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27 Domain-Specific Knowledge in Human Children and Nonhuman Primates: Artifacts and Foods

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One of the most important things an organism needs to recognize is where to direct its attention. In order to act effectively, an organism needs to focus its attention on properties and events that are relevant to the problem at hand. The task of discovering what information to attend to and what to ignore presents a challenge because different types of information must be selected in different situations. For example, a monkey in the canopy searching for a branch to climb on must pay attention to the shape, size, strength, and position of potential branches, ignoring other information such as the color of the branches and smell of the fruit. Later, the same monkey looking for a ripe piece of fruit to eat must attend to color and smell, the very features he disregarded earlier. How do organisms decide which features to attend to in order to build effective strategies for classifying the complicated assortment of objects in their world?

Researchers in a number of fields, including cognitive development (Gelman 1990; Hirschfeld and Gelman 1994; Keil 1989), evolutionary psychology (Cosmides and Tooby 1994; Pinker 1997), animal cognition (Gallistel 1990; Hauser 2000; Shettleworth 1998), neuropsychology (Caramazza 1998; Santos and Caramazza, in press), anthropology (Sperber 1994), and archaeology (Mithen 1996) have answered this question by appealing to notions of domain-specific constraints on learning. From a domain-specific perspective, the mind consists of a collection of specialized learning systems designed for processing different types of input. Advocates of the domain-specificity view argue that organisms are endowed with domain-relevant content that both biases and guides their attention to conceptually relevant perceptual inputs. The domains that make up an animal's cognitive architecture are thought to have evolved in response to the computational problems that were most salient over the animal's phylogenetic history.

In the past decade, considerable research has investigated the ontogeny of human domains of knowledge (Gelman 1990; Hirschfeld and Gelman 1994; Keil 1989; Keil et al. 1998). Relatively little work, however, has explored whether the domains of knowledge that constitute the human mind are shared with our closest evolutionary relatives, the nonhuman primates. If accounts of domain specificity are correct, then the domains of understanding that comprise human cognition may be phylogenetically quite ancient and thus shared by other nonhuman animals, especially nonhuman primates. It is also possible, of course, that human evolution led to the emergence of new domain-specific systems (e.g., Mithen 1996).

We have attempted to address this problem by examining how human children and two nonhuman primate species—captive cotton-top tamarins (*Saguinus oedipus*) and free-ranging rhesus monkeys (*Macaca mulatta*)—reason about problems in two different domains. Specifically, we have focused on the features that primates use when categorizing foods and artifacts. Here we systematically contrast the knowledge about food and artifacts shown by mature tamarins and rhesus monkeys with the human child's developing knowledge of these domains. We argue that there are important similarities in the ways that these three species reason about objects in these domains.

Children's Understanding of the Relevant Features of Artifacts

Human children are surrounded by artifacts from birth. As one might predict from this rich early experience, humans develop some understanding of artifacts at a rather young age. Five-year-old children understand which properties are important for classifying artifacts (e.g., shape, rigidity, size) and perceive these as distinct from the set of features that are important for categorizing other kinds of things, such as animals (e.g., color, material composition, surface markings; see Carey 1985; Keil 1989; Keil et al. 1998).

There is also evidence that toddlers possess some understanding of the causally relevant properties of an artifact, and specifically its functional capacity. Brown (1990) designed a tool task in which 1–3-year-old children were trained to use a cane-shaped tool to obtain an out-of-reach toy. Once children successfully obtained the toy with a particular tool, they were tested with new tools that were designed to assess the salience of particular featural transformations. Children readily used tools of a different color to perform the same function, which suggests that color plays a relatively insignificant role in the child's understanding of a functional tool. However, children rejected tools that were too flimsy to pull the toy or whose tops were shaped inappropriately for the pulling task. This suggests that shape and rigidity play significant roles in the child's understanding of a functional tool. More important, new evidence suggests that children as young as 2 years of age generalize new labels for objects based on information about an object's function, not merely its shape and overall physical appearance (Kemler Nelson 1999; Kemler Nelson et al. 2000).

Nonhuman Primates' Understanding of the Relevant Features of Artifacts

In contrast to the wealth of studies examining what children understand about the functional properties of objects, relatively few studies have critically evaluated nonhuman primates' understanding of artifacts. Tool use is present throughout a number of primate species, both in the laboratory (Povinelli 2000; Tomasello and Call 1997; Visalberghi and Tomasello 1998) and in the wild (Goodall 1986; Matsuzawa 1994; McGrew 1992). Although this research has conclusively demonstrated that several primate species use tools, only a few studies (Hauser 2000; Povinelli 2000; Visalberghi and Tomasello 1998) have explored nonhuman primates' understanding of tools and in particular the features that give tools their particular functions.

To examine these issues, Hauser (1997) initiated a research program with cotton-top tamarins. In the first task, modeled after Brown's (1990) studies of children, the subjects were required to pull one of two blue canes to gain access to an out-of-reach piece of food (figure 27.1). Once the subjects learned to selectively pull the blue cane with food inside the hook, in preference to a cane with food outside the hook, they were tested with a variety of new tools of varying sizes, shapes, colors, and textures. In

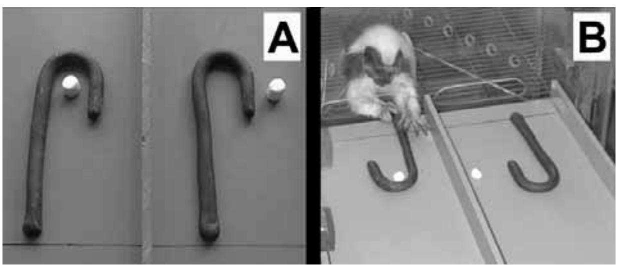

Figure 27.1
An example of an original tool training condition (A). Subjects learned to pull one of these two canes to obtain the food reward (B). (From Hauser 1997.)

critical test trials, the subjects were presented with a choice of two canes that differed from the original blue cane in only one feature (figure 27.2). They had to choose, for example, between a pink cane (new color) and a fat blue cane (new size) or between a blue cane with holes (new texture) and an oddly shaped cane (new shape). Based on both first trial and session performance, the results showed that tamarins chose tools with novel colors over those with novel sizes, and chose tools with novel textures over those with novel shapes. In the absence of explicit training, tamarins evidently understand that size and shape are more causally relevant to a tool's functionality than are color and texture.

After presenting his subjects with single-feature changes, Hauser presented the tamarins with new test trials in which additional features of the objects were altered, some of which changed their functional properties. The tamarins reliably preferred the more functional of the two tools, even when the more functional object was perceptually quite different from the original blue cane, and even when a novel but functionally appropriate tool was pitted against a familiar tool placed in an orientation that blocked the exercise of its function.

Hauser and colleagues (1999) turned next to a modified version of this task in which tamarins were trained to choose one of two pieces of cloth to obtain a food reward. As in the previous experiments, the tamarins focused on changes to the cloth that affected its functionality (see Gibson 1979). For example, subjects rejected cloths that did not allow pulling (e.g., pieces of cloth connected with chipped wood, sand, or a broken rope) and they chose cloths of radically different shapes (e.g., triangles, circles, teeth-shaped) that functionally supported the food reward. Furthermore, they distinguished between cloths that supported the food reward and those that were merely in contact with the food and thus functionally inappropriate.[1] Once again, the subjects distinguished the features that were relevant for the cloth tool's function from those that were not.

Santos et al. (under review) then set out to examine whether primates understand which features are most causally relevant to an artifact's function in the absence of direct physical experience with that type of artifact. To this end, Santos and her colleagues used an expectancy violation paradigm. The logic behind this paradigm is that subjects will look longer at events that violate their expectations about the physical world than at events that are consistent with those expectations (see Hauser and Carey 1998; Spelke 1985, 1991). Santos et al. habituated tamarins to an event in which a novel object—a purple L-shaped tool made of Play-Doh—pushed a grape down a ramp and onto a lower platform (figure 27.3A), they then presented subjects with one of two test trials.

In one test trial, the subjects saw a tool of a different color but a similar shape push the grape down the ramp (figure 27.3B). In the other test trial, they saw a tool of the same color but a different shape (an I-shaped tool) appear to push the grape down the ramp. This new shape test trial was considered unexpected from the perspective of a human observer because the base of the tool was too small to effectively push the grape (figure 27.3C). The results showed that the subjects looked longer during the new shape test trial than during the new color test trial, which suggests that a change in the tool's shape was more important to its functioning than a change in its color.

Santos and colleagues then extended their work to free-ranging rhesus macaques living on the island of Cayo Santiago, Puerto Rico, a population with far less experience with artifacts than the captive tamarins.[2] They conducted the same expectancy violation experiments involving the same Play-Doh objects and obtained similar results. Rhesus monkeys, who lack experience with artifacts of any kind, looked longer when the tool was used after a change in its shape—a change that should have impaired the tool's function—than after a change in its color. Even when free-ranging rhesus are presented with

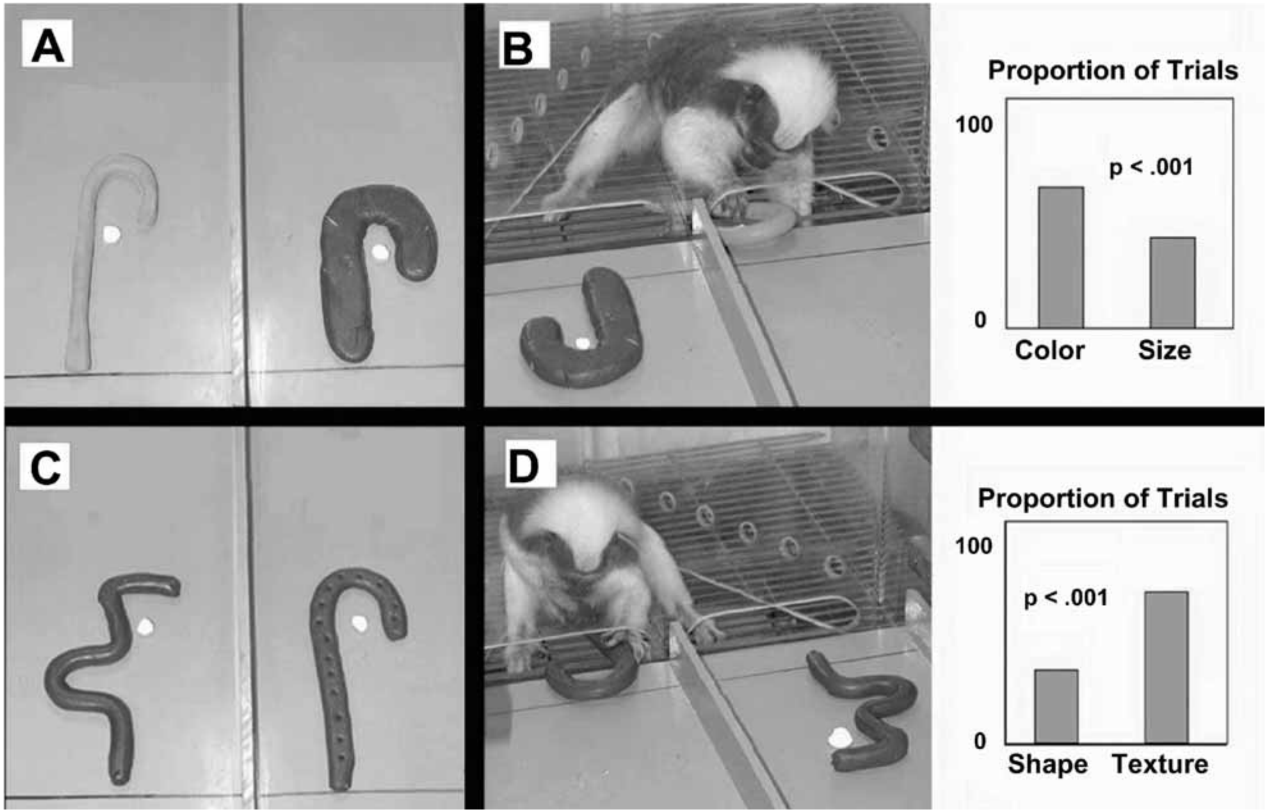

Figure 27.2
Feature change conditions. The subjects were presented with a cane of a new color and a cane of a new size (A) or a cane of a new shape and a cane of a new texture (B). The subjects preferred canes with new colors (C) and textures, respectively (D).

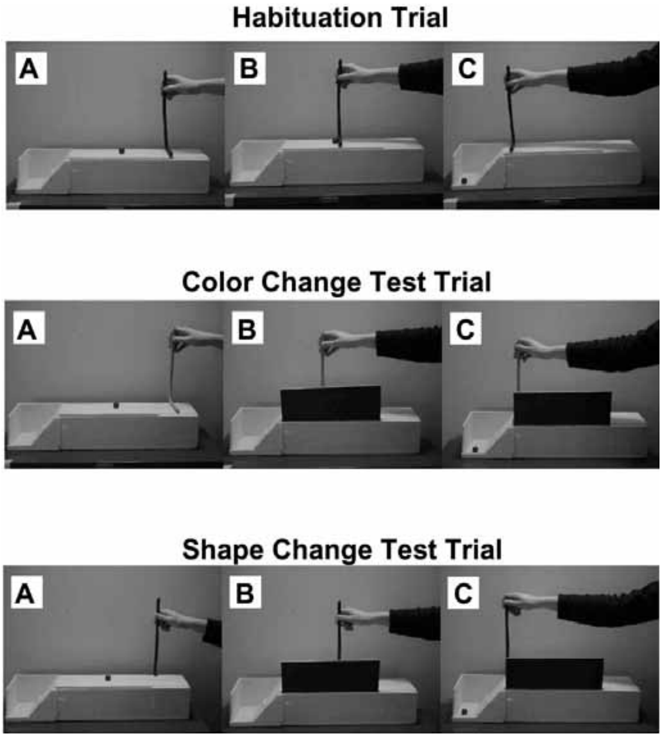

Figure 27.3
Santos et al. (under review) expectancy violation experiment. In the habituation trial, subjects were habituated to an event in which a purple L-shaped tool (A) was used to push a grape across a stage (B) and down a ramp (C). They were then given two test trials, one in which the color of the tool changed (color change test trial) and one in which the shape of the tool changed (shape change test trial). The subjects looked reliably longer during the shape change test trial.

tools with which they have no direct physical experience in tasks that involve no training, they appear to understand at some level which features are relevant to an artifact's function.

Children's Understanding of the Relevant Features of Foods

In light of evidence that both human and nonhuman primates attend to the features of shape and orientation when reasoning about artifacts, we now turn to a different domain—food—in which these features play little or no causal role. Despite the fact that food is critical to the survival of all animals, relatively few studies have been devoted to examining children or nonhuman animals' understanding of this domain (see Macario 1991; Rozin 1990 for exceptions). The little work that has been done suggests that children possess some understanding of food objects from a rather early age.

Children as young as 2 and a half years of age predict that objects of the same color will have

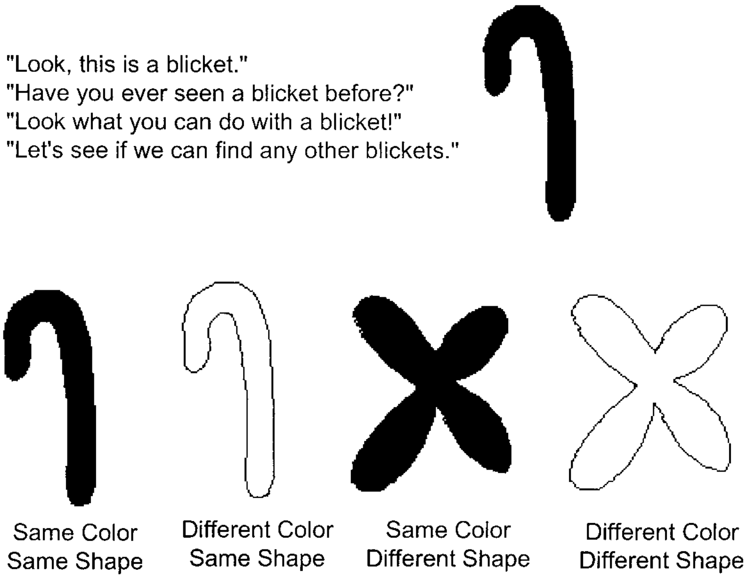

Figure 27.4
Santos et al. (1999) word learning experiment. The subjects were taught a label for a novel food or artifact and then were asked to transfer this label to objects of the same and different colors and shapes.

the same smell and taste (see Macario 1991). Santos et al. (1999) (see figure 27.4) examined the features that 4-year-old children attend to when learning the words for food objects. They first taught children the labels for novel objects made of pretzel material of a particular shape and color (e.g., blue cane shape) and then asked whether other objects of similar shapes and colors shared the same label. When children were told that the novel object was a tool, they transferred the label to objects of the same shape (see also Landau et al. 1998). When children were told that the novel object was a kind of food, in contrast, they transferred the new label to objects of the same color as the originally labeled object. In other words, children used the feature of color, not shape, when generalizing labels to new food objects. Similarly, Lavin and Hall (1999) found that 3-year-old children use color and texture information when learning the labels for novel food objects, disregarding information about the object's shape. Taken together, these results suggest that young preschoolers have some understanding that substance properties such as color and texture, are more relevant to categorizing food objects than form properties such as shape. Children's substance bias for food objects stands in contrast to their selective attention to form when categorizing and reasoning about artifacts.

Nonhuman Primates' Understanding of the Relevant Features of Foods

Despite the enormous attention that behavioral ecologists in the field and laboratory have devoted to studies of foraging (Stephens and Krebs 1986; Ydenberg 1998), relatively little research has explored what nonhuman animals understand about food objects. Garcia's groundbreaking work on avoidance learning established

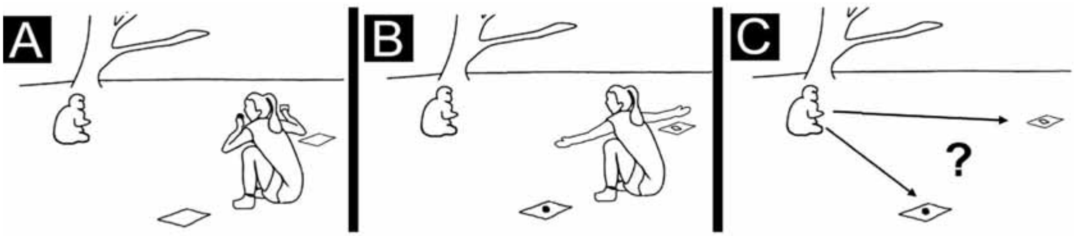

Figure 27.5
Santos et al. (2001) social facilitation test. Rhesus macaques watched a human experimenter eat one of two novel objects (A). The objects were then put down (B) and the subjects were allowed to choose one of the two items (C).

that rats are more likely to associate nausea with the ingestion of a novel food than with a bright light or other stimulus (Garcia and Koelling 1966). Although this result suggests that organisms take into account different information when learning about food than when learning about other kinds of stimuli, it does not speak to the question of whether organisms spontaneously divide objects into different categories (e.g., foods and nonfoods) and attend to different properties of each.

To better examine these questions, Bovet and Vauclair (1998) examined whether captive baboons naturally categorize objects as edible or inedible. They trained baboons to pull one rope when presented with an apple and to pull a different rope when presented with a padlock. After this initial training, they presented their subjects with 80 novel objects, half of which were food, half of which were not food. The baboons spontaneously generalized their responses to the appropriate objects, pulling the apple rope for food objects and the padlock rope for nonfood objects. These results suggest that baboons classify objects as foods or nonfoods in the absence of training, although they do not reveal the features the baboons use when making these categorizations.

We have initiated a research strategy that explores how nonhuman primates spontaneously categorize novel food objects using a somewhat different technique and have focused especially on the features that guide categorization in the absence of training (Santos et al. 2001) (figure 27.5). We tested adult rhesus macaques from the Cayo Santiago population with natural but unfamiliar food objects. In the first condition, an experimenter presented a subject with two novel foods (e.g., a baby carrot and a lemon slice); the experimenter ate one while holding the other near her face, placed one of each of these foods on spatially separated platforms, stepped away, and allowed the monkey to approach and eat one of the food objects. We found that subjects selectively approached the platform containing the object that the experimenter had previously eaten. These findings provide evidence that monkeys show an effect of past experience on their food choice, and they set the stage for our critical studies.

In these experiments, rhesus monkeys were initially presented with two objects of different colors and shapes, each of which was made of the same material (Play-Doh) as the objects in our previous studies of tool use in this population (Santos et al. under review). As the experimenter presented the two objects to a subject, she pretended to eat one of the objects and acted on the other object in a different, attention-getting way (e.g., rolling it on the ground or sticking it in her ear). Then the experimenter placed copies of the two objects on two platforms, as in our previous studies, and watched the subject's patterns of approach to the platforms. The monkeys selectively approached the object with the same shape and color as the object that the experimenter had pretended to eat. These findings provide evidence that monkeys show a social facilitation effect across species (i.e., from a human facilitator) and across novel kinds of objects (i.e., objects that fail to resemble any foods the monkey might have eaten). They set the stage for our critical tests of domain-specific learning and generalization.

In these tests, the monkeys again observed an experimenter pretend to eat one of two Play-Doh objects of different colors and shapes, but then they were given an approach task in which objects were presented that differed in shape or color, or both. When both test objects had the same shape as the originally eaten object, but only one had the same color, the monkeys selectively approached the object with the same color. When both test objects had the same color as the originally eaten object, but only one presented the same shape, the monkeys selected at random between the two objects. Finally, when one object differed from the originally eaten object in color and the other object differed in shape, the monkeys selectively approached the object with the same color. These findings provide clear evidence that monkeys generalize their learning about edible objects along the dimension of color, not along the dimension of form.

Conclusions

Our social facilitation studies with monkeys support three conclusions. First, just as monkeys can learn about the functional properties of tools by observation, without direct physical experience, they can also learn about the functional properties of food by observation. Monkeys who observed a person raking a grape with a stick learned to represent the stick as a tool, and those who observed a person eating a pink Play-Doh ball learned to represent this object as food. Second, observational learning is a robust process, which can take place even when a monkey observes a demonstrator of a different species (a human) acting on an object that is entirely artificial (Play-Doh). Third and most important, monkeys show different patterns of attention, and therefore generalization, to the features of objects in different domains. Presented with Play-Doh objects that are used as food, monkeys generalize their learning to new objects of the same color and different shapes. Presented with Play-Doh objects that are used as tools, monkeys generalize their learning to new objects of the same shape and different colors. These findings closely resemble those obtained in our studies of human children (Santos et al. 1999), who generalized from one object to new objects by color when the object was presented as food and by shape when the object was presented as a tool. Like humans, monkeys represent and reason about objects differently in different domains.

The data presented here suggest that human and nonhuman primates share important similarities in the way they categorize objects in two different domains.[3] Adult monkeys and human children recognize that the properties that are important for categorizing food objects are different from those that are important for categorizing artifacts. These findings suggest that at least two domains of human knowledge are shared with other primate species.

While these results provide an important first step toward understanding what other species know about different kinds of objects, more work is needed to assess the deeper similarities between human and nonhuman reasoning in different domains. For example, when human children reason about an artifact, they often take into account its intended history, the function for which it was originally designed (see Bloom 1996). Given that no nonhuman animals create tools as extensively and flexibly as humans do, it is important to ask whether any nonhuman animals share our intuition that an artifact's original purpose is important for its current use.

Further questions about human categorization of objects are suggested by our studies of nonhuman primates. For example, when learning whether an object is edible, nonhuman primates pay attention to the behavior of other individuals and particularly, whether another individual eats a novel food (see Santos et al., 2001). Do human children similarly use the eating behavior of other animals, human and nonhuman, to help them categorize food objects? An examination of questions like these will provide a richer understanding of the deeper similarities and differences between human and nonhuman domains of knowledge, and of the contributions of our phylogenetic history and ontogenetic experience in the development of these knowledge systems.

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Notes

1. Surprisingly, chimpanzees tested on a comparable task fail to appreciate this distinction (Povinelli 2000).

2. The only artifact the monkeys on Cayo Santiago have regular contact with is a food trough that holds the chow that they eat.

3. Human children and nonhuman primates also share an understanding of other domains of knowledge. These at least include the domain of animate objects (see Gelman 1990; Hauser 1998; Mandler and McDonough 1993; Santos and Caramazza, in press), spatial navigation (see Cheng 1986; Cheng and Gallistel 1984; de Ipolyi et al. 2001; Hermer and Spelke 1996; Wang et al. 1999), number (Hauser and Carey 1998; Hauser et al. 1996; Wynn 1998), and some of the building blocks of a theory of mind (see Hare and Wrangham, chapter 44 in this volume).

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