Primate theory of mind

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Abstract

Primates, human and non-human alike, have large brains with large neocortices. It has been suggested that primates owe their large brains to the increased social demands of large groups. Within the last 40 years, much research has been done on the socio-cognitive abilities of primates, and since Premack & Woodruff (1978) first coined the term "theory of mind", many laboratory experiments have been conducted on human and non-human primates' ability to attribute mental states to others. In the present paper, most of these experiments with non-human primates and a representative part with human children were reviewed. Differences and similarities between human and non-human primate theory of mind were discussed within an evolutionary framework with a special emphasis on enculturation in which non-human primate individuals are hypothesized to develop more advanced socio-cognitive capacities than their conspecifics by living in intimate, extensive contact with humans from an early age. '

Target article

Jill Byrnit	Primate theory of mind: A state-of-the-art review	2
Commentaries		
James R. Anderson	Looking into primate theory of mind	22
Simon Baron-Cohen	Mindreading: evidence for both innate and acquired factors	26
Christine A. Caldwell	Competition, Cooperation and Social Cognition in Nonhuman Primates	28
Joseph Call	Can the chimpanzee mind be upgraded?	31
Niels Engelsted	Humans are apes, only they know	34
Henrik Høgh-Olesen	Gaze following and shared attention: Limitations for the story telling primate and relevant experimental conditions for its relatives	38
Peter Krøjgaard	Comparative psychology, developmental psychology, and methodology	41
Simo Køppe	Too early birth	45
Philippe Rochat	What does it mean to be human?	48
Erik Schultz	Do you mind?	52
Author's response		

Jill Byrnit

56

(NB: this download contains the target article only – please find the commentaries on the webpage)

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Primate theory of mind: A state-of-the-art review

Primates, human and non-human alike, are a brainy order of animals (Jerison, 1985). Compared to the average living mammal brain, when corrected for variations in body size, primate brains are about twice as large (Jerison, 1973, 1985), and neocortical areas constitute between 41-76 % of that size (Barton & Dunbar, 1997). While the significance of relative brain size is currently considered somewhat unclear (Barton & Dunbar, 1997), the relative neocortex size reflects the organism's information processing capacity (Dunbar, 1995; Jerison, 1973, 1985). In trying to stay clear of the rather pointless debate on whether primates are consequently more intelligent than other animals (see excellent discussions in Tomasello (with peer commentaries), 1998; Tomasello & Call, 1997), suffice to say that, given their brain morphology, we would expect to find evidence of high-level cognitive integration (Barton & Dunbar, 1997) in at least some primate species.

Field studies have long reported the existence of complex cognitive abilities in non-human primate species (e.g., Boesch & Boesch, 1990; Cheney & Seyfarth, 1980, 1982; Goodall, 1990), and for the last 40 years we have witnessed a wealth of experimental research on a wide variety of cognitive capacities in non-human primates as displayed in tool-use and tool-production, counting, object manipulation, language acquisition, mirror self-recognition, imitation, discrimination learning, etcetera (e.g., Bering, Bjorklund, & Ragan, 2000; Gallup, 1970, 1979; Matsuzawa, 1985, 1990; Parker, 1977; Rumbaugh, 1971; Savage-Rumbaugh, 1981; Savage-Rumbaugh, McDonald, Seveick, Hopkins, & Rubert, 1986; Suarez & Gallup, 1981. See Tomasello & Call, 1997, for an exhaustive review).

The purpose of the present article is to review the data on a particular area of primate social cognition that has gained much attention within the last 20 years: the individual's ability to attribute mental states, such as desires and beliefs, to herself and others, the so-called theory of mind (Premack & Woodruff, 1978). With regard to humans, strong empirical cases show that children do not display a fully developed theory of mind in which they attribute beliefs and thoughts until they are about four years old (e.g., Moses & Flavell, 1990. See Wellman, 1990, for an overview). Thus, it has often been concluded that children's theory of mind develops relatively late in ontogenesis, which has left many developmental scientists wondering why it is not present in younger children. A number of theoretical claims have been made to explain the purportedly late appearance of theory of mind (see Wellman, 1990, for an overview), ranging from a Piagetian approach, in which theory of mind develops experientially through the cognitive processes of assimilation and accommodation, to viewing theory of mind as a sociocultural convention. The latter has been construed in some societies (typically, industrialized Western ones) through linguistic discourse and is, by implication, not a universal, human-given convention, just waiting to evolve in the growing child.

However, although human children do not show fullfledged "theory of beliefs" before approximately their fourth year, quite persuasive evidence exists (Meltzoff, 1995; Tomasello & Barton, 1994) that they show an understanding of other mental states much earlier than this, such as intentions and desires. Very early on, children seem capable of understanding the actions of others within a framework involving "theories" of certain mental states, even if they do not seem capable of theory of mind as far as beliefs are concerned. Also, it appears that almost all human beings (with the notable exception of people with autism) do develop theory of mind in time despite having been reared under the influence of markedly different socio-cultural conventions, or having been diagnosed with specific language disorders or certain mental handicaps (see Baron-Cohen, 1995). This has led other researchers to theorize that humans may be innately endowed with the capacity to "mind-read"; or, in other words, theory of mind may well be a universal, human-given capacity (Baron-Cohen, 1995; Tomasello, 1999).

In the attempt to resolve the critical issue regarding the respective contributions of innate endowment and sociocultural conditions in the ontogenesis of theory of mind, it is of pivotal importance to place this area of research within an evolutionary and comparative perspective (see e.g., Tomasello, 1999; Tomasello & Call, 1997). Like all other animal behavior, human behavior is a product of evolutionary selection, and it has evolved over time. To understand theory of mind in humans more fully, we must answer the question of what would have been the evolutionary benefits for individuals displaying theory of mind. Even more basically, we first need to address the question whether theory of mind is even a uniquely human capacity or one we share with other animals. Given the fact that we humans, together with more than 180 other species, belong to the mammal order of primates and, hence, find our closest living relatives among these species, a logical place to start our search for answers would be within the cross-disciplinary field of primatology.

In the following, I will present the results of most of the experiments on non-human primates' theory of mind that have been conducted to date and a representative part of the results of the large amount of research in young human children in order to conduct a comparison and put human and non-human primate theory of mind into perspective. Special attention will be paid to so-called enculturated great apes, i.e. individuals who, for various reasons, have been raised by and lived with humans from an early age. These examples of cross-fostering provide us with a unique possibility to examine whether humans alone are biologically equipped to develop at least full-fledged theory of mind, or whether an undefined element in human life, which may also influence a young great ape individual, facilitates such development. To shed more light on this issue, I will take a brief look at the developmental trajectory of theory of mind in children. Finally, differences and similarities in human and non-human primate theory of mind will be discussed within an evolutionary framework with a special emphasis on the explanatory power of some of the most influential theories on the ontogenesis of theory of mind.

However, in order for the reader to appreciate the theory-of-mind debate, I will start by presenting the leading theories on how primates came to be the brainy order that we are.

The evolution of primate encephalization

Several theories have been put forth to explain the evolutionary origins of the large brains and cognitive capacities found in primates, including humans. Following Whiten & Byrne (1988b), these theories may be grouped together according to whether or not they propose that primates owe their advanced cognitive capacities to technical or social challenges. As their starting point technical intelligence theories have the challenges primates face in dealing with their physical or ecological surroundings. Almost all primate species live exclusively in tropical climates (Tomasello & Call, 1997), dwell in forest habitats, or savannahs, and are fully or partially dependent on plant food and fruit. In these habitats, plants and fruit are widely dispersed and show temporally complex ripening patterns. Thus, it has been suggested that a special intelligence premium has been placed on primates due to technical challenges related to foraging behavior. Milton (see 1988) proposes that especially the cognitive demands of remembering and locating ripe food patches has been the key instigator of primate brain enlargement. Parker and Gibson (Gibson, 1986; Parker & Gibson, 1977, 1979) have placed a special emphasis on the embedded nature of some highly nutritious primate food items such as nuts and insects in tree trunks, and hypothesize that the phylogenesis of higher cognitive capacities was driven by increased demands to use tools to perform extractive foraging on embedded food sources. Chevalier-Skolnikoff, Galdikas, and Skolnikoff (1982) have suggested that advanced cognitive capacities in at least the orangutan have selected for dealing with locomotion in dense forest habitats. Along the same line of argument, Povinelli and Cant (1995) have hypothesized that the capacity for self-conception evolved as a mechanism to enable large, arboreal primates to engage in flexible clambering in a habitat that is fragile and unpredictable due to these primates' heavy body weight.

Several problems present themselves with some of the above-mentioned technical intelligence theories. First, primates do not really face ecological challenges that are any more complex than many other animal taxa do (Barton & Dunbar, 1997). Birds, fish, rodents, and insects, for instance, also feed on widely dispersed food matters, and all seem to possess cognitive maps of their environment equivalent in complexity to the ones that have been postulated in primates (see references on non-primate data in Barton & Dunbar, 1997; Tomasello, 1998). Second, while tool use may be a particularly sophisticated way to extract food from hard-toprocess surfaces, very few non-human primate species (2-3!) actually employ tools in the wild: chimpanzees (Pan troglodytes. Boesch & Boesch, 1990; Lawick-Goodall, 1971), and, at least, some Sumatran orangutans (Pongo abelii. See Fox, Sitompul, & van Schaik, 1999) and capuchin monkeys (Cebus libidinosus. Fragaszy, Izar, Visalberghi, Ottoni, & de Oliveira, 2004), though more species may come to do so in captivity (see review in Tomasello & Call, 1997). It is hard to see how such limited scope may have selected wider variance in brain and neocortex size among primate species in general (Barton & Dunbar, 1997). Another kind of criticism (e.g., Marshack, 1979, and see below for social intelligence theories) has focused on the relative importance of relational in opposed to technical skills. Primate infants have long dependency periods, and many technical skills are learned from caretakers or group-members during childhood (Boesch & Boesch, 1990; Galdikas, 1995; Lawick-Goodall, 1971). Thus, in order to acquire more basic, technical survival skills, the infant must possess certain socio-cognitive capacities.

Inspired by Nicolas Humphrey (1976) and Allison Jolly (1966), among others (see Byrne & Whiten, 1988), Byrne & Whiten in 1988 forcefully suggested that anthropologists and primatologists look elsewhere for the evolutionary origins of primate intelligence. In their much cited book "Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes, and humans" (Byrne & Whiten, 1988), they argued engagingly that what has led to higher cognitive abilities in primates is not technical/physical challenges, but rather having to deal with the complexities (see below) and daily challenges of group living. As support for their argument, much observational data (e.g., Kummer, 1967; Lawick-Goodall, 1971; de Waal, 1982) and a few experiments (Cheney & Seyfarth, 1980, 1982; Dasser, 1987a, 1987b) indicate that not only do primates understand their own relationships with group-members (as do many other animals), but they also understand something about the relationships of other group-members. Thus, in an experiment done on free-ranging vervet monkeys (Cercopithecus aethiops), Cheney & Seyfarth (1980, 1982) played a recording of the scream of a juvenile to three adult females, all of whom had offspring in the group and one of whom was the mother of the juvenile. Not surprisingly, the juvenile's mother responded appropriately by looking toward or approaching the loud speaker. The other females, however, responded by looking toward the mother, often before she herself had made any movements, indicating that they realized the relationship between a particular scream, a particular juvenile, and a particular adult female. Even more impressively, primates may even understand the concept of relationships. Dasser (1987a, 1987b) presented long-tailed macaques (Macaca fascicularis) with a number of photo slides depicting familiar group-members. A few of the slides showed a mother with her offspring of any age while the majority showed other pair combinations of group-members of various social relationships and ages. Subjects were trained to respond to mother-offspring slides and subsequently were given a number of critical transfer trials in which they were presented with novel combinations of social pairs, some of these motheroffspring. Subjects differentiated almost entirely consistently between the new mother-offspring pairs and all other combinations, regardless of the age of offspring or the particular individuals involved. The same results were found when subjects were trained to respond to siblings instead of mother-offspring. When compared to the admittedly rather limited literature on other social mammals, primates appear to be unique in displaying such understanding of third-party social relationships (Tomasello, 1998; Tomasello & Call, 1997). Dasser's studies, however, have never been replicated, and were, at least up to around 1997, the only experimental studies demonstrating relational categories in the social domain of non-human primates (Tomasello & Call, 1997).

Byrne & Whiten's book has spurred on a huge amount of theoretical and experimental research both within the behavioral sciences and within fields such as neurophysiology. One big problem with social intelligence theories is that their reasoning tends to be quite circular (Gigerenzer, 1997). Proponents of the theory suggest that the complexities of primate societies have led to larger brains and hence higher cognitive capacities in primates. However, as Gigerenzer (1997) correctly points out, group living is only complex insofar as it is perceived as such by group-members, and this kind of perception certainly entails precisely the higher cognitive capacities, the development of which group complexity was supposed to explain! Gigerenzer illustrates this with the example that although termites live in huge groups and vary individually, group-members do not seem to recognize this variation, and hence are not able to exploit it in the way that primates, who perceive individual differences very well, are capable of. In order to break this kind of circularity, several theorists (Barton, 1996; Barton & Dunbar, 1997; Dunbar, 1992, 1995; Gibson, 1986) have used primate brain data to evaluate which features of lifestyle may have been responsible for primate cognitive abilities. Thus, Gibson (1986) analyzed the data of Stephan (1972) and found that large brains and neocortical sizes correlate with omnivorous extractive foraging in primates. Milton (see Milton, 1988) found support for the hypothesis that primate groups inhabiting a more complex foraging matrix (see above) show greater cerebral expansion and complexity. However, Barton & Dunbar (1997) interpreted the data and found that the correlations between brain features and ecological/technical factors often have used features of the brain, the significance of which is unclear (such as overall size). Furthermore, Dunbar (1995) found that if the species of humans and chimpanzees are excluded from Gibson's analysis, her hypothesis is no longer supported. Also, the anthropologist Thomas Wynn (1988) failed to find any connection between archaeological evidence of tool-use and -production in man and the fossil evidence of brain evolution. New analyses (Dunbar, 1992, 1995. Also, see review in Barton & Dunbar, 1997) using relative neocortex size as the dependent variable have shown that primate species with large average group sizes have larger neocortices compared to the rest of their brains than species with fewer group-members. Furthermore, this correlation is not an artifact of other ecological variables such as activity timing, home range size, or diet that may be the real correlate of neocortex size, but is a genuine correlation that appears to reflect selection on social cognition (Barton & Dunbar, 1997, p.249).

Conclusively, it is important to note that neither social nor technical intelligence explanations will per se tell the whole story of the evolution of primate cognition. In all probability, various types of selective pressures have been influential at different stages in the course of evolution (Byrne, 1997). Social intelligence theories, however, have brought new light on primates' socio-cognitive capacities. In the following, a particular aspect of these capacities, primate theory of mind, will be presented and examined within an evolutionary framework. As a crude simplifying device, experiments have been classified according to which attributional state they are set out to examine (e.g., theory of intentionality, theory of belief), though in reality, particular mental states seldom exist independently of or isolated from other mental states.

This paper is not intended to compare primarily great ape theory of mind to that of humans, but due to the much higher frequency of laboratory experiments on great ape subjects than on other non-human primates, much more data are available on their cognitive capacities than on that of other primate species'.

Finally, Call & Tomasello (1996) have cautioned that the rearing experiences of non-human primate subjects may be paramount to the development of their socio-cognitive capacities. Subjects in laboratory experiments differ widely in this respect and may belong to one or several of the categories of wild, laboratory-trained, or human-raised individuals. I will return to the issue of primate enculturation later.

The reader to whom primatology is a new field is referred to Appendix 1 on basic primate taxonomy.

Theory of mind

Premack and Woodruff first coined the phrase "theory of mind" in their now classic paper from 1978, "Does the chimpanzee have a theory of mind?" (Premack & Woodruff, 1978). The authors defined theory of mind as being present when an individual imputes mental states to himself and others (p.515). Human developmental psychology enthusiastically embraced the term, and theory of mind has become an essential topic in psychological textbooks. Also, a very large number of experiments on theory of mind have been conducted with human children and some on non-human primates. Premack & Woodruff (1978) used theory of mind to indicate what an individual may impute about any "mental

state" in himself or others, i.e. belief, desire, expectation, intention, and so forth. Leaving aside the rather complicated issue of whether the child's understanding of the mind really qualifies as a "theory" in a scientific sense of the word (Hobson, 1991. See Wellman, 1990, for a comprehensive discussion), in human developmental psychology, theory of mind is often treated synonymously with an individual's knowledge of not just any mental state, but others' or one's own belief state. Such "theory of beliefs" has been tested in children with the use of several false belief paradigms, notably the seminal Maxi study by Wimmer & Perner (1983) in which a child witnesses the movement of an object and is requested to judge whether a doll who has not witnessed this event will know that the object has been moved. In order to pass this test, the child needs to understand the relation between perception and beliefs. Repeatedly, it has been found that children do not pass the false belief test until they are about 4 years old, even when the task is made easier by stronger belief clues (e.g., Moses & Flavell, 1990). Children's theory of beliefs, thus, develops relatively late in ontogenesis, and much later than for instance their theory of desires and intentions (e.g., Meltzoff, 1995; Tomasello & Barton, 1994). Wellman (1990) suggests that children's dawning understanding of belief actually may build on an earlier understanding of desires. As such, children, and non-human primates as we will see below, may be quite capable of understanding the actions of others within a framework involving "theory" of certain mental states without them necessarily displaying a full-fledged theory of mind encompassing the whole range of mental states.

The premium that is placed on the command of language in these tasks put another limitation of focusing more or less exclusively on paradigms such as the (false) belief task (Lewis & Osborne, 1990; Meltzoff, 1995). Apart from the fact that this may confuse limitations in children's theory of beliefs with limitations in their language acquisition (see e.g., Pratt & Bryant, 1990), and consequently underestimate the age at which children acquire a full-blown theory of mind, it also makes it rather difficult to assess theory of mind in all other primate species than humans. For reasons like the abovementioned ones, research on theory of mind in non-human primates has had a much broader scope than research on children, and has focused on a variety of mind states (see below).

Theory of intentions and desires

Human children display evidence early on that they understand human acts in terms of underlying goals and intentions. Meltzoff (1995) eloquently demonstrated that children as young as 18 months old, at least in some situations, see beneath the "surface" behavior of others to the intentions underneath. Meltzoff had toddlers witness one of two experimental procedures. In the control condition, an adult performed a series of object-related acts such as pulling apart a dumbbell toy, or lowering beads over a cylinder. Immediately following target-demonstrations, the children were given a chance to handle the same objects as the adult had used, and rates of imitation of the target-acts were scored. In the experimental condition, children also witnessed an adult performing acts with the objects. This adult, however, never succeeded in performing the target-acts, but pretended to fail to do it exactly right by for instance placing beads in such a way as to having them slip to the side instead of on top of the cylinder, or not succeeding in pulling the dumbbell apart though doing the right pulling movements. The results were clear: infants were as likely to perform the correct target-act after seeing an adult demonstrating the intended objectbehavior as they were after seeing an adult intending to, but not succeeding. Meltzoff concludes that it was as if these infants had already adopted one fundamental aspect of theory of mind and understood others in terms not of physical, overt behavior, but in terms of a framework involving goals and intentions. Interestingly, when Meltzoff had a mechanical device mimic the exact movements of the adult who intended to, but did not succeed, in pulling the dumbbell apart, very few infants performed the correct target-acts. It seems as if even these very young children clearly differentiated between the acts of inanimate objects that were understood in the terms of overt physical movements and people who were treated as beings whose actions were caused by intentions and goals.

Meltzoff's results have been corroborated from an interesting angle in a series of lexical acquisition experiments. Tomasello & Barton (1994) examined how young children acquire new words in so-called nonostensive contexts, i.e. settings in which the referent of the word is not clearly pointed out and named to the child, but rather occurs naturally in the course of events. The authors sought to determine how children make the connection between new words and their referents and tested the possibility that children simply keep new words in mind until the next action is performed by the speaker (in the case of verb learning) or the next object is displayed (in noun learning). The first actions or objects to succeed the introduction of the new word would then be labeled as such. In a series of experiments, 2-year-olds were introduced to verbs or nouns they did not know beforehand such as "to plunk" or "a toma" (a specially designed noun which referred to a randomly chosen toy) in a paradigm in which the new word was either immediately followed by the correct referent or by various interfering actions or objects. An experimenter, for instance, told the child that they were going to look for "the toma" whereupon she looked under several buckets to find it. In one condition, the toma was the first object to be found in which case the experimenter picked up the object with an excited "ah!". In the other condition, the experimenter found and held up several non-target objects, which she looked at disapprovingly with a frown, before finally "finding" the correct one that she encountered with the gleeful behavior described above. An analogue experiment was conducted with the verb mentioned above. The results clearly indicated that children did not simply connect the new words with the first encountered object or action, but instead held the words in mind until the experimenter's behavior indicated that she had found the intended object or fulfilled her intended action.

On the basis of results as the ones above, it would be safe to say that even very young human children clearly seem to possess some kind of theory of others' intention and goals. A handful of primatologists have examined whether also nonhuman primates may understand others within an intentional framework. Povinelli, Perilloux, Reaux, and Bierschwale (1998) experimentally examined whether chimpanzees would be able to discriminate between intentional and accidental actions. A number of juvenile chimpanzees were trained to point toward human actors in order to receive food treats from the one they pointed to. During testing, subjects were presented with different actors who were going to serve juice in a cup to the chimpanzees. Instead of giving juice to the chimpanzees, one actor intentionally poured it on the floor whereas another actor pretended to "accidentally" spill the juice on the floor. Yet another actor aggressively threw juice and cup to the floor. Thus, the chimpanzees did not receive juice from any of the actors, but differences existed between the actors as to their intention behind not serving the juice. As for two of the actors, their bad intent caused the chimpanzees to receive no juice whereas the intentions of the last actor were benevolent though his actions were clumsy. Thus, the chimpanzees could quite possibly have come to prefer the accidental to the intentional or aggressive actors, were they interpreting the actors' actions in terms of intentions. This, however, did not happen. When the chimpanzees had the possibility to decide between actors who were going to bring them juice at the end of each experiment after having experienced the actions of all three actors, the subjects did not show any preference and were equally likely to choose the actors with bad intentions as the one who did not willingly spill the juice. Hence, the chimpanzees did not seem to take into account the difference between intentional and accidental actions.

Call and Tomasello (1998) suggest that Povinelli and colleagues' chimpanzee subjects did not show any preference between actors as they did not receive juice from either one of them, and therefore may have assumed that they would not get any juice later either no matter who they chose. Call and Tomasello therefore tested chimpanzees', orangutans', and 2and 3-year-old human children's ability to distinguish intentional from accidental actions in an object-choice set-up that would not inevitably lead to their misfortune. An experimenter placed an attractive piece of bait (food for ape subjects, toy stickers for human subjects) under one of three opaque boxes. Subjects could see that a hiding took place, but could not see which container was being baited. During a training phase, subjects learned that the bait was always hidden under the box that had been marked by the experimenter with a yellow wooden block and that by choosing the marked box they would receive the bait underneath. During testing, the experimenter hid the bait as usual under one of the boxes, and then in full view of the subjects, placed the marker on top of the baited box. Before the subjects had had the chance to choose a box, the experimenter, however, "accidentally" dropped another, similar marker on top of one of the other boxes. Subjects, thus, were faced with the decision to choose between two marked boxes, one marked intentionally and one marked by accident.

Call and Tomasello found that subjects of all three species preferentially selected the box that had been marked intentionally. However, 3-year old children clearly outperformed both younger children and apes.

In their own much-cited example, Premack & Woodruff (1978) gave the language-trained female chimpanzee, Sarah, a number of videotaped sequences depicting a human actor in a cage struggling to obtain bananas that were inaccessible in a variety of ways such as being attached to the ceiling and thus out of reach overhead, being placed outside the cage wall and thus horizontally out of reach, or being outside the cage, but with the extra difficulty that a box inside the cage was between the actor and the bananas outside, further impeding the actor's reach. In addition to the videotapes, the authors had photographs taken of the actor engaging in the behavior that solved his problems with obtaining the bananas. In one photo, for instance, he was shown stepping onto a box (to obtain the bananas from the ceiling). In another, he was lying on his side, reaching out of the cage with a stick (to obtain the bananas outside the cage) and so forth. During testing, Sarah was shown each of the videotapes in turn. The last few seconds of the respective videotapes were put on hold while Sarah was offered a choice between two of the photographs, one depicting the solution to the actor's problem, the other not. From the beginning, Sarah made very few errors in pairing the problems with the right alternatives, suggesting that she understood what constituted the actor's problem and how to solve it. Premack & Woodruff wanted to further strengthen this interpretation and tested Sarah on a more complicated variant of the previous experiment. This time, Sarah was watching videotapes of an actor troubled by very different kinds of problems such as trying to escape from a locked cage, shivering from the cold while looking wryly at and kicking a malfunctioning heater, or being unable to wash down a dirty floor because the hose he held was not attached to the faucet. As previously mentioned, the last seconds of the respective videotapes were put on hold, and Sarah was given a choice of photographs, one showing the solution, one not. Photographed solutions to the problems depicted a key, a lit cone of paper (of a kind normally used to light the heater), an attached hose, and so forth. In this experiment, Sarah made no errors whatsoever. Finally, the authors gave Sarah a greatly refined variant of the latter experiment. The actor's problems were the same, but Sarah was no longer required to choose among grossly different alternatives such as a hose and a lit cone of paper, but instead was presented with three versions of the respective object involved in the solution. For instance, a hose attached, unattached, or attached but cut, and a roll of paper unlit, lit, or burnt out. In this experiment, Sarah made only one error out of 12 choices. According to the authors, Sarah's one error was even attributable to the quality of this particular photo.

Theory of knowledge/belief

As described above, an extensive amount of research has been conducted with human children in order to assess their understanding of their own and other individuals' beliefs. We saw that children under the age of four years in the Maxi-test have great difficulty in disregarding their own state of knowledge upon witnessing an event when assessing the state of knowledge of someone who did not witness the same event (e.g., Wimmer & Perner, 1983). The same kind of difficulties is displayed by 4-year-olds in other false belief tasks. Thus, Perner, Leekam, and Wimmer (1987) showed 3-year-olds a tube of Smarties (well-known candy resembling M&M's) and asked them to state what they thought were inside the tube. The childrenmostly believed, of course, that Smarties would be inside, but the experimenter opened the tube and showed them that this tube actually contained pencils. After seeing the real content of the tube, children were again asked what they had thought was inside the tube before they had seen the content. A substantial majority of the children reported that they had all along been of the belief that the tube contained pencils, suggesting that they were unable to distinguish a previous false belief from what they now knew to be untrue. Even after the age of four, children may experience difficulties in understanding the intimate connection between perception and knowledge. Taylor (1988) had children between the ages of three to eight looking at pictures of, for instance, a giraffe or a rooster. During testing, the experimenter covered different parts of the pictures so that only small bits of the pictures were visually accessible, and asked the children to predict whether somebody else, who had not seen the whole picture would know what object was in the picture. On some trials, the displayed picture bits depicted parts necessary for identification of the picture object (such as the head of the giraffe), on others, only non-descriptive parts were shown. Children from about 4-6 years of age tended to believe that seeing a part of a picture, even a non-descriptive one, would be sufficient for someone to share the children's knowledge of the object's identity, whereas children older than six years understood that this was not the case.

All in all, it seems that children under the age of 4 do not understand the mind as a representational medium that reflects what it has been exposed to, rather than what may be the actual fact. Furthermore, they may continue to experience some such difficulty up until the age of 6, after which they, by and large, seem to have acquired a full-blown theory of knowledge. How about non-human primates? What kind of understanding of knowledge states do they display?

Following the suggestions in the discussion of Premack and Woodruff (1978), Povinelli and colleagues (Povinelli, Nelson, & Boysen, 1990) set out to investigate whether chimpanzees understand the difference in knowledge states between somebody who witnesses an event and somebody who is merely guessing. In an ingenious experiment, two experimenters randomly alternated between two roles, the guesser and the knower. The knower baited one of several containers with a food reward while the guesser waited outside the room. The chimpanzee subject could watch the baiting process, but could not see which of the containers hid the reward. The knower then pointed to the correct container while the guesser, simultaneously, pointed to an incorrect one, and the chimpanzee had to choose between the alternatives. All four chimpanzees quickly learned to respond to the information provided by the knower and disregard the information given by the guesser and showed immediate transfer in another more subtle variation of the experiment in which both the guesser and the knower stayed in the room during baiting; the guesser, however, with his head covered by a paper bag during the baiting procedure. Later Povinelli, Parks, & Novak (1991) conducted the same kind of experiment with rhesus macaques (Macaca mulatta). Contrary to the results with chimpanzees, even after several hundred trials the macaques did not reliably choose the informed experimenter over the ignorant one. These results suggest that chimpanzees, but not rhesus macaques, have an understanding that someone who has seen an event occur has a different state of knowledge about that event than someone who has not (Povinelli et al., 1990). It has been much debated (e.g., Heyes, 1993; 1998; Povinelli, 1994), however, whether the chimpanzees' performance really is indicative of mental state attribution, or whether they have simply learned to discriminate between conditions behavioristically. This will be discussed in more details below.

Wimmer, Hogrefe, and Perner (1988) examined 3- to 5-year-old children's understanding of the role of perception in knowledge formation. Children were paired in groups of two and placed on opposite sides of a table with an experimenter present. On the table between them was situated a box with small doors on either side that could be opened by the children or the experimenter. In the test situation, the experimenter placed an object inside the box and either let both children open their box doors and have a look, or only one of the children. This means that in some trials both children saw the object hidden inside the box, and in others, one child saw the object while the other child was ignorant as to the content of the box. Afterwards, the experimenter asked one of the children if the other child knew what was inside the box or not. Wimmer and colleagues found that most 3- and 4year-old subjects did not seem to understand at all the causal connection between having looked inside the box and knowing what was in there. Five-year-olds, on the other hand, showed no difficulties in understanding the connection.

However, on a later experiment, Pratt & Bryant (1990) found that even 3 to 4-year-olds understand that looking leads to knowing. In their study, the child subject was seated together with an experimenter and two assistants. The child was shown a box and told that the experimenter had hidden an object inside. The box was then handed over to one of the assistants who would look inside the box and to the other who would lift it up without looking inside it. Afterward, the child was asked which one of the assistants knew what was in the box. Twenty-nine of thirty-two children answered correctly in four out of five trials, and twenty of them were correct on all trials, proving that they understood quite well that looking at something produces information about it. To reconcile the discrepancy between their results and Wimmer et al.'s (1988), Pratt & Bryant hypothesized that the children in the Wimmer et al. study were confused by the double-barreled nature of the question presented to them: "Does (name of other child) know what is in the box or does she/he not know that?" In order to test this, Pratt & Bryant replicated Wimmer and colleagues' study with the one critical difference of simplification: "Does

(name of the other child) know what is in the box?" Given this version of the task, eleven 3-year-olds and fifteen 4-year-olds out of groups of sixteen each correctly inferred knowledge states from information about visual access. In a final experiment, Pratt & Bryant directly tested the hypothesis about question complexity by having 3- and 4-year-old children participate in two different sessions, one in which they were asked a single-barreled question and the other in which they were asked a double-barreled question. The analysis confirmed that significantly more single-barreled questions were answered correctly than double-barreled ones, leaving the authors to conclude that 3- and 4-year-olds do understand that looking leads to knowing, and that their difficulties in the Wimmer et al. study was due to the form of the question they were asked.

Povinelli and Eddy (1996) examined what young chimpanzees know about the connection between visual perception and knowledge. In an exhaustive series of experiments, the authors extended Povinelli et al.'s (1990) guesser/knower paradigm. Young chimpanzee subjects learned to gesture toward a human trainer in order to receive a food treat. In experimental trials, subjects were introduced to two trainers, one of whom had a clear, undisturbed view of the chimpanzee subject, the other having his/her vision occluded in one of several ways. For instance, in one experiment, the "seeing" trainer had as usual his/her front toward the subject, while the "occluded" trainer had his/her back turned toward it. In other experiments, visual occlusion was instantiated by the trainer being blindfolded, wearing a bucket over his/her head, having a screen covering his/her eyes, and so forth. The occlusion, no matter by what means, served to signify that this trainer would not be able to see the chimpanzees' gestures, and hence it would be much better to gesture toward the trainer whose vision was undisturbed. The chimpanzees, however, did not seem to take this visual obstruction much into account. They were just as likely to request food from an experimenter who had his/her vision obstructed to blind him/her from seeing the begging gesture than from one who could see the chimpanzees' gestures. In other conditions, they selected preferentially the seeing trainer only after several trials, leading Povinelli and Eddy to conclude that subjects had learned whom to choose. Only in one condition, back-versusfront, did the chimpanzees selectively gesture to the trainer with his/her front toward them from the beginning. The authors, however, suggest that the latter finding may have been due to the familiarity of frontal stimulus more than to the eve contact per se.

Povinelli and Eddy's experimental results seem to indicate forcefully that young chimpanzees do not really understand that seeing leads to knowing. As will be presented below, these findings seem contradictory to a number of field observations on deception, and also to other recent experiments by Hare et al. (Hare, Call, Agnetta, & Tomasello, 2000; Hare, Call, & Tomasello, 2001). Hare and colleagues reasoned that many experimental paradigms might not tap into the higher socio-cognitive capabilities of non-human primates due to the fact that they expose their subjects to situations that are unnatural for their species. Thus, the experiments of Povinelli and Eddy (1996) reported above all require that chimpanzees beg from a human experimenter who, then, in response to this hands over an attractive, monopolizable food item, and in the guesser/knower study of Povinelli et al. (1990) chimpanzees are even more explicitly being helped toward obtaining a food item by means of an experimentergiven pointing cue. Following Hare and colleagues, to the chimpanzee subjects in these and other studies it may seem highly peculiar that other individuals would deliberately give away attractive, undividable food instead of eating it themselves, given that chimpanzees compete almost exclusively with group mates for monopolizable food items. Hence, Hare et al. (2000, Experiment 3) introduced chimpanzees to a food competition paradigm to examine if they may know what conspecifics do and do not see. A subdominant and a dominant chimpanzee were placed on opposite sides of a middle room with their doors closed while an experimenter placed two pieces of food inside the middle cage. Both food items were placed within a constant visible range to the subdominant subject, but in some conditions, one or both of the food pieces were hidden behind opaque barriers on the subdominant's side, making them not visible to the dominant subject. Thus, in all conditions, subdominant subjects could see both food pieces, whereas dominant ones could see only some food pieces in some conditions. After baiting the middle room, the experimenter left the room and both subjects' doors were raised just enough for them to get a look of the food, the barriers and of the other participant looking through his or her door. The doors were closed again, and the subdominant subject was given a head start until he or she began to approach one of the food locations, at which point the dominant subject was also released. The subdominant's head start was introduced in order to prevent him or her from monitoring the behavior of the dominant subject and adjust his/her own behavior accordingly instead of displaying knowledge of what the dominant subject could or could not see. The results, unambiguously, showed that subdominant subjects obtained more food pieces that were hidden from the dominants' view than the ones that were out in the open for both of them to see. It was a distinct possibility that subdominants would approach one piece of food with their head start and then be frightened away when the dominant subject was released and, thereby, choose the food that was not visible to the dominant subject, simply because he or she would take the visible piece. In order to avoid this, data were also collected on the food pieces that the subdominant started out for (i.e. reach or walk half-way toward), regardless of whether he or she obtained it or not. Results revealed that subdominants not only obtained, but also started out for the hidden food. Furthermore, a control experiment (Experiment 5) revealed that subdominants did not choose the occluded food pieces due to a general preference for going to the location with a barrier. When encountering food pieces hidden behind transparent barriers, i.e. not occluded from the dominants' view, the subdominants did not preferentially choose "hidden" food instead of visible food, leaving the authors to conclude that chimpanzees take into account what conspecifics can and cannot see and use this knowledge in naturally occurring food competition contexts.

Another interpretation of these results has been made by Karin-D'Arcy and Povinelli (2002) who attempted to replicate the results of Hare et al. (2000). The authors, like Hare and colleagues, reasoned that subdominants might simply end up obtaining the food pieces that dominant subjects do not take and, hence, not show true appreciation of the knowledge state of the dominant subjects, but discounted Hare et al.'s start-out-measure as being too ambiguous. Thus following almost the exact methodology of Hare and colleagues, Karin-D'Arcy and Povinelli both collected data on which food pieces the subdominants obtained, but, as a different kind of start-out-measure, also the food pieces that the subdominants first reached for and the ones they first touched. Applying these criteria, the authors failed to replicate the study by Hare et al. They found that, although their subdominants, like Hare and colleagues', obtained more hidden than visible food pieces, they did not show an initial preference for the hidden food as measured by first reach and first touch. Rather, subdominants' food choices reflected that their rivals would typically take the food pieces in the open first, leaving only the hidden ones behind for them to obtain. Furthermore, in a variation of Hare et al.'s transparent-barrier experiment, subdominants did not differentiate between barriers that did or did not occlude dominants' view. Karin-D'Arcy and Povinelli concluded that, although chimpanzees might use many different strategies to outsmart their rivals on this task, they did not seem to reason about what their opponent to or did not see.

Hare, Call and Tomasello (2001) did a follow-up on the Hare et al. (2000) study, employing the same kind of competitive paradigm. The subjects were placed on opposite sides of a middle room and kept out of this room by partition doors that were opened or closed depending on the condition. During the experiments, the subdominant subject witnessed a human that placed pieces of food in various locations in the middle room. In some trials, the partition door to the dominant subject was open so that he or she could see the placing of food as well. In others it was closed, leaving only the subdominant subject with information about the food location. In addition, the subdominant subject always had visual access to whether the dominant's door was open or closed, and thus whether he or she had witnessed the placing of food. After the food had been placed, the partition doors were opened to allow subjects to enter the middle room. The question was whether the subdominant subject behaved differently in accordance with what the dominant subject had or had not seen. Also in this study, the subdominants were given a head start to monopolize as many food pieces as possible. Hare and colleagues found that subdominants retrieved significantly more food pieces when dominants did not have visual access to the baiting. The reason seemed to be the following: Though given the head start of 30seconds, subdominants would stay in their cages or not approach the pieces of food fully when they had seen dominants witness the baiting. These findings clearly suggest that subdominants took into account what more dominant animals had seen, and hence knew about the location of food and acted submissively or frisky accordingly. These results were corroborated and extended in another experimental condition in which the dominant subject, after witnessing the placing of food, was replaced by another naïve dominant subject. After the replacement, the partition door was partly opened allowing the subdominant subject to see that the identity of its competitor was no longer the dominant who had seen the baiting, but a dominant who had not. Analogue with the previous results, subdominants retrieved more food pieces after the replacement than when its competitor remained the same, indicating that they discriminated between dominants who had seen the baiting, and thus had knowledge about food location, and those who had not (but see Karin-D'Arcy & Povinelli, 2002, for another interpretation).

Deception

One type of behavior that has received a large amount of interest in the primatological research community as well as from within developmental psychology is deception. Deception is a widespread phenomenon among animals, where, for instance, it may take the form of a bird feigning an injury to keep a predator away from its nest. Deceptive behavior occurring between different species, however, is generally considered to be hard-wired responses that do not show much, if any, flexibility in performance nor involve much cognitive processing (Dawkins & Krebs, 1978; Mitchell & Thompson, 1986). In contrast, intraspecific deception between members of the same social group has been reported in non-human primates, both from the field (see numerous examples in Whiten & Byrne, 1988a), and involving individuals who have been raised by and lived in intimate, extensive contact with humans. Thus, Lawick-Goodall (see Whiten, 1997) reported from her field studies on wild chimpanzees how one chimpanzee who had learned how to open a box containing food outwitted more dominant groupmembers. He would place himself silently next to the box and unscrew the lock with one hand while he looked anywhere but at the operation. When the lock was unscrewed, he placed a hand or a foot on the handle to keep the lid from opening, and waited until everybody else had left, upon which he silently retrieved his food prize. Sue Savage-Rumbaugh (Savage-Rumbaugh & McDonald, 1988) repeatedly observed a humanreared chimpanzee, Austin, make use of the fact that his more dominant and somewhat bullying playmate, Sherman, was afraid of the dark and hesitant to go outside at night. When darkness fell, Austin would sometimes leave the room and make strange sounds outside, upon which he would rush inside and look out the door as if Evil incarnate was lurking outside. Trembling with fear, Sherman would immediately stop his bullying and run over and hug Austin, completely reversing their dominance order. Likewise, several instances of deception have been reported in other enculturated apes (the gorilla (Gorilla gorilla), Koko: Patterson & Linden, 1981; the orangutan, Chantek: Miles, 1990; Miles, Mitchell, & Harper, 1996). The developmental psychologists Chandler, Fritz, and Hala (1989) state that to deceive another individual intentionally, you necessarily must understand something about his beliefs to be able to manipulate with these to your

own advantage (Chandler, Fritz, and Hala, 1989). It seems that non-human primates are rather good at this. In 1986, Whiten and Byrne distributed a questionnaire on non-human primate deception to a large number of experienced primatologists and cataloged the answers (see Whiten & Byrne, 1988a, 1988c). An impressive amount of deceptive behavior serving a variety of functions was reported. When analyzing the data, Whiten and Byrne (1988b, p.212) found that much of the tactical deception in primates, in accordance with what would be expected from individuals possessing some kind of theory of beliefs, is concerned with the manipulation of the attention of other individuals, such as concealing something from another's view, or distracting their attention by for instance looking away.

Non-human primate deception, regrettably, has seldom been studied experimentally. However, the few experiments that have been conducted have yielded interesting results. Woodruff and Premack (1979) ingeniously designed a study in which four chimpanzee subjects were to co-operate with human trainers on an object-choice task in order to obtain food treats. A passive aide baited one of two opaque cups in full view of the chimpanzee subject, but out of sight of the trainers. Afterwards, the subject was to indicate to the trainers which cup had been baited and receive the food treat underneath. However, trainers were assigned one of two roles. The "cooperative" trainer was clad in the usual green laboratory scrub suit, behaved friendly toward the chimpanzees and gave the food to the subject when the latter chose the baited cup. The "competitive" trainer was clad as a bandit in a white coat and hat, dark sunglasses and a cloth over his mouth. Furthermore, he behaved in a hostile manner toward the chimpanzees and consistently kept for himself whatever food the subjects helped him achieve by indicating the baited cup. Results showed no initial differences in the subjects' behavior toward the cooperative or competitive trainers. They transmitted information equally effectively no matter if it served their own purpose (with the co-operative trainer) or thwarted it (with the competitive trainer). However, over the course of the experiment, and reaching significance from around trials 48 to 96 after pre-testing trials, the chimpanzees gradually changed their behavior patterns to signal "honestly" to the cooperative trainer and withhold information from the competitive trainer. Furthermore, two subjects systematically started to signal the wrong location to the competitive trainer, i.e. showed active deception, from around trials 72 to 96.

Recently, Anderson and colleagues (Anderson, Kuroshima, Kuwahata, Fujita, & Vick, 2001. See also Mitchell & Anderson, 1997) tested a monkey species on a variant of the task by Woodruff and Premack (1979). Three squirrel monkeys (*Saimiri sciureus*) were trained to reach reliably toward a baited container in the presence of a co-operative trainer upon which, following almost identical procedures to Woodruff and Premack, the authors introduced the monkeys to a competitive trainer and tested whether they would signal honestly vs. deceptively to the co-operative and competitive trainers, respectively. Results showed that even after 300 trials, only one subject systematically started to mislead the competitive trainer by showing him or her to the

unbaited container. The introduction of the competitive trainer, furthermore, resulted in a marked deterioration in the monkeys' response to signal toward the baited container to the co-operative trainer. In order to facilitate discrimination between the two types of trainers, different adjustments to the task were made. When color cues were added to the containers, the squirrel monkeys learned reliably to signal differentially according to whether they encountered the cooperative or the competitive trainer, and, although this discriminatory performance was noticeably diminished when the color cues were removed, performance remained significant. As a final test of whether the monkeys actually took into account the knowledge state of the competitive trainer when misleading him, subjects were presented with a new type of competitive trainer who would look underneath both of the containers conspicuously before awaiting the subject's response, i.e. displayed that he or she already knew where to find the bait, making it meaningless to mislead him/her. The authors found that the squirrel monkeys would still reach out deceptively when faced with this knowledgeable trainer, seemingly not taking into account his or her state of knowledge.

Conclusively, over the course of several hundred trials, squirrel monkeys were able to learn how to respond deceptively toward a competitive trainer, but seemingly were conditioned in a behavioristic way rather than showing a true appreciation of other individuals' mental states. The chimpanzees in Woodruff and Premack's (1979) study were not given a test in which to distinguish between knowledgeable and ignorant competitive trainers like the squirrel monkeys' test (Anderson et al., 2001). On a later experiment (Povinelli et al., 1990) as presented earlier, chimpanzees have been found to be able to distinguish between knowledgeable and ignorant individuals, although the conclusions have been much debated (e.g., Heyes, 1993; Povinelli, 1994; see also discussion about primate learning below).

In human children, results have been conflicting between different experiments. In an intriguing hide-and-seek task, Chandler et al. (1989) tested young children's ability to manipulate telltale signs and deceive an experimenter. Subjects between the ages of two and four were introduced to a board game on which were placed five plastic containers with lids. Materials also consisted of a puppet mounted on a movable wheel studded with feet that left clear sets of inky footprints as they turned. In a warm-up trial, children participated in a hide-and-seek game in which they left the room with an experimenter, while another experimenter moved the puppet across the board to bait one of the containers with a "treasure", clearly leaving foot-prints in its wake to facilitate the children's detection of the right container. Upon return, the children were strongly encouraged to look for clues at the board before they chose a container. In the experimental trial, roles were reversed making it the child's turn (with the help of another experimenter) to help the puppet hide the treasure by moving it across the board while one of the experimenters was outside the room. The children were told that they were to hide the treasure in such a way that the experimenter would not be able to locate it, and then were encouraged to think of something to do to make disclosure even more difficult. The experimenter returned from outside and visibly searched for the treasure by following whatever footprints had been left on the board. Afterward, the children were asked to explain why their strategy had/had not worked with questions such as: "Why was it a good idea to wipe up the puppet's track?" Chandler and colleagues found that children in all age groups were quite able to employ a variety of deceptive strategies to mislead the experimenter. The children would wipe out the puppet's tracks to the baited container as well as provide false tracks to another one, and the use of these strategies did not differ across ages. What did differ, however, was the children's ability to verbalize the deceptive strategies employed. Older children were significantly better to justify their deceptive acts. The authors later replicated their results (Hala, Chandler, and Fritz, 1991) with the additional finding that even 3-year-olds were able to make use of their strategic actions flexibly with the footprints, according to whether they were to deceive or aid an experimenter. The authors conclude that, contrary to the recurrent findings on standard false-belief tasks, even before the age of three, children make use of at least a rudimentary sense of theory of mind and are capable of understanding that other people have beliefs that may or may not be in tune with reality. Sodian, Taylor, Harris, and Perner (1991), however, found that 3-year-olds produced deceptive and informative ploys indiscriminately, whether they were to inform a collaborator or mislead a competitor. Also, children younger than four years of age required much prompting to display deceptive ploys and rarely anticipated their impact on the victim's beliefs.

Criticism of theory-of-mind experiments

As seen in the above, a relatively large amount of experiments have been conducted on both human and non-human primate theory of mind, especially great apes'. Regarding the latter, it is still a matter of much debate whether these employ theory of mind. Forceful arguments have been made by a large number of experienced theorists and researchers (e.g., Heyes, 1993; 1998; Povinelli, 1996; Tomasello & Call, 1997) that results be interpreted with caution. some of these researchers are the very same that previously claimed to have found evidence of theory of mind in non-human primates (e.g., Premack, 1988; Povinelli, 1994; 1996). Criticism has been directed both toward experiments yielding data support for the thesis of non-human primate theory of mind and toward experiments that do not. As to the former, it is often the case that discriminative learning may well explain good performance on experimental tasks that were supposed to uncover theory of mind. As for the latter, some primatologists (e.g., Itakura, Agnetta, Hare, & Tomasello, 1999; Neiworth, Burman, Basile, & Lickteig, 2002) have protested that many laboratory experiments are inherently unfair to non-human primates. Why, do these primatologists ask, should nonhuman primates be *motivated* to succeed on tasks requesting them to interact with *another species* in an *unnatural context*? Below I will examine these claims in turn. Afterward, I will present a point which recently has become the focus of much attention and may be crucial to the conclusions that theory-ofmind experiments allow us to make: the issue of primate enculturation.

Primate learning

Theory-of-mind experiments in non-human primates employ for obvious reasons non-verbal paradigms in which mental state attribution necessarily must be inferred from the subjects' behavior. In this regard, such experiments face some of the same interpretive difficulties as theory-of-mind research on pre-verbal children. The very real problem is first and foremost that discrimination paradigms, which are almost entirely the ones being used in theory-of-mind research with non-human primates (e.g., in the above: Povinelli et al., 1990; Woodruff & Premack, 1979; Call & Tomasello, 1998), cannot rule out the possibility that subjects are reacting to observable cues rather than to mental states (Heyes, 1993, p.179. See also Povinelli, 1996). Thus, it is entirely possible that subjects in, for instance, Povinelli et al.'s (1990) guesser-knower paradigm did not truly appreciate the differences in mental states between an experimenter who witnessed an event and one who did not, but instead, over time, simply learned to choose the one who stayed in the room/did not have a bag over his head, etc. In effect, an interpretation such as this would make more sense with respect to the puzzling results of Povinelli & Eddy (1996) that chimpanzees do not appreciate the role of perception in attaining knowledge. Likewise, only after 24 trials did Woodruff & Premack's (1979) chimpanzee subjects begin to misdirect the competitive trainer, suggesting that they learned to respond differently toward the two types of trainers on the basis of behavioral cues, not on differences in their intentions. The same results have been found with some monkey species, with the exception that they needed many more trials to succeed in the task. Incidentally, it is interesting how researchers tend to reason that if great apes as opposed to monkeys or prosimians succeed in a theory-ofmind task, results may truly indicate evidence of mental state attribution due to the close phylogenetic relationship between great apes and humans. However, it is entirely plausible that a great ape/monkey-prosimian divide has less to do with mental state attribution than with the fact that great apes are faster learners than monkeys (Rumbaugh & Gill, 1973).

A few comments may be made here about the role of learning in non-human primate experiments. First, though learning may not be ruled out as an explanation for the results of one isolated experiment, various alternative hypotheses may be outlined up front and evaluated on the basis of the results from various experiments (Povinelli, 1996). Povinelli & Eddy (1996) have exemplarily shown the way with their multiple-experimental design on seeing and knowing. Second, critiques may be just a little too rash to counter mental-state type explanations with learning explanations. In their

examination of anecdotal deception evidence, Byrne & Whiten (1991) quite correctly point out that sometimes the supposedly more parsimonous learning accounts take the form of rather implausible histories of conditioning that would have to be so laborious as to involve much more mental capacity than mental state attributions would. Besides, even if learning does take place, the discriminative behavior may take much longer to acquire than usually suggested. Povinelli et al. (1998. See also Call & Tomasello, 1998) report that their subjects averaged 452 trials with a range of up to 750 (!) to reliably learn to gesture with their hands through a hole to an experimenter. It is my experience as well (orangutans: Byrnit, 2004a, chimpanzees and gorillas: Byrnit, unpublished data) that not even great apes will always swiftly and effortlessly learn how to respond discriminatively. Third, in some experiments (e.g., Call & Tomasello, 1998), subjects were doing well from the very beginning of the experiment, deeming it rather unlikely that discriminative learning was behind their performance.

Primate motivation

It is an absolutely necessary requirement in cognitive experiments that subjects are motivated to participate in the task at hand. We may ask why non-human primates should be motivated to perform in laboratory-tasks. They may be quite capable of mental state attribution, but simply err out of a complete lack of motivation. This, however, seldom seems to be the case as witnessed by good performance during training and on baseline tasks (e.g., Byrnit, 2004a; Povinelli & Eddy, 1996), and my own clear impression is that during trials, subjects try hard to co-operate with a view to being rewarded with food treats. Also, efforts are being done to use only subjects that display high task motivation as judged by their apparent eagerness.

A related issue to the above-mentioned one is the inherent methodological concern in examining the cognitive capacities of non-human primates by demanding that they interact with a human experimenter. It may very well be the case that they possess a theory of conspecific minds, but not of human minds. To counter this possibility, a few, but enlightening studies (e.g., Call & Tomasello, 1995; Itakura et al., 1999) have employed specially trained conspecifics to act in the experimenter's role. Results have revealed no differences, however, between the subjects' performances when exposed to a human or a conspecific "experimenter", strongly indicating that the reason for non-human primates' lack of success on theory-of-mind tasks is not due to the fact that they are requested to "read the minds" of another primate species than their own. Even if the latter was true, Povinelli (1996) is right that this in itself would reveal an important limitation in non-human primates' theory of mind in comparison with humans that attribute mental states to all kinds of other animate (or inanimate) entities and most definitely not solely to conspecifics.

Finally, theory-of-mind experiments have been subjected to criticism on the grounds that the set-ups

employed often do not take into account the natural behavioral dispositions of the species in question. As mentioned above, chimpanzees are thus frequently requested to indicate the location of food to an experimenter though active food sharing is rarely seen in normal chimpanzee behavior (Byrnit, 2004b; Hare et al., 2000; 2001; Høgh-Olesen, 2004). Hare and colleagues (2000, 2001. But see Karin-D'Arcy & Povinelli, 2002) found that chimpanzees did seem to attribute mental states when testing was performed employing a competitive paradigm, cautioning primatologists to use more naturalistic paradigmatic shift toward experiments in *natural type settings* is much needed in order to disentangle irrelevant task demands on standard laboratory tasks from the examination of theory of mind.

Great ape enculturation

It has been brought to attention that certain particularities in the rearing histories of non-human primates seem to impinge noticeably and systematically on their performance of sociocognitive tasks (Call & Tomasello, 1996). Call & Tomasello (1996. See also 1998; Tomasello, 1998; Tomasello & Call, 1997) reviewed the experimental data on great ape performance and found that individuals who had been raised in intimate and extensive contact with humans and human culture (termed enculturation), as has been the case with a number of individuals of each great ape species but very few individuals of other primate species, unanimously displayed more complex levels of cognition. The authors suggested that enculturation might substantially enhance the cognitive development of non-human primates, especially their sociocognitive abilities. Call and Tomasello (1996) place great emphasis on the role of joint attention in the enculturation process and suggest that during the upbringing of great ape individuals in human cultural environments, their human caretakers structure and encourage triadic interactions (see below) in all kinds of manners like they would with human children. Thus, caretakers e.g. hold up objects to the ape to capture her attention and praise her for attending, or they follow into the ape's line of attention by attending themselves. The authors hypothesize that these kinds of interactions in which the ape is treated as an intentional being will make all kinds of triadic interactions relating to socio-cognitive skills possible and lead enculturated individuals to understand others as intentional as well (Call & Tomasello, 1996; Tomasello & Call, 1997. But see Tomasello & Call, 2004, for the authors' revised view on great apes' understanding of intentions). Striking contrasts have been revealed in the performances of enculturated individuals and nonenculturated ones in studies of e.g. the production and comprehension of pointing (Call & Tomasello, 1994), discrimination between intentional and accidental acts (Call & Tomasello, 1998), use of manual and visual cues in an object-choice task (Byrnit, 2004a; Itakura & Tanaka, 1998), and imitation (Bering et al., 2000; Bjorklund et al., 2000). Furthermore, enculturated ape individuals have been observed to be especially skilled at imitation (Miles, et al., 1996; Russon, 1996) and deception (Savage-Rumbaugh & McDonald, 1988) among other types of behavior that seem to require advanced cognition.

Many subjects from the theory-of-mind experiments presented above also have a history of enculturation. As such, these individuals' theory-of-mind capacities may not be representative of the capacities, which, in general, are present in non-human primates. Instead, they may represent the cognitive potential possible to members of these species. This will be expounded upon in the discussion below.

The developmental trajectory of theory of mind

Developmental scientists (e.g., Baron-Cohen, 1991, 1995; Bretherton & Bates, 1979; Bretherton & Beeghly, 1982; Corkum & Moore, 1995; Tomasello, 1999) have repeatedly suggested that an intimate link exists between the development of theory of mind in children and an earlier developed ability to participate in joint attention. The term "joint attention" is used to characterize a complex of social skills and interactions (Tomasello, 1999), but most basically it refers to the relational act of individuals attending to the same external entity or event while being aware that they are sharing attention. The prototypical example of joint attention is that of mother and child, both looking at the same toy while occasionally exchanging glances with each other to confirm that the other party is also attending. Behaviorally, joint attention may thus manifest itself by an individual visually following the direction of another individual's pointing gesture or line of vision. However, it is important to note that for the above-mentioned types of behavior truly to be considered to be indicative of joint attention, the participants involved must be aware of their shared attention.

Recent neurobiological studies have found that both humans and monkeys, as a reflex, orient their attention in the same direction as seen gaze (Deaner & Platt, 2003), even when the observer has no motivation to do so, or when it is directly counter to the observer's intentions (Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999). Furthermore, non-human animals as well as very young children may *learn* to follow the gaze or pointing gesture of another individual without necessarily appreciating that they are thus attending to the same thing (see discussion on nonhuman primates in Byrnit, 2004a).

Experimental studies have revealed that within the first year of life, normal human infants will follow the gaze of another person (Butterworth & Cochran, 1980; Corkum & Moore, 1995), and around the age of 12 months, they develop the ability to look toward the place at which another person is pointing (Butterworth & Grover, 1988; Morissette, Ricard, & Décarie, 1995). Also around this age, children try to direct others' attention to objects and events by pointing or holding up things while exchanging glances with the other person, indicating that these deictic gestures are not just learned by

rote, but emerge from a deeper understanding of shared attention (Tomasello, 1999).

Based on his extensive work with autistic children, Simon Baron-Cohen (e.g., 1991; 1995) stresses the importance of joint attention as a necessary precursor to theory of mind. He suggests that humans are innately endowed with "mindreading" modules that are involved in the development of theory of mind. He suggests that there are, at least, four such modules or mechanisms: The Intentionality Detector (ID), The Eye Direction Detector (EDD), The Shared-Attention Mechanism (SAM), and The Theory-of-Mind Mechanism (ToMM). ID and EDD are the most basic of these modules, being present even in very young children. During ontogenesis, ID and EDD feed into SAM that in turn paves the way for a full-fledged ToMM. Baron-Cohen (1995) has compared different groups of humans on their presence or absence of the mind-reading mechanisms and concludes that in order for theory of mind to be present, the shared-attention mechanism must also be operative. Thus, children with specific language disorders or certain mental handicaps display both shared attention and theory of mind, while a large number of autistic children notoriously show impairment both in their shared-attention abilities and in the development of theory of mind.

In contrast to Baron-Cohen, Michael Tomasello and colleagues (Tomasello, 1999; Tomasello & Call, 1997; Tomasello et al., in press) endorse a simulation view of the development of theory of mind. According to their account, two ontogenetic sources make the following development possible: the human ability to identify with conspecifics, and the human understanding of intentionality. Already from the early stages in ontogeny, the human infant identifies with the humans surrounding it, and around the age of 8-9 months, the infant begins to behave in clearly intentional ways (see Tomasello & Call, 1997), and this identification with others makes her experience the behavior of others as intentional as well. Once the infant has come to understand others as fellow intentional agents, various activities involving joint attention behavior are possible. Hence, the child is able to follow another person's line of attention and, importantly, understand that they are both attending to the same thing in the process. The child also comes to understand that it can direct another person's attention to something by attending to it herself. Likewise, language acquisition is made possible by this intersubjectivity, and, in turn, engaging in the shifting perspectives in joint attention behavior and linguistic interaction constitutes the material for constructing a theory of mind (Tomasello, 1999. See discussion below for deliberation on the interplay between language and theory of mind).

Bard and Vauclair (1984) examined the communicative style of adult primate mothers (human and *Pan*) and infants in relation to object manipulation. They found that, whereas adult humans would manipulate objects in order to engage infants' attention toward objects, great ape mothers rarely did, but rather manipulated objects independently of what their infants were doing. The human infant would respond to its mother's object stimulation by manipulating the same object while great ape infants did not seem to react to their mothers' exploration. Intriguingly, and

of great interest to the previous enculturation discussion (see above), one chimpanzee infant who had been reared by humans attended to a human adult's object manipulation and responded by looking at or contacting the same object in the same manner of a human infant.

In non-human primates, the capability to participate in joint attention has been examined experimentally primarily on object-choice tasks in which subjects, prior to explicit learning, are requested to use experimenter-given manual and facial cues to direct them toward food, hidden in one of several opaque containers (Anderson, Montant, & Schmitt, 1996; Byrnit, 2004a; Call & Tomasello, 1994; Itakura & Tanaka, 1998; Neiworth et al., 2002; Peignot & Anderson, 1999). Experimenter-given cues have ranged from quite explicit referential signals, such as tapping at and pointing toward the baited container to visual signals, such as looking at or glancing toward the container. The object-choice paradigm has yielded rather mixed results on non-human primates' capabilities of joint attention. In general, it seems that great apes are doing consistently better on object-choice tasks than monkeys or prosimians. The picture, however, may prove more complicated than this. Recently, Byrnit (2004a) pointed out that the great ape subjects, but no other nonhuman primates, of many object-choice experiments have a history of enculturation, and striking contrasts have been found between the performances of enculturated and nonenculturated subjects on object-choice tasks. Enculturated apes have been found to use manual and visual referential cues (Call & Tomasello, 1994; Itakura & Tanaka, 1998), whereas it is still undecided to what extent nonenculturated ones do (Byrnit, 2004a). Thus, species differences between great ape and monkey capacities for joint attention may have less to do with phylogenetic differences and more to do with ontogenetic peculiarities (Byrnit, 2004a). I will elaborate on the connection between joint attention and theory of mind shortly in the discussion below.

General discussion

In the above, a review was made of most of the laboratory experiments conducted to date on non-human primates' theory of mind and a representative part of comparable research in young children. It was shown that children as young as 18 months already seem to make use of a rudimentary "folk psychology" and interpret the actions of other people within a framework involving goals and intentions. Around the age of three years, children show some understanding that perception connects people's mental worlds with external reality, but do not seem to appreciate the causal connection between perception and knowledge. Such appreciation seems to require an advanced cognitive capacity, which is not fully developed in children until they are 4-6 years old (see Wellman, 1990, for a review). It has been objected that at least some child experiments may have confused the limitations in language skills with an undeveloped theory of mind. Thus, it has been suggested that child researchers, like primatologists, employ non-verbal tasks to tap into their subjects' emerging theory of belief. However, though some non-verbal experiments employing a deception paradigm have shown evidence that children younger than four years may understand the relation between perception and knowledge, replicating these results has proven difficult, and debate is still ongoing about the exact age at which children understand knowledge and beliefs.

What are we to make of non-human primates' capacities to attribute mental states to themselves or other individuals? As seen in the above review, experimental results have been conflicting. Recent studies have failed to show evidence of such capacity, and the results appear to be genuine rather than caused by confounding factors such as subjects' lack of motivation, or the fact that subjects often have to infer mental states in humans instead of conspecifics. In contrast, the results of other older studies have suggested that nonhuman primates possess a rather advanced understanding of mental states. However, as several critiques have pointed out, more parsimonous interpretations of these results exist. Clever behavior reading may easily be confused with mind reading, especially if the individuals in question are as skilled at reading behavior and as astute and flexible in adjusting their own behavior to that of others as it appears to be the case with many non-human primates. As illustration, I present the below example from my own experimental work (Byrnit, 2004a). Initially, while testing orangutans' ability to use experimentergiven cues, I was impressed by one particular individual's almost flawless performance of using my manual and visual cues to choose the baited plastic cup out of two possible cups. After a while, though, I realized that her response was not a display of mind-reading skills, but rather of a highly and equally impressive, sophisticated sensitivity to my behavior. Thus, she would direct the stick with which she used to indicate her choice toward one of the cups and immediately transfer it to the other cup if I did not start to lean forward as I would do when she had chosen between the cups and the trial had ended. Even the slightest jerk of my body would have her rest the stick at one particularly cup to indicate her choice, making us perform an almost exact replica of Clever Hans¹ and his trainer! I do not believe it is possible for me or any other experimenter to ritualize my behavior while testing nonhuman primate subjects more rigorously than I already do without leaving my experiments completely devoid of any natural interaction between living beings and of doubtful ecological validity. At the other end of the scale at the point where the ecological validity is perfect, we find plentiful field reports of behavior, notably deception, the enactment of which seems to imply at least some kind of theory of mind. However, the problem with field reports is that they do not permit us to rule out the possibility that smart behavior-reading is behind what seems to be mind-reading (Whiten, 1997, p.157), and

¹ Clever Hans was a horse living in Germany by the end of the 19th century. He thoroughly impressed the public by being able to perform mathematical operations given by his trainer and indicate the answers by tapping his hoofs. Later, however, it was found that Clever Hans' special talent was unfortunately not that of mathematics, but rather that of being highly responsive to behavioral cues unwittingly given by his trainer.

multiple anecdotes do not count multiple times as much as experimental evidence (Heyes, 1993). In this respect, controlled experiments such as Hare and colleagues' (2001) employing species natural contexts are much needed. They should be able to bridge the gap between field reports and laboratory data and help us make more sense of the results of both.

Personally, my experience with great apes. experimentally and otherwise, has led me to believe that as far as nonenculturated individuals are concerned, it is rather improbable if they react and adjust quickly to the behavior of others on the basis of what could reasonably be interpreted as theory of mind in the human sense. In my experience, smart behavior reading in some situations, at least, would be a perfectly adequate account of the adroitness with which many nonenculturated non-human primate subjects navigate socially and perform on socio-cognitive tests. This, of course, is a tentative conclusion that I may revise with growing experience with non-human primates. My observations, however, gain support from the fact that only enculturated apes seem to make consistent use of experimenter-given manual and visual cues in object-choice tasks, suggesting that they may participate in joint attention as opposed to their nonenculturated conspecifics. Thus, enculturated great apes might transform the typically astute primate behavior-reading into a more advanced understanding of minds, and thereby bridge the gap between human and non-human primate theory of mind.

If my account of non-human primate theory of mind is valid, we need to ask ourselves two related questions. First, why do normal humans display theory of mind from a young age as opposed to our closest primate relatives? Second, how do influential theories on the ontogenesis of theory of mind account for the fact that non-human primates, or at least the great apes, may possess some capacity to develop theory of mind, which lies dormant until the individual is exposed to the highly unusual circumstances of being reared by and live in intimate contact with humans and human culture?

The interplay between language and theory of mind

In searching for answers to why only humans display theory of mind under normal circumstances, it is logical to examine the interplay between language and theory of mind. Language acquisition is very complex and does not just consist of rote learning of symbols or combinations thereof. Instead, language is based on complex inter-individual expectancies that intertwine and coordinate interaction (Savage-Rumbaugh, Sevcik, Rumbaugh, & Rubert, 1985; Tomasello, 1999), and although great controversy exists as to great apes' language acquisition capabilities (see overview in Tomasello & Call, 1997), full-fledged language use is unique to man. In accordance with this, language is often included in the discussion as to why humans come to develop theory of mind (e.g., Smith, 1996).

Contrary to all other known animal communication systems, symbolic language enables us to label mental states and thus manipulate them internally (Smith, 1996), and this may be essential for the development of theory of mind in two different ways. First, if Whorf's hypothesis is correct that differences in language will result in corresponding differences in thinking, it could be the case that the developing human child acquires theory of mind as she is exposed to and over time acquires the numerous linguistic ways by which we routinely impute all mental states to ourselves and other individuals. Following this rationale, theory of mind would thus develop in an individual that internalizes the constructs of theory of mind. Interestingly, Premack and colleagues (review in Premack, 1988) have found that language-trained apes are able to perform certain mental operations that non-languagetrained apes are unable to perform, apparently because relevant linguistic terms by which to construe the problem are available to the former, but not to the latter.

However, neither theoretically nor empirically does language seem to be a necessary precursor to all aspects of theory of mind. Actually, it may well be that mind reading precedes language, both at a phylogenetic and ontogenetic level. Baron-Cohen (1995, p.132) asks the immensely interesting question if people would bother to talk at all, if they were not already mind readers with an interest in sharing their internal world and learning about that of others? He answers this in the negative and presents as evidence the case of autistic individuals that technically speaking may learn how to use words and sentences, but are unable to engage in social, normal communication, i.e. use language in a normal sense of the word, quite possibly because they do not share the mental attributional skills of normal people. Human language-use, thus, has much less to do with transferring information than with being an intersubjective exchange of perspectives (Baron-Cohen, 1995).

Furthermore, not only would humans lack any reasons to communicate if not to share perspectives, but conceiving of language acquisition without an already existing understanding of other people as intentional is simply not feasible (Tomasello, 1999). Tomasello argues that ontogenetically, the child is only able to acquire language when she understands that other people are using symbols (this being sounds, signs, or lexigrams) with the intention to get the child to attend to something. Citing Wittgenstein, Tomasello draws attention to the fact that in learning which words go with what, children are faced with the problem that entities have innumerable features that speakers may refer to. Thus, using Tomasello's example, when a person holds up a ball and says "ball", how does the child understand that the speaker refers to the ball as an entity and not to its color, the class of objects to which it belongs, or to the act of holding up the ball and so forth? Pivotal in assigning correct referentiality in these situations is that the speaker's communicative intention takes place in a "meaningful joint attentional scene" (Tomasello, 1999, p.108). Thus, the speaker's language can be grounded in shared experiences whose social significance the child already appreciates (p.109). Empirically, Tomasello's hypothesis has gained support in the very interesting study by Tomasello and Barton (1994), described previously, in which it is examined how small children acquire new words in nonostensive contexts, and also other studies reviewed above have confirmed that children understand the intentions of other people before acquiring language.

I fully acknowledge that language may be important for the development of more advanced mind-reading skills. For instance, the fact that the understanding of beliefs does not seem to be within the human child's capacity until the age of four where also his or her linguistic skills have become relatively advanced may not be coincidental. However, long before the human child becomes a proficient language user, she understands others in terms of their intentions, i.e. displays a fundamental theory of mind. This understanding of intentions paves the way for various attentional behavior and ultimately to the acquirement of language without which more advanced mind-reading skills, such as the theory of beliefs, may not be possible. Thus, great apes may understand intentions better than previously thought (see Tomasello, Call, & Hare, 2003), but, following the rationale presented above, the fact that they do not acquire language as sophisticatedly as normal human beings, no matter how language-trained they are, may hinder the development of more advanced mindreading skills. Summarily, I believe that rather than create theory of mind, language acquisition dramatically increases the complexity of mind reading in creatures that *already* have an understanding of others' intentionality.

The ontogeny of theory of mind: Consequences of the enculturation data

Above, I presented two different theories that have been especially influential in accounting for the ontogeny of theory of mind, a modularity approach and a simulation approach, here exemplified by Baron-Cohen (1995) and Tomasello (1999), respectively. Allowing for the fact that systematically collected data on enculturation is in sore need, how do these accounts correspond with the analysis of the data that enculturated great ape individuals may possess the potential to develop mind-reading abilities that resemble human ones to some extent?

Baron-Cohen (1995) advocates that theory of mind is made possible by the presence of four neurologically based mind-reading modules, some of which are hypothesized to be particular to humans and others possibly shared with at least the great apes. Although Baron-Cohen allows for the possibility that there may be a role for some learning in the development of the mind-reading modules, he is of the belief that the mind-reading modules are basically innate and will unfold during the course of ontogeny; that they are universal. Regarding the role of enculturation, if the mind-reading modules are basically innately and uniquely endowed in humans, then, obviously, no amount of human rearing and exposure to human culture would be able to create mindreading great ape individuals. It is hard to conceive how being human-raised could alter the neurological basis of the enculturated great ape individual fundamentally. Hence, Baron-Cohen's theory would have to be rejected in its present form.

However, a modified version of the theory might still correspond to data supporting the enculturation hypothesis. Maybe it is the case that the mind-reading modules are not unique to the human endowment, but are shared with at least the great apes and that something unique to human culture is needed to develop these modules. Hence, the mind-reading modules would lay dormant in all great apes, but would only develop in the few individuals that, like human children, were exposed to human rearing conditions. A view such as this implies that the mind-reading modules would have had to be present in the common ancestor of humans and the great ape species. This common ancestor dates back to the time prior to the phylogenetic divergence of orangutans from the common lineage of the rest of the great apes and humans about 10-16 million years ago. The modules are normally only activated in humans although they can be potentiated in great ape individuals given certain, as yet unspecified, socio-cultural conditions. This account has one major problem. Human culture is inconceivable without at least some kind of mental state understanding on the part of its members (Tomasello, 1999; Tomasello, Carpenter, Call, Behne, & Moll, in press). Consequently, if exposure to human culture supposedly is the critical factor in activating otherwise dormant mental state attributional skills, then how did the human culture arise in the first place? To rephrase: how could the mind-reading modules become activated in humans before they possessed the mindreading capacities necessary to build human culture, and, hence, create the social environment needed to activate the modules?

Furthermore, a modified version of Baron-Cohen's (1995) theory cannot satisfactorily identify exactly what features of human culture are needed in order to activate the mind-reading modules. Normal children of all human cultures examined seem to develop mind-reading skills, and this despite the fact that rearing conditions are markedly different across cultures (Baron-Cohen, 1995). Also, among children being raised in the same kind of cultural setting, autistic individuals do not get their mind-reading modules fully activated, and, hence, are not capable of mind reading. These two aspects of human mind reading, its universality and the case of autism, seem to put quite different emphasis on the roles of learning and genetic endowment. If human mind reading is universal despite widely different cultural rearing practices, it would seem to imply a great amount of plasticity with respect to the role of learning in the development of mind reading. In contrast, the case of autism implies that in some instances, no amount or type of learning will create a mind reader.

Although not a modularity approach like Baron-Cohen's (1995) theory, also Tomasello's approach (1999) proposes that the development of theory of mind is made possible by a "uniquely human biological adaptation" (p.71). In Tomasello's view, this uniquely human adaptation is the identification process in which the infant views others as "like me". In fact, he originally advocated that it might precisely be the lack of identification with conspecifics that would hinder

great apes from attributing intentionality (Tomasello, 1999; Tomasello & Call, 1997. But see Tomasello & Call, 2004, for a revised view). This is due to the fact that they were prevented from extrapolating their own experience from acting intentionally to view others' actions as intentional. How does the theory of Tomasello and colleagues correspond to the enculturation hypothesis? Again, we are faced with the difficult task of having to explain how innate biological mechanisms believed to be unique to humans and on which the development of theory of mind rests can suddenly appear in great apes with compliments to human rearing. The key question would then be: if only humans are biologically equipped to identify with others, and it is this identification process that leads to an understanding of others as intentional, then how could human-raised apes possibly understand intentions? I am ignorant of any account of Tomasello that offers an explanation, and this question is not made less pertinent by Tomasello & Call's (2004) revised view, that all apes, not just enculturated ones, have some understanding of intentionality.

Summarily, in their present forms, neither Baron-Cohen's (1995) modularity approach nor Tomasello and colleagues' (Tomasello, 1999; Tomasello & Call, 1997) simulation or identification view seem able to explain adequately how enculturation may alter the socio-cognitive capacities of great apes. Both theories assume that some kind of innate, biological endowment, unique to humans, is a prerequisite to the development of mental state attribution, and I find it unclear how such basic biological features might be fundamentally altered by human contact, no matter how intensive or extensive. Other ways exist, however, by which enculturation may influence great ape individuals rather than by creating major mental changes. Thus, it has been suggested that the human enculturation process facilitates mainly behavioral, not mental, changes in the enculturated individual (Bering, 2004; Povinelli, 1996). Bering (2004. Bjorklund, Yunger, Bering, & Ragan, 2002) summarizes his and his colleagues' view in an alternative explanation of the enculturation process: the apprenticeship hypothesis, which posits that the effect of enculturation on great ape individuals makes them perceive humans as problem-solving experts whose action it is well worth paying attention to. This happens over the years as they encounter difficulties with cultural objects and experience that human caretakers intervene in their unsuccessful behavioral strategies to solve the problem. Thus, enculturated individuals learn to pay attention to the behavior of humans without necessarily having any understanding of the intentions and goal-directedness of the actor.

When discussing the ontogenesis of theory of mind, it is important that we address the interplay between possible innate endowment and certain rearing particularities. With regard to the enculturation debate, this needs to be done with certain parsimony. Thus, when evaluating the claims of the enculturation hypothesis, we need to ask if it is at all conceivable that e.g. the chimpanzee, which is believed to be more closely related to the common ancestor of humans and chimpanzees than humans are, will develop the derived sociocognitive features of humans if "bombarded with humantypical social experiences" (Bering, 2004, p.206)? A more parsimonious suggestion would be that humans reared under chimpanzee-like social conditions would display chimpanzeelike social cognition. This latter scenario would only presuppose that being brought up in an environment, in which the social regularities lack ties to an understanding of intentionality, would cause a human individual to revert back to the phenotypic expression of the ancestral form in the face of an ancestral social environment (p.206). To illustrate, Bering (2004) draws attention to the cross-fostering experiments conducted on rhesus macaques and Japanese macaques in which Japanese macaques, a species that is assumed to have diverged from an ancestral rhesus population, will fail to develop certain derived behavior when being raised by rhesus mothers, whereas rhesus behavior is less influenced by being raised in the more derived Japanese macaques environment.

As concluding remarks, I want to express my belief that although much research is still needed within the field of primate theory of mind, at least two different conclusions appear fairly certain by now.

First, although non-human primates in time may prove to be more sophisticated "mind readers" than some experimental primatologists believe at the present, in very important ways, humans seem to be considerably more extensive "mind readers" than non-human primates and other animals. Not only do we attribute mental states to all other animate and inanimate entities besides conspecifics, we also understand a multitude of qualitatively very different situations in terms of mental states. In both respects - with whom and in what kind of situations we theorize about minds – it seems clear that we far surpass even our closest of primate relatives.

Second, by now it seems clear that with neither nonhuman primates nor human children viewing theory of mind as a cognitive entity that is either present or absent is not a particularly productive approach. Rather, theory of mind is better seen as a complex conglomerate in terms of which individual understands all other mental states in other individuals. This may happen at different levels of abstraction and may take different avenues in different primate species concerning what kind of mentalstate "theories" we entertain. However, the capacity to understand other individuals in terms of their mental states unquestionably enables more sophisticated social manoeuvers, compared to what mere mechanical behavior reading would produce. In turn, this places great demands on the mind-reading skills of any primate who aspires to be socially successful in her community.

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Appendix 1

Basic primate taxonomy (after Tomasello & Call, 1997)

Humans, together with more than 180 other species, belong to the mammal order of primates. Primates are a highly diverse order in many behavioral characteristics, partly due to the fact that they have exceptionally long periods of immaturity in which they must learn about their individual physical and social environment in order to survive and procreate, leading to more flexible and complex cognitive skills in the respective domains. Primates reach sexual maturity at a relatively late age, have few offspring at a time, and invest heavily in each offspring. Almost all primates live exclusively in tropical climates. Primates emerged in evolution 60-80 million years ago. Based on important similarities and differences, it is common to group primates into the four entities of prosimians, New World monkeys, Old World monkeys, and apes. The great apes are humans' closest primate relative, and prosimians, the primate group with whom the human evolutionary lineage departed the longest time ago.

Prosimians include species such as the lemurs from Madagascar and the lorises from Africa. As the name indicates, New World monkeys live exclusively in Central- and South America, and among many other species includes the marmosets, tamarins, and capuchin- and squirrel monkeys. Old World monkeys, so called because they live in Africa and southern Asia, are generally larger than New World monkeys and include species such as the baboons, macaques, and vervet monkeys. The apes consist of three broad groups of species: lesser apes, great apes, and humans. Lesser apes, the gibbons and siamangs, live in Southeast Asia and are the smallest of the apes. The great apes consist of the African species of chimpanzee, bonobo, and gorilla, and the only Asian great ape, the orangutan. The great apes are large sized animals with large brains, and being humans' closest relatives, psychologists, anthropologists, neuroscientists, and other academic disciplines have long employed great ape studies to help reconstruct human evolution. The great apes share many life history similarities with humans such as extraordinary long periods of immaturity and resulting dependency on adult caretakers. Molecular data and fossils have shown the chimpanzees and bonobos to be the great ape species closest related to humans, sharing an evolutionary lineage with humans that departed from each other only about five million years ago. In contrast, orangutans diverged from the other hominoids some 15 million years ago, and gorillas some ten million years ago.