which the child would perform the action with E2). Finally, the subject was given 60 s to perform the roles after each demonstration, rather than 30 s, and if the subject disengaged, the experimenter explicitly directed her to sit in the proper location (but never directed the subject to perform any specific action). Detailed descriptions of the task-specific procedures are given in Appendix B.

Coding and Reliability

All sessions were videotaped and coded from tape by the second author. One hundred percent of the sessions were independently coded by the first author to assess interrater reliability.

The scores for the level of coordination are described in Table 7. The trampoline task was not analyzed because none of the subjects showed interest in the game; they most frequently took the bell and played with it alone, sat on the trampoline, or ignored the trampoline and tried to play with the experimenter. Five double-tube trials were dropped

Table 7
Study 2. Coding Schema for Level of Coordination

Category	Definition
Task: Trapdoor	
No success	Unsuccessful. Engages with apparatus (in play or individual attempts) but ignores partner, or becomes distracted.
Uncoordinated	Success after more than 5 s of inappropriate actions such as standing on wrong side, letting door drop more than once, individual play or individual attempts.
(Very) coordinated	Success after no more than 5 s of inappropriate actions or waiting.
Task: Tube with handles	
No success	Unsuccessful. Engages with apparatus (in play or individual attempts) but ignores partner, or becomes distracted.
Uncoordinated	Success after more than 5 s of inappropriate actions such as standing on wrong side, letting tube drop more than once, individual play or individual attempts.
(Very) coordinated	Success after no more than 5 s of inappropriate actions; releasing handle not more than once.
Task: Double tube	
No success	Subject does not throw the bell through one of the tubes (role A); subject does not hold the hand under one of the tubes as the bell falls (role B).
Hit	Subject chooses the same tube as the partner when throwing the block (role A) or holding the can under the tube (role B).
Miss	Subject chooses the other tube.

from analysis due to experimenter error. The Study 1 categories *coordinated* and *very coordinated* were collapsed into a new single category, *(very) coordinated*, because the lower score was coded so infrequently.

Cohen's κ was calculated for categorical ratings and Cohen's weighted κ for ratings with ordinal scales. This resulted in κs ranging from .85 to 1 (trapdoor: κ = .85; tube with handles: κ = .90; double tube: κ = 1).

The coding of subjects' overall behavior during interruptions used four scoring categories (see Table 8). Three of the categories (*disengagement, individual attempt, waiting, reengagement*) were very similar to those used in Study 1. If the subject exhibited multiple behaviors in any given interruption period, we categorized the period based on the actions exhibited for the majority of the 15 s. Reengagement attempts did not occur. Interrater agreement using the remaining three categories was κ = .85.

As in Experiment 1, looking behavior and communicative acts were also coded. *Looks* to the partner were dropped from further analysis because they proved impossible to code reliably. As in other studies that have encountered difficulties in determining the exact target of chimpanzees' looks, our coding was limited by the significantly shorter duration of the chimpanzees' looks (Carpenter, Tomasello, & Savage-Rumbaugh, 1995), as well as by the chimpanzee's lack of a large area of visible white sclera that characterizes human eyes and makes human looks relatively easy to code. *Communicative acts* were not analyzed because they did not occur. Four trials in the tube-with-handles task were excluded from further analysis due to equipment failure (Alexandra was able to open the tube by herself).

Results

Analyses were again directed at two major questions: (1) apes' level of coordination and (2) their behaviors during interruption periods. As there were only three subjects, we tested all three in the same order, and did not analyze order effects for any of the tasks.

Trapdoor-Task Performance

All three subjects solved the first trial of role A (reaching in and taking food) successfully, requiring only one demonstration each. In role B (opening door), two subjects (Alexandra and Annet) passed trial 1; Alexandra required one demonstration and Annet required two. However, Alex repeatedly made individual attempts to reach the food, and did not pass trial 1 of role B.

In role A, all three subjects were successful in all trials. In role B, the two subjects who passed trial 1 succeeded in all subsequent trials. Each subject's level of coordination in roles A and B of the task is displayed in Figure 4.

Tube-With-Handles-Task Performance

Two subjects (Alex and Alexandra) were successful in solving trial 1, requiring only one demonstration each. However, Annet seemed afraid of the tube, and did not pass trial 1. The two subjects who passed trial 1 succeeded in all subsequent trials, and both achieved a median performance level corresponding to the *(very) coordinated* coding category as shown in Figure 4.

Double-Tube-Task Performance

Two subjects (Alexandra and Annet) passed the first trial of role A (the criterion for success was throwing the bell into the correct tube at least once per tube). Both successful subjects required only one demonstration each. Alexandra's hit rate was 67% (8/12); Annet's was 100% (7/7). Alex showed no interest in the game at all and did not pass either role.

In role B (catching the bell with the can), Alexandra and Annet never used the can and therefore

Table 8
Study 2. Coding Schema for Overall Behavior During Interruption Periods

Category	Definition
Disengagement	Subject leaves apparatus or plays on apparatus without pursuing the goal of the task.
Individual attempt	Subject attempts to retrieve the object individually in problem-solving tasks, or attempts to continue the game alone in the double-tube task.
Waiting	Subject remains on correct side of the apparatus and is ready to perform her role.
Reengagement	Subject is focused on E1 and tries to reengage her by gesture or touch.

Note. The 15-s interruption period served as the unit of analysis. For each interruption period, one score was given.

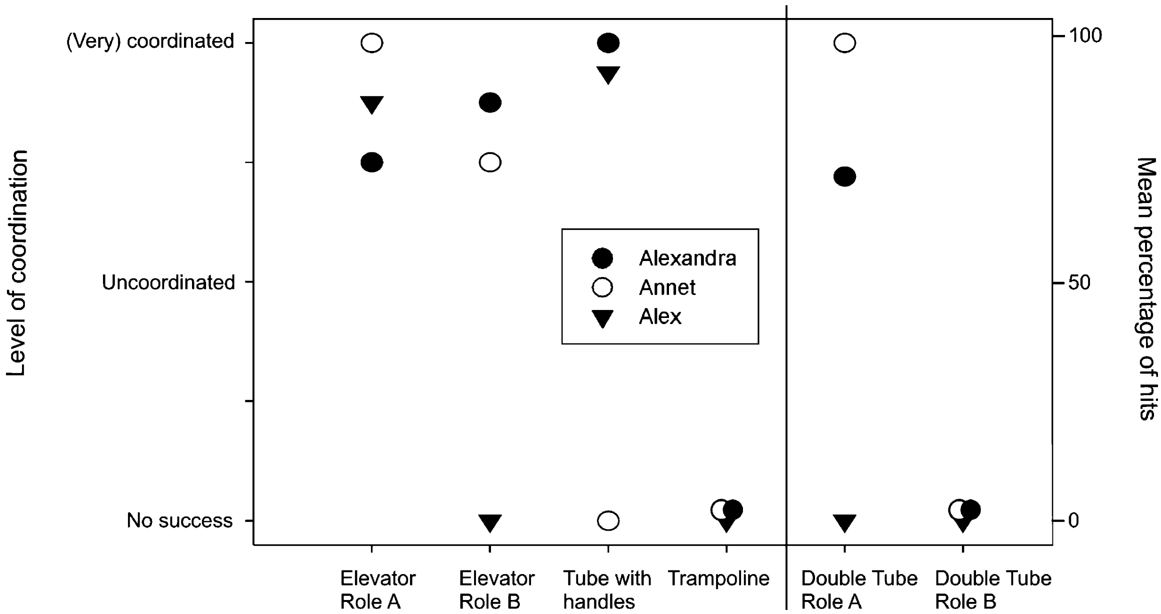

Figure 4. Study 2. Level of coordination per subject as a function of task.

did not play the game as it was supposed to be played. Because they showed no interest in using the can even after the final demonstration, but repeatedly reached into the correct tube with their hands and waited for their partner to throw the bell, the experimenter allowed them to use their hands as described in the procedure. Under this modified criterion for role B (using hands instead of a can), their success rate was 100% (12/12 for both subjects).

Although two of the subjects were quite successful in role A of the double-tube task by the criteria defined in Study 1, their participation was qualitatively different from that of the children. Their play was not continuous; in both roles they often left the apparatus immediately after throwing or catching the bell, and the experimenter had to direct them to sit in the correct position before the next trial. In many trials, the experimenter also had to repeatedly encourage the subjects in role A to throw the bell (in Study 1, the children typically did not require much encouragement from the experimenter). The fact that the chimpanzees threw the bell into the correct tube on any given trial seems to have been due primarily to the experimenter's strong encouragements. Unlike the children, the chimpanzees did not spontaneously participate in the game.

For role B it is critical to note that because the chimpanzees used their hands instead of the can to catch the bell, the success of two subjects is also not comparable to the success of the children. The chimpanzees *did* demonstrate a desire for the bell and an ability to predict the tube into which the experimenter would throw the bell. However, they again did *not* seem to participate in the role as part of a social game, as it was modeled by the two humans during the demonstration.

Trampoline-Task Performance

As mentioned above, none of the three chimpanzees had any interest in playing the trampoline game and could not be induced to do so.

Interruption Periods

Table 9 displays the frequencies and proportions of overall behaviors during interruptions separately for each chimpanzee. Because of the small sample, comparisons between categories were based upon the 22 interruption periods that were almost equally distributed between subjects (8 for Alexandra, 8 for Annet, 6 for Alex). A χ^2 goodness-of-fit test showed that there were significant differences in the proportions of behaviors during interruptions, $\chi^2(3, N = 22) = 13.27$, $p < .005$. A χ^2 subdivision analysis was performed to determine which categories occurred above or below random distribution: There was no significant difference between the categories *disengagement* and *individual attempts* on the one hand and between *waiting* and *reengagement* on the other hand ($ps > .24$). Collapsing each of the pairs revealed that *disengagement/individual attempt* occurred more

Table 9
Study 2. Overall Behavior During Interruption Periods

	Subject			
Category	Alexandra	Annet	Alex	Total
Disengagement	4 (50)	4 (50)	0 (0)	8 (33)
Individual attempt	2 (25)	3 (38)	6 (100)	11 (54)
Waiting	2 (25)	1 (13)	0 (0)	3 (13)
Reengagement	0 (0)	0 (0)	0 (0)	0 (0)
Total	8 (100)	8 (100)	6 (100)	22 (100)

Frequency (and percentages) of scores for each subject.

frequently than *waiting/reengagement*, $\chi^2(1, N = 22) = 11.64$, $p < .001$. This difference was also apparent on the level of the individual, as each of the three chimpanzees performed more disengagement/individual attempts than waiting for the partner to resume her role.

Looks to the partner could not be coded (as described above), and there were no *communicative attempts* by any individual during the interruption periods.

Discussion

The three young chimpanzees in this study, about double the age of the children in Study 1, showed a very different pattern of engagement in these cooperative tasks. The task that most engaged them and led to the most successful performance was clearly the trapdoor task. In this task, they reached in and retrieved the food when that was their role, and they quite often lifted the door when that was their role. Although it sometimes appeared that to some degree they lifted the door spontaneously or for fun, and that the coordinated action was achieved by the partner then timing her reach for the food accordingly, the end result was nevertheless a degree of coordination. In the tube-with-handles task, two of the subjects pulled at the same time as the human partner reliably and so opened the tube successfully to get the food inside.

Nevertheless, the performance of the chimpanzees differed from that of children in two important ways. First, they had little or no interest in the social games. They had zero interest in the trampoline game, and could not be induced to play it—although they did quite often play with the bell itself. In the double-tube task, two of the subjects did enjoy throwing and catching the bell, but they seemed to pay little attention to their partner while doing so. Critically, unlike the human children, the chimpanzees never once used the can to catch the bell. The children assumed that the can was an integral part of the game, whereas the chimpanzees seemed to engage with the apparatus in the way that they saw fit. In general, perhaps because these social games had no food involved, the chimpanzees simply played individually with some part of the apparatus and engaged very little with their partner.

Overall, we may say that when food was involved, the subjects used a coordinated strategy, but perhaps this was simply because this was the most effective way to achieve their own goal. They could easily maintain and reach an *individual* goal (e.g., ''I want the food'') by coordinating their actions with the experimenter's, without ever interpreting the experimenter as a cooperative partner who had the intention of solving the task with them. This is consistent with an analysis of chimpanzees' behavior as emulation driven—when a clear external goal is demonstrated, chimpanzees can reproduce the effect in the environment (Tomasello, 1996; Horner & Whiten, 2005). However, because there is no clear external goal to be emulated in the social games, they do not adopt the behaviors of the experimenter after the demonstrations, and instead invent their own ways of playing with the apparatus. Human children, on the other hand, closely imitate demonstrations in games that have no clear external goal (Carpenter, Call, & Tomasello, 2005). The motivational pattern shown by the chimpanzees in this experiment—high interest in problem-solving tasks and low interest in social games—is thus consistent with our hypothesis that, unlike human children, chimpanzees do not spontaneously form joint intentions and shared goals with their partners in the context of social play.

The second major difference is that during the interruption periods, the chimpanzees never once attempted to reengage their recalcitrant partner, even in problem-solving tasks with goals that the chimpanzees were motivated to achieve. During these periods, there were no communicative attempts of any kind; the chimpanzees simply disengaged from the task, made individual attempts to solve the task, or played with some part of the apparatus alone. Figure 5 summarizes this difference between human children and chimpanzees. This finding accords with that of other research (e.g., Povinelli & O'Neill, 2000), with the only reengagement attempts previously coming after much repeated experience and being effected not via communication but through physical efforts to pull the reluctant partner to the apparatus (Chalmeau, 1994; Crawford, 1937, 1941). Because we

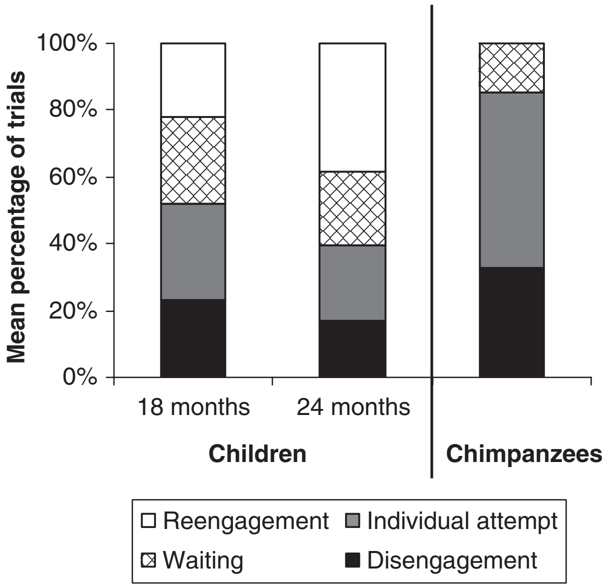

Figure 5. Comparison Study 1 and 2. Overall behavior during interruption periods.

could not reliably analyze the subjects' looking behavior, we cannot rule out the possibility that the subjects were using gaze alternation as a means of communication or, for that matter, any other subtle means that we simply did not notice and could not measure. However, it remains a fact that we found no clear evidence in the chimpanzees of any communicative attempts to reengage their partner. Gestural communicative acts are in their repertoire naturally (Tomasello, George, Kruger, Farrar, & Evans, 1985), and, most importantly, in other studies these same three chimpanzees gave objects imperatively or took the human's hand when they themselves failed to open a container (Tomasello & Carpenter, 2005). Yet in this experiment they displayed nothing resembling the vocal and gestural communicative acts of human children.

Overall, the chimpanzees never gave the clear impression of engaging with both the task and the partner simultaneously. Unlike human children, the chimpanzees' playful interactions with their partner appeared almost exclusively dyadic in nature; this is consistent with naturalistic observations that only rarely find chimpanzees spontaneously engaging in triadic play involving another actor and a shared object (Tomasello & Call, 1997). This striking difference from human children was apparent even in our human-raised chimpanzees, whose caretakers had attempted to engage them in triadic activities on many occasions. It will be the task of future research to determine whether there are other social games that may be more interesting and motivating for chimpanzees, to distinguish between the hypothesis that chimpanzees do not form joint goals in these games and the possibility that they simply were uninterested in the specific games used in this study. However, if it is the case that chimpanzees do not form joint goals in the absence of a clear external incentive, triadic social games may simply be incapable of motivating chimpanzee participation.

The overall pattern of interest versus disinterest in this study is also informative. Although the subjects all maintained interest in the problem-solving tasks while their partner played her role, their pattern of individual attempts or disengagement during interruptions suggests that they had never formed a joint goal. There was also a marked categorical difference in the chimpanzee's interest in problem-solving tasks versus social games, as well as between the chimpanzees' versus the children's interest in the same social games. It is striking that human-raised chimps with a life history of interacting with humans and playing with various enrichment objects seemed entirely unmotivated to play games that very young children will play spontaneously and eagerly. The various ways in which the behavior of chimpanzees in this study was different from that of human children—their relative interest in the tasks, lack of engagement with their partner and the apparatus simultaneously, and behavior during interruptions—all support our overall conclusion that the chimpanzees did not, during these cooperative tasks, form with the human partner a joint goal and joint intentions for reaching that goal.

General Discussion

Engaging in cooperative activities is difficult. It requires individuals to coordinate their attention both to a task and to one another. When the task is very simple, human children are able to achieve this coordination in the period from 18 to 24 months of age—most readily with a more competent partner. Our nearest primate relative, the chimpanzee, is also able to achieve this coordination at a fairly young age—most readily with a competent partner and also with food as the goal. But there seem to be some qualitative differences between the two species in the nature of the social engagement that takes place during cooperative activities.

First, children seem to be motivated not just by the goal but by the cooperation itself. They engaged more spontaneously in all of the tasks, most especially in the social games whose primary goal was the interaction itself, whereas the chimpanzees had little interest in social games without a concrete goal. Related to this, after only one brief viewing of two adults engaging in the task, children seemed to form a conception of how the game ''ought'' to be played. Most strikingly, in the double-tubes game whenever they played the recipient role they always used the can to catch the bell, whereas chimpanzees never did this. Children seem to be understanding the social, even normative, structure of the game as defined by the joint goal of the participants and their joint intentions for reaching that goal (even if the goal was simply playing a game together). Moreover, children were so engaged socially that sometimes they even turned the tasks aimed at retrieving an object into a game; after they retrieved the object, they were not interested in it, but immediately put it back in the apparatus to start the game again.

Second, when the adult partner ceased participating in the middle of the activity, the human children quite often attempted to reengage him through some communicative signal. Every child did this at least once, demonstrating that from 18 months of age young children understand something of the nature of cooperative activity and the partner's role in it. On the most generous interpretation, they have learned to form with others a joint goal, which, when it is breached, they attempt to reinstate; they understand that to accomplish the task the two participants must form such a joint goal and joint intentions to effect it. In contrast, although other studies have shown that gestural communicative acts are a part of their repertoire (Tomasello & Carpenter, 2005), none of the three chimpanzees ever made a communicative attempt to reengage their partner even when they were motivated to achieve the goal of the task. This result is consistent with those of the study of Povinelli and O'Neill (2000), in which chimpanzees in a cooperative context did not attempt to engage their partner. In two other studies, chimpanzees sometimes tried to encourage the other to participate after many repetitions (Chalmeau, 1994; Crawford, 1937, 1942); they did not do this by means of communication—attempting to engage the other intentionally—but rather by physically pulling the other toward her station. In general, when their partner left the task, chimpanzees either left also or tried to solve the tasks individually, suggesting that their only goal was individual, not shared or social. Human children, in contrast, persisted in the social character of the problem-solving process. Upon encountering a reluctant partner, chimpanzees immediately switched from a superficially social action to an individual attempt or complete disengagement, whereas children often tried to reorient him toward the joint goal and his part in this joint enterprise (the plan of action involving two roles). These are two important criteria for shared intentionality. Chimpanzees' lack of reengagement attempts suggests that they did not view the activity as including a joint goal to which the other could be redirected and did not view their actions as interdependent with the actions of the other (no joint goal, no joint plans of action).

There are two alternative accounts to our interpretation: (1) It could be argued that children did not form a shared goal but just complied with the goal of the adult. However, children's responses during interruptions contradict this interpretation: If they just complied with the adult, why would they take initiative in regulating his actions when he stopped participating? And why would they often want to return the object after retrieving it in problem-solving tasks? These behaviors should not occur if children were just acting in conformity with the adult and without any personal interest in the activity. (2) On the other extreme, one might claim that the children expected the other to comply with *their* individual goal, conceptualizing him not as a partner in a joint activity but as some kind of social tool. By this interpretation, communication during interruptions is aimed at reactivating the social tool because it is malfunctioning. Although this possibility cannot be fully ruled out, we would like to stress three points: First, even under the social tool interpretation, children's behavior during interruption periods is evidence for their understanding of the structure of the tasks—that both roles are conditional on each other. Secondly, as mentioned previously, children's motivation does not seem to be restricted to getting possession of an object (as they often attempted to reinstate the problem-solving task). Hence, even if the social tool interpretation applies, the children seem to be interested in continuing a *social* activity. Thirdly, reengagement attempts—be they directed at a cooperative partner or at a social tool—were not produced by the chimpanzees. Their ability to regulate an activity is by far less advanced than that of young children, although they are, in noncooperative contexts, capable of treating the other like a social tool by, for example, handing them containers that they themselves cannot open.

The current results thus support the phylogenetic hypothesis that human beings are especially adapted for some special types of cooperative interactions, namely, cooperative interactions with the special structure referred to as shared intentionality. Cooperative interactions with shared intentionality require the formation of a joint goal: both participants are aimed at the goal and they also want the other to be aimed at the goal along with them. They also require the forming of joint intentions, at some point translated into coordinated action, to achieve the goal. As stressed by Bratman (1992), this coordinating of intentions in most cases requires some form of communication in which partners attempt to influence the goals and intentions of the other. Clark (1996) has also argued that linguistic communication in its primordial form—face-to-face conversation in which interlocutors adjust to one another—is itself a cooperative activity involving shared intentionality, and Searle (1995) has argued that only through forms of shared intentionality is the creation of uniquely human social institutions possible. What we are witnessing here, we believe, are some of the earliest manifestations of children's emerging skills of shared intentionality enabling the creation of shared cultural practices.

This study thus establishes that by the second half of the second year of life, human children have begun engaging in the kinds of cooperative activities that enable not just cultural transmission but also cultural creation—the achieving of results in interaction with others that could not be achieved alone. Children's skills of shared intentionality also manifest themselves at around this same time in the mastery of linguistic communication and conversational skills (Tomasello, 1988, 2003), which also involve in small measure some forms of cultural creation. However, in the current study they are always doing this with more competent partners, and it remains for future research to investigate their skills of doing this with only equally competent peers. Future studies could also determine more precisely how far children perform differently in tasks requiring parallel versus complementary roles. This would require to have multiple exemplars of each task, with all other characteristics of the apparatus being equal, varying whether similar or different roles have to be executed to achieve a joint goal.

References

Ashley, J., & Tomasello, M. (1998). Cooperative problem-solving and teaching in preschoolers. *Social Development*, *7*, 143–163.

Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis*. New York: Cambridge University Press.

Boesch, C., & Boesch, H. (1989). Hunting behavior of wild chimpanzees in the tai-national-park. *American Journal of Physical Anthropology, 78*, 547–573.

Bratman, M. E. (1992). Shared cooperative activity. *Philosophical Review, 101*, 327–341.

Brownell, C. A., & Carriger, M. S. (1990). Changes in cooperation and self-other differentiation during the second year. *Child Development*, *61*, 1164–1174.

Brownell, C. A., & Carriger, M. S. (1991). Collaborations among toddler peers: Individual contributions to social contexts. In L. B. Resnick & J. M. Levine et al. (Eds.), *Perspectives on socially shared cognition* (pp. 365–383). Washington, DC: American Psychological Association.

Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science*, *8*, F13–F20.

Carpenter, M., Tomasello, M., & Savage-Rumbaugh, S. (1995). Joint attention and imitative learning in children, chimpanzees, and enculturated chimpanzees. *Social Development*, *4*, 217–237.

Chalmeau, R. (1994). Do chimpanzees cooperate in a learning task? *Primates*, *35*, 385–392.

Chalmeau, R., & Gallo, A. (1996). Cooperation in primates: Critical analysis of behavioural criteria. *Behavioural Processes*, *35*, 101–111.

Clark, H. H. (1996). *Using language*. New York: Cambridge University Press.

Crawford, M. P. (1937). The cooperative solving of problems by young chimpanzees. *Comparative Psychology Monographs*, *14*, 1–88.

Crawford, M. P. (1941). The cooperative solving by chimpanzees of problems requiring serial responses to color cues. *The Journal of Social Psychology, 13*, 259–280.

Eckerman, C. O. (1993). Toddlers' achievement of coordinated action with conspecifics: A dynamic systems perspective. In L. B. Smith & E. Thelen (Eds.), *A dynamic systems approach to development: Applications MIT Press/Bradford books series in cognitive psychology* (pp. 333–357). Cambridge, MA: MIT Press.

Eckerman, C. O., Davis, C. C., & Didow, S. M. (1989). Toddlers' emerging ways of achieving social coordinations with a peer. *Child Development*, *60*, 440–453.

Eckerman, C. O., & Didow, S. M. (1989). Toddlers' social coordinations: Changing responses to another's invitation to play. *Developmental Psychology, 25*, 794–804.

Eckerman, C. O., & Didow, S. M. (1996). Nonverbal imitation and toddlers' mastery of verbal means of achieving coordinated action. *Developmental Psychology, 32*, 141–152.

Eckerman, C. O., & Peterman, K. (2001). Peers and infant social/communicative development. In G. Bremner & A. Fogel (Eds.), *Blackwell handbook of infant development. Handbooks of developmental psychology* (pp. 326–350). Malden, MA: Blackwell Publishers.

Eckerman, C. O., & Stein, M. R. (1990). How imitation begets imitation and toddlers' generation of games. *Developmental Psychology, 26*, 370–378.

Fleiss, J. L., & Cohen, J. (1973). The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. *Educational & Psychological Measurement*, *33*, 613–619.

Fleiss, J. L. (1981). *Statistical methods for rates and proportions*. New York: Wiley.

Gilbert, M. (1989). *On social facts*. New York: Routledge.

Gustafson, G. E., Green, J. A., & West, M. J. (1979). The infant's changing role in mother–infant games: The growth of social skills. *Infant Behavior & Development*, *2*, 301–308.

Hauser, M. D., Chen, M. K., Chen, F., & Chuang, E. (2003). Give unto others: Genetically unrelated cotton-top tamarin monkeys preferentially give food to those who altruistically give food back. *Proceedings of the Royal Society, B*, *270*, 2363–2370.

Hay, D. F. (1979). Cooperative interactions and sharing between very young children and their parents. *Developmental Psychology*, *15*, 647–653.

Horner, V., & Whiten, A. (2005). Casual knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children *(homo sapiens)*. *Animal cognition*, *8(3)*, 164–181.

Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Edinia, MN: Interaction Book Company.

Melis, A., Hare, B., & Tomasello, M. (in press). Engineering cooperation in chimpanzees. *Animal Behaviour.*

Mendres, K. A., & de Waal, F. B. M. (2000). Capuchins do cooperate: The advantage of an intuitive task. *Animal Behaviour*, *60*, 523–529.

Povinelli, D. J., & O'Neill, D. K. (2000). Do chimpanzees use their gestures to instruct each other? In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from developmental cognitive neuroscience* (2nd ed., pp. 459–487). Oxford, UK: Oxford University Press.

Ratner, N., & Bruner, J. (1978). Games, social exchange and the acquisition of language. *Journal of Child Language*, *5*, 391–401.

Rogoff, B. (1998). Cognition as a collaborative process. In D. Kuhn & R. S. Siegler (Eds.), *Cognition, perception and language. Handbook of child psychology* (5th ed., *Vol. 2*, pp. 679–744). New York: Wiley.

Ross, H. S. (1982). Establishment of social games among toddlers. *Developmental Psychology*, *18*, 509–518.

Ross, H. S., & Lollis, S. P. (1987). Communication within infant social games. *Developmental Psychology*, *23*, 241–248.

Searle, J. R. (1990). Collective intentions and actions. In P. R. Cohen, J. Morgan, & M. E. Pollack (Eds.), *Intentions in communication*. Cambridge, MA: Bradford.

Searle, J. R. (1995). *The construction of social reality.* New York: Free Press.

Tomasello, M. (1988). The role of joint attentional process in early language development. *Language Sciences*, *10*, 69–88.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 103–130). Hillsdale, NJ: Lawrence Erlbaum Associates.

Tomasello, M. (1996). Chimpanzee social cognition. *Monographs of the Society for Research in Child Development*, *61*, 161–173.

Tomasello, M. (2003). *Constructing a language*. Cambridge, MA: Harvard University Press.

Tomasello, M., & Call, J. (1997). *Primate cognition*. Oxford, UK: 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., 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., George, B., Kruger, A., Farrar, M., & Evans, A. (1985). The development of gestural communication in young chimpanzees. *Journal of Human Evolution*, *14*, 175–186.

Trevarthen, C. (1979). Instincts for human understanding and for cultural cooperation: Their development in infancy. In M. von Cranach, K. Foppa, W. Lepenies, & D. Ploog (Eds.), *Human ethology: Claims and limits of a new discipline*. Cambridge, UK: Cambridge University Press.

Tuomela, R. (1995). *The importance of us: A philosophical study of basic social notion*. Stanford, CA: Stanford University Press.

Appendix A

Study 2. Detailed Description of Materials Used for Tasks With Chimpanzees

When not noted, task specifications were identical to those in Experiment 1.

Problem solving with parallel roles: Tube-with-handles task. The goal is to retrieve a piece of food inside the tube. The tube is 62 cm long closed and 8 cm in diameter, and made of a durable plastic material.

Social games with complementary roles: Double-tube task. The tubes are 100 cm long and mounted at a 17.5° angle. The wooden block in Experiment 1 was replaced with a spherical brass bell, because the subjects showed more interest in the bell.

Social games with parallel roles: Trampoline task. The trampoline consists of an 80 × 67 cm burlap cloth with 2.5 diameter wooden handles affixed along the entirety of the two short ends. Two persons can make a brass bell (again, the bell was used because it was more interesting to the subjects) jump on the trampoline by holding the handles on opposite sides.

Appendix B

Study 2. Detailed Description of Procedure for Each Task

Problem Solving with Complementary Roles: Trapdoor Task. *Demonstration:* The box was baited with several grapes. As in all demonstrations, the experimenters first ensured that the subject was watching them. Both experimenters pointed at the food. E1 grasped the handle of the sliding door, pulled the door up, and held it while E2 retrieved a grape and gave it to the subject through the wire mesh. This process was repeated at least two more times. After the last repetition, half a banana was left in the box. As in all tasks after demonstrations, E2 left the testing cage and remained passive during trials. The subject was then allowed into the testing cage.

Trial 1: In trials with role A for the subject, E1 pulled the door up and held it in place, and alternated gaze between child and the object. In trials with role B, E1 positioned herself on the retrieval side, reached through the hole in the screen, and made a grasping gesture toward the sliding door. When the subject retrieved the food in role A or pulled the sliding door up to make the object accessible to E1, trial 2 was administered. If the subject was not successful for 60 s, E1 moved the subject back into the holding cage, and the demonstration was repeated. After the second demonstration, E1 invited the subject's participation not only by gaze alternation but also by emphasizing her intent verbally for up to 60 s. In case of success, trial 2 was administered. If the subject was not successful for 60 s, the demonstration was repeated one last time. Again, if the subject was successful, trial 2 was administered; if the subject did not succeed after 60 s, the task ended.

Between trials, E2 distracted the subject while E1 surreptitiously baited the box with another piece of food.

Trials 2, 3, and 4: These trials followed the same basic procedure as the elevator task in Experiment 1. However, in the role A interruption, E1 grasped the sliding door handle but did not pull it; in role B, she reached for the object until the subject pulled the door up, at which point she withdrew her hand.

Problem Solving With Parallel Roles: Tube-With-Handles Task. The tube-with-handles task was identical to the task in Experiment 1, except as noted in the general procedure.

Social Games With Complementary Roles: Double-Tube Task. *Demonstration*: The experimenter threw the bell down one tube twice, switched to the other tube for two throws, and switched back to the first tube for two final throws.

Trial 1: Trial 1 was identical to Experiment 1, except as noted in the general procedure. However, subjects were allowed to use their hands to catch the bell in role B after demonstration 3 if they had previously shown no interest in the can. After the first two demonstrations, a catch by hand was not considered a success; after the last demonstration, however, it was considered a success.

Trial 2: E1 selected one of the tubes for two attempts.

Trials 3 and 4: Trials 3 and 4 were identical to Experiment 1, except that only one attempt occurred before and after each interruption.

Social Games With Parallel Roles: Trampoline Task. The trampoline task was identical to the task in Experiment 1, except as noted in the general procedure. Also, trials 1 and 2 lasted only 3 s.