

# Perspectives on Psychological Science

<http://pps.sagepub.com/>

---

## **Why Humans Are Unique: Three Theories**

David Premack

*Perspectives on Psychological Science* 2010 5: 22

DOI: 10.1177/1745691609356782

The online version of this article can be found at:

<http://pps.sagepub.com/content/5/1/22>

---

Published by:



<http://www.sagepublications.com>

On behalf of:



[Association For Psychological Science](http://www.sagepub.com)

**Additional services and information for *Perspectives on Psychological Science* can be found at:**

**Email Alerts:** <http://pps.sagepub.com/cgi/alerts>

**Subscriptions:** <http://pps.sagepub.com/subscriptions>

**Reprints:** <http://www.sagepub.com/journalsReprints.nav>

**Permissions:** <http://www.sagepub.com/journalsPermissions.nav>

# Why Humans Are Unique: Three Theories

David Premack<sup>1</sup>

<sup>1</sup>University of Pennsylvania, Philadelphia, PA


Perspectives on Psychological Science  
5(1) 22-32

© The Author(s) 2010

Reprints and permission: <http://www.sagepub.com/journalsPermissions.nav>

DOI: 10.1177/1745691609356782

<http://pps.sagepub.com>

 SAGE

## Abstract

Three recent papers reject Darwin's claim that there is no fundamental difference between humans and animals. Each offers a unique theory of the difference. The first theory holds that although animals can perceive perceptual relations, humans alone can reinterpret the higher order relations between these relations. The theory offers analogical reasoning as an example of the uniquely human ability to deal with higher order relations between relations. However, chimpanzees are capable of analogical reasoning if the analogies are conceptually simple. The second theory proposes that human intelligence has far better developed social than physical competence—a claim that ignores, and is contradicted by 20 years of infant research showing that the infant's social and physical modules are almost equally developed. The third theory finds that whereas animal abilities are limited adaptations restricted to a single goal, human abilities are domain general and serve indeterminately many goals. This article rejects the first two theories and explains the unique character of domain-general human competence in terms of the interweaving of evolutionarily independent abilities—an interweaving found in humans only.

## Keywords

human vs. animal cognition, interweaving of evolutionary independent abilities, domain-general vs. adaptation, analogies, modalities, social vs. physical

Animal research has been steeped in Darwin's judgment that "... there is no fundamental difference between man and the higher mammals in their mental faculties" (Darwin, 1871, p. 35). Darwin's opinion has been so closely linked with evolutionary theory that it has been virtually impossible to contest his opinion while supporting evolutionary theory. Only in the past decade has there been a willingness to separate the two issues. Although the separation has had the embarrassing effect of revealing a "giant" holding a parochial view, it has had no effect on evolutionary theory.

In a surprising development, three theories (Hermann, Call, Hernandez-Lloredo, Hare, & Tomasello, 2007; Penn, Holyoak, & Povinelli, 2008; Premack, 2007) that contest Darwin's opinion of the similarity of animals and humans have appeared recently. Why, after virtually 30 years of preoccupation with animal-human similarity, have three such theories appeared? Perhaps it is the recently inaugurated microscopic study of the brain that has revealed striking reorganizations of the human brain that have never been recognized previously (Preuss & Coleman, 2002). Perhaps, 30 years of preoccupation with animal-human similarities has finally been balanced with a consideration of dissimilarities (Premack, 2007). Or, perhaps, chance has played the leading role in the co-occurrence of the three theories.

Before discussing the theories, let us digress to explore the topic of analogical reasoning, for the ability to reason analogically is of major importance in the arguments presented by two of the three theories. One theory disputes the evidence for analogical reasoning in chimpanzees, proposing that because "higher order" representations are necessary for analogies, analogies are, therefore, uniquely human (Penn et al., 2008). A second theory supports the evidence that chimpanzees are capable of analogies and regards the evidence as an argument against the first theory (Premack, 2007). An explanation of the groundwork for this controversy makes it possible to discuss the theories.

## Excursus: From Physical Similarity to Analogy

Bees are reported to distinguish sameness and difference (Glurfa, Zhang, Jenet, Menzel, & Srinivason, 2001). Bees learn to match physically alike items: for example, A and A, B and B, C and C, (not D and E). Bees also show transfer—that

## Corresponding Author:

David Premack, 6163 Heatherton Drive, Somis, CA 93066

E-mail: [davidpremack@msn.com](mailto:davidpremack@msn.com)

is, they subsequently match novel items (items on which they were not trained). But sameness and difference is not a relation between objects or properties, nor is it concerned with physical similarity. The equating of sameness and difference with physical similarity, as presented in the above experiment, is incorrect.

Sameness and difference is a relation between relations (Premack, 1976, 1988; Premack & Premack, 1983, 2003). For example, it is the relation between AA and BB and CD and EF on the one hand, and AA and CD on the other. AA and BB are both instances of *same*, and the relation between them is “same.” CD and EF are both instances of *different*, and the relation between them is “same.” AA is an instance of *same*, and CD is an instance of *different*; therefore, the relation between them is “different.”

At about the 11th month, children react spontaneously to the physical similarity of objects (Sugarman, 1983). They place red blocks in one location and green blocks in another. Chimpanzees do not spontaneously sort objects, but they show a simpler form of matching, one that appears in children in about their 9th month (Premack & Premack, 2003; Sugarman, 1983). Chimpanzees contact alike objects consecutively—touching, for example, one red block after another, then one green block after another. Chimpanzees show temporal matching but not spatial matching. Although children match physically alike objects at an early age, they do not match relations until they are about 4 or 5 years of age (attempts to teach 3.5 year olds were unsuccessful; Premack, 1982).

Chimpanzees, by contrast, never match relations spontaneously. But they can be trained to do so by either of two methods: one is conventional, and the other is a surprise. When chimpanzees are taught to place a plastic word “same” between two oranges and the plastic word “different” between a banana and an apple, most will then show transfer by placing both “same” and “different” between novel pairs of like and unlike objects, respectively (Premack, 1976). The words *same* and *different* have an unexpected effect. They enable the chimpanzee to match relations, that is, to match AA to BB as *same*, CD to EF as *different* and, more surprising, to do analogies (e.g., small circle is to large circle, as small square is to large square). They pass analogies spontaneously, from the first trial (Premack, 1988; Premack & Premack, 2003).

Chimpanzees taught *same* and *different* can also match physically unlike proportions. Of course, an untrained animal can match half an apple with half an apple or half a glass of water with half a glass of water, and so on. But an animal taught *same* and *different* produces yet another surprise. It can match half a glass of water to half an apple (Premack & Premack, 2003)! The analogy provides a perfect format for comparing proportions of unlike objects. Picturing the part relative to the whole produces this analogy: Half an apple is to a whole apple, as half a glass of water is to a whole glass.

Words, however, are not the only way to teach chimpanzees to match alike relations. Training the animal on a restricted number of same (AA) and different (CD) cases is also successful (Premack, 1988). The animals gradually learn (over 300

trials) to match the alike relations (AA to BB), and following another 100 trials, they learn to match the unlike relations (EF to CD). No feedback is given, and none is required. All the animals’ choices are approved during training. The fact that feedback is not required strongly suggests that the animals learned on a perceptual basis (Premack, 1988).

## Analogies

The concept of sameness and difference makes analogies such as AA is to BB as CD is to EF possible. Ten- to 13 month-old infants show an ability to do analogies (Chen, Sanchez, & Campbell, 1997). Chimpanzees taught the words *same* and *different* can do both perceptual analogies such as “small square is to large square as small circle is to large circle,” as well as functional analogies, such as “can opener is to can as key is to padlock” (Gillan, Premack, & Woodruff, 1981).

The animal’s ability to do functional analogies corroborates evidence indicating that the chimpanzee can attribute goals (Premack & Woodruff, 1976). Turning a key and operating a can opener are not similar actions, nor are the types of objects in the analogy similar. Their equivalence lies in the goal that the two actions share: the goal of opening.

## False Claim: Only Humans Can Do Analogies

The chimpanzee’s ability to do analogies has been disputed on the grounds that the animal’s choice of the correct alternative on a “a/b: c/\_” test is based not on analogical reasoning, but on similarity (Penn et al., 2008). According to this analysis, the correct alternative often had more features in common with the analogy than did the incorrect alternative. However, even if this were the case, we cannot equate “could have used” with “actually used.” Is there any evidence for the actual use of similarity by chimpanzees when they do analogies?

This issue has been tested in four ways (Oden, Thompson, & Premack, 2001). The chimpanzee tested was Sarah, a 39-year-old African born female with extensive laboratory experience. In two of the tests, Sarah was required to complete partially constructed analogies. In another test, she was presented with an empty analogy board and required to construct an analogy on her own from a unique set of four or five objects. The objects used were squares of white cardboard, each with a geometric form stenciled on it. The forms varied in color (4), shape (3), size (2), and some forms were filled in with color or were simply a colored outline. All possible cases were used, creating a pool of 48 different items.

In the first test, she was given two pairs of relations (a/b and c/d), some of which formed analogies, and some of which did not. For example, “small yellow square/large red square: small green circle/large blue circle” did form an analogy, whereas “small yellow square/large red square: small green circle/small blue circle” did not.

The animal was required to distinguish analogies from non-analogies, placing the word *same* between a/b and c/d in the first case and the word *different* in the second case (Oden

et al., 2001). Given 70 trials of this kind, Sarah was correct about 75% of the time ( $p < .01$ ), which was the same level of accuracy she maintained when required to choose the alternative that completed the analogy. These results contradict the similarity hypothesis. They suggest further that similarity played no role in either test, as her level of accuracy was the same on both tests.

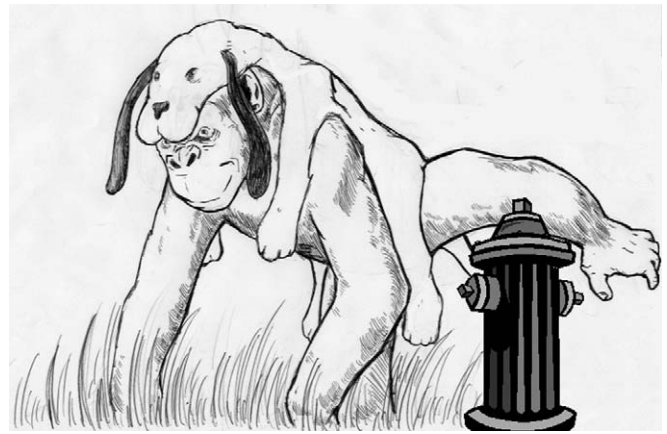
She was then given one relation (e.g., a/b) and four alternatives from which to form a relation equivalent to the one given. In this test, it was necessary not merely to recognize the correct relation, but to construct it by selecting the correct alternatives and placing them in the correct relation. Given 48 trials of this kind, Sarah once again was correct about 75% of the time ( $p < .001$ ). She was next given either four or five alternatives, a different set for each trial, and required to construct an analogy on her own. Her analogies were correct about 60% of the time ( $p < .001$ ). Chance is about 30% correct for the four-element case and 15% correct for the five-element case.

In examining videotapes of the 240 trials given Sarah, Oden found that Sarah occasionally “edited” her work (Oden et al., 2001). Rather than moving on to the next choice, she returned to a previous choice and either replaced an alternative with a new one or changed the position of an alternative she had already chosen. For example, on one occasion she placed “a/b” on one side of the board, and then placed “d/” across from a/b; a moment later, she moved “d” from “d/” to “/d” (so that d was now across from b, rather than across from a) and then went on to complete the analogy. Although she made only 15 such changes (out of a possible total of about 90), 14 of them were correct. The changes made it possible to complete an analogy that could not have been completed otherwise. Her changes, though few, were noteworthy, for metacognition of this kind is uncommon in animals.

In constructing analogies from scratch, Sarah used a strategy simpler than that used by human adults. She regarded the difference between a and b and c and d as equivalent if the two transformations both involved the same number of features. Humans, by contrast, attend not only to the number of features, but to their specific content. For example, humans regard a color and shape transformation as different from a size and color-fill transformation, whereas Sarah treated the two transformations as equivalent because they both entailed the same number of features (Oden et al., 2001).

Does this difference disqualify Sarah’s analogies? On the contrary, it suggests what we may find if we ask how children construct analogies. Young children, too, may use a strategy simpler than the one used by adults or older children. But if they do, an important difference remains. The young child who uses a Sarah-like strategy will abandon it when he becomes older, whereas Sarah will not abandon her strategy. She will always perform at the level of a young child.

Finally, we trained three young chimpanzees (ca. 4 years old) to do analogies using the conventional approach and then tested them on the standard “a/b: c/\_” complete-the-analogy test, giving them three kinds of alternatives. In one case, the correct alternative shared three features with “b,” whereas the incorrect alternative shared only one. In a second case, the similarity was



**Figure 1.** A depiction of the humorous analogy “Dogs will learn words when chimps say bow-wow”

reversed and the incorrect alternative shared three features with “b,” whereas the correct alternative shared only one. In the third case, the correct and incorrect alternatives to “b” shared the same number of features. What effect did similarity have on the animals’ performance? None. The animals performed at the same level (ca. 75% correct) in all three cases (Matsuzawa & Premack, 1985; Premack, 1986).

### Three Theories

The first theory we discuss in this article holds that the critical difference between humans and animals lies in their representational capacity. Humans and animals are both capable of learning about and acting on perceptual relations between events and objects in the world. But “. . . only humans appear capable of reinterpreting the higher-order relations between these perceptual relations in a structurally systematic and inferentially productive fashion. . .” (p. xx). The authors reviewed a number of cognitive abilities and found that animals not only fail, they fail because of representational inadequacies. Analogical reasoning is a key example—this form of reasoning is uniquely human, they hold, because analogies depend on reinterpreting the higher order relations between perceptual relations (Penn et al., 2008).

The usual model of analogies is based on structure mapping theory (D. Gentner, 1983), a theory that assumes individuals form predicate-argument mental representations and then map a base structure onto a target structure (e.g., Hummel & Holyoak, 2003). For example, in the analogy “swatter is to fly as hoe is to weed,” “kills” is the predicate; and the arguments are “swatter-fly” and “hoe-weed,” respectively. In the analogy “temper is to redhead as lava is to volcano,” “flared-up” is the predicate in one case “erupted-from” is the predicate in the other case, and the arguments are “temper-redhead” and “lava-volcano,” respectively. Finally, in the humorous analogy “dogs will learn words when chimps say bow-wow” (see Fig. 1), “will-learn” is the predicate in one

case, “when–say” is the predicate in the other case, and the arguments are “dogs–words” and “chimps–bow–wow,” respectively. The development of analogical reasoning is attributed to the child’s ability to deal with predicate arguments of increasing complexity. A toddler can cope only with relations that involve a single feature, but older children can cope with relations that involve four features.

If the Hummel-Holyoak model, with its dependence on higher order representational capacities, were correct, then, in all likelihood, chimpanzees could not do analogies. On the other hand, a simple model of analogies is highly compatible with analogical reasoning in chimpanzees. This model rejects both assumptions of structure mapping theory, denies that analogical reasoning is a special faculty, and instead derives analogies from two processes: priming, and transformations (Leech, Mareschal, & Cooper, 2008). Priming is an automatic low-level process of memory, so elemental that it is often retained in amnesia. Transformations are changes in physical states brought about by applying a tool to an object, such as a knife cutting an apple in two, a brush painting a wall, etc. In complex models of analogies, representations are instantiated by predicates and arguments; in the simple model, the complex representations are replaced by transformations (Leech et al., 2008). As we shall see in a later section, chimpanzees are experts at transformations.

In fact, chimpanzees definitely reason analogically, provided that the analogies are simple. Even the simplicity is not explained by lack of high-order representation, but by conceptual limitations. For instance, chimpanzees are weak on biological concepts—for example, the causal relations between seeds and the resulting plants, sexual reproduction, kinship relations, etc.—because biological processes involve time, and chimpanzees do not understand time (Premack & Premack, 2003).

Time, unlike space, cannot be seen or touched. It is not a sensory concept, but a metaphor on space. In English speakers, time is laid out on a horizontal plane, with past events on the left and recent events on the right; in Mandarin speakers, time is laid out on a vertical plane, with past events on the top and recent events on the bottom (Boroditsky, 2000). Only humans, by merit of their (uniquely human) metaphors can enjoy the benefit of nonsensory concepts—concepts that are often the most significant of human concepts (Boroditsky, 2000; Premack & Premack, 2003).

Holyoak, once a keen proponent of analogies (Holyoak & Thagard, 1995), has, with his coauthors, a new theory that absolutely requires chimpanzees not to do analogies. If chimpanzees can do analogies, the theory is wrong, for analogies are a perfect example of what the theory says nonhumans cannot do. So it is clear why Holyoak changed his mind. But his timing is bad. Evidence for analogies in chimpanzees, which was always strong, is now better than ever.

This section has an important lesson. Before explaining an animal weakness in terms of an overarching (in this case, representational) factor, it is essential to consider the nitty gritty of the case. The animal’s weakness may lie in low-level factors,

such as the chimpanzee’s inability to grasp time or nonsensory concepts in general. Failures of this kind pose little need for over-arching theories.

### **Imitation in Children and Chimpanzees**

It has been found that, though children imitate the superfluous actions of a model, chimpanzees do not, suggesting that chimpanzees are more sensible or flexible imitators than children. This is not the correct conclusion, I suggest. Rather, studies by Horner and Whiten (2005, 2007) indicate that the child, but not the ape, is a compulsive imitator. The child imitates to imitate, whereas the ape imitates to obtain food. A simple test, which they did not carry out, will, I think, distinguish child from chimpanzee. If one were to present 10 activities to a child and a chimpanzee, five of which lead to reward when imitated and five of which will not, I predict the child will imitate all 10, whereas the chimpanzee, by contrast, will imitate only the five that lead to reward. In addition, keep in mind that in the real world, where the child’s disposition to imitate evolved, models do not engage in superfluous actions. In the lab, however, they can, and when they do, the child can be made to look foolish; given his disposition to imitate, the child will imitate superfluous acts as well as purposeful ones.

### **Theory of Mind (TOM)**

Humans assume that others have minds and that their actions can be explained by mental states. The two most widely attributed mental states are intention and perception (Premack & Woodruff, 1976). When infants see an individual look at an object, they infer that the individual has perceived the object; similarly, when they see an individual reach for or pursue an object, they infer that the individual’s intention is to obtain the object (Premack & Woodruff, 1976). It is likely that both of these inferences or attributions are, like the attribution of cause in the Michotte illusion (1963), reflexive.

If the mental states above are considered primitive or reflexive, what then are nonprimitive mental states—those states that are not attributed reflexively and that probably are not attributed by animals? Many would answer “belief,” a mental state that is thought to be complex, as it is not attributed by children until they are 3 years old, (Wellman, 1990). This is a mistaken assumption, however, and the next section will show why.

When a child is shown a dog that sees a bone in a box, he expects the dog to get the bone; that is, he assumes the dog likes bones, that getting the bone is its goal, and that an unimpeded dog will act on its goals. In the next step, the child is shown that the dog sees that the box is now closed, and that the dog is then removed from the scene and returned sometime later. Suppose the child expects that the dog, when it is returned, will behave as it had earlier—attempt to open the box and get the bone. Such an assumption would indicate that the child assumes that the dog remembers what it saw in the first place (Surian, Caldi, & Sperber, 2007).

If the individual tested is a very young infant, the question is “Will the infant itself remember that it saw the dog observe the bone?”. If the interval exceeds the infant’s memory, then, of course, it will be unable to attribute memory to the dog. The infant can make the attribution only if its own memory is long enough to include the memory it attributes to the dog.

Individuals who report findings of this kind claim that it shows infants attribute “belief,” which they consider remarkable because, as noted in previous studies, children did not attribute belief until about 3 years of age (Surian et al., 2007). However, children do not acquire the word *belief* until about 3 years, and therefore they could not attribute belief earlier (Wellman, 1990). The child’s late attribution of belief would probably not have been assigned to the complexity of the state in the first place if a nonverbal test had been run earlier; it would have been assigned to the fact that the child did not possess the word.

Let us consider this question: What is meant by “belief”? Is it a complex mental state? In the present example, belief boils down to a simple mental state: a perception that has been remembered (Premack & Premack, 2003). The infant fulfills this condition: Despite the fact that the dog can no longer see the bone and that it has been a while since the dog last saw the bone, the infant still expects that the dog will try to get the bone (Surian et al., 2007).

How would chimpanzees fare if they were given this test? Provided the delay used in the test does not exceed the chimpanzee’s own memory, the animal will likely perform as the infants did. In other words, chimpanzees too are likely to attribute belief—that is, perception followed by memory. This state can be added to goal and perception as another of the simple mental states that even some animals attribute.

A recent test (He, Bolz, & Baillargeon, 2007) indicates that 2.5-year-old infants can pass false belief (Wimmer & Perner, 1983) and thus part company with chimpanzees. False belief can be explained by returning to the dog test above. If the infant were shown that an agent moved the bone from its present box to a new box when the dog was not looking, the infant would expect the dog to go to the original box to retrieve the bone when it returned (it would be surprised and look longer if the dog went to the new box). The infant would have this expectation because it can distinguish between its own knowledge of where the bone is actually located and where the dog falsely believes the bone to be (Wimmer & Perner, 1983). A chimpanzee, by contrast, would fail the test if shown the same scene. It would expect the dog to go to the new box (or have no expectation at all). The chimpanzee does not attribute false belief to the dog and does not therefore distinguish its own knowledge of where the bone is actually located from the dog’s false belief of where it is (Call & Tomasello, 2008; Hare, Call, & Tomasello, 2001).

Humans frequently engage in metarepresentation (Premack & Premack, 2003). For instance, they say such things as “Men think that women think that men think that a woman’s orgasm is different.” Or “Jack thinks Mary thinks that Donna hopes that Ted will take Chris out of the hockey team.” In these

expressions, each state is embedded in the preceding state in a recursive-like manner. As metarepresentation depends on language, it is obviously unique to humans. But beware the obvious, lest it mislead us.

The occurrence of embedded attributions in humans, and their nonoccurrence in animals, is not entirely explained by language. A behavioral counterpart to embedded mental attributions can be found in human social behavior. In the classroom, for instance, we may observe a child watch another child watch a third child as he looks at their teacher, each mental state embedded in the preceding one (Premack & Premack, 2003). Nothing comparable is found in animals. In the wild, we may see a chimpanzee infant watch its mother, see another infant watch its mother, and so on—an (iterative) string of independent acts, without any sequence in which each act is embedded in a preceding act. Animals neither attribute embedded mental states nor engage in embedded social behavior (Premack & Premack, 2003). Indeed, the complete lack of embedded social behavior in animals suggests that, even if animals had language, they would not engage in metarepresentation.

## Causality

Chimpanzees show their understanding of physical action, or cause, by selecting the tool that produces a specific transformation in an object. When shown a sequence consisting of an apple and an apple cut in two and offered a knife, pencil, or a container of water, they choose the knife, and when shown a blank piece of paper and a marked piece of paper and offered the same alternatives, they choose the pencil (Premack, 1976, 1988; Premack & Premack, 1983, 2003). Even monkeys pass simple tests of this general kind (Hauser & Spalding, 2006). Chimpanzees also recognize the reversibility of actions. When given a piece of paper followed by marked paper, they choose the pencil; when given marked paper followed by clear paper, they choose the eraser (Premack & Premack, 2003).

Tests that would very likely separate monkeys from chimpanzees are those that involve multiple transformations: for instance, paper that is initially cut in half and ends up both cut in half and wet. Chimpanzees can separate the tools that did (and did not) participate in transformations of this kind. In the present example, they place the container of water in the relevant bin and place the scissors and pencil in the irrelevant bin. The separation here is interesting because, although scissors and pencil are both irrelevant, they are irrelevant for different reasons: scissors were used prior to the test, and the pencil was not used at all. Chimpanzees do not rely on learned associations in passing tests of this kind. Tests based on anomalous transformations—ping-pong balls cut in two, fruit marked with writing, etc.—are passed by chimpanzees at the same level of accuracy as tests based on familiar transformations (Premack, 1976; Premack & Premack, 1983, 2003).

Certain animals make or use tools in the wild, few more conspicuously than the Caledonian crow. It makes “hooks” on the ends of wires that it uses to obtain bits of food (Hunt & Gray,

2004). The tool is simple, and the wire (the basis of the tool) is clearly visible. The visibility of the wire is critical, for the slightest change in how clearly a potential tool stands out from its context can have an overwhelming effect. When Kohler broke off tree branches and gave them to chimpanzees, the animals stripped the branches of leaves, turning them into tools by which to reach inaccessible fruit (Kohler, 1925). But when Kohler required the animals to provide their own branches, not a single chimpanzee tore a branch off the nearby tree. The problem was not the lack of strength, which is enormous in the chimpanzee, but the lack of ability to see a branch as an independent entity when it is embedded in a tree (Kohler, 1925). That leads us to a question: Can a crow see a wire within a fence?

Some animals fail at tool use not because of deficits in causal reasoning, but because their grasp of physical relations is weak (Visalberghi & Limongelli, 1994). They do not recognize that objects can fall through a hole or that objects heavier than water will sink. Physics and causal understanding are often confounded when testing animals.

### ***Inference in the 3.5-Month-Old Infant***

Surprising evidence for inference in the infant is demonstrated in this ingenious test (Aguiar & Baillargeon, 1999, 2002). The 3-month old is shown a toy mouse that “runs” behind one side of an occluder and emerges from the other side. The infant is surprised. He looks at the scene longer than usual. The infant’s surprise is explained by the fact that the entire center portion of the occluder has been removed, the mouse cannot pass from one side of the occluder to the other without showing up in the middle! Yet, this is exactly what the mouse appears to do!

It is interesting to note that a 3.5-month old shown the same scene is not surprised. Why not? Does the 3.5-month old have a “theory” that explains the mouse’s invisible passage? In fact, the infant does: The mouse only appears to pass from one side of the occluder to the other. There are actually two mice. One mouse is seen entering one side of the occluder, and another mouse, hidden behind the occluder, is seen exiting from the other side. A simple test confirms this interpretation.

Divide the infants into two groups and show both groups what lies behind the occluder. One group is shown two mice, the other group is shown one mouse, behind the occluder. The infants shown only one mouse behind the occluder are surprised. They look at the scene far longer than do the infants who were shown two mice (Aguiar & Baillargeon, 1999, 2002).

Because making inferences on unobserved events or objects is the basis of reasoning, it is surprising to find that infants as young as 3.5 months of age are capable of making such inferences. The infant’s inference, though simple, does not seem to differ in principle from inference in general. The scientist who infers an unobservable particle and the infant who infers an unobserved mouse would appear to engage in the same process.

The 3.5-month-old infant has the beginnings of a physical module that will develop over months and years into an adult appreciation of the action and properties of physical objects

(Spelke, Katz, Purcell, Erlich, & Breinlinger, 1994). This early module protects the infant from solving the problem with the use of magical hypotheses: for example, determining that the mouse changed into a long worm, crossing over invisibly, before becoming a mouse again. If the infant were shown scenes of this kind, it would be surprised and look longer than usual. On the other hand, a mouse that arrived earlier (and is therefore already behind the occluder) does not violate any of the principles in the infant’s module (Baillargeon, 1995; Spelke et al., 1994).

The above test suggests that the 3.5-month old does not passively accept events that violate its expectations about the physical world. Rather, the infant explains violations by inferring unobserved objects. Perhaps there is no better way to activate reasoning in an infant than to confront it with events that are at odds with its expectations. Infants are not helpless in the face of the unexpected, as they protect themselves with inferred objects and reasoning.

There is no suggestion that chimpanzees are capable of inferring unobserved objects or that, if they were capable, they would be motivated to use this device to explain conditions incompatible with their expectations.

### ***Recognizing the Equivalence of “Funny” Objects***

Although chimpanzees do not spontaneously place alike objects together (as do children) and must be taught to do so, once taught, they transfer this skill to new objects. Indeed, they transfer so impressively one could suppose that the training has turned them into children (Premack, 1988). However, we need take only one further step to dispel this view. The objects being matched are ordinary: toys, food, buttons, pieces of cloth, hardware, etc. Suppose we remove the “ordinariness” by modifying the objects in one way or another. Suppose, for example, we press two identical objects together in a vice and distort each in exactly the same way. Or we arbitrarily divide the ordinary objects into groups of large and small objects and form entirely new objects by gluing a small object on top of each larger one. We now repeat the match-to-sample tests using these “funny” objects.

The children are totally unaffected by the changes, matching funny objects as accurately as they did the ordinary ones. The chimpanzees, by contrast, fall to a chance level responding. They require from 50 to 100 trials to recover. Whereas children immediately recognize the equivalence of highly changed objects, chimpanzees are baffled and must relearn the equivalence of the transformed objects (Premack, 1988).

A comparable disparity appears when infants and chimpanzees are required to match objects and pictures (or visa versa). Children require no training to match objects with their pictures, but chimpanzees fail even after having received protracted training (Premack, 1988). The normal test, one that infants pass but apes fail, offers (for example) a banana as the sample and pictures of a banana and an apple as alternatives (or a picture of a banana as the sample and an apple and a banana

as alternatives). Offering an unconventional version of this test uncovers an insight into the nature of the animal's difficulty. Given, say, a banana as the sample and a picture of a banana and an actual shoe as alternatives, or a picture of a banana as the sample and a banana and a picture of a shoe as alternatives, the chimpanzee matches the banana to the shoe and the picture of the banana to the picture of the shoe. The similarity the animal finds between two objects (or two pictures)—any two objects (or pictures)—is greater than the similarity it finds between an object and its picture (Premack, 1988)!

Rather than continue with established examples of the child's uniqueness, let us return to reasoning and the 100-day-old infant. Chimpanzees are most unlikely to duplicate the infant's reasoning behind the inference of two mice with one already behind the occluder. Although the chimpanzee may have a preliminary version of the infant's physical module (untested regrettably), any weakness in this precursor will limit the animal's ability to reason. In addition, there is no evidence that chimpanzees infer unobserved objects. If shown events that disconfirm its expectations (assuming it has expectations), the chimpanzee is more likely to resemble the 3-month old and be surprised by the disconfirmation.

### ***The First Position Is Mistaken: Human Uniqueness Does Not Lie in the Reinterpretation of Higher Order Relations Between Perceptual Relations***

The uniqueness of the human species begins in the reflexes of the infant. Only the human infant infers unobserved objects (motivated by the disparity between what it expects and what it observes). Only the human infant has modules—innate learning mechanisms—that provide an intuitive understanding of the physical (Aguiar & Baillargeon, 1999, 2002; Baillargeon, 1995; Baillargeon, Needham, & Devos, 1992; Spelke et al., 1994), psychological (Premack, 1990; Premack & Premack, 1995, 1997), and (to a lesser extent) biological world (Premack & Premack, 2003)—a body of expectations that enables the infant to distinguish, in each of the three worlds, what it does and does not expect to see and that provides the reasoning to look longer at those scenes that violate expectations. No other species has this articulated body of expectations, the understanding of the three worlds, or the learning mechanisms for acquiring the understanding. The infant's reflexes are the seed bed of adult cognition: the source of the capacities that enable the adult—following a period of still largely mysterious development—to form mental representations of the world and to make computations upon them.

### ***Position Two***

According to this position, the key to human intelligence lies in social competence (Herrmann et al., 2007). The authors base this claim on a nonverbal questionnaire given to children and chimpanzees concerning both social and physical knowledge. Of course, the children performed better than the animals,

though not equally well on both topics. The children outdistanced the chimpanzees on social knowledge, but not on physical knowledge. These findings prove, the authors contend, that humans have specialized in social relations and are uniquely competent in this domain—a conclusion troubled by two problems, the first of which is largely technical.

Can we be certain that the questions concerning social and physical knowledge are of equal difficulty? Suppose researchers had a group of experts, holding no views on social and physical knowledge (and uninformed as to the purpose of the test) propose questions on the two topics. The questions are then drawn at random and rated for difficulty by a second group of experts. A test constructed in this manner could provide questions of equal difficulty. But the questionnaire used in the test was not constructed by blind, unbiased experts, but by individuals who are both highly biased in their views of social and physical knowledge and aware of the purpose of the test (Herrmann et al., 2007). This does not instill confidence in the equality of the difficulty of the two kinds of questions.

A more formidable difficulty is substantive rather than technical. The authors have managed to ignore at least 20 years of highly relevant data when reaching their conclusion (Aguiar & Baillargeon, 1999, 2002; Baillargeon, 1995; Baillargeon et al., 1992; Onishi & Baillargeon, 2005; Premack, 1990; Premack & Premack, 1995, 1997; Spelke et al., 1994; Spelke et al., 1992). Infants have been shown to have modules that guide their learning in fundamental domains such as space, number, language, social relations, physical relations, etc. (Premack & Premack, 2003). And the infant's physical domain is one that has been most closely studied. Infants have well-developed expectations about physical objects, such as how they move and are affected by objects that act on them. For instance, infants expect physical objects to move in a straight line and at a uniform speed; they do not expect objects to stop and start, turn corners, disappear and reappear, adhere to other objects forming clumps, etc. Researchers have established that infants have these expectations by showing them objects that violate these conditions; infants look longer at the objects that violate their expectations than they do at those that do not (Baillargeon, 1995; Spelke et al., 1994; Spelke et al., 1992). Three-month-old infants have expectations about gravity: When an unsupported object does not fall, they are surprised. But their concept of "support" is limited—they accept one object touching another on the side as support (Baillargeon et al., 1992). Four-month olds require the support to come from below, and eight-month olds require that the center (not the side) of the object be supported from below (Baillargeon et al., 1992). Infants have separate representations for object identity and for the spatio-temporal relations of an object. Infants take into account the size and speed of an object, expecting a large, fast-moving object that collides with another object to propel it further than would a smaller object moving at a slower speed (Baillargeon, 1995; Spelke et al., 1994; Spelke et al., 1992). These examples, which hardly exhaust the infant's "knowledge" about physical objects, indicate that infants have a well-developed physical module.



The infant can distinguish physical objects that are inert and move only when acted upon by another object from self-propelled objects that move on their own (Premack, 1990). Self-propelled objects interact, and infants assign valence to their interaction. They use two criteria in assigning valence: force of contact and sociality (Premack & Premack, 1997, 1995). Soft contacts such as a kiss or caress are coded positive; hard contacts such as a hit or a bite are coded negative. When one object helps another reach a goal, infants code the action positive; when one object hinders another from reaching a goal, they code it negative. Tests based on habituation and dishabituation suggest that infants equate caressing with help and hitting with hinder despite the physical difference of the actions, and they evidently make this judgment on the basis of the valence they assign to them. Valence takes priority over physical similarity: A difference in valence causes dishabituation, but a difference in physical similarity does not (Premack & Premack, 1997). These examples show that infants are impressively ready for understanding the fundamental relations of social behavior.

Is there a greater development in one module than in the other? We might answer this question by identifying the fundamental relations in the two cases and asking whether the infant understands the key relations better in one case than the other. Does the infant understand the social relations “self-propelled motion, goal, and valence” better than the physical relations “force, size, and momentum”? There is no hint of a disparity, certainly not one of the magnitude suggested by the questionnaire.

Once we leave the infant and turn to adult competence, a definite disparity appears, but it is one that favors the physical case. Physics is the only science that bears full witness to human imagination. Although social science struggles to escape the bounds of common sense, physics offers quantitatively precise accounts of both the visible and invisible universes—accounts that defy common sense and are strikingly counterintuitive. Does physics have this enormous lead simply because its primitives retain their identity even when they are isolated from the system, whereas the primitives of social science do not? (This question cannot be taken seriously, for if social science has primitives they remain largely unknown.)

The intuitive theories of psychology seem to have a stranglehold (Premack & Premack, 2003) on the human mind; those of physics do not. Consider the naive intuition that actions are intentional and goal directed. People have never replaced this intuition with a scientifically better-founded theory, yet researchers in the field of physics have replaced their naive intuitions about gravity with theories about curvature in space. Is it merely a matter of time? After all, physics is older than psychology. On the other hand, time may never alter the pedestrian character of social science. A fundamental gap in human intelligence may prevent the full power of human imagination from ever shining on social science.

### **Position Three**

This position offers a theory that claims to explain the difference between the generalist character of human intelligence

and the specialist character of animal intelligence (Premack, 2007). We examine the claim by comparing human and animal abilities, starting with teaching. Even though most animals do not teach at all, the few that do teach offer instructive examples. The cat teaches its kittens to stalk mice, injuring and weakening the mice before bringing them to the kittens; later, as the kittens progress, the cat brings her kittens uninjured mice (Leyhausen, 1979). Meerkats eat “dangerous” food, such as scorpions, that the adult teaches its pups to eat without being stung. In a repetition of evolutionary strategy, the adult meerkat first incapacitates the scorpion, then, as the pups improve, offers ever more intact prey (Thornton & McAuliffe, 2006).

Teaching in both these species is an adaptation: it serves only one goal. The cat teaches its kittens to stalk; the meerkat teaches its pups to eat without being stung. Neither species can teach any other activity. Picture humans who evolved the ability to teach their children to blow their nose, or tie their shoes, or chew with their mouth closed—that is, to teach one, but only one, of these activities. This is inconceivable because no human competence is of this kind, whereas—and this is the important point—all animal competence is of this kind.

Human teaching is not an adaptation but a domain-general competence that serves indeterminately many goals. Humans teach all possible activities (Premack & Premack, 2003). The goals of human teaching change from one culture to another. For example, toilet training, prominent in the West, is not taught in certain rural areas (e.g., China) where the child’s pants open automatically when he or she squats in the field. Conversely, walking and sitting are never taught in the West, but in the Kalahari San, infants are carefully taught to do both (sand is piled behind the infant’s back to facilitate sitting), because the early onset of walking and sitting are advantageous to a desert-living people (Konner, 1976).

“Domain generality” does not concern the stimuli or responses that are involved in carrying out an activity. If a cat were to learn to take a new path in bringing injured mice to its kittens, this would not be an example of domain generality. Only if the cat were to teach another activity, such as avoiding predators, would it qualify as domain general. Similarly, if a mother changed the food or spoon she gave the child while teaching table manners, this too would not qualify as domain general; however, when she teaches the child to dress herself, it would qualify as an example of domain generality.

The teaching of the cat and meerkat involves adaptations on the part of both teacher and student. The teacher brings injured mice or scorpions to the young, and the young learn to stalk the mice or eat the scorpions. The teaching and learning are linked systems. The adult cat or meerkat cannot teach indeterminately many actions any more than the young can learn indeterminately many actions. The response of the teacher (to the mice or scorpions) is no less an adaptation than is the student’s response to the mice or scorpions. In human teaching, the adult and young are also a linked system: The teacher can teach indeterminately many actions, and the student can learn any of the actions he teaches. Neither party is limited.

The first source of human flexibility and animal inflexibility, then, is the contrast between the nature of their abilities. Teaching is a paradigmatic case—not a unique one. All human abilities are like human teaching (domain general; Premack, 2007; Premack & Premack, 2003), and all animal abilities are like animal teaching (adaptations restricted to one goal; Premack, 2007).

A second factor that contributes to human flexibility is the sheer number of abilities found in the human. There is no official count of abilities, but whatever the number, humans have all of them. Animals, by contrast, may have one or perhaps two human-like abilities, if they have any at all. Notice how interesting we find it that crows make tools in the wild. Why? because most animals do not do so (Premack, 2007). We are struck by the finding that cats and meerkats teach for the same reason—they are virtually the only animal species that teach (Premack, 2007). The planning seen in scrub jays, too, (Raby, Alexis, Dickenson, & Clayton, 2007) is noteworthy because other species do not plan (Premack, 2007).

When we consider the negative implications of this positive information, this is what we are told: crows make tools in the wild (but do not plan or teach), scrub-jays plan (but do not teach or make tools in the wild), and cats and meerkats teach (but do not plan or make tools in the wild). The flexibility of human intelligence is, at one level, hardly a mystery: Humans command all cognitive abilities, and all of them are domain general, whereas animals, by contrast, command very few abilities, and all of them are adaptations restricted to a single goal or activity.

These simple facts make the case that human and animal intelligence differ dramatically (pace Darwin). The question is why? Why are human competencies domain general, whereas animal competencies are narrow adaptations? Can we give an evolutionary explanation of this difference?

Evolutionary theorists are fond of noting that there are no general solutions because the problems to which evolution provides solutions are always specific. This view accords well with animal intelligence. The animal's adaptation is a perfect example of a solution to a specific problem. However, the view does not accord well with human intelligence, for domain-general competence is not a solution to a specific problem. How do we resolve the seeming paradox between standard evolutionary theory and the domain-general character of human intelligence?

Human faculties seem to consist not of a solution to one problem, but of the knitting together of the solutions to a number of problems. Although each of the individual components solves a specific problem, their combination provides the solution to a general problem.

Language, with its phonological, semantic, and syntactic components, may be a case of this kind. Teaching appears to belong to the same mold. A number of components are interwoven in this case too (Premack, 2007). An aesthetic factor plays a prominent role. Humans practice, swing a golf club, flip an omelet, write a poem, and carry out a variety of activities to improve their performance. They start their day at the mirror, combing their hair, and applying makeup to improve their

appearance. The mental representations of these preferred actions and appearances are not seen only in the demands humans make on themselves, but in the corrections they make of their children when teaching them. Teaching, the attempt to correct others, is the social side of the attempt to correct the self. It is not a coincidence that humans both practice and teach, whereas other species do neither (Premack, 2007).

TOM is a second factor interwoven with the aesthetic component; the highly developed human TOM enables the individual to recognize that the young are incompetent and need to be taught. Language and a capacity for passive guidance (placing another's body in a desired position) are third factors; they provide the technologies that are needed to carry out the activity of teaching. Thus, the human capacity for domain-general teaching (Premack, 2007) is a compound competence, based on an interweaving of at least these components: aesthetics, TOM, and language.

Unlike the planning of the scrub jay, which is restricted to the caching of food (over short intervals of time; Raby et al., 2007), humans can plan for any activity (over unlimited periods). Not only, for example, a trip to Detroit, but how they will spend a vacation, and even how they will educate their young children in the future (Premack, 2007). What individual components combine to produce this domain-general ability? First of all, human episodic memory applies to episodes of all kinds, not just those of a particular kind, such as caching. In addition, humans can sense their future as an extension of their past, for they know their past in detail thanks to autobiographical memory (for which there is no evidence in animals; Bayley, Gold, Hopkins, & Squire, 2005). Finally, the unique human capacity for metaphor gives them a sense of time that is lacking in animals (Premack & Premack, 2003). The interweaving of these several capacities enables the human to treat the future like the present and lay plans for all conceivable events.

Even the human predecessor, *Homo erectus*, made tools more complex than those made by animals. Reconstruction shows that *Homo erectus* made their tools in a multistep sequence (Conroy, 1997). First, they found a stone to use as a hammer, then, heading in another direction, they found a flint, the object from which to make the final tool. Striking the flint with the hammer, they caused it to fracture into a central core surrounded by flakes. They then "napped" edges of the best flakes, turning them into blades that were both strong and sharp (Conroy, 1997). The chimpanzee picks up a twig on its way to a termite mound, stripping the twig of its leaves, then pushes the twig into a termite orifice to fish for termites (Premack & Premack, 2003). Should the word *tool making* be used for both the constructions of *Homo erectus* and chimpanzee?

Evolutionarily independent factors are interwoven to produce human toolmaking. They begin with the hands and the brain (Napier, 1993; Wilson, 1999). A lateralized brain that allows the fine control of powerful action also controls the unique dexterity of human hands. It produces a system that makes all kinds of tools—from cotton balls to bumper jacks—possible. At the next level, human imitation contributes to tool making. Humans can copy not only the object and

location chosen by a model, as virtually all species can, but in addition they can copy the topography of the model's actions, as few species can (Premack & Premack, 2003). Further, the human ability to plan allows for a multistep procedure, such as one tool being used to make another (an ability found even in *Homo erectus*; Conroy, 1997).

The interweaving of independent competencies presupposes two abilities: the ability to accumulate or "load the shelf" with competencies, and the ability to combine the separate items on the shelf. Animals may have less ability in both or either of these factors, less ability to accumulate competencies, and/or less ability to combine them.

Do humans and animals load the shelf with equivalent independent competencies? When confronted with the same problem, do they evolve the same solution?

Consider the chimpanzee's (and even the monkey's) alleged ability to attribute both perceive and want. This appears to be a case in which nonhuman primates have knit two competencies together in forming the higher order competence TOM (violating the claim that animals do not combine separate competencies). But are *perceive* and *want* independent states? Although, in the human, the cognitive state of perceiving and the motivational state of wanting (dislike, fear, etc.) are dissoluble, the animal, I suggest, may have evolved perceiving and wanting as a joint state—"perceived what he wanted"—and cannot use the states separately. Thus, humans and animals may not always evolve the same solution to a common problem. Some, perhaps many, of the competencies on the animal's shelf are not comparable with those on the human shelf. Humans may have more, and finer grained, primitives than animals.

The individual items that compose the combinations that produce teaching, planning, tool making, etc. need not themselves be primitives. For example, TOM, a component of the combination that produces teaching, may itself be made up of a combination of elements. And the same may be true of other would-be components of combinations. Human intelligence may consist of levels in which the primitives of one level are the combinations of a lower level.

Animals sometimes show a surprising disparity between a competence that is present in one activity but lacking in another. For instance, though monkeys and birds are capable of computing simple finite state grammars, this capacity does not appear in their communication systems (Fitch & Hauser, 2004; T.Q. Gentner, Fenn, Margoliasch, & Nussbaum, 2006). Disparities of this kind already hint that the interweaving of computational capacities, arguably an important aspect of human intelligence, is lacking in animals.

Though the interweaving of independently evolved abilities is the principal determinant of human uniqueness, the uniqueness of human intelligence also lies in a seldom-mentioned property: the variance of human intelligence. Differences in intelligence among humans are vastly greater than they are among nonhumans (Premack, 1995). A hint of the limited variability of animal intelligence is contained in an early attempt to breed "bright" and "dull" laboratory rats. Although the attempt appeared to succeed, the bright rats turned out to be

less anxious than the dull rats, and the difference disappeared when the dull rats were calmed. Though doubtless other nonhuman species have greater variability in intelligence than the laboratory rat, in no case is the variability comparable with that of the human. Consider the contribution that gifted humans make to the material basis of the life of their group. Perhaps less than 5% of the population contribute the fire, wheel, bow and arrow, gunpowder, domesticated plants and animals, alphabet, car, electronics, jet, or computer that the whole group benefits from. Animals do not owe the material basis of their life to the contributions of a selected 5% of the population. There is, among animals, no "gifted few."

### Acknowledgments

My thanks to Renee Baillargeon for sharing her knowledge of infants, to Kent Berridge and Mort Mishkin for helpful comments, and to Ann Premack for editing the article.

### Declaration of Conflicting Interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

### References

- Aguiar, A., & Baillargeon, R. (1999). 2.5-month-old infants reasoning about when objects should and should not be occluded. *Cognitive Psychology*, *39*, 116–157.
- Aguiar, A., & Baillargeon, R. (2002). Developments in young infant's reasoning about occluded objects. *Cognitive Psychology*, *45*, 267–336.
- Baillargeon, R. (1995). Physical reasoning in infancy. In M. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 181–204). Cambridge, MA: MIT Press.
- Baillargeon, R., Needham, A., & Devos, J. (1992). The development of young infant's intuitions about support. *Early Development and Parenting*, *1*, 69–78.
- Bayley, P.J., Gold, J.L., Hopkins, R.O., & Squire, L.R. (2005). The neuroanatomy of remote memory. *Neuron*, *46*, 799–810.
- Boroditsky, L. (2000). Metaphoric structuring: understanding time through spatial metaphors. *Cognition*, *75*, 1–28.
- Call, J., & Tomasello, M. (2008). Does the chimpanzee have a TOM? 30 years later. *Trends in Cognitive Science*, *12*, 187–192.
- Chen, Z., Sanchez, R.P., & Campbell, T. (1997). Analogical transfer of problem-solving strategies in children. *Developmental Psychology*, *33*, 790–801.
- Conroy, G.C. (1997). *Reconstructing human origins: A modern synthesis*. New York: Norton Press.
- Darwin, C. (1871). *Descent of man*. London: J. Murray.
- Fitch, W.T., & Hauser, M. (2004). Computational constraints on syntactic processing in a nonhuman primate. *Science*, *303*, 319–320.
- Gentner, D. (1983). Structure-mapping: a theoretical framework. *Cognitive Science*, *7*, 155–170.
- Gentner, T.Q., Fenn, K.M., Margoliasch, D., & Nussbaum, H.C. (2006). Recursive syntactic pattern learning by songbirds. *Nature*, *440*, 1204–1206.

- Gillan, D., Premack, D., & Woodruff, G. (1981). Reasoning in the chimpanzee: I. Analogical reasoning. *Journal Experimental Psychology: Animal Behavior Processes*, 7, 1–17.
- Glurfa, M., Zhang, S., Jenet, A., Menzel, R., & Srinivasan, M. (2001). *Nature*, 410, 930–933.
- Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know and do not know? *Animal Behavior*, 61, 139–151.
- Hauser, M., & Spaulding, B. (2006). Wild rhesus monkeys generate causal inferences about possible and impossible conditions. *Proceedings of the National Academy Sciences, USA*, 103, 7181–7185.
- He, Z., Bolz, M., & Baillargeon, R. (2007, March). *Understanding of false belief in 2.5-year-olds in a violation-of-expectation test*. Paper presented at the Biennial meeting of the Society for Research in Child Development, Boston.
- Herrmann, E., Call, J., Hernandez-Lloredo, M.V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science*, 317, 1360–1366.
- Holyoak, K.J., & Thagard, P. (1995). *Mental leaps*. Cambridge, MA: MIT Press.
- Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition*, 8, 164–181.
- Horner, V., & Whiten, A. (2007). Understanding a trap-tube test by young chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Journal of Comparative Psychology*, 121, 12–21.
- Hummel, J.E., & Holyoak, K.J. (2003). A symbolic-connectionist theory of relational inference generation. *Psychological Review*, 104, 427–466.
- Hunt, G.R., & Gray, R.D. (2004). The crafting of hook tools by wild New Caledonian crows. *Proceedings of the Royal Society of London*, 271, 588–590.
- Kohler, W. (1925). *The mentality of apes*. New York: Liveright.
- Konner, M.J. (1976). Maternal care, infant behavior and development among the !Kung. In R.B. Lee & I. Devore (Eds.), *Kalahari hunter-gathers: Studies of the !Kung San and their neighbors* (pp. 219–246). Cambridge, MA: Harvard University Press.
- Leech, R., Mareschal, D., & Cooper, R.P. (2008). Analogy as relational priming. *Behavior Brain Science*, 31, 357–378.
- Leyhausen, P. (1979). *Cat behavior: The predator and social behavior of domestic and wild cats*. London: Garland.
- Matsuzawa, T., & Premack, D. (1985). [Chimpanzees do not use similarity when doing analogies]. Unpublished raw data.
- Michotte, A. (1963). *The perception of causality*. Andover, MA: Methuen.
- Napier, J. (1993). *Hands*. Princeton, NJ: Princeton University Press.
- Oden, D., Thompson, R.K., & Premack, D. (2001). Can an ape reason analogically? Comprehension and production of analogical problems by Sarah, a chimpanzee (*pan troglodytes*). In D. Gentner, K.J. Holyoak, & B.N. Kiconov (Eds.), *The analogical mind* (pp. 471–498). Cambridge, MA: MIT Press.
- Onishi, K.H., & Baillargeon, R. (2005). Do 15-month-old infants understand false belief? *Science*, 308, 255–258.
- Penn, D.C., Holyoak, K.J., & Povinelli, D.J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behavioral and Brain Sciences*, 31, 109–130.
- Premack, D. (1976). *Intelligence in ape and man*. Hillsdale, NJ: Erlbaum.
- Premack, D. (1982). [The 3.5-year-old child cannot be taught to match relations (e.g., AA to BB)]. Unpublished raw data.
- Premack, D. (1986). *Gavagai, or the future history of the animal language controversy*. Cambridge, MA: MIT Press.
- Premack, D. (1988). Minds with and without language. In L. Weiskrantz (Ed.), *Thought without language* (pp. 46–65). Oxford, United Kingdom: Clarendon Press.
- Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition*, 36, 1–16.
- Premack, D. (1995). On the control of human individual differences. In D. Lubinski & R.V. Dawis (Eds.), *Assessing individual differences in human behavior* (pp. 329–340). Palo Alto, CA: Davies-Black.
- Premack, D. (2007). Human and animal cognition: Continuity and discontinuity. *Proceedings of the National Academy of Sciences, USA*, 104, 13861–13867.
- Premack, D., & Premack, A.J. (1983). *The mind of an ape*. New York: Norton.
- Premack, D., & Premack, A. (1995). Origins of human social competence. In M. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 205–218). Cambridge, MA: MIT Press.
- Premack, D., & Premack, A. (1997). Infants attribute value +/- to the goal-directed actions of self-propelled objects. *Journal of Cognitive Neuroscience*, 9, 848–856.
- Premack, D., & Premack, A. (2003). *Original intelligence: Unlocking the mystery of who we are*. New York: McGraw-Hill.
- Premack, D., & Woodruff, G. (1976). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, 4, 515–526.
- Preuss, T.M., & Coleman, G.Q. (2002). Human-specific organization of primary visual cortex: Alternating compartments of dense Cat-301 and calbindin immunoreactivity in layer 4A. *Cerebral Cortex*, 12, 671–691.
- Raby, C.R., Alexis, D.M., Dickenson, A., & Clayton, N.S. (2007). Planning for the future by western scrubjays. *Nature*, 445, 919–921.
- Spelke, E.S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, 99, 605–632.
- Spelke, E.S., Katz, G., Purcell, S.E., Erlich, S.M., & Breinlinger, K. (1994). Early knowledge of object motion: Continuity and inertia. *Cognition*, 51, 131–176.
- Sugarman, S. (1983). *Children's early thought: Developments in classification*. Cambridge, United Kingdom: Cambridge University Press.
- Surian, L., Caldi, S., & Sperber, D. (2007). Attributions of belief by 13-month-old infants. *Psychological Science*, 18, 580–586.
- Thornton, A., & McAuliffe, K. (2006). Teaching in wild meerkats. *Science*, 313, 227–229.
- Visalberghi, E., & Limongelli, L. (1994). Lack of comprehension of cause-effect relations in tool-using capuchin monkeys. *Journal of Comparative Psychology*, 108, 15–22.
- Wellman, H.M. (1990). *The child's theory of mind*. Cambridge, MA: MIT Press.
- Wilson, F.R. (1999). *The hand: How it's used to shape brain, language, and human culture*. New York: Random House.
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representations and constraining functions of wrong beliefs in young children's understanding of deception. *Cognition*, 13, 103–128.