Cognitive Development and the Understanding of Animal Behavior

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Introduction

A 2-year old child at the forest edge encounters a strange object moving along a leaf. Elongated and green, the object changes shape in a fluid way, one end rising, bending and contorting in the air as it reaches the edge of the leaf, then lowering back down and continuing its undulating motion along the leaf’s edge. Some things about this thing the child does not understand: what it is called, what it eats, whether it is harmful. Other things are clear to the child, even at this age: the thing is alive; it is probably a “bug” of some kind, either worm or insect; when it moves, it moves with purpose, in the direction that its sensory apparatus takes it, lifting its head when it reaches the end of the leaf to sample its surroundings before moving on. None of these things is written in the movement or features of the object itself, but rather are inferred by the child. She observes the moving object from a distance, fascinated, and cannot help but try to figure out what this new creature is up to.

Parents and others who interact with young children frequently observe that they show an intense interest in animals. Children want to know what animals are called, how they are categorized, where they live, what they eat, how they stalk their prey, why they have stripes or whiskers or rattles on their tails, and so on. Most of us have encountered children whose expertise on these matters rivals or even outstrips our own: a child who knows the difference between a rainbow wrasse and a bluehead wrasse, or which of Ceratosaurus and Hadrosaurus was a predator. From a certain perspective, this is quite odd, given that the kinds of activities that our children actually engage in during their day-to-day lives have little to do with live animals, at least wild ones. Children’s interest in the details of animal biology and behavior is often, if not usually, far out of proportion to what the actual ecological usefulness of this information will be for them. Children in industrialized countries are very unlikely to encounter wild lions, jaguars, crocodiles, or sharks, and they are unlikely indeed ever to encounter a Tyrannosaurus rex. Why, then, are children’s cognitive resources so devoted to an understanding of animals and their behavior?

An evolutionary developmental perspective might help to shed light on this question. As in evolutionary psychology in general, an evolutionary approach to children’s understanding of animal behavior begins with the supposition that mechanisms
shaping children’s cognitive skills evolved to solve adaptive problems they faced in ancestral environments, and tries to deduce through a combination of the logic of adaptive design and empirical evidence what these mechanisms might be. Because encounters with animals loomed larger in children’s lives in the past, it is perhaps not surprising to discover that animals loom large – perhaps “irrationally” so – in the minds of modern children. But an adaptationist perspective on this question implies and demands more than the mere observation that children should be interested in animals. It is a source of hypotheses about the design of the cognitive machinery and knowledge stores responsible for children’s thinking about animals. While much was known about the cognitive development of children’s understanding of animal behavior prior to widespread adoption of evolutionary view, an evolutionary perspective not only helps us to organize what we already knew, but to point us in new directions that have only begun to be explored. This chapter will review our present state of knowledge about children’s understanding of animal behavior, and will attempt to organize this knowledge into a broad picture of how the cognitive system that children bring to bear in understanding animal behavior – what I refer to as the *agency system* – is organized.

**Mechanisms and Domains in Development**

All of the mechanisms involved in acquiring and constructing knowledge and cognitive skills in children have evolved functions; the problem is merely discovering what they are. In the case of the cognitive development of the understanding of animal behavior, as for any domain of cognition, the underlying mechanisms can in principle be sorted into several categories: (1) those whose proper (evolved) function is specifically related to knowledge acquisition and inference about animal behavior *per se*; (2) those whose proper function is broader but is applied, in particular cases, to cognitive development of animal knowledge (e.g., mechanisms of working memory, object individuation mechanisms in the perceptual system, word parsing mechanisms, and so on); and (3) those that are being applied to problems specifically outside their proper, evolved domain (e.g., mechanisms evolved for making inferences about conspecifics that are then applied to non-human animals). Here, the distinction between *proper* domain and *actual* domain is relevant: a mechanism’s proper or evolved domain is the set of inputs that the mechanism was designed by natural selection to process, whereas a
mechanism’s actual domain is the set of inputs that it actually processes (Sperber, 1994). For example, a mechanism designed to process information about living, animate agents might process information about automobiles, because they emit cues that satisfy the device’s input conditions, even though they are not part of its proper domain (Barrett, 2001).

In the case of cognitive development of the understanding of animal behavior, all three kinds of mechanisms described above are involved. However, when trying to get a sense of how cognitive development in a particular domain is organized, it is useful to begin by asking: what are the adaptive problems associated specifically with this domain, and what kinds of mechanisms might have evolved to solve them? For some domains (chess, for example) it may well be the case that there are no evolved mechanisms specific to that domain, and that problems in that domain are solved by mechanisms evolved for other purposes. For others, e.g., speech processing, there might well be mechanisms specific to that problem domain. Whether there are, of course, depends on factors such as whether or not the adaptive problem in question existed over sufficient periods of time and space during our evolution, whether the ability to solve it had an impact on fitness, and so on (Tooby & Cosmides, 1992). What about children’s understanding of animal behavior? What are the relevant adaptive problems, and might we expect specialized cognitive machinery to solve them?

Before turning to this issue, it is important to note that “understanding of animal behavior” should not really be regarded as a domain. Rather, the mechanisms involved in development and deployment of knowledge about animal behavior are manifold, and each mechanism has its own proper domain. Whether any correspond strictly to the actual biological category animal or non-human animal is an empirical matter, and many certainly do not. For example, there are mechanisms whose proper function is to make inferences about animate agents -- objects capable of goal-directed action -- the proper domain of which includes any such object, including both human and non-human animals, but not all non-human animals (i.e., animals that do not exhibit goal-directed action, such as corals). Defined from a biological perspective, humans are of course animals, and therefore all of the mechanisms of social cognition are technically mechanisms whose proper function is the understanding of animal behavior. From this
perspective, if one were to plot the ideal boundaries of domains in terms of sets of objects using Venn diagrams one would draw concentric circles, with, for example, the circle representing animal-specific mechanisms completely containing the circle representing human-specific mechanisms. However, this tidy, logical nesting (e.g., all humans are animals, therefore, all inferences general to animals should also be applied to humans; all inferences about humans are also inferences about animals; and so on), while “philosophically correct,” and indeed, phylogenetically correct, might not be reflected in the workings of the mind, which evolved not to satisfy the criteria of philosophers or biologists, but rather, the exigencies of survival and reproduction (Boyer & Barrett, in press).

Rather than conceiving of domains as sets of objects in the world or as categories defined by objective scientific criteria, domains should be conceived as input conditions for computational devices, where the inputs to a device include the information necessary to solve the computational problem to which it is dedicated, i.e., which it evolved to solve. We may well decide to describe some mechanisms or systems as having “animal behavior” as their proper domain, but this language is only permissible if we insist on cashing out the term “animal behavior” in terms of the specific triggering conditions and information inputs to the system (e.g., certain types of motion representation in the visual cortex, propositions referring to intentional agents) rather than the scientific or folk concepts to which the term “animal behavior” refers.

**Animals as Selective Agents**

On a priori grounds, why might we expect children to exhibit any understanding of animal behavior at all? In other words, why would there be any reliably developing aspects of cognition about animal behavior, or any mechanisms specifically dedicated to making inferences about it?

To begin with, it is certainly uncontroversial that non-human animals have been present in the environments that humans have inhabited over the course of evolutionary history. But this simple observation can be refined and expanded to produce a variety of insights about the adaptive problems that animals posed for children and adults in the past. When we look at modern foraging societies, we see that there are several ways in which humans regularly interact with animals. First, there are animals that pose a threat
to humans, which can be subdivided into several categories. There are animals that prey on humans, such as tigers and leopards, animals that are dangerous because of their aggressive behavior, such as hippos and cape buffalo, and animals that are dangerous because of their formidable weapons of self-defense, such as poisonous spiders, snakes, and scorpions. These animals pose threats to humans today wherever their habitats overlap, and are likely to have done so in the past (Barrett, 1999, Kruuk, 2001).

The second way in which humans regularly interact with animals is as food. Hunting is a subsistence practice in existing pre-agricultural societies, is practiced by our closest evolutionary relatives, chimpanzees, and the archaeological record suggests that meat has been an important part of human and hominid diets for millions of years (Stanford, 1999). Humans and non-human animals may also have interacted in the past as competitors for food (Brantingham, 1998). Finally, there is the practice of keeping wild animals as pets or for food, practiced in many traditional societies today, and more recently, domestication, which is known to have shaped not only the morphology and physiology of domesticated species but also their cognitive skills (Hare, Brown, Williamson, & Tomasello, 2002), and may have also had an impact on human evolution.

Of these various modes of interaction with animals, the most important are likely to have been interactions with predators and other dangerous animals, and interactions with prey. For young children, interactions with dangerous animals, and decisions and behavior that influenced the likelihood of such interactions, are likely to have been of the greatest importance with respect to fitness. Interactions with prey, on the other hand, would have been less important for younger children than for older children. In traditional societies today, such as the Shuar of Ecuador, children begin to participate in subsistence activities involving prey (e.g., fishing) as young as age 4 or 5. However, such activities crescendo throughout childhood, and true hunting, in which knowledge of animal behavior is likely to play a major role, becomes important in later childhood. This suggests that there may be a difference in the developmental trajectories of predator knowledge and prey knowledge. Early acquisition of knowledge about prey behavior may serve more of a preparatory role, organizing knowledge for later use, whereas early acquisition of knowledge about the behavior of predators and other dangerous animals may have direct utility for children even at early ages. For example, even though a 4-
year-old Shuar child might not be able to fend off an attacking anaconda in a direct encounter, knowledge that anacondas tend to hunt near riverbanks could have major fitness benefits for the child.

What kinds of cognitive problems would animals have posed for children in the past? In other words, what burdens would animals, be they predators, prey, or otherwise, have placed on children’s developing information-processing capacities? Because of the adaptive importance of predator avoidance for children I will focus here on predators and other dangerous animals as examples, but the same logic applies to other categories of animal as well.

In principle, one can identify two broad classes of problem that animals (as well as any other category of things in the world) would have posed for children: problems of prediction, or inference, and problems of knowledge acquisition, or learning. Here, I will use prediction and inference interchangeably to refer to the use of observed or known information (perceptual cues, propositional utterances or other representations, conceptual knowledge, etc.) to produce new representations – inferences, guesses, deductions – that were not previously known to be true. The major fitness-relevant problem with this class of cognitive operation is that the results are uncertain. I might infer or predict that a predator in a particular situation is not going to attack, and yet be wrong. Natural selection shapes the mechanisms responsible for such inferences and predictions as a result of their fitness outcomes, iterated over populations and generations, leading to mechanisms that are more likely to make correct inferences, or more specifically, fitness-promoting inferences (in general, correct inferences tend to promote fitness more than incorrect ones, but there are many possible correct inferences that would have no effect on fitness). The result of the evolutionary process is mechanisms that are increasingly predisposed to attend to, acquire, and use causally relevant information about animals, and to disregard or discount types of information that have tended to have poor predictive power over evolutionary time. Because predictive inferences make use of both databases of acquired information (knowledge) plus a variety of cognitive capacities that process this information, natural selection will act on the many systems evolved so that they interface effectively and embody principles or rules that are “ecologically rational” in the sense of being well-fitted to the causal structure and
statistical regularities of animal behavior (Gigerenzer & Todd, 1999; Tooby & Cosmides, 1992).

With these considerations in mind, let us examine the specific skills relevant to understanding animal behavior that one might expect natural selection to have favored in children. These range from the ability to distinguish things that behave (animals capable of movement) from things that cannot (non-mobile animals, plants, non-living things), to the ability to sort and categorize animals for different purposes (e.g., to categorize animals into taxa based on relatedness, or into functional categories such as predators), to knowledge about the ecology and behavioral dispositions of particular taxa, to the ability to predict animal behavior on the basis of inferences about goals, intentions, beliefs, and other internal states. Many of these skills, such as the ability to distinguish agents from non-agents, are not unique to humans. Others, such as the ability to predict behavior based on beliefs, may be uniquely present, or at least uniquely elaborated, in humans. Because the problem of understanding and predicting the behavior of predators and prey is composed of many subtasks, each with its own computational demands, the agency system is comprised of multiple components, each of which I will review in turn.

**Distinguishing Animals from Non-Animals: Agency Detection**

In order to make inferences, organisms must make distinctions between different kinds of things in the world. At minimum, this is because there must be a fit between any given inference procedure and the target of inference, in order for inferences to be systematically correct. For example, applying the same kinds of inference to rocks or water that one applies to living things would lead to systematically invalid inferences. Living things share properties that rocks, water, and other non-living things do not. Moreover, an organism that failed to distinguish between its mother, a predator, and a rock and to behave differently towards them would soon be dead. This is why natural selection equips organisms with *intuitive ontologies*: means of sorting the world into kinds that share properties relevant for inference (Boyer & Barrett, in press).

A substantial literature in infant development suggests that basic ontological categories or distinctions emerge early in infancy (Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wellman & Gelman, 1992). The category of things with which we are concerned here is animals, and specifically, of animals that “behave,” i.e., that exhibit
goal-directed activity. From an evolutionary perspective, the benefits of distinguishing things that behave from those that do not are manifold. In the developmental literature, entities that are capable of acting in a goal-directed fashion (which are a subset of both living things and animals) are called intentional agents, or agents for short. A growing body of research has begun to explore agent-specific information processing systems in the brain (Gergely, Nádasdy, Csibra, & Bíró, 1995; Johnson, 2000; Leslie, 1994; Rakison & Poulin-Dubois, 2001). From the perspective of these systems, the understanding of animal behavior is synonymous with the understanding of the behavior of agents (including humans): the various inference systems used for understanding animal behavior are restricted to this class of entities and to no other. Agency detectors can be regarded as filters that admit information about animals to cognitive processes further downstream and block information about non-agents (Kurzban, 1996). This implies that animals that do not behave, including dead animals, are dealt with by other systems, i.e., systems for handling inanimate objects and substances (Barrett & Behne, under review).

Perhaps the most fundamental and phylogenetically ancient adaptive problem with respect to agents, then, is discriminating between things that are agents and things that are not. The costs of failing to make this discrimination are potentially quite large, and there may be asymmetries in costs of errors of different kinds, with failure to detect agency usually being more costly than mistaken attribution of agency (Guthrie, 1993; Haselton & Buss, 2000). One might therefore expect natural selection to have favored perceptual mechanisms that use reliable cues to agency to perform this discrimination task. Is there evidence for such mechanisms, and what cues do they use to discriminate agents from non-agents?

**Self-Propelled Motion**

The developmental literature suggests that there are several pathways to distinguishing agents from non-agents. Perhaps the most obvious feature that distinguishes agents from non-agents is the ability to move, or self-propelled motion, as opposed to motion caused by an external force. There is evidence that the perceptual system contains self-propelled motion detectors that distinguish between motion that has no obvious external cause, and motion caused by an external event such as a collision,
and that uses self-propelled motion as a cue to agency. Early work by Michotte (1963) showed that a moving shape on a screen “colliding” with a stationary one that is then “launched” produces a strong perception of causality. A qualitative change in how causality is perceived occurs when the first shape does not contact the second one prior to launching, and even infants are surprised when there appears to be no direct transmission of force, i.e., when the object appears to react at a distance (Leslie & Keeble, 1987). Since these initial studies, a variety of studies have shown that self-propelled whole-body motion is an important cue to agency (Rakison & Poulin-Dubois, 2001; Scholl & Tremoulet, 2000). There are several important components to such motion, including simple initiation of motion in the absence of external cause (Leslie & Keeble, 1987, Premack, 1990), change of trajectory without apparent external cause (Tremoulet & Feldman, 2000), and apparent “goal-directedness” of the motion (Opfer, 2003). The latter has been of interest since classic studies by Heider and Simmel (1944) showing that adults spontaneously attribute goals and other intentional states to self-propelled shapes moving on a screen, and a variety of studies have since tried to quantify “goal-directedness” more precisely, exploring the cues that are used to infer what a moving agent is trying to do (see, e.g., Abell, Happé, & Frith, 2000; Blythe, Todd, & Miller, 1999; Gergely et al., 1995).

In addition to whole-body motion, other types of motion cues may be important cues to agency as well, such as changes in object shape in the absence of external cause, or “nonrigid transformations,” such as breathing, postural changes, etc. (Gibson, Owsley, & Johnson, 1978; Johnson, Booth, & O’Hearn, 2001). An infant dishabituation study by Gergely et al. (1995) included breathing-like expansion and contraction of objects prior to whole-body movement, which may be a factor in triggering an agency mode of construal, although not strictly necessary (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999). A variety of experiments have also shown that children and adults are able to identify both moving humans and non-human animals from point-light displays, i.e., from stimuli in which all cues are removed except points of light attached to limbs and other body parts (Bertenthal & Pinto, 1994; Mather & West, 1993). These studies suggest that certain properties of the motions of animals, such as coordinated movements of
limbs, oscillation around a center of gravity, and so on, can be used to distinguish animals (agents) from objects whose movement is not biological in nature.

**Contingency and Distant Reactivity**

Another feature that distinguishes agents from non-agents is the ability to engage in contingent and reciprocal interactions with other agents (Johnson, 2000). This may also be thought of as the reactivity of agents to distant external stimuli, i.e., distant reactivity (Boyer & Barrett, in press). There are several ways in which such behavioral contingency might manifest itself. For example, agents might exhibit contingent whole-body motion trajectories, as when a predator pursues its prey and modifies its trajectory to match that of the prey (Barrett, 1999). Contingent motions might take the form of contingent gestures, movements, or facial expressions, as when one agent’s gaze follows the gaze of another, or when one individual’s fear evokes fear in another (Baron-Cohen, 1995). Contingency might also take the form of communicative interaction, as when one agent makes a sound in response to a sound made by another (animal calls; human vocal utterances; etc). A series of experiments by Johnson, Slaughter, and Carey (1998) suggests that even in infancy, contingent behavior is a powerful cue used to discriminate agents. Johnson et al. used a gaze-following paradigm to measure infants’ categorization of objects as agents, where following the “gaze” of a stimulus object was taken as an indication that the object had been categorized as an agent, and failure to follow gaze indicated that the object had not been so categorized. Johnson et al. found that triggering the agency system depended both on contingency of the object’s behavior on that of the infant (in this case, beeping contingently in response to sounds produced by the infant) and presence of a face. These results were extended by a later study showing that imitation of goal-directed behavior and communicative gestures occurred only for objects that had a face and interacted contingently with the infant (Johnson et al., 2001).

Interestingly, the objects in both studies were categorized as agents on the basis of face and contingency cues despite the fact that they did not look at all like people and only vaguely like animals (they were furry, oblong blobs). This suggests that from the perspective of the agency system, agent is synonymous with behaving entity, or animal, rather than with human, even in young infants (Johnson, 2000).
**Morphology**

Because the defining feature of agency is the ability to engage in goal-directed behavior, motion is of primary importance in agency detection. However, there may be other, non-motion cues that are reliably correlated with agency. For example, as suggested by studies by Johnson et al. (2001), presence of a face or face-like cues, even static ones, may play a role in triggering the agency system. For example, the presence of eyes may be an important cue to agency (Baron-Cohen, 1995; Coss & Goldthwaite, 1995). In very young infants, a very simply stimulus array with eye, nose and mouth spots arranged in the pattern of a face draws infant attention, whereas the same objects arranged in a different spatial pattern does not (Morton & Johnson, 1991).

Other morphological cues may also be important in distinguishing animals from non-animals and perhaps in triggering the agency system, including asymmetry along one axis, the presence of four legs, a head, teeth, and so on, though none of these proposals has been tested to date (Baron-Cohen, 1995; Premack, 1990). Some specific types of animals have characteristic features that can be used both to identify them as agents, and to discriminate them from other kinds of agents. For example, snakes are a class of agents that have a particular morphology (shape), as well as a characteristic movement pattern, that can be used to identify them, and there may have evolved perceptual “templates” specifically for this class of agent (Öhman & Mineka, 2001). Evidence for such templates exists in other species that exhibit fear responses to predators despite being isolated from them for many thousands of years (Blumstein, Daniel, Griffin, & Evans, 2000). Other cues, such as patterns of fur coloration for common predators such as leopards, might also be part of a recognition system (see Coss & Ramakrishnan, 2000). In humans, a variety of studies have shown that even infants are able to sort animals from non-animals (e.g. vehicles) on the basis of static morphological cues (Mandler & McDonough, 1998; Quinn & Eimas, 1996).

**Predicting and Interpreting Animal Behavior: The Agency System**

From the perspective of natural selection, merely categorizing objects as agents or non-agents is not enough. The reason that there exist elaborate perceptual systems for discriminating agents from non-agents is that they allow organisms to respond differently to agents than to non-agents. In the presence of agents, an elaborate cognitive system is
activated that brings to bear specialized judgment, inference, and decision-making skills that are tailored to the special properties of sentient, behaving things, including both humans and non-human animals. This cognitive system and its subcomponents are referred to here as the *agency inference system*, or the *agency system* for short.

The agency system, rather than being a single undifferentiated system or “black box,” is likely to have many components, each with its own proper domain, including some with domains that do not span the entire category of agents, and others that extend beyond it. In addition, there are systems that feed into and modulate the activity of the agency system, such as perceptual and emotional systems. In recent years, a variety of strands of research have begun to elucidate the design features of this system and its many components. Here, I will specifically focus on processes of inference about animal behavior, offering one possible account of how the agency system is organized.

Any given inference about the behavior of animals is likely to make use of many kinds of information. Imagine, for example, a child who sees her cat sitting on the kitchen floor, looking up at the cabinet where the cat food is kept, and meowing. The child infers from this that the cat wants to be fed. This seems a simple inference, but when one tries to reconstruct the inferential processes that lead from perceptual inputs (the visual and auditory cues the cat is emitting) to the final inference, one realizes that the inferential chain must be a complex one that integrates perceptual information with internal representations in a chain of several steps to produce the inferential output. Sub-inferences leading to the inference that “the cat wants to be fed” might include that the object in question is an agent, and a cat; that the cat is attending to, and perhaps referring to, the cabinet with its gaze and meows; that it knows or believes that there is food in the cabinet; that if it is referring to the food, it must be hungry, and so on. Clearly, many kinds of information must be integrated, and multiple mechanisms are involved.

In principle, one can identify at least three different types of inference that devices within an agency system might make: (1) inferences specific to particular *contexts* or *situations*, such as predator-prey interactions, social exchange, play, mating, behaviors such as sleeping, breathing, eating, and so on; (2) inferences specific to particular *categories* of agent, including taxonomic categories such as HUMAN, MAMMAL, BIRD, DOG, PARROT, and role categories such as PREDATOR, PREY, PARENT,
FRIEND, MATE, and so on; and (3) inferences specific to specific agents, including agents for which a permanent “identity file” is maintained, which are mostly humans but sometimes also certain animals, as well as agents that are being tracked during the course of a specific interaction, such as that dog who is watching me right now or the mouse that just ran under the fridge. Note also that inference devices not specific to the agency system must also interact with this system to produce complete inferences: for example, working memory may play a role in processing relevant information, systems for reasoning about objects and object permanence may be necessary to handle inferences about the position of agents in space, and so on.

Figure 1 shows one way in which the agency system can be conceptualized as an assemblage of mechanisms that carry out inferences of these various kinds to produce inferences about animal behavior. While there is often a tendency in cognitive science to think of mechanisms as organized hierarchically, it is at present an open question how these different mechanisms are organized with respect to each other (Figure 1 depicts one possibility). For our purposes, what matters is that each component of the agency system carries out a specific function and has its own proprietary domain (e.g., inferences specific to cats are not extended to dogs; inferences specific to predator-prey interactions are not extended to mating; and so on) and that complete inferences about animal behavior (e.g. the cat wants to be fed) are likely to make use of more than one type of inference mechanism, including mechanisms not specific to the agency system per se. In the following sections, I will review evidence for various subcomponents of the agency system.

**Context-Specific Inferences: Intentional Schemas**

Since Dennett’s (1987) influential volume on the intentional stance, it has come to be widely accepted that in understanding the behavior of agents (people and animals), both children and adults make use of intentional reasoning. To adopt the intentional stance with regard to an object is to implicitly assume that its behavior can be both explained and predicted as caused by unobservable internal states such as beliefs and desires, and that these states influence observable behavior in a manner that is directed towards some goal or intention. Currently, the term that is most widely used to refer to the inferential apparatus that instantiates the intentional stance in children and adults is
Some authors prefer to reserve the term theory of mind to refer only to types of inferences involving belief attribution, i.e., attribution of “epistemic” states, as opposed to inferences about non-epistemic states such as desires, which would not necessarily require the use of theory of mind (see Baron-Cohen, 1995; Wellman, 1990). While this distinction is an important one, here I will use the term agency system, rather than “theory of mind,” to refer to the set of inferential procedures involved in making inferences about intentional agents, because many of the types of inference discussed here do not require attribution of epistemic states (a capacity that some authors claim is unique to humans).

According to theorists of the intentional stance, in order to either explain or predict the behavior of an agent in a particular situation, it is necessary to attribute a goal to that agent, which in turn requires an inference from the agent’s observed behavior. For example, to make sense of John’s going to the refrigerator and opening it, we might attribute to John the goal of getting food, along with the desire-like state HUNGER, which (we assume), when present in an organism, leads it to attempt to achieve the goal of finding food. This set of inferences makes use of “theory-like” information about hunger. Each of us has a (mostly implicit) “theory” or “concept” of hunger – it might also be called a “hunger schema”– that contains inferential principles such as: hunger is not present immediately following a meal (i.e. a meal satiates hunger); hunger increases with time since the last meal; the greater an organism’s hunger, the more it will attempt to seek food; and so on (encoded, of course, in a language of conceptual primitives or computational rules rather than in natural language, as depicted here). One might think of the “hunger schema” as a miniature conceptual structure or inference system, activated in certain conditions (e.g., when an organism is observed interacting with or seeking food), and with specific inferential outputs that are applied only in certain situations. As discussed below, there are likely to be many such schemas.

At what age do intentional schemas, and the ability to make inferences using them, develop? Gergely, Csibra, and colleagues (Gergely et al., 1995; Csibra et al., 1999) have demonstrated that from an age as early as 9 months, infants are able to use intentional schemas to make predictive inferences about the behaviors of agents. To demonstrate this, Gergely et al. (1995) used a dishabituation paradigm, which measures...
infants’ surprise at events they were not expecting in order to assess predictive intuitions, as follows. Infants were “habituated” to a repeated display, in this case, a depiction of two objects on either side of a barrier, seen in side view. The objects displayed contingent behavior in the form of expansion and contraction, one object in the response to the other. Following this, one object was seen to approach the barrier, “jump over” it, and finally reach the other object. Gergely et al. hypothesized that this sequence would lead infants to infer that the moving object had the goal of reaching the other. In other words, something like an “approach schema” is activated. Part of this intentional schema, according to Gergely et al., is the assumption that an agent will take the shortest possible path to reach its goal. This assumption generates implicit predictions about the motion trajectory of an object, predictions that can then be violated. Gergely et al. demonstrated the existence of an approach schema in infants, and that this schema had been activated by the motion sequence just described, by observing infants’ reactions to schema violations, i.e., violation of the assumption of shortest path to goal. When infants were shown the identical “jumping” motion trajectory without an intervening wall, the infants dishabituated: they were surprised that the approaching agent would jump when no wall was present. In other words, they were surprised by the schema violation. In contrast, infants did not dishabituate when the agent approached the other agent in a straight line – consistent with the approach schema – despite the fact that the infants had not previously seen this particular trajectory.

These results are important not only because they establish that infants are capable of taking the intentional stance with regard to objects as early as 9 months (and perhaps earlier, if appropriate means of testing can be found), but also that the infants in this study used a particular schema to infer the likely behavior of an object, i.e., that it would take the shortest path because it was trying to reach, or had the goal, intention, or desire of reaching, the other object. One can further speculate that the schema involved is a social one rather than, e.g., a predator-prey schema, because both agents “signaled” contingently towards each other prior to approach, and the approached agent did not attempt to flee or evade the approaching agent. In later work, Csibra and colleagues (Csibra, Biró, Koós, & Gergely, 2003) have also found an early-developing pursuit-evasion schema that may represent the initial stages of predator-prey understanding.
Several other studies have documented the understanding of particular intentional
interactions using motion stimuli (Scholl & Tremoulet, 2000).

Developmentally, the ability of 9-month-old infants to adopt the intentional stance
with respect to particular objects is only the beginning of a long trajectory leading to the
full-blown theory of mind capacities, including the ability to engage in multi-leveled
metarepresentational inferences, that are present in older children and adults. A large and
extremely rich literature in developmental psychology documents the emergence of
theory of mind during childhood (for reviews, see Baron-Cohen, 1995; Mitchell & Riggs,
2000; Wellman, 1990). Because comprehensive reviews of this literature exist elsewhere,
the large literature on theory of mind and its development will not be reviewed here. This
does not mean, however, that theory of mind abilities are not relevant to children’s
understanding of animal behavior. Indeed, as suggested above and argued by Johnson
(2000) and others, many of the mechanisms involved in making mentalistic inferences
about human behavior may have, as their proper domain, all intentional agents, including
human and non-human animals.

Most current theories of ToM postulate some kind of content-general conceptual /
inferential apparatus into which specific intentional contents, equivalent to what I am
calling schemas, can be slotted (Fig 1). For example, Baron-Cohen’s model of theory of
mind involves four components: an Intentionality Detector (ID), Eye Direction Detector
(ED), Shared Attention Mechanism (SAM), and Theory of Mind Mechanism (ToMM)
(Baron-Cohen, 1995, this volume). Each of these mechanisms has a particular function:
note, for example, that the proposed function of ID is approximately the same as that of
the set of mechanisms described in the section on “agency detection,” above. The
function of ToMM is to handle representations involving epistemic states such as
knowledge, belief, and pretense. Leslie (1994) proposes a similar system, though
functionally differentiated along slightly different lines, with his ToMM system1 being
responsible for inferences regarding “agents and action,” e.g., inferences of the sort
described in the Gergely et al. experiments above, that do not require attribution of
epistemic states, and ToMM system2 being responsible for inferences about “agents and
attitudes,” e.g., agents’ beliefs about or representations of states of affairs in the world, or
epistemic states.
Accounts involving relatively content-free inferential devices into which can be slotted more content-specific information presuppose, even if implicitly, the existence of something like intentional schemas, or at least quasi-theory-like information about specific intentional states and how they influence the behavior of organisms. It is important to note that simply “having an intentional stance” is useless without specific intentional or goal schemas of the sort described here. Having the intuition that John’s refrigerator-opening behavior is caused by internal states – even with a mechanism like Baron-Cohen’s ToMM or Leslie’s ToMM₂, which contain a slot for John’s belief about what is in the refrigerator – is useless unless one has principled knowledge about particular kinds of intentional states (in this case, hunger, or the intent to eat) and the behaviors and subgoals associated with them (food search, change in mood, and so on).

From an evolutionary perspective, it is not implausible to assume that the basic set of intentional schemas that are part of children’s and adults’ capacity to reason about animal and human behavior have been shaped by natural selection, albeit perhaps in skeletal forms that are then fleshed out by experience (see Mandler, 1992, for one such proposal). How many schemas might one expect, and which schemas would one expect to be reliably developing in the human cognitive architecture? Here, one expects conceptual structure to capture something of the causal structure of animal and human minds themselves, with a particular intentional schema for each internal state that has distinctive causal properties that influence behavior. Intentional states are likely to be something like “natural kinds” that recur across organisms, and that cohere due to causal regularities across different tokens or instantiations of the kind. For example, HUNGER is a state, both physiological and psychological, that leads organisms to act in particular goal-directed ways, and there are commonalities between organisms in how they behave when hungry. BELIEF is an epistemic state with variable contents that influence the goal-directed behavior organized by motivational states like hunger and fear.

The inferential power of such conceptual primitives depends on causal links between the primitives in the system, ultimately leading to inferences about behavior: for example, knowing or believing that a predator is present leads to fear, which leads to escape behavior, with the goal or intent of avoiding capture. In other words, individual conceptual primitives are assembled into larger interaction or situational schemas, such
as the approach schema (Gergely et al., 1995), the predator-prey schema (Barrett, 1999), or others involving mate choice, kin interactions, social exchange, and so on (Tooby & Cosmides, 1992, Fiske, 1991).

Consider, for example, the predator-prey schema. Barrett (1999) hypothesized that the recurrence of interactions with predators and prey over human evolutionary history would have selected for a reliably developing understanding of predator-prey interactions in the form of an inference system or schema containing inferential principles for predicting predator and prey behavior using the intentional stance. Such a system would play a role not only in guiding children’s real-time decisions, for example, concerning where and when to play, but also would serve a preparatory function for later childhood, when foraging activities bring children into more frequent contact with predators and prey. Csibra et al. (2003) found evidence for early development of a pursuit-evasion schema. Later in childhood this is elaborated into a full-blown conceptual schema that children use to reason about predator and prey behavior. A study in which children were asked to play out an imaginary predator-prey interaction using animal models found that by age 4, children reliably attribute the goals of prey capture and predator evasion to predator and prey respectively, and use these goals to accurately predict the responses of predator and prey to each others’ behavior, as proposed by the predator-prey schema hypothesis. Identical results were found both for city-dwelling children in Berlin, Germany, and rural children among the hunter-horticulturalist Shuar of Ecuador (Barrett, 1999; Barrett, Cosmides, and Tooby, under review). Furthermore, children understood that encounter with a predator can lead to death, and were able to make realistic judgments about the behavioral consequences of death, i.e., that the ability to act ceases at death, and that this is irreversible. These results were confirmed by a follow-up study (Barrett & Behne, 2001).

Keenan and Ellis (2003) propose that there might be two distinct systems for dealing with predators and prey: a predator-avoidance system and a prey-capture system. Under this account, the predator-avoidance system develops early, whereas the prey-capture system develops relatively later, because the fitness benefits of the latter system do not accrue until later childhood, whereas predator avoidance is important even for young children. An asymmetry in development of the ability to reason from the
perspective of predators versus prey was also suggested by Barrett (1999) and hinted at by results (Barrett et al., in preparation) showing that young children more often infer malicious intent in predators than fear in prey (perhaps because it is more useful for a prey animal to infer the intentions of a predator than to infer its own intentions; therefore, children exhibit less uncertainty about predator intentions).

Whereas Barrett’s (1999) predator-prey schema theory proposes that attribution of mental states is part of the design of early developing systems for reasoning about predators and prey, Keenan and Ellis’ theorizing about the predator-avoidance system does not explicitly address the mental states of predators and prey. Rather, Keenan and Ellis conceptualize the predator-avoidance system as constituting basic decisions rules, such as “prey move away from predators,” that, when activated by relevant content, function to reduce the probability of predation. As a result, Keenan and Ellis propose that activation of the predator-avoidance system generates fast, prepotent responding that can impair mental state reasoning in cases where, for example, children are asked to make inferences about prey moving towards a hidden predator about whose location the prey has a false belief, but the child does not. The same impairment should not occur for prey stalking scenarios, argue Keenan and Ellis, because the prey-capture system has not yet developed in young children and thus does not generate comparable prepotent responding. Using the false belief task, a method that requires prediction of an agent’s behavior on the basis of a belief whose content differs from that of the true state of the world (see Wellman, Cross, and Watson, 2001, for a recent review), Keenan and Ellis found that ability to correctly attribute false belief was significantly higher in playmate-avoidance conditions than in predator-avoidance conditions, when the false belief would lead to the protagonist approaching a hidden playmate or a hidden predator, respectively, and that activation of a prey-seeking scenario did not result in a similar impairment. These results are consistent with the proposal that activation of the predator-avoidance system interferes with the outputs of a mental state reasoning system, and that the predator-avoidance system develops earlier than a prey-capture system. It is also possible that children have difficulty with scenarios that require them to predict that a character will act to destroy itself, predator encounter being one such scenario. An important topic for future research will be to examine the nature of the underlying mechanisms involved
in behavior prediction about predators and prey, to determine whether there are distinct mechanisms for predator and prey scenarios or a single system, and to determine the nature of the inputs and representational formats the system uses (e.g., whether predator and prey intentions and mental states are part of its proper domain).

Descent and Design in the Understanding of Behavior

In the study of children’s understanding of animals, there has been considerable research on children’s understanding of biological functions, such as growth, reproduction, breathing, and so on. These are design features of living things which, while not intentionally caused, are relevant to behavior. It is currently a matter of contention just how much the intentional stance is used by children to interpret biological functions such as these (see Carey, 1985; Inagaki & Hatano, 2002; Medin & Atran, 1999). Some researchers, such as Carey (1985), suggest that children’s early understanding of biological functions in animals makes use, by analogical mapping, of children’s understanding of intentionality, because children have no “autonomous” or core domain of biological understanding. Others, such as Inagaki and Hatano (2002) propose that children’s early understanding of biological functions is “vitalist”: that children implicitly or explicitly represent some “vital force” that is responsible for processes such as growth, but that is not under intentional control of the animal (agent) in question.

Barrett (2001, in press) has argued that because two distinct processes shape the distribution of traits across organisms – inheritance of traits by descent, and modification of traits by design – descent and design relationships may play distinct roles in the understanding of animal behavior. For example, taxonomic categories such as MAMMAL, BIRD, RODENT, or HUMAN might serve to constrain inferences about behavioral regularities common to members of the taxon but not shared by species or individuals outside the taxon (see Atran et al., 1999; Carey, 1985; Markman, 1989 for reviews of studies of taxon-based inference). Doing so is ecologically rational (Gigerenzer & Todd, 1999) in that many traits, such as live birth, are shared within a taxon such as mammals due to descent from common ancestors. Other categories, such as PREDATOR, are ecological in nature, defined by particular goals or adaptive problems, and not confined to particular taxa. Predators in many taxa possess similar adaptations.
due to convergent evolution, and there are many inferences about behavior that are better predicted by membership in the category PREDATOR than in a particular taxonomic category (e.g., traits that eagles and caimans have in common that sparrows do not). Distinct descent and design modes of reasoning about behavioral and other traits appear to be present in children by early childhood (Gelman & Markman, 1986; Kelemen, 1999). In a recent study, Barrett (in press) found that Shuar children reason differently about properties shared by descent in closely related taxa and properties shared by design in convergently evolved but more distantly related predator taxa. Predators therefore appear to represent a special category of inductive inference, standing out against a general background of taxonomy-based inference that is relatively insensitive to the functionality of traits. These results are even more striking in light of Shuar children’s relative lack of exposure to modern biology and Darwinism, suggesting an intuitive rather than explicitly educated basis for the observed patterns of inference.

**Anthropomorphism**

It is often assumed that anthropomorphism is common in both children’s and adults’ thinking about animal behavior (Guthrie, 1993; Mitchell & Hamm, 1997). In its most common usage, “anthropomorphism” refers to the attribution of strictly human traits (usually psychological and behavioral traits) to non-human animals. A looser definition would be attribution of traits that are not strictly human to non-human animals, but this would render the etymology of anthropomorphism inappropriate because it would not be, by definition, human-centered (consider, for example, attribution of breathing to non-human mammals: it is human but not strictly human). For this reason, anthropomorphism as commonly conceived implies mistaken over-attribution. There are several sources for the claim that children anthropomorphize. First, there is the notion, advanced by Piaget, that children are “animists”: they see agency in the world where there is none, overattributing intentional causes to non-intentional phenomena. Piaget’s proposal was that young children have no explanatory framework or causal stance other than the intentional one, and so apply it where it is unwarranted (but see Guthrie, 1993, for a different account of overattribution as a form of error management; Haselton & Buss, 2000). This proposal was later refined by Carey (1985), who argued that children use their intuitive psychology to understand and explain purely “biological” (i.e. non-
intentional) phenomena, and moreover, that human psychology in particular is the source domain for children’s inferences about non-human animals. Again, the central notion is that the possession of an intentional stance, along with the fact that children are intimately familiar with human motivations, thoughts, and feelings, gives children a single conceptual brush with which they use to paint the world of living things. One consequence of humans being the anchor point for children’s inferences about animals, according to Carey, was her finding that rather than overattributing properties to animals, children tended to underattribute basic biological traits, such as eating, to animals that were perceived as dissimilar to humans (Carey, 1985). Although later studies cast doubt on the universality of these findings (Atran et al., 2001; Coley, 1995; Gutheil, Vera, & Keil, 1998), the general idea that children use humans as the source domain for inferences about animals retains an intuitive appeal. Indeed, it is widely held that adults do the same thing, not only in traditional cultures that do not have a formal, “non-anthropomorphic” vocabulary for describing animal behavior, but even among highly trained scientists, who are often accused of anthropomorphically overattributing mental states and abilities to animals (Mitchell & Hamm, 1997).

Interestingly, Hebb (1946) observed that, among scientists working with chimpanzees, those who used “anthropomorphic” terms to describe chimps’ behavior were often more successful at predicting their behavior than those who restricted themselves to non-anthropomorphic behavioral descriptions (e.g., “A got angry at B and attacked her” vs “A moved to and hit B on the head”; see also Mitchell & Hamm, 1997). This fits with the observation that “intuitive psychology is still the most useful and complete science of behavior there is” (Pinker, 1997, p. 63). As German and Leslie (2000, p. 230) note, “It is striking to reflect that the best efforts of several generations of the brightest research scientists have done so little to improve upon the ideas that are grasped effortlessly by every untutored 4-year-old, mostly before they can add two and two.” In other words, given that the proposed function of the intentional stance, the reason that it is a central part of our cognitive architecture to begin with, is to be able to predict the behavior of living things, it is not surprising that people spontaneously apply it to animals, and are more successful at predicting their behavior when doing so than when using more “objective” or supposedly uncolored scientific language.
The notion that follows from Hebb’s observation is that far from being a mistake, as assumed in Piaget’s notion of overextension, anthropomorphism may be a “good” thing to do in that it can lead people to make correct inferences about animal behavior. In the anthropological literature, this has been proposed many times in regard to hunters’ “personification” of animals in hunting societies (Blurton-Jones & Konner, 1976; Liebenberg, 1990; Mithen, 1996). For example, Mithen (1996, p. 168) writes that anthropomorphism is “universal among all modern hunters and its significance is that it can substantially improve prediction of an animal’s behavior. Even though a deer or a horse may not think about its foraging and mobility patterns in the same way as Modern Humans, imagining that it does can act as an excellent predictor for where the animal will feed and the direction in which it may move.”

These descriptions all presuppose that what people are doing when they attribute mental states to animals is, in fact, anthropomorphizing. But is it? Remember that the definition of anthropomorphism is the extension of strictly human traits to non-human animals. If one were to say of a dog, for example, that it is hungry, it would be strange to call this “anthropomorphizing,” because hunger is not a strictly human trait. It is often implicitly assumed that any use of the intentional stance or mentalistic inference with regard to animals is anthropomorphizing, but this in turn presupposes that the proper domain of the intentional stance is humans. As argued herein and by others (e.g., Johnson, 2000), the proper domain of the agency is likely to be all animals, or at least all animals capable of goal-directed activity, and only some subcomponents of the system are specific to humans (though these may be many, including all of the mechanisms of social cognition).

The conception of the agency system depicted in Figure 1 allows for a cognitively precise definition of anthropomorphism. Each component in the system has a proper domain, defined as the class of inputs the device evolved to process. Some devices in the system, such as agency detection devices, evolved to discriminate any kind of agent from non-agents. Therefore, when such devices are triggered by any animal, human or otherwise, no anthropomorphism is occurring. Similarly, many of the intentional schemas, such as the HUNGER schema described above, are not specific to humans, so use of such a schema to make inferences about the behavior of, for example, a dog,
would not be anthropomorphic. Anthropomorphism would occur when a mechanism whose proper domain is specifically humans – for example, a SOCIAL EXCHANGE schema (Tooby & Cosmides, 1992) – is activated by, or applied to, a non-human animal. According to the account presented here, each intentional schema is linked to the taxonomic inference system; there may be something like a “scope tag” (Cosmides & Tooby, 2000) that restricts the set of taxa to which that schema will normally be applied (e.g., HUNGER → all animals; SOCIAL EXCHANGE → humans only).

It may be that human-specific inferences are sometimes extended to non-human animals by mistake. A child might mistakenly think, for example, that the caterpillar that she is playing with is angry with her. But it might also be that human-specific inferences are sometimes extended to non-human animals in a “decoupled” or pretense mode (Cosmides & Tooby, 2000; Leslie, 1987), in which inferences can be entertained but are specially marked as being not literally true, and are therefore not allowed to propagate inferences through the system as they would if taken to be true. For example, a Koyukon hunter from Arctic North America may assert or believe that he is engaged in a social exchange relationship with the deer that he has just killed, thanking it and treating it with respect so that it will reincarnate and return as another deer (Nelson, 1983), but he is unlikely to believe or even consider all of the inferences that would logically follow if he were literally engaged in a social exchange with the deer. For example, if the deer were actually willingly sacrificing itself to the hunter, it would be unnecessary to pursue it; there would be no need for the hunter to conceal himself when approaching the deer; and so on.

There are several pieces of evidence suggesting that peoples’ thinking about animal behavior may be more nuanced than a simple anthropomorphism account would have it. In a study of American adults, Mitchell and Hamm (1997) examined subjects’ willingness to make attributions of jealousy and deception to humans and animals in different contexts. They found that subjects’ attributions of these states depended much more on contextual cues than on the actual taxa involved. In other words, what led subjects to attribute a state such as jealousy were features of the situation, regardless of whether the character being described was human or a non-human animal. Although this is consistent with an anthropomorphism account of mental state attribution in that
jealousy and deception might not actually occur in all of the taxa examined (otters, for example), it does not appear that subjects were basing their judgments on similarity to humans, psychologically or otherwise (Mitchell & Hamm, 1997). Rather, jealousy is attributed when it seems to best account for the behavior in question (aggression by a mate in the presence of a rival). In this sense, the adults in this study did not show the pattern found by Carey (1985) in children, with attributions declining as similarity to humans decreased.

Even in children, the use of humans as a source domain for the attribution of properties might not be universal. In a study of Mayan children by Atran et al. (2001), children did not show the human prototype effects reported by Carey for American children, but rather, extended traits on the basis of taxonomic relatedness. Gutheil et al. (1998), using a property extension task similar to that of Carey (1985), found that extensions of biological properties to animals by young children became more adult-like (i.e., less human-centered) when contextualized in terms of their function. Coley (1995) found that patterns of attribution of psychological traits differ for different kinds of animals, with some traits being more readily attributed to predators and others to domestic animals. This suggests that even young children have distinct mental models of what predators and non-predators are like. This is not easily explained on an anthropomorphism account, because different kinds of psychological properties should not dissociate unless there is an equivalent dissociation in humans. A study by Barrett, Cosmides, and Tooby (in prep; see also Barrett, 1999) is consistent with this claim, showing that over 60% of mental state attributions to predators and prey by 3 year olds, and over 80% of those by 4 and 5 year olds, were realistic and consistent with predictions of predator-prey schema theory (e.g., “the lion wants to eat the zebra”), whereas only 1.5% of the total number of responses were “anthropomorphic” in the sense defined here (e.g. “the zebra wants to go to the hospital”). The study was conducted with both German and Shuar children, and the proportion of realistic, schema-consistent responses was high in both populations.

A recent study by Barrett (2003), examining attributions of psychological traits and states to prey animals by adult Shuar hunters in the Ecuadorian Amazon, supports the view that anthropomorphism is rare in the inferences that people use to actually predict
animals’ behavior. In the sample of Shuar hunters’ attributions, the vast majority were realistic ones, both consistent with the predator-prey schema, and of the sort that professional biologists would make, often referring to animals’ sensory capacities and to whether or not they had detected the hunter. Interestingly, Shuar hunters appear to make use of mentalistic reasoning when explaining phenomena such as the use of imitative calls to attract animals; in this case, virtually all of the explanations of the animals’ behavior attributed a belief to the animal, and specifically, the false belief that the call was being produced by a member of their own species. These findings are consistent with those of Blurton-Jones and Konner (1976), Liebenberg (1990), and others who have examined the kinds of reasoning hunters in traditional societies use when pursuing prey, and who report that hunters’ knowledge of animal behavior and psychology is quite realistic and in some cases more accurate and detailed than that of western zoologists studying the same animal taxa. Of course, both adults and children across societies frequently anthropomorphize, in contexts from fairy tales to cartoons. However, when they do so, I suggest that they are likely to be engaging either explicitly or implicitly in a form of pretense, or decoupled reasoning, in which a distinction between “real” and anthropomorphized behavior is maintained (Cosmides & Tooby, 2000; Leslie, 1987).

**Knowledge Acquisition**

The view of children’s understanding of animal behavior developed here holds that children come equipped by natural selection with framework or skeletal cognitive systems that help to organize knowledge and inferences about animal behavior. For example, the evidence on agency detection reviewed above suggests that children do not have to learn certain basic distinctions between agents and non-agents, such as the fact that agents move in a goal-directed fashion and non-agents do not. Rather, this distinction is built implicitly into perceptual mechanisms that then are able to identify which things in the world are agents and which are not. Beyond the level of perceptual distinctions, natural selection may prespecify certain kinds of conceptual information as well, such as the concepts of BELIEF, DESIRE, and PRETEND (which might be extremely hard to learn through observation; German & Leslie, 2000; Leslie, 1987), and perhaps even more content-specific conceptual structures, such as the intentional schemas (hunger, predator-prey, etc.) hypothesized above. It might be that children do not have to learn what hunger
is, only to identify when it is occurring; they might not have to learn that there are predators, only to identify which things in their environment are predators. From this perspective, learning is crucial, but evolved structures guide it.

For example, it is possible that the perceptual systems of children are designed so that animals are inherently appealing, and that their perceptual features have aesthetic properties for children that draw their attention, not as a matter of accident, but as a matter of design. In a Gibsonian sense, animals might have “affordances” that make them compelling objects for children, drawing their attention to them and thereby facilitating learning (Gibson, 1988). There might even be something like a “critical period” of intense interest in animals – marked by things like fascination with dinosaurs and such -- that subsides by adulthood. Several studies suggest that the barrage of cues emitted by real animals can exert a very strong pull on children. For example, Kidd and Kidd (1987) compared the reactions of infants age 6 months and up to real dogs and cats versus mechanical, battery-powered ones, and found that the interactivity of the real animals (nuzzling, making noises, etc.) made the real animals far more compelling than the artificial ones, consistent with findings of Johnson et al. (1998) regarding the importance of behavioral contingency. Nielsen and Delude (1989) compared the reactions of 9 month olds to different kinds of animals, robot animals, and people, and found that the real animals evoked much more interest. And, as expected, several studies have shown that experience with real animals makes a difference in both the rate of acquisition and quality of children’s knowledge about animals and their behavior (Inagaki & Hatano, 2002; Kellert, 1997).

Boyer (2001) has suggested that learning about animals is guided by a particular kind of skeletal cognitive structure that he calls an animal template. According to this proposal, when the child encounters a new animal, she opens a new, blank template for that animal: for example, WALRUS. Initially, the name and perceptual information for identifying the taxon are all that are present in the newly formed template. But the template has particular “slots” that are filled as relevant information is encountered: for example, the animal’s habitat, its preferred diet, how it reproduces, and so on. Although a new token template must be created for each new animal the child learns about, the type of template is the same for all animals, and allows the child to “fill in” information that is
true of all or most members of the ontological kind ANIMAL. For example, upon learning that there is a kind of animal called a WALRUS a child may not initially know what walruses eat, but will infer, without being told, that walruses eat, and that they have a preferred diet. When this information becomes available (e.g., overheard in a conversation about walruses), the DIET slot in the WALRUS template will be filled. Similarly, the child will infer that walruses have a preferred habitat, even if she doesn’t know at first whether it is land or sea, and that walruses reproduce, even if she doesn’t know whether by laying eggs or live birth. These assumptions will not be made for artifacts, because the blank ARTIFACT template has different kinds of slots (not DIET, for example, but perhaps a slot for FUNCTION, which an animal template would not have). Boyer, Bedoin, and Honoré (2000) have provided initial experimental evidence that children do make unprompted assumptions about the kinds of traits that it is possible or not possible for a new, previously unknown animal to have (e.g., “turns black when angry” is possible, “is made of sand” is not).

One implication of Boyer’s template model is that new token templates or files will be opened for each new taxon a child encounters, and the input necessary to open a new template may be fairly minimal: possibly, simply overhearing an unfamiliar taxon name might be sufficient. Indeed, children might be predisposed from an early age to begin building taxonomies of the animals in their local environment. In modern environments, where information about extinct or non-existent animals is abundantly available, children may construct taxonomies for these animals as well, if the available information about them satisfies the minimal input criteria for opening new templates. For example, children may acquire and maintain fairly encyclopedic knowledge databases about dinosaurs, even though the actual knowledge contained in these databases is ecologically useless (because dinosaurs do not exist). A recent study in England suggests that when information about real animals is impoverished, children may fill their taxonomic knowledge system with information about imaginary creatures. Balmford, Clegg, Coulson, and Taylor (2002) compared English children’s knowledge of their local flora and fauna with their knowledge of the cartoon characters known as Pokémon, and found that the children’s knowledge of Pokémon (for example, ability to
categorize individual exemplars) was greater than their knowledge of real local animal taxa.

There may be other learning mechanisms that help children to acquire knowledge that will be useful in negotiating encounters with animals. Steen and Owens (2001) have proposed that a particular form of pretend play, chase play, is an adaptation that allows children (and young of other mammals as well) to learn predator-prey skills without actually having to encounter a predator. Those features of chase play that make it entertaining, or compelling, are precisely what cause children to engage in interactions that will hone both cognitive and motor skills, and draw their attention to relevant features of chase play scenarios that will enable them to learn pursuit and evasion strategies. Barrett (1999) proposed that the predator-prey schema may play a similar role in drawing third-party attention to predator-prey interactions for the purposes of learning. It is far better to learn about predator-prey interactions by participating in safe simulations (Steen & Owens, 2001) or by observing from a third-party perspective (Barrett, 1999) than to rely upon actual first-person encounters with predators as a source of information. In the case of third-party observation of predator-prey encounters, there is the additional advantage of being able to acquire detailed information about the attack strategies of particular predators, or escape strategies of prey, by observing the actual predators and prey themselves. The various triggering conditions for the predator-prey schema may therefore serve an attention-drawing function as well, and people may find third party depictions of predator-prey interactions in documentaries or fictional films particularly compelling when observed from a distance, a proposal that I have called the “Jurassic Park hypothesis” to explain the popularity of films that are full of stimuli that would, at first glance, be expected to be highly aversive. Indeed, media aimed at both adults and children may be designed, either explicitly or implicitly, to trigger these attention drawing mechanisms, whose evolved function is to guide learning, but which now provide the basis for entertainment (Steen & Owens, 2001).

Conclusion

Although much is known about children’s understanding of animal behavior, much remains to be discovered. Living as many of us do in urban environments where our food is packaged and the likelihood of encounter with animals of any kind other than
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pets, pigeons, and squirrels is minimal, it is easy to forget the importance that interactions with animals has had in our evolution and in the daily lives of our ancestors. There may be hidden architecture for thinking about animals that psychologists have not yet imagined, much less discovered. In modern hunting cultures, the knowledge that adults possess about animal behavior is extraordinary, often rivaling or exceeding that of trained zoologists in certain aspects, and involving sophisticated, quasi-scientific chains of reasoning (Blurton-Jones & Konner, 1976; Liebenberg, 1990). This knowledge is acquired and deployed by the same kinds of minds as those who live in non-hunting societies, which likely contain capacities for learning and thinking about the natural world that are never put to the test. In children we see the beginning of a trajectory towards this kind of knowledge, even in Western industrialized societies where, by the time of adolescence, those activities that are important in our societies shift children’s interests away from animals and the further development of skills that, in hunting societies, would continue to be elaborated and refined well into adulthood (Blurton-Jones & Marlowe, 2002; Kaplan & Robson, 2002). At early ages, though, children have not yet realized that it really doesn’t matter whether they know about lions, tigers, and bears; their interests have been shaped by a history of selection to solve survival problems, and these interests remain even when the survival problems have changed.

The view that I have proposed here is that humans have a multi-faceted “agency intelligence” that allows them to predict and understand both human and non-human animal behavior. In modern environments, the normal inputs to this system might be relatively impoverished, and in some cases, it might be pressed into service outside of its proper domain. It has often been remarked, for example, that we can use the intentional stance to understand things such as thermostats and computers (Dennett, 1987). But, given that many aspects of our mind are centered around interactions with the living world, from perceptual systems geared to appreciate and understand patterns that appear organic to an almost telepathic ability to interact contingently with other sentient agents, it may be that the artifacts that we create are themselves “evolving,” with increasing technological sophistication, to mesh with these aspects of how our brains work. For example, computers are becoming more and more like contingently interactive agents, designed to behave and interact in ways that we intuitively grasp. It will be interesting to
observe how our environments and lives will change as the diversity of real biological agents decreases and the diversity of artificial ones grows.
References


Figure 1. Components of the agency system

Inputs

Cues

- Self-propelled & contingent motion
- Goal-directed motion, behavior
- Morphological cues etc.

Mechanisms

Detection and categorization mechanisms

Inference and reasoning mechanisms

Agency inference system

Intentional schemas
- Predator-prey
- Social exchange
- Mating, etc.

Belief-desire reasoning mechanisms

Theory of Mind mechanisms

Outputs

Inferences about animal behavior

Interacting systems:

- Emotion
- Attention
- Working memory
- Object tracking etc.