

Chimpanzees know what others know, but not what they believe

Juliane Kaminski*, Josep Call, Michael Tomasello

Department of Developmental and Comparative Psychology, Max-Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany

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ABSTRACT

There is currently much controversy about which, if any, mental states chimpanzees and other nonhuman primates understand. In the current two studies we tested both chimpanzees' and human children's understanding of both knowledge–ignorance and false belief – in the same experimental paradigm involving competition with a conspecific. We found that whereas 6-year-old children understood both of these mental states, chimpanzees understood knowledge–ignorance but not false belief. After ruling out various alternative explanations of these and related findings, we conclude that in at least some situations chimpanzees know what others know. Possible explanations for their failure in the highly similar false belief task are discussed.

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1. Introduction

In 1978, Premack and Woodruff asked, “Does the chimpanzee have a theory of mind?” This question sparked much research, most immediately on human children with a focus on their understanding of false beliefs (Wimmer & Perner, 1983). More recently, research has focused on how young children understand the psychological states of others more generally, including everything from goals and intentions to perceptions, knowledge, and beliefs.

Human infants begin to understand that others have goals quite early, before the first birthday (e.g., Behne, Carpenter, Call, & Tomasello, 2005; Gergely, Nadasdy, Csibra, & Biro, 1995), and they understand others' rational choices of means toward goals (intentions) soon after (Gergely, Bekkering, & Kiraly, 2002; Schwier, van Maanen, Carpenter, & Tomasello, 2006). Infants understand that others see things from around the first birthday as well (e.g., Brooks & Meltzoff, 2002; Moll & Tomasello, 2004), and they understand that others have perspectives that differ from their own by at least the second birthday (Level 1: Moll & Tomasello, 2006). Of particular importance to the current stud-

ies, recent research has shown that infants at around the first birthday even understand that others know things, that is, that others' actions are governed by things they saw some moments before (e.g., Moll & Tomasello, 2007; Onishi & Baillargeon, 2005; Tomasello & Haberl, 2003). In contrast, if one requires children to express their knowledge in action (as in most of the studies cited above), they show no understanding of false beliefs – that others' actions are governed by things the child knows are not true – until much later at around 4 years of age (see Wellman, Cross, and Watson (2001), for a review and meta-analysis). Importantly, in a direct comparison Wellman and Liu (2004) found that children develop an understanding of knowledge–ignorance before they develop an understanding of false beliefs.

As for Premack and Woodruff's original question about chimpanzees, there has been controversy from the beginning. Thus, Savage-Rumbaugh, Rumbaugh, and Boysen (1978) presented data from their chimpanzees suggesting that the Premack and Woodruff (1978) goal-understanding tasks could be solved through simple association. Subsequent experiments on other mental states also yielded negative results. Most prominently, Povinelli and Eddy (1996) found that juvenile chimpanzees begged food from a human gesturally even when he was blindfolded or had a

* Corresponding author.

E-mail address: kaminski@eva.mpg.de (J. Kaminski).

bucket on his head, suggesting no understanding of visual perception. Similarly Povinelli, Rulf Alyssa, and Biersch-wale Donna (1994) found that when chimpanzees saw two humans pointing to different locations to indicate the location of a single piece of hidden food – and one of those humans had watched the original hiding process whereas the other had not – they followed the two humans' pointing gestures indiscriminately, suggesting no understanding of the distinction between knowledge and ignorance. And Call and Tomasello (1999) found that whereas 5-year-old children passed a nonverbal false belief test readily, chimpanzees failed it.

All of these data led researchers to the conclusion that chimpanzees and other nonhuman primates do not understand the psychological states of others (Heyes, 1998; Povinelli & Vonk, 2003, 2004; Tomasello & Call, 1997). That is, nonhuman primates can predict others' actions in many situations based on past experience (and perhaps some specialized cognitive adaptations), but they do not go beneath the surface to an understanding of the goals, perceptions, knowledge, and beliefs that guide others' actions. But as always, negative experimental results have many possible interpretations, and there have always been a number of informal observations by fieldworkers suggesting that perhaps chimpanzees and other nonhuman primates can understand some mental states in some situations. Most prominently, Byrne and Whiten (1990) reported a number of informal observations from fieldworkers on so-called tactical deception, which might, in some interpretations, suggest some form of mental state understanding.

Hare, Call, Agnetta, and Tomasello (2000) and Hare, Call, and Tomasello (2001) noted that almost all of the experiments with negative results from the laboratory required cooperative communication with humans (e.g., interpreting a pointing gesture, requesting food, etc.), whereas many of the potentially positive informal observations from the wild involved competition with conspecifics. They therefore devised experiments in which chimpanzees competed with one another for food. Of particular importance in the current context, Hare et al. (2001) investigated chimpanzees' understanding of knowledge. They placed a subordinate and a dominant chimpanzee into rooms on opposite sides of a third room. Each had a guillotine door leading into this middle room which, when opened at the bottom, allowed them to see into the middle room – and to see the other individual looking under her door as well. There was one piece of food in this middle room, which the subordinate could always see on her side of one of two barriers. The dominant could never see the food at the moment of choice, but in one condition she had witnessed the hiding process a few moments before (her door was open at that time and the subordinate could see this), and in another condition not (because her door was down). The doors for both individuals were then opened (subordinates had a slight headstart so that they could not react to the dominant's behavior). The clear finding was that in the trials in which the dominant had not previously witnessed the food being hidden, subordinates went for the food; in the trials in which the dominant had witnessed the food being hidden some moments before, subordinates stayed away. Subordinates seemingly knew whether or not the

dominant knew the food was there, even though he could never see choice.¹

There were several additional control conditions in the two Hare et al. studies that ruled out various more conservative, less mentalistic interpretations of these results. However, one final conservative interpretation is the so-called evil eye hypothesis. Perhaps subordinates believe that any piece of food observed by a dominant is 'contaminated' – it is forbidden once the dominant has put the evil eye on it – and so the only safe food is food that he cannot see and indeed has never seen. In a final study of Hare et al. (2001), both the dominant and the subordinate watched the food being hidden behind one of the two barriers, as usual; the dominant's evil eye was thus placed on it, and so on this interpretation the subordinate should avoid it at all costs. But then in one experimental condition only the subordinate watched the food being moved to a new location (dominant's door down), whereas in another condition they both watched it being moved. Subordinates went for the food when only they alone had watched the moving process, not when both competitors had watched the moving process. Subordinates thus clearly did not believe in any dominant evil eye, since they went for the food whose movement to a new location the dominant had not witnessed (even though he had put his evil eye on it earlier). Nevertheless, one other more conservative explanation is still viable. It could be that chimpanzees have learned the behavioral rule: if a dominant individual orients to a piece of food in a particular location, then that food must be avoided (see Povinelli & Vonk, 2003, 2004, and also Heyes, 1998, for more on the behavioral rules approach). To be completely confident that chimpanzees sometimes know what others know, we must rule out this alternative hypothesis.

In the current studies, we developed a new methodology – again based on competition with a conspecific – that enabled us to pursue two goals. First, it enabled us to directly compare the hypothesis that chimpanzees sometimes know what others know to the new evil eye hypothesis. Second, it enabled us to compare chimpanzees in both a test for knowledge–ignorance and a test of false belief understanding using the same basic methodology. The general method was a "game" in which subject and competitor took turns back-and-forth choosing from a row of three opaque buckets, some of which contained food. In the key condition in the test for knowledge–ignorance in Study 1, the task for the subject was to determine which bucket might still contain food after the competitor had chosen a bucket for himself – given that the subject had seen that competitor witnessing the hiding of one of

¹ Hare et al. (2000) focused on chimpanzees' understanding of visual perception. Karin-D'Arcy and Povinelli (2002) failed to replicate this study, but the size of their testing area was too small, which affected the nature of the competition. Braeuer, Call, and Tomasello (2007) replicated the original Hare et al. (2000) findings with a new set of chimpanzees using the correct spacing, and they also demonstrated the crucial role of space in the process. Also, recent studies show that chimpanzee sometimes attempt to conceal their approach to hidden food from a competitor, further evidence of an understanding of visual perception (Hare, Call, & Tomasello, 2006; Melis, Call, & Tomasello, 2006; see also Flombaum and Santos (2005), for similar evidence for rhesus monkeys).

the two pieces of food but not the other. To rule out the modified evil eye hypothesis, there were control conditions in which the subject chose first, in which case it should not matter what the competitor had and had not seen. We then used this basic methodology in Study 2 to create a false belief task closely matched to the knowledge–ignorance task in terms of task demands and so forth – and, importantly, still in a competitive paradigm with conspecifics, which has so far not been done. In this study, the subject saw the experimenter mislead the competitor by seeming to place the food in one bucket but actually placing it in another – the question being whether the subject could use this information to predict the competitor's choice. In both of these studies we also tested human children, so that we could compare children's and chimpanzees' understanding of both knowledge–ignorance and false belief all in a single experimental paradigm involving competition with a conspecific.

2. Study 1: knowledge–ignorance

The basic idea of this study is that subjects take turns choosing buckets and receiving their contents in the apparatus pictured in Fig. 1. It is a test of knowledge–ignorance because the subject has to choose before or after her knowledgeable or ignorant competitor has already chosen. The subject's choice could thus potentially be based on the fact that she has previously witnessed her competitor seeing one of the pieces of reward, but not the other, being hidden. The new evil eye hypothesis predicts that the subject should avoid the piece of reward her competitor directed his behavior to (put her evil eye on in that specific location) irrespective of whether she chooses first or second, as he behaved towards it the same in both cases. In contrast, a more mentalistic hypothesis would predict that only when the subject chooses second should she avoid the piece of reward that the competitor saw being hidden; when she chooses first it should not matter what the competitor saw (unless she is considering her second turn after that – which we explain later).

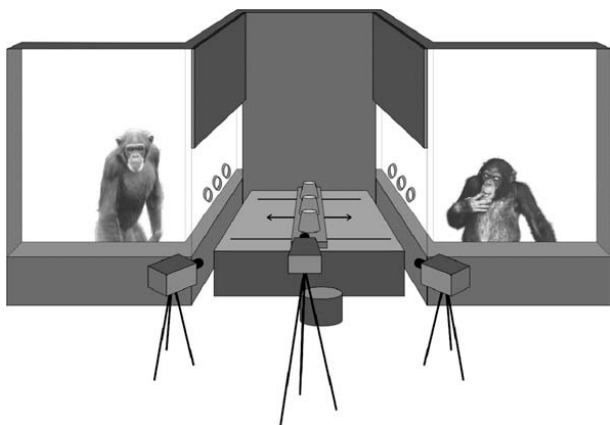


Fig. 1. Experimental set up. Two subjects sat on opposite side of the table. The task was a back-and-forth task in which a subject and a competitor took turns choosing from a row of three opaque buckets, some of which contained a reward.

2.1. Methods

2.1.1. Participants

Ten chimpanzees (*Pan troglodytes*) participated in this experiment, eight females and two males ranging in age from 4 to 29 years. Six apes were nursery reared whereas four were mother reared. All subjects were housed at the Wolfgang Köhler Primate Research Center in the Leipzig Zoo (Germany), where they lived with conspecifics in a social group and had access to both indoor and outdoor areas. Subjects were tested in their indoor cages, were fed according to their normal daily routine, and were not food or water deprived at any time. Subjects had previously participated or were currently participating in other studies, so they were comfortable participating in tests.

Twelve 6-year-old children also participated in this experiment, six boys and six girls ranging in age from 5;11 to 6;02 (year; months). Children were recruited from kindergartens in a middle-sized German city. Children were not informed of the purpose of the study and were encouraged to compete against an informed adult to obtain access to toys. Twelve human adults also participated in the experiment, four females and eight males ranging in age from 21 to 41 years. Prior to the study the adults were not informed of the purpose of the study, but were told that they should compete to get as many tokens as possible. After the study was completed the participants got full information of the purpose of the study.

2.1.2. Apparatus

For the chimpanzees, a table (80 cm × 93 cm) with three cups (10 × 12 cm) attached to a sliding board (91 cm × 31 cm) was placed on a platform which was located just outside their enclosure (see Fig. 1). The platform was placed between two Plexiglas panels in a testing booth (81 cm × 110 cm). At the bottom of each panel were three holes (each 3.6 cm in diameter) arranged in a straight line. The holes were 29 cm apart, as measured from the center of one hole to the centre of the next. The food reward for the chimpanzees were grapes, pieces of banana, or food-pellets depending on the individual's preference.

For the 6-year-olds, a platform (56 cm × 46 cm) with a sliding board attached (46 cm × 19 cm) was placed on a table. There were three chairs on three separate sides of the table for the two competing individuals and the experimenter to sit on. Three cups (8 cm × 9 cm) were placed on the table to hide the toys. For the children the rewards were toys. The toys consisted of regular children's toys small enough to fit into the cups.

For the adults, a platform (80 cm × 93 cm) with a sliding board attached (91 cm × 31 cm) was placed on a table. There were three chairs on three separate sides of the table for the two competing individuals and the experimenter to sit on. Three cups (9 cm × 11 cm) were placed on the table to hide the tokens. The tokens consisted of yellow cardboard pieces.

2.1.3. General procedure

The general procedure was similar for all three groups. To give each subject some experience with the general set

up, each subject received several warm-up trials before the experiment started. In a warm up trial both individuals received all possible relevant information and they chose in turns. This was to see if individuals paid attention to the general course of events, that is whether they picked the reward which was still there after they had seen their competitor choosing. All subjects received at least six of these warm up trials. If an individual subject was not successful in four or more of these trials it received an additional set of six trials. Human subjects were instructed not to talk during the entire session, and they were encouraged to compete. Chimpanzee subjects had learned prior to this experiment to poke a finger through one of the holes of a Plexiglas panel to request the container located in front of the hole. For test trials, the experimenter (E) sat behind the table with one individual located on the left side and one individual on the right side such that both subjects were facing each other (see Fig. 1). A trial started with E showing the rewards to both individuals. After that E started baiting the cups. E always baited two of the three cups with food (chimpanzees), cardboard tokens (adult humans), or toys (children), always starting with the cup closest to her, then baiting the middle cup, and then the furthest cup.

In all conditions in these test trials the subject could see the baiting of both cups (and so she also saw which cup was empty). What the competitor saw varied depending on condition, with his view blocked by an opaque occluder when necessary. There were two experimental conditions and two control conditions:

2.1.3.1. Experimental: competitor first. The baiting of one piece of reward (the known reward) was visible to the subject and the competitor. The baiting of the second reward (the unknown reward) and the empty cup were visible only to the subject and not to the competitor. The competitor started the task by choosing first.

2.1.3.2. Experimental: subject first. Everything was identical to the Competitor First experimental condition, except that the subject started the task by choosing first.

2.1.3.3. Control: nothing known. The baiting of both pieces of reward was visible only to the subject and not the competitor (and the subject could see this). In half the trials the competitor chose first and in half the trials the subject chose first. This control condition was to make sure that subjects were not making their choices based on some source of information other than the competitor's visual experience during baiting.

2.1.3.4. Control: all known. The baiting of both pieces of reward was visible to both the subject and the competitor. In half the trials the competitor chose first and in half the trials the subject chose first. This control condition was to make sure that subjects paid attention to the competitor's choice.

To further ensure that behavior-reading could not account for chimpanzees' behavior in these conditions, we conducted an additional control for the chimpanzee subjects only:

2.1.3.5. Control: subject first and competitor visible. Everything was identical to the subject first experimental condition, except that the subject could see the competitor watching while she was choosing. This was an additional test of the evil eye behavioral rule hypothesis to make sure that the subject did not avoid the known piece because the competitor made some kind of threat or claim on it, or that the subject could tell that the competitor was going to choose the known piece by reading her behavior.

Each subject was tested in a total of four sessions: two with the competitor first experimental condition, and two with the subject first experimental condition. In each of these sessions the subject received six trials in the experimental condition and three trials in each of the two main control conditions (all known and nothing known). Within each session, order of conditions was randomized. Each subject thus received 12 experimental trials in each experimental condition and 12 trials in each control condition, summing to a total of 48 trials altogether. Half of the subjects started with subject first trials in the first session and then received competitor first trials in the second session, and vice versa in the third and fourth sessions. The other subjects were given the opposite order. The additional control condition for the chimpanzee subjects (subject first and competitor visible) was presented as a follow up and included 12 trials per subject which were presented to the subjects in one session.

The location of the two rewards in the experimental conditions (known and unknown) was randomized and counterbalanced across trials. After the baiting was completed, the subject got the first or second choice depending on condition. To give an individual the opportunity to choose, E slid the table to one side and, after this individual had made a choice and received the reward, slid the table immediately to the other side. The first choice occurred in private so that neither individual could see the other (except in the final control for the chimpanzees); thus, the competitor could not see the subject's choice when she chose first and the subject could not see the competitor's choice when he chose first. After the first choice in each trial the view of neither the subject nor the competitor was blocked and the table was slid back and forth between individuals, allowing them to choose until both pieces of reward were gone.

2.1.4. Scoring and reliability

For the chimpanzee subjects a choice was considered made when she poked her finger through one of the Plexiglas holes, where each hole corresponded to the location of one of the three cups. A poke consisted of inserting a finger through one of the Plexiglas holes so that parts of the finger were visible on the experimenter's side. If the subject poked through two holes at one time the experimenter considered the choice to have not yet been made, and she waited until the subject poked a finger through only one hole. All trials were videotaped with three cameras (one camera filming the subject, one filming the competitor, and one filming the overall setup). The videotapes were later coded by the first author. A second coder blind to

condition coded 20% of the trials for reliability purposes, also from videotapes. Interobserver reliability was excellent (Cohens Kappa = 0.92, $n = 442$). For the Human subjects a choice was considered made when the subject clearly pointed to one of the cups. A second coder blind to experimental condition coded 20% of the trials for reliability purposes from videotapes. Interobserver reliability was again excellent (Children: Cohens Kappa 0.97, $n = 156$, Adults: Cohens Kappa = 0.98, $n = 502$).

2.2. Results

Fig. 2 presents the percentage of trials in which subjects selected the reward that was known only to them (hidden) as a function of the order in which they chose (Table 1 presents the raw individual data). Chimpanzees selected the hidden food significantly more often when they chose second than when they chose first (paired sample t -test: $t_9 = 3.43$, $p = 0.007$, Cohen's $d = 0.701$). Moreover, they selected the hidden food above chance levels when they chose second (one sample t -test: $t_9 = 2.35$, $p = 0.043$), and 8 of the 10 chimpanzees did so on the very first trial. In contrast, they did not select the hidden food at above chance levels when they chose first (one sample t -test: $t_9 = 0.02$, $p = 0.98$). Subjects did not change in the nature of their choices in the first versus the last half of the trials, either when they chose second (paired sample t -test: $t_9 = 0.110$, $p = 0.91$, Cohen's $d = 0.054$) or when they chose first (paired sample t -test: $t_9 = 0.669$, $p = 0.52$, Cohen's $d = 0.309$).

A similar analysis of the competitors' behavior in the two experimental conditions showed that they used the predicted search strategy of getting the food that was known to both partners. Overall, competitors significantly selected the known food over the hidden food irrespective of whether they chose first (one sample t -test: $t_7 = 6.39$, $p < 0.0001$) or second (one sample t -test: $t_7 = 4.64$, $p = 0.002$). Moreover, they selected the hidden piece equally often when they chose first than second (paired t -test: $t_7 = 1.85$, $p = 0.108$, Cohen's $d = 0.671$).

Table 1
Number of trials subjects aimed for the known, the unknown, and the empty piece of reward in both conditions of Study 1

	Subject first			Competitor first		
	Known	Unknown	Empty	Known	Unknown	Empty
Chimpanzees	8	3	1	8	4	0
	7	5	0	4	7	1
	5	6	1	5	7	0
	5	7	0	3	7	2
	7	5	0	3	4	5
	6	6	0	4	5	3
	7	5	0	6	5	1
	6	5	1	4	7	1
	2	8	2	3	8	1
	5	7	0	3	8	1
Children	6	6	0	0	11	1
	5	6	1	5	5	2
	7	4	1	4	5	3
	4	8	0	2	8	2
	3	7	2	1	10	1
	5	7	0	3	9	0
	10	1	1	1	11	0
	11	1	0	1	11	0
	6	6	0	6	5	2
	12	0	0	2	9	1
	9	3	0	3	8	0
	5	6	1	3	8	1
Adults	8	4	0	1	11	0
	7	5	0	1	11	0
	6	6	0	1	10	0
	9	3	0	2	10	0
	5	7	0	2	10	0
	11	1	0	0	12	0
	6	6	0	6	6	0
	9	3	0	2	10	0
	9	3	0	5	7	0
	9	3	0	0	12	0
	4	8	0	0	11	1
	8	4	0	3	9	0
8	4	0	1	11	0	

The children selected the hidden toy significantly more often when they chose second than when they chose first (paired sample t -test: $t_{11} = 3.74$, $p = 0.003$, Cohen's

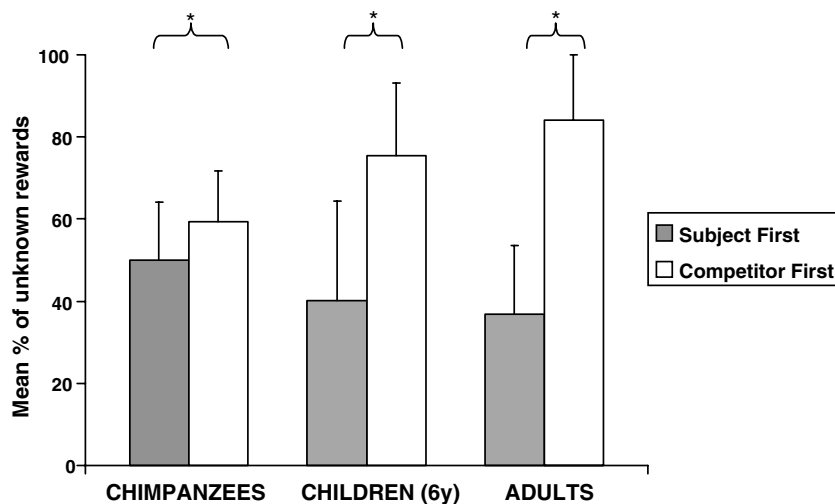


Fig. 2. The mean percentage of experimental trials [\pm SD] in which subjects from each group chose the unknown piece across condition in Study 1. * represents significant difference ($p < 0.05$).

$d = 1.68$). Moreover, they selected the hidden toy above chance levels when they chose second (one sample t -test: $t_{11} = 5.06$, $p < 0.0001$) but not when they chose first (one sample t -test: $t_{11} = 1.41$, $p = 0.19$). Children did not change in the nature of their choices in the first versus the last half of the trials when they chose second (paired sample t -test: $t_{11} = 1.05$, $p = 0.32$, Cohen's $d = 0.335$). When they chose first, before the competitor, they came to prefer the known toy – paired sample t -test between first and second half: $t_{11} = 3.49$, $p = 0.005$, Cohen's $d = 1.034$ – and they chose the unknown toy below chance in the second half of trials, one sample t -test: $t_{11} = 4.0$, $p = 0.002$. This may suggest that they were learning to anticipate their second chance, after the competitor chose, and thus chose first the reward that was “at risk”.

The adults selected the hidden reward significantly more often when they chose second than when they chose first (paired sample t -test: $t_{11} = 6.82$, $p < 0.001$, Cohen's $d = 2.868$). Moreover, subjects selected the hidden reward above chance levels when they chose second (one sample t -test: $t_{11} = 7.34$, $p < 0.0001$) and below chance levels when they chose first (one sample t -test: $t_{11} = 2.71$, $p = 0.02$). The adults in this condition were thus clearly anticipating their second chance by choosing first the reward that was “at risk”. They did not change in the nature of their choices in the first versus the last half of the trials, either when they chose second (paired sample t -test: $t_{11} = 0.32$, $p = 0.75$, Cohen's $d = 0.078$) or first (paired sample t -test: $t_{11} = 0.68$, $p = 0.51$, Cohen's $d = 0.285$).

In the all known control condition, in which everything was visible to both individuals throughout, including the hiding of both pieces of reward and the competitor's choice (to make sure subjects paid attention to the competitor's choice), subjects of both species (chimpanzees and humans) performed well, as they found the reward successfully above chance independently of whether they were to choose first (one sample t -test: chimpanzees: $t_9 = 10.49$, $p < 0.0001$, children: $t_{11} = 22.99$, $p < 0.0001$, adults 100% successful) or second (one sample t -test: chimpanzees $t_9 = 7.83$, $p < 0.0001$, children: $t_{11} = 18.57$, $p < 0.0001$, adults $t_{11} = 23.0$, $p < 0.0001$). This control condition shows that subjects were attentive, knew how the task worked, and attended to the other's choice.

We conducted the Nothing Known control condition, in which the competitor did not see the original hiding event to ensure that concealing the view of an individual truly resulted in this individual being ignorant to the location of the reward. In both conditions competitors did not find the reward at above chance levels – demonstrating that individuals were not using any uncontrolled cues: first (one-sample t -test: chimpanzees: $t_7 = 0.43$, $p = 0.68$, adults: $t_5 = 1.024$, $p = 0.353$) or second (one-sample t -test: chimpanzees $t_7 = 1.13$, $p = 0.29$, adults: $t_5 = 0.23$, $p = 0.83$) respectively. (Since the competitor for the children was an informed experimenter this measure was only analyzed for the chimpanzees and the adult humans).

In the subject first and competitor visible control condition, which was a direct test of the new evil eye hypothesis, chimpanzee subjects chose randomly (while the competitor watched) between the piece that was known or unknown to the competitor, thus showing that they were

not influenced by the competitors' gazing or other behavior (paired sample t -test: $t_8 = 0.69$, $p = 0.51$, Cohen's $d = 0.459$).

2.3. Discussion

These results suggest that, at least in some situations, chimpanzees know what others know, in the sense of *have seen*. Specifically, in the current study naive chimpanzees correctly inferred what a competitor did some moments before based not on the competitor's behavior, but on what the competitor had seen earlier. Thus, subjects made their choice differently depending only on whether they were choosing first, before the competitor, or second, after the competitor. When choosing before the competitor, they felt free to choose either piece of food. When choosing after the competitor, however, they tried to maximize their gains by guessing which cup the competitor had chosen which was in turn based on what she had seen some moments before then. Interestingly, competitor experience did not enhance any of the subjects' performance in the task and had in fact the exact opposite effect for the chimpanzees (footnote 2). This is most likely because performing as competitors required no cognitive engagement or attention to the other at all – the competitor simply chose the only piece of food whose location he knew – and this inattention to the other likely carried over into the main test so that they ignored the competitor's experience.

These results are not susceptible to the same alternative explanation as those of Hare et al. (2001): the new evil eye hypothesis. That is, in that study subjects could label a piece of food as “dangerous” as soon as the competitor had looked at it (and as “not dangerous” if not), without any inferences about what the other did and did not know at the moment of choice. In the current study, if the evil eye hypothesis were correct subjects should have avoided the food piece that the competitor had seen in both experimental conditions equally, but they did not. Moreover, subjects should have avoided choosing the known piece when the competitor was visible (subject first and competitor visible control), but again, they did not. Instead, chimpanzees combined their knowledge of what the competitor had seen with the timing of their own and their competitors' choices to maximize their food intake. One could argue that chimpanzees' performance in this task, although statistically significant, is not overwhelming in the sense that the effect is not as strong as it has been in other studies (e.g., Hare et al., 2001). However, note that chimpanzees in the current study had to memorize what had been hidden where (as they had no visual access to the food while making their decision) and in addition, had to inhibit grabbing for the food the competitor had seen. This makes this task more demanding than others, where the location of the food was perceptually available throughout the time of choice.

The fact that children and adult humans also showed this same basic pattern of results validates the task. However, there was one main difference with human adults. When human adult subjects chose first, they preferentially chose the reward that the competitor had also seen, presumably in anticipation of their next turn after the

competitor had chosen. By choosing in this way, adult subjects diminished the competitor's chances of success while simultaneously increasing their own chances on their next turn. Neither 6-year-old children nor chimpanzees followed this strategy, suggesting that they were not thinking prospectively. However, with some experience, the 6-year-old children developed the same strategy as the adults. This could be due to their becoming more experienced with the general course of events in the task, but it could be due to their facing a more predictable competitor (an "informed" adult) and therefore a more predictable outcome than the chimpanzees.

Interestingly, Hare et al. (2000) did document the use of a similar "grab the food at risk now" strategy in dominant chimpanzees when there was one piece of food that both the dominant and subordinate chimpanzee could see and another piece that only the dominant could see. However, in that study chimpanzees did not take turns but attempted to get as much food as possible in the same turn – and the food was always visible. Thus, targeting the piece that was 'at risk' was a strategy that allowed dominant chimpanzees to maximize their present gains, not their future ones.

Although there is some recent evidence that apes plan for future needs (Mulcahy & Call, 2006), this negative result is perhaps more surprising in children because even 4-year-olds can already make some claims about future events, and by the age of five to six they have already developed some knowledge of future hypotheticals even when these include weighing several possibilities (Beck, Robinson, Carroll, & Apperly, 2006). Although it is true that over time children, unlike chimpanzees, developed a preference for the 'at risk' reward when they chose first, it is unclear whether this was a consequence of differential reinforcement or prospective strategic planning. It is conceivable that chimpanzees' and children's apparent lack of spontaneous prospective strategic planning is related to the likelihood of getting the reward. Note that in the current study, picking the reward at risk does not lead to another reward with certainty but it simply increases the subject's subsequent chances for a reward on the next turn. Perhaps chimpanzees and children may be less skilful than adults at computing such probabilities. This is clearly a question for future research, but in either case, the advantage of the adult humans in this experiment may not be in social cognition but rather in some non-social cognitive skill such as projecting into the future or computing probabilities.

3. Study 2: false belief

In this study, using the same basic experimental set up as Study 1, the subject saw the experimenter mislead the competitor by seeming to place a single piece of reward in one bucket but actually placing it in another – and the subject then had to predict the competitor's choice of the incorrect bucket based on his false belief (by knowing which piece remained when it was her turn to choose). This is the first study to test chimpanzees' and children's understanding of false beliefs in a competitive task with a conspecific, and the positive findings from Study 1 enable us to, in a sense, control for basic task demands.

3.1. Methods

3.1.1. Participants

Eight chimpanzees participated in this experiment, six females and two males ranging in age from 4 to 28 years. The chimpanzees were randomly recruited from the same groups as the ones participating in Study 1. Two apes were nursery reared whereas six were mother reared. Six of the subjects had participated in the previous study while two were naïve. Twenty 3-year-old human children participated in this experiment as well, 10 males and 10 females ranging in age from 3;04 to 3;09. Twenty 6-year-old children also participated, 10 males and 10 females ranging in age from 5;10 to 6;03. Children were recruited in the same manner as Study 1, and were not informed about the purpose of the study. None of the children had participated in Study 1.

3.1.2. Apparatus

The apparatus for each group was the same as in Study 1. However, an additional small table was placed next to the subject such that only the subject had access to the cup (8.5×13.5 for the chimpanzees and $8 \text{ cm} \times 9 \text{ cm}$ for the children) that was placed on top of it. For each group there were two types of rewards present during each trial, a high quality reward (a piece of banana for the chimpanzees and a toy for the children) and a low quality reward (a piece of apple for the chimpanzees and a small wooden block for the children). The high quality reward was always placed in one of the cups on the sliding table apparatus, and the low quality reward was always placed on the table next to the subject. The idea was that if the subject was not sure if the high quality reward was still available when it was her turn to choose, she could choose the "safe" option on the table.

3.1.3. General procedure

The general logic of the paradigm was similar to Study 1, but slightly different. A trial started with E showing the low quality reward to the subject and placing it under the cup on the table beside her; choosing this "safe" option was possible on every trial (presumably when the subject was unsure if the high quality reward on the sliding table was still available). After that, E placed the high quality reward under one of the three cups on the sliding table. E manipulated the cups in a constant order, always starting with the cup closest to her, then the middle cup, and then the furthest cup. In all conditions the subject and the competitor both saw the initial baiting of the high quality reward (initial baiting) on the sliding table. After this, E rebaited the reward (final baiting) either by lifting it and then placing it back in its initial location (lift) or by lifting it and placing it in a different location (shift). Whether or not the competitor had information about this final baiting depended on experimental condition.

3.1.3.1. Known lift. After the initial baiting the experimenter lifted the reward and placed it back in the initial location with both individuals having visual access to this manipulation.

3.1.3.2. Known shift. After the initial baiting the experimenter lifted the reward and placed it to a new location with both individuals having visual access to this manipulation.

3.1.3.3. Unknown lift. After the initial baiting the experimenter lifted the reward and placed it back in the initial location with only the subject having visual access to this manipulation.

3.1.3.4. Unknown shift. After the initial baiting the experimenter lifted the reward and placed it in a new location with only the subject having visual access to this manipulation.

Whenever necessary, an opaque occluder was held up to block the view of the competitor. After the baiting was completed the table was always first slid to the competitor's side and the competitor was the first to choose. The subject never witnessed the competitor's choice. After the competitor made her choice, the table was slid to the subject's side and it was the subject's turn to choose. Each subject received six trials per condition with conditions presented in a randomized order, summing up to 24 experimental trials. Additionally, each subject received six motivation trials. Trials were presented in two sessions with 15 trials each. Motivation trials were interspersed with experimental trials and had the same general structure as experimental "Shift" trials but here baiting and choice of each of the competing individuals were visible throughout the trial. These trials were conducted to assure that the subjects followed the general course of events and understood the idea of the less valuable reward as an alternative if no high quality reward was left.

3.1.4. Scoring and reliability

All trials were videotaped. The videotapes were later coded by the first author. We scored the number of trials in which subjects selected each of the three following options: (1) the cup where it had last seen the high-quality reward after the second manipulation (high quality cup), (2) the alternative cup (low-quality cup), and (3) one of

the cups in which the reward had never been located (empty cup).

Choices were coded as in Study 1 and again a second coder who was blind to experimental condition coded 20% of the trials for reliability. Interobserver reliability was excellent (chimpanzees: Cohens Kappa = 1.0, $n = 59$; 3 year old children: Cohens Kappa = 0.93, $n = 120$; 6 year old children: Cohens Kappa = 0.87, $n = 120$).

3.2. Results

Recall that in this study subjects always chose second. The analysis was thus a 2×2 ANOVA on the percent of choices of the high-quality reward with the factors: Manipulation (shift or lift reward) and Witnessing (competitor did or did not know about the manipulation). As can be seen in Fig. 3, chimpanzees chose the high-quality cup (where they last saw the reward) more often when their competitor had not witnessed the final baiting than when he had, main effect ($F_{1,7} = 14.99$, $p = 0.006$, Partial $\eta^2 = 0.68$), thus replicated the findings on knowledge-ignorance from Study 1. There were no other significant effects, and in particular chimpanzees did not care whether the reward was shifted in position or not (and this did not interact with Witnessing). In the motivation trials in which the chimpanzees could see the other individual choosing the high-quality reward before their own choice, they clearly chose the alternative low-quality cup at above chance levels (one sample t -test: $t_7 = 4.16$, $p = 0.004$) showing that they followed the general course of events and accepted the low-quality reward as an alternative.

We conducted a second repeated measures ANOVA analyzing the overall choice pattern of the chimpanzees. As chance probabilities for choosing the empty cup (the cup in which the reward had never been) was different in the shift (chance probability of choosing an empty cup is 33.33%) than in the lift conditions (chance probability of choosing an empty cup is 66.67%), we ran this analysis after correcting the data by subtracting the value expected by chance from the observed value divided by the value expected from chance. This analysis showed that the chimpanzees overall preferred some choices over the other as

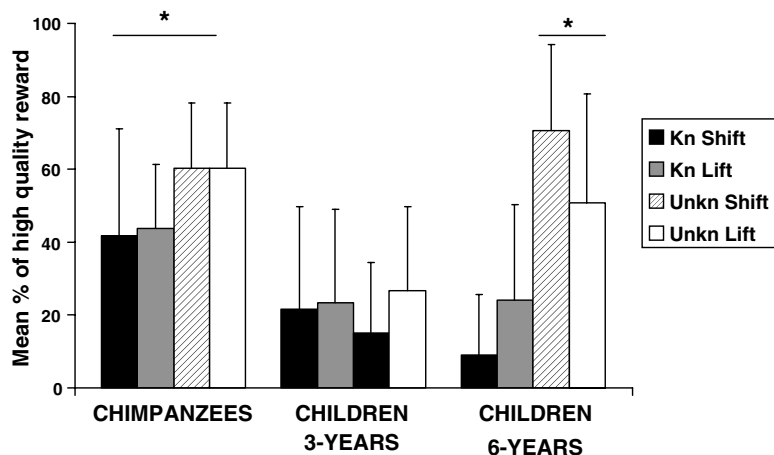


Fig. 3. The mean percentage of trials [\pm SD] in which subjects from each group chose the high-quality cup (where they had last seen the reward) in the different conditions of Study 2. * represents significant difference ($p < 0.05$).

the ANOVA did show a significant effect of Choice ($F_{2,14} = 19.54$, $p < 0.001$, Partial $\eta^2 = 0.736$). Post-hoc comparisons revealed that the chimpanzees preferred the high-quality cup over the empty cup ($p = 0.001$) as well as the low-quality cup ($p = 0.005$). They chose the low-quality cup and an empty cup with equal frequency ($p = 1.0$), perhaps reflecting a high-risk strategy in favor of the high-quality reward.

The 3-year old children chose the high-quality cup at low levels overall (see Fig. 3). The 2×2 repeated measures ANOVA on the percent of choices of the high-quality reward with the factors: Manipulation (shift or lift toy) and Witnessing (competitor did or did not know about the manipulation) showed a significant effect for the main factor Manipulation ($F_{1,19} = 6.91$, $p = 0.017$, Partial $\eta^2 = 0.267$). Overall children chose the high-quality reward more when the reward had only been lifted than when it had been shifted – with no attention to the known–unknown manipulation as there was no significant effect of the other main factors or and no interaction between the two main factors. In the motivation trials again the three year olds chose the alternative low-quality reward at above chance levels (one sample t -test: $t_{19} = 23.13$, $p < 0.0001$) indicating that they accepted the alternative reward as an option, but clearly in the test trials they were not tuned in to the competitor's experience.

The 6-year-old children were affected by both manipulations (see Fig. 3). The 2×2 ANOVA again with the two main factors Manipulation (shift or lift toy) and Witnessing (competitor did or did not know about the manipulation) showed a significant effect of the main factor Witnessing ($F_{1,19} = 116.64$, $p < 0.0001$, Partial $\eta^2 = 0.86$). Overall the 6-year-olds chose the high-quality reward more when the competitor had not seen the final baiting than when she had seen it, thus demonstrating their sensitivity to knowledge–ignorance, just like the chimpanzees. The other main factor, Manipulation, did not have a significant effect. However, there was a significant interaction between the two main factors ($F_{1,19} = 16.54$, $p = 0.001$, Partial $\eta^2 = 0.465$) indicating that the knowledge state of the competitor affected the subjects behavior based on how the reward had been manipulated. A comparison between the two conditions in which the competitor was not knowledgeable showed that the children chose the high-quality cup more when the reward had been shifted than when it had only been lifted (paired sample t -test: $t_{19} = 2.4$, $p = 0.027$, Cohen's $d = 0.728$), whereas the opposite was true in the two conditions in which the competitor was knowledgeable (paired sample t -test: $t_{19} = 2.98$, $p = 0.008$, Cohen's $d = 0.689$). This shows that the children understood that the competitor was less likely to have taken the high-quality reward when he had not seen its location being shifted, that is, when he held a false belief about its location. In the motivation trials again the 6-year-olds chose the alternative low-quality reward well above chance levels (one sample t -test: $t_{19} = 53.1$, $p < 0.0001$).

3.3. Discussion

In the current study chimpanzees showed once again an understanding of knowledge–ignorance, but they showed

no evidence of understanding false beliefs. Specifically, chimpanzees chose the high-quality cup on the sliding apparatus (i.e., where they last saw the high-quality reward) more often when their competitor had not seen its final placement than when he had seen its final placement, thus showing an appreciation of the competitor's knowledge state. But they did not differentiate between two critical cases in which the competitor did not see the final placement: the case in which the reward was placed back in its original location (only lifted), so that the competitor was likely to know where it still was, and the case in which its location was shifted, so that the competitor could not know where it was. They did not choose in a way that took advantage of their competitor's likely false belief when he did not see the shifting of the high-quality reward's location. When chimpanzees did not choose the cup where they last saw the high-quality reward, they chose an empty cup on the apparatus and the alternative cup on the table equally often – perhaps reflecting a high-risk strategy in favor of the high-quality reward in preference to the safe, low-quality reward.

In contrast, the 6-year-olds not only appreciated knowledge–ignorance, but also false beliefs. That is, they clearly differentiated the cases in which the competitor did and did not see the second, final placement of the reward. But, in addition, given that the competitor did not see the final placement, they also chose the high-quality cup on the apparatus more often when its location had been shifted (so that the competitor had a false belief about its final location) than when it was simply placed back in its original location (only lifted). They knew when the competitor would be fooled into having a false belief about the high-quality reward's location, and they took advantage of this. The behavior of the 6-year-olds would thus seem to validate this task as tapping into some kind of understanding of false beliefs.

We tested 3-year-old children in hopes of replicating the chimpanzee pattern of understanding knowledge–ignorance but not false beliefs. However, this did not happen as the behavior of the 3-year-old children was mainly guided by the movement of the high-quality reward during the final baiting. They actually went for the reward slightly more when it was simply lifted and placed back into the same location than when it was shifted, regardless of the competitor's visual access. This may reflect their poor memory for the different events in the task rather than their understanding of the social situation itself. Moreover, the 3-year-old children had a strong preference to go for the low-quality, safe alternative cup on the table, perhaps reflecting their general uncertainty over the location of the high-quality reward on the apparatus.

The behavior of the chimpanzees in this study is comparable to other false belief studies, which have provided no convincing evidence of false belief attribution (Call & Tomasello, 1999; Krachun, Carpenter, Call, & Tomasello, submitted for publication). The difference is that in the current two studies chimpanzees showed skill in almost exactly the same task when they simply had to appreciate whether the competitor was knowledgeable or ignorant. This means that their failure in the false belief version of this second study is not due to their inability to deal with

the task demands in general. The strategic behavior of the 6-year-old children further validates the task as a test of false belief understanding.

4. General discussion

The current findings provide evidence that chimpanzees understand when others are knowledgeable and ignorant – in the sense of what those others have and have not seen in the immediate past – at least in some situations. In both Study 1 and Study 2 we found that chimpanzees (and human children and adults) preferentially selected a piece of reward that their competitors had not seen being hidden over one he had seen being hidden. The previous studies of Hare et al. (2000, 2001) had a number of different control conditions that ruled out very low level explanations of the chimpanzees' behavior in the basic competitive paradigm. But the behavioral rule as manifest in the new evil eye hypothesis – that chimpanzees would avoid food that another had directed her behavior to at its current location – was still a possibility. The current Study 1 eliminated this possibility by showing that under certain conditions they do not do this. It is of course possible that some other behavior reading explanation (Povinelli & Vonk, 2003; Povinelli & Vonk, 2004), could be devised to explain the results of both previous and current results, but the diversity of findings makes this extremely unlikely.

Study 2 found that in the same experiment in which they discriminated knowledge and ignorance in their competitor, chimpanzees did not distinguish their competitor's true belief from his false belief. If the experimenter tricked the competitor by moving the high-quality piece of reward (and the subject saw this), the subject gained no further advantage over the case in which the competitor simply did not see the hiding at all. In contrast, 6-year-old children did gain an additional advantage when they saw that the competitor had a false belief over the case in which he was simply ignorant. This finding is consistent with the experiment of Call and Tomasello (1999), who also found that children, unlike chimpanzees and orangutans, provided positive evidence of false belief attribution in a cooperative experimental paradigm. Moreover, our current chimpanzee results are consistent with the data of Hare et al. (2001) in a competitive situation in which chimpanzees once again provided evidence consistent with the knowledge–ignorance distinction but not with false belief attribution. In that study, chimpanzees behaved in the same way regardless of whether their competitor was uninformed (knowledge–ignorance) or misinformed (false belief) about the location of the reward.

To fully explain chimpanzees' success in understanding knowledge–ignorance, but failure in understanding false belief, we would need a comprehensive theory of the ontogeny of false belief understanding – which does not exist. However, there would seem to be three obvious hypotheses. First is simply that the understanding of beliefs requires a fully representational theory of mind in a way that the understanding of other mental states does not, and chimpanzees simply do not have this fully representational theory of mind. Humans have evolved this

capacity and it emerges in human ontogeny relatively independent of particular types of individual experience. Second is the possibility that chimpanzees have the capacity for understanding false beliefs, but the “pull of the real” is even stronger for them than it is for young children. It is well-known that children's skills of inhibition and executive control influence their performance on false belief tasks (Moses, 2001), and it is also the case that chimpanzees are less skilled at inhibition and executive control than are young children (e.g., Vlamings, Uher, & Call, 2006). There are no studies correlating these two sets of skills in chimpanzees, however. Third is the possibility that children's development of a fully representational theory of mind, including false beliefs, is dependent on several years of linguistic communication – and of course chimpanzees are not evolved for this. There is much evidence for the role of language in the development of false belief understanding, including the findings that deaf children who do not learn sign language in the normal way are much delayed in this task (Peterson & Siegal, 2000) and that children who are given special training in certain kinds of linguistic discourse pass the task earlier than those who are not given such training (Lohmann & Tomasello, 2003; see Astington, (2001), for a review). At the moment, we are unable to choose among these three alternative hypotheses, and there are very likely other potential hypotheses as well.

Finally, we found no evidence that either chimpanzees or 6-year-old children could use their understanding of knowledge–ignorance to anticipate some steps ahead in the task of Study 1, as the human adults did. Although a number of nonhuman species are able to plan for future events (Clayton & Dickinson, 1998; Mulcahy & Call, 2006), humans have developed this ability to a much greater degree (Roberts, 2002; Suddendorf & Corballis, 1997; Tulving, 2005). And, in the current context at least, it would seem that developing the capacity to apply this ability in mental state understanding takes some ontogenetic time.

The field of primate social cognition has made great advances in the last decade. We have now moved beyond the simple question of “do they or don't they” have a theory of mind, yes or no? Research with both young children and various nonhuman primates, especially chimpanzees, has shown that mental state understanding does not come all at once, but rather it emerges differently for different mental states at different stages of ontogeny – and this may even differ across species. We must therefore investigate social understanding across species specifically for different mental states on their own terms: goals, intentions, visual perception, auditory perception, attention, perspective, desire, beliefs, and others. In our view, current research demonstrates that chimpanzees have a basic perception–goal psychology in which they understand the goal-directed actions and perceptions, and even knowledge (in the sense of what another has seen in the immediate past), of others. At the moment there is no evidence that they understand others' false beliefs, that they have a fully representational theory of mind, but that may change if in the future researchers can devise an improved experimental methodology.

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References

- Astington, J. W. (2001). The paradox of intention: Assessing children's metarepresentational understanding. In B. F. Malle, L. J. Moses, & D. A. Baldwin (Eds.), *Intentions and intentionality: Foundations of social cognition* (pp. 85–103). Cambridge, MA, US: The MIT Press.
- Beck, S. R., Robinson, E. J., Carroll, D. J., & Apperly, I. A. (2006). Children's thinking about counterfactuals and future hypotheticals as possibilities. *Child Development, 77*(2), 413–426.
- Behne, T., Carpenter, M., Call, J., & Tomasello, M. (2005). Unwilling versus unable: Infants' understanding of intentional action. *Developmental Psychology, 41*(2), 328–337.
- Brauer, J., Call, J., & Tomasello, M. (2007). Chimpanzees really know what others can see in a competitive situation. *Animal Cognition, 10*(4), 439–448.
- Brooks, R., & Meltzoff, A. N. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Psychology, 38*(6), 958–966.
- Byrne, R. W., & Whiten, A. (1990). Tactical deception in primates: The 1990 database. *Primate Report, 27*, 1–101.
- Call, J., & Tomasello, M. (1999). A nonverbal false belief task: The performance of children and great apes. *Child Development, 70*(2), 381–395.
- Clayton, N. S., & Dickinson, A. (1998). Episodic-like memory during cache recovery by scrub jays. *Nature, 395*(6699), 272–274.
- Flombaum, J., & Santos, L. (2005). Rhesus monkeys attribute perceptions to others. *Current Biology, 15*(5), 447–452.
- Gergely, G., Bekkering, H., & Kiraly, I. (2002). Rational imitation in preverbal infants. *Nature, 415*(6873), 755.
- Gergely, G., Nadasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*(2), 165–193.
- Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. *Animal Behaviour, 59*(4), 771–785.
- Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know? *Animal Behaviour, 61*(1), 139–151. Jan 2001.
- Hare, B., Call, J., & Tomasello, M. (2006). Chimpanzees deceive a human competitor by hiding. *Cognition, 101*(3), 495–514.
- Heyes, C. M. (1998). Theory of mind in nonhuman primates. *Behavioral and Brain Sciences, 21*(1), 101–134.
- Karin-D'Arcy, M., & Povinelli, D. J. (2002). Do chimpanzees know what each other see? A closer look. *International Journal of Comparative Psychology, 15*(1), 21–54.
- Krachun, C., Carpenter, M., Call, J., & Tomasello, M. (submitted for publication). *Children Read Minds but Apes Read Reaches in a Competitive, Nonverbal False Belief Task*.
- Lohmann, H., & Tomasello, M. (2003). The role of language in the development of false belief understanding: A training study. *Child Development, 74*(4), 1130–1144.
- Melis, A., Call, J., & Tomasello, M. (2006). Chimpanzees (*Pan troglodytes*) conceal visual and auditory information from others. *Journal of Comparative Psychology, 120*(2), 154–162.
- Moll, H., & Tomasello, M. (2004). 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Science, 7*(1), F1–F9.
- Moll, H., & Tomasello, M. (2006). Level 1 perspective-taking at 24 months of age. *British Journal of Developmental Psychology, 24*(3), 603–613.
- Moll, H., & Tomasello, M. (2007). How 14- and 18-month-olds know what others have experienced. *Developmental Psychology, 43*(2), 309–317.
- Moses, L. J. (2001). Executive accounts of theory-of-mind development. *Child Development, 72*(3), 688–690.
- Mulcahy, N. J., & Call, J. (2006). Apes save tools for future use. *Science, 312*, 1038–1040.
- Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 308*, 255–258.
- Peterson, C., & Siegal, M. (2000). Insights into theory of mind from deafness and autism. *Mind and Language, 15*(1), 123–145.
- Povinelli, D. J., Rulf Alyssa, B., & Bierschwale Donna, T. (1994). Absence of knowledge attribution and self-recognition in young chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology, 108*(1), 74–80.
- Povinelli, D. J., & Eddy, T. J. (1996). What young chimpanzees know about seeing. *Monographs of the Society for Research in Child Development, 61*(3), 1–152.
- Povinelli, D. J., & Vonk, J. (2003). Chimpanzee minds: Suspiciously human? *Trends in Cognitive Sciences, 7*(4), 157–160.
- Povinelli, D. J., & Vonk, J. (2004). We don't need a microscope to explore the chimpanzee's mind. *Mind and Language, 19*(1), 1–28.
- Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences, 1*(4), 515–526.
- Roberts, W. A. (2002). Are animals stuck in time? *Psychological Bulletin, 128*(3), 473–489.
- Savage-Rumbaugh, E. S., Rumbaugh, D., & Boysen, S. (1978). Sarah's problems in comprehension. *Behavioral and Brain Sciences, 1*, 555–557.
- Schwier, C., van Maanen, C., Carpenter, M., & Tomasello, M. (2006). Rational imitation in 12-month-old infants. *Infancy, 10*(3), 303–311.
- Suddendorf, T., & Corballis, M. C. (1997). Mental time travel and the evolution of the human mind. *Genetic, Social, and General Psychology Monographs, 123*(2), 133–167.
- Tomasello, M., & Call, J. (1997). *Primate cognition*. New York, NY, USA: Oxford University Press.
- Tomasello, M., & Haberl, K. (2003). Understanding attention: 12- and 18-month-olds know what is new for other persons. *Developmental Psychology, 39*(5), 906–912.
- Tulving, E. (2005). Episodic memory and autoevidence: Uniquely human? In H. S. Terrace & J. Metcalfe (Eds.), *The missing link in cognition: Evolution of self-knowing consciousness*. New York: Oxford University Press.
- Vlamings, P., Uher, J., & Call, J. (2006). How the great apes (*Pan troglodytes*, *Pongo pygmaeus*, *Pan paniscus*, and *Gorilla gorilla*) perform on the reversed contingency task: The effects of food quantity and food visibility. *Journal of Experimental Psychology: Animal Behavior Processes, 32*(1), 60–70.
- Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development, 72*(3), 655–684.
- Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child Development, 75*(2), 523–541.
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs – Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*(1), 103–128.